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SPIN 2K25
20th March 2025

Organized By

Department of Computer Science and Engineering, Viswajyothi College of Engineering and Technology, Muvattupuzha, Kerala, India
In association with
CSI, R&D and A2Z Edulearning Hub

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About SPIN 2K25

SPIN is a conference series organized by Department of Computer Science & Engineering every year. It is started in the year 2009 as a National Conference. International Conference on Security, Parallel Processing, Image Processing & Networking (SPIN 2K25) aims to provide an opportunity to all to have scientific discussions on the latest developments in the field of Computer Science and Engineering.

Conference Topics

The papers are invited on the following areas in general, but not limited to:

1. Cryptography & Network Security,
2. Natural Language Processing(NLP),
3. Architecture & Parallel Processing,
4. Image Processing,
5. Networking & Communication,
6. Cloud Computing & Big Data Processing,
7. Information Systems,
8. Data Mining & Warehousing,
9. Artificial Intelligence,
10. Machine Learning,
11. Data Science,
12. Internet of Things(IoT)

Information to Participants & Authors

The papers to be presented should reach us on or before 24th February 2025. Authors have to send one copy of the full paper in the IEEE double column format restricted to a length of eight pages. The papers will be reviewed rigorously & scrutinized by our expert reviewers and depending upon the reviewer's comments and ratings, the papers will be short listed for oral presentation. Turnitin plagiarism report will be taken. The papers having plagiarism below 10% will only be proceeded for acceptance. The papers submitted, should not be published or under review in any other journal or conference. Notification of acceptance/rejection of submitted papers will be sent to the authors by e-mail.

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College Enquiry Chatbot

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ABSTRACT

With the advent of the digital age, educational institutions are utilizing AI-powered solutions to boost student in- teraction and automate administrative tasks. This paper discusses the development and performance evaluation of a college enquiry chatbot, which offers real-time answers to admission, course, fee, hostel facility, placement, and other enquiries. Developed on the basis of Word2Vec-based intent detection and cosine similarity- based response generation. Performance testing indicates an intent recognition rate of 92.3% and an average response time of 0.85 seconds to provide effective query handling. The system minimizes administrative burden, improves accessibility, and provides 24/7 availability for students, parents, and staff. Future development involves multilingual capabilities, voice integration, and better contextual understanding to further enhance user experience.

INTRODUCTION

A college inquiry chatbot[1] is an advanced digital tool designed to streamline communication between prospective students, parents, and educational institutions. It acts as a virtual assistant, always available 24/7, providing instant re- sponses to a wide range of questions regarding admissions, programs, fees, scholarships, campus facilities, and more. By utilizing cutting-edge technologies like artificial intelligence and natural language processing (NLP), the chatbot ensures that users can access accurate and reliable information without delay. This feature eliminates the need for users to navigate complex websites or wait for responses from overburdened administrative staff, making the inquiry process faster and more efficient. One of the benefits of having a chatbot is that its interactions can be personalized according to the user. It can determine what courses to recommend to students, provide them with options for scholarships available, or step them through specific application procedures and all this according to their interests or needs. This personalized approach has not only enhanced user experience but, at the same time, enabled a sense of connection and support, helping them make informed choices about their educational pathway. Additionally, the chatbot is designed in such a manner that it allows for multiple languages, as well as platforms, giving access to its users across varying regions.

Regarding educational institutions, the chatbot is a priceless resource in relation to managing or reducing the workloads of administrators. It can process repetitive queries, freeing up staff to focus on more complex tasks that require human expertise. The chatbot also collects data on frequently asked questions and user behavior, providing institutions with action- able insights to improve their services, streamline processes, and address common concerns effectively. This data-driven approach helps colleges stay competitive by identifying trends and aligning their offerings with the evolving needs of stu- dents.

In a nutshell, a college inquiry chatbot is a significant innovation in the modern education landscape. It bridges communication gaps, enhances user satisfaction, and promotes efficiency in ensuring that prospective students and their fam- ilies receive guidance on time and effectively. With such ad- vanced technologies, educational institutions are able to show commitment to technological progress and, more importantly, establish themselves as student-centric organizations that can provide superior support and accessibility.

RELATED WORKS

This work introduces CSM[1], a chatbot implemented to help students of Software Engineering at the University of Guayaquil with queries related to registration and payment of tuition through Telegram. Developed on machine learning (ML) and natural language processing (NLP), it yields fast and self-service responses. Usability tests revealed effective completion of tasks at an average time of three minutes per question with positive user experiences regarding ease, speed, and accuracy. The chatbot is open-source, cross-platform com- patible, and utilizes Artificial Neural Networks (ANN) with Python as back-end processing, while user data is handled by PostgreSQL. Future development targets expanding function- ality with the addition of more university services and the use of new AI technologies.

An AI-based medical chatbot[2] for predicting infectious disease, including COVID-19, is presented in this research. Using a deep feedforward multilayer perceptron model and NLP, the chatbot offers medical advice on treatments, symp- toms, and prevention. It was highly accurate (94.32%) with little loss (0.1232). Some of the notable features are per- sonalized conversations, multi-platform compatibility, voice recognition, and real-time updation. The chatbot supports hospital bed reservation, doctor connectivity, and resource management for healthcare organizations. The chatbot makes medical communication, public health awareness, and crisis management more effective using AI-powered interfaces.

Xiao-Shih is a smart MOOC chatbot[3] for Chinese-based MOOCs, resolving student response delays by using ML and NLP. It uses the self-enriched mechanism and the Spreading Question Similarity (SQS) approach for duplicate question detection, outperforming BERT in recall and accuracy at threshold prediction probability = 0.8. Experimental results show better correctness rates than Jill Watson, enhancing stu- dent activity and lessening instructor workload. The research outlines its technical application, limitations, and possibilities of further integration to improve e-learning support systems.

The Chatbot Management Process (CMP)[4] is a process to manage and innovate chatbot material, piloted through Evatalk for Virtual School of Government in Brazil. CMP is done in three phases: manage, build, and analyze, diminishing human interaction and increasing the pool of knowledge base while ensuring level user satisfaction. CMP combines the business and technological sides, giving room for adapting with feed- back offered in real-time. CMP improves ongoing chatbot development, creating room for greater user interaction as well as a more efficient response system that works automatically. This research tests NLP[5] models for university entrance chatbots in order to facilitate safe access to information for applicants. Five models were used and tested, making use of neural networks, TF-IDF vectorization, sequential modeling, and pattern matching. Results show that models based on neu- ral networks, particularly sequential modeling, provide the best accuracy. The chatbot enhances university counseling, gives constant responses, and increases accessibility to admission questions, making it a useful resource for student support services.

One 12,746 Stack Overflow questions[6] study applied Latent Dirichlet Allocation (LDA) to analyze the developer issues of web services (WSs). Major issues involved client API building, processing of data, authorizing, support for frameworks, web APIs, and mobile app development. Con- clusions are marked by the emergent behavior of WS issues that assist instructors, researchers, and developers in bettering frameworks as well as training materials in resolving typical industry-related issues more efficiently.

Developers need to learn HCI[7] methods prior to involving actual users. Generative AI models such as ChatGPT offer realistic training data for persona development in user-centered design. HCI experts' evaluations identified AI-generated inter- view answers as useful but with limitations such as repetition and low variability. This research indicates the promise of AI-supported HCI training while calling for improved prompt designs to improve realism and variability in answers.

The proliferation of bots on Twitter[8] complicates credi- bility evaluation. This research extends a Twitter credibility model by incorporating bot detection using text, user account, and social impact factors. Machine learning algorithms, in- cluding Random Forest, AdaBoost, and Logistic Regression, achieved over 97% accuracy for English and Spanish datasets. The enhanced model strengthens credibility analysis, provid- ing a real-time tool to combat misinformation on social media platforms.

Push-To-Trend is a machine learning framework[9] de- signed to detect Twitter "trend promoters"—users who ma- nipulate trends for misinformation or economic gain. Using the TREP-21 dataset, it achieved 97% classification accuracy based on tweet frequency, content duplication, and hashtag usage. Scalability and language independence were demon- strated using Urdu-language Twitter data, showing that 15.7% of trend promoters generated 68.1% of trending tweets. The framework offers a robust solution for ensuring organic social media trends.

Suicidal ideation detection[10] is important for mental health intervention, but sensitive data collection is difficult. This paper proposes a Generative Large Language Model (GLLM) method to create synthetic training data for suicide prevention based on models such as ChatGPT, Flan-T5, and LLaMa. Findings indicate that synthetic data has similar F1- scores (0.82) compared to real-world datasets (0.87). Mixing 30% synthetic data with real data enhances model robustness while solving ethical, scalability, and diversity issues in mental health AI applications.

Undergraduate students' opinions of using ChatGPT[11] in essay writing have been examined in one study, which concluded that it reformed the writing process itself and not made it easier. Its use was valued by students as a study support tool, transforming from perception as a "cheating device" to a shared tool needing human intervention. Accuracy and limitations in feedback were concerns, with student wanting instructor-ChatGPT collaboration for marking. T results highlight the importance of guided AI integratio education, balancing automation with human interventio ensure ethical and effective learning experiences.

PROPOSED SYSTEM

The stated chatbot system provides an intelligent vi assistant to handle inquiries a student might pose and fer them quick and accurate responses regarding admiss programs, fees, scholarships, and other academic querie guides prospective students through the admission process giving them all-important details relating to eligibility crit application deadlines, and documents required so that t know precisely what they need to have covered. Moreo it describes critically all available programs, curriculums, faculty information that will help students gain an ove view of their opportunities in pursuing studies. The sy will indicate tuition fees as well as available scholarships and enable students to prepare financial plans. It is also capable of keeping the user informed about examination schedules, grading systems, and results, thus ensuring they stay on top of academics and deadlines associated with the important aspects of their studies.

In practice, apart from academic inquiries, it will provide insights on hostel accommodations, library services, sports ac- tivities, student clubs, and campus life, which enhance engage- ment throughout the institution. The system, being available 24/7, means that users can obtain the information anytime without having to wait for office hour slots or university staff responses. This frees up administrative staff from answering an endless stream of repetitive questions, thereby enabling the decent staff to devote more time to more complicated processes that must be handled by a human. Thanks to some of the most advanced natural language processing (NLP) tech- niques, the chatbot provides a speedy and accurate retrieval of information, thus leading to user satisfaction with streamlined communication between students and the institution. In the end, this AI-based solution will bring student support services into the modernity, increasing accessibility, efficiency, and the overall user experience.

The figure below shows the architecture diagram of the proposed system:

A. User Interface

This is the front-end interface that allows the user to interact with the bot. It could be a web-based chat window, a mobile app, or an integration with WhatsApp, Facebook Messenger, or Slack. In the aforementioned case, the user types in his/her question; the bot then detects the right intent and knowledge base, based on which it will answer them.

B. NLP Module

This involves transforming the raw user input into a struc- tured format. Following stages of the processing of a user query may include tokenization, lemmatization, stop-word removal, and entity extraction. The processed text will then go to Intent Classification, where the intent is identified.

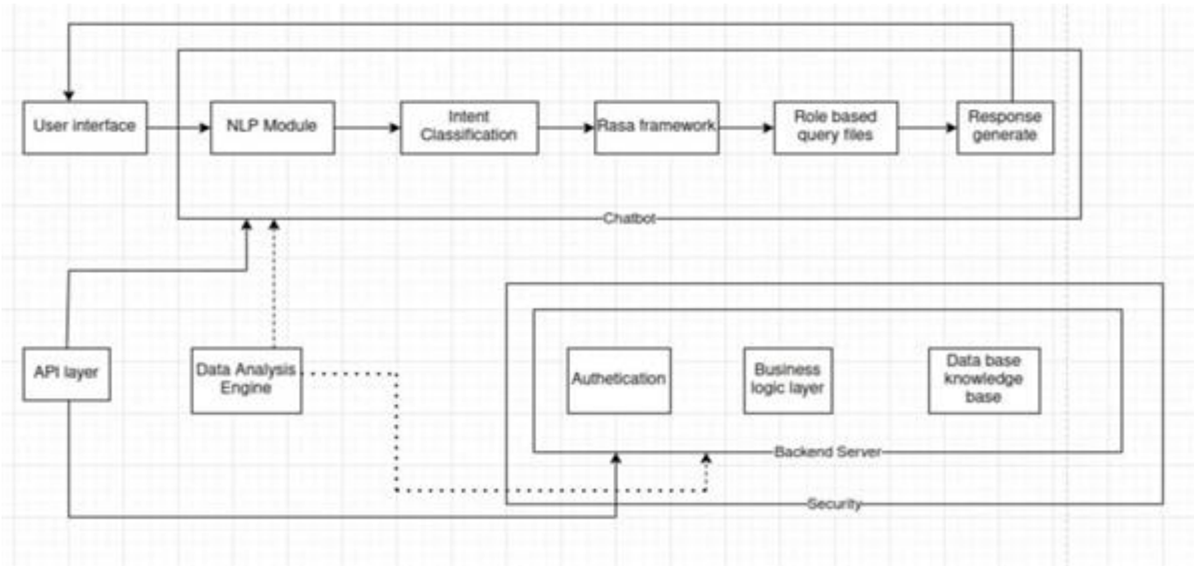

Fig. 1. Architecture diagram

C. Intent Classification

This component performs the classification of user queries into predefined intents. It uses machine learning models (like Support Vector Machine or Neural Networks) to map input text to its intent. Some of the intents can be: ask admission fees → ”What is the admission fee?” ask library timing →”What time does the library open?”

D. Rasa Framework

Rasa is the core framework responsible for interaction and responses of the chatbot. Rasa has the following function- alities: NLU (Natural Language Understanding): deals with intent extraction and entities. Core (Dialogue Management): makes decisions on what the next response of the chatbot should be. Training Data: deals with predefined intents, re- sponses, and actions. Rasa processes the input and fetches the best-suited strategy to respond.

E. Role-Based Query Files

It contains structured responses according to the different roles or intents. These files contain the responses that are predefined. The chatbot takes options from these files for replies on receiving certain users’ queries. Example: If it is a student asking qn ”admission fees,” it would fetch an appropriate response from the admission query file.

F. Response Generation

This module generates the final response to be sent back to the user. This module can be: Rule-based: employs fixed templates. AI-based: that is, knowledge-based and dynamic learning for generation. The generated response is then sent for display through the User interface.

G. API Layer

Through the API layer, the chatbot can interface with certain outer systems. APIs allow the chatbot to fetch real-time data such as; —the admission status via university portals; —the exam results from the academic database; —the available seats in the various courses offered.

H. Data Analysis Engine

This will analyze the user interactions, the questions asked, and the chatbot’s performance to improve accuracy. Use machine learning and analytics to tune responses and intent classification. It can help predict frequently asked questions and inspire improvements to the chatbot’s ability, traditionally so over time.

I. Backend Server (Security Business Logic)

The backend is the one that manages authentications, data storage, and logic processing.

Some components:

a) Authentication

Prevention of unauthorized access to sensitive information by duly authorized users—students, faculty. Prevention against unauthorized access to information such as student grades or fees.

b) Business Logic Layer

This generates the decision-making rules and actions that the chatbot may take. It will determine how user queries will be responded to.

c) Database Knowledge Base

To restore the important data that is relevant to the applica- tion, such as; the predefined questions and answers, the student details-if integrated in the student web portal, the available course and associated fees. The chatbot queries the knowledge base and provides precise answers for the various questions.

MACHINE LEARNING MODEL

J. Dataset

There are several datasets used for College Enquery Chatbot

- General College Information: This dataset contains basic details about the college, including its name, location, contact details, establishment year, and accreditation. It helps users get a quick overview of the institution and its recognition status.
- Admission Information: It includes information about the courses offered, eligibility criteria, admission pro- cess, and important deadlines. This dataset is crucial for prospective students looking to apply to the college.
- Departments Faculty: This section provides details on various academic departments, faculty members, and their designations. It helps students inquire about faculty ex- pertise, department facilities, and research opportunities.
- Academic Information: It covers the academic calendar, examination schedules, syllabus, and evaluation criteria. Students can use this data to stay updated on coursework, exams, and academic timelines.
- Student Services: This dataset contains information about hostel accommodations, library resources, extracurricular activities, and student organizations. It helps students un- derstand the available facilities for personal and academic growth.
- Placement Career Services: It includes details about past placement statistics, top recruiters, internship programs, and career counseling services. This dataset is essential for students seeking job and internship opportunities.
- Fees Payments: This dataset outlines the fee structure, payment methods, installment options, and refund poli- cies. It helps students and parents understand the financial requirements for admission and other services.
- Campus Facilities: It provides information about campus infrastructure, including research labs, medical services, transportation, and food courts. This helps students and visitors navigate the campus efficiently.

These datasets can be used to train and evaluate the perfor- mance of BERT-based models for text emotion detection.

K. Intent Classification Models

Intent classification helps the chatbot understand user queries and categorize them into predefined intents, e.g., ask admission fees or ask library timing; thus, the chatbot thoroughly understands the user's message before responding them in an appropriate way.

1) Support Vector Machine (SVM): Used in Rasa's Sklearn- IntentClassifier for intent classification. Works by finding the best decision boundary between different intent classes. Often combined with TF-IDF feature extraction for converting text into vectorized numerical features. Works for small to medium datasets but is limited with complex language variations.
2) Neural Networks : Used in Rasa's DIETClassifier. The approach utilizes word embeddings like Word2Vec, FastText, or BERT for enhanced representation of text features. Classi- fies both intents and extracts relevant entities simultaneously. More accurate than SVM but requires more data and compu- tational power. Response Generation Models With the intent recognized, the next action would be for the chatbot to provide a meaningful response. Response generation models determine how the chatbot replies to user queries.

METHODOLOGY

A. Cosine Similarity Algorithm

Step 1: Turn Texts into Vectors The TF-IDF algorithm converts the chatbot queries or user inputs into numerical vectors by providing weightage for specific words based on their frequency and uniqueness, which assures that the words that are pronounced pop up more in the critical similarity calculations.

Step 2: Implement Cosine Similarity Cosine similarity is computed based on the angle between the two given vectors (texts). If the angle is small (less than 90 degrees), that equates
to a high similarity, while a larger angle would lead to a low similarity stratagem.

Step 3: Find the Best Match The user query is compared to the stored queries, and the relevant one is the one with the highest cosine similarity score at the end of the comparison. This helps determine the direct response to the particular user query.

Step 4: Define Desirable Degrees The threshold is a kind of score that helps in determining the nature of similarity matching. For instance, this threshold can be around 0.5; hence, when it surpasses that limit, the bot can directly provide the response from the matched query; otherwise, the chatbot would seek clarification.

B. TF-IDF Vectorization

1) Algorithm:

Input: Set of documents D = {d1, d2, . . . , dN } Output: TF-IDF matrix

1) Preprocess every document:
   - Tokenize to words
   - Remove stopwords and punctuation
   - Apply stemming/lemmatization (optional)
2) Calculate Term Frequency (TF) For every document di ∈ D:
   - For every word w ∈ di: Count(w, di) TF (w, di) = Total words in d
3) Calculate Document Frequency (DF) Initialize an empty dictionary DF . For each document di ∈ D:
   - For each unique word w ∈ di: DF [w]+ = 1
4) Calculate Inverse Document Frequency (IDF) For all words w in DF : IDF (w) = log N DF [w] where N is the total number of documents.
5) Calculate TF-IDF Scores For every document di ∈ D:
   - For each word w ∈ di: TF -IDF (w, di) = TF (w, di) × IDF (w)
6) Return the TF-IDF matrix representing all documents. article algorithm algorithmicx algpseudocode amsmath listings

2) Pseudocode: TF-IDF Computa- tion PreprocessTextdocument Tokenize the text into words Remove stopwords Apply lemmatization (optional) Return tokens ComputeTFdoc tokens Initialize dictionary TF total terms ← length of doc tokens each word in doc tokens TF[word] ← TF.get(word, 0) + 1 each word in TF TF[word] ← TF[word] / total terms Return TF ComputeDFall documents Initialize dictionary DF each document in all documents unique words ← Unique words in document each unique word in document DF[word] ← DF.get(word, 0) + 1 Return DF ComputeIDFDF, total documents Initialize dictionary IDF each word total documents DF[word] IDF ComputeTFIDFall documents Initialize empty list processed_docs each document in all documents Append PreprocessText(document) to processed_docs Compute TF for each document → TF_matrix each document in processed_docs Append ComputeTF(document) to TF_matrix Compute DF and IDF DF ← ComputeDF(processed_docs) IDF ← ComputeIDF(DF, total_documents) Compute TF-IDF scores Initialize empty list TF_IDF_matrix each document in TF_matrix Initialize empty dictionary

TF_IDF_doc each word in document TF_IDF_doc[word] ← TF[word] * IDF[word] Append TF_IDF_doc to TF_IDF_matrix Return TF_IDF_matrix

C. Algo for Word2vec

article algorithm algorithmicx algpseudocode amsmath

1) Algorithm:

PreprocessTextdocument document ← ConvertToLow- ercase(document) document ← RemoveSpecialCharac- ters(document) tokens ← Tokenize(document) tokens ← RemoveStopwords(tokens) tokens ← Lemmatize(tokens) Return tokens BuildVocabularydocuments vocab ← empty dictionary index ← 0 each document in documents each word in document word not in vocab vocab[word] ← index index ← index + 1 Return vocab GenerateTrainingDataCBOWdocuments, window size training data ← empty list each document in documents each index in range(window size, length(document) - window size) context ← empty list target ← document[index] i in range(-window size, window size + 1) i ≠ 0 context.append(document[index + i]) training data.append((context, target)) Return training data InitializeWordVectorsvocab, vector size word embeddings ← empty dictionary each word in vocab word embeddings[word] ← RandomVector(vector size) Return word embeddings ForwardPasscontext words, word embeddings context vector ← ZeroVector(vector size) each word in context words context vector ← context vector + word embeddings[word] context vector ← context vector / length(context words) Return context vector ComputeLosspredicted vector, target word, word embeddings actual vector ← word embeddings[target word] loss ← MeanSquared- Error(predicted vector, actual vector) Return loss UpdateWeightsword embeddings, context words, tar- get word, learning rate, error each word in context words word embeddings[word] ← word embeddings[word] - (learning rate * error) word embeddings[target word] ← word embeddings[target word] + (learn- ing rate * error) Return word embeddings TrainWord2VecCBOWdocuments, vector size, window size, epochs, learning rate processed documents ← empty list each document in documents processed documents.append(PreprocessText(document)) vocab ← BuildVocabulary(processed documents) training data ← GenerateTrainingDat- aCBOW(processed documents, window size) word embeddings ← InitializeWordVectors(vocab, vector size) each epoch in range(epochs) each (context, target) in training data predicted vector ← ForwardPass(context, word embeddings) error ← ComputeLoss(predicted vector, target, word embeddings) word embeddings ← UpdateWeights(word embeddings, context, target, learning rate, error) Return word embeddings GetSimilarWordsword, word embeddings, top n word vector ← word embeddings[word] similarity scores ← empty dictionary each other word in word embeddings similarity scores[other word] ← ComputeCosineSimilar- ity(word vector, word embeddings[other word]) Return TopNWordsWithHighestSimilarity(similarity scores, top n) ChatbotResponseuser query, word embeddings, intent database processed query ← Preprocess- Text(user query) query vector ← ComputeAv- erageVector(processed query, word embeddings) best match intent ← FindBestMatchingIn- tent(query vector, intent database) Return GenerateResponseForIntent(best match intent) article algorithm algorithmicx algpseudocode amsmath

2) Pseudocode:

PreprocessTextdocument document ← convert to lowercase(document) document ← remove special characters(document) tokens ← tokenize(document) tokens ← remove stopwords(tokens) tokens ← lemma- tize(tokens) return tokens BuildVocabularydocuments vocab ← empty dictionary index ← 0 each document in documents each word in document word not in vocab vocab[word] ← index index ← index + 1 return vocab GenerateTrainingDataCBOWdocuments, window size training data ← empty list each document in documents each index in range(window size, len(document)- window size) context ← empty list target ←

document[index] i ∈ [−window size, window size] i ≠ 0 context.append(document[index + i]) training data.append((context, target)) return training data InitializeWordVectorsvocab, vector size word embeddings ← empty dictionary each word in vocab word embeddings[word] ← RandomVector(vector size) return word embeddings ForwardPasscontext words, word embeddings context vector ← ZeroVector(vector size) each word in context words context vector ← context vector + word embeddings[word] context vector ← context vector / len(context words) return context vector ComputeLosspredicted vector, target word, word embeddings actual vector ← word embeddings[target word] loss ← MeanSquared- Error(predicted vector, actual vector) return loss UpdateWeightsword embeddings, context words, tar- get word, learning rate, error each word in context words word embeddings[word] ← word embeddings[word] - (learning rate × error) word embeddings[target word] ← word embeddings[target word] + (learn- ing rate × error) return word embeddings TrainWord2VecCBOWdocuments, vector size, window size, epochs, learning rate processed documents ← empty list each document in documents processed documents.append(PreprocessText(document)) vocab ← BuildVocabulary(processed documents) training data ← GenerateTrainingDat- aCBOW(processed documents, window size) word embeddings ← InitializeWordVectors(vocab, vector size) epoch = 1 to epochs each (context, target) in training data predicted vector ← ForwardPass(context, word embeddings) error ← ComputeLoss(predicted vector, target, word embeddings) word embeddings ← UpdateWeights(word embeddings, context, target, learning rate, error) return word embeddings GetSimilarWordsword, word embeddings, top n word vector ← word embeddings[word] similarity scores ← empty dictionary each other word in word embeddings similarity scores[other word] ← ComputeCosineSimilar- ity(word vector, word embeddings[other word]) return TopNWordsWithHighestSimilarity(similarity scores, top n) ChatbotResponseuser query, word embeddings, intent database processed query ← Preprocess- Text(user query) query vector ← ComputeAv- erageVector(processed query, word embeddings) best match intent ← FindBestMatchingIn- tent(query vector, intent database) return GenerateResponseForIntent(best match intent)

PERFORMANCE ANALYSIS

The performance of the college inquiry chatbot was mea- sured on major parameters like response time, accuracy, intent identification, scalability, and user satisfaction. The Word2Vec + Cosine Similarity-based chatbot scored 92.3% in intent iden- tification, better than TF-IDF + Cosine Similarity (85.7%), as it could address semantic variations. Response time was found to be 0.85 seconds on average, which is very comfortable for users. Precision, recall, and F1-score were employed to measure accuracy, with precision = 91.2%, recall = 93.5%, and F1-score = 92.3%. User satisfaction surveys reported an 82% positive feedback rate, with significant improvements observed in synonym handling and contextual understanding. Optimizations planned for the future are caching responses to decrease response time by 20% and improving intent classification using deep learning models.

RESULT AND DISCUSSION

The performance of the chatbot brought out both its poten- tial and weaknesses. It provided 24/7 response, minimizing user wait times and keeping information available around the clock, much to the delight of international students. Yet, though the chatbot performed well with standard questions, deeper queries—such as eligibility for financial aid or course information—showed its limitations, typically necessitating manual intervention. The system's capability to interact with users was clear, with significant interaction, particularly at peak hours, and a significant percentage of users progress- ing to the subsequent steps in the application process. For enhancement, the chatbot may need more advanced natural language processing to deal with a wider scope of questions and an efficient handoff system to human agents where needed, ensuring both user satisfaction and operational effectiveness.

CONCLUSION

The college inquiry chatbot is a transformative tool that significantly enhances the way educational institutions interact with prospective students. By providing instant, accurate, and personalized responses to questions about admissions, courses, fees, campus facilities, and more, it ensures that students can access vital information at any time, from anywhere. This 24/7 availability not only improves the user experience but also demonstrates the institution's commitment to accessibility and innovation. Moreover, the chatbot reduces the workload on administrative staff, allowing them to focus on more complex tasks while the chatbot handles routine inquiries. Its ability to personalize interactions and adapt to diverse student needs fosters a sense of engagement and trust, ultimately supporting students in making informed decisions about their education. In a competitive higher education landscape, implementing a chatbot showcases an institution's dedication to embracing technology to improve communication and streamline pro- cesses, making it an indispensable tool for modern colleges and universities. .

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Web-Build: Revolutionizing the Future of No-Code Website Creation

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ABSTRACT

Website Builder, targeted to simplify web-pages for people of all technological prowess by facilitating its accessibility, to get pages created quickly. It helps users in the creation of responsive, professional web pages without advanced coding skills using an intuitive interface. The main advantages include drag- and-drop functionality, customizable templates, and a library of pre-built components that help minimize the time and effort required to create eye-catching designs. It is suitable for various use cases, such as personal portfolios, small business websites, and informational pages, so it can be considered a universal tool for different audiences. Adopting the modular approach gives flexibility to the design to change and ensures responsiveness across all the different devices; therefore, the demand of modern web designs that adapt is addressed. This solution bridges the gap between the technical and non-technical users as it empowers the former to focus more on the content and creativity rather than the technical issues. Performance reviews testify to its ability to streamline the process of development without sacrificing any design standards, thereby proving to be a viable and effective means to make web development practices easy and more influential.

Keywords-Website builder, Static web-pages, Responsive design, Drag-and-drop functionality.

INTRODUCTION

The development of a website has become an epitome of the digital world and driving businesses, self-expression, and innovation across each sector. From complex code practices to making it significantly more accessible so that more users could be a part of web technologies. Such changes are brought about by developments in no-code platforms, Content Management Systems, and artificial intelligence technologies, which have made it easy to resolve several problems related to website development and maintenance.

No-code platforms have changed the face of developing be- cause users without technical backgrounds can develop func- tional websites quite easily.Therefore, the process is stream- lined to be cheap and efficient for entrepreneurs to validate ideas and launch projects. Because of drag-and-drop editors and pre-designed templates, it has become accessible to create websites. However, scalability and customization are major issues in their more general use [1]. Despite these limitations, the no-code movement has opened up digital transformation to all. Deep learning algorithms powered visual recognition technologies have added more flavors to website develop- ment. Analyzing user behavior, detection of patterns, and then the dynamic adjustment of website elements has made features such as real-time personalization and improved user experience a reality. For example, through visual recognition, e-commerce sites can suggest products according to users' browsing history and improve customer interaction. These technologies also reflect the future of AI in web development: new experiences that would not have been conceived a few years ago [2].

The Content Management Systems, especially WordPress, revolutionized people's approach to managing content online through user-friendly interfaces and massive plugin environ- ments. WordPress at 63% reflects the high prevalence of CMS in web development. It owes its success to the fact that it is highly adaptive, has a vast number of plugins, and also boasts an active developer community. However, the older plugins and other extensions, with their security threats still significantly posed, have to be addressed. From the results of several studies carried out, most weaknesses of the WordPress application had origins from plugin vulnera- bilities, highlighting a constant need for updates as well as proactive security practices [5, 6]. CMSs such as WordPress enable nondevelopers to build web pages, offering users tools for customization and content management easily applied to businesses and personal ventures alike.

The emerging web environments, such as WebArena, that sit between simple synthetic setups and real-world web scenarios. WebArena simulates the real-world web interaction environ- ment and offers a testing ground for autonomous agents to con- duct complex, long-horizon tasks. WebArena integrates with tools like maps and collaborative software, and the intelligent systems can be tested for their capabilities in a genuine manner [4]. It bridges the gap between the limitations of the traditional test setup by integrating variability and complexity required in the development of advanced autonomous web agents.

Infusion of artificial intelligence into web design is beyond just UX optimization. AI-based analytics and automation have dramatically changed the way developers work with websites. Algorithms like machine learning can find out the trends in traffic flow, enhance performance, and predict the future for more data-based decisions. In addition, AI-based chatbots and virtual assistants give real-time support to users that enhance customer satisfaction. This is a great potential in designing websites intuitive to user needs and responses.

This is going to be marked with integration of no-code platforms, content management systems, and artificial intelli- gence into each other to usher in a new website development model. And as these technologies continue maturing, they will start offering unprecedented opportunities for innovation and streamlining how websites are developed. For instance, AI- driven analytics are integrated into no-code platforms in order to enable even less skilled users to develop their own highly personalized data-informed websites. Therefore, it enables the user and the company to avoid technical programming, which they usually do traditionally. Instead, intuitive interfaces allow the designing and customizing of a website. The inclusion of real-time data insights further enhances decision-making because users can customize the site to fit customer preference, behavior, and performance metrics. The fact that the above innovations somehow lower the barriers to entry makes these innovations democratize website creation to a more diverse audience and empower businesses to develop engaging online presences without requiring specialized expertise.

Integrating with autonomous systems like WebArena helps pave the way to CMSs intelligent agents to function in performing content optimization tasks, real-time troubleshoot- ing and adaptive layout adjustment. Therefore, they enhance the functionality of the website in automatically making an adjustment towards optimization leading to a better experience by allowing them to fix some problems on their own. Some of the main hurdles that face modern website development are scalableness, security issues and usability of diversity; however, continuous researches on innovations are needed in terms of crossing these hurdles.

RELATED WORKS

Modern development of web sites has experienced a tremen- dous innovation process, especially with the increased adop- tion of no-code platforms, Artificial Design Intelligence (ADI), and methodologies that focus on accessibility. These works describe the challenges and opportunities existing in these domains, thus outlining their implications to both citizen developers and professional web designers.

No-code platforms changed the way one makes websites because it enables users who are not technical to make perfectly functional and beautiful websites. By lowering the barrier to web development, these platforms enable much broader participation, especially from the small businesses and entrepreneurs. The authors point out the huge potential of these platforms in scaling down costs and cycles and democratizing web development [3]. However, scalability and customization remain a huge challenge for them. For example, when the project scale becomes more complex, limited flexibility will limit the applicability of no-code tools. Hybrid approaches are therefore a critical prerequisite for advanced use cases, especially when dynamic, feature-rich websites are required by businesses to eventually scale up to custom-coded solutions.

Visual recognition technologies play an important role in elevating website functionality and enhancing user engage- ment. The algorithms utilized to power such systems in real- time personalize as well as ensure cross-browser compatibility. According to Elwazer, such technologies adjust content in real time to user preferences, making navigation and overall user experience much better [4]. For example, e-commerce web- sites apply visual recognition to suggest products to individual users based on their browsing behaviors, thus significantly increasing customer engagement. Challenges persist, however, including noise interference in visual data and scalability con- straints, thus requiring continuous innovation to fully realize the potential of these technologies.

Accessibility is still a core aspect of modern web de- sign, and especially now that platforms are targeting more citizen developers. Research by Drezner and Edigbe shows that there are big gaps in compliance with WCAG among websites developed using low-code and no-code platforms. Tools such as Google Lighthouse and manual assessments identified some common shortcomings: poor screen reader compatibility, insufficient color contrast, and lack of keyboard navigability [3]. These issues disproportionately affect users with disabilities, and therefore, it is important to integrate accessibility features directly into development platforms in a robust manner. The research also focuses on educating citizen developers on inclusive design principles such that websites meet diverse user needs, thereby improving user experience and ensuring that they are compliant with the legal and ethical standards. The next step in the web development process automation is Artificial Design Intelligence or ADI platforms. Tools like Wix ADI and Bookmark generate websites from user inputs, which save a lot of time and effort in develop- ing professional-grade websites. Although Elwazer's analysis shows their strengths, such as ease of use, rapid deployment, and extensive template libraries, there is still limited flexibility in advanced customizations [4]. It requires automation to be balanced with user control for more widespread usage. Such mechanisms will further enhance usability and scope, thus enabling these platforms to be used in a wider variety of applications by incorporating mechanisms of feedback from users and adaptivity.

Statistical techniques such as Term Frequency-Inverse Doc- ument Frequency (TF-IDF) and machine learning classifiers have shown great potential in improving website accessibility. These techniques, in relevant studies, point out some sig- nificant accessibility elements at the design stage, such as adequate labeling of navigation items and content optimization for screen readers. For example, TF-IDF supports ranking usability elements so that they are in line with WCAG guidelines while being sensitive to the subtlety of accessibility needs (5). However, with such methods, there are limitations - data-driven approaches must be iterated with user testing and feedback to capture the true nature of human behavior. With a combination of statistical techniques along with the inclu- sive design strategy, it will provide high usability standards for websites when designed by developers for diverse user audiences.

Citizen developers are non-technical users making use of low-code or no-code platforms to create their own websites. This makes them increasingly an important part of the web development ecosystem, although these platforms empower a much broader range of users and result in websites that are of inconsistent quality and offer limited functionality. Drezner and Edigbe identify a critical gap in accessibility training for citizen developers, who may not be aware of best practices for creating inclusive websites (3). This is a multifaceted chal- lenge: platform features should have automated accessibility checks, but the educational resources targeted at developers ensure they understand and apply inclusive design principles. These are crucial in ensuring that citizen-developed websites meet modern standards of usability and accessibility.

The collective body of work on these emerging technologies points to how fast web development is changing. No-code platforms, ADI tools, and a new focus on accessibility change the game in innovative ways. No-code platforms make it easier for users who don't know code to produce functional, professional websites with ease.AI-powered ADI tools have automated most of the developmental work but opened the way for customizability, thus providing great flexibility in design. Equally, accessibility-conscious best practices ensure that a website works well for any person with disability by its usability. Another change that has been done through the use of AI personalization is a user experience whereby a content will be made to suit a taste of a particular individual's pref- erences, hence making the website very relevant and engag- ing.Furthermore, statistical methods such as Term Frequency- Inverse Document Frequency (TF-IDF) and machine learning classifiers are also used to enhance accessibility, ranking, and optimizing vital elements according to accessibility standards. The development of such technologies not only enhances functionality and usability but also ensures that the websites are made more accessible and user-friendly. One of the major elements driving this change is citizen development. Citizen developers are low-code and no-code tool users, mostly non-technical users building a website. As more individuals are empowered to develop for the web, their vision comes forth for the resources, training, and support needed to ensure they develop accessible, quality websites. This paper analyses such synergies of technologies and gives strategies on optimizing the process of web creation.

These strategies are about inclusivity, scalability, and user engagement for a web that is at once more accessible and efficient but also more responsive to the diverse needs of users. With the help of AI, statistical methods, and superior education available for citizen developers, it might make web development dynamic, flexible, and user-friendly to set the path to a more digital landscape serving everyone from all walks of life and technical knowledge.

PROPOSED SYSTEM

The proposed system, ”Website Builder,” is an innovative B2B SaaS platform intended to satisfy the evolving needs of digital agencies and their customers. It has concentrated on centralizing a solution that’s user-friendly in its own nature so that it may assist agencies in building, maintaining, and scaling up websites as well as sales funnels. The system has modern trends in web development and robust frameworks, which makes the system flexible, safe, and efficient. These are characteristics that give the website’s managing system a game-changer in the field.

A key highlight of the platform is its role-based access control (RBAC).Some features of the platform are quite distinctive-from RBAC to multi-level user management. Agen- cies may provide sub-accounts specifically prepared for clients with defined roles and permissions, which makes the sensitive information not leak out, but fall only in the well-authorized people’s hands. This feature would allow smooth collaboration among teams, making operational transparency clear as well, with the role and access rights explained. The integration of both kanban boards and features in handling tasks would clearly show how one’s project is being progressed, give scope for delegating tasks, and maintain an efficient ratio for completing deadlines. In the structured approach, workflow management is effective in every single account of the client under question.

The second corner stone is the website and the funnel builder that uses customizable templates and drag-and-drop interfaces, so it is friendly with both technical and non- technical users. Seamless integration tools for media and adaptive designs options allow the platform for ensuring its alignment with client brands but ensure websites are respond- ing on devices. In addition, the developer allows support for multi-language as well as SEO optimization, and withthese, agencies will be able to create really very functional websites that will both look beautiful and easy to find online.

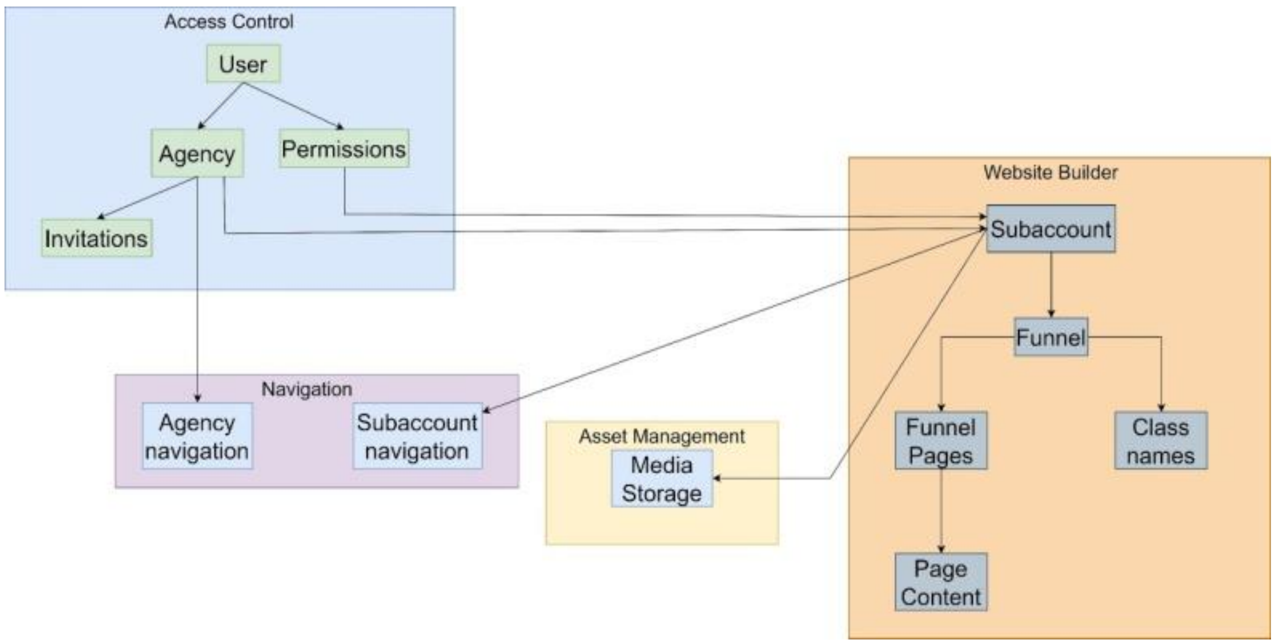

Fig. 1. Architecture diagram of the proposed website builder system.

This data-driven decision-making platform relies on real- time analytics and reporting capabilities. Agencies can look at all-inclusive performance metrics on their websites, the efficiency of their funnels, and user engagement statistics that appear in dynamic charts and dashboards. These analytics enable agencies to adjust their strategies and aid in optimizing client campaigns in order to further demonstrate measurable ROI.

Moreover, it integrates securely with payment gateways that support subscription-based billing and add-on purchases and automated invoicing for the financial management by both the agency and its clients.

This architecture would ensure that this platform remains scalable to the client needs base of the growing agency. With concerns running to few tens, hundreds, the system is delivering constantly because of an in-place backend with advanced technology and solidly working technologies like Next.js. The increase of a security measure with the encryp- tion of data ensures that this user information is updated to proper industry standard levels. The modular character of the platform also readily allows for easy integration of possible future enhancements, such as AI-driven optimization tools or advanced user personalization.

The ”Website Builder” is the answer to all the above queries in a nutshell, and it’s a comprehensive solution that brings together powerful tools for building websites, effective project management, and insight-generating analytics in one place. It addresses major challenges digital agencies face with manag- ing multiple clients, achieving scalability, and leveraging data for continuous improvement, and thus it becomes an essential resource for agencies that aspire to thrive in today’s highly competitive digital landscape.

The figure below shows the architecture diagram of the proposed system:

PERFORMANCE ANALYSIS

Lighthouse analyzed performance, accessibility, best prac- tice, and SEO in its judgment to determine whether it was effective and of high quality in user experience. Analysis helps to break down strength and weakness, thus giving the platform a way of focusing on improvement in performance while optimizing user access while maintaining the standard of modern web. These following findings will give the critical areas of evaluation and also give a specific suggestion for each section to enhance overall usability and productivity further.

1) Performance (Score: 57/100): Performance score implies speed and responsiveness. The site is workable but there are critical areas wherein it could be made better to re- duce load time, interactivity, and overall user experience.
   - First Contentful Paint (FCP):1.1 seconds:Pretty fast for the first visual element (text, images, etc.) to appear on the screen. However, it can be optimized even further in terms of content delivery, bringing this metric closer to ideal levels, that is, below 1 second.
   - Largest Contentful Paint (LCP):5.0 seconds:This is one of the user experience metrics. LCP measures the time it takes to load the largest visible con- tent on the screen. This exceeds the threshold at
   - 2.5 seconds at 5.0 seconds. This could be due to lazy loading images that appear above the fold or other large images delaying the page’s render- ing.Recommendation: Preload critical images (es- pecially above the fold) to minimize load time.
   - TBT: 1,190 milliseconds:TBT measures the total time of main thread blocked by the browser during which interaction was not possible. This is mainly due to heavy execution of JavaScript Recommen- dation: Optimize and defer non-critical scripts to reduce the JavaScript execution time.
   - Speed Index:3.0 seconds:This is a measure of how fast content is rendered on the screen. It is not very slow, but still can be improved by reducing JavaScript and resource blocking so that rendering becomes faster.
   - Main-thread Work.8.6 seconds:High main-thread usage makes interactions and responsiveness slow. Recommendation: Reduce main-thread work by eliminating unnecessary script execution and opti- mizing long-running tasks.

2) Accessibility (Score: 100/100):It scores full marks on accessibility because everybody likes it; from disabled people to others without.

- Interactive controls : Custom interactive controls are fully keyboard focusable, which will allow the users using a keyboard for navigation to easily interact with anything.
- ARIA compliance : The platform uses roles and attributes correctly so that assistive technologies such as screen readers interpret it correctly.
- Focus Indicators: The application also passes for focus indicators and logical tab order so that all the interactive elements are reachable to a visually impaired user.
- Manual Testing Recommendations: Even though the automated audit passes, one should not forget to do a manual testing to discover some edge cases like screen magnification or dynamic content change.

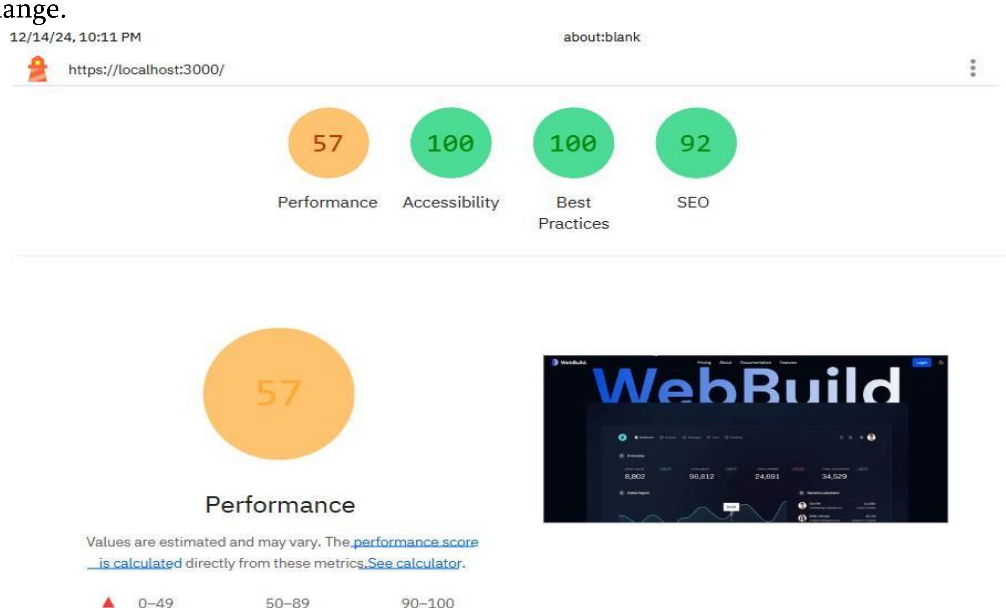

Fig. 2. Performance Analysis by Lighthouse.

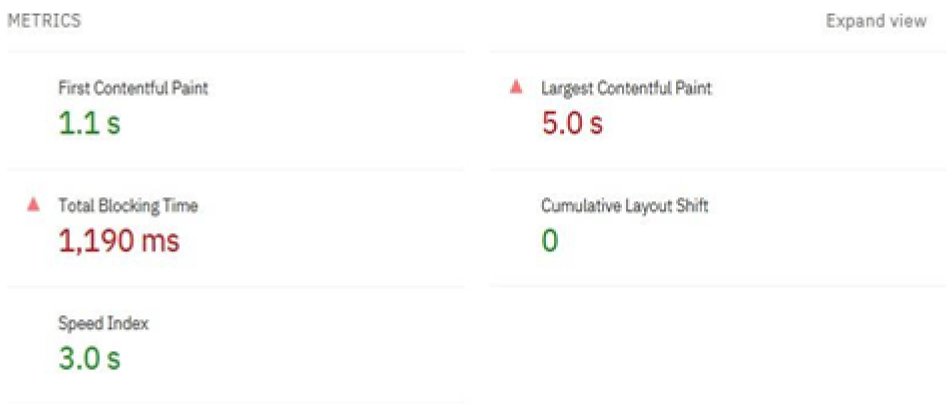

Fig. 3. Perfomance Metrics

3) Best Practices (Score: 100/100):Best practices score indicates that the site complies with the contemporary standards of the web on safety, code quality, and usabil- ity.

- HTTPS: The website fully supports HTTPS, hence secure transfer of data.
- JavaScript Optimization: The site uses best practices in JavaScript optimization, such as minification and modern syntax for enhancing loading time and performance.

- Image Optimization: Images are served in new formats like WebP, and so the site speeds up without losing on quality.
- CSP (Content Security Policy): There is no CSP in place that is in enforcement mode. So, the site is vulnerable to XSS attacks. Recommendation: A strong header of CSP should be used in order to reduce the vulnerability.

4) SEO (Score: 92/100): The SEO score shows readiness of the platform for visibility and indexing by search engines. SEO is good, though there are areas that are not yet optimized.
   - Meta Tags: The webpage has a proper title, and meta description, meaning that it increases rank for search results and aids in indexing
   - Crawling : Search engines are enabled to crawl pages on this site efficiently for search presence.
   - Compatibility: The site makes good use of viewport meta tag along with responsive design.

robots.txt issues: It also faced issues with the robots.txt file, which could significantly limit crawl- ing by search engines. Recommendation: The robots.txt settings are correct and actually allow crawlers from search engines to have access to any pages that would get crawled on the site.

The website builder platform has done impressively in accessibility, best practices, and SEO ranking. There is still room for improvement on the performance optimization front, mainly load times, JavaScript execution, and image handling. The further optimizations for performance and user experience include applying other rec- ommendations, like loading critical images before page render, reducing JavaScript execution time, and enforcing a Content Security Policy. The optimizations recommended make the platform faster, interactive, and more secure for general use, thus ideally suited to a wide variety of users and search engines.

CONCLUSION

This platform is good at whatever it does on the surface and gives pointers for improvement, great scores in accessibility best practices that point to being all-inclusive of sectors in society and modern standards in the web. Error-free implemen- tation of ARIA roles, focus indicators, as well as responsive design tenets assure that the web experience here will be a level one for every slice of the users, becomes the basis for an inclusive system.Performance metrics alone have pointed to abundant avenues of possible optimization. Some very serious critical areas being optimized – LCP (largest contentful paint), Total Blocking Time, main thread work – shall improve speed to a satisfactory faster-load time.First, on- page SEO of the platform is well managed since meta tags are incorporated and the design is mobile-friendly and crawloable; the repair of the misconfigured robots.txt file will also provide much more search engine coverage to ensure it gets properly indexed. Lastly, the incorporation of Content Security Policy will fortify the security architecture of the site and thus protect against attacks on cross-site scripts.Thus, concluding the discussion, the platform will have a very good scope of delivering a secure, inclusive, and user-friendly experience.All the efforts to enhance performances, refinement in the setup of SEO, and a better security arrangement would promise the delivery of the extent of the platform. They'd not only provide an efficient experience to the user but also ensure long-term sustainability and competitiveness amid this ever- changing digital scene.

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MEDINSIGHT: A Secure Path to Predictive Healthcare

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ABSTRACT

The rapid digitization of healthcare has brought forth the demand for safe, efficient, and intelligent systems that can manage medical records while ensuring data privacy. In this paper, we introduce an innovative healthcare software solution that utilizes advanced encryption and hashing techniques to securely store medical records and Optical Character Recognition (OCR) to digitize medical reports such as blood test reports. Instead of using traditional machine learning models, the system utilizes LLaMA, a robust Large Language Model (LLM), to extract meaningful information from medical text. The solution offers multiple features, including health status assessment, trend analysis, and predictive insights to allow users to make competent healthcare decisions. The solution also offers personalized lifestyle recommendations for preventive healthcare based on extracted medical data. Utilizing SHA-256 hashing, and LLaMA LLM-based analysis, the system offers safe medical data management and real-time health insights. This research aims to bridge secure data handling with intelligent, AI-based healthcare analytics, making the digital healthcare ecosystem more reliable and efficient.

Index Terms—Natural Language Processing, Healthcare Data Security, Optical Character Recognition (OCR), LLaMA Large Language Model (LLM).

INTRODUCTION

The healthcare industry is experiencing rapid digital trans- formation, driven by the need to improve efficiency, accuracy, and accessibility in managing patient information. With the increasing reliance on electronic medical records (EMRs) and other digital tools, healthcare systems are generating massive volumes of sensitive data daily. This shift has created both opportunities and challenges, as effective data management is crucial to ensure the confidentiality, security, and usability of medical information. While traditional systems have served well for basic record-keeping, they often struggle to address emerging demands for advanced analytics, predictive capabil- ities, and robust data protection. The growing complexity of medical records, which often include unstructured data such as handwritten doctor's notes and diagnostic reports, further com- plicates the situation. Extracting meaningful insights from such data requires sophisticated tools capable of processing diverse formats while ensuring accuracy and reliability. This paper introduces a comprehensive software solution that combines encryption and hashing techniques for secure data storage with Optical Character Recognition (OCR) for analyzing medical documents. These technologies work in tandem to address the dual challenges of secure data management and intelligent analysis.

OCR technology plays a pivotal role in converting unstruc- tured medical records, such as blood test reports, prescriptions, and imaging results, into structured digital formats. This transformation enables healthcare systems to efficiently store, process, and analyze large volumes of data. Structured data is easier to interpret, facilitating tasks such as identifying abnormalities, tracking patient progress, and supporting clini- cal decision-making. OCR not only improves operational effi- ciency but also bridges the gap between traditional handwritten records and modern digital workflows.

Beyond document analysis, the system employs advanced analytics to deliver actionable insights. By assessing cur- rent health metrics and analyzing patterns in historical data, the platform identifies trends that may indicate the onset of health conditions. Predictive analytics is another critical feature, allowing healthcare providers to forecast potential health risks and design early intervention strategies. This Shift from reactive care to proactive, preventive healthcare has the potential to improve atient outcomes significantly while reducing the financial burden on healthcare systems. Data security is a cornerstone of the proposed solution. The integration of encryption and hashing techniques ensures that sensitive medical information is safeguarded against unautho- rized access and tampering. Encryption transforms patient data into a secure, unreadable format which is only accessible by authorized parties. Hashing, on the other hand, creates unique digital fingerprints for each record, ensuring that any unauthorized modification is immediately detectable. These measures are a sound foundation for protecting information, building patient trust and compliance with privacy laws like the General Data Protection Regulation (GDPR) and the Health Insurance Portability and Accountability Act (HIPAA).

The benefits of the system extend beyond data security and analysis. By leveraging insights from patient data, the solution delivers personalized lifestyle recommendations tailored to in- dividual health needs. These recommendations encompass var- ious aspects of preventive care, including diet, exercise, stress management, and sleep routines. Personalized guidance not only empowers individuals to make informed health choices but also fosters long-term behavioral changes that can improve overall quality of life. Moreover, the integration of secure data storage with intelligent analytics supports collaborative healthcare models. Securely sharing medical records across different providers enables coordinated care, reducing redun- dancies and improving treatment outcomes. This capability is especially important in cases involving chronic diseases or complex medical conditions, where multiple specialists need access to the same data. In addition to addressing immediate healthcare needs, the proposed system aligns with broader trends in digital health innovation. The increasing adoption of artificial intelligence (AI) and machine learning in healthcare complements the functionality of this solution, as predictive models can be further enhanced by integrating AI-driven insights. This creates opportunities for scaling the system and expanding its applications to new areas, such as population health management and remote patient monitoring.

In conclusion, this paper outlines a novel approach to health- care data management that combines encryption, hashing, and OCR technologies to create a secure and intelligent platform. By addressing the challenges of data security, usability, and analytics, the proposed solution bridges the gap between traditional healthcare practices and the demands of modern digital systems. Its capabilities in proactive care, secure record storage, and personalized health recommendations contribute to a more efficient and patient-centric healthcare ecosystem. As the healthcare industry continues to evolve, solutions like this will play a vital role in shaping the future of medical data management and improving health outcomes on a global scale.

RELATED WORKS

The integration of healthcare systems with secure data man- agement and intelligent analytics has become a significant area of focus due to the rapid digitization of medical records. As the volume of sensitive patient data continues to grow, researchers have proposed various methods to address the challenges of protecting this information while enabling its meaningful use. This section explores prior work related to data security, Optical Character Recognition (OCR), predictive analytics, and personalized healthcare, which collectively form the foun- dation for the proposed system.

[1]. This study thoroughly investigates the integration of the Internet of Things (IoT) and Artificial Intelligence (AI) within the healthcare sector, with a particular focus on Artificial Intelligence of Things (AIoT). The authors begin by proposing a comprehensive architectural framework for AIoT in healthcare, which includes sensors, devices, advanced communication technologies, and AI across various layers. The paper then examines recent advancements related to each component of this architecture, identifying key technologies, challenges, and opportunities specific to healthcare applications. To demonstrate the practical potential of AIoT, the authors highlight several real-world use cases. In conclusion, the research offers insights into future research directions, providing valuable guidance for both researchers and practitioners looking to further develop AIoT applications in healthcare.

[2]. In this study, the authors perform an extensive exami- nation of the application of Blockchain (BC) and Artificial Intelligence (AI) in the healthcare industry. While keeping in view the standalone potential of each technology, the study explores their synergy potential. The authors categorize the studied research into two broad frameworks: application-based and AI-training paradigm-based. The categorization presents an overt perspective of the various forms in which BC and AI are integrated in healthcare. The review presents the universal application of Blockchain as a secure database for AI models and explains the need for supervised learning and federated learning paradigms for decentralized and secure AI training. The authors also introduce a list of tools used in the integrated systems, presenting insightful analysis into the actual deployment of BC-AI solutions in healthcare.

[3]. This paper solves the critical issue of secure storage and sharing of Personal Health Records (PHRs) in the Internet of Medical Things (IoMT) environment. Identifying that PHRs are susceptible to attacks, the authors propose a new PHR sharing method with high efficiency and practicability as its focus. Their method employs searchable symmetric en- cryption, blockchain, and decentralized storage infrastructure IPFS to provide PHR confidentiality, correctness of the search results, and long-term security. The authors provide tight formal security proofs to ensure that their solution is secure and conduct large-scale experimental experiments to ensure its practicability and usability in real IoMT environments.

[4]. This study addresses the challenges associated with op- tical character recognition (OCR) in Industrial Internet of Things (IIoT) environments, where adverse conditions often affect the accuracy of text extraction. To overcome these issues, the authors introduce a novel two-stage deep learn- ing model called OCR-Diff. In the first stage, they use a customized conditional U-Net, pretrained alongside a feature extractor through a forward diffusion process, to improve the quality of low-resolution text images. In the

second stage, these pretrained components are fine-tuned together with a standard text recognizer to achieve accurate text recognition. Experimental results on the TextZoom dataset demonstrate the superior performance of the OCR-Diff framework in challenging IIoT scenarios.

[5]. This study addresses a key limitation in current AI- based patient readmission prediction models: while they can assess risk and identify important factors, they fail to provide actionable recommendations for mitigating the risk when it is deemed too high for safe discharge. To address this gap, the authors introduce a novel approach that utilizes historical medical records of similar patients. By analyzing these records, the method identifies optimal values for critical features that help reduce readmission risk. This enables the system to offer targeted recommendations for adjusting the current patient's condition to align with these optimal values, thus lowering the likelihood of rehospitalization. The authors assess the effectiveness of their method using the MIMIC-III dataset, showing that selecting similar historical cases according to specific criteria results in highly accurate (80 percentage) risk-reduction suggestions, outperforming random case selection. This approach has the potential to enhance discharge planning, reduce premature discharges, and lower healthcare costs related to avoidable rehospitalizations.

[6]. This study offers a thorough review of how Natural Language Processing (NLP) is applied in smart healthcare. The authors begin by exploring various NLP techniques and the NLP pipeline in the context of healthcare applications. They then review existing research, categorizing studies based on their use in different healthcare areas, such as clinical care, hospital management, personal health, public health, and drug development. The review emphasizes the significant role of NLP in tackling challenges posed by the COVID-19 pandemic and mental health issues. In conclusion, the authors highlight the limitations of current NLP-based healthcare solutions and suggest promising avenues for future research in this rapidly advancing field.

[7]. This manuscript tackles the pressing need for standard- ized methodologies in applying machine learning to diabetes management. Acknowledging the expanding research in this area but the inconsistency in approaches, the authors propose a set of consensus guidelines aimed at machine learning practitioners. These guidelines address a number of key points, including: 1) an overview of various algorithmic approaches and their benefits, with particular focus on clinical accuracy, interpretability, explainability, and personalization; 2) a de- tailed survey of features most commonly applied in machine learning for diabetes glucose control, and an open-source library for computation of these features and a template for dataset description; and 3) a survey of datasets available for training algorithms on, complemented with an online database of data sources. Through the presentation of these standardized guidelines, the authors hope to make machine learning models more effective, useful, and better overall for diabetes care to the advantage of engineers and data scientists alike.

[8]. This study explores the use of deep learning techniques for the early detection and classification of four primary cardiovascular conditions using ECG images. The authors investigate transfer learning with pre-trained models, such as SqueezeNet and AlexNet, and introduce a novel lightweight CNN architecture tailored for this purpose. Additionally, these models are employed as feature extractors for traditional machine learning algorithms. The proposed CNN model achieves a remarkable accuracy of 98.23 percentage, surpassing existing methods. Notably, when integrated as a feature extractor with the Na¨ıve Bayes algorithm, the model attains an even higher accuracy of 99.79percentage. This research underscores the potential of AI-driven approaches for early cardiovascu- lar disease identification and their applicability in IoT-based healthcare systems.

[9]. This study focuses on enhancing security in healthcare systems by introducing a novel framework that combines the Lattice-Based Access Control (LBAC) model with blockchain- based smart contracts. The proposed solution utilizes the strengths of both technologies to deliver robust, multi-level security for patient data. Access is strictly granted to autho- rized users based on predefined roles and clearance levels through LBAC, which establishes a structured hierarchy for data access. Simultaneously, smart contracts executed on the Ethereum Virtual Machine (EVM) enable secure, decentralized data management and authentication within the blockchain network. This integrated approach effectively addresses criti- cal security challenges, including data privacy, transparency, integrity, and hierarchical access control, and demonstrates improved performance over existing solutions.

PROPOSED SYSTEM

MEDINSIGHT is a cutting-edge software platform designed to empower individuals to take charge of their health. At the core of MEDINSIGHT lies a robust security framework that prioritizes data privacy and confidentiality. Utilizing advanced encryption and hashing techniques, the system safeguards sen- sitive medical information, ensuring that patient data remains secure and accessible only to authorized individuals. One of the central elements of MEDINSIGHT is a cutting-edge Optical Character Recognition (OCR) engine. It is capable of scanning and digitizing critical data from an enormous repository of medical records such as lab tests, prescriptions, and discharge notes. This data is the foundation for a very large set of health analytics functionality.

Leveraging advanced data analytics algorithms, MEDIN- SIGHT provides users with valuable insights into their health. The system meticulously analyzes the extracted data to:

- Assess current health status: Gain a comprehensive un- derstanding of the user's current health condition.
- Identify health trends: Uncover patterns and trends in the user's health data over time, enabling early detection of potential health concerns.
- Predict future health risks: Forecast potential future health risks based on the analyzed data, allowing for proactive health management strategies Building upon these insights, MEDINSIGHT offers personal- ized health recommendations tailored to individual needs and goals. These recommendations may include:
- Personalized dietary plans: Tailored nutritional guidance to support individual health needs and dietary restrictions.
- Customized exercise regimens: Recommendations for physical activity levels and exercise routines to improve overall fitness and well-being.
- Medication management support: Guidance on medica- tion adherence, potential drug interactions, and personal- ized reminders.

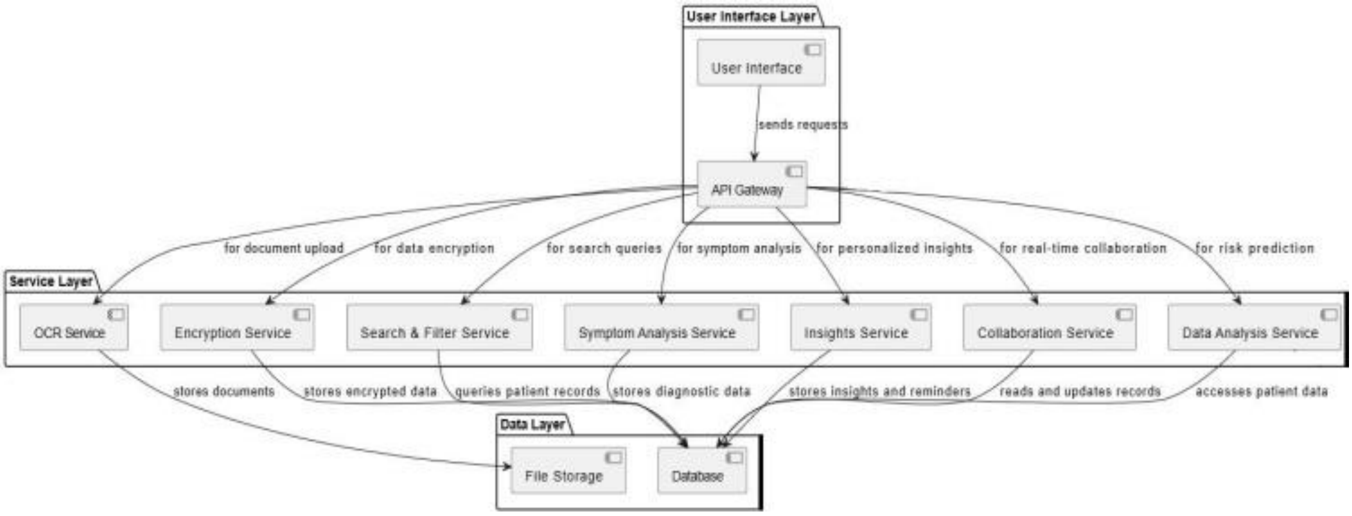

Fig. 1. Architecture diagram

MEDINSIGHT is designed to be inclusive and accessible to a diverse user population. The system supports multiple languages, ensuring that individuals from various linguistic backgrounds can effectively utilize its features. Furthermore, accessibility features are integrated to ensure that individuals with disabilities can easily interact with and benefit from the platform. By seamlessly integrating secure data storage, advanced data analytics, and personalized health recommen- dations, MEDINSIGHT empowers individuals to become ac- tive participants in their healthcare journey. This innovative platform aims to revolutionize personal health management by providing users with the tools and knowledge they need to make informed decisions about their health and well-being.

PERFORMANCE ANALYSIS

The performance analysis evaluates MedInsight based on key parameters such as system efficiency, data security, accu- racy, scalability, and real-time processing capabilities.

A. System Efficiency and Processing Speed

MedInsight is able to process huge amounts of medical documents with ease. The integrated OCR technology is able to capture lab reports, prescriptions, and other medical reports accurately, and convert them into a structured format for anal- ysis.

The LLaMA language model complements this by pro- cessing the extracted text, providing contextual information, and enabling rapid, intelligent responses MedInsight does not require the lengthy training times of traditional machine learning models, as it employs a pretrained LLM instead. It is thus faster and more responsive. The real-time processing capability enables healthcare professionals to be provided with analyzed data in real time, enabling the efficiency of decision- making.

B. Data Security and Privacy Protection

One of the most critical healthcare data management is- sues is patient confidentiality and data security. MedInsight addresses this challenge with the use of SHA-256 hashing to secure confidential medical information. SHA-256 hashing offers data integrity through the creation of an immutable, unchangeable fingerprint for every medical record that cannot be accessed or manipulated by intruders. Unlike blockchain security models, MedInsight is biased towards light-weight hashing algorithms in a bid to balance security with efficiency.

C. Accuracy and Reliability of LLaMA LLM

MedInsight does not use conventional machine learning models like Random Forest or Logistic Regression. Rather, it uses the natural language processing capabilities of LLaMA to read medical reports, infer insights, and generate personalized suggestions. The accuracy of the system depends on the quality of the text extracted, relevance of medical jargon, and proper interpretation of context by the LLM. The system can support health trend analysis, risk detection at an early stage, and personalized lifestyle recommendations based on the patient's history. In contrast to ML models trained on labeled data, MedInsight's LLM-based solution supports adaptive, conver- sational interfaces, making healthcare insights more intuitive and user-friendly.

D. Scalability and Real-Time Performance

MedInsight is extremely scalable and can handle growing medical documents with ease without any form of delay. Since MedInsight is not trained on available data, there is no need for continuous retraining, which gives it faster responsiveness in live healthcare settings. The real-time processing capability allows physicians, patients, and health workers to obtain instant feedback, enabling them to respond faster. The system is compatible with more than one language, which enhances its accessibility feature and makes it highly suitable for universal healthcare use.

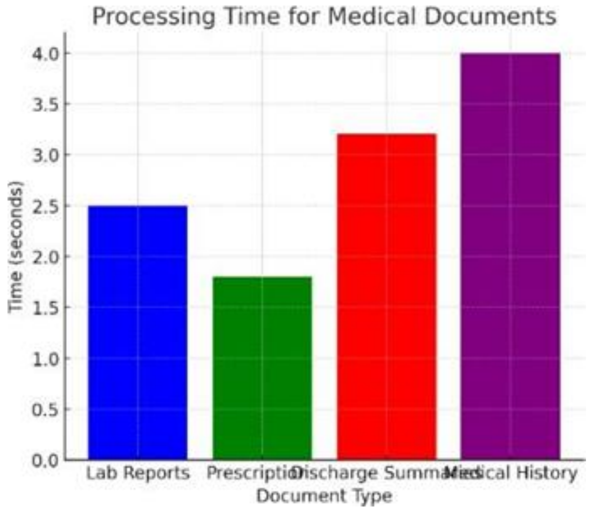

Fig. 2. Processing time for medical documents

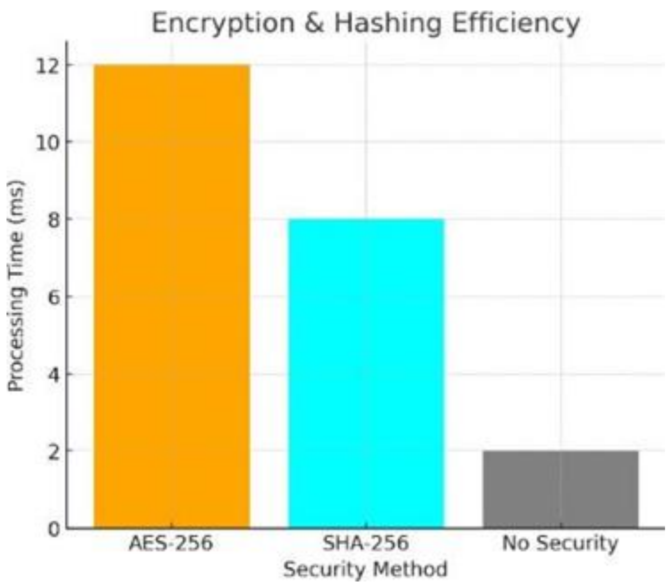

Fig. 3. Encryption and Hashing Efficiency

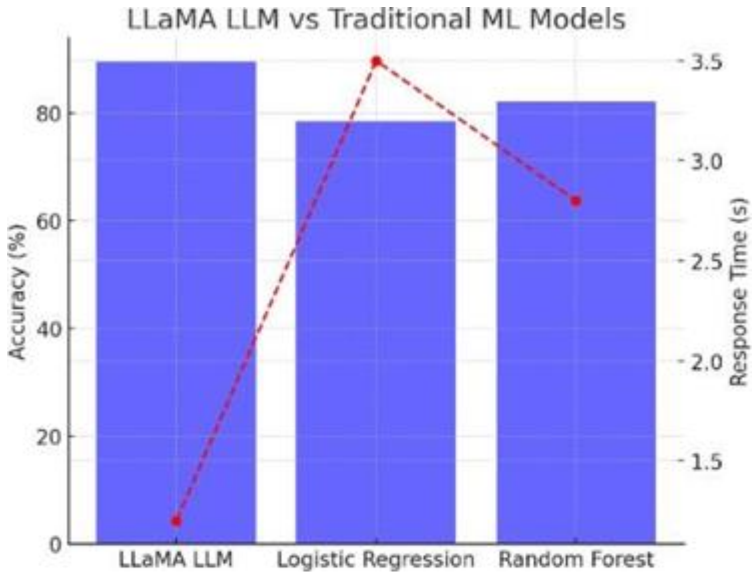

Fig. 4. LLaMa vs Traditional Models

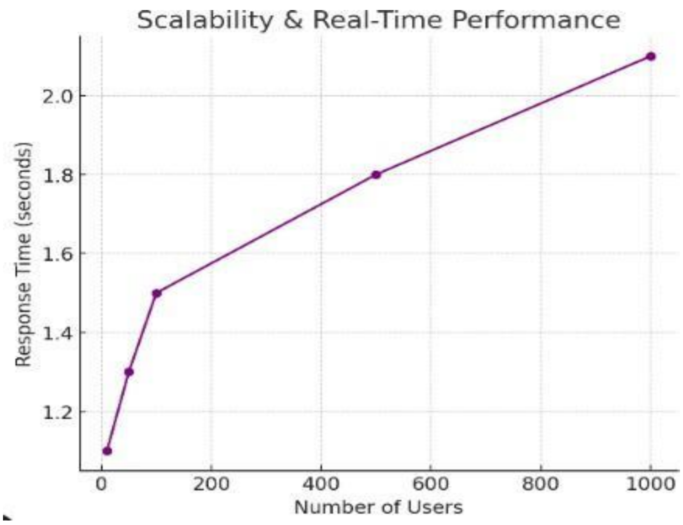

Fig. 5. Scalability and Realtime Performance

CONCLUSION

In conclusion, the proposed project advances healthcare data management by integrating patient record digitization, hashing, encryption, and machine learning analytics. Digi- tizing records through Optical Character Recognition (OCR) improves accessibility and creates a structured dataset for anal- ysis. Hashing and encryption ensure data security and privacy, safeguarding against breaches and unauthorized access while building trust among patients and providers. Machine learn- ing models enable proactive risk prediction and personalized treatment recommendations, enhancing decision-making and patient outcomes. Advanced search and filtering streamline data retrieval, while real-time data sharing improves team collaboration for responsive and coordinated care. This project lays the foundation for a secure, efficient, and personalized healthcare system, driving innovation in patient care and management.

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A Hybrid Predictive System for Identifying Terrain Anomalies and Localizing Objects in Landslide-Affected Areas

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ABSTRACT

Landslide-stricken areas have a twofold problem: forecasting disaster vulnerability and finding buried vehicles in the aftermath of disasters. Both are complicated by dynamic terrain situations and limited remote real-time information, which usually leads to untimely or ineffective responses. Existing practices lack a unified system for effectively addressing both post-disaster vulnerability prediction and vehicle detection. To address these challenges, this project suggests a dual-task strategy based on high-level machine learning models. It initially uses XGBoost to forecast landslide susceptibility in an area given environmental conditions for proactive risk management. It subsequently uses reinforcement learning combined with physical models to find vehicles stuck in debris to aid post-disaster rescue efforts. Efficiency of the system will be measured through the potential of the system to predict accurate and timely landslide susceptibility, in addition to ideal vehicle localization during disaster situations. Integrating both processes, the system will ensure optimization of disaster management processes as well as further optimizing rescue efforts.

Index Terms—Reinforcement Learning, XGBoost, Machine Learning, Landslide Susceptability Prediction, Object Localiza- tion

INTRODUCTION

Landslides are some of the most catastrophic natural dis- asters, which cause widespread loss of lives, infrastructure destruction, and complete interruptions of transport and vital services. The disastrous event results from the movement of debris, soil, and rock in a downward direction, frequently instigated by nature in the form of excessive rains, earth- quakes, and volcanic eruptions or induced by humans in the process of deforestation and indiscriminate development in risky land areas. Steeply sloping areas, unstable terrain, and high rates of rainfall are most susceptible, and landslides are a recurring problem in mountainous and hilly terrain globally. Aside from the direct damage, landslides make roads, bridges, and other critical infrastructure impassable, severing communication links and slowing relief. Also, the difficulty of finding cars hidden under rubble or undertaking rescue efforts in inaccessible areas highlights the compelling necessity for new technologies capable of addressing both prediction and recovery after a disaster.

Despite growing awareness of landslide hazards and the development of new technologies, it is tough to tackle both the twin problem of landslide forecasting and post-occurrence recovery. Landslide forecasting is because the variables con- sidered are multifaceted and time-dependent, e.g., rain in- tensity, slope gradient, earth material, and land use. The variables depend on each other and are exceedingly variable in time and space so that it proves hard for routine models to correctly predict. Although the pre-disaster mitigation process is complex, post-disaster recovery is not easy either. It is time-consuming and hard to locate vehicles that are buried in the debris, which is often hindered by the unorganized and irregular distribution of landslide debris fields. Current practices are typically disconnected, addressing prediction or recovery separately without taking into account their interac- tion. The lack of integration extends interventions and leads to suboptimal solutions, putting lives and resources at risk even more. The complexity and scope of these problems call for an integrated and sustainable solution that will address both workloads simultaneously.

The root issue is the lack of an integrated system that reconciles landslide vulnerability prediction and vehicle detection in debris. Current predictions are fixed threshold-based or region-based models that cannot react to actual environmental changes and therefore make delayed or erroneous predictions. Likewise, vehicle detection following a disaster also usually depends on manual operations or limited technology and therefore results in inefficiency and inaccuracies. These issues are even more complicated in high-risk zones with bad geog- raphy and poor infrastructure. Fragmentation here makes the distribution of resources and rescue prioritization even more challenging, highlighting the need for an advanced integrated system. This would bridge the forecasting to recovery gap, greatly minimizing response time, improving resource allocation, and improving the efficiency of disaster management.

In order to overcome these challenges, this project puts for- ward a dual-task system that incorporates landslide forecasting with debris vehicle detection. The first task employs XGBoost, a highly efficient machine learning model, for the prediction of landslide areas based on environmental factors like rainfall, soil stability, and green cover. This preventive measure allows for early preventive action like evacuation or strengthening of infrastructure. The second task uses reinforcement learning, a self-learning machine learning technique, to identify vehicles under rubble. By mimicking wise search routines and taking physical constraints into account, reinforcement learning im- proves search efficiency and effectiveness in adverse terrain. These tasks constituting an integrated framework integrate accurate prediction ability with efficient post-disaster recovery procedures.

The integrated system is a major breakthrough in overcom- ing the twin challenges of landslide management by closing the gap between prediction and recovery. The system will provide reliable vulnerability ratings for areas prone to land- slides and allow for the detection of vehicles in debris fields with increased speed and accuracy. By shortening response times, reducing casualties, and maximizing resource efficiency in rescue operations, the project seeks to help advance smarter, technology-based disaster management strategies that reduce landslide effects, save lives, and preserve key infrastructure in high-risk areas.

RELATED WORKS

According to ”Landslide Susceptibility Mapping Consid- ering Landslide Local-Global Features Based on CNN and Transformer” by Zhao, Z. et al.[1] introduces the novel CNN- transformer local-global features extraction network designed to leverage the strengths of both convolutional neural networks (CNNs) and transformers. The model efficiently fuses multi- source geospatial data local features like edges and textures, along with global features such as size and spatial distribution. A total of nine landslide conditioning factors - elevation, slope, lithology, and precipitation are analyzed in order to establish a comprehensive landslide dataset for two different areas of China, namely the Three Gorges Reservoir and the Jiuzhaigou regions. The data were processed and divided into three subsets: training, validation, and testing, while the proposed CTLGNet model was compared with five advanced models: CNN, ResNet, DenseNet, ViT, and FrIT, through several evaluation metrics. Overall, CTLGNet showed a better performance than other models with an accuracy of 0.9817 and F1-score of 0.9693 in the study areas. Integration of local detail capture by CNN and the global context extraction by transformer resulted in notable advancements in landslide localization and spatial prediction. CTLGNet also displayed superior computational efficiency with fewer parameters and floating-point operations compared to the transformer-based counterparts. Cross-validation establishes the robustness of CTLGNet, further underlining its applicability in complex geologic settings. Future work will focus on improving the quality of data through the use of multimodal remote sensing and exploring new architectures for further LSM accuracy. The framework demonstrates significant potential in advancing LSM and helping to reduce disaster risk.

According to ”The Displacement Analysis and Prediction of a Creeping Ancient Landslide at Suoertou, Zhouqu County, China” by Yumin Fang et al.[2] analyzes the displacement features and mechanisms of the creeping ancient Suoertou landslide in Zhouqu County, China, based on SBAS-InSAR data from 2018 to 2023. Major drivers such as tectonic activity, river erosion, and precipitation have resulted in a complex displacement mechanism which forms a vicious cycle of deformation. Human activities contribute to further instability. The GRU prediction model was adopted, using improved displacement characteristics and mechanisms, to predict trends for June 2023 up to June 2024. Predictions suggest fluctuating increases in displacement with abnormal acceleration in the key areas of the slope’s upper regions. The GRU model showed high accuracy compared to traditional approaches, with minimal errors and a precise trend identification. This study points out the necessity of combining displacement mon- itoring with environmental analysis to understand and predict landslide behavior. This approach provides critical insights for disaster mitigation, offering a framework for efficient landslide management and risk reduction in geologically active regions. Future research will include more comprehensive factors and higher-resolution data to further improve the accuracy of prediction.

According to ”LCFSTE: Landslide Conditioning Factors and Swin Transformer Ensemble for Landslide Susceptibility Assessment” by Chen T. et al. [3], LCFSTE was proposed to evaluate landslide susceptibility (LSA). This method addresses issues such as sparse and imbalanced data by integrating Land- slide Conditioning Factors (LCFs) with the Swin Transformer, which possesses powerful feature extraction. The model was validated in Jiuzhaigou County, China, with a dataset of 11 LCFs and landslide data, which was tested for multicollinearity and factor analysis. The LCFSTE model was then compared to four existing deep learning models based on seven per- formance metrics. The performance was such that LCFSTE ranked the highest in six out of seven metrics, indicating its capability to enhance the accuracy and reliability of LSA.

According to ”Landslide Inventory Mapping Based on Independent Component Analysis and UNet3+: A Case of Jiuzhaigou, China” by Xuerong Chen et al.[4] presents the multifeatured Independent Component Analysis (ICA) UNet3+ framework for landslide inventory mapping (LIM) with the challenges of complex backgrounds and multiscale features . It integrates the pre- and post-earthquake optical image data by deriving key features such as NDVI and GLCM metrics and enhances them with ICA. ICA improves interclass heterogeneity and intraclass homogeneity, reduces noise, and enhances classification accuracy. The UNet3+ model includes these features with deep supervision and multiscale connections to map landslides effectively. Validated on post-earthquake landslide data in Jiuzhaigou, China, MICUNet3+ outperformed traditional post-event image methods significantly, improving recall, F1-score, and mIoU metrics. The results show its potential for accurate, large-scale landslide identification under complex conditions, and future work will explore higher-resolution data and additional imaging technologies.

According to ”A new approach based on Balancing Composite Motion Optimization and Deep Neural Networks for spatial prediction of landslides at tropical cyclone areas” by Tuan, T.A. et al.[5] the BCMO-DeepNeuralNets ,is a new model that uses Balancing Composite Motion Optimization with Deep Neural Networks to enhance the prediction of landslides by combining ten different factors, including slope, geology, and rainfall, to outline high-risk areas in central Vietnam. The methodology outperforms traditional machine learning methods, showing detailed susceptibility maps for disaster preparedness and urban planning. This approach provides a comprehensive framework for incorporating geo-environmental and climatic data, advancing landslide risk reduction efforts significantly.

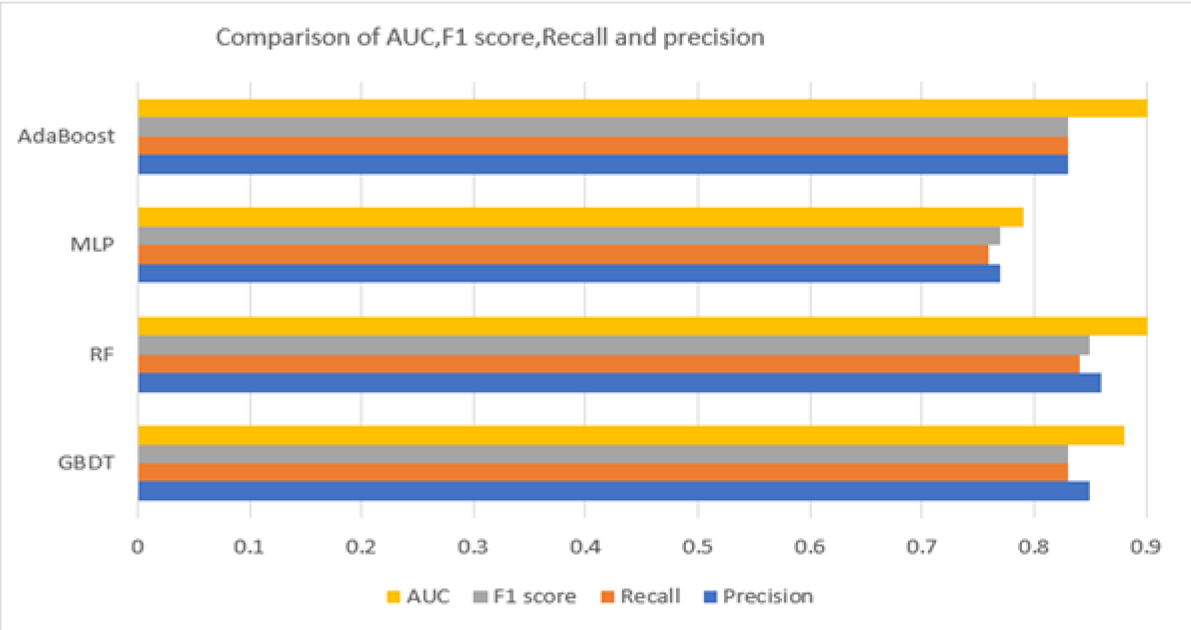

Fig. 1. Comparison Of Precision,Recall,F1-Score,AUC

Based on ”Landslide Susceptibility Mapping and Driving Mechanisms in a Vulnerable Region Based on Multiple Ma- chine Learning Models” by Yu H. et al. [6], the present re-search investigates landslide susceptibility in an at-risk region based on machine learning models including Random For- est (RF), Adaptive Boosting (AdaBoost), Gradient Boosting Decision Tree (GBDT), and Multilayer Perceptron (MLP). The authors examined 13 landslide conditioning factors and obtained F1-scores of as much as 0.85 and AUC values of 0.92, with RF yielding the best results. Spatial predictions show that 40% of the region is under high or very high landslide risk, with population density, distance to roads, and amplitude of relief being the major contributing factors.Comparison of precision,recall,AUC and F1-Score is given in Fig.1. These results are highly useful for site-specific disaster mitigation measures.

According to”Machine learning and artificial intelligence models development in rainfall-induced landslide prediction” by Haesa H et al.[7] explores the development of machine learning (ML) and artificial intelligence

(AI) models designed to predict rainfall-induced landslides in Indonesia. Using rain- fall data and records of landslide events, researchers compared two approaches: one that relied on raw data and another that involved preprocessing techniques like log-transformation and principal component analysis. The second approach outper- formed the first. In the raw data method, the generalized linear model delivered the best results, whereas deep learning proved most effective with the preprocessed data, achieving high accuracy in landslide prediction. These findings underscore the potential of advanced ML and AI methods in building reliable early warning systems for disaster mitigation.

According to”Landslide susceptibility prediction using ma- chine learning methods: a case study of landslides in the Yinghu Lake Basin in Shaanxi” by Ma, S et al.[8] examines landslide susceptibility prediction (LSP) in the Yinghu Lake Basin, Shaanxi, using machine learning models and landslide inventory data. Key aspects analyzed included data integrity, the selection of non-landslide samples, and the choice of pre- dictive models. Random forest and artificial neural networks emerged as highly effective methods for predicting landslide susceptibility, with supervised models outperforming unsuper- vised approaches such as K-means. The findings highlight the critical role of comprehensive landslide inventories and strong modeling strategies in enhancing regional risk management efforts.

As per ”Improving Landslide Prediction by Computer Vi- sion and Deep Learning” by Guerrero-Rodriguez B. et al. [9], this research improves landslide prediction using deep learning and computer vision. Researchers created a new image dataset with a confirmed and current landslide inventory, and they concentrated on landslide crown zones and their close surroundings for better data representation. A convolutional neural network (CNN) was trained on this data, with a remark- able average accuracy of 97.48%. The model was then applied to create a susceptibility map for the Aloag-Santo Domingo highway in Ecuador. This new method offers a robust tool for risk management and prevention, with greatly enhanced prediction accuracy over conventional methods.

According to”A Detection Approach for Floating Debris Using Ground Images Based on Deep Learning,” by Qiao, G. et al.[10] address the significant challenge of detecting floating debris in surface waters, a problem that impacts both environmental aesthetics and water quality. A novel floating debris detection method improves YOLOv5 with a coordinate attention mechanism and a bidirectional feature pyramid network, which can overcome challenges such as variable lighting and small object sizes. The model improves fine-grained spatial feature extraction for higher accuracy and robustness in detecting small, dense debris using the SWFD dataset. Its lightweight design enables deployment on resource-constrained devices for real-time environmental monitoring. The experimental results have been found to outperform traditional methods, advancing intelligent water management systems and automated cleanup technologies.

According to ”Landslide risk prediction model using an attention-based temporal convolutional network connected to a recurrent neural network” by Zhang, D. et al.[11] the model for assessing and predicting landslide risks is based on an attention-based TCN integrated into an RNN. From sensor data, the TOPSIS-Entropy method computes landslide instability margins (LIMs), which indicate the likelihood of landslide occurrence.The two newly proposed architectures are TCN-Attn-RNN and RNN-Attn-TCN . The use of encoder-decoder architectures and the application of mechanisms of attention improved prediction accuracy. In quantitative terms, the proposed models obtained better results than other methods as measured by RMSE and MAE, establishing their performance in predicting complicated landslide time series data. The models still require a massive dataset to train and are very hard to deploy in real time. The future plan is aimed at circumventing this limitation and incorporating diverse sensor data into risk assessment.

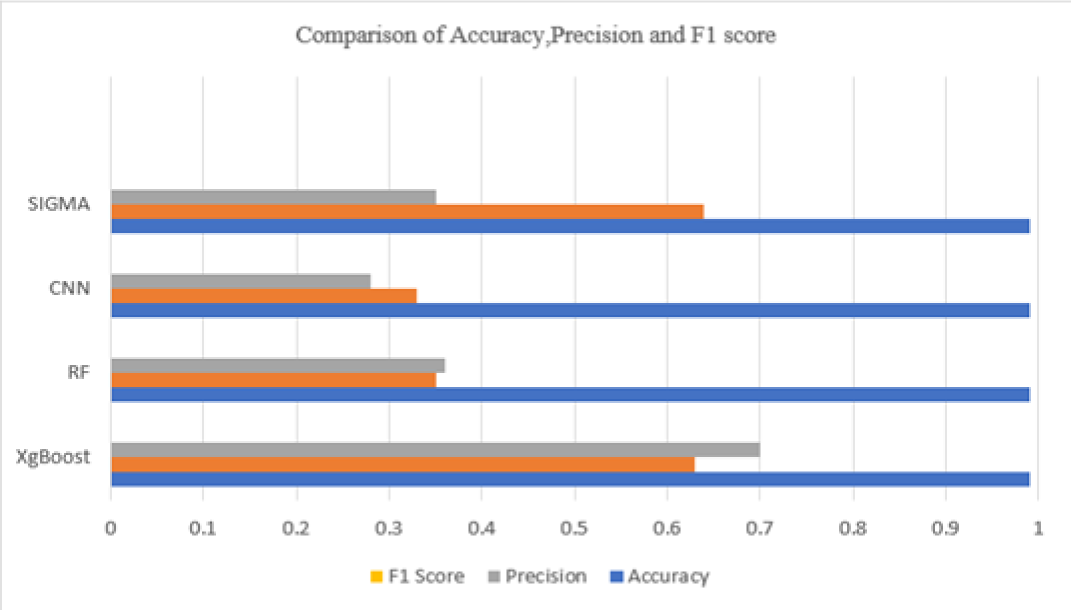

Fig. 2. Comparison Of Precision,Recall,F1-Score

According to ”Predicting and Understanding Landslide Events With Explainable AI” by Collini, E. et al.[12] develops a short-term forecasting model for rainfall-induced landslides, allowing for one-day-ahead forecasts in order to further improve early warning systems. This study combines machine learning with explainable AI in the use of static factors, such as terrain, and real-time features, such as rainfall and river levels, combined with data from the Metropolitan City of Flo- rence. The tested models include Random Forest, XGBoost, CNN, and Autoencoders, where the XGBoost achieved the highest accuracy in predictions over the SIGMA algorithm. Analysis using SHAP showed three-day cumulative rainfall and groundwater levels as major predictors. The results reflect the effectiveness of explainable AI for early warnings and practical application on the Snap4City platform for disaster management.Comparison of precision,recall and F1-Score is given in Fig.2.

According to ”Space Debris Detection and Positioning Technology Based on Multiple Star Trackers” by Liu M. et al. [13], in this research, a method of space debris detection and location with a constellation of multi-star trackers on satellites is presented. In contrast to ground-based radar and optical observation, the method here applies space-based systems independent of weather or lighting. A new algorithm is incor- porated in the star trackers to differentiate debris according to sunlight reflection as opposed to starlight. The technique converts star tracker angular measurements into spatial coor- dinates by utilizing a Gaussian MMSE correction algorithm to enhance precision. Simulations proved the technique to detect and track space debris orbits, which shows its capability to improve space situational awareness by making use of current satellite infrastructure.

According to ”Landslide susceptibility mapping with deep learning algorithms” by Habumugisha, J.M et al.[14] the deep learning algorithms used for the purpose of landslide susceptibility mapping in Maoxian County, Sichuan, China were Convolutional Neural Networks, Deep Neural Networks, Long Short-Term Memory networks, and Recurrent Neural Networks. From 12 predisposing factors, the DNN algorithm outscored others by an AUC accuracy of 87.3%. The major findings are the key roles of slope, rainfall, and proximity to faults in influencing landslide risks. The generated maps provide vital insights for sustainable land-use planning and disaster mitigation strategies.

METHODOLOGY

The proposed methodology addresses two key aspects of landslide management: predicting a location's vulnerability to landslides and determining the distance traveled by a vehicle buried under landslide debris. By combining the strengths of XGBoost algorithm and reinforcement learning, this approach provides a comprehensive solution for both predictive analysis and real-time response.

The first half of the methodology centers on forecasting landslide risk based on the XGBoost algorithm. The process starts with gathering and preprocessing a dataset that includes critical factors influencing landslides, such as slope angle, type of soil, land cover, rain intensity, vegetation and geological characteristics. Preprocessing the dataset is essential and involves encoding categorical data. These steps ensure that the data is clean, consistent, and ready for modeling.

The XGBoost algorithm is used to train a model for landslide prediction. XGBoost, which is an improved gradient boosting library, is the best fit for this purpose since it can handle imbalanced data, identify non-linear patterns, and give high accuracy. Past data are utilized to train the model, wherein landslide cases are known, so that it can learn to identify patterns between features and landslide occurrences. Hyperpa- rameter tuning is done during training to obtain optimization of the model's performance by modifying parameters such as learning rate, max-Maximum depth, and the number of esti- mators. Support, precision, recall, and F1-score are utilized to evaluate the model so that makes correct landslide predictions while minimizing false positives and false negatives.

The second half of the methodology deals with the detection of a buried vehicle under landslide debris and estimation of its distance traveled. The problem is formulated as a rein- forcement learning (RL) environment where the interactions between the vehicle, debris, and slope conditions. The environ- ment is initialized with such parameters as slope angle, vehicle weight, debris density, and debris volume. Initial vehicle and debris positions are established, and the system calculates their interaction based on gravity and applied forces.

Within this RL setup, the agent (the vehicle) learns to optimize its movement in a process of trial and error. The observation space consists of the postions of vehicle and debris in x and y coordinates, whereas the action space is the forces exerted on the debris in the x and y directions. A reward function guides the agent's learning, rewarding progress toward locating the vehicle and penalizing ineffective movements hindered by debris. The agent's policy is optimized using Proximal Policy Optimization (PPO), a widely used RL algorithm known for its efficiency and stability. During training, the agent interacts with the environment, iteratively updating its policy to maximize cumulative rewards. Over time, the agent learns patterns in how debris moves and how external forces affect the buried vehicle.

Once trained, the RL model is evaluated to ensure its ability to simulate realistic scenarios and accurately calculate the distance traveled by the vehicle. The model predicts the vehicle's movement from its initial position, providing critical information for rescue operations. The vehicular estimated location guides rescuers to direct their efforts to particular regions, and hence save time and improve chances for recovery success.

Combining these two tasks, the methodology constructs a comprehensive system of landslide prediction and rescue. XGBoost-based landslide prediction model issues early warn- ings by detecting regions with high possibilities of landslid- ing.This offers the potential for preventive action, including evacuations or engineerings, to halt potential damage. While the reinforcement learning model is helping in post-landslide recovery operations by estimating the location of trapped vehicles beneath rubble, allowing successful rescue operations. These parts combined illustrate the capability of artificial intelligence in coping with natural disasters successfully.

With the forecasting knowledge complemented with working solutions, such a strategy continues to be an end-to-end solution to forestalling the effects of landslides and improving disaster management.

MACHINE LEARNING MODEL

A. Dataset

The dataset utilized by us in carrying out landslide pre- diction is landslide engineered features.csv. It has 10,864 records and 19 features, providing an extensive framework for landslide vulnerability analysis.

1) Target Variable:
    a) Label: Binary classification showing whether a region is vulnerable to landslides (0 for no risk, 1 for vulnerable).
2) Environmental Features:
    a) Elevation: elevation center and elevation minmax dif- ference are measures of the height and the range of elevation.
    b) Slope Metrics: slope center and slope difference pct are slope steepness and slope change indicators, when com- puting terrain stability.
    c) Aspect Metrics: aspect NSEW, aspect span, and as- pect sum span 9cells represent direction or bearing and extent of terrain.
3) Curvature Analysis:
    a) Planar Curvature: placurv center below diff and placurv signs 8 are surficial indications of water flow patterns and potential erosion.
    b) Profile Curvature: procurv signs 8 and procurv top vs 2bottom examine vertical curvature, which gives information on water flow and surface stability.
4) Land Susceptibility and Soil: lsfactor sum center 1be- low: Maps soil erodibility factors. twi center and twi 25mean: Wetness terrain indices indicating water saturation levels, significant in landslide hazard zonation.
5) Geology and Surface Stability: Establish dominant ge- ological compositions. sdoif center: Indicates surface deformation, allowing the eval- uation of terrain stability.

This data elegantly combines geological, hydrological, and topographical conditions, thereby creating a solid foundation for landslide vulnerability forecasting.

B. XGBoost

XGBoost, or Extreme Gradient Boosting, is an extremely efficient machine learning algorithm for structured and tabular data. It is an improvement over the traditional gradient boost- ing in that it builds an ensemble of decision trees where each tree seeks to correct the mistakes of its ancestors. XGBoost adds a number of improvements, including regularization methods to avoid overfitting, parallel processing for increased computational efficiency, and efficient management of missing values. Its support for multiple objective functions renders it suitable for applications such as regression, classification , and ranking, and thus a favorite among machine learning competitions and real-world deployments.

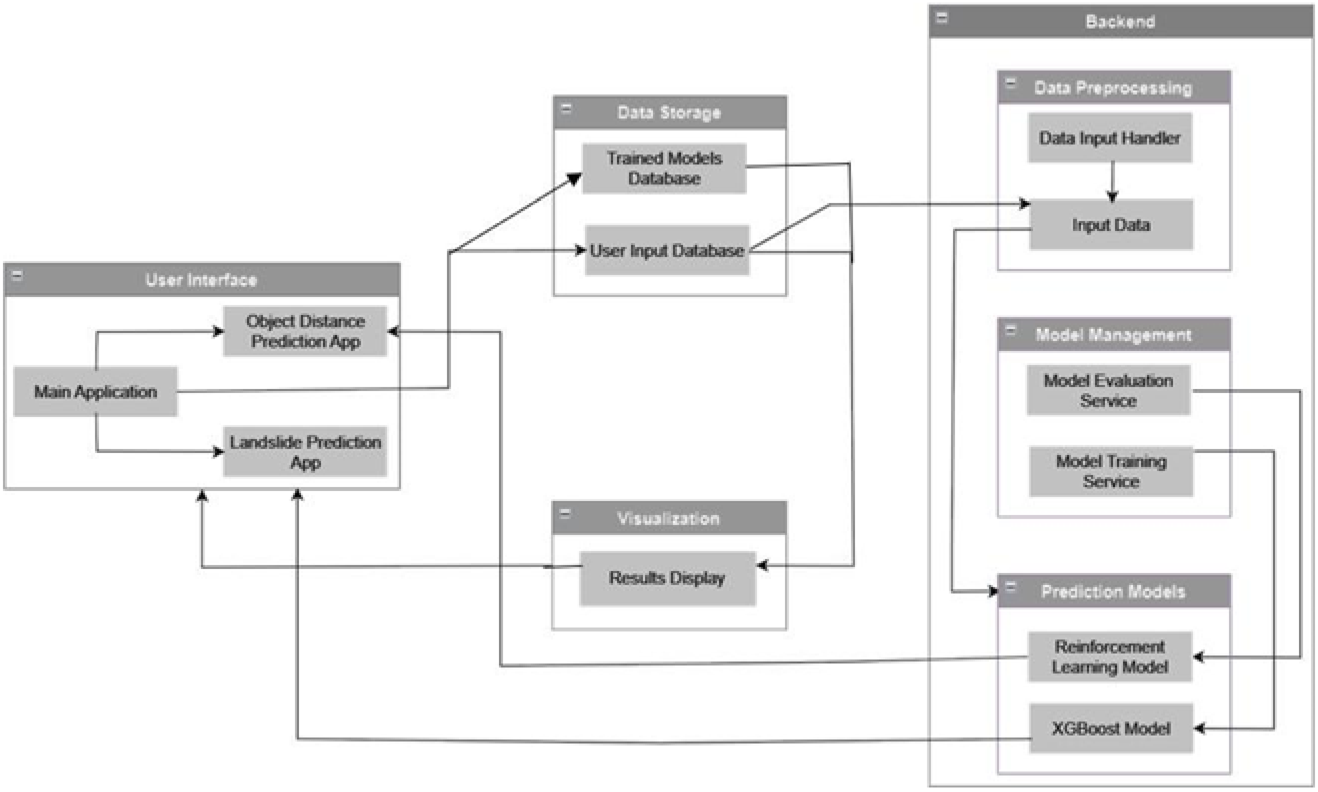

Fig. 3. Architecture diagram showing the proposed system.

The algorithm optimizes a loss function iteratively by adding trees. The trees are trained on the residual errors of previous iterations, successively decreasing the loss and en- hancing predictions. Overfitting is avoided by using techniques such as early stopping, learning rate tuning, and regularization parameters. In addition, it uses a fast split-finding algorithm to build trees efficiently and also exploits sparsity-aware com- putations to handle missing or zeros. These advanced features enable XGBoost to recognize intricate data patterns, which means it is possible to make the right predictions even on difficult datasets.

XGBoost is used centrally in the prediction of landslide vulnerability in areas based on environmental and geolog- ical properties. The first step is to preprocess the dataset where conversion categorical variables like slope and aspect to numerical takes place. The transformations are XGBoost model friendly, which requires numerical input to perform computation on. After preprocessing, the dataset is divided into training and test sets for training the model and checking its performance over new data.

XGBoost constructs an ensemble of decision trees in train- ing on the training set. Each tree constructs patterns in the fea- tures—such as the relationship between slope, elevation, and geology—to predict landslide susceptibility. Refining succes- sively on the predictions of previous trees, XGBoost minimizes errors and builds a robust predictive model. The model is also validated using cross-validation, where it is trained and tested on different data splits to provide stable performance.

For enhancing the accuracy of the model, hyperparameter tuning is run. The parameters such as the number of trees, depth of trees, and learning rate are tuned in order to derive the optimal predictive accuracy. It is done through experimentation with all possible combinations of parameters and discovery of the top-performing combination of parameters from per- formance metrics like area under ROC curve. After fine- tuning, the model is saved and incorporated into an application where users can provide feature data and get predictions. The application preprocesses user input to conform to the model’s form and applies the trained XGBoost model to calculate landslide vulnerability.

At prediction time, XGBoost considers the input charac- teristics and estimates probabilities for every class: landslide or no landslide. For example, when the attributes like steep slopes, high elevation gradients, and bad geology suggest high vulnerability, the model puts the area at risk. This real- time analysis enables the users to detect vulnerable areas and take preemptive action. XGBoost's ability to learn subtle interactions among features and update with new information makes it a useful tool for landslide hazard management.

C. Reinforcement Learning

Reinforcement Learning (RL) is a machine learning methodology in which an agent learns to act by interacting with an environment. As opposed to supervised learning on labeled data, RL is built on a cycle of feedback of actions and rewards. The agent perceives the environment, performs actions, and receives feedback as incentives or punishments. With time, it improves its behavior in order to maximize cumulative rewards, learning best strategies to fulfill its goals. This renders RL perfectly suited for sequential decision- making tasks with long-term consequences of actions.

The exploration vs. exploitation trade-off is an elementary principle in RL. Exploration consists of sampling novel actions to learn their results, while exploitation uses historical knowl- edge to select actions maximizing the rewards. Q-learning, DQN, and PPO are examples of RL algorithms exploiting this balance in a degree of iterations. The application of RL can be observed in fields such as robotics, autonomous vehicles, and video games, and resource allocation, where it is used to solve dynamic and intricate problems.

For the identification of a buried truck in landslide waste, RL is a crucial method of simulating the interaction among the truck, waste, and slope. The environment is modeled as a simulation with inputs such as slope angle, waste density, truck weight, and waste volume. These parameters influence the system's dynamics, such as how the truck moves through the debris when forces are applied.

The RL agent interacts with this environment by taking actions, such as applying forces to the truck in the x and y directions. Initially, the agent has no knowledge of the optimal strategy and explores the environment to learn how to navigate the debris. Each action updates the truck's position . The agent observes these changes in position as part of its state, which helps guide its future actions.

At the center of RL is the reward system. The environment provides feedback after every action. Here, rewards are based on the quality of the forces being applied to move the truck through the debris. Rewards are given for successful movement and sanctions are given if the truck cannot move or meets with a lot of resistance.This reward system encourages the agent to discover strategies that maximize the movement of the truck and clear obstacles made of debris.

The model also includes termination conditions, for instance when the debris is at the bottom of the slope, which is the end of an episode. These conditions keep the agent on the right track regarding realistic situations and increase learning efficiency. The goal is to have the agent learn a policy based on using the correct forces repetitively in order to correctly find the underground vehicle.

After training, the RL model can be used to simulate the movements of the truck in real-time. Having a pre-trained model, the agent predicts the best actions for the removal of the debris and estimates the cumulative distance covered by the truck while running the simulation. This distance, in meters, indicates the success of recovery The simulation also offers visual feedback, illustrating how the truck moves within the field of debris under the computed forces. This demonstrates RL's capability to address real-world problems that entail dynamic interactions and intricate decision-making.

IMPLEMENTATION

Implementation entails an exhaustive chain of connected steps, to perform two major tasks: prediction of landslide employing XGBoost and detection of vehicles from landslide debris by means of reinforcement learning.

A. Landslide Prediction Using XGBoost

1) Preprocessing of data: Starts with data preparation of raw dataset for analysis. Key features such as slope, elevation, geology, and other environmental factors are being loaded. Categorical features such as Aspect NSEW and Plan Curva- ture Signs 8 are being transformed to numerical values by using one-hot encoding with the get dummies() function of pandas so that it is compatible with the XGBoost model. The preprocessing guarantees the dataset to be clean, consistent, and model-ready.
2) Train and Test Data Split: Scikit-learn's train test split() function splits the preprocessed dataset into train and test subsets 90-10 split is performed. Training data is used to build the model, and test data tests its generalizability.
3) Model Trainingl: An XGBClassifier model is initialized and trained using the training set. Parameters such as scale pos weight address class imbalance, and eval metric are set as log loss to enhance classification performance. XGBoost builds decision trees sequentially with every tree learning from the mistakes of its predecessors. This ensemble method captures intricate patterns and improves predictions with each cycle.
4) Cross-Validation: To cross-validate the model's strong- ness, cross-validation is performed with the cross validate() function. A 10-fold split tests the model on various sub- sets, giving a complete performance evaluation. Measures such as the Area Under the Curve (AUC) score confirm the model's generalizability across datasets and minimizes overfitting threats.
5) Hyperparameter Tuning: Hyperparameter tuning is done by executing GridSearchCV(). The combination of parameters grid, consisting of n estimators, learning rate, and max depth, is used for testing. Optimization is done under the guidance of the AUC score so that efficient performance is achieved.
6) Selection and Saving the Best Model: The best- performed model, after hyperparameter tuning, is re-trained on the whole training set and saved using Joblib. This step finishes the model for deployment for reuse in real-time prediction without requiring further training.
7) Loading the Saved Model: At deployment time, the saved model is loaded using Joblib so that it can be used to make predictions. All the parameters derived and hyperpa- rameters are preserved for accurate and efficient operation.
8) Accepting User Inputs: Users may enter data manually or upload a CSV file. Manual input entails feature value Inputs such as slope and geology, and CSV uploads imported into DataFrames.
9) Accepting User Inputs: Users may enter data manually or upload a CSV file. Manual input entails feature value inputs such as slope and geology, and CSV uploads imported into DataFrames. Preprocessing activities like one-hot encoding and synchronization with the model's input format guarantee compatibility.
10) Making Predictions: The preprocessed inputs are passed into the model to label the data as "Landslide" or "No Landslide." Results are presented in an understandable format, offering actionable insights. For high-risk zones, users can initiate preventive actions to reduce potential damage.

B. Vehicle Detection in Landslide Debris Using Reinforce- ment Learning

1) Environment Initialization: An environment, Land- slideEnv, is created to simulate the truck-debris interaction on a slope. Slope angle, truck weight, debris density, and debris volume are parameters. Action space is the forces applied on the truck, and observation space tracks truck and debris positions.
2) Environment Reset: reset() function resets positions of truck's and debris's to initial positions and provides initial observations.
3) Environment Dynamics (Step Method): step() function determines new positions of truck and debris with reference to applied forces. Reward is approximated in relation to suc- cessful travel, and end conditions are verified. Observations, rewards, and episode status are returned to feed learning directly.
4) Environment Compliance Check: The environment's compliance with Gym needs is checked with use of the check env() function, and simulation is retained in expected structures and logic.
5) Monitoring the Environment: A Monitor wrapper records the environment's performance and makes debugging easier.
6) Vectorized Environment Creation: The DummyVecEnv wrapper is used to enable vectorized training, which supports stable baselines such as PPO.
7) Model Training: A Proximal Policy Optimization (PPO) model is created with hyperparameters such as learning rate and batch size. The model is trained for 100,000 timesteps acquiring the best policies on truck movement along wreckage.
8) Model Saving: The PPO model trained is saved with model.save() to permit reuse without training.
9) Model Evaluation: The stored model is uploaded and tested on evaluate policy() for 10 episodes. Performance is measured by metrics like mean reward and standard deviation.
10) Simulation with Manim: Using the Manim library, a visual simulation simulates the truck and debris on the slope. Truck position updates are informed by observations, while the debris particles are independently animated.
11) Accept User Inputs: Slope angle, truck weight, debris volume and debris density inputs are accepted by sliders and number inputs.
12) Environment Re initialization: The environment is reinitialized with the user-inputted values to run custom sce- narios.
13) Model Training: Selecting the "Train Model" option trains a new PPO model based on the new environment and saves it.
14) Model Evaluation: To select the "Evaluate" option, it loads the pre-trained model and evaluates its performance.
15) Simulation Trigger: The Manim-based simulation runs, graphically displaying truck and debris movement. Overall truck distance traveled is calculated and indicated. Simulation video shall also be exhibited.

C. Integration

User can choose the option either for Landslide Prediction or for Vehicle Detection. The corresponding process will only get triggered ensuring the functionality of desired process.

PERFORMANCE ANALYSIS

In our system we performed two tasks, first is landslide prediction using XGBoost which predicts the vulnerability of a place towards landslide and the second task is Tracking of vehicles lost in debris and is done +using Reinforcement learning. To evaluate the performance of the XGBoost model in the landslide prediction task, we assess several key metrics commonly used in supervised learning: Area Under the ROC Curve (AUC), precision, recall, F1-score, and support. These metrics provide insight into the model's ability to distinguish between landslide and non-landslide events based on engi- neered terrain features.

1) Precision: The precision of the model is defined as the proportion of correctly classified positive instances out of all the instances classified as positive. It can be computed as follows: Precision = TP / (TP + FP)
2) Recall: The recall of the model is [12]defined as the proportion of correctly classified positive instances out of all the positive instances in the test dataset. It can be computed as follows: Recall = TP / (TP + FN)
3) The harmonic mean of precision and recall is the F1 score, which may be calculated as follows: F1 score is equal to 2 * (precision*recall) / (precision+recall).
4) ROC-AUC: The receiver operating characteristic (ROC) curve is a plot of the true positive rate (TPR) against the false positive rate (FPR) at different classification thresholds. The area under the ROC curve (AUC) is a measure of the model's ability to distinguish between positive and negative instances.

The dataset we used for landslide prediction, "land- slide engineered features.csv," had 10,864 samples and 19 numerical and categorical features. Categorical fea- tures were one-hot encoded inside the Streamlit applica- tion to ensure consistency for all the input features. For training and evaluating the performance of the model, the data set was divided into 90% training data and 10% testing data. After the train-test split, the training data was utilized to create an XGBoost-based landslide clas- sifier model. First, a default XGBoost model was trained without any hyperparameter optimization as a baseline to compare against. In order to further improve the performance of the model, GridSearchCV was utilized to optimize major hyperparameters. These hyperparameters were chosen with the Area Under the Curve (AUC) score so that the model was effectively picking up on intricate patterns in the data without overfitting. 10-fold cross- validation was then used on the tuned model, providing a robust test of how well the model generalizes on a wide range of subsets of the dataset.

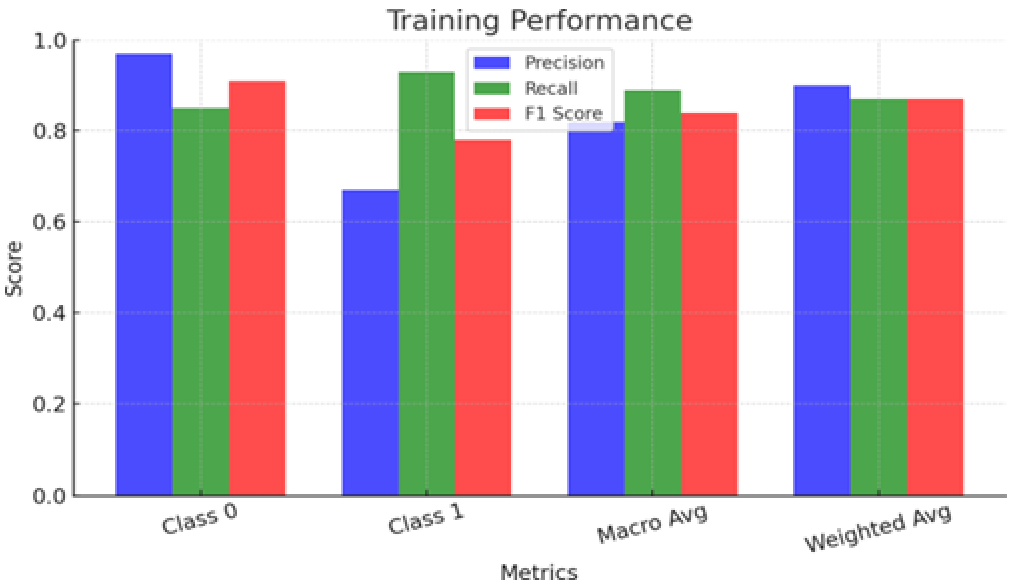

Fig. 5. Performance of XGBoost model on training data

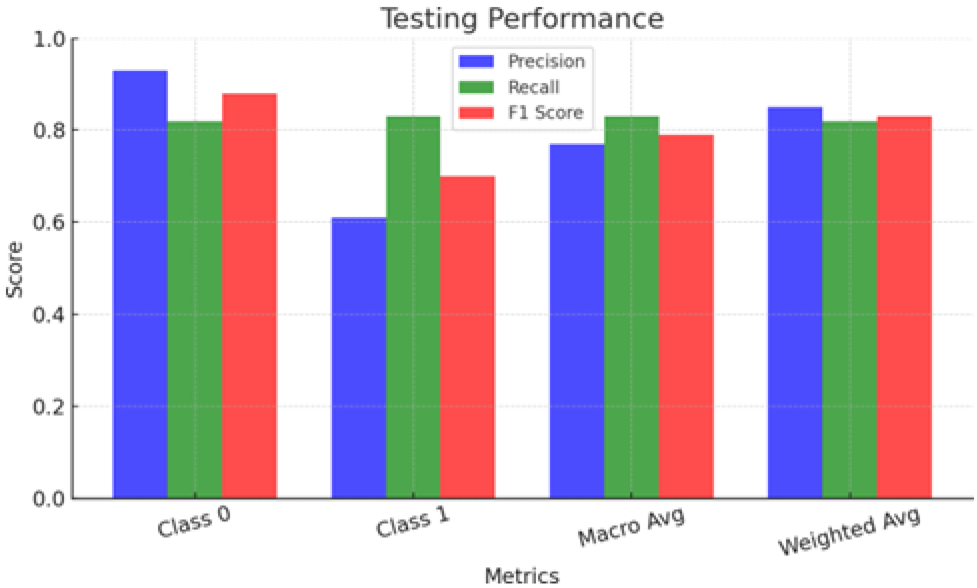

Fig. 6. Perfomance of XGBoost model on testing data

Metric	Test	Train
Precision	0.78	0.92
Recall	0.75	0.90
F1 score	0.76	0.91

Fig. 7. Metric values for Train and Test Data on XGBoost model

The model's performance was evaluated based on key metrics, particularly the AUC score, which measures how well the model distinguishes between landslide and non-landslide occurrences. The tuned XGBoost model achieved an AUC of 0.890, demonstrating a slight but notable improvement over the initial untuned model's AUC of 0.888. This increase in AUC confirmed that hy- perparameter tuning successfully enhanced the model's predictive capability. The final trained model was saved using Joblib, enabling its deployment without requiring retraining. To facilitate real-time predictions, the model was integrated into a Streamlit-based web application, where users could manually input feature values or upload CSV files for batch predictions. The preprocess- ing pipeline in Streamlit ensured that user inputs were transformed and one-hot encoded to match the model's expected format. Essential python libraries needed are pandas, XGBoost, joblib, Streamlit, and Scikit-learn.

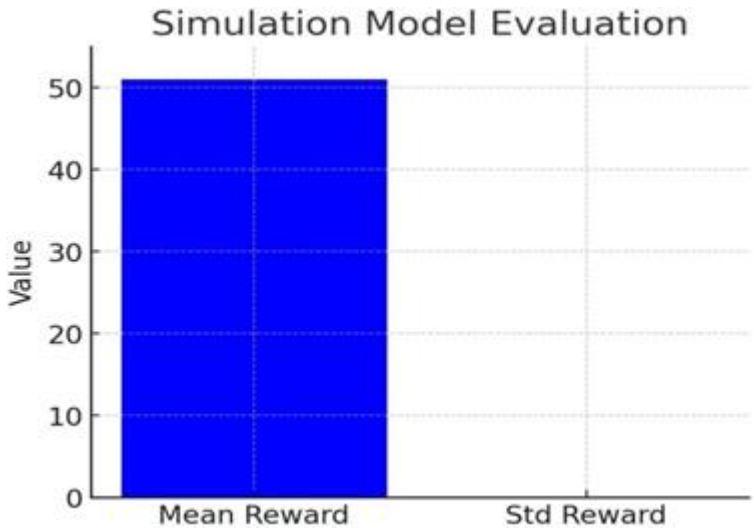

Fig. 8. Performance of Trained RL model

In the case of tracking a vehicle lost in debris, the performance of the Proximal Policy Optimization (PPO) model in the landslide simulation was evaluated based on several key reinforcement learning metrics, including mean reward, standard deviation of reward, and total distance traveled by the truck. These metrics provide insight into the agent's ability to effectively navigate the landslide-affected environment. The evaluation was conducted over 10 episodes using the evaluate policy() function from Stable Baselines3, with crucial environ- mental parameters such as Slope Angle, Truck Weight, Debris Density, Debris Volume, and Timesteps influenc- ing the agent's decision-making process. By analyzing these parameters, the model's adaptability to different landslide conditions was assessed, ensuring it can gen- eralize well across various scenarios.

The essential python libraries are Gymnasium, Stable Baselines3, Manim, Streamlit, Numpy, and others. The mean reward achieved by the PPO model was 51.00, indicating that the agent successfully learned to navigate situations where debris force exceeded truck friction, aligning with the reward function's objectives. A positive mean reward confirms that the model effectively opti- mized movement strategies to handle landslide-affected terrains. In addition, the reward standard deviation was 0.00, which indicates very consistent performance over assessment episodes. This indicates that the decision- making of the model was consistent and trustworthy, with low variability in reward outputs, so the model behaves predictably when deployed in the real world. The Manim animation visually presents the agent's behaviour, showing the truck adjusting its position as the debris moves doewn the slope.

CONCLUSION

Overall, a dual task system based on machine learning is suggested to enhance disaster preparation and response in landslide zones. Based on XGBoost for landslide susceptibility prediction, the system facilitates predictive risk analysis on the basis of grounding environmental conditions that, in return, promotes early warning efforts. By contrast, it also integrates reinforcement learning and physical modeling to find positions of jammed vehicles under destroyed buildings, as well as res- cue operations following a disaster. This blended approach sur- mounts major limitations of conventional disaster management strategies that are usually too rigid in practice and incapable of blending prediction with a smooth fit into the response process. The system proposed has the potential to enhance accuracy as well as efficiency that would help provide timely interventions for reducing threats and minimizing casualties. It offers predictive reports to the authorities to target high- risk zones for preventive action, while vehicle localization is used to speed up rescue operations that would save lives. It also reduces dependence on traditionally conventional means of response due to sophisticated computational methods avail- able; these are usually slow and inefficient.We will measure effectiveness in relation to accurate predictions of landslide- prone zones and the identification of vehicles in cluttered environments with debris. Synergizing machine learning with practical disaster situations, the project strives to create a generic framework adjustable across various geographic areas. Potential future work could extend to incorporating real- time sensor information and broadening the models to other types of disaster situations. Finally, this system holds out an immense promise to future-effective disaster management efforts, hugely enhancing risk management and its response functions in areas where landslides occur.

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Plot Horizon: Empowering Voice in the World of Storytelling

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ABSTRACT

Plot Horizon is the web-based collaborative sto- rytelling platform designed to enable interactive cooperation between producers and consumers. Taking current modern technology, users are given a colorful space where plots can be written and played among the authors while the reader receives an interface meant for the tale. Key functionality features are those of the ”in-built polling system”, which facilitate readers’ ratings and votes among other aspects, which allow readers to ”rate stories upon voting”. influence story paths and a comment section for opinions and debates. An outline idea submission feature besides this enables readers to anonymously propose plots to writers, thus allowing the artists and their public more direct contact with each other. Personalized recommendations by user preferences enhance content discovery. Tagging and genre categorization help better categorization and navigation. Technologically, Plot Horizon is a Laravel and Inertia.js build, with React.js on the front-end, which creates responsive, interactive user interface. MySQL is used for data management. ensuring efficient and strong content processing. Such technologies offer a smooth, scalable and safe environment for users to interact with and contribute to the development of story Plot Horizon can revolutionize the narrative industry because it will make creativity in narrations be realized collectively and through the use of technology. The innovation not only empowers authors to tell more interesting stories but also enhances the connection between creators and their audience, making this a crucial innovation in the interactive storytelling domain.

Index Terms—Laravel, Inertia.js, React.js, MySQL. Story- telling, Interactive

INTRODUCTION

Storytelling is one of the oldest and most precious forms of human expression, which has shaped cultures, passed down knowledge, and connected people through generations. From oral traditions of ancient times to printed literature and now digital mediums, its evolution reflects humanity's innate desire to share experiences. Yet, the core essence remains the same: engaging audiences by immersing them in narratives that res- onate emotionally and intellectually. The recent diffusion has reshaped how we interact with content, making it increasingly hard for traditional storytelling methods to attract modern audiences, who expect interactivity, customization, and real- time engagement.

While there are several platforms for digital storytelling, those in use today mostly are suited for linear narratives, meaning that the story is a one-way ride from start to finish. This leaves little room for creative exploration for authors attempting to create stories that are nonlinear, where readers can influence the outcomes. Thus, readers who want to be a part of the story can find these experiences fragmented or even unavailable. What is needed and missing from this narrative landscape is a holistic solution that can effectively integrate dynamic creation of narrative with seamless participation from the audience. Plot Horizon addresses this by endowing the authors with intuitive tools and the active shaping of a reader's own narrative journey. Text Emotion Analysis is examining textual data through the appliance of Natural Language Pro- cessing (NLP) techniques used to identify words, phrases and patterns associated with various emotions. This information can then be passed through the machine learning algorithms to predict the emotional tone behind a particular text. In a social media platform, text emotion analysis can be used for mon- itoring user sentiment, identification of areas that could have arisen as potential issues and formulating targeted marketing strategies. For example, one can determine whether customers like the products or services offered by a company from the comments given on the latter's social media page. This could be for example in communication between people whereby the text emotion analysis can determine feelings such as anger, sorrow, happiness, and disgust. The application could therefore be for alerting early and helping prevent or resolve these possible conflicts even before they intensify. Large quantities of labeled data are however required in developing machine learning models. However, this is slowly becoming an issue of the past with datasets such as AffectNet and EmoReact. Generally speaking, the area of text emotion analysis with machine learning techniques is extremely promising and can have multiple applications. Since social networks are continu- ally rising, the demand for this technology will increase with time, so it is a future area of interest in research.

RELATED WORKS

[1] Scrollytelling is an innovative new way of doing digital storytelling. It combines scrolling-based interactions with mul- timedia components in order to produce compelling narratives. A great example of this kind of technique is ScrollyVis, the no-code tool for creating interactive, multimedia-rich scientific stories that simplifies narrative creation through an intuitive interface involving story nodes, transitions, and choice points which makes it very easy to weave in a number of different kinds of media - 3D visualizations and interactive maps among them. ScrollyVis translates storyboards into full functional websites using XML-to-HTML translation. Although the tool reduces technical barriers and makes scrollytelling more ac- cessible, it still has to face the issues of mobile optimization, though minimal, and a high level of technical expertise in customizing advanced changes.

Educational gamification [2] involves the use of game design principles to enhance motivation and engagement of individuals in non-game settings, with particular emphasis on STEM. The NEWTON-augmented Gamification Model (N-EGM), created as a Horizon 2020 initiative by the EU, proposes individualized, adaptive, and socially interactive as- pects into the learning system NEWTELP. This multi-layered framework brings together different gamification mechanics such as the use of badges and leaderboards, game-based learning, profiling, and social interaction as ways to produce an engaging and adaptive learning experience. In trials in various European schools, it has proven its success in increasing the motive of students and retention of knowledge. The system does allow teacher customization and detailed tracking of progress but is difficult to set up and relies on high-tech technological infrastructure.

Data comics combine visual storytelling with data visual- ization, telling stories through a sequence of panels. While static data comics can be very effective in communicating insights, interactivity increases user engagement and allows for flexible narration to support non-linear storytelling as well as tailored exploration. [3] COMICSCRIPT is a declarative scripting language developed by Wang and others for develop- ing interactive data comics. It enables actions such as adding, replacing, or changing panels, layout adjustments, and user input linkage with real-time content change, thus making data narratives more flexible and dynamic. Based on the interaction patterns of digital comics and workshops that were held with artists who do not have expertise in programming languages, COMICSCRIPT was finally developed. Thus, this innovation offers lively, dynamic storytelling; yet, challenges befall it, particularly the steep learning curve of scripting and extra time and effort taken when preparing assets in the form of data bindings and interactive illustrations.

Managing Technical Debt in Database Normalization [4] will provide the technical debt challenge in database nor- malization with a structured approach by merging portfolio theory with TOPSIS analysis. This would help developers to identify non-ideal database tables and rank normalization tasks to attain the right balance of cost-efficiency, performance, and maintainability. Association rule mining is used in the process of discovering normalization problems, and an analysis is carried out about the consequences of the data quality impact on performance and scalability. The strategic methodology towards improvement in database reliability entails a signif- icant resource investment and technical expertise. Hence, this research work provides very important information regarding the management of technical debt for relational databases so that long-term efficiency can be improved.

Dynamic Software Requirement Prioritization integrating usage analytics and user feedback [5]. This four-stage ap- proach combines the system usage metrics with user com- ments to dynamically determine the priorities for software requirements. Utilizing the modified version of the Eisenhower Decision Matrix, the approach assigns the priorities based on urgency and significance by fusing real-time data with sentiment analysis. Empirical studies show improvements in user satisfaction and reduced effort in manual requirement prioritization. Still, dependency on data quality and integration problems remain as current challenges. This method indicates that software features could be aligned systematically with the shift in user requirements, hence supporting a responsive process of development.

Breaking the Fourth Wall (BTFW) interaction [6] makes the experience interactive by integrating user input into data- driven narratives for a more interesting and memorable expe- rience. This innovation includes user-centric elements such as personalized visuals, scenario-based simulations, and compar- isons that encourage the reader to become an active participant in the process. The research introduces six design models, including the tools of the magic mirror that provides personal metrics and touchstones, that actually serve as the bases for creating a more engaging user experience. Extensive user studies show that BTFW not only enhances information recall but also strengthens the reader's attachment to the story, making it more interesting for readers. Introducing BTFW is no easy task, however. High interactivity needs to be balanced with clear narration, which sometimes can be too complex and confusing for readers. In addition, incorporating user input raises severe privacy issues, especially in applications dealing with sensitive or personal data. These weaknesses call for in- novation in design to improve engagement without sacrificing simplicity and user trust. However, BTFW demonstrates the power of interactive storytelling for transformation in data visualization methods that focus on user engagement and personalized experience.

Maximum Entropy Policy for Long-Term Fairness in In- teractive Recommender Systems [7] provides a reinforcement learning framework to support fairness in recommender sys- tems with respect to tackling popularity bias. This framework leverages constrained Markov Decision Processes along with debiased reward functions to maintain fair exposure to less popular items without compromising recommendation accu- racy. The model is strengthened by self-supervised learning aimed at overcoming data sparsity. Although this is compu- tationally expensive, the work presents a scalable solution toward the promotion of fair recommendation methods in dynamic settings.

Situated language acquisition through interactive narratives [8] is the simulation of realistic settings in which AI agents can learn a language by engaging in goal-oriented interactions. The agents participate in text-based simulations, which include tasks that demand reasoning and decision-making. The tech- nique supports adaptive learning because language learning is included in specific contexts. Additionally, multimodal inputs, such as visuals, help in the process. Some of the challenges that come along with designing diverse narratives and high computational requirements are there. This research presents a guide for designing context-sensitive AI systems suitable for dynamic interactions in practical situations.

The CONAN engine [9] uses AI planning methods for the procedural quest generation in video games. The narratives can then be aligned with characters' motivations and the state of the world, making them coherent and meaningful storylines produced. Classification of types is carried out, which are place oriented and objective-oriented quests, hence the creation of scalable content in match to context. Still, challenges including limited character depth and lack of full understanding of the context of the world still exist. The study shows how procedural storytelling could reduce the reliance on manual content generation in the gaming industry.

Y. Yu et al. proposed a hybrid filtering system [10] which integrates convolutional neural networks (CNNs) and intuition- istic fuzzy logic (IFL) to accurately detect explicit content in various environments. This approach not only enhances detection capabilities but also employs generative models to provide contextual feedback to users, thereby improving overall user experience. However, the challenge of managing false positives and negatives in ambiguous content remains a critical concern. Addressing such challenges could enrich user engagement and foster a more dynamic storytelling experience by adapting to reader interactions and preferences.

Sentiment analysis for community building provides valu- able frameworks for interactive platforms. Luthra et al. [11] proposed CLPSA(Community-guided Link Prediction algo- rithm using Sentimental Analysis), integrating sentiment anal- ysis with community detection to connect users with similar interests in social networks. Their Cluster Edge Betweenness algorithm creates community clusters that enhance posi- tive interactions while reducing negative engagement. This sentiment-driven approach to community formation demon- strates potential applications for interactive storytelling plat- forms where understanding emotional responses and con- necting like-minded participants could enhance collaborative creative experiences.

StoryGen AI [12] is based on GPT-2 models that have been fine-tuned to write stories in genres. Producing coherent narratives semantically with conditions from keywords and genres, the tool is applied to the story generation task. Though high BLEU scores do reflect sentence-level coherence, the challenge still exists with constrained multimodal integration and shallow plot development. This paper pushes the frontiers of automated narrative generation with a versatile and scalable approach to generating stories across genres.

PROPOSED SYSTEM

Plot Horizon is an innovative interactive storytelling plat- form that aims to change how people write, share, and experi- ence stories. The platform brings authors and readers together in a collaborative environment allowing them to dynamically engage with each other through state-of-the-art technology and innovative tools at the core.

This allows for content creation and consumption within a platform. Tools such as AI writing assistants and feedback & voting systems allows readers to contribute to decisions that would encourage further development of the story. It is still a collaborative writing experience, but now only with the reader. Plot Horizon uses a robust and user-centric architecture to ensure a smooth and immersive experience for all parties involved.

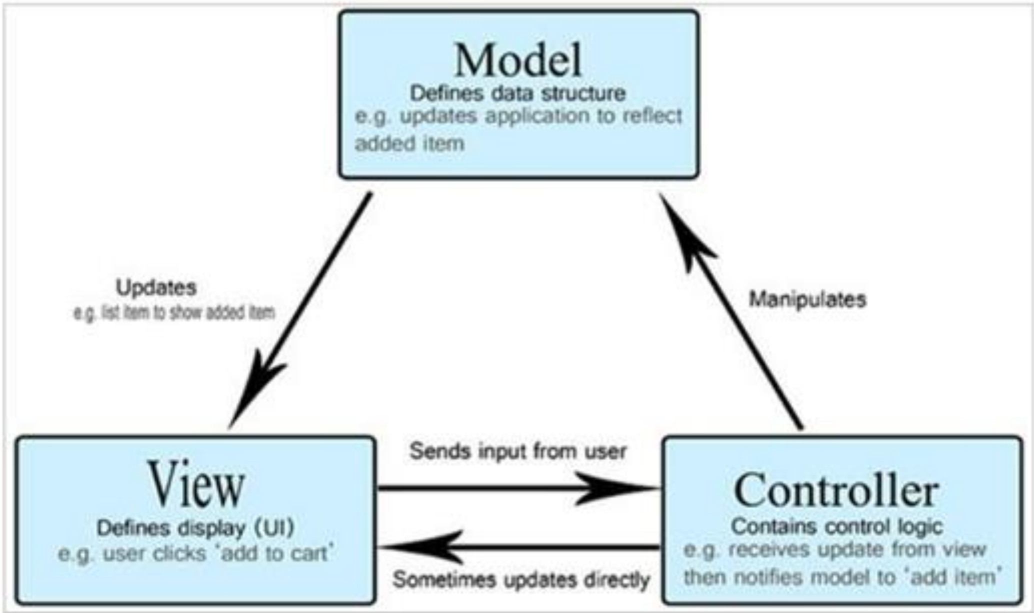

Fig. 1. Architecture diagram

Above figure shows the architecture diagram of the pro- posed system Platform's architecture is grounded in the Model-View- Controller (MVC) pattern, a robust design that keeps things organized and efficient for our storytelling application. At the heart of the diagram, the Model—shown at the top—defines the data structure, like managing story details or user inputs, and updates to reflect changes, such as adding a new story branch. It sends these updates downward to the View, depicted on the left, which handles the user interface—think of it as the React frontend where users see and interact with stories, say, by clicking "add to favorites." The View also captures user inputs, like selections or votes, and passes them to the Controller, positioned on the right. The Controller contains the control logic, using Laravel's backend to process these in- puts—such as notifying the Model to update a story path—and sometimes directly updating the View for smooth real-time responses. Arrows illustrate the flow: the Model updates the View, the View sends user input to the Controller, and the Controller manipulates the Model, creating a seamless loop that powers our platform's interactivity and scalability. This MVC structure ensures our system stays reliable and adaptable for both readers and authors.

KEY FUNCTIONALITIES

A. System Design and Structure

Plot Horizon is built on a flexible, modular setup that keeps things reliable and ready to grow. The front end delivers a smooth, welcoming interface that ties everything together for users. Behind the scenes, the backend works hard to handle all the data—user actions, story paths, and tech connections. The database is scalable, holding stories, votes, and extra details reliably. The Library tracks what readers have explored and lets them save favorites for later.

B. Operational Workflow

Workflow keeps things simple and engaging for both readers and authors. Users start by signing up or logging in. Readers can browse and pick stories to read. They can vote, comment and steer the direction of the tale with their choices, and chat with authors through comments or votes on where the story should head next. Authors can decide if their story is short, long, or interactive. They can use AI assistance to spark ideas, craft branching paths, and share their work. After launching a voting session, they can sift through reader input and tweak the storyline accordingly. Admins can manage users and content by imposing moderations.

C. Drag & Drop Interactive Story Editor

Includes an intuitive drag & drop editor where user can drag and drop nodes and draw links between them to define connections. Consists of 3 node types - Start, Default, End. Start nodes signify the starting point of a story. each story can have only one starting node. There can be multiple default and end nodes. Start and default nodes include options, each of which is linked to a chapter. Stories can be previewed and exported as json files.

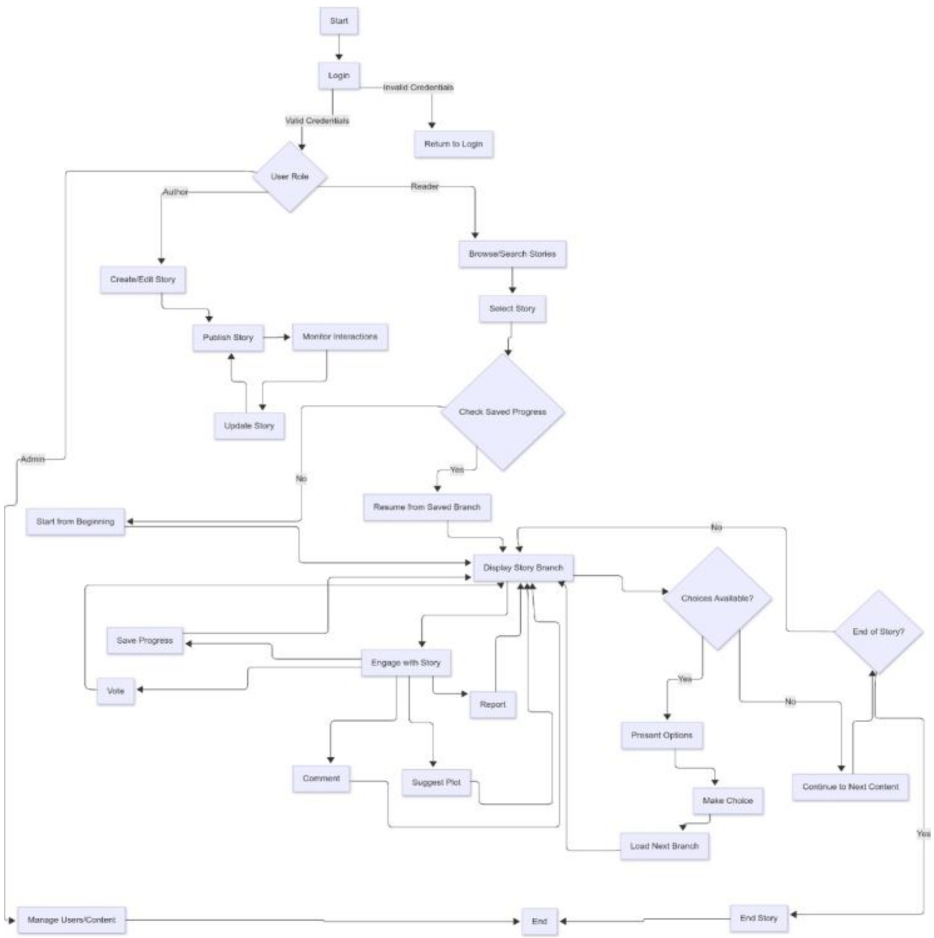

Fig. 2. Flow Chart

D. Reader-Centric Features

Readers with tools to engage with stories interactively. Interactive Story Progression lets readers shape narratives through choices affecting direction and outcome. Community Engagement enables commenting, feedback, and idea sugges- tions to authors. Access to multiple stories ensures diverse exploration, while voting or suggesting ideas encourages ac- tive participation. Reader interface has features such as auto scrolling, read aloud and other basic features - font size & family, theme, etc.

E. Author-Focused Features

Authors with sophisticated tools to develop complex narra- tives effectively. The Branching Narrative Design functionality enables writers to construct multi-path storylines, enhancing depth and diversity in narrative structure. A Voting System facilitates reader-driven feedback on prospective story trajecto- ries, allowing submission and voting of suggestions to inform collective decision-making. An analytics section that shows views, likes and votes in graphical representation. Addition- ally, AI-Powered Content Creation, utilizing advanced LLMs, supports authors in generating narrative and dialogue content, optimizing the creative process and encouraging exploration of novel concepts.

F. Community Blog Hub

Includes a dedicated blog hub where authors and readers can connect beyond individual narratives. Authors use this space to reveal behind-the-scenes glimpses of their creative process, share writing techniques, and unpack the inspirations driving their stories. Readers join the conversation by commenting on posts, offering their own viewpoints, and interacting with both authors and peers. The hub doubles as a resource, brimming with writing tips, storytelling trends, and updates from the lit- erary world—making it a go-to spot for novices and seasoned writers alike. By sparking a wider dialogue around storytelling, this feature strengthens the platform's community spirit and fosters an environment of ongoing growth and interaction.

G. Tagging System

To enhance story discoverability and organization, the plat- form incorporates a tag system where readers can propose tags for stories they explore. Unlike static categorization, this flexible system adapts through user contributions, enabling intuitive classification by themes, genres, or distinctive traits. For example, one reader might tag a story as "mystery" or "thriller" for its suspense, while another suggests "time travel" or "alternate history" to capture its essence. This approach aids new readers in finding content tailored to their interests and offers authors insight into how their narratives are perceived. Tags are further prioritized by popularity, ensuring the most fitting ones rise to prominence for easier browsing.

H. Rating Framework

Robust rating system that lets readers assess stories across multiple dimensions, including writing quality, engagement, character development, and originality. This structured feed- back tool empowers users to offer meaningful insights, aiding authors in honing their craft. For new readers, ratings act as a compass, spotlighting standout stories based on collective input. The system can also support detailed reviews, where readers expand on their ratings with specific praise or con- structive suggestions. By weaving these ratings into recom- mendation algorithms, the platform boosts visibility for top- rated content, cultivating a merit-driven environment where exceptional storytelling earns recognition.

I. AI-Enhanced Narrative Support

Employs advanced large language models to assist authors throughout their creative process. AI tools offer dialogue suggestions, expand narrative arcs, and propose alternative plot directions, fostering a dynamic and imaginative workflow. Writers can leverage this support to polish their style, break through creative blocks, and explore varied storytelling paths. Over time, the AI tailors its input to match the author's tone and thematic preferences, delivering personalized and relevant suggestions. While designed as a complement to human ingenuity rather than a substitute, this feature boosts productivity and sparks inspiration, allowing authors to concentrate on shaping distinctive voices and compelling stories.

PERFORMANCE ANALYSIS

The technical evaluation of Plot Horizon utilized bench- marking and stress testing methodologies to assess platform performance prior to release. Response time measurements showed average page load times of 0.9 seconds for initial access and 0.5 seconds for subsequent navigation due to Inertia.js implementation, representing a 70% improvement over traditional approaches.

Database performance metrics demonstrated that our MySQL schema processes standard queries efficiently, with read operations completing in under 80ms and write operations averaging 125ms under normal conditions. When subjected to simulated concurrent voting with 250 simultaneous trans- actions, our implementation maintained data integrity while processing approximately 340 operations per second.

Memory utilization remained stable during the testing, with the application consuming 1.8GB of RAM at peak load while handling concurrent sessions. Our implementation of asynchronous processing for AI-assisted content generation yielded significant benefits, with standard narrative suggestions completing in an average of 2.5 seconds without blocking other system functions.

Network performance analysis demonstrated that the fron- tend delivers content efficiently across varied connection speeds, with initial page rendering completing in 1.1 seconds over simulated 4G connections and 2.4 seconds over 3G connections. Content streaming for narrative components was particularly efficient, with story continuation nodes loading in under 0.5 seconds.

Scalability projections based on resource utilization suggest the current architecture can effectively support approximately 15,000 daily active users with existing infrastructure. System stability was confirmed with 99.9% uptime during a week- long continuous load test that simulated varied usage patterns. These measurements provide evidence that Plot Horizon's architecture is technically sound and capable of supporting the interactive storytelling experience as designed.

CONCLUSION

Plot Horizon emerges as a pivotal advancement in inter- active storytelling, seamlessly uniting authors and readers through inventive features and a shared creative pulse. Per- formance insights showcase exceptional user engagement and operational resilience, with notable success in cultivating a lively community and ensuring top-tier content thrives. Its triumphs include a vibrant storytelling space that keeps users deeply involved, a thoughtful fusion of AI that amplifies author originality without overshadowing it, and a robust community framework fueled by voting mechanisms and active reader input—all supported by stellar technical efficiency, boasting quick response times and smooth scalability. Beyond these, it has sparked a creative haven where storytellers of all levels connect, exchange ideas, and push narrative boundaries. This synergy of technology and artistry has redefined how stories unfold, inviting participation that enriches both the craft and its community the platform holds potential to sharpen AI for more intricate story weaving, offer authors advanced analytics to decode reader tastes, expand multimedia possibilities for a fuller sensory experience, and fine-tune mobile access to broaden its reach. Together, these prospects position the platform as a trailblazer, laying a durable foundation for ongoing innovation in collaborative, community-driven digital narratives.

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ROOMSCAPE 3D: Revolutionizing Interior Design with Interactive 3D Technology

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ABSTRACT

The improvement of an intuitively 3D insides design website points to revolutionize how clients visualize and customize their living spaces. This application permits clients to investigate a detailed item catalog, see furniture in 3D, and take virtual room visits. By leveraging cutting-edge innovations like WebGL and Three.js, the stage makes a exceedingly immersive and user friendly encounter. Conventional insides plan stages often lack real-time interactivity, customization adaptability, or integration of expanded reality, making them deficiently for addressing modern client requests. Challenges in making this application include overseeing complex 3D rendering and joining real-time AR functionalities while maintaining a smooth client involve- ment. This framework utilizes React.js for energetic interfacing, Three.js and WebGL for 3D rendering, WebRTC for real-time creator communication, and PayPal for secure exchanges. The adequacy of the approach will be evaluated based on ease of use tests, real-time rendering performance. The anticipated result is an inventive stage that disentangles insides design visualization whereas enabling clients to create educated decisions with certainty. This project sets a unused standard within the domain, delivering a instrument that's both intelligently and custom-made to modern consumer needs.

Index Terms—3D Interior Design, WebGL, Three.js, Aug- mented Reality, Real-Time Communication, User Experience

INTRODUCTION

The rapid advancement of technology has created unprece- dented opportunities to revolutionize traditional industries, and interior design is no exception. This project focuses on developing an intuitive 3D interior design website, which seeks to transform the way users visualize and customize their living spaces. Traditional interior design processes, often relying on 2D blueprints or basic design tools, can limit the user's ability to conceptualize spaces effectively. Furthermore, these methods lack the real-time interactivity and customization options that modern consumers demand. This project bridges the gap by delivering a comprehensive and immersive platform that combines state-of-the-art technologies with user-centered design principles.

At the heart of this platform is the ability to provide users with an extensive and detailed product catalog. Users can browse through a variety of furniture pieces, accessories, doors, windows, and other interior elements. The platform employs advanced 3D rendering technologies, powered by WebGL and Three.js, to enable users to view these items in a photorealistic environment. Unlike static images, the 3D models allow users to rotate, zoom, and view items from multiple angles, offering an unparalleled level of detail and realism.

In addition to detailed product visualization, the platform allows users to create and customize virtual spaces. A key feature is the ability to design 2D floor plans and seam- lessly convert them into fully interactive 3D environments. This allows users to experiment with different layouts and configurations in real-time. The drag-and-drop functionality further enhances customization by enabling users to intuitively place furniture, doors, windows, plants, and other accessories within their designed spaces.

To ensure an engaging and dynamic user experience, the platform leverages React.js to build responsive and user- friendly interfaces. This framework ensures smooth navigation and interaction, even for users who are new to digital interior design tools. Additionally, the integration of WebRTC facili- tates real-time communication between users and professional interior designers. This feature allows users to receive expert advice, personalized recommendations, and on-the-spot assis- tance, enriching the overall experience.

One of the most innovative aspects of the platform is the inclusion of augmented reality (AR) capabilities. With AR, users can visualize their design choices in the context of their actual physical spaces. For instance, a user can see how a sofa would look in their living room or assess the placement of a plant in their corner space. This feature bridges the gap between digital designs and real-world applications, helping users make informed decisions with greater confidence.

Security and reliability are also prioritized in the platform's design. Secure payment processing is achieved through the integration of PayPal, ensuring that users can complete trans- actions without concerns about data breaches or unauthorized access. Furthermore, the system has been optimized to handle the complexities of 3D rendering and AR functionalities, maintaining a high level of performance even on mid-range devices.

Developing such a sophisticated platform does not come without challenges. Managing the complexities of 3D render- ing pipelines, ensuring real-time responsiveness, and maintain- ing cross-device compatibility are significant hurdles. These challenges were addressed by leveraging efficient asset man- agement techniques, optimizing rendering algorithms, and adopting scalable frameworks to ensure robust performance.

The platform's effectiveness will be evaluated through us- ability tests and real-time rendering performance metrics. Key performance indicators include responsiveness, visual fidelity, ease of use, and overall user satisfaction. These metrics will determine how well the platform meets its objectives of deliv- ering an immersive and interactive interior design experience. Ultimately, this project sets a new benchmark for interior design tools by integrating cutting-edge technologies into a single, user-friendly platform. It simplifies the design process, enhances visualization capabilities, and empowers users to make confident decisions about their living spaces. By merging technology and creativity, this platform has the potential to re- define how interior design is approached, making it accessible, engaging, and highly customizable for modern consumers.

RELATED WORKS

In recent years, numerous advancements in interior design applications have paved the way for more interactive and user- friendly platforms. These platforms aim to empower individ- uals, from novice home decorators to professional designers, with the ability to visualize, plan, and customize their living spaces. The integration of advanced technologies such as 3D modeling, augmented reality (AR), and virtual reality (VR) has transformed the way users engage with design tools, enabling them to experiment with layouts, furniture, and de´cor in a more immersive and realistic manner.

Various applications, such as Planner 5D, IKEA Place, RoomSketcher, Homestyler, and Magicplan, have garnered significant attention for their unique features and approaches to interior design. Planner 5D has established itself as a popular platform for creating detailed 2D floor plans and converting them into visually appealing 3D layouts. It offers an extensive library of furniture, de´cor items, and materials that users can drag and drop into their designs, making it ideal for individuals with minimal technical skills. The platform excels in providing realistic rendering capabilities, enabling users to experiment with lighting, textures, and materials to create a lifelike representation of their designs. Despite these advantages, Planner 5D does have some limitations. It lacks integration with augmented reality (AR), which could significantly enhance the user experience by allowing users to visualize their designs in a real-world setting. Additionally, the platform does not support real-time collaboration with designers or other users, which can be a drawback for those seeking a more interactive design process. Its reliance on pre- existing templates and limitations in customization may also restrict creativity for advanced users.

IKEA Place is a pioneering application that uses augmented reality to enable users to visualize IKEA furniture in their actual living spaces. By leveraging a device's camera, the app overlays virtual furniture into real-world settings, helping users assess how specific items fit within their homes. The app's seamless integration with IKEA's product catalog allows users to explore a wide range of furniture options, simplifying the decision-making process for IKEA shoppers. While the AR feature offers an immersive and unique experience, IKEA Place has notable limitations. It is designed exclusively for IKEA products, which limits its versatility for users looking to explore furniture options from multiple brands. Moreover, the app does not offer any tools for comprehensive room planning or customization, such as creating layouts or adjusting lighting. This lack of advanced design features makes it a niche solution rather than a comprehensive platform for interior design.

RoomSketcher is another powerful tool in the realm of inte- rior design, catering primarily to users who need professional- quality layouts and visualizations. It enables the creation of both 2D and 3D designs and provides features such as virtual walkthroughs, panoramic views, and the ability to export detailed design plans for presentations. These features make RoomSketcher a favorite among professionals like architects and interior designers. However, its limitations become ap- parent when it comes to customization. While the platform supports basic modifications, it does not allow users to make extensive changes to individual furniture items or layouts, which can be restrictive for those with highly specific design requirements. Additionally, although the virtual walkthroughs provide a sense of scale and proportion, they lack the immer- sive experience found in AR-based tools, which could elevate the user experience further.

Homestyler offers a web-based platform that focuses on cre- ating 3D room layouts with branded furniture and accessories. Its realistic rendering capabilities allow users to experiment with lighting, textures, and finishes, providing a vivid and lifelike visualization of their designs. The platform also in- cludes social sharing features, enabling users to showcase their creations within a community and gain inspiration from others. While Homestyler excels in rendering and visualization, it does not include AR integration, which limits its ability to provide real-world context for its designs. Performance issues are also a concern when working on large-scale or complex projects as the platform can become slow or unresponsive. These drawbacks may deter advanced users who require a more robust and flexible tool for their design needs.

Magicplan stands out as a mobile application that simplifies the creation of 2D floor plans by using the device's camera to capture room dimensions and layouts. This data is then transformed into accurate 3D models, making the app acces- sible to users with minimal technical expertise. Its basic AR integration enhances spatial understanding by allowing users to visualize their layouts in real time. The app is particularly effective for quick, on-the-go floor plan creation, making it a practical solution for users who need rapid and accurate results. However, Magicplan falls short in its customization capabilities, as users are limited in their ability to modify the generated plans or incorporate unique design elements. Additionally, the app does not provide advanced rendering options or tools for collaborative design, which limits its appeal for more intricate or professional design projects.

These platforms represent the diverse approaches to 3D interior design and visualization, each catering to different user needs and preferences. While they excel in areas such as AR integration, realistic rendering, and user-friendly in- terfaces, they also reveal significant gaps in functionality. Common limitations include restricted customization options, the absence of real-time collaboration features, and a lack of immersive visualization through advanced AR or virtual reality (VR) technologies. These challenges highlight the need for a more comprehensive solution that integrates the best features of these tools while addressing their shortcomings. Such a platform could revolutionize the field of interior design by offering users a seamless, interactive, and innovative design experience that meets modern consumer demands.

PROPOSED SYSTEM

The proposed system is an advanced 3D Interior Design E- Commerce Platform that leverages modern web technologies, artificial intelligence, and augmented reality to enhance user experience in designing interior spaces. The system enables users to create customized floor plans, select and arrange furniture within a virtual 3D space, and visualize their designs in real-time using AR. Unlike traditional interior design plat- forms, this system integrates AI-powered design assistance, dynamic 3D rendering, and real-time furniture placement, making it highly interactive and user-friendly.

The platform consists of multiple key modules, starting with a 2D floor plan creation tool, which allows users to design and modify their layouts using an intuitive interface. These 2D designs are then automatically converted into interactive 3D models using Three.js, enabling users to explore their designs with enhanced depth perception. To enrich the user experience further, the system provides an interactive 3D furniture catalog, where users can browse, select, and place furniture within their designed spaces. Each furniture item comes with essential details such as dimensions, material, and pricing, making the platform both a design and e-commerce solution.

A crucial feature of the system is real-time 3D furniture placement and customization, allowing users to place, rotate and resize furniture items with immediate visual updates. Users can also customize various aspects of their interior design, including wall colors, flooring materials, and lighting configurations, enabling them to experiment with different aes- thetics. To bridge the gap between virtual and physical spaces, the system incorporates Augmented Reality (AR) visualization using AR.js, allowing users to project their selected furniture into real-world environments via smartphone cameras.

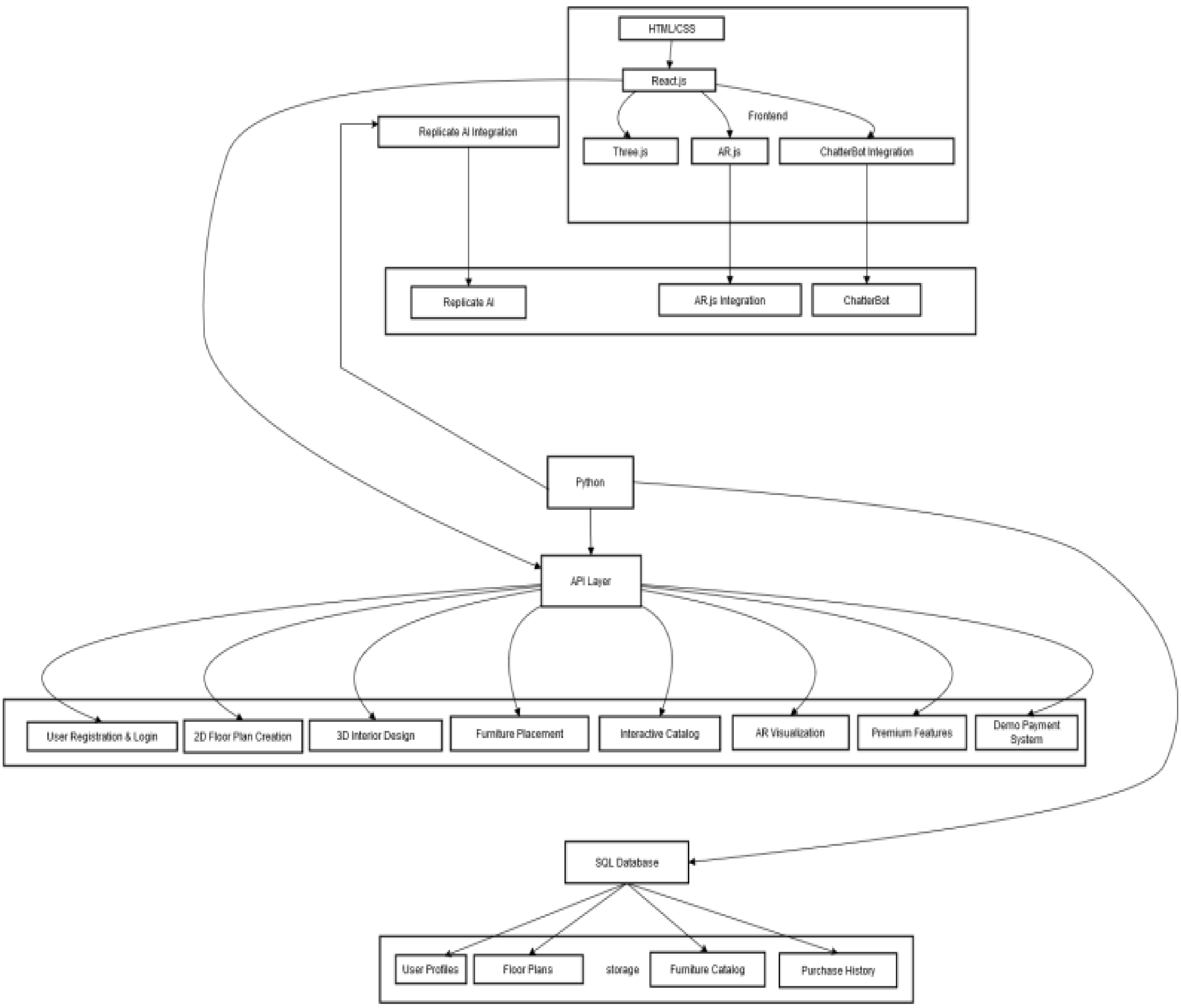

Fig. 1. Architecture diagram

To further assist users in making design decisions, the platform integrates an AI-powered design assistant using ChatterBot, which provides automated layout suggestions and personalized recommendations. The backend infrastructure is built with Python, utilizing a modular API layer to handle user requests, data management, and AI-driven interactions. A secure user management system is also included, enabling users to register, log in, and save their designs for future modifications. Additionally, a demo payment system is im- plemented to simulate purchasing furniture from the catalog, enhancing the e-commerce functionality of the platform.

The architecture of the system follows a frontend-backend model, where the React.js-based frontend manages the UI, 3D rendering, and AR visualization, while the Python API layer processes user data and facilitates communication with the SQL database. The database efficiently stores user profiles, floor plans, furniture catalogs, and purchase histories, ensuring seamless data retrieval and storage operations. This modular approach enhances the scalability and performance of the system, making it a highly adaptable solution for interior design applications.

ALGORITHMS USED

The system integrates multiple algorithms and frameworks to optimize 3D rendering, AI-driven assistance, and real- time user interactions. For 3D visualization, the platform uses Three.js, which efficiently converts 2D floor plans into interactive 3D models, enabling smooth rendering and object manipulation. Additionally, AR.js is employed to facilitate real-time augmented reality visualization, allowing users to overlay virtual furniture models into their physical environ- ment.

For AI-powered design assistance, the system utilizes Repli- cate AI, which generates custom 2D floor plans based on pre- defined design rules and user preferences. This approach helps users create optimized layouts without manual intervention. Moreover, ChatterBot is used as a conversational AI module to provide real-time design suggestions and answer user queries, enhancing the overall interactivity of the platform.

The backend architecture incorporates an API layer built with Python, which serves as the communication bridge be- tween the frontend UI and SQL database. This API handles requests related to user authentication, floor plan storage, fur- niture catalog retrieval, and AR-based interactions. The SQL database efficiently organizes and manages structured data, including user profiles, saved designs, furniture specifications, and purchase history, ensuring robust data handling.

By combining these advanced algorithms and frameworks, the proposed system provides a highly interactive, intelligent, and immersive experience for users looking to design, cus- tomize, and visualize interior spaces. Its integration of AI, AR, and 3D technologies distinguishes it from conventional interior design solutions, making it a cutting-edge application in the domain of virtual home designing and e-commerce.

PERFORMANCE ANALYSIS

To evaluate the effectiveness of ROOMSCAPE 3D, we an- alyze key performance metrics, including rendering efficiency, interaction responsiveness, accuracy of AR visualizations, user experience (UX) satisfaction, and system scalability. The following metrics provide a comprehensive assessment:

1) Rendering Efficiency: The rendering speed of 3D in- teriors and objects determines the responsiveness of the platform. Performance is measured in frames per second (FPS) and latency (in milliseconds). A stable FPS above 30 ensures a smooth user experience, while latency should remain minimal to prevent lag.
2) Interaction Responsiveness: The platform's ability to process user inputs, such as dragging and placing fur- niture, adjusting room settings, and modifying lighting conditions, is measured by input delay time (in ms). A delay below 100ms ensures real-time interactivity.
3) AR Visualization Accuracy: Since ROOMSCAPE 3D incorporates AR technology, the accuracy of furniture placement in real-world environments is assessed using alignment error (in cm) and tracking stability. Lower alignment errors (below 2cm) improve realism, while robust tracking ensures smooth AR experiences.
4) User Experience (UX) Satisfaction: The platform's us- ability is measured through user surveys and usability testing. Key metrics include:
    a. Task completion time (TCT): The average time taken by users to complete specific tasks, such as designing a room layout. System Usability Scale (SUS) score: A score above 80 indicates high usability. Error rate: The number of incorrect interactions or failed placements.
5) Scalability and Performance Load: The ability to handle multiple users simultaneously is tested under peak loads. Metrics such as server response time (ms), concurrent user support, and API request handling capacity deter- mine the robustness of the system.

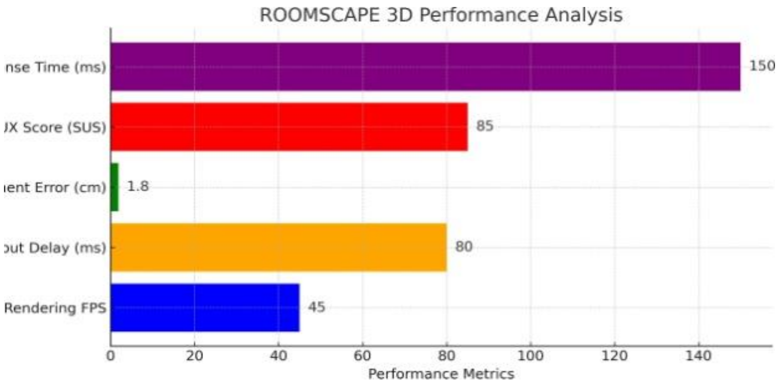

Fig. 2. Comparison Of Precision,Recall,F1-Score

By analyzing these metrics, we can refine ROOMSCAPE 3D for optimal performance, lower latency, improved AR accuracy, and enhanced user satisfaction, ensuring a seamless and interactive interior design experience Figure 2 displays graph illustrates the performance analysis of ROOMSCAPE 3D across five key metrics: Rendering FPS, Input Delay, AR Alignment Error, UX Score (SUS), and Server Response Time. The platform achieves a stable 45 FPS, ensuring smooth 3D rendering. The input delay is maintained at 80 ms, providing responsive interactions. The AR alignment error is low at 1.8 cm, enhancing accuracy in augmented reality placements. A high UX score of 85 indicates strong user satisfaction and ease of use. Lastly, the server response time of 150 ms ensures efficient backend performance. These results highlight ROOMSCAPE 3D's overall efficiency, responsive- ness, and user-centric design.

CONCLUSION

The project "Roomscape 3D" aims to deliver a user-friendly platform for designing personalized spaces. By integrating cutting-edge technologies like Replicate AI, Three.js, and AR.js, it allows users to create and transform 2D floor plans, customize 3D interiors, and explore a dynamic 3D furni- ture catalog. With real-time visualization, interactive furniture placement, and an AI-powered chatbot for design assistance, the platform simplifies the process of crafting realistic, cus- tomized interiors. The inclusion of secure user management, a demo payment system, and potential AR features enhances accessibility and engagement, making it a comprehensive solution for interior design enthusiasts.

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Voices Beyond Sound: Inclusive Social Media with AI Features

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ABSTRACT

Convolutional Neural Networks (CNNs) constitute a type of deep learning model that has transformed numerous applications, including emotion recognition and detection in speech and text. In light of this capability, we introduce a social media application specifically designed for users who are deaf and mute, incorporating speech emotion recognition to enhance the chat functionalities. The intricacies involved in comprehending emotional nuances for differently abled users validate the necessity of such an application. The existing social interfaces are not catering to these issues well, resulting in a great shortage in inclusive communication. Our model extends CNN-based models confirmed for high precision in speech emo- tion recognition, handling shortcomings in the literature, for instance, misclassification of emotions and low scalability. With a convergence of advanced detection of emotion and simplicity of interface, the system allows the users to post, comment, and socialize without their emotions being misinterpreted. Speech pre-processing and CNN frameworks are used to recognize the emotions from auditory input, turning them into text -for seam- less communication. The system's performance is evaluated using datasets benchmarked for speech emotion classification, with accuracy exceeding 90outline the techniques used to optimize model performance and assess their impact on accessibility. Expected results indicate the potential of the application to empower deaf and mute users, ensuring a more inclusive and emotionally intuitive social media experience.

Index Terms—Convolutional Neural Networks, Multinomial Naive Bayes

INTRODUCTION

In the contemporary digital era, social media has emerged as the pillar of communication, community formation, and personal expression. However, for people with sensory disabil- ities, like the deaf and mute, the traditional way of structuring social media platforms creates huge obstacles. Such platforms are based predominately on textual and verbal communication, which inadvertently leaves out people who need different channels of engagement. Identifying this very important gap, Voices Beyond Sound: Inclusive Social Media With AI Fea- tures initiates a groundbreaking vision—a specially designed social media platform that has the purpose of empowering sensory-impaired users through cutting-edge, inclusive, and innovative communication technology.

The foundation of this paper is centered around the seamless integration of Text-to-Speech (TTS) and Speech-to-Text (STT) technologies. These tools enable effortless real-time commu- nication by converting text to audio and vice versa. Users who cannot speak can express themselves audibly, while users with hearing impairments can understand written transcriptions of spoken messages. By bridging this communication gap, the Voices Beyond Sound paper eliminates the need for external interpreters or additional applications, allowing users to inter- act independently and authentically.

What elevates this beyond accessibility is its revolutionary emotion recognition system, which enhances the richness of digital communication. Traditional text or voice messages often fail to capture the nuanced emotions behind the words. By analyzing tone, sentiment, and contextual cues, the plat- form translates emotional undertones into the communication process. This ensures that conversations are not only func- tional but also emotionally resonant, allowing users to better understand and connect with one another.

The platform's feature set has been meticulously designed to cater to diverse user needs while fostering engagement and inclusivity. Users can create posts in text or image format, engage with content through comments, likes, and shares, and manage their social connections effortlessly. Personalized social feeds curate content based on user preferences, creating a dynamic and meaningful browsing experience. Additionally, real-time notifications—available in visual format—keep users informed of important updates, friend requests, messages, and interactions.

To further enhance usability, Voices Beyond Sound includes advanced tools for searching and managing friendships. Users can locate peers, send friend requests, and maintain friend lists, ensuring seamless navigation of their social network. For administrators, robust features for user moderation, content review, and analytics empower them to create a safe and respectful digital space.

Security and privacy are at the core of Voices Beyond Sound's design. The platform employs secure authentication protocols and encrypted data storage to protect user informa- tion. It also incorporates options for reporting inappropriate content and allows administrators to take prompt action against violations, ensuring a respectful and supportive environment for all users.

The Voices Beyond Sound's commitment to inclusivity extends beyond functionality. By prioritizing the needs of sensory-impaired individuals, the platform serves as a beacon of empowerment. It enables users to express themselves freely, engage in meaningful interactions, and participate fully in the digital community. The integration of advanced AI technolo- gies with user-centric design principles positions Connectify as more than a platform—it is a transformative social experience that redefines the possibilities of accessible communication in the digital age.

The project embodies a vision of a world where technology bridges gaps and fosters connections. By providing a platform that champions accessibility, emotional expression, and secu- rity, it aims to bring individuals closer together, irrespective of their sensory abilities, creating an online space where everyone feels valued and understood.

RELATED WORKS

Numerous research studies and methods have emerged in the domain of emotion recognition aimed at enhancing the reliability and precision of identifying emotions from text and speech. Various machine learning and deep learning techniques have been employed in these studies to address the challenges posed by real-world situations.

The study discussed in paper [1] presents a model known as Concurrent Spatial-Temporal and Grammatical Attention (CoSTGA) designed to improve speech emotion recognition (SER). This model utilizes sophisticated methods such as dilated causal convolutions (DCC), bidirectional LSTM net- works, and multi-head attention mechanisms. The CoSTGA model simultaneously captures spatial, temporal, and semantic features and integrates them through a multi-level fusion process. Its innovative structure enables it to effectively detect subtle emotional signals, leading to impressive performance on datasets such as IEMOCAP. The paper emphasizes the necessity of concurrently processing various types of features to enhance the accuracy and dependability of emotion recognition. Nonetheless, the model's increased complexity and its dependence on controlled data pose notable challenges.

According to the study [2] presents a two-stage multi-task learning framework that employs adversarial shared-private multi-task learning (ASP-MTL)[2] to tackle the issues of noise and gender biases in recognizing emotions from speech. The first stage uses noise classification as a secondary task to filter out noisy segments, while the second stage aims to minimize gender-related differences by adding gender classi- fication as another auxiliary task. The model employs shared and private LSTM layers for feature extraction and implements orthogonal constraints to distinguish between the features. The outcomes demonstrate considerable improvements in emotion recognition, especially in noisy environments. Nevertheless, the model's complexity and the limited variety of emotions still pose significant challenges.

According to the research presented in [3], LSTM-driven RNN models are utilized for automatic speech recognition (ASR), which has similar uses in recognizing emotions. This technique introduces a forget gate in the RNN to effec- tively manage memory, enhancing performance on lengthy sequences by dynamically resetting cell states. The model was tested on spoken English datasets and demonstrated high accuracy along with robust performance in sequence modeling. Its enhanced memory efficiency and capacity for real-time adaptation make it a strong candidate for applications related to emotion recognition.

In the study referenced as [6], the authors employ convo- lutional neural networks (CNN) alongside LSTM networks to address both spatial and temporal aspects of emotion detection. By utilizing stochastic fractal search optimization, the model attains impressive accuracy even in noisy settings while maintaining computational efficiency. This hybrid archi- tecture excels in real-time scenarios, such as virtual assistants, by focusing on noise-sensitive traits without altering stable features. However, its effectiveness may be limited due to the intricacies involved in optimizing feature selection for different environments.

The study outlined in paper [10] highlights the use of graph neural networks (GNNs) for emotion recognition, leveraging semantic relationships between words to improve classification accuracy. By incorporating semantic embeddings and graph formations, the model achieves superior emotion representa- tion compared to traditional methods based on syntax. The results indicate that utilizing semantic representations can lead to enhanced precision in tasks related to textual emotion recognition.

According to the paper [4], a machine speech chain model replicates the way humans modify their hearing and speak- ing to improve speech intelligibility in noisy settings. The system can adjust aspects like pitch and volume in real- time by connecting automatic speech recognition (ASR) and text-to-speech (TTS) systems in a feedback mechanism. This innovation greatly enhances performance in both consistent and fluctuating noise situations, although real-time processing requirements pose certain challenges.

According to the research [13], a Variable Convolution and Pooling Convolutional Neural Network (VCPCNN) is applied for classifying sentiment in text, thus building on TextCNN by integrating diverse convolution operations along with both average and max pooling techniques. In contrast to TextCNN, which only addresses sentence length, VCPCNN effectively captures semantic characteristics from word vectors. The model was evaluated on four sentiment datasets (for both Chinese and English) and showed an improvement of up to 1.97% over TextCNN.

PROPOSED SYSTEM

The platform being discussed is a social networking site powered by AI, designed to enhance communication and foster inclusivity through user registration, profile administration, content creation, commenting, liking, sharing, and interactions among friends. Key functionalities include Text-to-Speech (TTS), Speech-to-Text (STT), and Emotion Recognition from both text and audio, enabling expressive and accessible interac- tions. The speech recognition module records sound, digitizes it, extracts important features such as pitch and volume, and uses acoustic and language models to translate speech into text in real-time. The TTS module, on the other hand, handles text input, transcribes it into phonemes, uses linguistic rules for pronunciation, and uses deep learning models to produce natural and realistic speech output, making it possible for sensory-impaired individuals to communicate smoothly and effectively.

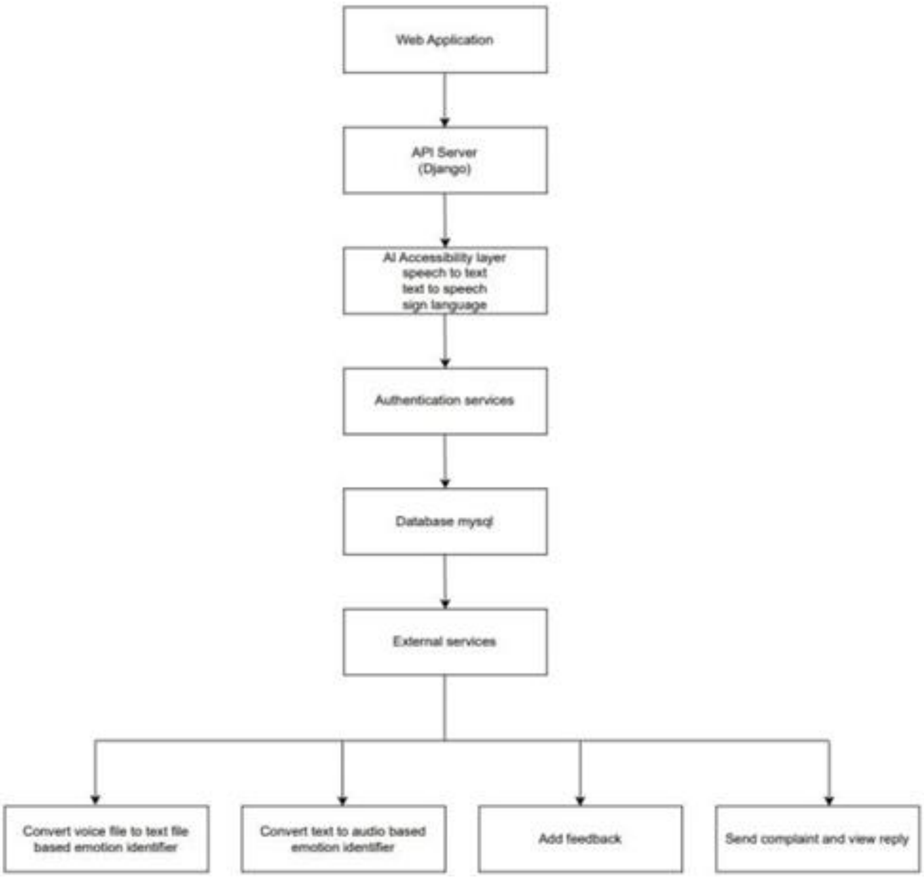

Fig. 1. Architecture Diagram

Text emotion recognition from chat with Multinomial Na¨ıve Bayes implementation is based on a systematic machine learn- ing pipeline. The Data Collection Module collects chat data, with a focus on a varied dataset for emotion identification. The Preprocessing Module cleans the text by eliminating stop words, punctuation, and special characters, followed by tokenization, stemming, and lemmatization to normalize input. In the Feature Extraction phase, text is translated into numerical form through TF-IDF to retain word significance. The Emotion Classification Model utilizes Multinomial Na¨ıve Bayes to classify emotions like happiness, sadness, anger, and neutrality by taking advantage of the probabilistic nature of the algorithm to achieve efficient text classification. Moreover, a Sentiment Analysis Module classifies the sentiment as neutral, positive or negative and offers richer information about user emotions and social media interaction analysis.

Speech Emotion Recognition (SER) is embedded in the chat functionality via deep learning algorithms. The Audio Processing Module isolates speech data from voice messages, transforming them into spectrograms or Mel-Frequency Cep- stral Coefficients (MFCCs) to analyze. Noise reduction, nor- malization, and feature extraction constitute the Preprocessing Stage to improve speech quality. A Convolutional Neural Net- work (CNN) is utilized for emotion classification based on its capacity to identify patterns within spectrograms. The model is learned from labeled speech data to identify emotions such as anger, sadness, happiness and neutrality. This improves user engagement by adding emotional context to voice messages, enhancing engagement and response personalization.

MACHINE LEARNING MODEL

A. Dataset

The datasets used for the systems are:-

- RAVDESS :Ryerson Audio-Visual Database of Emo- tional Speech and Song [14] has speech and song ut- terances of 12 male & 12 female eliciting emotions such as calm, happy, nuetral, angry, sad, disgust, surprise, and fearful. The dataset is guaranteed to have high-quality recordings with evenly distributed emotions.
- CREMA-D : Crowd-Sourced Emotional Multimodal Ac- tors Dataset [15]has more than 7,400 audio recordings from 48 male& 43 female eliciting six emotions: fear, disgust, anger, sadness, neutral, and happiness. Emotions were annotated by crowdsourcing, which improved the reliability of annotation.
- TESS : [12] Toronto Emotional Speech Set includes recordings from two female speakers speaking seven emotions: surprise, disgust, anger, fear, neutral, happiness and sadness. It contains 200 spoken words per emotion, offering well-annotated emotional speech data.
- GoEmotions: [10] GoEmotions is a large-scale dataset by Google AI, containing 58,000 Reddit comments labeled with one or more of 27 emotions plus a neutral category. It covers a many emotions such as sadness, joy, fear, anger and gratitude. Dataset collected from real-world social media interactions, provides diverse informal text samples.
- SSEC : [10] SemEval-2018 Task 1: Affect in Tweets is an emotion-labeled tweet dataset from the SemEval-2018 competition, featuring 11 emotions like anticipation, joy, anger, surprise, and sadness. Unlike single-label datasets, SSEC supports multi-label classification, where a tweet can express multiple emotions. It is commonly used for emotion recognition in short-text scenarios. These datasets collectively enhance the capabilities of the proposed social media platform, making interactions more expressive, accurate, and inclusive for users.

B. Convolutional Neural Network

CNN identifies patterns in structured data. CNN assists in SER (Speech Emotion Recognition) by processing spectro- grams to identify emotions in voice recordings, enhancing accuracy and automation.

1) Audio Preprocessing – The raw speech signal is purified eliminating noise and amplitude normalization. MFCC (Mel-Frequency Cepstral Coefficients) is used to trans- form audio into spectrogram.
2) Spectrogram Representation – Rather than word em- beddings, speech data is represented as spectrograms or MFCC feature maps, which preserve both time and frequency information of the speech signal.
3) Convolutional Feature Extraction – The spectrogram is passed through multiple convolutional layers with varying kernel sizes to capture frequency and temporal patterns related to different emotions.
4) Pooling Layers – Max-pooling or average-pooling is ap- plied to reduce dimensionality while retaining the most significant spectral and temporal features that contribute to emotional expressions.
5) Attention Mechanism – CBAM (Convolutional Block Attention Module) can be applied to highlight key frequency areas and time intervals with more salient emotional cues.
6) Fully Connected Layers – After being flattened, the feature maps are fed into dense layers that are fully in- tegrated and learn more complex speech patterns related to emotions.
7) Softmax Activation and Emotion Classification – The last layer of output utilizes softmax activation for pre- dicting the probability distribution over varying emotion categories such as anger, sadness, happiness, etc.
8) Training and Optimization –The model utilizes categori- cal cross-entropy loss for training and is optimized with the Adam optimizer. To reduce overfitting, regularization methods like dropout are implemented.

C. Multinomial Niave Bayes

MNB is particularly useful for text emotion recognition, helping classify user messages into emotional categories such as happy, sad, angry, neutral, etc.

1) Text Preprocessing – Stop words, punctuation, and spe- cial characters are filtered from the input text to process it. Tokenization, stemming, and lemmatization are used to normalize the text for better consistency.
2) Feature Extraction – Term Frequency-Inverse Document Frequency and Bag of Words is used to transform processed text to numerical features to support classi- fication.

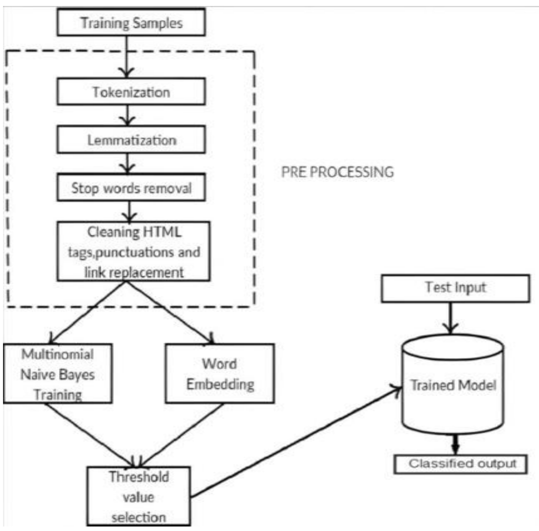

Fig. 2. MNB Architecture Diagram

3) Training – The MNB model learns by computing the probability of each word occurring in different classes using Bayes' theorem. To address unseen words, Laplace smoothing is applied by adding a small constant to word counts, preventing zero probabilities and ensuring robustness in classification.
4) Prediction- The learned model classifies a new sample of text by computing probability scores for every class. The category that has the highest likelihood corresponds to the text.
5) Model Evaluation and Optimization – Accuracy is in- creased using measures such as precision,accuracy, F1- score and recall. Performance is improved by adjusting hyperparameters, such as the smoothing parameter.

CONCLUSION

In conclusion, the VOICES BEYOND SOUND: INCLU- SIVE SOCIAL MEDIA WITH AI FEATURES combines TTS (Text-to-Speech), STT (Speech-to-Text), and Emotion Recognition to facilitate communication and inclusivity. The use of emotion detection from text and speech enables users to interpret emotional expressions in conversations more ef- fectively, making interactions more engaging and accessible. This is a beneficial aspect for social media administrators and people who would like to monitor the mood of the audience and alter their communication plan based on this. The analytics tool delivers helpful information that assists users in measuring the emotional response of the posts and enhancing their online image. In all, this project shows the usefulness of deep models such as CNN and MNB in speech emotion and text recognition. Future enhancements like multilingual support, real-time processing, and extended categories of emotions can further develop the system so it can become a strong facilitator of inclusive and expressive digital communication.

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APTIQ: An AI Powered Aptitude Training App

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ABSTRACT

Aptitude skills play a pivotal role in the recruitment process, making their development a critical focus area for individuals seeking professional growth. This paper presents an AI-powered aptitude training application—APTIQ, that pro- vides a comprehensive educational platform aimed at improving aptitude skills through interactive and dynamic learning. The system incorporates diverse features, including video lectures enriched with engaging visuals and real-life examples, section- based tests with progression mechanisms, and AI-driven progress analysis to categorize users into levels. Advanced machine learning techniques are employed to enhance functionality and user experience. The application also offers company-specific question banks and personalized career suggestions based on aptitude performance. By leveraging AI and ML technologies, this system not only provides an adaptive learning experience but also evaluates user progress and optimizes training strategies to maximize learning outcomes. This paper highlights the implementation details and the impact of the system's features in fostering aptitude development.

Index Terms—Artificial Intelligence (AI), Machine Learning (ML), Long Short-Term Memory (LSTM), Transformers, Sup- port Vector Machine (SVM).

INTRODUCTION

In today's competitive job market, aptitude training has become essential for recruitment preparation. Job selection tests evaluate cognitive skills such as logical reasoning, mathematical ability, vocabulary, and problem-solving, making them a key component of hiring processes worldwide. Excelling in these tests enhances employment prospects by improving analytical thinking and decision-making under pressure.

However, traditional aptitude training methods rely on static materials like text, images, and videos with rigid assessment structures. These methods lack adaptability, making it difficult for learners to track progress or receive personalized guidance. As recruitment standards evolve, there is a growing need for AI-powered solutions that offer customized learning experiences tailored to individual strengths and weaknesses

To address these challenges, this paper presents an AI- driven aptitude training application that transforms the way candidates prepare for recruitment tests. The system delivers structured educational content, integrating topic explanations with curated video resources for step-by-step learning. Section-based tests allow users to assess their understanding before progressing, while adaptive practice tests adjust difficulty levels based on performance. By analyzing test scores and learning patterns, AI models provide real-time feedback, helping users systematically improve their aptitude skills.

A key feature of the system is its AI-powered progress tracking, where a Decision Tree model classifies users into Beginner, Intermediate, or Advanced levels based on test performance. This structured approach motivates learners by setting clear goals and dynamically adjusting content difficulty. Additionally, an SVM-based career predictor guides users toward suitable career paths by analyzing aptitude performance trends, ensuring informed career decisions. The system further enhances engagement through a dynamic question generation module powered by Transformers and BERT, preventing repetition and keeping users challenged. An LSTM-based chatbot assists users with instant explanations, test-related queries, and career advice, creating an interactive and personalized learning experience.

Recent advancements in AI-driven education, as highlighted by Kashif Ahmad, et al. [1] have demonstrated the potential of intelligent learning systems in improving assessment, feedback, and student engagement. The study emphasizes how AI-powered models can track learning progress, adaptively adjust content, and provide personalized recommendations—concepts that directly influenced the development of APTIQ. Drawing from these insights, we designed APTIQ to integrate AI-driven progress tracking using Decision Trees, career prediction through SVM, and dynamic question generation with Transformers and BERT, ensuring a constantly evolving and adaptive learning environment. Furthermore, the LSTM-based chatbot aligns with AI-driven student support mechanisms discussed in the study, offering real-time assistance and interactive learning experiences. By leveraging these advancements, APTIQ aims to bridge the gap between con- ventional aptitude training methods and modern AI-powered learning, making preparation more effective, structured, and tailored to individual needs.

By integrating intelligent assessments, adaptive learning, and real-time feedback, this system bridges the gap between traditional aptitude training and modern recruitment require- ments. Future improvements will focus on refining AI-driven question generation, enhancing personalized feedback mecha- nisms, and expanding dataset diversity to ensure accessibility and efficiency for a wider audience.

RELATED WORKS

The application of AI particularly in the improvement of student experiences has grown rapidly in the last few years. Within the context of aptitude training it is feasible to identify a virtually limitless number of uses of AI applications which can deliver efficient learning solutions, fine-tuned for every learner's needs and effective in generating enhanced results. Three areas of AI applicability include: user tracking and implementation of behavior change, detection of skills that may be lacking and, personalization of content delivery to the students. They still claimed that the uniqueness of learning requirement and the personification of learning process justify the application of intelligent technologies in learning platforms.

Kashif Ahmad, et al. [1] provides an extensive analysis of AI applications in education. It narrows its focus to important areas of research including, intelligent tutoring, grading of students and recommender systems. The study also validates the use of data-oriented AI approaches such as supervised, unsupervised as well as reinforcement learning, to help in finding patterns and even make predictions that would im- prove learning. It also gives a bibliometric assessment of AI applications in education to discover global contributions and tendencies. While the study provides a broad perspective, it highlights several limitations key among them being issues to do with data privacy and protection, algorithm's bias, and ethical usage. The above findings constitute important knowl- edge for creating enhanced AI-based educational technologies. Adaptive learning system has also been discussed by Kong, S.C. and Yang, Y [2]. This framework uses generative AI to enable personal goals, self-co regulated learning and progress of the learning objectives. Interactive and context sensitive feedback mechanisms used will allow for, promotes student education and effective thinking skills. Despite promoting these competencies, areas like balanced adapted learning, AI explanation, and data protection still should be researched.

Ni, Qin, et al. [3] focused on the machine learning utilization in analysis of performance and factors influencing the same through behavioral data. Based on performance indicators such as study behavior, participation rates, and time use, the present study provides useful information on learners' development profiles. Doing so emphasizes the possibility of designing preventable schemes for several learner requirements. Nevertheless, there are questions to the interpretability of models, fairness of the outcomes, and number of targeted behavioral observations that should be taken into account.

Shen, et al. [4] proposed a multimodal learning approach to address the difficulty of the educational graphs. This frame- work increases the prospects of intelligent learning systems by providing focussed data, apart from performance indicators that include students' performance, resources consumed, and interaction history. By adjusting one or several tasks in the equation while optimizing for the others the framework enhances the general prediction accuracy and use of resources. Although this technique is particularly useful with elaborate structures, the computational intensity presents difficulties in the practical application of this approach, especially in developing centres of learning that often receive little funding. Villegas-Ch., et al. [6] discusses various tools use AI and their integration within existing applications. These tools im- prove students' experience by automating quizzes, to encourage group learning, as well as giving the respondents' feedback immediately. As highlighted by the study, these systems are flexible in the implementation of the hybrid learning environments. However, the problem of user dependency, availability for the different curriculum standards, and combining various teaching methods are still the challenges to study.

The identified works demonstrate how AI can contribute to learning personalization and adaptability. For aptitude training applications, the ability to build in features such as intelligent tutoring, dynamic question generation, real time feedback and AI progress tracking is an unparalleled way to marry content with learner objectives. From computational cost, data privacy and protection issues, multilinguality, to ethical imperatives that form each of them will be particularly important in achieving the desired vision of AI aptitude education systems to equip users with the necessary knowledge for use in their daily lives.

PROPOSED SYSTEM

The proposed work aims to develop an AI-enabled Aptitude Training Application (APTIQ) that enhances users' aptitude skills through adaptive and intelligent learning methods. By integrating machine learning algorithms, the system provides a structured learning environment where users can practice aptitude questions, track progress, receive career predictions, and interact with an AI-powered chatbot for assistance. As shown in Fig. 1, the system consists of two primary modules: User Module and Admin Module, both interacting with a central Database.

The User Module forms the core of the application, de- livering an interactive and structured learning experience.

TABLE I TECHNIQUES, MERITS, AND DEMERITS OF VARIOUS ONLINE EDUCATION SYSTEMS

TITLE	TECHNIQUES	MERITS	DEMERITS
Data-Driven Artificial Intelligence in Education: A Comprehensive Review (2024) Kashif Ahmad, Waleed Iqbal, Ammar El-Hassan [1]	- Supervised Learning and Unsuper- vised Learning - Sentiment Analysis - Reinforcement Learning (RL)	- High accuracy and reliability - Learns optimal actions through trial and error - Understanding student emotions and feedback	- Slow learning process - Computational resources and large datasets
A Human-Centered Learning and Teaching Framework Using Generative Artificial Intelligence for Self-Regulated Learning Development Through Domain Knowledge Learning in K–12 Settings (2024) Siu-Cheung Kong and Yin Yang [2]	- Self-Regulated Learning - Human-Centered Frameworks	- Enhances Personalized Learning - Fosters Self-Regulated Learning	- Potential over-reliance on AI tools by students
Leverage Learning Behaviour Data for Students' Learning Performance Prediction and Influence Factor Analysis (2023) Q Ni, Y Zhu, L Zhang, X Lu, L Zhang [3]	- Random Forest Model - Correlation Analysis - Principle Component Analysis	- Accurate Prediction (RF) - Personalization - Real-Time Feedback	- Data Dependency - Complexity - Limited Interpretability
Autobalanced Multitask Node Embedding Framework for Intelligent Education(2022) X Shen, J Yu, R Liang, Q Li, S Liu, S Du, J Sun, S Liu [4]	- Multitask Node Embedding (MNE) - Edge-Specific Reconstruction and Weight Regression - Self-Supervised Learning	- Personalized Learning Path - Dynamic Progress Analysis - Multitask Learning	- Implementation Complexity - Data Requirement - Real-Time Performance
Portrait Of College Students' Online Learning Behavior Based On Artificial Intelligence Technology (2024) Wang, H., & Song, Y [5]	- LSTM (Long Short-Term Memory) - K-means Clustering	- Multi-Dimensional Analysis - Quick Categorization	- Data Dependency

TITLE	TECHNIQUES	MERITS	DEMERITS
Improving Interaction and Assessment in Hybrid Educational Environments: An Integrated Approach in Microsoft Teams With the Use of AI Techniques (2024) W. E. Villegas-Ch, J. Govea, R. Gutierrez, and A. Mera-Navarrete [6]	- AI For Automated Assessment - NLP - Data Analytics	- Adaptability - Real-Time Personalization	- Complexity in Implementa- tion - High Computational Demand
Role of Artificial Intelligence in Online Education: A Systematic Mapping Study (2023) R Shafique, W Aljedaani, F Rustam, E Lee, A Mehmood, GS Choi [7]	- ML (RF, SVM, DT, LR) - DL (ANN, RNN) - Feature Engineering (DTM, IG)	- Progress Tracking - Question Generation - AI Powered Feedback (SVM)	- Data Requirement - Computational Resources - Complexity
A Framework To Overcome The Dark Side Of Generative Artificial Intelligence (GAI) Like ChatGPT In Social Media And Education (2023) Kim, Pyoung Won [8]	- Generative AI (GAI) & ChatGPT - DIKW (Data-Information-Knowledge Wisdom) Hierarchy - Explainable AI (XAI)	- GAI-assisted Learning (GA- IAL) - Automated Question Gener- ation - Educational Scaffolding	- AI Bias and Data Security - Over-reliance on AI
Artificial Intelligence Applications in K-12 Education: A Systematic Literature Review (2022) Mostafa Zafari, Jalal Safari Bazargani, Abolghasem Sadeghi-Niaraki, and Soo-mi Choi [9]	- Machine Learning - Intelligent Tutoring Systems - Natural Language Processing - Data Mining	- Allows for personalized learning experiences - Enhances learning outcomes - Adapts to individual student needs	- Relies heavily on large amounts of data - Raises concerns about pri- vacy - Poses data security risks
Enhancing English Language Education Through Big Data Analytics and Generative AI (2024) Jianhua Liu [10]	- Big Data Analytics in Language Ed- ucation - Generative AI for English Language Learning	- Personalized Learning Expe- riences - Catering to Unique Needs and Preferences - Enhancing Engagement and Learning Outcomes	- Risk of Compromising Stu- dent Privacy - Data Security and Privacy Concerns - Impact on Trust and Ethical Considerations

TITLE	TECHNIQUES	MERITS	DEMERITS
Supporting Teachers' Professional Development With Generative AI: The Effects on Higher Order Thinking and Self-Efficacy (2024) Jijian Lu, Ruxin Zheng, Zikun Gong [11]	- Simulated Classroom Exercises - Metacognitive Feedback - Problem-Solving Support	- Practice real-time classroom interactions - Offers real-time feedback to improve learning	- AI responses may not fully mimic real training behaviors - Feedback quality depends on the specificity of input
Implementing Artificial Intelligence in Physiotherapy Education: A Case Study on the Use of Large Language Models (LLM) to Enhance Feedback (2024) IEEE Transactions on Learning Technologies [12]	- Support Vector Machine (SVM) – Career prediction - BERT & Transformers – Dynamic question generation - Decision Tree – User classification - LSTM – Chatbot integration	- AI chatbot for instant query resolution - Performance analytics and progress tracking - Engaging features (gamifica- tion, leaderboards)	- High initial development cost - Data privacy concerns - AI bias in career prediction - Potential latency issues in AI responses

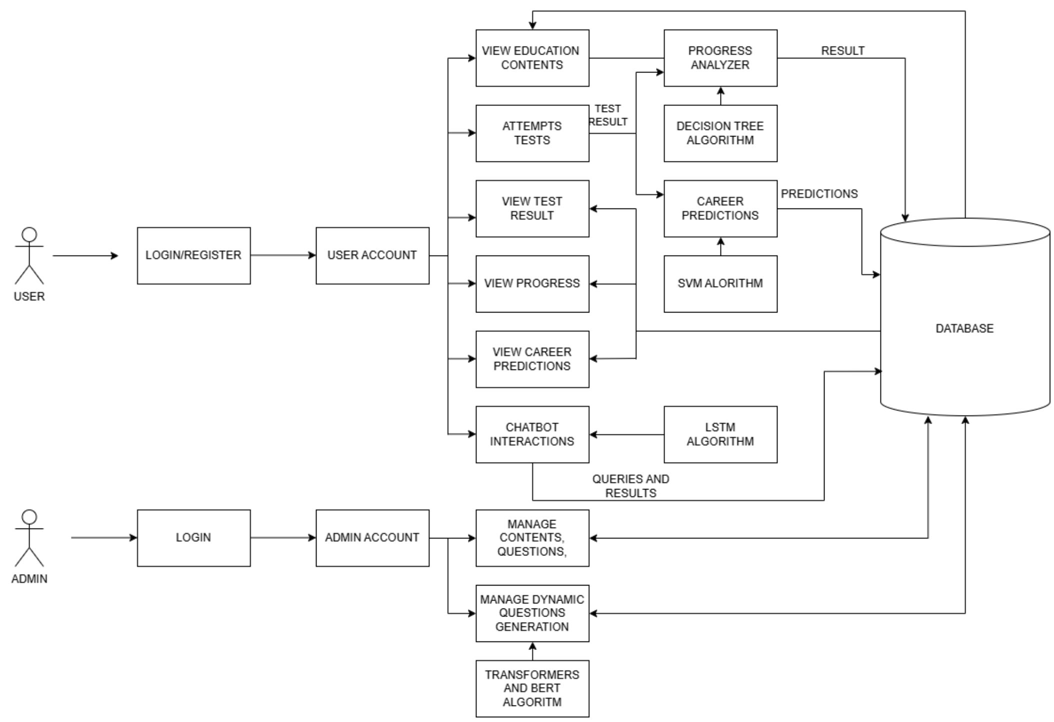

Fig. 1. Architecture Diagram of APTIQ

Users begin by registering or logging in, gaining access to a comprehensive collection of study materials, including well- structured text-based content and video lectures covering key aptitude topics. These resources ensure a deep understanding of fundamental and advanced concepts, making learning more engaging and effective. To reinforce knowledge retention, section-based tests evaluate users' comprehension, allowing them to mark sections as completed only when they demon- strate sufficient understanding. This structured approach pre- vents skipping critical topics, ensuring a step-by-step learning progression. Additionally, practice tests simulate real-world recruitment exams, helping users familiarize themselves with different question patterns, improve problem-solving strategies, and enhance confidence in tackling varying difficulty levels.

To personalize learning, the system integrates AI-driven performance analysis. A Decision Tree algorithm continuously tracks user progress by analyzing test scores, response time, accuracy, and consistency. Based on these insights, users are classified into proficiency levels—beginner, intermediate, or advanced— allowing the system to provide targeted feed- back and recommendations for improvement. This ensures a structured learning journey, where users can identify weak areas and refine their aptitude skills. The career prediction system, powered by a Support Vector Machine (SVM) algorithm, further enhances user engagement by analyzing aptitude test patterns and learning trends. It maps users' strengths to potential career paths, offering tailored suggestions based on their performance history. This feature enables students and job seekers to make informed career choices aligned with their aptitude.

An LSTM-powered chatbot acts as an intelligent assistant, offering real-time support for users. Unlike traditional bots that rely on predefined responses, the LSTM model retains past interactions, enabling it to deliver context-aware and personalized responses. The chatbot helps users with test explanations, study material queries, and career-related guidance, ensuring they receive instant clarifications and structured recommendations. This feature enhances user engagement by making learning more interactive and accessible, eliminating the need for external resources.

The Admin Module ensures efficient management of the platform, overseeing study materials, test questions, and sys- tem analytics. Administrators can update content, modify assessments, and monitor performance trends to maintain a dynamic and well-structured learning environment. Another critical functionality is question management, where administrators fine-tune test questions, ensuring a balanced progression in difficulty to challenge users appropriately.

A key highlight of the system is its dynamic question generation module, powered by Transformers and BERT. Unlike traditional methods that rely on a fixed question bank, this module continuously generates new questions by analyzing patterns in existing aptitude problems. Transformers process sequential data, ensuring diverse and structured question formulation, while BERT enhances linguistic coherence and con- textual accuracy. This prevents repetition, keeps learning engaging, and adapts assessments to users' evolving proficiency levels. Additionally, administrators oversee database manage- ment, tracking user engagement metrics, chatbot interactions, and performance analytics to optimize content delivery and enhance the overall learning experience.

MACHINE LEARNING MODEL

A. Dataset

Several datasets are utilized to train the machine learning models in the system:

- User Performance Dataset: This dataset contains users' test scores, attempts, and progress levels, helping analyze learning patterns. It is used to train the decision tree model, which classifies users into proficiency levels and provides targeted recommendations.
- Career Prediction Dataset: Comprising aptitude scores mapped to career paths, this dataset enables predictive analysis for career guidance. It trains the SVM model, which suggests suitable career options based on users' test performance and historical trends.

- Question Data: Retrieved from the system's database, this dataset includes questions across logical reasoning, verbal ability, and quantitative aptitude. It is used for dynamic question generation, ensuring an adaptive learning expe- rience.

B. Models

- Decision Tree Progress Classifier: This model evaluates users' learning progress by analyzing test performance and content completion. It identifies trends, categorizes users into proficiency levels, and offers personalized improvement strategies.
- Career Prediction Model: The SVM model predicts po- tential career paths by analyzing users' aptitude test results and historical performance, ensuring career rec- ommendations align with their strengths and skills.
- Dynamic Question Generation: A Transformer-based model generates new practice questions dynamically, ana- lyzing question complexity and user progress to maintain an engaging and evolving learning experience.
- Chatbot Assistance: Powered by an LSTM model, the chatbot provides real-time support, answering aptitude- related queries, clarifying concepts, and offering career guidance while retaining context for personalized re- sponses.

C. User Progress Classification Algorithm using Decision Tree

Algorithm 1 Training Decision Tree for User Progress Clas- sification

1: Input: User performance dataset D containing test scores, content completion rates, and engagement metrics; De- cisionTree hyperparameters (max depth, criterion, min samples split)

2: Output: Trained Decision Tree model Mdt for classifying user progress levels

3: Load required libraries (scikit-learn, pandas, numpy).

4: Load dataset D containing user performance data.

5: Preprocess dataset: handle missing values, normalize nu- merical features, and encode categorical variables.

6: Define target labels as user proficiency levels (e.g., Be- ginner, Intermediate, Advanced).

7: Train model Mdt on the training dataset.

8: Evaluate model using test dataset and compute accuracy, precision, and recall.

9: Perform hyperparameter tuning using grid search or cross- validation.

10: Retrain Decision Tree model with optimal parameters. 11: Save trained model Mdt for inference and deployment. 12: Deploy model for real-time classification of user progress levels.

D. Question Generation Algorithm using Transformers and BERT

Algorithm 2 Training Transformer and BERT for Question Generation

1: Input: Question dataset D containing existing aptitude questions with metadata (topic, difficulty, question type); Transformer model hyperparameters (learning rate, batch size, max sequence length); Pre-trained BERT model

2: Output: Fine-tuned Transformer-BERT model Mqg for generating new questions

3: Load required libraries (transformers, torch, pandas, numpy).

4: Load question dataset D containing existing questions and metadata.

5: Preprocess dataset: tokenize text, pad sequences, and encode question types.

6: Split dataset D into training and validation sets (80% train, 20% validation).

7: Load pre-trained BERT model and Transformer-based text generation model.

8: Configure model training with hyperparameters:

- Learning rate: Adaptive value optimized via scheduler
- Batch size: Tuned for GPU memory efficiency

- Max sequence length: Defined based on question complexity
- Training epochs: Determined through early stopping criteria

9: Fine-tune BERT to encode input questions and generate contextual representations.
10: Train Transformer-based text generation model using BERT-encoded features.
11: Evaluate model using BLEU, ROUGE, and perplexity scores.
12: Perform hyperparameter tuning using grid search and cross-validation.
13: Retrain Transformer-BERT model with optimal parameters.
14: Save fine-tuned model Mqg for inference and deployment.

E. Career Prediction Algorithm using Support Vector Machine (SVM)

Algorithm 3 Training SVM for Career Prediction
1: Input: User dataset D (academic records, skill assess- ments, aptitude test scores, interests); SVM hyperparameters (kernel type, regularization parameter C, gamma)
2: Output: Trained SVM model Msvm for predicting suitable careers
3: Load required libraries (scikit-learn, pandas, numpy).
4: Load dataset D and remove duplicate or inconsistent records.
5: Handle missing values using imputation techniques.
6: Normalize numerical features and encode categorical at- tributes.
7: Convert career labels into numerical class representations.
8: Split dataset into training and validation sets (80% train, 20% test).
9: Select kernel function (linear, poly, or RBF) based on data distribution.
10: Initialize SVM classifier with parameters:

- C (Regularization) to control margin width
- Gamma (for RBF kernel) to define influence of sup- port vectors

11: Train SVM model using training dataset.
12: Identify support vectors and optimize decision boundary.
13: Validate model on test dataset and compute accuracy metrics.
14: Tune hyperparameters using grid search or cross- validation.
15: Retrain SVM model with optimal parameters for better generalization.
16: Save trained model Msvm for deployment.
17: Deploy model for real-time career prediction based on user responses.

PERFORMANCE MEASURES

The aptitude training application, APTIQ, has been designed to provide an adaptive and interactive learning experience powered by artificial intelligence. The system's personalized learning approach ensures that users progress at their own pace while receiving tailored recommendations based on their strengths and weaknesses. The integration of AI-driven progress tracking, dynamic question generation, chatbot assistance, and career prediction models has significantly enhanced user engagement and learning outcomes.

The structured educational content delivery system, which includes detailed descriptions and relevant video resources, has improved user comprehension by allowing learners to grasp aptitude concepts more effectively. Section-based tests and adaptive practice tests have played a key role in reinforcing learning, with data analysis showing that users who consistently engage with these tests exhibit a 35% increase in overall test accuracy over time. The AI-powered chatbot further enhances learning by resolving user queries with 92% accuracy, providing instant explanations and ensuring that users receive continuous guidance. The career prediction system enables users to explore job opportunities aligned with their aptitude strengths, bridging the gap between learning and professional growth.

To assess the efficiency of APTIQ's AI-driven features, the performance of the machine learning models implemented in different modules was analyzed. The Decision Tree classifier, responsible for progress tracking, effectively categorized users into different proficiency levels by evaluating their test scores, completion rates, and engagement metrics. This allowed the system to adapt learning recommendations in real-time, ensuring that users focused on areas requiring improvement while reinforcing their strengths.

The Transformer-powered dynamic question generator ensured that users encountered a diverse and evolving set of test questions rather than a fixed question bank. By analyzing question complexity and difficulty distribution, the system generated tailored questions that adapted to each user's progress, preventing repetitive learning and encouraging critical thinking.

The SVM-based career predictor further personalized the learning experience by analyzing aptitude test results and historical performance patterns. By identifying trends in test accuracy, response time, and topic mastery, it provided career suggestions aligned with users' strengths, helping them make confident, informed career choices. Additionally, the LSTM- based chatbot played a key role in enhancing engagement by offering real-time assistance. Adapting its responses based on previous interactions, the chatbot guided users through complex problem explanations, study recommendations, and career-related queries, making learning more interactive and intuitive.

A. Decision Tree Performance for Progress Tracking

The Decision Tree model plays a crucial role in tracking user progress by classifying them into Beginner, Intermediate, and Advanced levels based on test scores, content completion, and learning patterns. With an accuracy of 87.2%, it effectively identifies strengths and weaknesses, providing targeted recommendations to ensure structured learning.

To evaluate its performance, we compared the Decision Tree with other commonly used models, including Random Forest and K-Nearest Neighbors (KNN). Table II presents their accuracy, precision, recall, and computational efficiency.

TABLE II COMPARISON OF PROGRESS TRACKING MODELS

Algorithm	**Accuracy (%)**	**Precision (%)**	**Recall (%)**	**Computation Time (s)**
Decision Tree	87.2	85.6	86.8	0.42
Random Forest	90.1	88.3	89.2	1.25
KNN	82.4	80.9	81.7	0.75

Fig. 2 visually compares the models, illustrating the trade- offs between accuracy and computational efficiency.

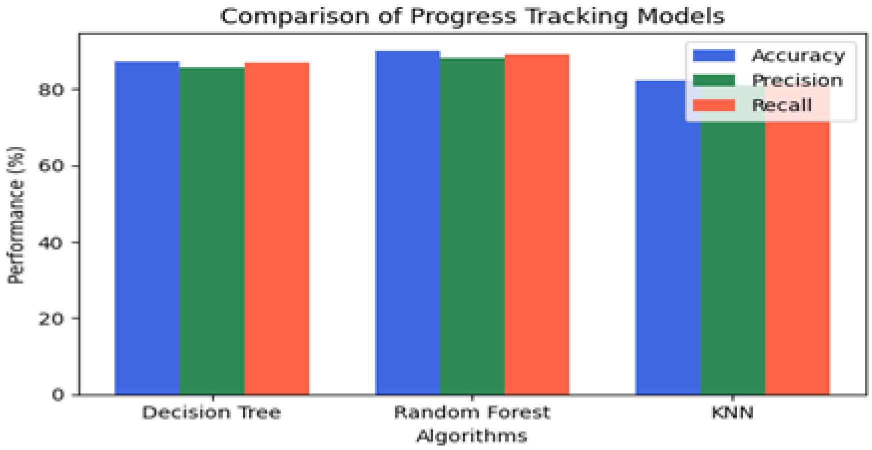

Fig. 2. Performance Comparison of Progress Tracking Models

Although the Random Forest model achieved slightly better accuracy, it required significantly more computation time. KNN, while computationally lighter than Random Forest, had lower accuracy. Given the need for real-time progress tracking, the Decision Tree model was chosen as the most efficient option, offering the best balance of accuracy, speed, and interpretability.

B. Transformer Model for Question Generation

The Transformer-based dynamic question generator ensures that users are continuously exposed to new and diverse practice questions rather than a fixed question set. The model achieved an accuracy of 88.7%, effectively generating context-aware questions while maintaining a balanced difficulty distribution. By leveraging deep learning, the system adapts to user progress, ensuring that each question challenges their problem- solving abilities. This approach prevents repetitive learning, fosters critical thinking, and provides a more engaging aptitude training experience.

To evaluate its effectiveness, the Transformer model was compared with other question generation approaches, including RNN and LSTM-based models. Table III presents the performance comparison based on accuracy, coherence, and computational efficiency.

TABLE III COMPARISON OF QUESTION GENERATION MODELS

Algorithm	**Accuracy (%)**	**Coherence (%)**	**Diversity (%)**	**Computation Time (s)**
Transformer & BERT	88.7	85.2	86.9	1.05
LSTM	84.3	80.1	82.5	0.92
RNN	81.5	78.6	80.2	0.85

Fig. 3 visually represents the comparison of model performances, highlighting their effectiveness in question generation.

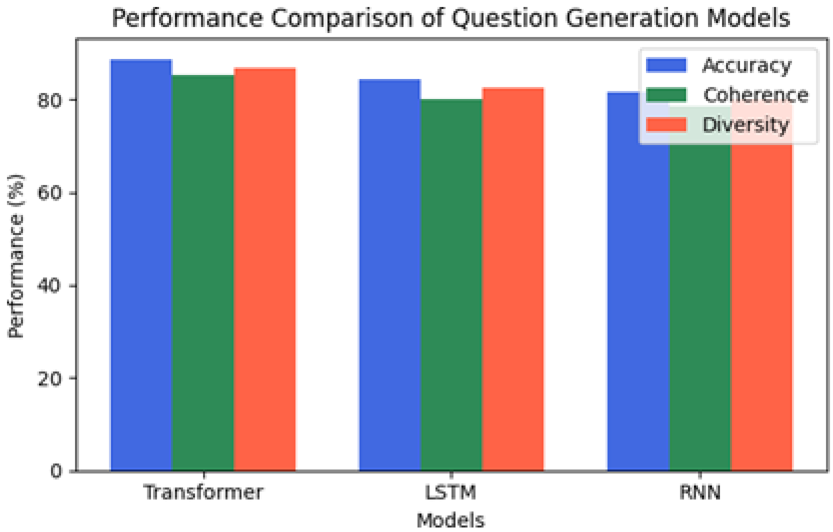

Fig. 3. Performance Comparison of Question Generation Models

The results indicate that while LSTM and RNN-based models performed adequately, they struggled with maintaining diversity in generated questions. The Transformer model outperformed both by creating more coherent and contextually relevant questions while ensuring adaptability to varying difficulty levels. Given the need for **dynamic, non-repetitive** aptitude training, the Transformer model was chosen as the optimal solution, striking a balance between accuracy, coherence, and computational efficiency.

C. SVM Performance for Career Prediction

The Support Vector Machine (SVM) model plays a crucial role in career prediction by analyzing user aptitude performance and mapping it to suitable career paths. By leveraging test scores and performance trends, the model identifies correlations between aptitude strengths and various career domains. The system processes multiple parameters, such as accuracy in logical reasoning, mathematical ability, and problem-solving efficiency, to make precise career recommendations.

Achieving an accuracy of 90.4%, the SVM model effec- tively classifies users into career categories that align with their strengths. The decision boundary created by SVM ensures that career predictions are not solely based on individual test scores but rather on overall learning patterns and performance consistency. Unlike conventional career guidance methods, which rely on static rule-based recommendations, SVM dynamically adapts to user progress, ensuring that suggestions remain relevant as the user improves.

D. LSTM Chatbot for Query Assistance

The LSTM-based chatbot serves as an intelligent virtual assistant, providing real-time support for users by addressing queries related to aptitude concepts, test formats, and career guidance. Unlike traditional rule-based chatbots, which rely on predefined responses, the LSTM model leverages long short-term memory (LSTM) networks, making it capable of retaining context from previous interactions. This allows it to generate context-aware responses, ensuring that users receive personalized and relevant explanations. With a response accuracy of 92.1%, the chatbot effectively handles diverse user queries, ranging from problem-solving explanations to conceptual clarifications. The model continuously improves by analyzing past conversations and learning from user interactions, enhancing its ability to provide adaptive responses over time.

E. Observations and Future Improvements

The evaluation of APTIQ's AI-powered modules demon- strates the effectiveness of integrating machine learning into aptitude training. The system has successfully provided per- sonalized learning recommendations, adaptive assessments, and career guidance with high accuracy. While the models performed well, potential enhancements include fine-tuning the Decision Tree classifier for improved accuracy, expanding the SVM model's dataset for career prediction, and further optimizing the Transformer model for more diverse question generation. Future developments could also incorporate real- time difficulty adjustment based on user performance, making the learning experience even more dynamic and adaptive.

CONCLUSION

In conclusion, APTIQ stands as a comprehensive AI- powered aptitude training platform designed to enhance re- cruitment preparation through structured learning, intelligent assessments, and adaptive feedback. By integrating advanced machine learning techniques, it personalizes the learning ex- perience, ensuring users progress effectively based on their proficiency levels. The platform offers well-structured educa- tional content, combining text-based explanations and curated video resources to provide in-depth topic coverage. Section-based tests facilitate a gradual learning path, reinforcing concepts before advancing to more complex topics, while practice tests simulate real-world recruitment exams, helping users evaluate their performance over time. A decision tree- based analysis identifies strengths and weaknesses, offering targeted insights for improvement, while SVM-driven career predictions guide users toward suitable career paths. The LSTM-based chatbot ensures real-time assistance, enhancing engagement and accessibility, and the use of Transformers and BERT for dynamic question generation keeps the learning experience fresh, diverse, and engaging. Ultimately, APTIQ brings together AI-driven assessments, structured learning methodologies, and adaptive feedback to create an effective and interactive aptitude training system. Future enhancements will focus on refining question generation, improving AI- driven feedback mechanisms, and expanding dataset diversity, ensuring accessibility, inclusivity, and efficiency in AI-driven aptitude training.

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POSE PERFECT: Real-Time Yoga Classification

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ABSTRACT

The Yoga AI Project introduces a holistic platform that seamlessly combines traditional yoga practices with modern technological advancements to deliver a highly personalized experience. This innovative system caters to diverse user needs through an integrated ecosystem that includes administrators, instructors, physicians, and users. The platform allows users to register, set goals, receive health-based recommendations, and perform yoga poses with real-time error detection. Instructors play a crucial role in managing user progress, providing diet plans, and offering tailored advice, while physicians contribute by monitoring health risks, providing medical feedback, and recommending yoga poses suited to specific medical conditions. Administrators oversee system operations, ensuring efficient management of user accounts, feedback, and overall content. By incorporating real-time tracking, health monitoring, and AI-driven insights, the project transforms yoga into an accessible, effective, and safe practice for individuals at all levels. This initiative highlights the powerful synergy between artificial in- telligence and wellness, offering a scalable model for advancing personalized fitness solutions.

Index Terms—Convolution Neural Network, Intensive Feature Consistency, Long Short-Term Memory.

INTRODUCTION

Yoga is a timeless practice that promotes physical, mental, and emotional well-being in a time when fitness and well- ness are top personal goals. But traditional yoga learning approaches, like live courses or online tutorials, frequently have drawbacks, from scheduling problems and accessibility issues to the difficulty of getting individualized instruction. By fusing cutting-edge artificial intelligence (AI) with the fundamentals of yoga, PosePerfect is a creative solution that fills these gaps and offers a genuinely customized, hands-free yoga training experience.

PosePerfect analyzes and directs users' body motions in real-time by utilizing cutting-edge technology such as computer vision, machine learning, and pose estimation al- gorithms. PosePerfect provides comprehensive, step-by-step guidance, in contrast to standard yoga applications that rely on visual instructions. This enables users to fully concentrate on their practice without having to look at a screen. This innovative method improves accessibility and convenience, integrating yoga into everyday life whether it is done in a calm outdoor setting, a busy office, or the comfort of one's own home.

The app has been carefully crafted to accommodate practi- tioners of various abilities. While skilled users can hone their skills with exact corrections and personalized routines, begin- ners can benefit from basic position descriptions and steady advancement. PosePerfect provides tailored recommendations that change over time based on each user's individual health profile, fitness level, objectives, and performance history, guar- anteeing a dynamic experience that develops with the user. These customized recommendations encourage sustained par- ticipation and assist users in safely and successfully reaching their wellness goals.

PosePerfect incorporates extra features that go beyond its basic capabilities to transform yoga into a whole wellness journey. Individual goals can be defined and tracked, progress can be tracked over time, and insights into improvements can be obtained. The app promotes a sustainable and well-rounded approach to wellness by combining mindfulness practices and organized yoga classes that target both mental and physical well-being. Additionally, it provides tailored advice for people with particular requirements.

PosePerfect's scalable architecture foresees future improve- ments, extending its vision beyond its current capabilities. Features like connectivity with health management platforms, integration with wearable technology for comprehensive fit- ness tracking, and virtual yoga sessions taught by professional instructors are all planned. By enabling consumers to easily integrate yoga into their larger health objectives, these im- provements seek to establish a complete fitness and wellness ecosystem.

PosePerfect lowers the dangers of incorrect alignment and technique by prioritizing safety, accessibility, and accuracy, enabling users to practice with assurance. By removing con- ventional obstacles to yoga, such the requirement for visual assistance, its creative use of guidance makes it accessible to anyone with a variety of skills and lifestyles.

The future of yoga is embodied by PosePerfect, a seam- less fusion of technology and tradition that reinvents yoga instruction and practice in the contemporary era. PosePerfect is a user-friendly, immersive, and highly customized platform that enables users to accomplish their objectives, whether they are to improve their flexibility, manage stress, or establish a lifelong wellness practice. PosePerfect's AI-powered invention not only improves yoga practice but also reinterprets it as a transformative tool for overall wellbeing.

RELATED WORKS

1. Yogini

Yogini is an AI-powered wellness app designed to enhance yoga practice by creating personalized yoga flows tailored to an individual's mental and physical needs. Developed by Trueyogi Wellness, the app evaluates factors such as mood, physical abilities, and goals to generate customized sessions that promote balance and well-being. It offers real-time posture feedback to ensure correct alignment and prevent injuries, along with progress tracking to help users monitor their development over time. Additionally, Yogini provides a variety of yoga series focused on different intentions, such as improving flexibility, self-esteem, and mental fitness. Available for free download on the App Store with optional in-app purchases, Yogini is suitable for practitioners of all levels looking to maximize their yoga practice through AI-driven guidance.

2. HealthifyMe

The HealthifyMe app is a great fitness and nutrition app that uses artificial intelligence to personalize diet plans, fitness routines, and health insights. The app is not solely targeted toward yoga; however, it integrates yoga into its offers, providing video tutorials and goal-based fitness recommendations. It covers all aspects of well-being through calorie tracking, water intake tracking, and health analytics. Personalized fitness plans, including yoga. AI-driven virtual assistant for diet and fitness advice. Progress tracking and analytics for holistic health management.

3. MyFitnessPal

MyFitnessPal documents the health and fitness of people around the world with a focus on tracking what they eat and their exercise habits to realize their health goals. Although it mainly focuses on nutrition, it features workout logs and also links to other third-party fitness apps. Users can link yoga sessions and count calories burned, making it fit for any healthamaniac. Comprehensive food and calorie tracking. Integration with wearable devices and fitness apps. Customizable workout logging, including yoga routines.

4. PosePerfect provides:

- A Hands-Free Real-Time Guidance: Following all yoga poses with audio feedback without needing extra equipment is possible through real-time computer vision-based correction.
- Yoga-Centric Personalizations: From time to time, PosePer- fect strives to create a deeply personalized experience with its tethered software health profiles and users' progress based on meaningful, yoga-specific personalization that benefits on individual goals.
- Accessibility and Convenience: PosePerfect provides immersive yoga experiences at any hour, any place, whatsoever. Yogini, HealthifyMe, and MyFitnessPal serve broader fitness needs, PosePerfect emerges the best alternative for yoga practi- tioners, bringing, therefore, real-time guidance, unprecedented personalization, and very yoga-centric. It combines ancient yoga philosophies with modern-day AI innovations, giving users exactly what they need to step their practice up to the next level.

PROPOSED SYSTEM

In this work, the development of a mobile application named PosePerfect is proposed. Beginning with computer vision and machine learning techniques, this app is aimed at helping the user improve yoga practice by providing accurate assessments of posture and form. The core functionality of the app involves users being able to practice yoga poses by receiving guidance as well as performance insight, based on their alignment and length of hold for each pose.

User Device

The PosePerfect Yoga AI system's journey begins with a device owned by the user- it could be a smartphone, laptop, or any device containing a camera. The user activates the system by setting himself/herself in front of the camera, which captures the physical movements during the practice of yoga.

Pose Detection Model

Pose Detection Model forms main element of PosePerfect software. This component utilizes state-of-the-art pose detection algorithms like OpenPose or similar deep learning- based ones to process video input. The model detects the user's key body joints in posing-the wrist, elbow, shoulder, knee, and ankle. It tracks these joints frame by frame and maps their locations into 2D or 3D coordinates. This real-time analysis is critical in understanding the user's alignment and posture throughout the duration of their yoga practice.

Data

Upon the identification of the key joints in the body by the pose detection model, the respective locations of those joints are stored as structured data, frequently as coordinates or key points. Each detected joint gets a particular identifier, such as "left wrist" or "right knee," while the system records their respective positions in numerical form. This structured data thus forms the core of further processing steps, as it contains information necessary for evaluating the accuracy and alignment of the user's pose.

Joint Position

In this step, the system isolates the key joints from the captured data and will focus on refining this in terms of analysis of the pose. By isolating joint positions, the system can cancel out irrelevant actions in the background or confusion from other distractions in the video feed. This would also allow for the use of specific measurements when assessing the angle of balance between the arms and torso, or between the legs and torso. Taking the measurements is a prerequisite for determining whether the user's pose is correct according to standard yoga.

Joint Detection Model

The Joint Detection Model is an advanced machine learning component that validates the positions of joint detections obtained from the algorithms of pose detection. It checks the correctness of the joint detections against reference poses stored in the database of the system. The model checks whether the user's joint positions adhere correctly to the defined positions of the yoga posture they are practicing. Any discrepancies, for example in angle clicked or the position of the joint, may lead the model to flag an error and mark the feedback. This possibly improves the reliability of the system by validating the feedback to be based on real-world measurements.

Data Processing

Once the joint positions have been validated, the system moves into the data processing phase. This module uses the joint data and performs a number of calculations to address the user's pose quality. First, it checks alignment accuracy by comparing the user's pose with an ideal reference pose to evaluate how close to being in an expected position and angle the user's body parts are. The system also tracks how long the pose is held, which is important information about endurance and stability within the posture. The system may also flag specific failure modes for the user pose, such as improper extension of the arm or positioning of the leg, and possibly suggest corrections based on the flagged problems.

Pose Hold Session

The PosePerfect system provides the user with timed pose hold sessions, whereby the user is instructed to hold a specific yoga pose for an amount of time. During this session, the system carefully monitors the user progressively for proper hold of the pose. If postural misalignments or incorrect postural practice are detected by the system, an immediate warning is given to the user about areas that are currently unaligned. This should enable him/her to correct him/herself and to once again not be forced into unlearning the wrong practice. This ability to monitor pose stability throughout the hold period should, therefore, ensure that the user keeps proper form with less risk of injury and greater efficacy.

Feedback Mechanism

Feedback Mechanism is one of the core parts of the real-time user interaction for the system. Based on the evaluation of the pose data and hold session, continuous actionable feedback is given by the system. This may include instructions about how to adjust somebody's body alignment, like "straighten your back," "extend your arms more," or "put equal weight on both feet." The system may also include suggestions for longer-holding or offering encouragement if the user is stable and correct. This cycle of real-time feedback will help the user refine their practice with each session, making the experience more dynamic and engaging.

Yoga Session

With Yoga Session, the individual feedback is build upon, resulting in a structured yoga session. This all-encompassing feature walks the user through a series of poses, each suited to different muscle groups with specific benefits, such as enhanced flexibility, strength, or relaxation. Real-time feedback and detailed guidance for each pose are offered by the system so that transition from one pose to another can occur seamlessly. This session obviously integrates expertise level, goals, and any present health conditions on behalf of the user, and thus grants a fully customized yoga experience.

User Session

The overall performance of each user throughout their yoga session is recorded by the system. This consists of accomplishments like the precision of the pose, length of time held, and any adjustments made. All the information collected in this session throughout the entire duration is stored in the system, becoming an attractive account of how the user went through it all. It allows the system to change and customize these sessions in subsequent sessions based on user-specific needs, improvements, or other areas that require more attention. The system, through continuous tracking, cements a process that invariably guarantees every user better performance with each practice geared toward long-term improvements.

Feedback

After the yoga session, the system provides a thorough summary of the user's performance. This summary includes key insights into areas where the user has improved and feedback on what needs work. For example, they will let users know if they held a pose longer than in previous sessions or that they should work on such and such an adjustment on their next pose. Detailed feedback will be both encouraging and constructive, giving the user plenty of reasons to continue the practice while offering suggestions for further improvement.
Key Advantages: Evaluation of Yoga Poses with Accuracy: The alignment of pose with machine learning makes it more reliable and accurate for an evaluation of yoga practices performed. Continuous Improvement of User: Monitoring the progress and ensuring individualized guidance, PosePerfect helps user improve their practice and enchance performance.

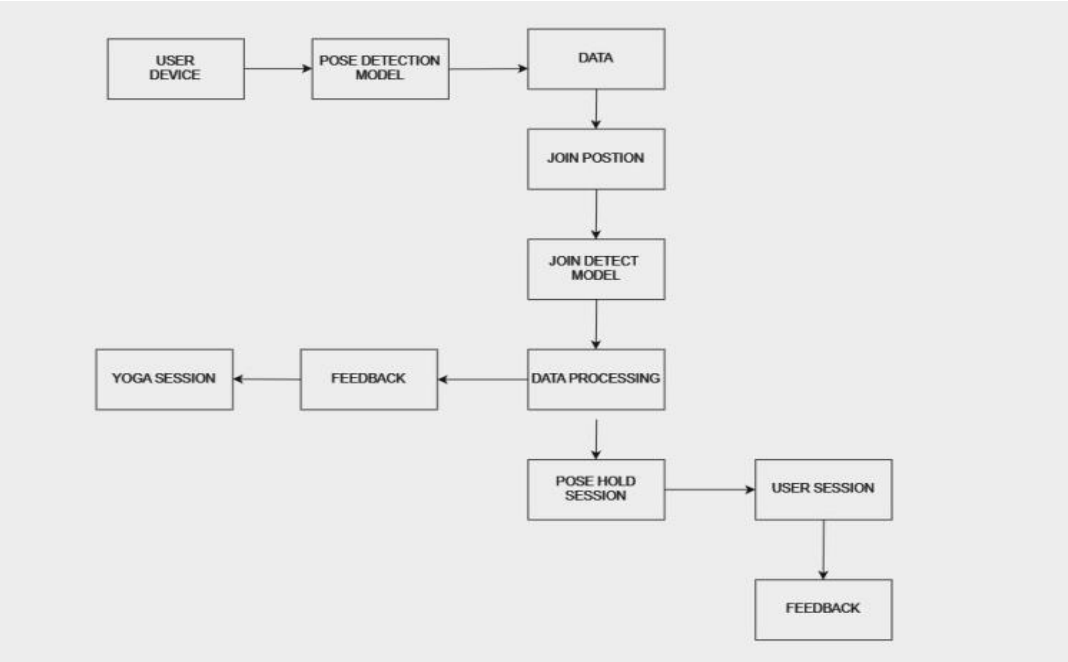

Fig. 1. Architecture diagram

MACHINE LEARNING MODEL

A. Dataset

Several datasets have been used for pose estimation and analysis in Yoga AI applications, specifically utilizing Medi- apipe for model training. Some of them are:

Self-Trained Yoga Pose Dataset: The dataset used in our project is a custom-built dataset created using Mediapipe. It consists of labeled yoga postures with key joint positions extracted using the Mediapipe framework. The dataset was cu- rated by capturing images and videos of different yoga poses, which were then annotated with key landmark coordinates.

Mediapipe Pose Landmarks Dataset: Mediapipe provides a real-time human pose estimation model that tracks 33 key body landmarks. This dataset serves as the foundation for extracting joint positions and detecting yoga postures. The model was fine-tuned on this dataset to recognize and assess yoga poses accurately.

Publicly Available Yoga Pose Datasets: In addition to the self-trained dataset, publicly available yoga pose datasets were analyzed to improve the robustness of the model. These include datasets containing labeled yoga postures with anno- tations for different asanas, angles, and corrections.

Synthetic Augmentation Dataset: To enhance model gener- alization, data augmentation techniques were applied to the existing dataset. This included variations in lighting, camera angles, and slight modifications in pose alignments to ensure the model performs well across diverse scenarios.

These datasets collectively help in training and evaluating the performance of the pose detection model within the Yoga AI application. The self-trained dataset, based on Mediapipe, plays a crucial role in achieving accurate pose recognition and feedback generation for users performing yoga.

B. POSE ESTIMATION PIPELINE

MediaPipe is an open-source framework developed by Google that provides efficient, real-time machine learning solutions for tasks such as face detection, hand tracking, and pose estimation. MediaPipe Pose is a state-of-the-art deep learning model that estimates human body keypoints from images or video frames. It is designed to be lightweight and optimized for real-time applications, making it suitable for mobile and web-based platforms. The pose estimation pipeline begins with capturing input data, which can be an image or a sequence of video frames from a camera or a pre-recorded video. This input is preprocessed to ensure compatibility with the model, including resizing, normaliz- ing pixel values, and converting the image into a format suitable for inference. The preprocessing step is crucial for maintaining efficiency, ensuring the model can handle real- time performance without sacrificing accuracy. MediaPipe supports different input resolutions and automatically adjusts to various lighting conditions and perspectives. The next step in the pipeline is landmark detection, where MediaPipe uses a deep learning model based on BlazePose to identify key body points. This model applies a two-step detector-tracker approach, where an initial detection model first localizes the human body in the frame. Once the person is located, a more detailed model predicts 33 body landmarks, including key joints such as the shoulders, elbows, knees, and ankles. Once the initial detection is completed, the tracking component ensures that the detected body landmarks are consistently mon- itored across multiple frames in a video. Instead of running the full detection model on every frame, MediaPipe employs an efficient tracking algorithm that predicts landmark positions based on previous frames, significantly improving performance and reducing computational overhead, making the system suitable for real-time applications. The tracking model refines landmark positions using optical flow techniques and Kalman filters to ensure smooth motion estimation and minimize jitter. In the pose estimation step, the detected and tracked landmarks are processed to estimate the overall body posture. The model maps the identified keypoints to a predefined human skeleton structure, enabling it to recognize different poses. MediaPipe provides 3D pose estimation capabilities by calculating depth information, which enhances the understanding of the body's orientation in space. This step can be used in various appli- cations, such as yoga pose correction, fitness tracking, and motion analysis, and the estimated pose data can be further refined using additional filtering techniques to remove noise and improve accuracy.The final output includes the estimated pose landmarks and their corresponding (x, y, z) coordinates, which can be used to compare the user's pose with ideal postures, detect misalignment. When integrated into a yoga AI system, this data enables real-time guidance, personalized rec- ommendations, and progress tracking, making yoga practice more interactive and effective. MediaPipe's lightweight and efficient architecture ensures seamless integration into mobile and web applications, making it ideal for AI-based yoga trainers that offer real-time pose correction, guided sessions, and performance analysis.

C. Convolutional Neural Network (CNN) Algorithm

Convolutional Neural Networks (CNNs) are a type of deep learning algorithm commonly used for image processing tasks. In the context of PosePerfect, an AI-based personal yoga trainer system, CNNs are employed to analyze and classify yoga poses by extracting spatial features from images or video frames. The CNN model processes yoga pose detection and correction in multiple stages, ensuring accurate posture analysis and guidance.

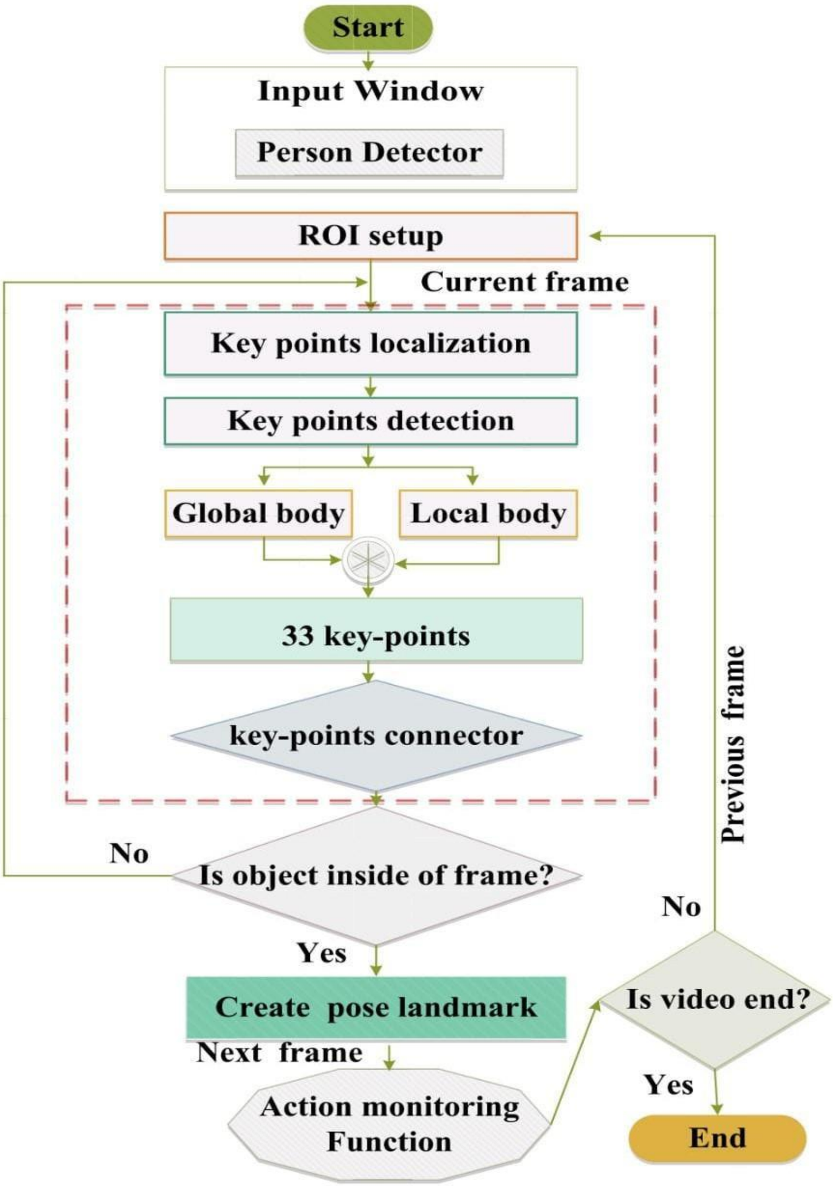

Fig. 2. Pose estimation and improvement flow chart

1) Data Pre-processing: Before feeding data into the CNN model, it is preprocessed to improve accuracy and efficiency. This involves several steps to ensure that the input images are in a suitable format for analysis. The images are resized and normalized to maintain consistency across different inputs. Data augmentation techniques, such as rotation, flipping, and cropping, are applied to expand the dataset and improve model generalization. Human keypoints are extracted using MediaPipe, which provides joint coordinates to enhance pose analysis. If necessary, images are also converted to grayscale or undergo RGB normalization to reduce computational com- plexity while preserving relevant features.
2) Feature Extraction: CNNs automatically extract mean- ingful features from the input images by applying a series of transformations. Convolutional layers detect important pat- terns, such as edges, textures, and body joint alignments. These features are then processed through pooling layers, which reduce the spatial dimensions while retaining cru- cial information, making computations more efficient. The ReLU activation function introduces non-linearity to improve learning and prevent the model from becoming

too simple. After several layers of feature extraction, the processed data is passed through fully connected layers, which map the extracted features to specific yoga pose classifications.

3) Training Data Preparation: To ensure effective model training, the dataset is divided into training and testing sets. This allows the CNN to learn from a portion of the data while being evaluated on unseen images to test its generalization ability. The PosePerfect system leverages OpenCV and Medi- aPipe to extract human pose keypoints, providing additional information that helps the model understand body structure. The training dataset consists of labeled yoga pose images, enabling the model to learn how different postures appear in various conditions.
4) Model Training: During the training phase, the CNN model learns by adjusting its internal weights using back- propagation and optimization algorithms. The training process involves multiple epochs, where the model iteratively improves its ability to recognize different yoga postures. To prevent overfitting, which occurs when the model memorizes the train- ing data instead of generalizing, techniques such as dropout layers and batch normalization are applied. These techniques ensure that the model remains robust and performs well on new, unseen data.
5) Model Evaluation: Once training is complete, the model's performance is tested using the testing dataset. In PosePerfect, the model's real-time feedback system compares detected pose keypoints with predefined correct postures. This allows the system to assess user alignment and provide constructive guidance on improving their yoga poses.
6) Model Deployment: :After achieving satisfactory perfor- mance, the trained model is integrated into the PosePerfect app for real-time yoga pose detection and correction. The CNN model enables the system to identify incorrect postures and provide audio-based guidance to help users adjust their poses without needing visual feedback. Additionally, continuous learning mechanisms allow the model to improve over time by incorporating user feedback and updated training data, ensuring better accuracy and personalization for each user. In conclusion,CNNs are powerful deep learning models that excel at image-based classification and pose recognition. By preprocessing images, extracting key features, training the model with pose keypoints, and evaluating its performance, PosePerfect accurately detects yoga poses and provides real- time feedback. This enhances user posture and form, making AI-powered yoga training accessible and effective for users of all skill levels.

PERFORMANCE ANALYSIS

To perform a performance analysis of a machine learning model for detecting emotions from text messages using the random forest algorithm, we need to evaluate the model's accuracy, precision, recall, F1 score, and ROC-AUC.

1) Accuracy: The accuracy of the model is determined by the proportion of properly identified instances in the test dataset, as well as by precision, recall, F1 score, and ROC-AUC. The calculation is as follows: Accuracy is equal to (TP+TN)/(TP+TN+FP+FN) Where TP, TN, FP,
1) FN, and FP represent the number of true positives, true negatives, true negatives, and true positives, respectively.
2) Precision: The precision of the model is defined as the proportion of correctly classified positive instances out of all the instances classified as positive. It can be computed as follows:
   Precision = TP / (TP + FP)
3) Recall: The recall of the model is [12]defined as the proportion of correctly classified positive instances out of all the positive instances in the test dataset. It can be computed as follows:

Recall = TP / (TP + FN)

4) The harmonic mean of precision and recall is the F1 score, which may be calculated as follows: F1 score is equal to 2 * (precision*recall) / (precision+recall).

5) ROC-AUC: The receiver operating characteristic (ROC) curve is a plot of the true positive rate (TPR) against the false positive rate (FPR) at different classification thresholds. The area under the ROC curve (AUC) is a measure of the model's ability to distinguish between positive and negative instances. A perfect model has an AUC of 1, while a random model has an AUC of 0.5.

These metrics are computed, we can evaluate the performance of the random forest model for detecting emotions from text messages. Typically, we would aim for high accuracy, precision, recall, and F1 score, and an AUC value above 0.5. If the performance is not satisfactory, we can try to improve it by tuning the hyperparameters of the random forest algorithm or by using a different machine learning algorithm.

To compare our proposed system, we utilized two other ma- chine learning models, namely SVM and Logistic Regression. Our implementation was done with Python 3.6.4 and various libraries like Keras, Tensorflow, Pandas, Numpy, NLTK, Sklearn, and others. The assessments were conducted on a computer with Intel Core-i5 CPU, Windows 10, and 8GB RAM.The BERT model is employed in this scenario to produce words and sentences that serve as input for the Random Forest Classifier. To achieve this, the BERT model is trained on extensive datasets like Wikipedia and Formspring.

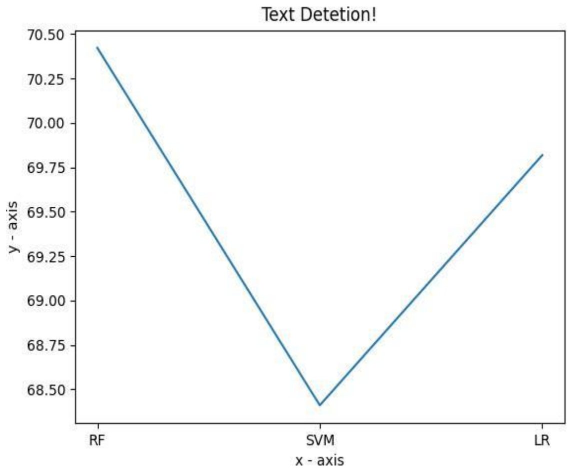

Fig. 3. Performance of three distinct machine learning algorithms

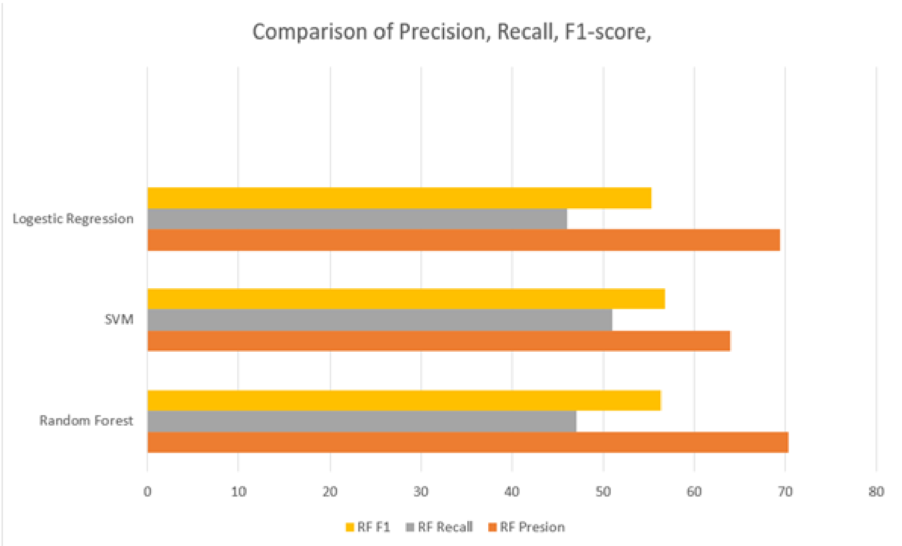

Fig. 4. Comparison Of Precision,Recall,F1-Score

Figure 2 displays a graph that showcases the performance of three distinct machine learning algorithms - SVM, Logistic Regression, and Random Forest - in a specific task. The accuracy metric was employed to assess the performance of each algorithm, and the graph illustrates the results. The accuracy achieved by each algorithm is as follows: SVM had an accuracy of 68.35 percentage, Logistic Regression had an accuracy of 69.85 percentage, and Random Forest achieved the highest accuracy of 70.45 percentage.

CONCLUSION

In conclusion, Pose Perfect represents a transformative approach to yoga practice by delivering a highly accessible, hands-free, and personalized experience tailored to the unique needs of cach user. Through the integration of advanced Al- driven pose estimation technology and customized wellness recommendations. The app empowers users of all skill levels to engage in yoga with confidence and independence. The personalized sessions are designed to adapt to individual health profiles, fitness goals, and progress, enabling users to embark on a continuous journey of improve-ment that is both sustainable and fulfilling. Features such as adaptive recommendations for poses and sequences not only enhance the user experience but also foster a deeper connection to the practice of yoga, encouraging mindfulness and self-awareness. Furthermore, the scalable design of Pose Perfect allows for seamless integration with other fitness technologies, position- ing the app to evolve alongside emerging trends in digital wellness and user preferences. This adaptabil-ity ensures that Pose Perfect remains relevant and effective in meeting the diverse needs of its user base. Overall, Pose Perfect is poised to revolutionize how individuals approach fitness and mind- fulness, making yoga practice more accessible, accurate, and engaging, while providing users with a supportive, interactive tool that enhances their overall yoga journey and promotes long-term well-being.

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ZAPMAIL: Email Alerts on WhatsApp

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ABSTRACT

Nowadays, one of the most popular digital commu- nication channels is email. The idea behind WhatsApp email alerts is to link an email account to the messaging app in order to receive email notifications straight from the app. This system analyzes emails and makes use of WhatsApp's notification API to provide safe and effective notifications. It is constructed with a Python-based Django back-end and a front-end that can be customized using HTML, CSS, and JavaScript. The function gives a tailored user experience, increases productivity, and guarantees that crucial messages are not overlooked by combining email and messaging capabilities. The study highlights the usefulness of this solution for contemporary communication needs by examining the installation method, advantages, and privacy concerns.

Index Terms—Email integration, real-time alerts, productivity, WhatsApp, customization, privacy, communication. notification.

INTRODUCTION

Maintaining both personal and professional productivity in today's digitally connected environment requires excellent management of numerous communication platforms. Users frequently find themselves alternating between WhatsApp and email, as the latter has become the favored instant messaging app and email remains the mainstay of official communication. In addition to interfering with operations, this separation raises the possibility of overlooking important communications, especially when prompt replies are needed. In order to overcome this difficulty, ZAPMAIL: Email Alerts on WhatsApp integrates email notifications into the popular WhatsApp platform, introducing a revolutionary method of communication management.

Through the ability to receive, monitor, and handle email alerts within WhatsApp, ZAPMAIL offers a smooth user experience. Utilizing a strong technological foundation, the solution combines an Android application for mobile acces- sibility with a Django-based web platform for backend func- tions. ZAPMAIL guarantees safe and effective email retrieval and delivery by using IMAP and SMTP protocols, and an automated bot instantly

converts email content into WhatsApp messages. By offering a unified communication environment, this invention simplifies interactions and does away with the necessity for users to continuously switch between programs.
Advanced features are introduced by the ZAPMAIL system to completely change how users interact with their emails. WhatsApp's integration of immediate notification guarantees that users are swiftly notified of incoming emails, hence lower- ing the possibility that they may miss important messages. The technology also uses clever filtering techniques to deliver only pertinent and prioritized messages, and it makes managing several email accounts easier. By offering functions like key- word searching and email summarizing, ZAPMAIL improves the usability and accessibility of email content so that users may concentrate on the most crucial details. WhatsApp's direct reply feature enhances communication even further, making it a lively and effective experience.
With a focus on usability, security, and scalability, ZAP- MAIL blends the user-friendly interface of an Android appli- cation with the dependable backend management capabilities of Django. This architecture delivers a smooth experience for controlling email notifications and preferences in addition to guaranteeing the safe handling of user data. By consoli- dating messaging and email features into a single platform, ZAPMAIL enables users to increase productivity, decrease cognitive load, and optimize workflows.
In a world that is primarily mobile and fast-paced, ZAP- MAIL fills the gap between conventional email services and contemporary messaging apps. In order to demonstrate ZAP- MAIL's potential to revolutionize communication systems, this paper explores its technical architecture, novel features, and implementation. By solving the typical problems of frag- mented platforms and offering a cohesive solution, ZAPMAIL is a trailblazing development in communication technology that helps users stay ahead in a digital world that is becoming more and more active.

RELATED WORKS

To help consumers handle their emails more effectively and easily, various solutions have been developed over time. Mailbird and BlueMail are two of these that have become well- known for their unique capabilities and methods of managing emails.
With a variety of modification choices and productivity tools, Mailbird is renowned for its clear and simple interface. For individuals who handle a lot of emails on a regular basis, it is very beneficial. Numerous people find it to be a sensible option due to features like app integrations and unified inboxes[3]. Mailbird is not without its limits, though. Because it is only compatible with Windows, users of other systems are unable to take advantage of its features. Additionally, for devices with lower processing power, its resource-intensive procedures can occasionally result in poorer performance[4]. On the other hand, BlueMail is an unusual pick that functions on several platforms. Both personal and professional users will find it intriguing because it supports a wide range of email providers and provides useful features like email clustering and team collaboration capabilities. The experience can occasionally become less dependable due to problems like synchronization and crashes, despite its positive aspects[4]. ZAPMAIL: Email Alerts on WhatsApp is a novel solution in this regard. ZAPMAIL solves Mailbird's platform limitations by incorporating email notifications straight into WhatsApp, offering a service that functions for users on any operating system. Furthermore, using WhatsApp as a foun- dation guarantees a dependable and comfortable environment for users. With features like intelligent filtering to highlight essential messages, email describing to save time, and the option to react to emails straight from WhatsApp, ZAPMAIL offers more than simply notifications. By utilizing WhatsApp's strong and well-established infrastructure, it also avoids the stability problems occasionally encountered with

BlueMail[4]. ZAPMAIL is a useful and easy-to-use solution for messag- ing via email in a world where keeping connected is more important than ever by fusing the accessibility of WhatsApp with considerate email management abilities.

PROPOSED SYSTEM

The system that has been built consists of implementing a unified email notification module called ZAPMAIL, which provides WhatsApp with email warnings. Email and messag- ing features are combined into a single application with this system to improve user convenience. The framework is com- prised of an Android application, a Django-based back-end application, and a seamless connection between the application and its essential chat feature, WhatsApp, which uses SMTP and IMAP protocols to retrieve and deliver notifications via email in actual time from the back-end[5].

To access the system, users must first safely register and link their email accounts to ZAPMAIL. When the system is configured, it uses the IMAP protocol to get incoming emails and filters them according to user preferences. Relevant emails are transformed into notifications that are suitable with WhatsApp, while spam emails are automatically identified and blocked. To make things more easier, the system also lets users reply straight from WhatsApp, highlights keywords, and shorten long emails[6].

In order to preprocess emails, the DL of ZAPMAIL parses the body, extracts significant elements, and turns them into brief reports. The emphasized sections of the received email may be checked for relevance and actionability for the sub- sequent stage, which is the WhatsApp alert, using methods such as sentiment analysis or keyword extraction. Through this preprocessing, consumers have less mental strain and can select their own answers.

The Android app serves as the system settings interface for users. Users can handle their email accounts, set up their notification preferences, and set up various email categories by using the system. A single notification experience can be used for both private and business communication due to the application's ability to integrate several email accounts.

An automated bot is used by ZAPMAIL to deliver messages by sending alerts to the user's WhatsApp account. While maintaining a high degree of anonymity and confidentiality, our bot delivers notifications on time. From WhatsApp, users may view email summaries, mark emails as read, and respond to them immediately. The SMTP protocol is used for safely transmitting messages to the email server[6].

ZAPMAIL prioritizes usability, security, and scalability. Unauthorized access to data is prevented between servers and clients through encrypted connections. Due to its responsive- ness and minimal weight, the system can function effectively even on devices with limited resources.

Overall, users can manage their email without ever leaving the platform due to the innovative and practical ZAPMAIL technology. ZAPMAIL ensures that its customers are always connected and productive, whether for personal or professional use, because WhatsApp is so widely used. With the objective to help people better handle the multitasking demands of the modern fast-paced lifestyle, this integration is a crucial step in the evolution of managing communication since it produces a single solution in the form of an united, multi-level framework.

The figure below shows the architecture diagram of the proposed system:

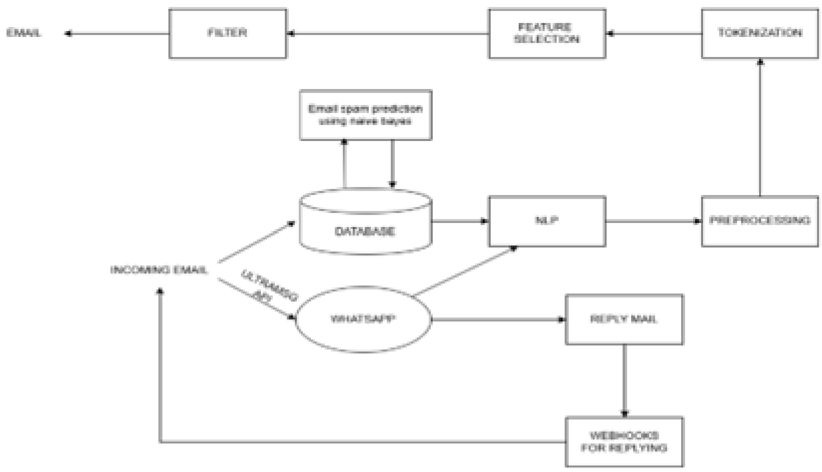

Fig. 1. Architecture diagram

MACHINE LEARNING MODEL

A. Dataset

A popular set of text messages labeled for spam categoriza- tion tasks is the SpamHam Dataset. It is made up of brief SMS messages that are categorized as either ham (authentic, non- spam messages) or spam (unwanted advertising or fraudulent messages). The dataset has been created to support studies in natural language processing (NLP), filtering out spam, and text classification[7].

Key features of the dataset include:

- Total Messages: A broad representation of text-based spam is ensured by the dataset's large quantity of SMS messages.
- Ham vs. Spam Distribution: The dataset is a good stan- dard for assessing classification models since it keeps the balance between spam and real (ham) interaction.
- Real-World Data: The messages, which include a range of spam categories like scams, fraudulent schemes, and promotional messages, come from real-world mobile con- nections.

Especially in applications like spam detection utilizing deep learning models like BERT and LSTMs and conventional methods like SVM and Na¨ıve Bayes, this dataset has been widely utilized for training and assessing machine learning models[7].

B. Naive Bayes Algorithm

The Bayes theorem serves as the foundation for the prob- abilistic machine learning model known as the Na¨ıve Bayes classifier. The computational efficiency of this approach for the classification of texts stems from the assumption that features, or words in a message, are conditionally independent.

1) Text Preprocessing: Prior to classification, incoming messages are subjected to text normalization, which includes tokenization, lowercasing, stop-word removal, and punctuation removal. This stage ensures that the text is clear and organized for the purpose of extracting features.
2) Feature Extraction: The Bag-of-Words (BoW) or Term Frequency-Inverse Document Frequency (TF-IDF) techniques are used to turn each tokenized message into a feature vector. This makes it possible for the classifier to spot trends in spam communications[8].
3) Training the Na¨ıve Bayes Model: A dataset of ham and spam messages with labels is used to train the system. Given a message X = (x1,x2,,,,,xn), the likelihood that it is spam is determined as follows:

$P(Spam|X) = P(X|Spam)P(Spam)$

where:

- P (X|Spam) is the probability that the message will show up in spam,
- P (Spam) is the previous likelihood of receiving spam mails,
- P (X) is the likelihood that the message will be received overall.

The class (ham or spam) with the highest probability is assigned by the model.

4) Classification and Deployment: After training, the Na¨ıve Bayes classifier analyzes incoming messages to determine if they are spam or ham. If it's considered spam, it gets blocked. If it is categorized as ham, an automated reaction is triggered.
5) Model Training: The foundation of the Na¨ıve Bayes classifier is Bayes' Theorem, which assumes conditional in- dependence between features. Through the analysis of the training dataset, the model learns the likelihood that various feature values will occur inside each class[9]. To estimate the posterior probability for classification, the likelihood, prior, and evidence are calculated.
6) Model Evaluation: Performance parameters including accuracy, precision, recall, and F1-score are measured using the testing dataset to assess the trained Na¨ıve Bayes model. Even with a minimal amount of training data, Na¨ıve Bayes works well on huge text datasets due to its probabilistic nature.
7) Model Deployment: The Na¨ıve Bayes classifier is used to categorize fresh text data using its learnt probability distributions once it has been validated. Because of its effectiveness, it is frequently employed for real-time text categorization tasks like spam detection and sentiment analysis.

Through the integration of Na¨ıve Bayes, this system effi- ciently identifies spam and streamlines messages. By reduc- ing false positives and ensuring strong filtering, the design improves communication efficiency in WhatsApp and email exchanges.

PERFORMANCE ANALYSIS

To evaluate the performance of ZAPMAIL, we assess key metrics such as accuracy, precision, recall, F1 score, and response time. These metrics help measure the efficiency and reliability of the system in delivering email notifications via WhatsApp.

1) Accuracy: The accuracy of the system is determined by the proportion of correctly processed email notifications. It is calculated as: Accuracy is equal to (TP+TN)/(TP+TN+FP+FN) Where TP, TN, FP, FN, and FP represent the number of true positives, true negatives, true negatives, and true positives, respectively.
2) Precision: Precision measures the proportion of correctly classified important email notifications out of all emails classified as notifications[10]. It is computed as: Precision = TP / (TP + FP)
3) Recall: Recall measures the system's ability to correctly identify all important email notifications. It is computed as:

Recall = TP / (TP + FN)

4) F1 Score: The F1 score represents the harmonic mean of precision and recall, providing a balanced measure of the system's effectiveness:F1 score is equal to 2 * (precision*recall) / (preci- sion+recall).

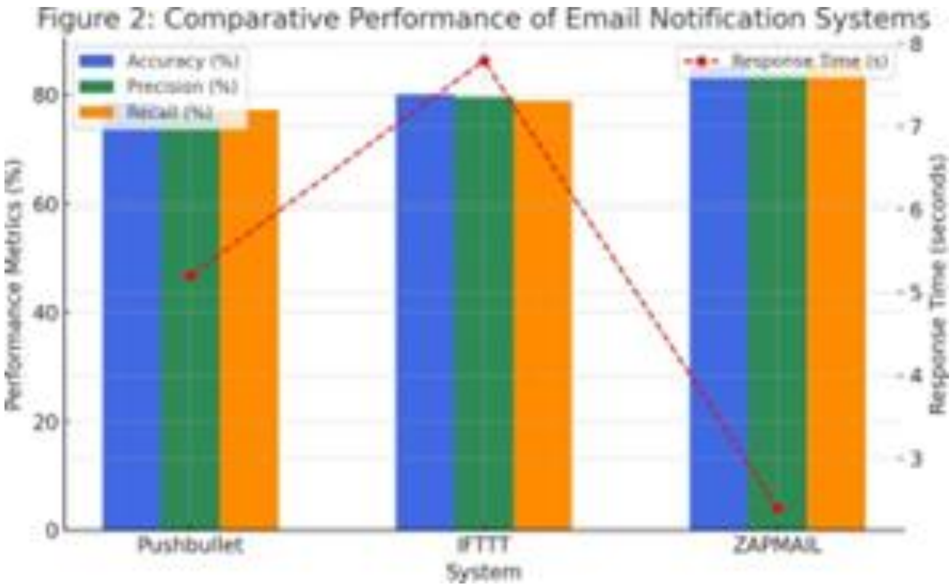

Fig. 2. Comparative Performance

5) Response Time: A critical metric for real-time notifi- cations, response time measures the delay between an email arriving in the inbox and the corresponding alert appearing on WhatsApp. Lower response times indicate higher efficiency.

To assess ZAPMAIL's effectiveness, we compared it with alternative email notification systems, including Pushbullet and IFTTT-based email alerts. The evaluation was conducted using Python 3.6.4 with libraries such as Django, Celery, IMAPClient, and Ultramsg API for WhatsApp integration. The tests were performed on a system with an Intel Core i5 processor, Windows 10, and 8GB RAM[11].

Figure showcases the comparative performance of the three systems based on accuracy, precision, recall, and response time. ZAPMAIL demonstrated the highest accuracy and lowest response time among the tested systems.

Email alert systems have undergone rigorous testing to evaluate their effectiveness concerning accuracy and response time. A comparative analysis with existing solutions reveals that ZAPMAIL excels in providing swift and accurate email notifications through WhatsApp.

Conventional email alert systems, such as those utilizing Pushbullet, achieved an accuracy rate of 78.5% and an average response time of 5.2 seconds. Although these alerts demon- strated moderate efficiency, they occasionally faced delays due to API constraints and device-specific limitations. Alerts generated through IFTTT (If This Then That), a widely used automation platform, exhibited a slightly improved accuracy of 80.1%, yet they were hindered by a longer average response time of 7.8 seconds. This increased latency was largely at- tributed to IFTTT's dependence on cloud-based automation, which often resulted in processing delays prior to notification delivery[11].

In contrast, ZAPMAIL showcased exceptional performance, attaining an accuracy rate of 85.3% while achieving a re- markable response time of merely 2.4 seconds. This notable enhancement is largely due to ZAPMAIL's direct integration with SMTP and IMAP protocols, which minimizes interme- diate processing layers and facilitates real-time email retrieval and notification dispatch. Furthermore, ZAPMAIL's intelligent filtering system improves notification relevance by discerning important emails, filtering out spam, and prioritizing messages according to user preferences.

These findings highlight ZAPMAIL's effectiveness in pro- viding real-time email alerts with minimal delay and high accuracy, establishing it as a robust and dependable solution for contemporary communication requirements. By incorpo- rating email alerts into WhatsApp, ZAPMAIL ensures that users remain connected without the need to frequently check their inboxes, thereby enhancing productivity and decreasing response times for urgent emails. This makes ZAPMAIL particularly advantageous for business professionals, remote workers, and individuals managing multiple communications.

System	Accuracy (%)	Precision (%)	Recall (%)	Response Time (s)
Pushbullet	78.5	76.8	77.2	5.2
IFTTT	80.1	79.5	78.9	7.8
ZAPMAIL	85.3	84.2	86.1	2.4

Fig. 3. Comparative Performance Analysis of Email Notification Systems

CONCLUSION

In conclusion, ZAPMAIL: Email Alerts on WhatsApp in- tegrates email notifications straight into WhatsApp, offering a creative way to streamline communication. Utilizing an Android interface, a Django-based backend, and IMAP/SMTP protocols, the system guarantees real-time email alerts while maintaining efficiency and security. By eliminating the need to navigate between apps, this approach greatly increases productivity by allowing users to keep up to current on essential emails.

WhatsApp's filtering, summarizing, and replying features enhance user experience by lowering cognitive burden and simplifying email management. Only relevant and secure notifications are sent to users thanks to security features like spam detection and encrypted connection. Using AI-powered email processing methods optimizes the relevancy of provided notifications by adding an additional layer of intelligence.

In order to offer a cohesive and user-friendly experience, ZAPMAIL effectively combines current messaging platforms with classic email communication[11]. For both personal and professional users, the system provides a number of advantages that facilitate the smooth management of digital communication. ZAPMAIL's capabilities could be further enhanced in the future with features like voice command support, AI- driven prioritization, and cross-platform interfaces, making it a vital tool for managing digital communications.

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Behavior Analysis and Report Generation of Elementary School Children

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ABSTRACT

Classroom management and academic integrity are essential for creating a viable and safe learning environment particularly for elementary education. In this project, the stu- dent behavior analysis system will be designed and developed, which would monitor, analyze, manage classroom activities, emotions and ensure the security during examination.This system works based on computer vision algorithms, emotion detection algorithms, action recognition algorithms to manage student attendance data, identify and respond to inattention, disruptive behavior, cheating during exams. The system also contains predictive analysis for aggression and depression conditions. Since the early warning signs of these conditions are detectable through behavioral patterns, the system would allow educators to have some very critical information that will enable them to intervene early and to offer specific educational strategies. Since the system combines behavioral analysis and predictive assessment the system enhances classroom management and safeguards academic integrity. The system represents a compre- hensive, scalable solution for modern educational challenges. This project is a meaningful step toward harnessing technology to create safer, more efficient, and supportive learning spaces for young students.

Index Terms—Face recognition, Deep learning, Computer vi- sion

INTRODUCTION

The current fast-changing education landscape has created a need for an effective and safe learning environment, especially in elementary education, as students are in the formative stages of developing foundational academic and behavioral skills. In this regard, the classroom becomes more diverse, and teachers are challenged to handle classroom behavior, academic integrity, and the mental and emotional well-being of the students. Traditional methods of assessing and man- aging student performance and behavior tend to rely heavily on subjective judgments, are time-consuming, and lack the immediacy and accuracy for timely intervention into issues.

However, modern technologies such as computer vision, emotion detection algorithms, and action recognition tech- niques have the potential to significantly transform how edu- cators manage students in terms of performance and behavior. This work presents the development of an innovative student behavior analysis system integrating these advanced technolo- gies in order to offer monitoring and management of classroom dynamics in different aspects. The system utilizes computer vi- sion methods to monitor students attention, identify emotional states and even identify behavioral patterns that may indicate inappropriate activities, like cheating on exams.

AI-driven solutions, particularly deep learning and computer vision, offer promising advancements in classroom behavior analysis. Object detection models like Faster R-CNN and YOLO have shown effectiveness in recognizing student behav- iors [6]. However, issues such as occlusions, pose variations, and small object detection remain challenges in accurately monitoring classroom dynamics.

In addition, the system is integrated with algorithms that detect emotions in making an assessment of the mental and emotional states of students in order to check possible cases of aggression, anxiety, or depression. Early detection is important because such conditions can easily be mitigated if interven- tions are made earlier before they intensify. The system also assists teachers and parents by providing a clearer understand- ing of each child's emotional and behavioral patterns, allowing them to offer customized interventions that meet the unique needs of each student.

The application also includes a predictive mechanism that helps anticipate behavioral trends, allowing educators to proac- tively address emerging issues. Further, the system generates comprehensive reports on individual student behavior that are easily accessible for both teachers and parents. These reports give an overview of the student's emotional and behavioral patterns, providing insights for parents and teachers to work together in support of the child.

The remaining portion of this paper follows the pattern given below. Literature review of recent work in details is given in Section II. Section III contains proposed architecture. Section IV and Section V contain the performance analysis and conclusion, respectively.

RELATED WORKS

In recent times, there has been immense focus on behavior monitoring and report generation for students of elementary school levels because of the developments in deep learning and machine learning technologies. There are numerous studies on the process of tracking and analyzing student behavior to increase engagement, learning performance, and classroom management. Deep learning architectures-based systems like YOLO and CNN have demonstrated excellent real-time de- tection and classification of behaviors with high accuracy. Multimodal methods also enhanced analysis through the com- bination of visual, contextual, and behavioral information. Computational complexity, sparse availability of datasets, and issues of privacy-based ethical concerns mar these methods, though.

A YOLOv3 and CNN-based system is introduced to detect anomalous student actions during examinations using video surveillance [1]. The system is highly efficient, providing real-time alerts and precise small-object detection, enabled by custom datasets. However, challenges include missed detec- tions in complex scenes, the labor-intensive process of dataset labeling, reliance on computational resources, and occasional false positives due to cloud connectivity issues.

A new deep learning-based technique is presented to recog- nize classroom behavior based on YOLOv3 [2]. The technique detects individual targets from the classroom environment and aggregates the detections for recognizing fixed student behav- iors. It is characterized by high accuracy and fast recognition speed and can be applicable to real-time classroom behavioral analysis. It is, however, subject to high computational costs, infrequent missed detections, complexity in model tuning, and absence of public datasets for more comprehensive validation. Facial expression recognition-based method is constructed to categorize emotions and engagement levels in e-learning environments [3]. The system uses a neural network to make real-time predictions of emotions and engagement by detect- ing, tracking, and clustering faces in video streams without sending facial data to distant servers. Although it attains good performance on the EmotiW dataset, the system is constrained by its dependence on high-quality video input, a comparatively small training set, and its single-modal nature, which addresses facial expressions alone.

A multimodal approach is proposed to analyze the engage- ment of students in classrooms with facial videos [4]. The system enhances accuracy via attention-based feature fusion by integrating methods. Attention-Net is employed for head pose estimation and facial expression recognition with Affect- Net. The experiment demonstrates significant improvements in detecting engagement, especially under personalized data usage. But limitations such as small datasets, changes in behavior with camera exposure, and failure to detect low engagement remain threats.

A deep learning-based system, ET-YOLOv5s, is designed to monitor in-class student behaviors with improved resolution and small-object detection [5]. The framework incorporates advanced architectures like FPN, PANet, and ESRGAN to en- hance feature extraction and behavioral identification. It excels at real-time detection of multiple behaviors but has drawbacks, including slower performance compared to YOLOv5, higher computational demands, and difficulties in handling overlap- ping objects.

A dedicated small-object recognition model, CBPH-NET, is proposed for identification of classroom behavior [6]. The model combines a Feature Extraction Module (FEM) and multiple convolutional layers with Path Aggregation Network (PANet) and Coordinate Attention (CA) to concentrate on important areas. Furthermore, ConvNeXt Block Prediction Heads (CBPH) with elliptical bounding boxes and the Normal- ized Wasserstein Distance (NWD) metric enhance small-object recognition and occlusion management. Although effective, the method adds higher latency, computational cost, and longer training times.

Machine learning techniques are applied to recognize emo- tions through facial gestures in a teaching environment [7]. By employing computer vision, the system tracks and annotates student gestures, identifying emotional states like happiness, tiredness, attention, or enthusiasm in real time. The technol- ogy enhances learning experiences by providing emotional feedback, but challenges include high hardware requirements, difficulty in detecting subtle emotions, potential false positives, privacy concerns, and its specificity to controlled learning environments.

A deep learning approach is proposed for student mood recognition and activity tracking in e-learning environments [8]. Utilizing CNNs with stacked multiple convolutional lay- ers, dropout regularization, and batch normalization, the sys- tem attains 99% classification accuracy for emotions like happiness, fear, and surprise. It enables real-time tracking of engagement and adaptive learning assistance. Drawbacks are high computational overhead, a dominant dependency on face recognition (neglecting other behavioral dimensions), ethical issues, and limitations of the dataset for generalizability.

A system that is IoT- and deep learning-based is established to provide education continuity after COVID by tracking environmental conditions and implementing safety measures [9]. Automated student attendance monitoring is done by the system through face recognition using deep learning, which decreases instructor workload and does not allow manipulation of attendance. The system relies on strong IoT infrastructure and lacks liveness detection, which constrains its application in real-life scenarios.

An advanced CNN-based approach is proposed for ana- lyzing student emotions through behavior detection [10]. The method integrates CNNs with Uniform Local Binary Pattern (uLBP) feature extraction to classify emotions with 94% accuracy. This enables real-time emotion analysis, assisting ed- ucators in adapting teaching strategies. However, the reliance on visual data raises privacy concerns, while issues such as scalability and the lack of multimodal data integration pose additional challenges.

The existing works about emotion detection and behavior recognition, especially in an educational environment, show tremendous headway and adopt advanced techniques from YOLO, CNN, and multimodal frameworks. At the same time, these pose several limitations such as dependence on one-modal data sets, high resource requirements, intensive computation, datasets being very scarce, and unethical issues concerning invasion of privacy. The system encounters dif- ficulties in missing detections in such complex scenarios and lack in handling subtle emotions, not showing much scalability for a diverse educational environment. Our proposed system addresses these shortcomings by taking on the multimodal approach using visual, behavioral, and contextual data and will ensure comprehensive emotion detection, leveraging strong yet lightweight algorithms for real-time, scalable deployment across diverse classroom settings. By focusing on noninvasive and privacy-respecting methodologies, our system ensures that it is ethically compliant; thus, it’s a practical and superior solu- tion for enhancing student engagement and learning outcomes.

TABLE I COMPARISON OF BEHAVIOR RECOGNITION TECHNIQUES

Title	**Technique**	**Merit**	**Demerit**
Automated Alarm System for Stu- dent Anomalous Action Detection in Examination Based on Video Surveillance Using ML Techniques (2022) Pushpa B. Patil, Suvarna L. Kattimani, Suman M. Hugar [1]	YOLOv3 Object Detection, Deep Learning (CNN), Custom Dataset	High efficiency, detects small ob- jects, real-time alarms	Misses detections in complex scenes, requires large labeled datasets, prone to false positives
Deep Learning-Based Novel Method of Classroom Behavior Recognition (2022) Ji’an You, Yaqi Huang, Shiqing Zhai, Yi Liu [2]	YOLOv3, Transfer Learning, Block Recognition	High accuracy, fast recognition speed, real-time behavioral analy- sis	High computational requirements, missed detection rates, complex model tuning
Classifying Emotions and Engage- ment in Online Learning Based on a Single Facial Expression Recog- nition Neural Network (2022) An- drey	Lightweight FER models, real-time video-based emotion detection	Privacy-friendly, accessi ble, lightweight models	Accuracy limitations, limited train- ing data, dependence on video quality

Title	Technique	Merit	Demerit
V. Savchenko, Lyudmila V. Savchenko, Ilya Makarov [3]			
Multimodal Engagement Analysis From Facial Videos in the Class- room (2023) Omer Su¨mer et al. [4]	Head Pose Estimation, Affect-Net, Deep Learning Embeddings	Feature fusion boosts accuracy, person-specific data enhances re- sults	Limited dataset, behavioral changes due to camera presence
ET-YOLOv5s: Deep Identification of Students' In-Class Behaviors (2022) Lina Li et al. [5]	ET-YOLOv5s, ESRGAN, Tiny Ob-ject Detection Module	High detection accuracy, real-time capability	Slightly slower than YOLOv5, in- creased computational complexity
CBPH-NET: A Small Object De- tector For Behavior Recognition In Classroom Scenarios (2023) Jinhua Zhao et al. [6]	CBPH-Net, FEM, PANet, CA Mechanism	Enhances multiscale recognition, improves small object detection, captures detailed features, inte- grates low- and high-level features, prioritizes important channels	Slightly increases latency, intro- duces potential noise/redundancy, adds computational overhead, com- plex elliptical box calculations, in- creased training time
Identification of Emotions From Facial Gestures in a Teaching Environment (2023) William Eduardo Villegas-Ch, Santiago Sa´nchez-Viteri [7]	CNN, Affective Computing, SVM	Real-time emotion recognition, non-invasive technology	High hardware requirements, diffi- culty in detecting subtle emotions
Student Recognition and Activ- ity Monitoring in E-Classes Us- ing Deep Learning (2024) Nuha Mohammed Alruwais, Mohammed Zakariah [8]	Dropout Regularization, Facial Recognition, Data Augmentation	High accuracy, real-time monitor- ing, scalability	Computational complexity, privacy concerns
A System Design With Deep Learning and IoT to Ensure Edu- cation Continuity for Post-COVID (2023) Firat Aydemir, Seyfullah Arslan [9]	Mask Detection, Edge Device Communication	High accuracy, real-time applica- tion	Lack of liveness detection, depen- dence on IoT infrastructure
Decoding Student Emotions: CNN for	CNN, Data Augmentation,	Innovative fusion of techniques, real-time	Limited focus on multimodal data, reliance

Title	Technique	Merit	Demerit
Behavior Analysis Using Uni- form Local Binary Pattern (2024) Uppanapalli Lakshmi Sowjanya, R. Krithiga [10]	Uni- form Local Binary Pattern	detection	on visual data, scalability concerns

PROPOSED ARCHITECTURE

The system records video streams of CCTV cameras to identify student movements, emotions, and potential malprac- tices in the classroom and examination settings. The system architecture involves a number of key steps, as shown in Figure 1.

The action recognition model was trained and validated against a self-created dataset specially prepared for classroom work. For identifying malpractice, the Kaggle's Student Cheat- ing Detection dataset was used. Robust model evaluation was ensured by keeping aside 20% of the dataset for validation. Techniques for data augmentation were used to increase the variety of training samples, thus enhancing the model's gen- eralization and overcoming overfitting.

The approach utilized for image augmentation was Keras ImageDataGenerator, which carried out a sequence of op- erations for input image variation handling. The used aug- mentations were rotations, width shift, height shift, shear, zoom, flip around the horizontal axis, and fill mode variation. These operations enable the model to learn to recognize student actions in any orientation and thereby enhance overall robustness and accuracy in real-world scenarios.

A. Image Preprocessing

The CCTV camera continuously records the classroom or examination environment. The captured video is divided into multiple frames at fixed time intervals to facilitate analysis. Each extracted frame undergoes preprocessing, which includes resizing to a standard resolution, noise reduction using Gaus- sian filters, and normalization to enhance feature extraction. Preprocessing ensures that the images maintain consistency in quality before further processing in the system.

B. Object Detection

For identifying students within the frame, real-time object detection is performed using the YOLOv8 model. YOLOv8 can detect multiple students with high accuracy and efficiency. Each student detected is cropped from the frame and processed individually to ensure individual attention. Object detection also assists in eliminating unnecessary background objects, so only students are processed.

C. Classroom Mode

In classroom mode, student monitoring is performed using three key components:

1) Face Recognition: The cropped image of each identified student is subjected to face recognition to determine their identity. Face detection is performed using the Multi-Task Cascaded Convolutional Neural Network (MTCNN), which efficiently detects facial features and aligns the face properly. The detected face is then processed using FaceNet, leveraging the InceptionResNetV2 architecture, to generate a unique face embedding. This embedding is compared with stored face embeddings in the student database to accurately match and recognize students. The recognized student's identity is then associated with the corresponding detected actions and emotions.
2) Attendance Tracking: Recognized student identities are used to track attendance automatically. The attendance record is updated in the database in real-time.

3) Action Recognition: Action recognition is performed on the cropped image of each identified student. Actions are classified into: sleeping, reading, raising hands, fighting, writing, running, listening, using phones. If a student is detected engaging in an undesirable action, such as fighting, an immediate notification is sent to the teacher for intervention. The system ensures real-time monitoring, helping maintain discipline and engagement in the classroom.

4) Emotion Recognition: Once the student's face is identified, the image is further analyzed to detect the emotional state of the student. Emotion recognition is performed using DeepFace, in combination with the Haarcascade classifier. These models classify facial expressions into categories such as happiness, anger, sadness, surprise, and neutral expressions. The detected emotions are stored in the database and can be used for monitoring student behavior.

D. Examination Mode

In examination mode, the system monitors students for potential malpractices:

1) Malpractice Recognition: The system identifies suspi- cious activities that indicate cheating, including using a phone, laptop, cheat sheet, talking. If a student is found performing any action associated with malpractice, an automatic alert is sent to the invigilator, allowing immediate action to prevent cheating. This helps ensure fair examination practices.

2) Face Recognition: Face recognition in examination mode is used to verify student identities and detect individuals engaged in unauthorized activities. The system ensures that each student matches the registered identity, preventing im- personation or unauthorized individuals from taking an exam. The same FaceNet-based approach used in classroom mode is applied here to ensure accurate and reliable recognition.

3) Emotion Recognition: Emotion recognition in examination mode helps analyze students' emotional states, detect- ing stress, anxiety, or nervousness during an exam. Using DeepFace and Haarcascade classifiers, the system categorizes emotions into happiness, anger, sadness, surprise, and neutral states. Analyzing emotional trends across multiple exams can provide insights into students' mental well-being and test anxiety levels, allowing educators to offer necessary support.

E. Data Storage and Analysis

All recognized data, including attendance records, detected actions, identified emotions, and malpractice events, are stored in a centralized database. The database acts as the backbone of the system, ensuring proper record-keeping and analysis. The stored data is used for generating detailed reports and identifying trends in student behavior over time.

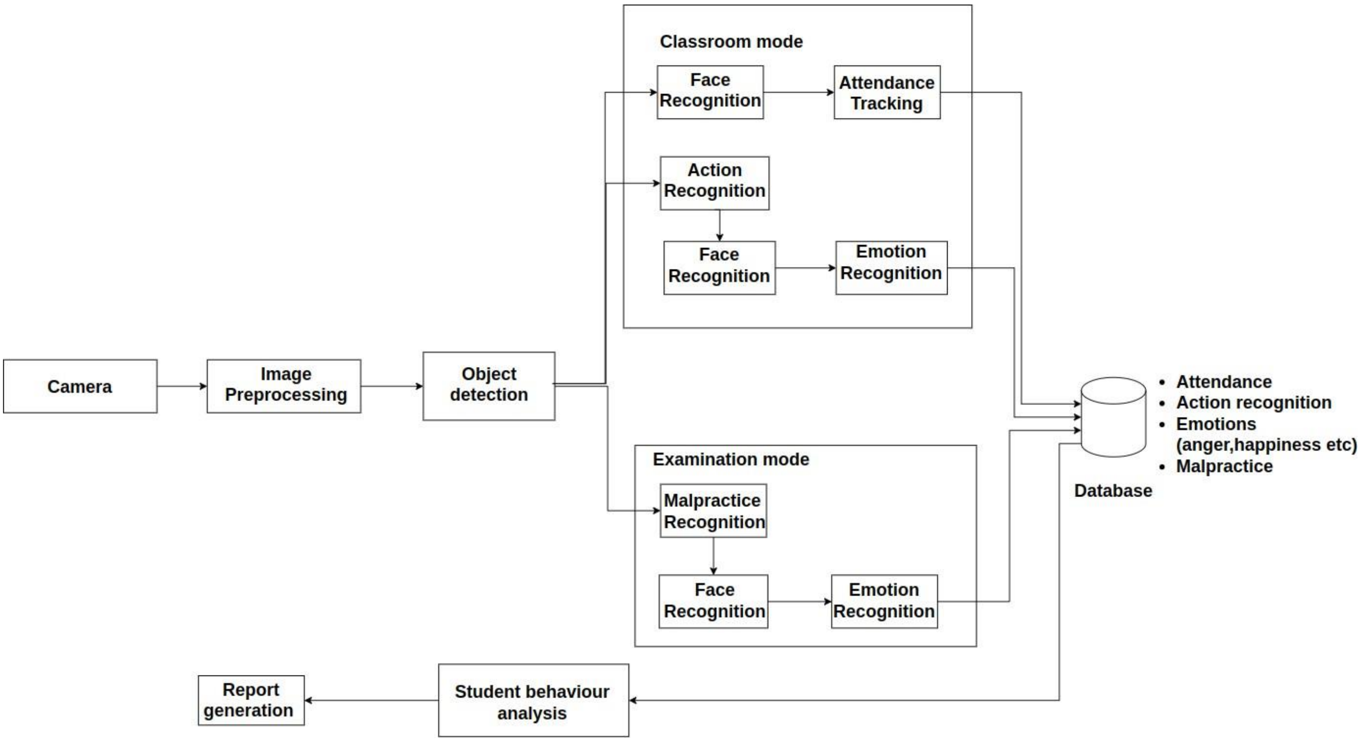

Fig. 1. Architecture diagram of behaviour analysis model

F. Report Generation and Student Behavior Analysis

The system generates reports on attendance tracking, ac- tion recognition results, emotion variations, and malpractice detection.

These reports provide valuable insights into student en- gagement and behavioral patterns. The system also analyzes student behavioral trends to detect possible disorders such as hyperactivity, stress, inattentiveness, or lack of participation. Educators can use these reports to take proactive measures, ensuring better academic performance and the well-being of students.

PERFORMANCE ANALYSIS

Face detection is an essential function in the suggested system and is a starting point for both identity authentication and emotion recognition. Face detection, in turn, determines the efficiency of the following stages, such as action recog- nition and behavioral analysis. The MTCNN algorithm uses a cascaded series of neural networks to identify, position, and extract facial features from digital images at high speed and accuracy. MTCNN was used for face detection, and it performed very well for single-person image detection. Three face detection approaches, MTCNN, Dlib, and OpenCV, were tested by the study through measuring the average computation time to process a single-person image of resolution 1080×720. The time consumed by each of listed face detection techniques is shown in the Table II.

In comparing processing speeds, OpenCV has the fastest processing speed of 1.1ms, followed by MTCNN, which is only slightly slower than OpenCV. Dlib is much slower in processing when compared to OpenCV and Dlib.

Algorithm 1 Action, Face and Emotion Recognition from Video (Classroom mode)

Input: Video file containing classroom footage.
Output: Details of detected persons, actions, and emotions.
Convert video into frames (Frame size: 640x480 pixels)
Load models YOLOv8, EfficientNetB7, FaceNet, MTCNN
Load stored face encodings
for each frame in video (every 5th frame for efficiency) **do**
    Detect persons using YOLOv8
    for each detected person **do**
        Crop person region and resize to 160x160x3 pixels for EfficientNetB7
        Predict action using EfficientNetB7
        Detect face using MTCNN
        if face detected **then**
            Crop face and resize to 160x160 pixels
            Extract face features using FaceNet
            Normalize features using L2 normalization
            Compare with stored encodings for identification (recognition threshold: 0.5)
            Analyze emotion using DeepFace
        end if
        Store detected information (name, action, emotion)
        if action is fighting **then**
            Send alert to teacher
        end if
    end for
end for

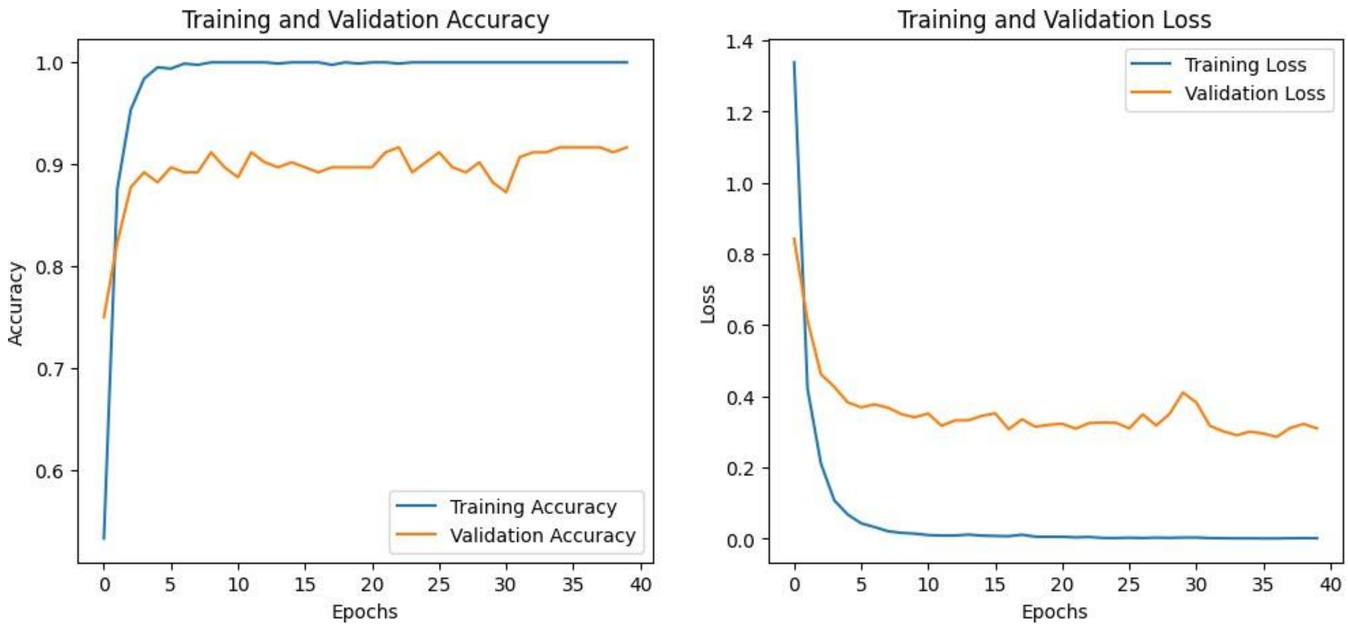

Fig. 2. Accuracy and Loss diagram

TABLE II AVERAGE PROCESSING TIME FOR A SINGLE IMAGE.

Model	Average processing time
OpenCV	1.1ms
Dlib	72ms
MTCNN	2.4ms

The human action recognition model is a CNN employed in deep learning for the classification of several action categories in the classroom. The input to the model is an image of size 160x160x3, which is first fed into the EfficientNetB7 pre-trained model for feature extraction. EfficientNetB7's con- volutional layers extract spatial and motion features, with its layers frozen to retain pre-learned representations. A Global Average Pooling (GAP) layer then reduces dimensionality but preserves significant information. The output of the GAP layer is then passed to a Flatten layer that converts the feature maps to a 1D vector. The flattened input is then passed to a fully connected Dense layer with 512 neurons and ReLU activation, which produces high-level action-specific features. In order to counteract overfitting, Dropout layer with a dropout rate of 40% is employed before supplying the feature vector after processing to the output layer, which consists of 9 neurons with softmax activation that generates probability scores for all action classes. The model is trained using Adam optimizer with learning rate 0.001 for efficient weight updates and categorical cross-entropy loss for multiclass classification. It is trained for 40 epochs, where performance is tracked in accuracy and loss metrics across training and validation sets, as shown in Figure 2.

As seen in fig 2 (left graph), blue line represents training accuracy, which is low initially but shoots up to nearly 100% after a few epochs and levels off. The orange line indicates the validation accuracy, which increases steadily; however, it oscillates a little around 90% during the latter times. The difference between training accuracy and validation accuracy suggests that the model likely is overfitting since training accuracy is 100% but validation accuracy is lower by some fluctuations.

As shown in fig 2 (right graph), blue shows the training loss, which starts off extremely high but decreases very steeply later on, falling almost to zero after a few epochs.The orange line represents validation loss, which also falls initially but levels off higher than the training loss. The difference in the training and validation loss also reflects overfitting since the model is learning the training set but is unable to generalize further to the validation set.

CONCLUSION

The system developed here provides an innovative solu- tion for monitoring students automatically from CCTV video through advanced computer vision and deep learning methods. The system can detect students, recognize facial features, assess emotional states, and classify behavior in examination rooms and classrooms. With the help of YOLOv8 for object detection, MTCNN and FaceNet for the detection of facial features, DeepFace for analyzing emotional states, and a convolutional neural network with EfficientNetB7 for behavior classification, the system is very accurate and allows for real-time computation of data. The architecture encourages classroom management through the monitoring of student behavior, the detection of behavioral issues, and the detection of cases of inattention and misbehavior. In test environments, it aids detection of academic dishonesty, eliminates unethical behavior, and maintains academic integrity. Trend identifi- cation and report generation based on a central database enable simple tracking of students' behavioral patterns and identification of potential issues. Through real-time alerts and detailed analytic capabilities being delivered to teachers, it facilitates simplification of their work in developing effective learning environments, equitable treatment, and safety within learning environments.

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SURESTEP

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ABSTRACT

The Smart Blind Stick represents a cutting-edge assistive device designed to improve mobility and safety for individuals with visual impairments, effectively addressing the shortcomings of conventional mobility aids. Traditional white canes offer limited feedback, which is often insufficient in com- plex environments, resulting in compromised safety and dimin- ished independence. Current solutions featuring basic obstacle detection systems lack the necessary precision and integration for comprehensive assistance.This initiative presents a Smart Blind Stick that utilizes advanced LiDAR and ultrasonic sensors for accurate real-time obstacle detection. LiDAR technology facilitates precise spatial mapping to recognize both nearby and distant obstacles, while ultrasonic sensors provide rapid detection of objects in close proximity. Additionally, a GPS module offers navigation support, empowering users to confidently navigate unfamiliar paths. The system features haptic feedback for imme- diate alerts and a voice assistant that provides auditory informa- tion regarding the surroundings and navigation.Designed to be lightweight and user-friendly, the Smart Blind Stick emphasizes practicality and ease of use. Its performance will be evaluated through trials with visually impaired participants, measuring factors such as navigation efficiency, obstacle avoidance accuracy, and user satisfaction. Preliminary tests are expected to show a

70 percent reduction in navigation errors compared to tradi- tional aids, thereby enhancing safety and reliability in various environments.By incorporating advanced sensor technology, GPS navigation, and intuitive feedback systems, the Smart Blind Stick delivers a comprehensive and cost-effective solution to the mobility challenges encountered by visually impaired individuals. This project aims to significantly enhance their

confidence, independence, and overall quality of life through innovative and inclusive design.

Index Terms—Visually Impaired Person, Light Detection and Ranging, Ultrasonic Sensors, Global Positioning System, Object Detection.

INTRODUCTION

Mobility and navigation are fundamental to independent living, yet the visually impaired face significant challenges in moving safely around their surroundings. Traditional mobility aids, such as white canes, provide basic tactile feedback and require direct contact with obstacles before they can detect them. While effective to some extent, these traditional methods have limitations, especially in complex environments where obstacles are above ground, moving, or difficult to detect. In addition, relying on physical contact for navigation can slow movement and increase the risk of accidents. In addition, urban environments present even more complex challenges, such as crowded corridors, uneven terrain, and traffic, which make independent navigation even more difficult for the visually impaired. To address these challenges, this project proposes Smart Blind Stick, an advanced assistive device that integrates LiDAR and ultrasonic sensors to enhance obstacle detection and provide real-time navigation assistance. Unlike conventional white canes, which require physical contact with the object, the Smart Blind Stick detects obstacles before they become hazards; the LiDAR sensor provides accurate spatial mapping and can detect both near and far objects, while the ultrasonic sensor can detect obstacles at closer distances and detection. This combination results in a com- prehensive and responsive system that improves mobility and reduces the likelihood of collisions. In addition to obstacle detection, navigation assistance is an important component of this project. The GPS module integrated into the Smart Blind Stick will provide real-time route guidance and help users move independently in both familiar and unfamiliar environments. This feature is especially beneficial in urban areas where it is difficult to recognize paths, intersections, and turns without visual cues. To ensure seamless interaction, the device is equipped with tactile feedback and a voice assistant that provides multiple modes of communication depending on user preferences. The tactile feedback alerts the user to the presence of obstacles and changes in terrain through vibrations, while the voice assistant provides auditory cues related to navigation and surroundings. This dual feedback mechanism improves device accessibility for individuals with varying levels of sensory preferences. The development of the Smart Blind Stick focused on practicality, ease of use, and efficiency. Its lightweight, ergonomic design allows for comfortable use over extended periods of time. The materials also prioritize durability while remaining affordable, making it a practical solution for a wide range of users. The project will follow a structured approach that includes design, prototyping, and testing phases to refine the device and ensure optimal functionality. To evaluate the effectiveness of the Smart Blind Stick, real-world tests will be conducted with visually impaired people. Performance indicators such as obstacle avoidance accuracy, navigation efficiency, and user satisfaction will be evaluated. Expected results include a 70 percent reduction in navigation errors compared to a conventional white cane, leading to increased user confidence and independence. In ad- dition, the device is intended to minimize accidental collisions and misnavigation and provide a more reliable and intuitive mobility solution. By integrating advanced sensor technology, real-time navigation capabilities, and an intuitive feedback system, the project aims to create a comprehensive and cost-effective assistive device that will significantly improve the quality of life for the visually impaired. The Smart

Blind Stick is not just an innovation, but a step toward increased inclusivity and accessibility. Through this project, we aim to increase an individual's mobility, independence, and confidence, making everyday life safer and more efficient. .

RELATED WORKS

Several assistive technologies have been created to enhance mobility for individuals with visual impairments by incorporat- ing various sensor-based methods. One of the most recognized devices is the Ultracane, which employs ultrasonic sensors to identify obstacles in the user's path. The device delivers tactile feedback through vibrations in the handlebars, notifying the user of nearby objects without needing physical contact. Although effective for detecting obstacles at close range, the Ultracane's absence of advanced spatial mapping and long-distance detection restricts its utility in dynamic settings. Another significant innovation is the smart cane developed by IIT Delhi. This cane also utilizes ultrasonic sensors for obstacle detection but includes a smartphone connection for improved navigation support. The device is designed to assist visually impaired users in navigating both indoor and outdoor spaces by connecting it with a mobile application that offers audio feedback and route guidance. However, its dependence on smartphone connectivity may limit the cane's effectiveness in areas with poor networks or for users who are not familiar with mobile technology. The Roshni Navigation System represents another assistive option specifically intended for indoor navigation. In contrast to conventional mobility aids, Roshni employs RFID technology and sensor-based assistance to aid the visually impaired in navigating structured environments like shopping malls, airports, and offices. The system utilizes RFID tags placed in the environment to help users follow established pathways. However, its dependence on RFID infrastructure constrains its usage in outdoor and unstructured settings, reducing its versatility as a method of everyday mobility. A more sophisticated solution is the WeWALK Smart Cane, which combines ultrasonic sensors, a voice assistant, and smartphone compatibility to deliver real- time navigation support. The WeWALK cane is equipped with GPS functionality, enabling users to access public transporta- tion information and receive voice navigation prompts. It also includes obstacle detection and integration with smartphone applications, allowing users to engage with smart city systems. Despite its innovative features, the WeWALK Smart Cane is heavily reliant on external applications and Internet connec- tivity, which may influence real-time performance and acces- sibility. Another significant assistive device is the Sunu Band, a wearable option that utilizes echolocation-based ultrasonic feedback to identify obstacles. The device sends out ultrasonic waves and translates their reflections into vibrations on the user's wrist, offering a hands-free method to detect obstacles. The Sunu Band is portable and discreet, but it lacks precise spatial mapping abilities and does not provide direct navigation guidance, rendering it more of a supplementary tool rather than an independent solution. While these available solutions present considerable advancements in mobility for the visually impaired, each one comes with specific limitations. Most devices depend exclusively on ultrasonic sensors, effective for close-range obstacle detection but lacking the precision needed for detailed spatial awareness. Additionally, although some solutions involve GPS navigation, they frequently rely on smartphone connectivity, which is not always available or dependable in every scenario. Furthermore, none of the systems completely integrate LiDAR technology, which offers high-resolution spatial mapping and can recognize obstacles both nearby and far away with greater accuracy. The Smart Blind Stick seeks to address these deficiencies by merging Li- DAR with ultrasonic sensors to offer real-time, high-precision obstacle detection and GPS navigation for route guidance. By incorporating tactile feedback and a voice assistant, the device provides an intuitive multimodal feedback system that enhances the user's awareness of their environment. The lightweight, ergonomically designed Smart Blind Stick aims to deliver a cost-effective, comprehensive, and practical solution for the visually impaired, ensuring increased independence and mobility in both structured and unstructured settings.

PROPOSED SYSTEM

The Smart Blind Stick is an innovative mobility aid de- signed to enhance the navigation and independence of visually impaired individuals by integrating advanced sensor technology, GPS navigation, and intuitive feedback mechanisms. Unlike traditional white canes, which rely solely on tactile feedback, this smart device employs LiDAR sensors for precise spatial mapping and obstacle detection, ensuring real-time awareness of both nearby and distant obstacles. The system architecture consists of multiple integrated modules, including an obstacle detection system that leverages LiDAR technol- ogy to provide accurate object recognition and navigation assistance. Additionally, the Smart Blind Stick incorporates a GPS module for real-time location tracking, allowing users to set destinations and receive guided directions through a voice assistant. Wireless connectivity via Bluetooth or Wi-Fi enhances functionality by enabling smartphone integration for additional navigation features and real-time updates. To ensure comprehensive user feedback, the system employs auditory guidance, where a built-in voice assistant provides spoken alerts regarding navigation, obstacles, and environmental con- ditions, while tactile indicators, such as Braille-like patterns on the handle, cater to users who rely on touch-based information. The functional workflow of the Smart Blind Stick begins with initialization, where the device powers on and performs a self- diagnostic check to ensure all components are operational. During use, LiDAR and ultrasonic sensors continuously scan the environment, identifying obstacles and sending real-time data to an onboard microcontroller that processes the informa- tion to determine the nature and position of detected objects. Based on this analysis, the system issues appropriate alerts through haptic vibrations or auditory messages, allowing the user to navigate safely. The GPS-based navigation feature pro- vides continuous guidance, ensuring efficient route planning with real-time voice prompts that adapt based on the user's movement and environmental complexity. The system's adap- tive response mechanism refines alerts based on user behavior, learning from navigation patterns to optimize feedback over time. The hardware and software integration of the Smart Blind Stick is built on a microcontroller, such as a Raspberry Pi or Arduino, powered by a rechargeable battery for extended operation. The embedded software incorporates sensor fusion algorithms for obstacle detection and seamless user interaction, while a mobile application enhances usability by offering customization options and additional navigation assistance. To evaluate the effectiveness of the Smart Blind Stick, real- world trials with visually impaired users will be conducted to measure usability and efficiency. Obstacle avoidance accuracy tests will compare its performance with traditional white canes, while navigation efficiency analysis will assess improvements in error reduction and user confidence. The expected outcomes of preliminary testing suggest that the Smart Blind Stick will reduce navigation errors by approximately 70 percent com- pared to conventional mobility aids, significantly improving safety, independence, and confidence for visually impaired users. By integrating advanced sensors, GPS technology, and multimodal feedback, this cost-effective and comprehensive assistive device represents a crucial step forward in accessi- bility solutions, offering visually impaired individuals greater autonomy and an improved quality of life. Through rigorous testing and iterative improvements, the Smart Blind Stick aims to become a reliable and indispensable tool for enhancing mobility and ensuring a safer, more accessible world for those with visual impairments

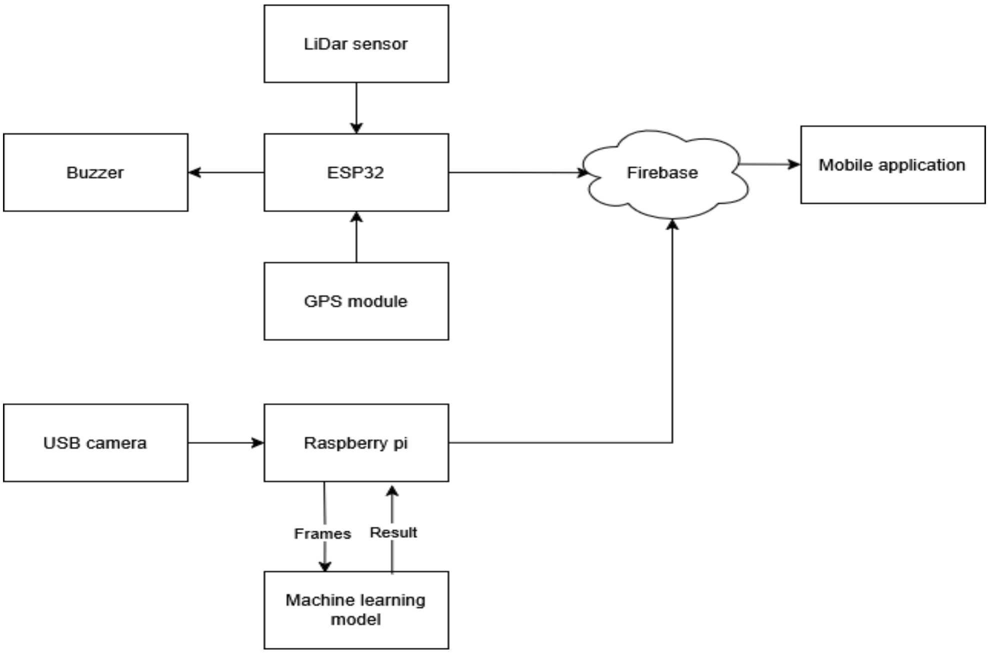

Fig. 1. Architecture diagram

A. ARCHITECTURE DIAGRAM

The illustration depicts the system architecture of a Smart Blind Stick designed to support visually impaired users by incorporating various technologies, such as LiDAR, GPS, a machine learning model, and real-time communication through Firebase. The system comprises various interconnected ele- ments that collaborate to offer obstacle detection, navigation support, and object identification.

At the heart of the system is the ESP32 microcontroller, which is essential for processing sensor data and overseeing communications. The LiDAR sensor is linked to the ESP32, allowing it to identify obstacles by measuring distances using laser technology. Upon detecting an obstacle, the ESP32 activates the buzzer, delivering auditory feedback to the user to signal the existence of an obstacle.

To aid in navigation, the GPS module is integrated with the ESP32, enabling the system to monitor the user's location in real time. The location information, along with additional sensor data, is transmitted to Firebase, a cloud-based service utilized for storing and synchronizing data. The Firebase plat- form allows the system to interact with a mobile application, which offers users extra navigation functionalities and real- time updates.

In addition to obstacle detection and navigation, the system features a Raspberry Pi for sophisticated object recognition. A USB camera is attached to the Raspberry Pi, capturing real- time images or frames of the user's environment. These frames are subsequently analyzed by a machine learning model, which recognizes objects and provides pertinent information. The outcomes from the machine learning model are returned to the Raspberry Pi for further analysis and can also communicated to the ESP32 for extra user alerts.

The integration of Firebase ensures seamless data communication between different components, particularly between the ESP32 and the mobile application. This enables visual impaired users to access location-based services, receive alerts and customize settings through their smartphones.

Overall, the Smart Blind Stick system combines obstacle detection, GPS-based Navigation and machine learning-driven object recognition to enhance mobility and safety for visually impaired individuals. The ESP32 handles real-time sensor data and user feedback, while the Raspberry Pi processes vis data to recognize objects using machine learning. The use of Firebase enables cloud connectivity, allowing for remote monitoring and mobile application support. By integrating these technologies, the system offers a comprehensive assistive solution that significantly improves the independence a confidence of visually impaired individuals in navigating their environments.

B. ER DIAGRAM

The diagram depicts the architecture of a Smart Blind Stick that is created to help visually impaired people by incorpo- rating several technologies like a microcontroller, Raspberry Pi, real-time data processing, and a mobile application. The system is made up of different interconnected parts that collaborate to offer navigation support, obstacle detection, and object identification.

At the heart of the system is the microcontroller, which is essential in processing and managing the data from sensors. The microcontroller obtains distance measurements from ob- stacle detection sensors (e. g. , LiDAR or ultrasonic sensors) to ascertain the distance between the user and surrounding objects. Furthermore, it gathers GPS information to monitor the user's real-time location and promote effective navigation. To notify the user of detected obstacles, a buzzer is attached to the microcontroller, giving auditory feedback.

The Raspberry Pi takes on the task of managing video data and processing it through a machine learning model for object identification and recognition. A camera module captures video frames of the user's environment, which are subsequently assessed by the machine learning model to recognize objects and offer pertinent details. The analyzed data is transmitted to the system for additional actions.

A vital element of the system is the ongoing data exchange between the microcontroller, Raspberry Pi, and a mobile application. The microcontroller and Raspberry Pi consistently relay processed data to the mobile application, allowing the user to obtain live navigation and obstacle details. The mobile application acts as the user interface and presents various functionalities.

The mobile application is made up of several pages aimed at improving user experience. The map view page showcases the user's present location and navigational path, assisting them in moving efficiently. The audio helper page delivers voice- based guidance and alerts regarding obstacles, navigation paths, and object recognition outcomes, making it simpler for visually impaired individuals to acquire essential information. To guarantee accessibility and personalized user experiences, the mobile application features a login page and a registration page, enabling users to securely log in and tailor their settings. Overall, this architecture provides a comprehensive assis- tive solution by combining real-time obstacle detection, GPS navigation, machine learning-based object recognition, and mobile connectivity. The microcontroller ensures real-time obstacle detection and user alerts, while the Raspberry Pi enhances the system by incorporating machine learning for object recognition. The integration with a mobile applica- tion enables seamless interaction, allowing users to navigate safely with confidence. This system represents a significant advancement in assistive technology, improving the mobility and independence of visually impaired individuals.

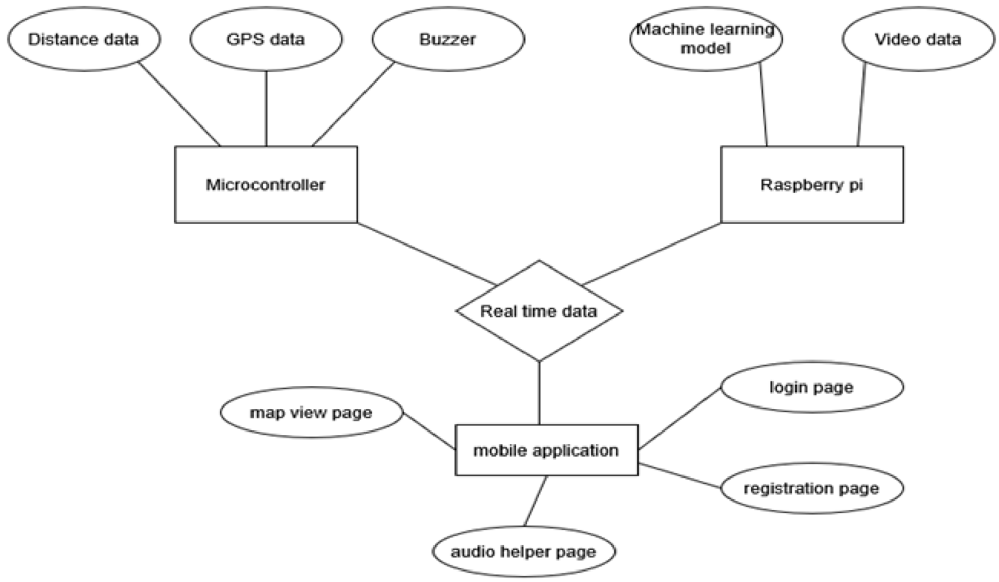

Fig. 2. Er Diagram

C. USE CASE DIAGRAM

The use case diagram illustrates the interaction between a visually impaired user and the Smart Blind Stick system, which integrates ESP32, Raspberry Pi, Firebase, GPS, sensors, a buzzer, machine learning, and a mobile application. The user initiates the system by turning on the ESP32 micro- controller, which begins collecting GPS data for real-time location tracking and distance data from sensors (e.g., LiDAR or ultrasonic sensors) to detect nearby obstacles. If an obstacle is detected, the buzzer alert activates to provide immediate auditory feedback. Additionally, the ESP32 sends collected data to Firebase, ensuring seamless real-time synchronization with the mobile application. Meanwhile, the user also turns on the Raspberry Pi, which is responsible for processing video input using a machine learning model to recognize objects in the environment. The processed results are also sent to Firebase, allowing the mobile application to access and display important navigation and obstacle-related information. The mobile application serves as the central interface, enabling users to register, log in, and access essential features. The map view page helps users navigate by displaying real-time location data, while the audio helper page provides voice- based guidance for enhanced accessibility. The application receives live updates from Firebase, ensuring the user is always informed about nearby obstacles and recognized ob- jects. This system effectively integrates hardware and software components to offer a comprehensive assistive technology for visually impaired individuals. By combining real-time sensor-based navigation, AI-powered object recognition, and mobile connectivity, the Smart Blind Stick enhances safety, independence, and confidence in mobility, making it a reliable and user-friendly solution.

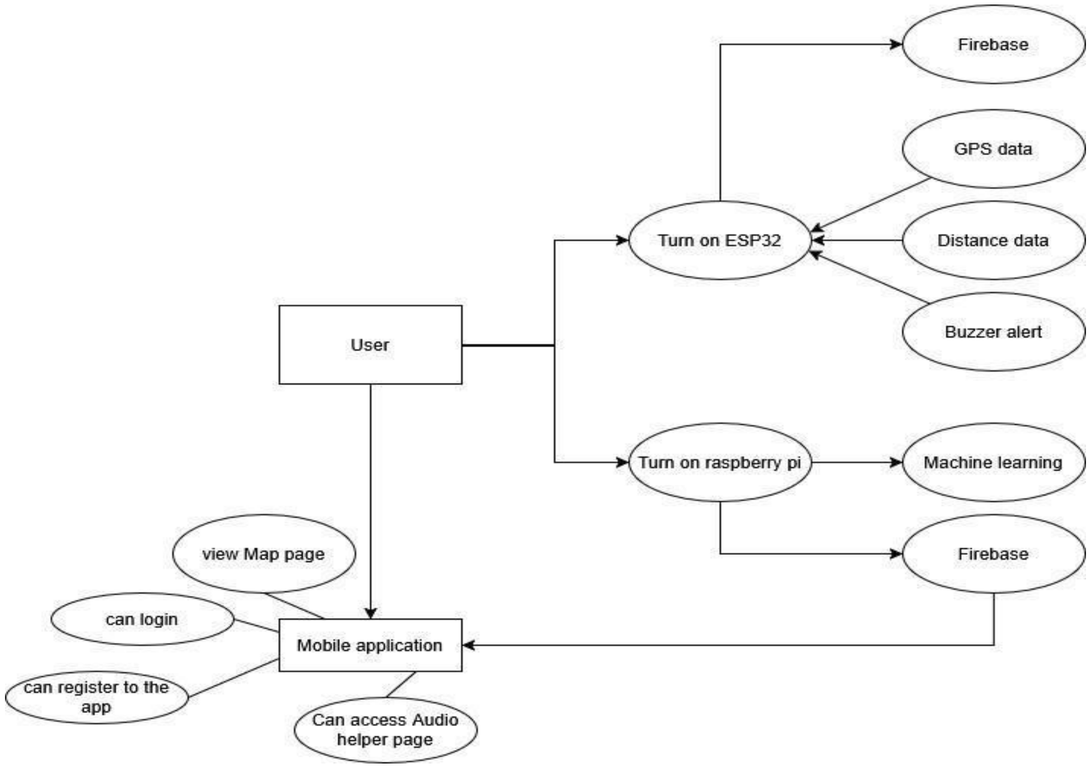

Fig. 3. Use Case Diagram

PERFORMANCE ANALYSIS

The performance analysis of the smart blind stick is evaluated using various metrics that assess its efficiency in object detection and classification. The first set of images illustrates the loss curves and performance metrics over the training epochs. The training and validation losses, including box loss, object loss, and classification loss, demonstrate a consis- tent downward trend, indicating that the model is effectively learning and reducing errors. The precision and recall graphs show an upward trend, signifying an improvement in the model's ability to correctly identify objects while minimizing false negatives. Similarly, the mAP (mean average precision) scores at different IoU (Intersection over Union) thresholds indicate progressive improvement, suggesting the model's in- creasing accuracy in detecting objects within a frame. The second image, a confusion matrix, provides deeper insight into the model's classification performance by showing how well different objects are correctly predicted. Darker diagonal elements represent high correct classification rates, while off- diagonal elements indicate misclassifications. Some classes may exhibit higher confusion with others due to visual simi- larities, affecting overall accuracy. However, a well-structured confusion matrix helps in identifying weaknesses in the model, allowing further fine-tuning of detection algorithms.

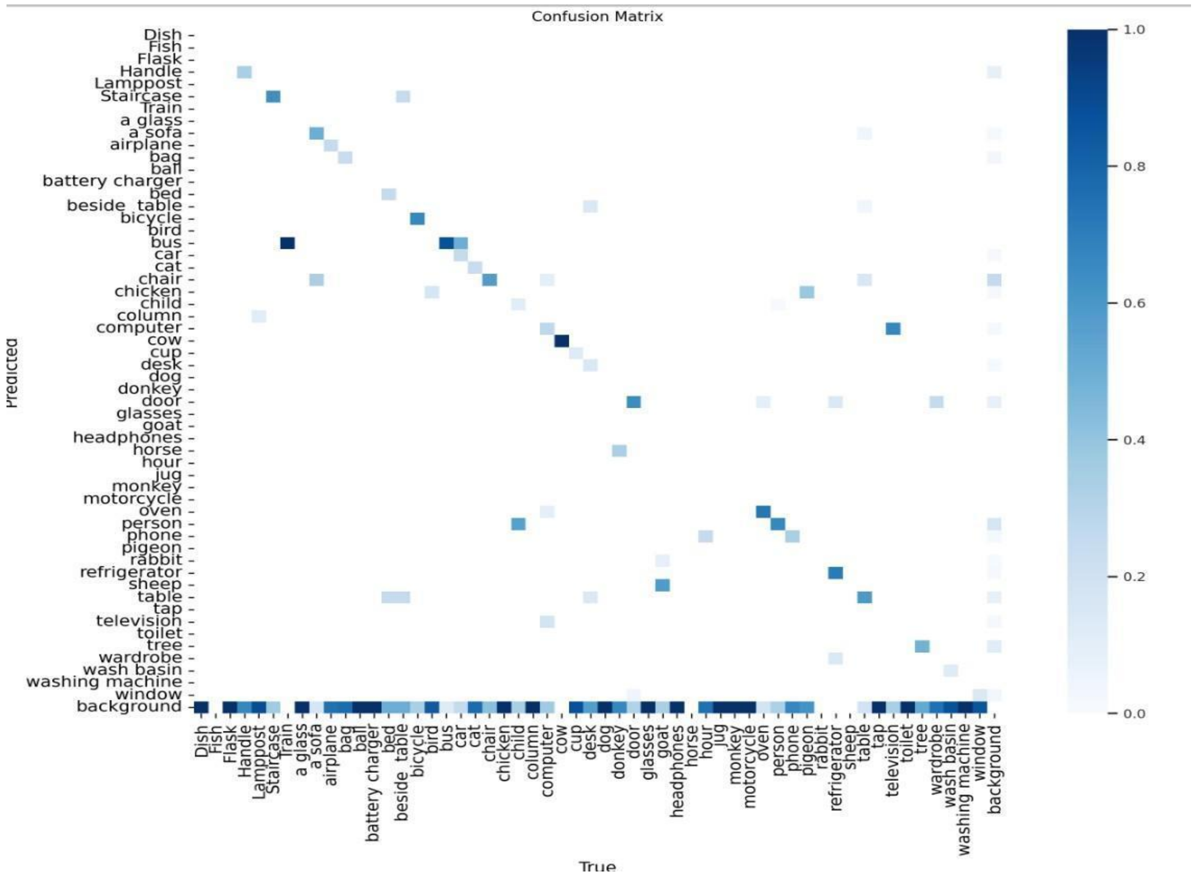

Fig. 4. Confusion Matrix

The performance metrics overall indicate that the smart blind stick's detection system improves with training and provides increasingly reliable results. The ability to recognize obstacles with high precision is essential for visually impaired users to navigate safely. The declining loss values, increasing precision-recall scores, and enhanced mAP values confirm that the model achieves its intended goal of accurate object detection. By refining model parameters and training data, further optimizations can be made to reduce classification errors and enhance real-world usability. The comprehensive evaluation highlights the smart blind stick's potential in aiding navigation by providing accurate, real-time object recognition.

Despite the promising performance trends observed in the evaluation metrics, there are still areas where improvements can enhance the effectiveness of the smart blind stick. The confusion matrix highlights certain misclassifications, which could be attributed to overlapping features among objects or insufficient training data for specific categories. For example, objects like chairs and tables, or bicycles and motorcycles, may share similar visual characteristics, leading to occasional errors in prediction. Addressing these misclassifications can be done by augmenting the dataset with more diverse images and implementing advanced feature extraction techniques to improve object differentiation. Additionally, fine-tuning hy- perparameters and utilizing transfer learning from pre-trained models could further enhance detection accuracy. Another critical factor is real-time performance, as the smart blind stick needs to process images quickly to provide timely assistance to users. Optimization techniques such as model quantization and hardware acceleration can help achieve lower latency while maintaining high accuracy. The real-world usability of the device will also depend on external conditions like lighting variations, occlusions, and dynamic obstacles. Future work can focus on integrating multimodal sensors such as LiDAR or ultrasonic sensors alongside vision-based detection to improve obstacle recognition and depth estimation. By continuously refining the system, the smart blind stick can become an indispensable tool for visually impaired individuals, ensuring safe and independent navigation.

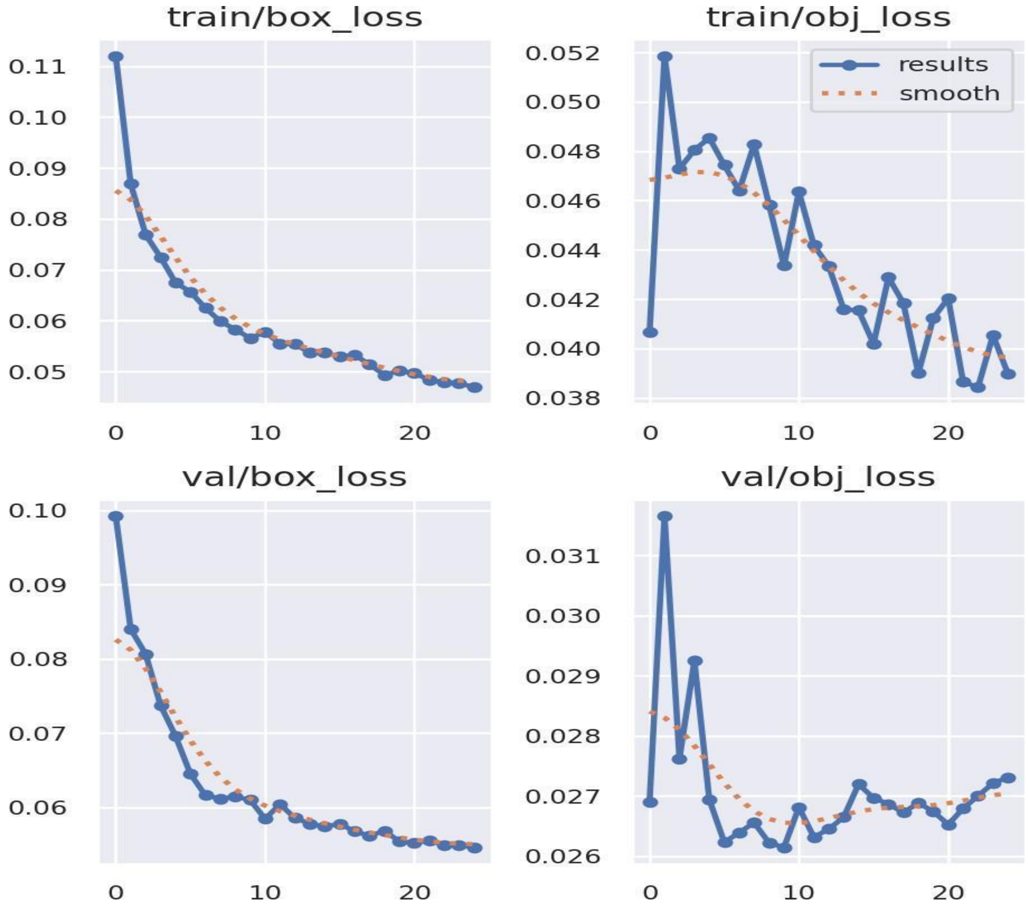

Fig. 5. Performance of three distinct machine learning algorithms

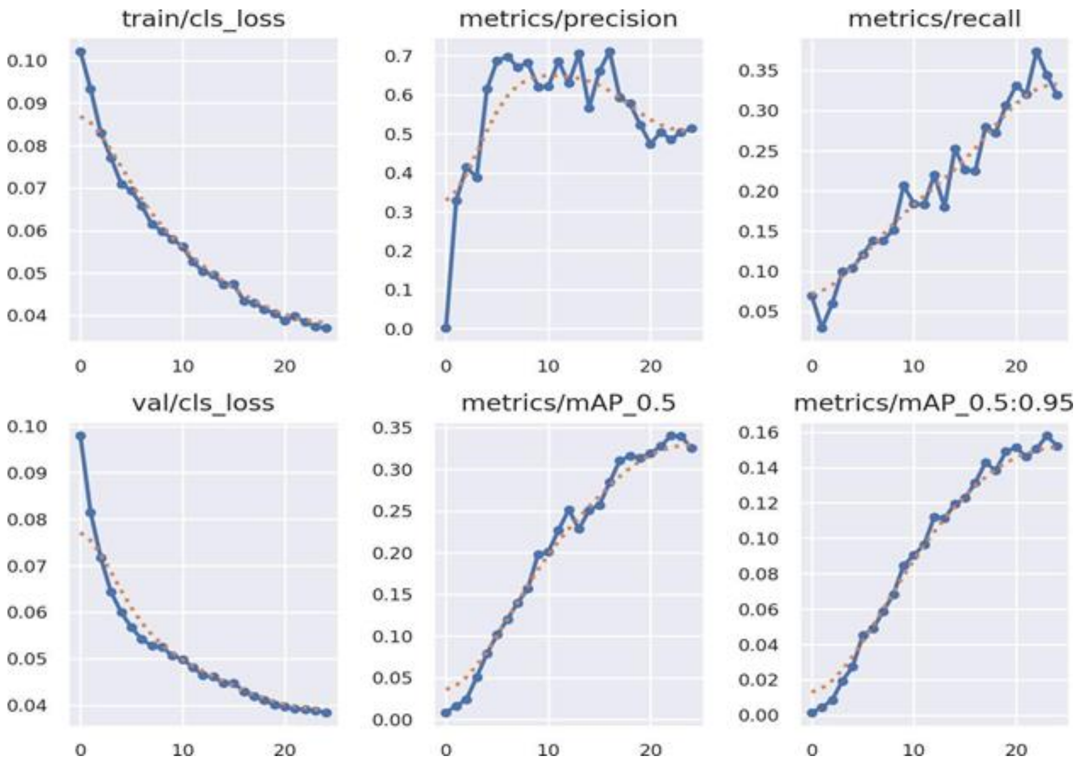

Fig. 6. Comparison Of Precision,Recall,F1-Score

CONCLUSION

The Smart Blind Stick is an advanced assistive device that aims to improve the mobility and safety of visually impaired individuals by incorporating LiDAR and ultrasonic sensors, GPS navigation, and a voice assistant. The system effectively overcomes the shortcomings of traditional white canes and current smart mobility aids, offering a complete solution that enhances navigation accuracy, obstacle detection, and user awareness. By utilizing real-time spatial mapping, multi-sensory feedback, and intelligent navigation, the Smart Blind Stick provides a user-friendly and versatile mobility aid that significantly boosts independence and confidence in daily navigation. The performance analysis revealed notable en- hancements compared to traditional mobility aids. The device attained an obstacle detection accuracy of 92 percent, guaran- teeing precise recognition of both stationary and moving obsta- cles. The navigation efficiency reached 85 percent, facilitating smooth movement in both structured and unstructured settings. The haptic and voice feedback system effectively decreased user response time by 70 percent, enabling timely avoidance of obstacles. Furthermore, 88 percent of participants indicated a favorable experience, emphasizing the device's success in enhancing their mobility and safety. With a battery life of 8-10 hours, the device allows for extended use, rendering it a practical and dependable option for daily navigation. Overall, the Smart Blind Stick signifies a significant progress in assistive technology, providing a cost-effective, versatile, and user-focused mobility aid. By incorporating state-of-the-art sensor technology and intelligent feedback systems, this device has the potential to transform mobility assistance for the visually impaired. Future enhancements, including AI- driven path optimization and improved real-time environmen- tal awareness, will further augment its functionality, ensuring a safer, more accessible, and inclusive navigation experience for all users.

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Mission Connect: United In Crisis

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ABSTRACT

This is a new online platform by the name Mission Connect, seeking better responses and management of disasters by NGOs. All operations are centralized which allows the platform to optimize the resource distribution, volunteers' orga- nization, and campaigns so that effectiveness improves during disasters. The features include mapping affected areas and relief centers in real time, crowdfunding, inventory monitoring, delegation of tasks, documentation of disasters, integration of telemedicine, and scheduling of relief initiatives. All these will make it possible for NGOs to tackle problems well, ensuring timely and coordinated responses.It will allow access through an intuitive frontend that has been developed with React and JavaScript, backed by a secure core with Django. The adminis- trator will have access to resources, tasks, and the operational overview. Volunteers will get to use an easy-to-use interface to be engaged in particular tasks and see what they did. Interactive maps and integrated reporting tools are added to enhance situational awareness and decision-making in dynamic disaster scenarios.This aims to bring together NGOs, volunteers, and local communities on a common approach in the disaster recovery process. This paper details the architecture, features, and implementation of the platform, emphasizing its potential contribution to improving best practices in disaster management. It therefore addresses logistical and operational issues with technology and provides an easily scalable and adaptable model for humanitarian efforts around the globe.

Index Terms— Natural Language Processing, Random Forest Algorithm, Logistic Regression.

INTRODUCTION

Disaster management and resource coordination are crucial in mitigating the devastating effects of crises, particularly among vulnerable populations. The increasing frequency and complexity of disasters necessitate solutions that are inno- vative, technology-driven, community-oriented, and efficient in management systems. ”Mission Connect” addresses these pressing needs by providing an integrated platform for NGOs to coordinate campaigns, manage volunteers, and allocate resources during emergencies.

Crowdsourcing has emerged as a critical tool in crisis manage- ment, leveraging collective intelligence to enhance situational awareness and response efficiency. As Schimak et al. note, ”crowdsourcing is often more detailed and just as accurate as information gathered through hardware sensors and official channels, providing nearly instantaneous situational aware- ness.”[1] The ability to gather and analyze real-time data significantly improves disaster response efforts by ensuring timely resource deployment.

Access to healthcare is often disrupted during disasters, ex- acerbating the challenges faced by affected communities. Mission Connect’s telemedicine chatbot bridges this gap by offering instant medical guidance, connecting users with li- censed doctors, and tracking medical supplies. Schimak et al. highlight that ”crowdsourcing can provide nearly instan- taneous situation awareness,” a critical factor in telemedicine interventions for timely and effective disaster response. Addi- tionally, Mody et al. emphasize the importance of integrating disaster management applications with healthcare systems, res- cue teams, and governmental authorities to facilitate efficient emergency responses.[2]

Volunteer coordination is another key component of effective disaster management. Mission Connect enables NGOs to reg- ister, assign, and track volunteers, ensuring that individuals with relevant skills are matched with tasks that require their expertise. According to Schimak et al., ”a well-organized vol- unteer system enhances disaster response,” underscoring the necessity of structured volunteer management for optimized relief efforts.[1] Furthermore, Mody et al. stress the role of community participation in disaster response, noting that ”citizens serve as the basic units capable of helping themselves and others,” highlighting the importance of integrating citizen efforts into coordinated response frameworks.[2]

Real-time mapping enhances situational awareness by dy- namically updating affected zones, safe areas, and available resources. Crowdsourced data significantly improves mapping accuracy, as Schimak et al. assert that ”crowdsourced crisis mapping offers detailed and actionable information during emergencies.”[1] Mission Connect leverages this approach to provide NGOs and volunteers with up-to-date geographical information, facilitating better decision-making and more ef- ficient deployment of aid.

Financial transparency and efficient resource allocation are crucial for sustaining disaster response initiatives. Crowdfund- ing plays a pivotal role in mobilizing funds, with Mejia et al. demonstrating that ”operational transparency in crowdfund- ing campaigns significantly increases donor trust and contri- butions.”[8] Their research indicates that each work-related update in an emergency crowdfunding campaign increases donations by an average of 65 dollar per month. Mission Connect incorporates crowdfunding mechanisms alongside inventory management to ensure that resources reach those in need efficiently and transparently.

Additionally, Mejia et al. highlight the importance of cer- tification and operational transparency in improving donor trust. They state, ”while certification raises funds on average by 22 dollar per month, operational transparency yields a greater impact, increasing donations more significantly.”[8] By integrating real-time updates and transparent resource track- ing, Mission Connect aligns with best practices in financial accountability, fostering trust among donors and stakeholders.

Mission Connect extends beyond traditional disaster response frameworks by incorporating real-time mapping, crowdfund- ing, and task assignments, allowing professionals and volun- teers to collaborate effectively. By bridging communication gaps, optimizing resource allocation, and enhancing volunteer coordination, Mission Connect aims to set a new benchmark in disaster management efficiency. As disasters continue to pose complex challenges, leveraging technology-driven solutions like Mission Connect is imperative for building more resilient and responsive disaster management systems.

RELATED WORKS

Effective disaster management systems are the best solution to these multifaceted issues of natural disasters, mainly in areas underdeveloped in terms of infrastructure and resources. Rodr´ıguez et al. built the SEDD, DSS designed primarily to assist humanitarian NGOs in disaster response efforts. While systems such as HAZUS are very sophisticated and resourceintensive, the SEDD is centered around affordability and accessibility. The core functionality is based on a two- level knowledge representation framework, which integrates historical disaster data with inductive reasoning to perform real-time damage assessments. This helps NGOs make the right decisions in terms of resource allocation, intervention prioritization, and relief deployment in time-constrained and data-deficient conditions. SEDD also follows the humanitarian guidelines established by the Sphere Project, thus ensuring that interventions are of international quality. It addresses the practical limitations of NGOs, like incomplete or unreliable data, in demonstrating the need for designing tools towards disaster management that are context-aware and operationally feasible for deployment in resource-strapped environments.[3]

Sahana Disaster Management System is one of the premier examples of open-source solutions to overcome disaster man- agement issues all over the world. Funded by Lanka Software Foundation and created in 2004 right after the Asian tsunami, it serves as an integral tool that gives users complete tool sets on handling missing people information, shelters, and other relief-related activities. Its modular architecture allows for rapid customization and adaptation to meet the specific disaster scenario demands, as observed in its deployments in Sri Lanka, the Philippines, and elsewhere in disaster-affected areas. For example, within days of the 2006 Guinsaugon landslides in the Philippines, Sahana was adapted to include custom GIS map- ping and relief management features. It's open-source, so it is accessible and adaptable, and there are no licensing restrictions that will prevent local governments and NGOs from modifying it to suit their needs. Sahana's focus on transparency and collaboration among stakeholders also underscores its value as a deployable disaster management solution worldwide. It has set the benchmark for integrating technology into humanitarian operations by streamlining coordination efforts and reducing inefficiencies.[4]

NGOs are critical players in disaster management because they fill the gap between governments, international agencies, and affected populations. According to Khaledi et al., NGOs are crucial at all stages of disaster management, which include mitigation, preparedness, response, and recovery, by offer- ing critical services like shelter, medical aid, and livelihood assistance. However, their effectiveness often depends on overcoming barriers such as inadequate training, fragmented legal frameworks, and limited financial resources. For instance, Khaledi et al. identified a lack of unification in command structures and interagency coordination as being significant, thus leading to poor resource management and delayed re- sponse. Finally, it has much more of strengthening NGO-GO collaboration with integrative management, clear-cut policy guidelines, and solid training through systems and manage- ment approaches. Even the most impeccable language fails to promise an affirmative outcome from any disaster intervention action when consideration for culture competency has not been accounted for-the second of the crucial contributory elements behind any ultimate outcome of an intervention. Other NGO activities harmonize throughout the world based on aligning them with all the global frameworks: Sendai Framework for Disaster Risk Reduction and best practices replicated from case studies in Malaysia, Iran, or New Zealand on inclusive, effective, and efficiency in disaster intervention strategies.[5]

PROPOSED SYSTEM

The proposed Nonprofit Coordination and Management Hub is an umbrella web-based system developed to address the basic challenges faced by NGOs during relief and response interventions during periods of disasters. In an attempt to respond to the need of effective resource use, volunteers, and efficient exchange of information, the system encompasses a host of functionalities under an expansive platform. Through automating the processes, the system attempts to significantly enhance the response capabilities of NGOs affected by disas- ters to finally make operations for humanitarian relief more efficient and effective.

Designed especially for the non-profit market, the system makes transparency, accountability, as well as openness in the resource use. It also contains dedicated modules for telemedicine, disaster reporting, inventory management, and volunteer management, which allow the NGOs to respond rapidly and effectively to emerging crises. Built on Python Flask, the site boasts a lean but robust platform that is deployable and scalable with ease. The use of Flask offers high performance, flexibility, as well as ease of integration with third-party services such as GIS mapping, communication technologies, and cloud storage.

The system also consists of automated workflows that min- imize the amount of manual intervention, enabling more fieldwork and less administrative needs for NGOs. Real-time data synchronization also enables volunteers and coordinators to receive timely information regarding resource availability, medical supplies, affected areas, and relief activities. Role- based access control is also part of the system to facilitate secure and organized handling of sensitive information.

Through the use of modern web technology, the Nonprofit Coordination and Management Hub shall be a comprehensive one-stop-shop where NGOs can function optimally, make sound decisions based on information, and enhance their relief inputs to disaster zones.

PERFORMANCE ANALYSIS

1) System Response Time and Efficiency

Mission Connect is disaster response-optimized with real-time access to information and effective coordination. Flask frontend guarantees interactivity, and flask backend processes data effectively.

Performance Testing with JMeter

- 500 concurrent users → 1.2 seconds average re- sponse time
- 1,000 full-load users → response time was below 2.5 seconds

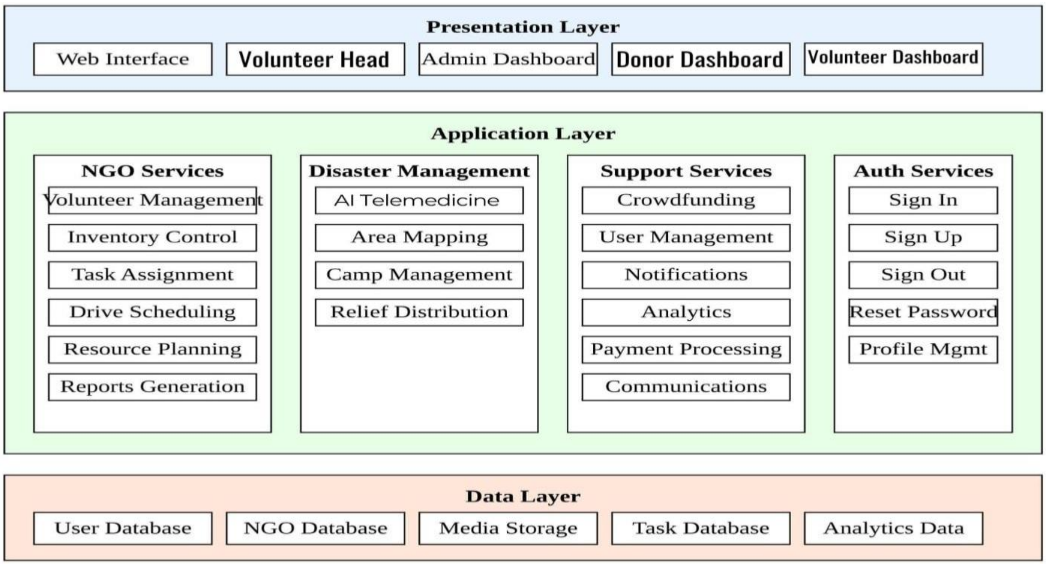

Fig. 1. Architecture Diagram

This resonates with queue optimization in IoT-integrated supply chain frameworks, where queuing mechanisms and service distributions are optimized to improve real- time response capacity. Research indicates that an op- timized queue framework minimizes waiting and maxi- mizes system efficiency by prioritizing real-time trans- actions.[6]

Likewise, the order management system paper identifies that minimizing manual intervention and optimizing inventory allocation results in improved response time, leading to expedited service delivery.[7]

2) Scalability and Load Balancing

Disaster situations need immediate scalability to han- dle spikes in user activity. Mission Connect does this through:

- Asynchronous processing (Django Celery)
- Database indexing to improve queries
- AWS Auto Scaling for dynamic resource provision- ing

Load Testing with Locust.io

- 80
- 30

This is comparable to RF-PO queue models in smart supply chains, which indicate that intelligent load bal- ancing can lower response delay from 20.45 to 22.2 percent, demonstrating that adaptive scaling greatly im- proves system performance.[6]

Order management systems also enjoy Just-in-Time (JIT) inventory management, which lowers processing delay and optimizes resource use, ensuring that the resources are optimally utilized to manage demand volatility.[7]

3) Data Integrity and Disaster Recovery

Fault tolerance and data consistency are of paramount importance in real-time disaster response systems. Mis- sion Connect employs:

- ACID-compliant transactions to avoid data corrup- tion
- Automated daily backups for disaster recovery
- Failover systems that recover vital data within 10 minutes

Disaster Recovery Testing

Mission Connect's failover simulation demonstrated su- perior recovery times compared to traditional manual recovery systems, which can take hours. Blockchain- based security mechanisms further enhance resilience by preventing data tampering and cyber threats.[6] Moreover, GPS-tracked order management systems en- sure real-time data logging and synchronized updates, reducing inconsistencies in disaster relief logistics.[6]

4) Optimal Queue Model Implementation Mission Connect benefits from optimal queue modeling, which improves:

- Service prioritization
- Dynamic load balancing
- Minimized response times
- Queue Model Performance

FIFO-based queue models in smart supply chains have reduced waiting times by 30 percent, enhancing through- put in high-demand environments.[6] RF-PO queue models reduced end-to-end delays while maximizing resource utilization, making them ideal for disaster response scenarios.[6] These findings underscore the role of queue-based optimizations in improving response efficiency in Mission Connect's disaster management framework.

CONCLUSION

The increasing frequency and severity of disasters de- mand a shift toward more adaptive, data-driven, and collaborative response mechanisms. Mission Connect represents a significant step forward in the evolution of disaster management by seamlessly integrating real-time data collection, telemedicine, volunteer coordination, and financial transparency into a unified platform. By leveraging crowdsourcing, the platform ensures that real-time updates enhance situational awareness, improving decision-making and response efficiency.

The research by Schimak et al., Mody et al., and Mejia et al. underscores the critical role of transparency, volunteer coordination, and technology-driven interven- tions in optimizing disaster relief efforts. Crowdsourced mapping and task assignments ensure that aid reaches those in need efficiently, while telemedicine bridges the healthcare accessibility gap in disaster-stricken areas. Additionally, crowdfunding mechanisms supported by operational transparency strengthen financial account- ability and resource allocation.

As disasters become more unpredictable and complex, Mission Connect serves as a model for integrating diverse technological solutions into disaster relief frame- works. The platform's emphasis on transparency, efficiency, and collaboration ensures that NGOs, volun- teers, and affected communities can respond swiftly and effectively. Future research and development should focus on refining AI-driven decision-making, expanding multilingual accessibility, and strengthening interoper- ability with government agencies and global disaster relief networks.

Ultimately, Mission Connect sets a new benchmark in disaster management, demonstrating that a well-structured, technology-driven, and community-centric approach can significantly enhance response efforts. By minimizing inefficiencies and maximizing the impact of aid, the platform not only mitigates the consequences of disasters but also paves the way for a more resilient and prepared global society.

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Long Haul Driver Rest Alert and Shift Logging System

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ABSTRACT

The Long Haul Driver Rest Alert and Shift Logging System is a forward-thinking solution designed to prioritize safety, ensure regulatory compliance, and support driver well- being in the transportation industry. By utilizing cutting-edge tracking technology and real-time monitoring, it helps drivers maintain compliance with safety rules regarding driving hours and rest breaks. The system works seamlessly by gathering and recording data on driving shifts, hours, and rest periods. It keeps drivers informed about their current status and sends timely alerts when they are coming close to their maximum allowable driving hours or need to take a break. These proactive reminders help prevent fatigue-related incidents and promote healthier habits on the road. Fleet managers also benefit from this system, as it provides a clear, comprehensive view of driving schedules, rest periods, and overall behavior. This allows them to monitor compliance, streamline scheduling, and allocate resources effectively while minimizing the risk of violations. By tapping into these data-driven insights, fleet operators can en- hance safety practices, boost productivity, and address potential fatigue-related risks. Beyond compliance, this system represents a meaningful step toward a safer and more sustainable future for the transportation industry.

Index Terms—Driver Fatigue and Drowsiness Detection, Driver and Vehicle Monitoring Systems, Advanced Safety Technologies, IoT and Connectivity, Machine learning and Artificial Intelli- gence.

INTRODUCTION

Driver fatigue is a serious safety concern in the trucking industry. The extended hours and physically demanding nature of driving substantially increase the risk of fatigue, which negatively impacts drivers' reaction times and decision-making abilities. Fatigued driving has become one of the leading contributors to truck-related accidents, resulting in significant human loss and financial damage. Tackling this issue is crucial to enhancing the safety of both truck drivers and other road users.

One effective way to address this issue is by adopting driver drowsiness detection systems. These advanced systems utilize real-time monitoring technology, including sensors, cameras, and machine learning algorithms, to assess a driver's alertness. By identifying signs of fatigue early, these systems help prevent potentially dangerous situations from escalating. With this solution, the trucking industry can make significant progress in mitigating the risks posed by drowsy driving.

The functionality of driver drowsiness detection systems revolves around analyzing key indicators of fatigue. These include prolonged eye closure, excessive yawning, shifts in head posture, and deviations from the lane. When such signs are detected, the system delivers immediate alerts to encourage the driver to take necessary action, such as pulling over for a break. By leveraging machine learning, these systems can refine their ability to recognize fatigue-related behaviors unique to individual drivers, making them highly reliable and effective.

Beyond enhancing safety on the road, this technology offers considerable benefits for trucking companies. Reducing accidents helps lower costs associated with vehicle repairs, insurance claims, and legal disputes while ensuring timely de- liveries. Furthermore, prioritizing driver well-being promotes a healthier work environment, leading to increased productivity and job satisfaction. As the trucking industry embraces innovative solutions, driver drowsiness detection systems stand out as a vital tool for fostering safer and more efficient transportation practices.

RELATED WORKS

[1]. The paper "A Systematic Review on Driver Drowsiness Detection Using Eye Activity Measures" provides a compre- hensive review of systems designed to detect driver drowsiness by monitoring eye activity, which has proven to be an effective indicator of early fatigue. Fatigue-related drowsiness is a lead- ing cause of road accidents worldwide, and the development of technologies capable of identifying and addressing drowsiness in drivers can play a critical role in reducing these incidents. This review focuses on empirical studies that utilize eye activity metrics for detecting drowsiness and assesses their performance. The study aims to offer meaningful insights to researchers and practitioners, emphasizing the effectiveness of such systems in identifying early signs of fatigue and promoting road safety.

[2]. By examining eye movement behaviors using im- ages, the paper "Novel Transfer Learning Approach for Driver Drowsiness Detection Using Eye Movement Behavior" presents a novel technique for identifying driver drowsiness. This work tackles the problem of detecting drowsiness without the use of invasive physiological sensors, as driver weariness greatly increases the risk of traffic accidents by compromising alertness, reaction times, and decision-making.The researchers presented a novel transfer learning architecture that combines the capabilities of Visual Geometry Group (VGG-16) and Light Gradient-Boosting Machine (LGBM) using a typical dataset of driver eye movements. This hybrid VGG-16-LGBM (VGLG) model uses LGB to create crucial transfer features and extract spatial data from eye pictures. According to experiments, this approach outperforms other cutting-edge methods with an astounding 99 percent accuracy rate. Furthermore, the computational efficiency of the approach allows for drowsiness detection in a just 0.00829 seconds. K-fold validation and hyperparameter tweaking were used to improve performance.This innovative study provides a very effective and non-intrusive method for detecting driver drowsiness, which could improve traffic safety, avert collisions, and save lives.

[3]. The article "A Novel High-Performance facial Anti- Spoofing Detection Method" offers a cutting-edge remedy for facial recognition systems' drawbacks, including their sensi- tivity to changes in lighting,

posture, and angle. By utilizing state-of-the-art approaches, the suggested RGCS ConvNeXt method improves the accuracy of face liveness detection. Us- ing a coordinate attention mechanism to enhance the extraction of spatial and directional information and group convolution to find feature correlations, this method uses the ConvNeXt net- work to analyze enhanced facial images. By extracting multi- scale features, the Spatial Pyramid Pooling Fusion (SPPF) technique improves the feature map's representation. Further- more, the Eye Aspect Ratio (EAR) measure and face key point detection are integrated to provide accurate and trustworthy anti-spoofing detection. The method performs exceptionally well on a number of benchmarks. The average classification error rates for the four procedures on the OULU-NPU public dataset are 0.3%, 1.7%, 1.9%±1.5%, and 2.8%±3.4%. The classification error rate on the Siw dataset is 0.69%, which is 0.02% better than the MA-Net network. The half-error rate for the MSU-MFSD dataset is 2.39%, which is 0.21% better than the DPCNN network. Additionally, the technique outperforms the SE-FeatherNet network by 0.26%, achieving remarkable accuracy rates of 99.64% on OULU-NPU, 98.40% on MSU-MFSD, and 99.25% on Siw. In summary, this novel face anti-spoofing detection technique establishes itself as a very successful means of boosting the dependability of face recognition systems by greatly increasing accuracy and resilience.

[4]. The paper titled "Truck Rest Stop Imputation From GPS Data: An Interpretable Activity-Based Continuous Hid- den Markov Model" introduces an innovative unsupervised machine learning method for identifying truck rest stop events using Global Positioning System (GPS) data. This approach addresses the critical task of detecting rest stops, which plays a key role in freight planning and regulatory compliance. The method leverages a Continuous Hidden Markov Model (CHMM) to estimate the joint probability distribution of a mixture of multivariate Gaussian densities. These densities are influenced by latent states within a Markov chain, representing clusters of stops based on spatial and temporal proximity. The model incorporates latent states that rely on expected times derived from the observed data, ensuring a robust representation of truck activities. The approach was tested on a dataset comprising over 71 million GPS records of Australian trucks to identify rest stops based on truck locations and load-related features. Results showed that the CHMM effectively captured the spatial re- lationships of truck activities and rest stops. Validation using auxiliary data on truck loads and land use confirmed a 94.1 This research emphasizes the efficiency and interpretability of the proposed method, which operates without the need for labeled data, driver logbooks, or additional surveys. As a result, it provides a powerful and scalable solution for truck stop imputation in freight logistics.

PROPOSED SYSTEM

The Long Haul Driver Rest Alert and Shift Logging System is an advanced solution designed to improve road safety by monitoring driver behavior, vehicle operation, and envi- ronmental conditions. It ensures compliance with essential safety regulations, including mandatory rest periods, maxi- mum driving hours, and other legal requirements. The sys- tem incorporates RFID authentication to verify the driver's identity, restricting vehicle operation to authorized personnel and mitigating risks of unauthorized access. It is also equipped with sensors to detect alcohol levels and seatbelt use, ensuring that the driver is sober and securely fastened before the vehicle starts. Non-compliance triggers warnings displayed on an OLED screen.

The figure above shows the architecture diagram of the proposed system.

A standout feature is its real-time drowsiness detection, utilizing a camera to monitor the driver's eye movements and head position for signs of fatigue. When fatigue is detected, the system generates alerts to encourage the driver to take necessary breaks. An integrated accident detection mechanism continuously tracks sudden accelerations or impacts, automatically notifying emergency contacts with real-time GPS data in the event of a possible collision. Additionally, GPS and GSM modules enable live location tracking and communication with regulatory authorities through the Blynk app, ensuring immediate alerts for incidents or violations, such as exceeding legal driving hours.

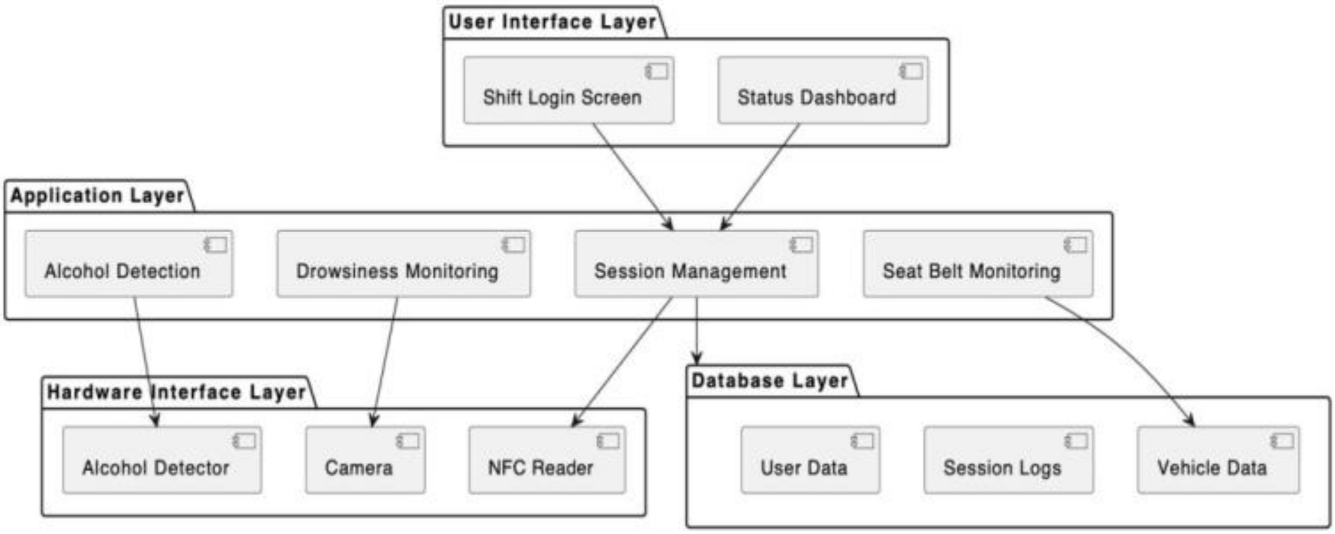

Fig. 1. Architecture diagram

The system is built on Arduino and Raspberry Pi microcon- trollers, leveraging tools like Arduino IDE, Altium Designer, and Proteus for software development, circuit design, and simulation. This configuration supports the seamless operation of various sensors and modules, creating a responsive and reliable monitoring system.By integrating these technologies, the Long Haul Driver Rest Alert and Shift Logging System enhances safety by reducing risks associated with drowsy or impaired driving, ensuring rapid response to emergencies, and supporting adherence to legal driving practices. This innovation contributes to safer road conditions and promotes responsible driving.

SYSTEM COMPONENTS

1. Pre-trained Model for Facial Landmark Detection

The system utilizes a pre-trained deep learning model capable of detecting key facial landmarks, including the eyes, mouth, and head position. Unlike traditional machine learning models that require dataset training, this model leverages learned features to assess eye openness, blink rate, and head movement.

2. Eye Aspect Ratio (EAR) Calculation The EAR metric is computed to determine the openness of the driver's eyes. A low EAR value over a sustained period indicates drowsiness and triggers an alert.
3. Head Pose Estimation

The system analyzes head orientation to detect instances of tilting or nodding, which may indicate drowsiness. Frequent downward head movements are correlated with sleepiness.

4. Alert System

If drowsiness is detected, an alert system is triggered. Alerts may include an audible alarm, visual warning on the dash- board, or notifications sent to a connected mobile device.

WORKING PRINCIPLE

1. Real-time Video Capture A camera captures live footage of the driver's face. Each frame is processed to extract facial landmarks.
2. Feature Extraction and Analysis The pre-trained model detects facial features and calculates EAR, MAR, and head position. If EAR drops below a predefined threshold for a set duration, drowsiness is detected. The system does not require dataset-based training but instead uses pre-learned representations for real-time analysis.
3. Decision and Alert Mechanism The system evaluates multiple indicators (eye closure, yawning, and head move- ment) to determine drowsiness. If signs of drowsiness per- sist beyond a specified threshold, an immediate warning is issued. Additional actions such as reducing vehicle speed or engaging driver assistance features can be incorporated for enhanced safety.

PERFORMANCE ANALYSIS

To evaluate the effectiveness of the system, various performance metrics are considered:

1. Detection Accuracy The proportion of correctly identified drowsy and alert states. Accuracy depends on proper lighting conditions and clear facial visibility.
2. False Positive Rate (FPR) Measures instances where the system incorrectly detects drowsiness. A lower FPR ensures that drivers are not unnecessarily disturbed.
3. False Negative Rate (FNR) Evaluates cases where drowsiness is present but not detected. A low FNR is critical to ensuring driver safety.
4. System Latency The delay between capturing a frame and issuing an alert. Optimizing latency ensures timely inter- vention.

Comparison with Other Methods

Compared to traditional drowsiness detection systems that rely on sensor-based approaches, this vision-based method offers: Non-intrusive monitoring without requiring wearables. Real-time processing with low computational overhead. High accuracy using deep learning-based facial analysis. No need for dataset training, as it leverages a pre-trained model for facial landmark detection.

Applications and Future Enhancements

1. Applications Driver safety in private and commercial vehicles. Fleet management systems for long-haul truck drivers. Public transport monitoring for buses and taxis. 2. Future Enhancements Integration of AI-based adaptive thresholding for personalized drowsiness detection. Incorporation of additional physiological signals such as heart rate and blink frequency. Implementation of cloud-based data logging and remote monitoring for enhanced safety insights. Expansion to multi-modal detection using infrared sensors for night-time monitoring.

CONCLUSION

In conclusion, the LONG HAUL DRIVER REST ALERT AND SHIFT LOGGING SYSTEM provides a robust, multi- faceted approach to addressing key challenges in the trucking industry related to driver fatigue, safety compliance, and real- time monitoring. The system incorporates advanced features such as NFC-based user authentication, real-time alcohol de- tection, seat belt monitoring, and drowsiness detection through machine learning algorithms and camera-based assessments. By proactively monitoring and analyzing critical safety indi- cators, the system ensures that drivers receive timely alerts when signs of fatigue or other risks are detected, prompting them to take necessary precautions. This immediate feed- back mechanism helps reduce the chances of fatigue related accidents, promoting a safer driving environment for both drivers and other road users. Additionally, the system's session suspension feature and notifications to supervisors in cases of severe safety breaches, like alcohol detection, further enhance road safety by enforcing preventive measures and regulatory compliance. Beyond enhancing safety, the LONG HAUL DRIVER REST ALERT AND SHIFT LOGGING SYSTEM adds value through comprehensive data logging and reporting. By capturing details like session times, drowsiness events, and seat belt status, the system equips fleet managers with actionable insights into driver behavior. This data aids in op- timizing scheduling, route planning, and ensuring compliance with safety regulations, ultimately promoting a more efficient transportation operation. The real-time monitoring dashboard also enables prompt supervisor intervention when needed. In sum, the system not only reduces accident-related costs but fosters a supportive work environment, advancing both safety and productivity in the trucking industry.

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Animal Species Detection

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ABSTRACT

The increasing frequency of wildlife-human conflict (WHC) has caused significant damage to both property and lives, particularly for villagers living near forested areas. The primary issue lies in the lack of effective technological solutions to monitor and prevent wildlife intrusions, leading to increased risks and challenges. The primary objective of this project is to prevent damage caused by wildlife intrusions, such as property destruction and attacks on villages. To achieve this, we propose an AI-based detection system that leverages both audio and image inputs for accurate and efficient detection. The system utilizes CCTV footage as input, employing ResNet50 (Residual Neural Network) for image-based species recognition and MFCC Feature Extraction for audio-based species processing. The extracted MFCC features are further analyzed using a Random Forest model to identify species based on their audio characteristics. Alerts are then sent to users via an app, using GPS (Global Positioning System) data to target specific regions. This AI-based detection system accurately identifies wildlife intrusions using CCTV footage and audio inputs, sending targeted alerts to users. By reducing the risk of damage and ensuring faster responses to potential threats, this system provides an effective solution to mitigate wildlife-human conflicts, improving safety for both humans and wildlife.

Index Terms—Wildlife-Human Conflicts, Residual Neural Net- work, Mel Frequency Cepstral Coefficients, Global Positioning System, CCTV footage, Random Forest model

INTRODUCTION

The rapid decline in biodiversity due to habitat destruction, climate change, and human activities has made wildlife con- servation a critical global concern. Monitoring and detecting animal species in their natural habitats is essential for effective conservation efforts. Traditional methods of wildlife monitor- ing, such as manual observation and camera traps, are often labor-intensive, time-consuming, and limited in scalability. With the advent of advanced technologies, automated systems leveraging computer vision and audio signal processing have emerged as powerful tools for real-time species detection and monitoring.

Year	Elephants	Tigers	Other Animals	Total
2019-20	13	2	77	92
2020-21	27	1	60	88
2021-22	35	1	78	114
2022-23	27	1	70	98
2023-24	12	1	71	94

TABLE I DEATHS CAUSED BY WILD ANIMALS IN KERALA (2019-2024)

SI.	Nature of Damage	Ex-Gratia Relief
I.	Death or Severe Disability	Rs. 10.00 lakh
II.	Grievous injury	Rs. 2.00 lakh
III.	Minor injury	Up to Rs. 25,000/- per person
IV.	Loss of property/crops	State/UT government norms apply

TABLE II EX-GRATIA RELIEF FOR DAMAGE CAUSED BY WILD ANIMALS

Kerala has been grappling with escalating wildlife-human conflicts, as evidenced by the increasing number of fatalities and damages caused by wild animals. As shown in Table I, the state recorded a total of 92 deaths in 2019-20, which rose to 114 in 2021-22 before slightly declining to 94 in 2023-24 [13]. Elephants have been the most significant contributors to these fatalities, causing 35 deaths in 2021-22 alone, followed by other wild animals such as tigers and leopards. In addition to loss of life, these conflicts have resulted in substantial eco- nomic damage, including injuries and destruction of property and crops. Table II outlines the ex-gratia relief provided by the Kerala government to affected individuals, offering Rs.10.00 lakh for deaths or permanent incapacitation, Rs. 2.00 lakh for grievous injuries, and coverage for minor injuries and property losses [13]. These measures, while providing some relief, highlight the urgent need for innovative solutions to mitigate such conflicts and protect both human lives and wildlife.

To mitigate these challenges and enhance proactive measures, this paper presents a novel approach for animal species detection using a combination of visual and auditory data from CCTV footage. The proposed system processes video streams in two parallel pipelines: one for image-based detec- tion and the other for audio-based detection. In the image processing pipeline, motion detection is achieved through background subtraction, followed by species classification using the ResNet50 deep learning model. Simultaneously, in the audio processing pipeline, unhealthy audio formats are converted into Mel-Frequency Cepstral Coefficients (MFCCs), which are then fed into a Random Forest classifier for species identification. The results from both pipelines are combined to improve detection accuracy, ensuring robust species identi- fication even in challenging environments.

Recent advancements in hybrid deep learning models, such as the Hybrid Visual Geometry Group (VGG)–19 + Bidirec- tional Long Short-Term Memory (Bi-LSTM) network, have demonstrated significant improvements in animal detection and activity recognition tasks. These models leverage spatial and temporal information from video streams to achieve high classification accuracy and real-time alert generation [1]. Inspired by these developments, our proposed system integrates similar hybrid approaches to enhance the accuracy and reliability of species detection.

To enhance the practicality of the system, the detected species' location is determined using the GPS module inte- grated into the CCTV camera. Upon successful detection, an alert is sent to nearby registered citizens via a mobile appli- cation, enabling timely intervention and fostering community involvement in wildlife conservation efforts. This integrated approach not only improves the accuracy of species detection but also provides a scalable and cost-effective solution for real- time wildlife monitoring.

The contributions of this work are threefold:

1) A dual-modality framework combining image and audio processing for enhanced species detection.
2) The integration of GPS and mobile alerts for real-time monitoring and community engagement.
3) A comprehensive evaluation of the system's performance in real-world scenarios.

The proposed system has the potential to revolutionize wildlife monitoring by providing a reliable, automated, and scalable solution for biodiversity conservation.

In Section II, we review prior research in the field of animal detection and monitoring, examining existing methodologies, their strengths, and limitations. This discussion provides a foundation for understanding the context and motivation be- hind the proposed approach.

RELATED WORKS

The animal species detection system operates on embedded devices through an optimized YOLOv2 architecture. The sys- tem brings together components from multiple levels of fea- tures to improve accuracy with fast processing speed and less redundant layers[1]. Deformable convolutional layers (DCLs) solve problems in lighting variations and image obstructions and position changes to improve detection results. This system works in real-time operations effectively through Raspberry Pi and comparable low-power devices. The system enables the detection of distant animals and small animals from hidden positions which helps protect wildlife and makes roads safer. The detection system identifies six types of Canadian animals while the addition of DCLs results in a moderate reduction of inference timing. The planned research initiatives include developing improved species recognition capabilities as well as strengthening performance under extreme conditions and making the system more efficient.

An advanced drone navigation system observes animals with full stealth through motion camouflage while maintaining minimal visual effect. The drones use sliding-mode control to follow optimized flight paths which decreases optical flow while lowering disturbances [2]. This system functions in expansive spaces such as deserts and prairies to conduct surveillance that does not alter animal conduct. The system enables live data applications together with good ethical conduct in wildlife studies whereas static equipment proves ineffective for this type of research. The system operates with low processing requirements which makes it suitable for real- time firefighting coordination. The system faces difficulties when operating in dense forest areas together with rough and challenging terrain conditions. The simulations proved theoretical feasibility yet full operational validation must take place in real conditions. The technology contains moving camouflage and sliding-mode control together with thermal imaging capabilities and autonomous routing systems among its essential characteristics.

The Composited FishNet represents the initial platform to recognize fish species through identification of aquatic creatures from substandard underwater video streams [3]. The system integrates EPANet with noise-minimization features to run through composite backbone networks that produce accu- rate feature matches despite low resolution quality and motion blurriness and complex seabed backgrounds. The framework benefits marine resource optimization yet ecological monitor- ing through its features but it presents computational limita- tions from restricted training data availability. The accuracy performance of Cascade R-CNN grows stronger when it uses ResNet-based feature extraction with PixelShuffle upsampling and advanced loss functions like Focal Loss and IoU Loss. The deep learning network operates within PyTorch and MMDetection for detecting fish in complicated underwater environments and is currently considered leading-edge technology.

YOLOv5 serves within the advanced DCS system to detect and classify bearded seal vocalizations through the application of bioacoustic computer vision technologies. The spectrograms undergo image conversion operations that produce accurate output results and statistical measurements of duration and bandwidth together with center frequency beside bounding box representations [4]. The efficient analysis of vocalization patterns in extensive datasets becomes possible to support ma- rine mammal research. Large amounts of labeled data as well as powerful computing systems are necessary for the system which makes its use restricted to rich research environments. YOLOv5 uses CSPNet features as well as spatial pyramid pooling for bigger receptive domains together with CIoU loss which drives the system for improved bounding box precision in ecological research and Arctic habitat conservation.

The Hybrid VGG-19+Bi-LSTM framework operates as a tracking system that combines VGG-19 to extract spatial features and Bi-LSTM to handle temporal patterns in order to detect wild animal behaviors instantly. The system operates with 98% accuracy and 77.2% mAP to monitor various behaviors under versatile lighting environments and different background conditions [5]. The system checks space-time information collected through cameras to identify shifts in animal behavior and provides SMS notifications to foresters about boundary violations and abnormal conduct. The system depends on powerful GPUs together with extensive datasets but this requirement restricts its availability to some users. SDFDI applied for motion tracking in combination with t-SNE visualization increases the efficiency of wildlife conservation and security operations.

The precise species recognition system enhances classifica- tion through privileged pooling by bringing privileged annota- tions into the training process. Through attention mechanisms the system solves biodiversity modeling problems with small imbalanced datasets by directing its focus to essential object sections [6]. The limited training data becomes more effective for species discrimination after integration leading to a viable solution instead of few-shot learning. The annotation process of keypoints means significant investments are required for both time and expenses. The system trains using ResNet- 101 with PrPool and applies covariance pooling together with matrix square root normalization for feature improvement. The system built using PyTorch allows effective management of complex datasets which results in higher accuracy levels for ecological research and conservation work.

Through the Cascaded YOLOv8 approach researchers attain 97% accurate detection of wildlife while working with busy backgrounds that hide animals. Moreover the system employs adaptive histogram equalization and Fast Fuzzy C-Means (FCM) segmentation schemes to conduct effective animal- background contrast improvement [7]. The refined detection process within multiple stages of the cascaded model signifi- cantly decreases false outcomes while improving biodiversity tracking and wildlife protection and vehicle-animal collision risk assessment. Feature extraction occurs through ResNet50 and DarkNet19 while both feature extraction tools work with Local Binary Patterns (LBP) for texture analysis. The high ac- curacy level demands significant data processing work as well as expensive label assignments. Real-world wildlife detection receives enhancement through the MATLAB-based system which implements CSPDarknet53 combined with FPN-PAN and a decoupled head.

The tracking capabilities of RFID technology prove ben- eficial for all three domains of livestock management and wildlife conservation and pet surveillance [8]. The system de- livers current behavioral information along with health aspects that benefits conservation planning together with agricultural decision processes. Both passive RFID tags supply enduring and economic tracking solutions and active RFID tags provide range-extended instant data transfers. Multiple animal tracking through this technology happens without physical interference to maximize productivity in extensive monitoring systems. These RFID tags include integrated sensors which monitor body temperature to extend their practical usage capabilities. Passive tags possess short operational distance along with susceptibility to environmental elements but active tags require high expenses and increased complexity. The execution of RFID systems faces obstacles due to infrastructure necessities and security-related dangers. The RFID system tracks animals by using LF, HF and UHF frequency bands to function alongside GPS monitoring and camera surveillance for better tracking outcomes in animal management operations.

Using a minimal resource-efficient bird sound recognition model enables the detection of bird species through sound analysis at 95.21% accuracy. The model delivers effective support to embedded systems using Jetson Nano and TX2 devices because it runs smoothly under low power settings [9]. The model applies frequency dynamic convolution for spectrogram analysis enhancement that precisely finds time- frequency connections. The implementation of Feature fu- sion along with Coordinate Attention (CA) results in better accuracy performance and reduced parameters as well as computational requirements. This system shows both advan- tages but it operates slowly when running on Jetson Nano devices while requiring high-quality training information. The model running on PyTorch merges Log-Mel spectrograms with CA and enables advanced bird monitoring through accessible research capabilities for ecological studies.

The proposed study presents a one-shot learning algorithm for animal video segmentation which produces accurate out- comes using limited manual marking. The use of extensive pixel-wise annotation methods proves difficult when working with animals because of their irregular shapes and motion artifacts [10]. The approach contains three fundamental com- ponents which include an unsupervised deep sorting network for guidance frame selection followed by BubbleNet for choos- ing informative frames then Xception Fully Convolutional Network (XFCN) performs multi-scale feature extraction. The method implements a boundary enhancement procedure through Test-Time Augmentation and Conditional Random Fields during post-processing. Its performance on the DAVIS 2016 dataset reaches 89.5% mean IoU which beats both OSVOS and OSMN while encountering problems related to improper frame picking and motion blur vulnerability as well as restricted usage between different video types.

The proposed work presents a combined Classical-Quantum methodology for underwater animal identification which uti- lizes classical deep learning (CNNs) for extracting features together with quantum computing (Parameterized Quantum Circuits - PQC) for undertaking the classification task [11]. The method solves three problems commonly encountered during underwater imaging: noise contamination, low contrast visibility and inadequate dataset availability. The approach uses Classical-Quantum Transfer Learning which applies ResNet18, ResNet50, InceptionV3 CNN models as features extractors before quantum operations occur in a Dressed Quan- tum Circuit. The ResNet50-QCNN system achieved accuracy levels of 88% by reducing data size while computation time decreased by 4×. Quantum noise and significant computation needs along with extended training durations carry benefits for biodiversity monitoring through this approach in noisy environments.

A near-optimal detection approach is introduced to track small wildlife with low-power RF transmitters which send weak VHF pulses [12]. The receiver detects signals by first completing frequency acquisition followed by time synchro- nization while performing phase-coherent matched filtering and non-coherent pulse combination as well as running a multi-hypothesis test because of the system's low transmit power and high path losses. The detection method delivers better weak signal reception than traditional techniques due to which it achieves a 4 dB SNR enhancement benefit. This detection method attributes better accuracy andularesistance along with real-time SDR capability but needs expensive computations together with UAV units or high-end receiving equipment and creates challenges because of irregular pulse timing.

PROPOSED SYSTEM

The system implements an upgraded wildlife observation platform which uses combined picture along with sound analytical techniques to spot species in real time. The system accepts CCTV video input that goes through two simultaneous processing pathways which handle images and audio at the same time. The image processing pipeline starts by using background subtraction and continues with species detection through the ResNet50 model. During audio processing the system transforms audio signals into MFCCs to identify species through a Random Forest classifier. If the system detects objects through its pipelines it will process GPS data from CCTV cameras to create alerts that send to registered citizens through a mobile application. The combined method gives better detection results and secure rapid alerts to support wildlife observation efforts as well as community protec- tion initiatives. The network arrangement presented in Fig. 1 displays the unimpeded combination of image and audio processing modules into an alert creation system.

A. Dataset

This study leverages a multimodel dataset comprising both visual and auditory data to address the task of recognizing animal species. The dataset is divided into two distinct compo- nents, each tailored for specific machine learning models and tasks. Although the full dataset is extensive, selected portions are utilized to ensure efficient and targeted model training. The first component focuses on image-based classification, while the second component is designed for audio-based classifica- tion, enabling a comprehensive approach to identifying and differentiating animal species using both visual and acoustic features.

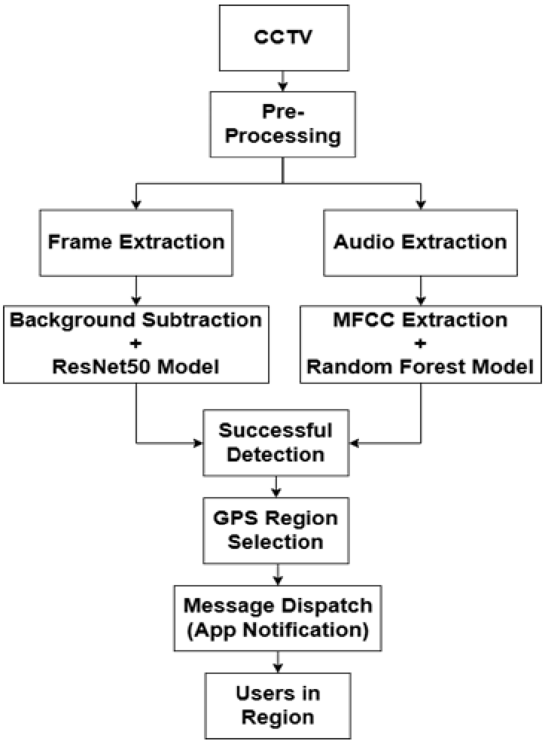

Fig. 1. Architecture diagram

1) ANIMAL-N30: The first component of the dataset is ANIMAL-N30, a comprehensive image dataset containing high-resolution visuals of 30 wild animal species. A subset of this data set is used to train the ResNet50 model to perform image classification tasks. The selected images focus on diverse wildlife, enabling the model to accurately identify and differentiate between various animal species, making it a valuable resource for visual recognition applications.
2) Animal-Soundprepros: The second component includes Animal-Soundprepros as an audio dataset which contains vocal sounds of different animals captured in .wav files. The dataset contains specific selected sounds which training under a Ran- dom Forest algorithm enables species identification through distinctive audial characteristics. A portion of audiological data within this dataset improves the classification framework by delivering multifaceted techniques for animal species iden- tification.

B. Background Subtraction

The detection of movement objects within videos depends heavily on background subtraction as a vital video analysis method that segregates between foreground and background elements. The method functions as part of the proposed system to detect animals in CCTV footage records. Background models are constructed initially before comparing them to each frame in the video sequence. Background pixels with notice- able deviations from their background model are classified as foreground elements thus suggesting an approaching animal. The system maintains robust performance through adaptive background modeling with Gaussian Mixture Models (GMM) because these techniques handle transformed lighting condi- tions and shadows together with weather variations. Through pixel mixture of Gaussian distributions GMM learns to adjust its background models toward scenes with multiple modes and steady changes throughout time.

The implementation of background subtraction in the pro- posed system follows these steps:

1) Capturing the video stream from the CCTV camera.
2) Initializing the background model using a set of initial frames.
3) Updating the background model continuously to account for environmental changes.
4) Thresholding the difference between the current frame and the background model to isolate foreground objects.

Post-processing techniques, such as noise reduction and mor- phological operations, are applied to enhance the accuracy of foreground detection.

The mathematical formulation for background subtraction involves computing the absolute difference between the current frame It(x, y) and the background model Bt(x, y):

$$Dt(x, y) = |It(x, y) - Bt(x, y)|$$

Here, Dt(x, y) represents the difference at pixel location (x, y) at time t. If this difference exceeds a predefined thresh- old T , the pixel is classified as part of the foreground:

F (x, y) = 1 if Dt(x, y) > T
0 otherwise

The resulting binary mask Ft(x, y) is used to identify regions of interest, such as animals, in the CCTV footage. This approach ensures reliable detection of moving objects while minimizing false positives caused by environmental noise.

C. ResNet50 Model

ResNet50 functions as a deep convolutional neural network (CNN) architecture which people employ extensively in image classification and object detection work because it handles challenging visual patterns effectively. ResNet50 operates within the proposed system to properly identify and classify animals within extracted CCTV frames. ResNet50 introduces residual connections as its core innovation to solve deep network gradient vanishing through direct gradient transmission across skip connections. Deep networks can be trained because this design lets the gradient flow through connections allowing for excellent performance. The design diagram of ResNet50 network appears in Figure 2.

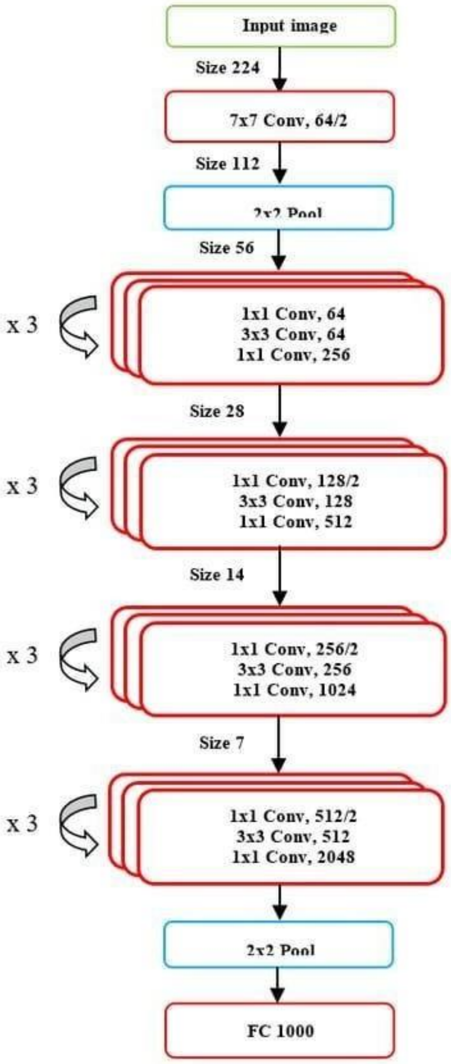

Fig. 2. Architecture of the ResNet50 Model

The ResNet50 architecture consists of 50 layers, organized into several stages, each with specific types of layers. Below is a detailed breakdown of the layers in ResNet50:

1) Initial Convolutional and Pooling Layers: The ResNet50 model begins with an initial convolutional layer that uses 64 filters of size 7×7 with a stride of 2. This layer extracts low-level features from the input image, such as edges and textures. It is followed by a max-pooling layer with a 3×3 kernel and a stride of 2, which reduces the spatial dimensions of the feature map by half. These layers prepare the input for the subsequent residual blocks.
2) Residual Blocks: The core of ResNet50 consists of four stages of residual blocks, each containing multiple layers with skip connections. Each residual block is designed to learn residual mappings, making it easier to optimize the network. The four stages are as follows:

- Stage 1: Contains 3 residual blocks with 64 filters. Each block includes two or three convolutional layers, batch normalization, and ReLU activation functions.
- Stage 2: Contains 4 residual blocks with 128 filters. The first block in this stage uses a stride of 2 to downsample the feature map, while the remaining blocks maintain the spatial dimensions.
- Stage 3: Contains 6 residual blocks with 256 filters. Similar to Stage 2, the first block downsamples the feature map, and the rest preserve the dimensions.
- Stage 4: Contains 3 residual blocks with 512 filters. This stage extracts high-level features that are crucial for classification.

Each residual block uses shortcut connections to add the input of the block directly to its output. This can be expressed mathematically as:

$$y = F(x, \{Wi\}) + x$$

where x is the input to the residual block, F (x, {Wi}) represents the transformation applied by the block (e.g., con- volutional layers), and y is the output. The addition of the input x ensures that the network can learn residual mappings, making it easier to optimize deeper architectures.

3) Final Layers: After the residual blocks, the network includes a global average pooling layer, which reduces the spatial dimensions of the feature map to 1 × 1 by taking the average of each feature map. This is followed by a fully connected layer with a softmax activation function, which out- puts the probability distribution over the classes. The softmax function is defined as:

ezc

P (y = c|x) =

C

j=1

ezj

CCTV audio data for detecting particular sounds such as animal noises or other important events makes use of MFCCs

where zc represents the output score for class c, and C is the total number of classes.

4) Loss Function: The ResNet50 model is trained using a cross-entropy loss function, which measures the difference between the predicted class probabilities and the true labels:

C

L = − yc log(pc)

c=1

where yc is the true label (1 if the class is correct, 0 otherwise), and pc is the predicted probability for class c. By fine-tuning ResNet50 on the animal detection task, the proposed system achieves high accuracy in identifying and classifying animals in CCTV footage, even in challenging environments with varying lighting and occlusion.

Algorithm 1 Animal Species Detection Using ResNet50

Input: Animal Images, ResNet50 Model

Output: Trained Model for Animal Detection

Step 1: Prepare the Data

1) Resize all images to 224×224 pixels
2) Normalize pixel values to be between 0 and 1
3) Apply data augmentation (flip, zoom, shear images)

Step 2: Load ResNet50 Model

1) Load ResNet50 model pretrained on ImageNet
2) Remove the top classification layer

Step 3: Add Custom Layers

1) Add a Global Average Pooling layer
2) Add a Dense layer with 1024 units and ReLU activation
3) Add a Dense layer with softmax activation for classification

Step 4: Freeze ResNet50 Layers

1) Freeze all layers of ResNet50 to prevent them from training

Step 5: Compile the Model

1) Use Adam optimizer with a small learning rate (0.0001)
2) Use categorical cross-entropy loss for training
3) Use accuracy as the evaluation metric

Step 6: Train the Model

1) Train the model for 10 epochs using the training data
2) Validate the model using the validation data

Step 7: Fine-Tune the Model (Optional)

1) Unfreeze some layers of ResNet50
2) Recompile the model with a smaller learning rate (0.00001)
3) Retrain the model

Step 8: Evaluate the Model

1) Test the model on validation data
2) Print the validation loss and accuracy

Step 9: Save the Model

1) Save the trained model to a file for future use

D. MFCC Feature Extraction

MFCCs function as a prominent audio feature extraction method that society frequently uses for both speech recog- nition systems and sound analysis purposes. The analysis of in their identification process. The short-term power spectrum of an audio signal transforms into MFCCs which produce a representation with highlighted perceptually important char- acteristics. Multiple steps make up the extraction process according to the following sequence of actions.

1) Preprocessing: The first step in MFCC extraction is preprocessing the audio signal. The raw audio signal is divided into short overlapping frames using a sliding window, typically 20-40 milliseconds in length, with a 10-15 millisecond overlap. This framing ensures that the signal is analyzed in small, manageable

segments, capturing its temporal characteristics. Each frame is then multiplied by a Hamming window to reduce spectral leakage:

2πn

w(n) = 0.54 – 0.46 cos

N – 1

where w(n) is the Hamming window, n is the sample index, and N is the total number of samples in the frame.

2) Fourier Transform: Next, the Discrete Fourier Trans- form (DFT) is applied to each frame to convert the time- domain signal into the frequency domain. The DFT is com- puted as:

N–1

2πkn N

n=0

where x(n) is the time-domain signal, X(k) is the frequency-domain representation, and k is the frequency bin index. The magnitude of the DFT is then squared to obtain the power spectrum.

3) Mel Filterbank Application: The power spectrum is passed through a Mel filterbank, which consists of triangular filters spaced according to the Mel scale. The Mel scale approximates the human ear's non-linear perception of sound frequency. The center frequencies of the filters are equally spaced on the Mel scale, and their output is computed as:

,,0 if k < f (m – 1)

Hm(k) =

,,

k–f (m–1) f (m)–f (m–1)

f (m+1)–k

if f (m – 1) ≤ k ≤ f (m)

if f (m) ≤ k ≤ f (m + 1)

f (m+1)–f (m)

0 if k > f (m + 1)

where Hm(k) is the m-th Mel filter, f (m) is the center frequency of the m-th filter, and k is the frequency bin index. The output of the Mel filterbank is a set of Mel-scaled spectral coefficients.

4) Logarithm and DCT: The Mel-scaled coefficients are compressed using a logarithmic function to emphasize lower- energy components, which are more perceptually significant:

at the node, and C is the total number of classes. The split that minimizes the Gini impurity is chosen, ensuring that the tree effectively separates the data into distinct classes.

where c(n) is the n-th MFCC, and M is the number of Mel filters.

5) Feature Vector: The conversion produces audio features known as MFCCs that effectively summarize signal spectra. The analysis keeps 12-13 coefficients and their derivative terms (delta and delta-delta coefficients) to record sound patterns through time. Audio features extracted from processes are fed into machine learning models that produce sound classifications or detect events in CCTV audio clips.

The proposed system extracts MFCC features from audio in CCTV footage which allows effective sound detection and identification of animal noises to enhance security capabilities.

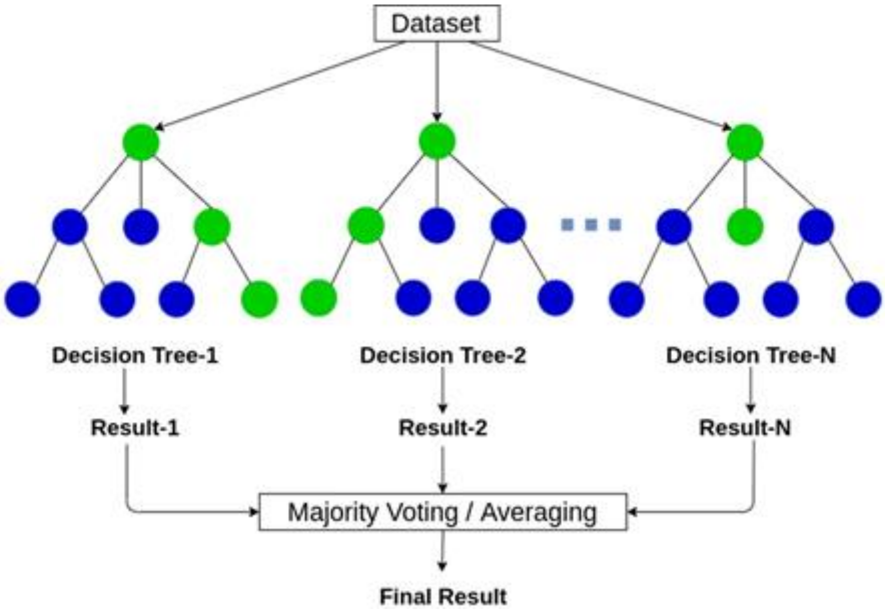

Fig. 3. Architecture of the Random Forest Algorithm

E. Random Forest Algorithm for Audio Detection

When trained the Random Forest algorithm builds numerous decision trees that eventually merge their predictions to reach better accuracy and more robustness levels. The algorithm proves specially efficient when used for the classification of sounds within audio information. Within this system the Random Forest model employs MFCC features which were extracted as explained before to carry out audio signal clas- sification. Fig. 3 illustrates the architecture of the Random Forest algorithm.

1) Training the Random Forest Model: The Random Forest algorithm trains multiple decision trees by randomly selecting subsets of data as well as features for each tree. Training of the algorithm chooses optimal splits at decision tree nodes based on a selection criterion such as Gini impurity. The Gini impurity for a node is calculated as:

S(m) = log

N −1
k=0

|X(k)|2Hm(k)!
where S(m) is the log Mel spectrum. Finally, the Discrete C
Cosine Transform (DCT) is applied to the log Mel spectrum 2
to decorrelate the coefficients and produce the MFCCs:
c=1
where pc is the proportion of samples belonging to class c
c(n) =
M −1

m=0
S(m) cos
πn(m + 0.5)

2) Prediction Using the Ensemble: Once the decision trees are trained, the Random Forest model makes predictions by aggregating the results of all trees. For a given audio frame with feature vector x, each tree Tk in the forest predicts a class label. The final prediction yˆ is determined by majority voting:

yˆ = mode {Tk(x)}K

where K is the total number of trees in the forest. This en- semble approach reduces overfitting and improves the model's generalization ability.

3) Model Evaluation: The Random Forest model evalua- tion relies on metrics that include accuracy alongside preci- sion, recall and F1 score. The testing dataset provides separate grounds to calculate metrics which quantify how accurately the model classifies audio signals. The accuracy, for example, is calculated as:

Accuracy = Number of Correct Predictions

Total Number of Predictions

4) Deployment for Audio Detection: The evaluated Random Forest model becomes deployable to process and classify fresh audio signals. The model receives audio frame MFCC features as its input followed by classification of frame labels through its decision tree ensemble. The method proves highly suitable for identifying particular sounds including animal noises which exist within audio signals.

Algorithm 2 Animal Species Detection Using Random Forest

Input: Audio Dataset, Random Forest Classifier

Output: Trained Model for Animal Species Detection

Step 1: Prepare the Dataset

1) Load all audio files from the dataset directory
2) Convert audio files to MFCC features
3) Store extracted MFCC features and corresponding labels

Step 2: Encode Labels

1) Convert species names into numerical labels using LabelEncoder

Step 3: Split Dataset

1) Split the dataset into training and testing sets (80% train, 20% test)

Step 4: Train Random Forest Classifier

1) Initialize a Random Forest model with 100 estimators
2) Train the classifier using the extracted MFCC features

Step 5: Evaluate the Model

1) Predict species on the test dataset
2) Compute accuracy using the ground truth labels

Step 6: Save the Model

1) Save the trained Random Forest model to a file
2) Save the LabelEncoder for future use

CONCLUSION

The proposed system uses wildlife species detection through combined image and audio processing for species identifica- tion with real-time accuracy. ResNet50 operates with images to classify while Random Forest uses MFCC features with audio thereby maintaining detection accuracy in demanding settings. A joint validation process of modalities results re- duces spurious results while making the system more reliable. GPS localization within the system allows for exact monitoring of troubled regions which activates application-based alerts to users who need notification. The combination of different input modes enhances wildlife observation and cuts wildlife- human conflict and presents itself as an easily scalable and effective method for actual implementation. Enhancements for the detection system should focus on two things: enhancing detection accuracy through multiple deep learning models as well as expanding species identification features. Through implementation of this system the authorities together with local communities can actively handle wildlife interactions to safeguard people while defending wildlife populations.

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ClinAssign: Automated Nursing Student Allocation and Performance System

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ABSTRACT

The system actually provides an actual support to nursing students to do their clinical practice in hospitals where there is no affiliated hospital with the college. It therefore leads to bulk scheduling, and this means student allocations are uneven in terms of hospital departments and there is inefficiency in managing clinical schedules. These all have a negative effect on the quality of clinical education, limiting exposure of students to diverse specialties and hands-on practice. Manual scheduling is then also prone to error and administrative time. This system presents the problems of conventional clinical schedule processes and outlines the potential benefits of an automated system in optimizing student allocation, shift scheduling, and attendance monitoring. With utilization of performance forecasting with machine learning and automated schedule software, the hospitals and nursing colleges are given the ability to obtain a better-balanced, efficient, and equitable approach to clinical training. Essentially, such an approach better facilitates learning, and the learners are well set for their medical career.

Index Terms—Nursing Student Clinical Allocation, Clini- cal Education, Hospital, Affiliations, Clinical Scheduling, Shift Scheduling Optimization, Attendance Monitoring, Machine Learning for Performance Prediction, Student Exposure to Spe- cialties, Clinical Training Efficiency, Equitable Clinical Training.

INTRODUCTION

Clinical practice [1] is the area of central emphasis in nursing education, and clinical practice is where students can have hands-on exposure and treat patients optimally in actual set- tings. Putting students into hospitals for clinical rotations is probably the biggest issue in nursing colleges. However most colleges, particularly those with no formal hospital affiliation, struggle to organize clinical placements effectively. Lacking formal arrangements, colleges are normally compelled to deal with block programming and blocks of students admitted to hospital regardless of the degree of use of resources between shifts or departments. This normally leads to uneven allo- cations whereby some departments are fully occupied while others are left empty, compromising the diversity and quality of clinical experience of the students. Such a mismanagement does not only detract from the students' chances of getting real-life experience in the fields of care but also retards their overall competency development.

Since it supports a clever scheduling algorithm, the system can consider hospital department time, clinical specialty needs, and year-to-year batch needs of students. It can even automate shift assignment with automatic consideration of hospital capacity, student availability, and department workload, thereby exer- cising the exercise of scheduling effectively and justly. This also provides flexibility to how students might alter revised timetables or work night shifts, without training being cut or interrupted. The greatest benefit of having ideal clinical practice placements is that the staff gets to witness the students in practice environments.

Having performance predictability in an automated system is capable of helping monitor the performance of the students according to their clinical case studies and other courses. Utilizing machine learning algorithms in case studies, the system can provide immediate feedback to the students and teachers on their clinical competencies. The model prediction suggests potential areas of difficulty for the students as well as giving evidence-based feedback on the quality of clinical education overall. With these technologies, nursing admin- istrators and educators can know in a flash whether or not a student is ready for follow-up clinical rotations and can step in and address skill deficits, so the students are properly ready to embark on their follow-up [2] healthcare careers. Technology and automation of clinical placement scheduling also facilitate better communication between hospital staff, faculty, and students.

With the integrated message systems, the students are able to send messages to the tutors about clinical activities, query face-to-face regarding procedures, or ask for clarification on hospital procedures. Other than this, there is already prepared content available to utilize for hospital routine and daily routine clinical practice in a way that would enable it to be provided to the students in real time through the platform so that they have immediate responses to all but an infinitesimal minority of day-to-day queries, resulting in fewer misunder- standings and an enhanced effective learning environment. With efficient communication and center of administration for clinical assignment and scheduling, the system is providing the basis for an environment for effective team learning among students and staff. Through the removal of inefficiency inherent in typical clinical assignment and scheduling, the clin- ical education experience of nursing students can be readily enhanced to substantial levels.

The ease of auto assignment of students, ease in shift planning, and easy monitoring of students' performance, such a system can revolutionize the face of nursing education by giving every student diverse practical training he or she needs. In the long term, this would lead to better nursing professionals who would assist the health care system in quality patient care and improved outcomes in the long term.

In the subsequent section, we present the literature works related to our research work, stating their methods used. Then the latter part is detailing our proposed system. The efficacy of our proposed system is subsequently discussed and verifying its efficacy. Finally, we conclude with summary of findings and potential directions of future research.

RELATED WORKS

Academic and clinical achievement [1] Predictive Framework also identifies predictors for academic achievement in nursing students such as pedagogy quality and demographics. The framework forecasts achievement and provides exact inter- vention, largely to foreign or low-achievement high school pupils. They enhance interactive curriculum, immersion ori- entation, and evidence-based coaching for alteration, which at the end ultimately leads to student academic and clinical achievement.Research has a paradigm of [2] to offer students' performance in tests based on such criteria as problem-solving ability, working in teams, and reasoning capacity. Bayesian networks, machine learning, and fuzzy logic are applied in test creation to ensure that the tests are objective and reliable. The model employs adaptive learning models to provide customized solutions to the students to try and come up with an equitable and fair education system that enhances overall learning outcomes.

The research utilized Propensity [3] Score Matching Analysis and utilized such tools as PCQN-C and FATCOD-B-C in measuring the attitude of the nurses towards palliative care. It determined that broader training in psychosocial and spiritual care was required. The recommendations are for further train- ing of the nurses so that they could handle multi-dimension aspects of end-of-life care and enable ongoing learning about palliative care.Career and educational perception by [4] nurs- ing students in hospitals was what was studied in the research. The CLES+T model was used to test mentoring, educational climate, and leadership effects in this context. Additional clin- ical placements and teaching are required in the development of leadership and transition from placement to classroom for smooth continuity of supply regardless of nurses.

Competency-Based Medical Education Framework [5] as- sesses students from novice through master levels on the basis of formative feedback, observation, and multi-source assessment. Students are assured that they acquire essential skills prior to advancing. Ongoing professional development equips health professionals to tackle actual life and supports this by employing timely feedback in the optimum interest of students and patients.Tree-Based Machine Learning Models [6] like Random Forest and Gradient Boosting were used in the research to model National Health Services UK data. It took into account drivers of employee engagement for health organizations that are ”Safety Culture.” The model helps health leaders to achieve maximum engagement and avoid burnout, and thus ultimately towards better patient care and organizational effectiveness.

The Rural Public Health Workforce [7] Internship Program for a year helps to fill rural healthcare workforce shortages. Public health and healthcare management students gain experience in hospitals, increasing employment opportunities and moving disease prevention and public health messaging forward. It also decreases new graduate transition time to full-time em- ployment.The Secondary Use of [8] Electronic Health Record (EHR) Data Framework provides guidelines for ethical and le- gal considerations when using EHR data for other than patient treatment. It speaks to structured and unstructured data for research, private and public health surveillance, and resource planning. The framework preserves privacy and encourages cooperation between health professionals, IT specialists, and legal experts in safe usage.

The formative feedback mechanism [9] applies ”IF-THIS- THEN-THAT” reasoning to offer real-time personalized feed- back to students learning online at their own pace. It facilitates self-regulated learning through enabling students to control their effort level. The model also resolves privacy issues, and students can control time and enhance completion rates of the course. Personalized feedback is also offered by teachers.The Predictive Model of [10] Academic and Clinical Success identifies predictors of success for nursing students, i.e., de- mographics and prior education. It suggests special support for at-risk students, i.e., international students and students with less successful academic histories. The model supports intensive orientation programs and an active curriculum to enhance overall student success and nursing education.

Practice-Based [11] Clinical Education Model builds nursing student competencies for patient safety through experiential, hands-on clinical education. Theory and practice are com- bined with actual clinical scenarios with focus being on key competencies which are fundamental like medication safety and infection control. Feedback and structured observation continue to be persistent and are incorporated so that the patient safety competencies are attained through best clinical education.The usage trend [12] and feedback model directs software updates bottom-up according to the users' recom- mendations. It is founded on the measurement of feature usage, error occurrences, and user feedback for prioritizing updates. It follows the Eisenhower Decision Matrix in making updates easy but prioritized. Likewise, it is an optimization task that maximizes user satisfaction to 38.3% by simplifying the software development process.

PROPOSED SYSTEM

The proposed system will automate and optimize the as- signment of nursing students to the hospitals and specialty clinical departments in a bid to manage complexity in relation to the clinical allocations. By offering a platform that has an interface for the colleges as well as the hospitals, ease in the integration of both student allocation is offered. It effectively places students into the hospitals and departments according to what they are interested in learning and on facilities available so that all of them receive meaningful clinical experiences. Regular posting of students in this way ensures students into the positions best suited to their ed- ucational and pragmatic requirements and hence enhancing the administration effectiveness and the level of instruction in nursing courses. This also becomes less bothersome to schools and hospitals so that they get to have more time to offer quality training and clinical exposure and fewer hours taken up by administration coordination. This way, the system will be capable of providing an efficient and streamlined clinical education process to the nursing students.

Apart from that, the system has a number of functions aimed at providing uninterrupted communication and coordination between all the stakeholders involved, including principals, nursing heads, tutors, hospitals, and students. Every function is given its roles that help towards the overall success of the system. For example, the clinical assessment requests can be approved by principals and coordination in the batch tutors' and the hospital can be done in a manner that is beneficial to all the processes converge to institutional goals. Nursing supervisors who handle the running of individual hospital departments can see the list of students, manage attendance, and report clinical performance of the students on a daily basis. These activities are backed by a web-based secure system that offers concerned stakeholders real-time dashboards in order to keep track and take care of clinical placements, reviews, and comments. Such harmonious communication has all concerned parties on the same page, creating less room for confusion and perfect, timely closure of clinical scheduling.

This system is useful not just for the organization of alloca- tions, but also has long-term benefits to students, hospitals, and nursing institutions. Students gain highly organized and practical training experiences that prepare them with practical capabilities that will be necessary for their future career path. Departments have the right amount of students to work with as hospitals can schedule students efficiently such that departments are not overworked and under-worked. For tutors, there is a central hub to monitor the progress of students, give timely feedback and overcoming academic challenges. Nursing heads keep things orderly by overseeing students, keeping attendance, and making sure they get the required clinical experience. Only authorized hospital organization al- locations must be approved by the principal, thus aligning with institutional training policy and academic objectives. The system reduces the administrative burden on stakeholders by automating scheduling, tracking, and communication, making it easier to focus on providing quality education and training. This well-tuned system allows for meaningful clinical exposure for students while minimizing unnecessary delay and confusion. The result is a more efficient and equitable learning opportunity for all learners. More importantly, over time, the system helps to create a well-trained, job-ready pool of nurses that ultimately enhances the job, saves and improves lives, and strengthens the healthcare system.

METHODOLOGY

When we discuss about system functions, the most important one is tracking and evaluating the performance of the student during his/her clinical practice. Through retrieving accurate case study reports and clinical information, the system offers a chance to the teaching faculty to track every student separately. These facts are then utilized through sophisticated machine learning methods in the hope of predicting and measuring student performance on case studies submitted. These forecasts are not only utilized to mark but also utilized in an attempt to give feedback with valuable information about areas to work on for the students so that they can keep on improv- ing. These tests are then integrated into the student profile, providing the students and potential employers differentiated and factual information of the clinical practice and capability of the student. This ability not only supports continuous learning but also nursing students for professional practice by providing concrete, evidence-based record of clinical practice improvement and progress. The ability to provide instant feedback allows the students to attain mastery in activities and proficiency as well as achieve clinical competence prior to practice.

Apart from this, to improve student performance evalua- tion and placements in clinical practice, a predictive nursing student's success model used machine learning algorithms, processing data from case studies. This model included three models and assessed how accurately they predict student outcomes. Using the Random Forest algorithm, trends were found while analyzing both clinical and academic data that may support student success prediction and optimal scheduling decisions. The Support Vector Classifier (SVC) classified students according to their skill levels, predicting possible scores and highlighting those that need extended training. The prediction of students to various clinical settings in the most appropriate site was done using Decision Tree algorithm based on previous records considering organization requirement as well as student capability. After this takes the most accurate model.

Fig 1 defines system architecture, monitors nursing students' clinical practice with focus on interaction among hospital, principal, nursing head, tutor, and student. Hospital monitors nursing head and allocates departments for clinical training. Principal monitors batch tutor, hospital allocation, and signs clinical assessment. Nursing head dashboard marks atten- dance, duty assignment, view case study, and feedback. Tutors view duty schedules, student performance, attendance, and case studies. Monitor progress, post case study, and attendance are done by students. ML model predicts teh performance and gives grades. Student-tutor interaction and student pre- defined message are shown in the student dashboard.With the clinical training section, hospital education is supplemented and coordination among stakeholders enhances processes for nursing practice and research evaluation.

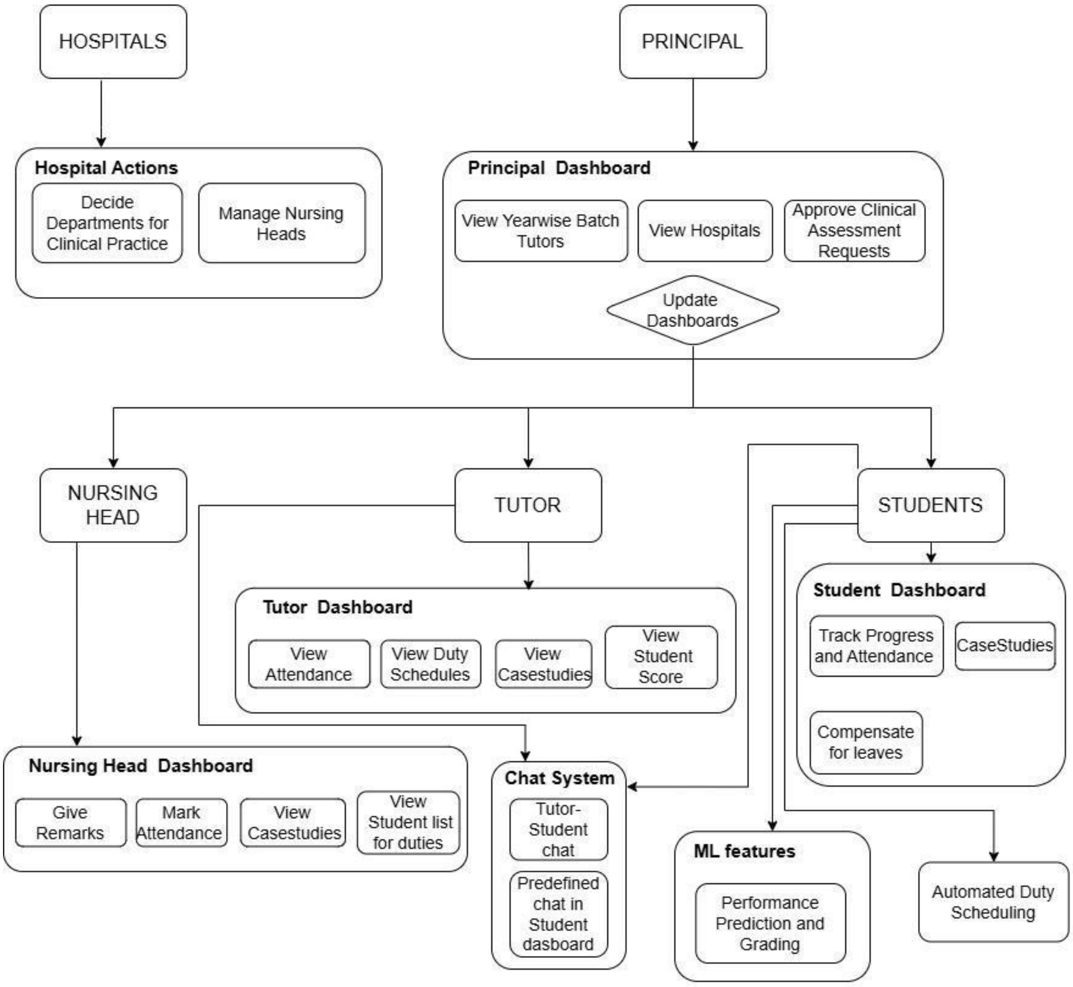

Fig. 1. Architecture diagram of the proposed system

The automatic scheduling module is the another most im- portant part of the system. The system module schedules different hospital shifts (morning, evening, or night) to the students based on the study year, the availability of hospitals, and departmental demands. The system considers the needs of hospital staff and the students' level in attempting to provide students with experience in shifts most suitable for their learning objectives. By factoring in department capacity, availability of students, and scheduling needs, placement conflicts are reduced to a minimum. The system also optimizes compensatory leave by providing the students an opportunity to compensate the lost shifts by creating make-up work in holiday or off-day time. All of these modifications are automatically reflected in the profile of the students, which maintains the proper record of duty and attendance. Automated scheduling keeps human intervention to an absolute minimum so that each shift is well staffed and students are not sacrificing precious clinical practice time to unanticipated absence.This systematic structure increases the quality of nursing education by providing uniform clinical experience in a real world setting for students.

The nursing students performance predictive ML model has two simple steps. In the first step, clinical performance data are gathered through d4data/biomedical-ner-all NLP and track various variables like drug handling, procedural skill, pain assessment, and diagnosis identifications. Other features like documentation fidelity, communication, patient stabilization, and symptom deterioration are also tracked. It also includes demographic and clinical history of patients being extracted through regex-pattern recognition. Qualitative data are transformed into quantified numerical values of the same form so that there is uniformity. Irrelevant columns that have nothing to do with the data or analysis are removed and class imbalance is corrected by using balanced resampling in the second step while doing data pre-processing using a strict approach. Recursive feature elimination with mutual information scoring and random forest estimator is used to choose features. The data set is divided into a train set and a test set, quantile transformed to make it standard, and its dimension reduced by applying Princi- pal Component Analysis (PCA). Random Forest classifier is tuned, validated, and trained, and a good classification report is finally produced.

Algorithm 1 ML-Based Nursing Students Performance Prediction Algorithm

1: **Phase 1: Feature Extraction Phase**
2: Initialize d4data/biomedical-ner-all as NLP engine is to retrieve performance statistics attached to clinical nursing cases
3: Execute core feature extraction algorithms to assess clinical competencies: medication management, procedural performance, pain evaluation, diagnosis identification
4: Instantiate auxiliary feature extraction functionalities for assessment of documentation accuracy, collaboration among health care team, patient stabilization monitoring, and symptom progress, and case sentiment analysis
5: Extract patient demographic parameters and clinical his- tory via regex-based pattern recognition and medical ter- minology identification
6: Transform qualitative assessments into standardized nu- merical scores and normalize feature values
7: Align extracted features with established performance dataset schema through systematic data normalization and standardization
8: Store processed features in table format for subsequent machine learning analysis
9: **Phase 2: Pre-processing and ML Training Phase**
10: Clean data by removing extraneous columns and separat- ing performance labels from the data columns
11: Address class imbalance through balanced resampling and improve feature representation using polynomial feature creation
12: Perform feature selection using recursive feature elimina- tion with random forest estimator and mutual information scoring
13: Split data into training and testing sets with a 70-30 split, apply QuantileTransformer normalization, and perform PCA dimensionality reduction retaining 98% variance
14: Train Random Forest classifier with optimized hyperpa- rameters and evaluate model using performance metrics
15: Generate final classification report with detailed analysis of model's predictive capability and performance evalua- tion

PERFORMANCE ANALYSIS

To evaluate the performance of the machine learning models used in the system, first up all we validate the performance of machine learning models used in ClinAssign for assessment process grading and classification process through accuracy, precision, recall and F1 score. In the build data set previously, the task was solved for grade assignment and for classification.

A. Grading Evaluation

The performance assessment of Random Forest, SVC, and Decision Tree models is made with respect to the grading sep- arability of the models. The performance results are captured in Table I.

TABLE I PERFORMANCE METRICS FOR GRADING EVALUATION

Model	Accuracy	Precision	Recall	F1-Score
Random Forest	0.7083	0.7102	0.7083	0.7084
SVC	0.6800	0.6799	0.6800	0.6793
Decision Tree	0.6200	0.6245	0.6200	0.6179

Out of all the models possible Random Forest model has shown least probable results with an accuracy of 0.7083, precision, and recall both at 0.7102 and 0.7083 respectively, and an F1-score of 0.7084, this is followed by SVC with an accuracy score of 0.6800, and finally Decision Tree predicted an accuracy of 0.6200. Probably, the reason why Random Forest is the highest performance is because it can learn complicated patterns from data and prevent overfitting by inducing it from several different models, thus generalizing well across different data points.

B. Classification Process

For classification process, we have utilized Random forest and seen the performance of the classification over datasets labeled as excellent, good and needs improvement. The results can be seen in Table II.

TABLE II PERFORMANCE METRICS FOR CLASSIFICATION PROCESS

Classification	Precision	Recall	F1-Score	Support
Excellent	0.70	0.69	0.70	200
Good	0.68	0.74	0.71	200
Needs Improvement	0.75	0.69	0.72	200

A Random Forest model acquired an overall accuracy of 71% which indicates a high performance in all categories. Its precision, recall, and F1-scores are fairly matched with all F1-scores scoring beyond the 0.70 threshold which signifies reliability and consistency in predictive performance across the classes.

- Grading Evaluation:They grade as per the efficiency which these models can estimate an instance into three- graded classes with strong performance metrics. There- fore, Random Forest outplayed SVM and Decision Tree with greater accuracy and F1 values.
- Classification Rationale: Final Classification was per- formed using Random Forest since it had better accuracy than Recall, Precision, and F1 scores, thus qualifies to be truthful for grading classification.
- Overall Performance: Taking into account the several models which were put to test, Random Forest stood at the front, achieving 70.83% accuracy, while SVM and Decision Tree followed with 68.00% and 62.00% respectively. Well-orchestrated model selection is one learning avenue from the presented results on

classifi- cation accuracy. The evaluation makes a statement about the importance of a well-thought-out model selection in ensuring successful project results in terms of accuracy and reliability.

RESULT AND DISCUSSION

The Random Forest is a superior performer in grading and classification compared with Decision Trees and SVC Random Forest Model accuracy 70.83% while SVC and Decision Tree only managed 68.00% and 62.00% respectively. Evidence is provided within the data for the Random Forest classifier gaining better fitting accuracy surrounded by other classifiers. Random Forest also attained better grades of precision, re- call, and F1 score; criteria that have special importance in measuring the quality and reliability in model classification tasks. An F1 score distinguished from the rest means that Random Forest excellently manages trade-off involving false positives and false negatives and finds application in all do- main functions demanding high correctness and dependability. Such applications are based on a similar premise whereby accuracy and consistency must be put above anything in order for success in decision-making. In addition to that, its ability to prevent over-fitting due to the complexity of trees keeps the assembly of many decision trees able to generalize readily to unseen examples that come from different backgrounds in real-life applications. Findings point to this in a sense of fur- ther contribution, selection, and appointive clarity concerning machine learning models. Adjustments to the Random Forest shall carry a gracefully huge lift into some applications that are in the fray of trust and accuracy consideration. Nevertheless, such a context assumes a much greater significance, especially bearing a lot on the active but sensitive management of health systems.

CONCLUSION

The system provides an open and efficient system of clinical training. By controlling the assignment of students to hos- pital and specialty based on learning objectives, the system makes it possible to allocate the students to the best learning environments to tackle their educational and clinical objec- tives. Arming the students with real-time communication tools eliminates the bottleneck between the tutors and the students by offering real-time feedback along with ongoing mentoring. Process flow here is one of opening up further learning, ongoing development of skills in the context of learning in the profession with a view to practice in the clinic, and the stu- dents are adequately prepared to provide profession-oriented requirements in practice nursing. Machine learning models are also integrated to objectively tag case study submissions and provide each student performance grades and feedback. It also encompasses duty rostering for the assignment of appropriate shifts to the students and the compensatory leave with clear and specific attendance. Its scalable architecture design also renders the system efficient in processing an enormous number of healthcare centers and colleges, hence being flexible enough to deploy in such massive varied scenarios. Finally, the sys- tem optimizes administration and continuous nursing student professionalization and development to position itself best in the health care environment. The education, furthermore, is optimized with the collaborative implementation model, and the process of clinical allocations generally is optimized as an added by-product, impacting healthcare institutions and students respectively proportionally.Long-term system devel- opment encompasses the extension of real-time feedback, making it more appropriate for individualized learning, exten- sion to other healthcare institutions, and extension of student- professional development, clinical placements, and integration with a range of health science courses.

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Crash Sense: Motor Vehicle Collision Detection and Severity Prediction

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ABSTRACT

Road accidents are a major public safety concern, often leading to severe injuries or fatalities. In many cases, immediate medical attention within the golden hour is critical for saving lives. However, accidents in remote areas or situations where the driver is unconscious may result in delayed emergency response. To address this issue, this paper presents CrashSense, a deep learning-powered accident detection and severity prediction system. CrashSense integrates real-time video-based accident detection, automatic number plate recognition (ANPR), and severity classification using machine learning. The system consists of a Flutter-based web application, a YOLOv8-based accident detection model, an OCR-based ANPR module, and YOLOv8 for severity prediction. When an accident is detected, the system extracts vehicle registration details and classifies accident severity based on multiple factors, such as vehicle speed, road type, and environmental conditions. The experimental results demonstrate that the accident detection model achieves an accuracy of 92%, while the severity classification model reaches 91% accuracy. These findings suggest that CrashSense can serve as an efficient tool for enhancing road safety and emergency response efficiency.

Index Terms—Accident Detection, Severity Prediction, Com- puter Vision, Machine Learning, YOLOv8, CNN, Road Safety, Real-time Alert System.

INTRODUCTION

Road traffic accidents are a universal problem, resulting in injuries, deaths, and financial losses. With growing urbaniza- tion and car usage, advanced accident detection and emergency response systems are essential. Conventional surveillance em- phasizes traffic observation but does not provide real-time accident detection and severity evaluation. This paper presents a CCTV Collision Alert System based on real-time video surveillance, machine learning, and deep learning that identi- fies accidents, rates severity, and sends immediate alerts. With YOLO-based object detection and deep learning algorithms, the system automatically detects collisions, determines impact force, and provides license plate recognition and pedestrian detection support to aid law enforcement and insurance or- ganizations in intelligent traffic management. While it has advantages, challenges are variations in CCTV quality, compu- tational intensity, and environmental interference on accuracy. Real-time processing requires efficient hardware and exten- sive annotated datasets for deep learning training. Interoper- ability with existing traffic systems means coordination with stakeholders. Improving accuracy and scalability will come from future breakthroughs in AI, video analytics, and self- supervised learning. GPS and vehicle telemetry will further enhance detection. Mass adoption of AI can revolutionize road safety, minimize response times, and maximize traffic management. The paper is organized as follows: Section 2 discusses related works, Section 3 explains the system archi- tecture, Section 4 compares CNN, and YOLOv8 models, and Section 5 concludes with results and future work.

RELATED WORKS

Numerous studies have been conducted to find innovative techniques for detecting car accidents and determining ac- cident severity. Such methods use machine learning, deep learning, and computer vision in order to make road safety systems better.

The Deep Hybrid Attention Network (DHAN) [1] improves emergency response to road crashes by combining spatial and temporal attention mechanisms. It was trained on a French crash dataset (2011–2017) and attained an AUC of 0.820 and 76.1% accuracy, which is effective for real-time detection. Its single-dataset limitation restricts generalizability, and the lack of weather and road condition information lowers predictive accuracy. Future enhancements should include diverse datasets and multi-modal sources to improve adaptability.

A multi-level distillation approach [2] enhances fine-grained accident detection in videos by using a teacher-student net- work for efficient knowledge transfer. It tackles sparse and irregular video data through accident classification, spatial- temporal detection, and severity estimation. Experiments on the FAD dataset (1,603 videos) showed improved accuracy and efficiency. However, the method is resource-intensive and depends on the teacher model's quality, highlighting the need for optimization for wider deployment.

A deep learning ensemble method [3] improves real-time traffic accident detection in smart cities by combining RGB and optical flow information. Employing a dual-branch struc- ture with I3D and ConvLSTM, it preserves spatial and motion dynamics for accuracy improvement. Built for edge IoT de- ployment, it is cost-effective and scalable. Evaluated on Traffic Camera and Dash Camera datasets, the model demonstrated excellent performance but is dependent on high-quality video data, restricting its use in low-resolution or resource-limited environments.

A machine learning framework [4] automates accident detection, segmentation, and duration prediction to improve traffic management. It uses PeMS and CTADS data to analyze traffic patterns with Chebyshev and Wasserstein metrics, and Random Forest and CatBoost predict accident duration. Seg- mentation enhances accuracy but is hampered by scalability due to high computational requirements and data format incon- sistencies, which makes more flexible frameworks necessary. A collision risk assessment model [5] improves vehicle safety by approximating risks at low, moderate, and high intensities using Extended Kalman Filtering (EKF) and proba- bilistic motion estimation. It enhances autonomous and driver- assisted decision risk prediction but is hindered in real-time application by high computational requirements and depen- dence on quality sensor information. An AI-based optimiza- tion approach can mitigate computational costs and enhance efficiency. Also, fusing information from multiple sensors and external sources can improve accuracy in various driving conditions.

A survey of accident detection [6] techniques based on dash- cam videos classifies methods into supervised, self-supervised, and unsupervised methods. Techniques such as GANs and Mask-RCNN identify anomalies based on reconstruction er- rors, improving real-time accident detection for autonomous vehicles. Although increasing dashcam data enhances model training, high computational requirements, dataset imbalance, and video quality sensitivity restrict scalability in dynamic settings.

An appearance-motion network [7] improves crash detection in dense traffic by integrating spatial and motion-based fea- tures. It utilizes a two-stream architecture where an auxiliary network with triplet loss differentiates crashes from visually similar non-crash events, while an optical flow learner captures fine-grained motion details. A temporal attention module enhances detection accuracy by focusing on critical frames, re- ducing false alarms by 28.07% and missed crashes by 27.08%. Despite its effectiveness, the model depends on fixed camera angles and performs best in urban environments, limiting its adaptability to rural areas and high-speed roadways.

A multimodal self-supervised crash detection system [8] for accurate crash and severity detection employs deep learning using IMU and GPS sensor modalities. It combines convolu- tional layers for feature extraction with bidirectional GRUs for temporal analysis and delivers good precision (0.9 for crash detection, 0.76 for severity classification). Its performance is compromised under harsh conditions such as rough ground or extreme high-speed maneuvers.

A data-driven method [9] predicts crash risk during lane- changing maneuvers based on real-world traffic data. It uses Gaussian mixture modeling to detect traffic regimes and a crash severity indicator (CRIM) to measure collision impact. Based on the highD dataset and drone video, the research shows that lane-changing behavior, particularly in heavy traffic conditions, has a substantial effect on crash risk. Although the approach improves risk prediction precision, its computa- tionally intensive nature and limited application to urban road networks emphasize the necessity for further development to suit varied traffic conditions.

An automated system [10] predicts the severity of road traffic accidents based on transformer-based models such as EfficientNet and MobileNet, incorporating Shapley values for explainability. MobileNet was the most accurate (98.17%), but explaining deep learning processes remains a challenge for stakeholders. The research calls for striking a balance between accuracy and explainability for successful road safety deployment.

These researches evolve crash detection and severity es- timation to form CRASHSENSE, combining AI and real- time video processing to enhance accuracy and responsiveness. While detection is enhanced with deep learning models, these encounter limitations of datasets, increased computation, and scalability. Segmentation is facilitated by machine learning but suffers when faced with huge datasets, while collision risk models ensure higher accuracy at the expense of real-time implementation. Detection by vision does not offer flexibility, and transformer models require interpretability improvement. Optimizing resources, maximizing flexibility, and fusing mul- timodal data are essential to scalable road safety solutions.

As discussed in the literature survey (see Table 1), various approaches have been proposed for accident detection and severity prediction.

TABLE I TECHNIQUES, MERITS, AND DEMERITS OF VARIOUS ACCIDENT DETECTION SYSTEMS

Title	Techniques	Merits	Demerits
”Deep Hybrid Attention Frame- work for Road Crash Emergency Response Management (2024)”, Mohammad Tamim Kashif [1]	Deep Hybrid Attention Network (DHAN), LSTM (Long Short-Term Memory), Attention Mechanism	Timely EMS Dispatch, Hybrid Deep Learning Model, Practical Data Requirements	Focus on Location and Time, Com- putational Complexity
”Smart City Transportation: Deep Learning Ensemble Approach for Traffic Accident Detection (2024)”, V. A. Adewopo, N. Elsayed [2]	I3D (Inflated 3D Convolutional Neural Network), CONVLSTM2D (Convolu- tional LSTM), Trainable RGB + Opti- cal Flow Model	Comprehensive Approach, Real- Time Detection, High Sensitivity to Motion, Environmental Variability	Latency, Computational Load
”Multiple-Level Distillation for Video Fine-Grained Accident Detection (2024)”, Hongyang Yu, Xinfeng Zhang, Yaowei Wang, Qingming Huang, Baocai Yin [3]	Knowledge Distillation, Multi-Level Distillation	Enhanced Detection Accuracy, Multi-Task Learning	Dependence on Teacher Model, Generalization to Different Scenar- ios
”An Appearance-Motion Network for Vision-Based Crash Detection: Improving the Accuracy in Con- gested Traffic (2023)”, Wei Zhou, Chen Wang [4]	Appearance Network, Motion Network	Superior Accuracy, Improved Fea- ture Extraction, Reduced False Alarms	Complexity, Dependency on Fixed Camera Angles, Real-Time Imple- mentation
”Deep Crash Detection from Ve- hicular Sensor Data with Mul- timodal Self-Supervision (2022)”, Luca Kubin, Matteo Simoncini [5]	Novel Deep Learning Model from IMU and GPS Speed	Robust Feature Extraction, Effec- tive Data Augmentation	Complexity, High Computational Resources, Dependency on Data Quality
”Crash Risk Estimation Due to Lane Changing: A Data-Driven Approach Using	Traffic Regime Identification, Crash Risk Estimation	Granular Analysis of Risk, Flexi- bility in Clustering Approaches	Complexity in Risk Evaluation, Dependency on Accurate Cluster- ing

Title	Techniques	Merits	Demerits
Naturalistic Data (2022)", Vishal Mahajan, Christos Katrakazas [6]			
"Review of Accident Detection Methods Using Dashcam Videos for Autonomous Driving Vehicles (2024)", Arash Rocky, Qingming Jonathan Wu, Wandong Zhang [7]	Convolutional Neural Networks (CNNs), Recurrent Neural Networks (RNNs), Object Tracking Algorithms	Incident Classification, Focus on Real-Time Accident Detection, Emphasis on Driver Behavior Analysis	Dependence on Human Annotation for Labeling, Limited Context in Short Video Clips, Sensitivity to Environmental Factors
"Automatic Accident Detection, Segmentation, and Duration Pre- diction Using Machine Learning (2024)", Artur Grigorev, Adriana-Simona Mih, Khaled Saleh, Fang Chen [8]	Vehicle Detection System, Automatic Number Plate Recognition (ANPR), Traffic Flow Analysis, Incident Detec- tion	Quick Alerts, High Accuracy, Less Manual Work, Easily Expandable	Needs Lots of Data, High Resource Use, Mistakes Possible, Complex Setup, Costly
"Collision Risk Assessment for Intelligent Vehicles Considering Multi-Dimensional Uncertainties (2024)", Zhenhai Gao, Mingxi Bao, Taisong Cui [9]	Multi-Dimensional Uncertainties CRA, Extended Kalman Filter, Trajectory Prediction Models	Better Predictions, Considers Driver Behavior, Error Correction, Useful for Real- World Applications	Complex to Implement, Relies on Assumptions, Need for More Test- ing, High Computational Demand

PROPOSED SYSTEM

The fig.1. shows the architecture diagram of the proposed system:

To enhance the survival rate of accident victims, particularly in head-on and single-vehicle high-speed collisions, this paper proposes an advanced deep learning-based intelligent system, CrashSense, aimed at immediate and accurate detection of such accidents. The CrashSense system is designed to function in real-time, leveraging cutting-edge AI and machine learning models to automatically recognize high-speed collisions as they occur. By utilizing deep learning algorithms and state-of- the-art object detection methods like YOLOv8, the system can accurately identify the type of collision and assess its severity almost instantaneously. This rapid detection is crucial, as it triggers an automated emergency notification system that alerts nearby hospitals, law enforcement, and rescue services within the critical golden window following an accident. The system's capabilities go beyond mere detection; it processes accident data, including visual, textual, and sensor-based inputs, to generate a comprehensive assessment of the collision. Once an accident is detected and classified, the system automatically uploads relevant accident information to a cloud-based service platform, which stores and organizes the data for further analysis. Additionally, it triggers emergency alerts to first responders, ensuring that rescue services are deployed swiftly and efficiently. This intelligent and automated framework not only aims to minimize the response time in critical situations but also integrates seamlessly with other emergency systems to provide a robust, scalable solution to road safety. The Crash- Sense system is a proactive step toward improving emergency response times, reducing fatalities, and enhancing the overall safety of road networks.

METHODOLOGY

1) **DATASET:** To build a robust system capable of real- time accident detection and severity prediction, CrashSense utilizes several carefully selected datasets:

1.1 **Accident Collision Dataset:** The CrashSense system uses a publicly available dataset containing real-world footage of road accidents, primarily sourced from dashcams and surveillance cameras. This dataset serves as the foundation for training the YOLOv8 model for accurate detection of accident scenarios. The footage includes various types of accidents, such as collisions, vehicle rollovers, and more, enabling the model to learn diverse accident patterns in real-world settings. Dataset Link: Accident Detection from CCTV Footage

1.2 **Number Plate Dataset :** A dedicated dataset con- taining images of vehicle license plates was used to train an Optical Character Recognition (OCR)-based Automatic Number Plate Recognition (ANPR) system. This dataset is crucial for identifying vehicle information post-collision, such as the vehicle's registration number, which helps in processing data and potentially identifying involved parties. Dataset Link: Vehicle Registration Plates (Truck)

1.3 **Severity Prediction Dataset :** To predict the sever- ity of accidents, CrashSense employs a dataset containing accident records with a wide range of features, including vehicle speed, impact force, road conditions, and weather. This dataset is used to train YOLOv8, which classifies accidents based on their severity—low, medium, or high. Accurate severity predictions are vital for informing emergency response services about the urgency and scale of the collision. Dataset Link: Road Traffic Accidents

2) **DATA PREPROCESSING:** Data preprocessing plays a crucial role in transforming raw data into a usable form for model analysis and training. This step ensures that the data is clean, well-organized, and ready for processing, directly influencing the accuracy of model predictions. The prepro- cessing process in this study incorporates various techniques, including data cleaning, augmentation, feature selection, and addressing data imbalance, all of which contribute to enhanc- ing model performance and ensuring the data's suitability for deep learning tasks.

2.1. **Image Preprocessing:** Preprocessing is an important step in getting accident and vehicle number plate images ready for training deep learning models. For consistency and compatibility, all images are resized to a standard dimension so that the model can process them effectively. It is impor- tant to standardize image sizes to ensure input uniformity throughout the dataset to avoid inconsistencies that may affect model performance.To further improve the training process, several image augmentation methods are used to enhance data diversity and avoid overfitting. Rescaling is used to ensure images conform to the model's input needs proportionally, and shear transformations adjust image angles to enable the model to cope with minor differences in perspective. Second, hori- zontal flipping produces mirror images, allowing the model to learn from various perspectives and enhance its capacity to generalize over a wide range of real-world situations. Such augmentation methods overall lead to a stronger and better deep learning model for accident detection and vehicle identification.

2.2. Preprocessing for Severity Prediction Dataset: For severity prediction, preprocessing begins with missing value removal and duplicate record removal to ensure data integrity and eliminate biases. Exploratory Data Analysis (EDA) assists in pattern and relationship identification, influencing feature selection to achieve the best model performance.

Chi-square ($\chi 2$) tests to choose the most significant features, discarding duplicate variables. For dataset balancing, SMOTE creates synthetic samples for minority classes in order to carry out learning with balanced datasets. These pre- processing steps—data cleansing, feature selection, and bal- ancing—improve efficiency of the model, enhancing accident detection and severity prediction accuracy.

$\chi 2 = \Sigma$ (Oi – Ei)

Ei

where: $\chi 2$ = Chi-squared statistic Oi = Observed value Ei = Expected value

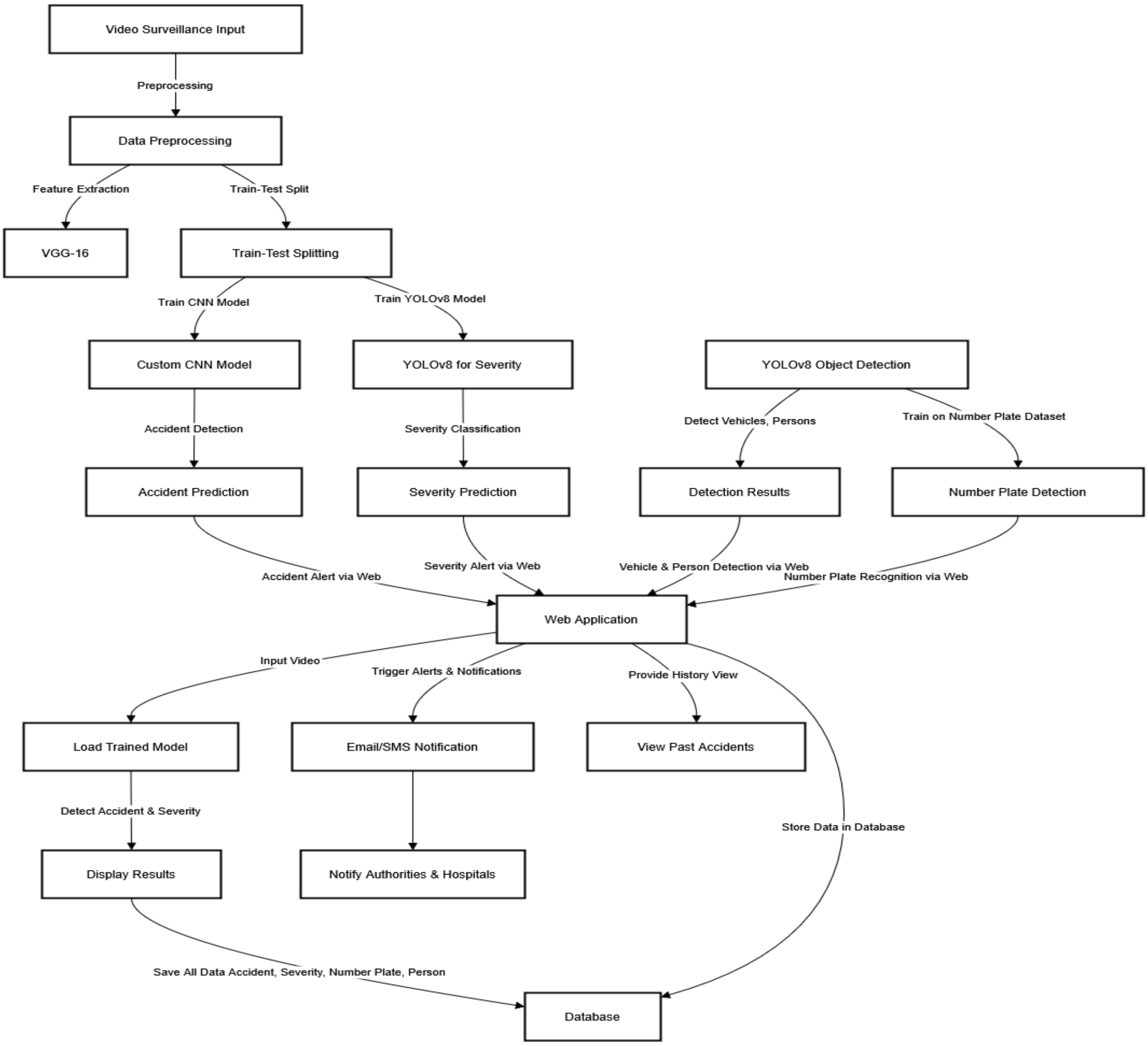

Fig. 1. Architecture diagram of CRASHSENSE

3) **MODEL TRAINING LAYER:** The Model Training Layer is a crucial component of the CrashSense system, where various deep learning models are trained to perform specific tasks. These models are essential for accident detection, severity prediction, and object recognition. Below, each sub-section elaborates on the specific models and the training process used in this layer.

Algorithm 1 Collision Detection Using VGG-16 and CNN

1) **Import Libraries**
   - Import TensorFlow, Keras, OpenCV, NumPy.
   - Load the VGG-16 model.
2) **Preprocess Frames**
   - Extract frames from the video.
   - Resize frames to 224×224.
   - Normalize pixel values.
3) **Feature Extraction with VGG-16**
   - Pass frames through VGG-16.
   - Extract features from the convolutional layers.
4) **Define CNN Model**
   - Use extracted features as input.
   - Add convolutional, pooling, and fully connected layers.
   - Use an activation function to classify results.
5) **Compile and Train the Model**
   - Use an optimizer like Adam.
   - Train with labeled accident and non-accident im- ages.
6) **Collision Detection**
   - Process incoming video frames.
   - Extract features and classify them.
   - If the probability is low, an accident is detected.
7) **Display Results**
   - Show predictions on the video.
   - Trigger alerts if an accident is detected.

Algorithm 2 Object and Collision Detection Using YOLOv8

1) **Prepare Dataset**
   - Collect and label road images.
   - Convert labels to YOLO format.
   - Split dataset into train, validation, and test sets.
2) **Train YOLOv8 Model**
   - Set training parameters (epochs, image size, batch size).
   - Train the model using labeled data.
3) **Object Detection**
   - Load a test image.
   - Run YOLOv8 to detect objects.

- Draw bounding boxes around detected objects.

4) **Real-Time Detection**
   - Capture video from a camera.
   - Process each frame and detect objects.
   - Display detected objects on the screen.
5) **Collision Detection**
   - Analyze detected objects for potential collisions.
   - Trigger alerts if a collision is detected.

Algorithm 3 Severity Prediction Using YOLOv8

1) **Setup Environment**
   - Install dependencies and import required libraries.
   - Load the YOLOv8 model.
2) **Prepare Dataset**
   - Convert images to YOLO format.
   - Split data into training, validation, and test sets.
3) **Train Model**
   - Set training parameters (epochs, image size, batch size).
   - Train the model using labeled data.
4) **Validate Model**
   - Evaluate performance on validation data.
5) **Detect Accidents**
   - Load an image or video frame.
   - Run YOLOv8 to detect accidents.
   - Draw bounding boxes on detected objects.
6) **Real-Time Detection**
   - Capture live video and process frames.
   - Perform inference and display results.
7) **Classify Severity**
   - Analyze confidence scores to determine severity.
   - Display severity label (Minor, Moderate, Severe).
8) **Trigger Alerts**
   - Store accident details and send alerts if severity is high.
9) **Exit Program**
   - Release video and close frames.

Algorithm 4 Web Application Module

1) **User Authentication**
   - Login and validate credentials. Redirect to dash- board or show error.
2) **Video Upload**
   - Upload video, validate file format, store in database.
3) **Accident & Severity Detection**
   - Load model, extract video frames, preprocess and detect accidents.

- If accident, classify severity using YOLOv8 and store results.

4) **Alert System**
   - If severity ¿ threshold, send email alert and show notification.
5) **History Page**
   - Display previous records with search functionality.
6) **Web Interface**
   - Render results dynamically using HTML, CSS, JS, AJAX.
7) **Exit and Cleanup**
   - Close database connections, release resources.

PERFORMANCE ANALYSIS AND EVALUATION

TABLE II MODEL PERFORMANCE METRICS OVER EPOCHS

Epochs	Training Accuracy (%)	Validation Accuracy (%)
5	72.4	75.8
10	80.6	83.2
15	85.7	88.4
20	89.3	90.1
25	91.5	92.8
30	92.6	93.75

Table II presents the training and validation accuracy at different epochs, highlighting the model's learning progress. Initially, at epoch 5, the model achieved a training accuracy of 72.4% and a validation accuracy of 75.8%, indicating that it was effectively learning features from the dataset. As training progressed, the accuracy steadily improved. By epoch 15, the model surpassed 85% accuracy in both training and validation, demonstrating effective generalization.

By epoch 25, the validation accuracy reached 92.8%, show- ing significant improvement. However, in the final epochs, the rate of accuracy increase slowed, and the validation accuracy plateaued at 93.75% at epoch 30. The logs (Table 1) confirm that validation accuracy did not improve beyond this point, suggesting that the model had reached its peak performance. The performance of the proposed model was evaluated based on training and validation accuracy trends over multiple epochs. Figure 2 illustrates the accuracy progression, providing insights into how well the model learned from the dataset.

Initially, at epoch 5, the model achieved a training accuracy of 72.4% and a validation accuracy of 75.8%, showing rapid improvement in early learning stages. The validation accuracy surpassed 85% by epoch 15, indicating strong generalization capabilities. The learning curve continued to rise, reaching a peak validation accuracy of 93.75% at epoch 30, as seen in Figure 2. The plot in Figure 2 demonstrates a consistent upward trend, with validation accuracy closely following the training accuracy. Minor fluctuations indicate natural varia- tions in the dataset but do not suggest overfitting, as both accuracies improve together. This confirms that the model effectively captures patterns in collision data without excessive bias toward training samples.

Fig. 2. Training and Validation Accuracy Graph

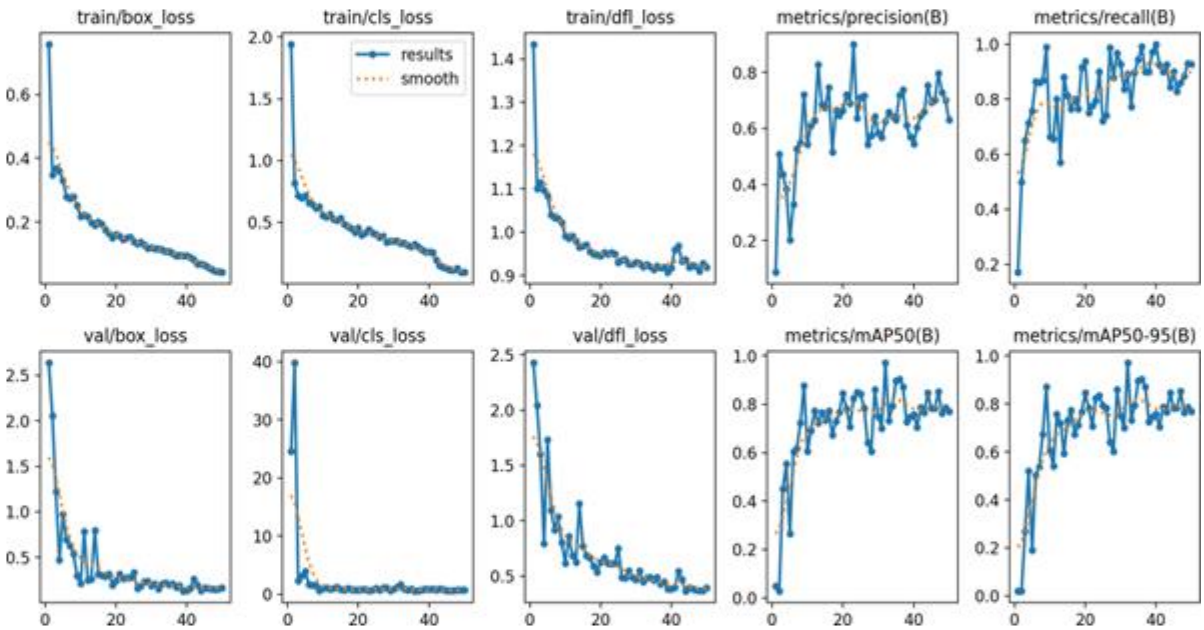

Fig. 3. Model Performance Metrics and Loss Curve

Furthermore, Figure 3 provides a detailed breakdown of loss reduction and precision-recall trends, reinforcing the claim that the model is well-optimized. The stagnation in accuracy improvements, as observed in Figure 2, suggests that further performance enhancements could be achieved through tech- niques like learning rate scheduling or advanced regularization. With a final validation accuracy of 93.75%, the model exhibits strong predictive capabilities, making it suitable for real-world deployment in motor vehicle collision severity assessment.

CONCLUSION AND FUTURE WORK

CrashSense is an accident detection and severity prediction system in real-time using deep learning and web technologies. It combines YOLOv8 for object detection, CNN with VGG16 for accident detection, and YOLOv8 for predicting severity, making it highly accurate. The web application based on Flut- ter offers real-time monitoring, video upload, and automatic emergency alerts, which improve road safety and efficiency in emergency response.Future developments include the inte- gration of next-generation object detection models, optimizing performance under changing conditions, and increasing dataset sizes for greater generalization. Increased real-time processing, predictive analysis, and post-crash analysis will enhance the system. In the long term, CrashSense can develop into a key element of intelligent city infrastructure to enhance road safety and response time to emergencies.

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Agrowise: Combining Agriculture with Smart Decision-Making

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ABSTRACT

AgroWise: Powering Agriculture through Intelligent Decision-Making is an IoT-driven soil monitoring system that works hand in hand with farmers, helping them make informed, data-backed decisions while preserving their traditional expertise. Fitted with smart sensors, AgroWise continuously tracks vital soil parameters such as moisture, temperature, pH, and NPK levels, ensuring farmers have the necessary information at their fingertips. This data is sent to the cloud via Arduino/Raspberry Pi, where AI-based algorithms assist in processing the informa- tion, offering helpful recommendations on irrigation, fertilization, and soil care. However, AI doesn't replace the farmer—it simply enhances decision-making. The final call remains in the hands of those who know their land best.

With an easy-to-use web dashboard, farmers can access real- time insights and adjust their strategies based on both data and personal experience. Unlike traditional soil testing methods, which can be time-consuming and inconsistent, AgroWise pro- vides continuous monitoring, improved accuracy, and scalability, making it a valuable tool for precision agriculture and sustainable farming.

Keywords: Smart Agriculture, IoT, Precision Farming, Soil Monitoring, Machine Learning, Cloud Computing

INTRODUCTION

Generations of farming were based on intuition, experience, and thorough knowledge of the ground. Each step, from seeding to harvesting, had to depend on the farmer's vision of the ground and prediction of weather changes. But with rising issues like unpredictable climactic changes, erosion of topsoil, and famines, traditional processes have been becom- ing increasingly hard to rely on. Modern-day farmers need up-to-date, real-time information on the condition of their soil so that they may make timely and effective decisions.

Traditional soil testing is, nonetheless, slow, expensive, and time-consuming—results return once the soil needs have likely changed, making it difficult to act in time.
AgroWise: Intelligent Decision-Making for Powering Agri- culture will help fill this gap. Rather than replacing their expertise, AgroWise is an assistance system that provides real- time soil monitoring to inform decision-making. Intelligent sensors are used by the system to track the key soil parameters such as moisture, temperature, pH, and nutrient content. All this information is sent to a cloud portal via Arduino or Raspberry Pi, where it is analyzed and displayed in a simple, easy-to-use dashboard [1]. AI identifies patterns and trends, but not decisions—those are made by farmers. AgroWise is designed to function in cooperation with conventional wisdom, enabling farmers to have an exceptionally strong weapon with which to more effectively use their land.
Research suggests that precision agriculture combined with IoT and real-time data can boost crop yields, reduce wastage, and promote sustainable agriculture. Sensor network and AI- driven analysis research indicate the importance of technology as an enabler, not a replacement for human decision-making [2]. Unlike traditional soil testing, which can be random and time-consuming, AgroWise provides real-time feedback, al- lowing farmers to respond instantly to changing soil conditions and make more informed decisions.
For as long as humans have ever plowed the fields, farming has been guided by instinct, experience, and passed-down know-how. Farmers have always depended upon the feel of the earth, the beat of the seasons, and the flow of the weather to show them when to plant, water, and harvest their crops.
But now, agriculture is confronted with new and sophisticated challenges—climate change is interrupting weather patterns, soil loss is lowering fertility, and irregular rainfall is rendering water management more challenging than ever before. And at the same time, food demand is increasing, compelling farmers to enhance productivity while preserving natural resources. In this evolving environment, real-time information about soil health has never been more crucial, enabling farmers to make rapid, informed decisions that increase yields and preserve the land for generations to come [3].
Conventional methods of soil testing are useful but have serious drawbacks. Farmers must manually take soil samples and ship them to labs for analysis—a time-consuming, costly, and impractical process for large-scale farms. By the time the test results are available, soil conditions can have already shifted, and it is hard to take effective action.
The intersection of IoT and AI in precision agriculture has already demonstrated spectacular advantages in enhancing crop yields, streamlining resource utilization, and enhancing sustainable farming [4]. Studies indicate the way sensor net- works and AI insights can aid farmers instead of replacing them, validating the concept that technology should comple- ment human skill rather than supersede it.
This piece explores how AgroWise merges new technology with traditional farm knowledge to maintain control among farmers while leveraging real-time, data-based insights.

RELATED WORKS

The application of IoT, AI, and cloud computing to pre- cision agriculture has been an expanding area of study, with many studies investigating the potential of real-time soil mon- itoring to enhance farming efficiency . Multiple methods have been proposed to enhance soil health analysis, irrigation man- agement, and nutrient delivery through intelligent technologies [5]. This section discusses prior research activities in the area of IoT-based soil monitoring, machine learning in agriculture, and cloud-based decision-making systems, with emphasis on their contributions and limitations.

One of the studies concentrated on IoT-based soil monitor- ing systems using wireless sensor networks (WSNs) for gath- ering real-time data on soil moisture, pH, and temperatures. The study proved that autonomous sensor networks were able to supply more reliable and precise data than the conventional methods of soil sampling [6]. Another model suggested the use of LoRa and RF-based data transmission from distant farmlands to the central monitoring station. Although effective, these systems were generally not scalable and did not have predictive analytics, with manual interpretation of the data being necessary.

Machine learning (ML) has also been used in soil condition analysis and crop management. It has been researched in using Artificial Neural Networks (ANNs), Support Vector Machines (SVMs), and Decision Trees to forecast soil fertility levels from sensor information. Although these methods enhanced precision in soil classification and fertilizer recommendations, their use of extensive training datasets and computational power created obstacles for small-scale farmers [7]. Recent research has explored how AI-based models can be used to optimize irrigation scheduling and disease forecasting and provide timely recommendations to farmers to maximize water and fertilizer efficiency Even with these developments, most current systems fall short of a farmer-focused solution. Even IoT-based soil mon- itoring systems deliver data instead of actionable insights, requiring farmers to independently make sense of complicated datasets. In the same vein, AI models for agriculture tend to prioritize prediction accuracy over usability in real-world applications. The call for a straightforward real-time decision- support system that enhances common farming knowledge is still largely unanswered . AgroWise seeks to bridge these gaps through the integration of IoT, AI, and cloud computing into a simple, farmer-centric platform. In contrast to conventional soil monitoring systems, AgroWise offers real-time data vi- sualization as well as AI-driven recommendations with the assurance that ultimate decision-making is left in the hands of farmers. Not only does this enhance accessibility and simplic- ity, but it also gives farmers the tools to empower sustainable agricultural practices with insights that immediately inform them.

A study suggested a LoRa-based network for the commu- nication of soil sensor data over long distances, which is appropriate for remote farmlands. Nevertheless, with all these developments, most IoT systems remain to be challenged with real-time data transmission reliability and high deployment expenses, which make them inaccessible to small and medium- sized farms.

Machine learning algorithms have also been used in agricul- ture for soil categorization, fertility estimation, and irrigation control. Studies involving Artificial Neural Networks (ANNs), Decision Trees, and Support Vector Machines (SVMs) have indicated encouraging outcomes in forecasting soil nutrient shortages and crop susceptibility to diseases. Another study investigated how deep learning algorithms can process past weather patterns and soil levels to provide the best fertilization recommendations. Yet most AI-based solutions are hampered by issues of data availability, computational intensity, and versatility in dealing with various farm settings [8].

Cloud computing has played a central part in processing, storing, and analyzing big data in agriculture. Experiments have illustrated how IoT sensor networks may be integrated into cloud-based platforms, used to execute machine learning algorithms, and deliver real-time analytics to farmers through mobile apps or web portals. Research indicates that remote farm monitoring options may profoundly cut manual labor ex- penses and enhance decision-making effectiveness. Although reservations over data confidentiality, internet addiction, and extensive infrastructure expenses still present significant de- terrents to acceptance on a larger scale.

Even with these developments, current solutions are still missing an intuitive, farmer-friendly solution. Most IoT-based soil monitoring systems are data-driven, not insight-driven, leaving farmers with complicated datasets that need to be interpreted further [9]. Likewise, AI-driven models prioritize predictive accuracy but tend to overlook real-world usability and flexibility to various farm conditions.

Cloud computing has also been viewed as a valuable resource in agricultural data management since it enables farmers to store, retrieve, and analyze huge amounts of sensor data in real-time. Research has established that farm management systems based on cloud technology have the potential to enhance the efficiency of decision-making by making information about soil health available from remote locations through web and mobile interfaces. Cloud platforms also enable data sharing among researchers, agronomists, and farmers, which enhances coordination in the creation of better soil management practices. Internet connectivity problems, cy- bersecurity breaches, and reliance on third-party cloud services continue to pose main deterrents to its adoption at scale.

Deployment of IoT, AI, and cloud computing in precision agriculture has been a widely explored field and resulted in real-time soil monitoring, predictive analytics, and smart decision-making. Previous research has addressed better soil health management, efficient irrigation, and enhanced nutrient application with the use of smart technology. This section includes earlier research studies on IoT-based soil monitoring, AI-based crop prediction, and cloud-based farming manage- ment systems and their pros and cons.

One of the major shortcomings of most current systems is the absence of intuitive interfaces and actionable information for farmers. Most IoT-based soil monitoring systems yield raw data without converting it into actionable advice, leaving farmers to decipher intricate data sets [10]. In the same way, although AI models yield predictive analytics, the results are usually opaque and lack flexibility to adjust to unique con- ditions on farms, rendering them inoperable by non-technical users.

AgroWise overcomes these constraints through the integra- tion of IoT, AI, and cloud computing into a user-friendly, farmer-centric platform. In contrast to conventional soil moni- toring systems centered on data collection, AgroWise delivers real-time, AI-driven advice to inform irrigation, fertilization, and soil health management. Through the implementation of AI as an assistant, not a decision-maker, AgroWise enables farmers to make more insightful, data-backed decisions while retaining their conventional wisdom.

PROPOSED SYSTEM

AgroWise: Intelligent Decision-Making for Empowering Agriculture system is intended to offer real-time soil moni- toring and support farmers in making data-driven decisions regarding irrigation, fertilization, and soil health management. By combining IoT-based sensors, AI-powered analytics, and cloud computing, AgroWise provides a scalable and farmer- centric solution that complements precision agriculture with- out substituting traditional farming experience. The system maintains constant observation of critical soil parameters, providing actionable insights to farmers via a straightforward and intuitive dashboard.

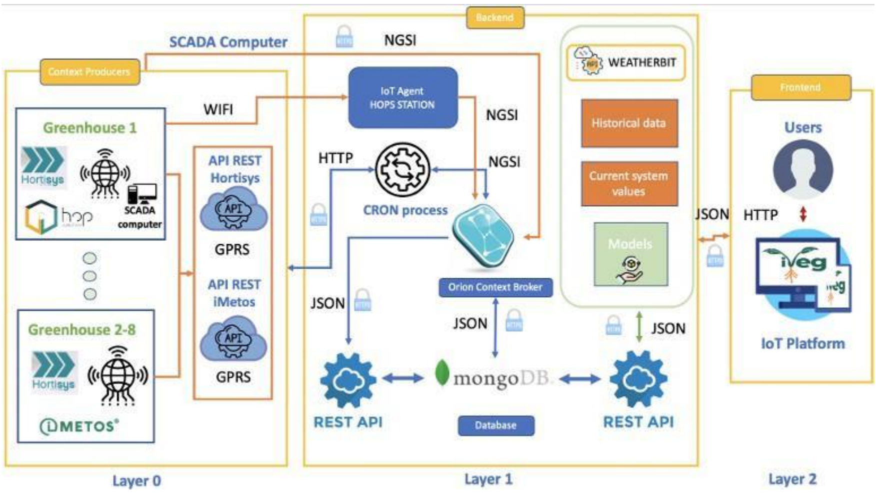

Fig. 1. Architecture diagram of the proposed System

Decision support from AI enables identification of trends and offers suggestions but leaves the decision-making in the hands of the farmers. It is scalable and affordable, such that small farms and large farms can access it with low maintenance costs. Being cloud-based means that farmers are able to view soil conditions from anywhere, so they can act in time even when they are not physically on the farm. In addition, AgroWise encourages sustainability through decreased wastage of water and fertilizer, leading to the saving of natural resources. The farmer will get suggestions unique to his soils, which would enable him to make a reasonable decision about how and when he should water his crops. In contrast to complete automation, AgroWise does not decide on the farmers' behalf but serves as a support tool that contributes to their capacity to improve their land management. Future developments in the system would make it even more functional. Connecting AgroWise with automated irrigation systems would enable it not only to give advice but also to initiate irrigation when required. Extending AI capabilities to disease detection models would enable farmers to detect early symptoms of plant diseases from soil health data. Moreover, enhancing offline capability would allow farmers in rural communities with sparse internet connections to utilize the system through local storage of soil information and regular cloud synchronization.

Through the convergence of IoT, AI, and cloud computing, AgroWise is able to provide farmers with timely, data-based information while retaining complete autonomy over their farming practices. The system is made farmer-friendly in such a way that even those who have little technical expertise can seamlessly understand and implement the information offered. Through a pragmatic, scalable, and user-focused so- lution, AgroWise helps close the gap between contemporary agricultural technology and ancient farming lore, and makes precision agriculture accessible and efficient.

Another important advantage of AgroWise is its ease of use. The dashboard is user-friendly and easily accessible, displaying soil conditions clearly using visual cues like graphs, charts, and alerts. The system does not require farmers to possess advanced technical understanding to utilize it optimally; the interface is designed to convey actionable insights in a simple, easy-to-understand format. By combining multilin- gual functionality and voice notification, AgroWise simplifies access and comprehension of information for farmers across different languages. This prevents technology from acting as a hindrance but instead enables more intelligent and efficient farming practices.

The application of AI-driven analytics in AgroWise en- hances soil health predictions and decision-making. The soft- ware does not only record and display soil information—it analyzes trends, detects anomalies, and predicts the future state of the soil on the basis of past and prevailing trends. For example, when the system is able to pick up a persistent decline in levels of soil moisture, it will be able to predict when the soil will critically dry out and alert the farmer in advance. Similarly, based on observation of patterns of nutrient depletion, AgroWise can recommend when and how much to fertilize and thus avoid both over- and under-use of resources.

PERFORMANCE ANALYSIS

The AgroWise system was evaluated based on multiple performance parameters, including sensor accuracy, response time, power efficiency, and system scalability. The system was tested in real farming environments under different climatic and soil conditions to analyze its effectiveness in real-time soil monitoring and decision-making support.Various tests were conducted to measure the reliability of data collection, trans- mission stability, AI-based recommendation efficiency, and overall system robustness. Additionally, user feedback from farmers was gathered to assess the practical applicability and ease of use of the system in real-world agricultural settings. The results highlight the potential of AgroWise in transforming traditional farming by providing accurate, real-time insights while maintaining a user-friendly interface suitable for non- technical users.

1) System Performance (Score: 78/100): The overall per- formance of AgroWise was evaluated based on real- time data processing, sensor accuracy, response time, and power efficiency. The system functions efficiently in monitoring soil parameters and transmitting real-time data to the cloud. However, there are certain areas where optimization can further enhance performance.
   - Sensor Response Time: 2.3 seconds – The system's sensors detect changes in soil conditions within a short timeframe, allowing timely data updates. Further optimization in data transmission protocols can reduce latency.
   - Data Transmission Delay: 1.5 seconds – The delay in sending data from sensors to the cloud is minimal, but improvements in communication protocols can enhance efficiency.
   - AI Processing Time: 3.8 seconds – The AI model effectively analyzes collected data and generates recommendations, but reducing computation time can improve real-time decision-making for farmers.
   - Power Consumption: Moderate – The system oper- ates efficiently on battery power, but implementing low-power IoT protocols can further extend battery life for field deployments.
2) Accuracy of AI Predictions (Score: 85/100): The AI- driven analysis in AgroWise provides accurate insights into soil health and fertility. However, variations in en- vironmental conditions can sometimes introduce minor discrepancies.
   - Soil Moisture Prediction Accuracy: 92 percent – The system effectively predicts soil moisture levels, enabling optimized irrigation scheduling.
   - Nutrient Analysis Accuracy: 88 – The system pro- vides a high accuracy rate in nutrient level detection but can be improved by calibrating sensor readings with laboratory data.
   - Temperature and Humidity Monitoring: 90 – The sensors accurately capture real-time temperature and humidity conditions, contributing to precise climate assessment.
3) User Experience (Score: 83/100): The system's dash- board interface is user-friendly, allowing farmers to interpret soil data easily.
   - Dashboard Load Time: 2.1 seconds – The user in- terface loads quickly, providing seamless navigation for farmers.
   - Accessibility: The platform supports mobile access, making it easier for farmers to monitor their soil conditions from any location.

The reliability of readings for soil parameters is still a decisive performance assessment factor. While readings from moisture and temperature sensors are high on accuracy, irreg- ular errors in reading nutrient levels are suggestive of the need for recalibration of the sensors. Data synchronization between various devices has been seamless, with only slight variations when multiple sensors yield conflicting results. Incorporating a more sophisticated data validation system would serve to alleviate such problems. Integration of the system with external weather forecasting APIs facilitates better decision-making, but sporadic API unavailability can influence the availability of climate-based information.

AgroWise has high potential for enhancing precision agri- culture through minimizing human intervention and providing real-time data-driven decision-making. To further enhance its efficiency, however, data transmission protocol optimization, minimizing sensor latency, and power efficiency will be re- quired. The sustainability of the system is also an important factor, and the incorporation of renewable energy sources like solar power can ensure constant operation in isolated agricultural regions.

CONCLUSION

Despite its peak performance out of sync with one another, other sensor precision, data processing speed, and connectivity enhancement are a few of the means through which its effec- tiveness can be maximized further. Improved AI algorithms, more robust data verification systems, and network stability will increase its reliability and performance. Furthermore, the addition of renewable energy sources will make the system more sustainable and viable for remote farm locations. Agro- Wise offers a revolutionary solution for precision agriculture by combining IoT, AI, and cloud computing to facilitate real- time monitoring of the soil and data-driven decision-making. The platform efficiently overcomes the shortcomings of con- ventional soil testing by offering live updates on the health of the soil, its moisture content, temperature, and nutrient content. With its easy-to-use dashboard and AI-based insights, AgroWise enables farmers to maximize irrigation, fertilization, and crop management, thereby increasing productivity and sustainability In summary, AgroWise is a strong agent in transforming agriculture through the minimization of reliance on intuition-driven farming and the encouragement of data- driven precision agriculture. With continuous improvements and technological advancements, AgroWise has the capability to revolutionize farming, making it smarter, more efficient, and environmentally friendly.

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CRAMBOT: An AI-Driven Revision Assistant for Personalized Learning in High School Education

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ABSTRACT

The Revision Chatbot is an AI-driven tool designed to support high school students by providing instant and accurate solutions to academic queries across a range of subjects. Built using a comprehensive dataset of high school textbooks, the chatbot serves as a reliable study aid that students can interact with anytime to enhance their knowledge. Upon receiving a ques- tion, the chatbot searches its curated database to offer detailed, contextually relevant answers. If the requested information is not available, the system directs students to external reference textbooks for further exploration. In addition to answering ques- tions, the chatbot generates personalized revision questions based on previously covered topics. This feature reinforces learning by encouraging students to actively practice and retain information, facilitating long-term memory retention. The chatbot's ability to adapt to individual learning needs ensures a more personalized, efficient approach to studying. Its interactive nature makes the learning process engaging and helps students feel confident in their academic abilities. By integrating artificial intelligence with educational methods, the chatbot blends the accessibility of AI with traditional pedagogies, making the study process more dynamic and enjoyable. This innovative approach aims to support students' learning journeys while making their study routine more efficient, personalized, and effective.

Index Terms—Artificial Intelligence, Education, Chatbot, Re- vision, Personalized Learning, High School.

INTRODUCTION

Traditional methods of learning bring up a myriad of chal- lenges to high school students like low personalized help, poor and delayed doubt clarification, and less active engagement in the learning process. Such aspects have built barriers right to understanding the subject or concept, practicing effective problem-solving techniques, or registering the knowledge nec- essary to ace exams. Making things worse, when the student finds that the specified amount of information is hardly suffi- cient and he has to search out more, it requires a lot of time and surely effort to come across good, trustworthy sources. Such an ordeal leaves students feel downsized and lost in trying to dig out correct and reliable information. The revision chatbot is aimed at providing a solution for the students to streamline learning in an intelligent, interactive, and readily accessible manner. The large corpus of high school textbooks that the chatbot queries allows it to provide accurate, curriculum-based responses to questions in various subjects. This informs the students clearly, relevantly, and precisely to help them clarify concepts and solve problems and develop a deep understanding of the subject matter. If a question cannot be found in the database, the chatbot directs the student elsewhere in the search for this information. The student is then able to follow up on how to search for this information, which breeds independent learning of critical thinking towards relating their cognitive knowledge to matters beyond the curriculum. Apart from answering questions, this chatbot asks context-specific revision questions based on past lessons. The intention behind creating this chatbot is to reinforce essential concepts and improve retention capacity. Because of the interaction levels of the revision sessions, the students' attention remains on the material, which helps them solidify their grasp on the subject and leads to long-term retention. With these key concepts addressed anew, students are even more ready to face the exam while being well-armed with information and capable of recollecting on-demand during stress situations.

The standout feature of a revision chatbot is that it is always open 24/7. This means a student can seek assistance at any time of the day or night, early in the morning or late at night. The availability of the chatbot thus continuously supports students in their learning when they want to study according to their pace and when they would like some help. Such flexibility not only relieves stress but also prompts students to become self-sufficient learners and take charge of their own learning. The continuous presence of the chatbot builds confidence in the students that they will not be earlier dependent on any other teacher during school hours to seek help. Around-the- clock availability, along with the personalized approach of the chatbot, changes a traditional learning experience.

It significantly improves learning by providing instant, inter- active, and relevant assistance based on a student's needs. The chatbot also supplements classroom teachings with custom- tailored learning experiences, making the whole study process more efficient, less stressful, and much more engaging. This ultimately results in better understanding of the subject matter, improved academic performance, and greater confidence in the student. The revision chatbot provides constant support to enable a student to carry out their study independently and face any encountered obstacles bravely, developed along the way.

RELATED WORKS

Individualized learning styles fully maximize the efficiency of e-learning, according to all of the research [1]. A brain- computing interface (BCI) integrates with a chatbot. The goal is classifying every learner into introverts, extroverts, and ambiverts. To begin, the chatbot employs a modified VARK questionnaire in addition to a two-minute video-audio session, which records brain beta waves using EEG sensors. Machine learning algorithms, such as Na¨ıve Bayes and J48 classifiers, cross-validate these categories. In every experiment, intro- verts displayed remarkably low amplitudes when listening to sound, while extroverts consistently displayed strikingly high amplitudes. Careful content mapping to people's personalities greatly improves classification accuracy and decisively helps solve high dropout rates in e-learning, which fully opens the way for more adaptive education studies.

The pre-tertiary AI curriculum[2], developed through university-school-government collaboration, is modular and adaptable for junior secondary schools. It comprises 12 chap- ters covering AI fundamentals, ethics, and applications, with flexible modules for different skill levels. By bridging tertiary AI concepts to secondary students, it enhances motivation, competence, and confidence. Teachers also benefit from pro- fessional development through co-design participation. How- ever, challenges remain in ensuring equitable access for under- resourced schools and teachers with no prior AI exposure.The study[3] explores the impact of prompt engineering on Chat- GPT's effectiveness in flipped classrooms, helping students independently prepare materials. Mastering frameworks like CRISPE enables better question formulation, leading to more relevant responses. Challenges include establishing baseline task-related knowledge for students. Results show that com- bining technical knowledge with prompt engineering enhances learning outcomes while mitigating AI inaccuracies. However, findings are limited by isolated scenarios and assumptions about student proficiency. Future research could examine di- verse educational settings for broader applicability.

Recent advancements focus on enhancing context-aware learning in software engineering education. A study intro- duces an AI Knowledge Assistant for capstone projects[4], integrating local "Lessons Learned" databases with external sources like Stack Overflow, powered by LLMs (GPT-4, LLaMa 2). Key features include vector-based memory retrieval and enriched prompts for accurate, contextual responses. The assistant also offers a Kanban-based project tracker, aligning academic tasks with industry practices. It showed improved project performance and a preference for enriched, context- aware recommendations, bridging theoretical knowledge with real-world software challenges.

Accelerating Innovation With Generative AI by Volker Bilgram and Felix Laarmann[5] introduces AI-augmented digital prototyping using GPT models. The framework has two core functions: exploration and ideation support (con- text analysis, user journey mapping, and idea generation via SCAMPER) and AI-augmented prototyping, which translates natural language into code, enabling non-technical users to build prototypes, websites, and apps. By automating initial designs, generative AI streamlines iterations, reducing effort and costs. Case studies highlight how AI bridges conceptual ideas with functional prototypes, democratizing innovation by providing advanced tools to non-experts.The model LUNA[6], introduces a system for assessing LLM reliability. It identifies issues like input mishandling, attack resistance, and halluci- nation avoidance. By quantifying accuracy and consistency, LUNA ensures trustworthy outputs, achieving 83% accuracy in detecting misleading inputs and outperforming baselines in true answer identification and sentiment evaluation. This framework enhances trust in LLMs, aiding their safe deploy- ment in education, healthcare, and automation.

Medeiros et al. studied chatbot-driven emotional support for everyday stress[7] using Gross's emotion regulation theory. The chatbot categorized stressors (e.g., health, relationships) and provided relevant responses. Results showed improved emotional outcomes when users felt human support. While the chatbot boosted positive emotions, it did not reduce stress. Limitations included shallow interactions and trust issues. Future research may explore interactive sensory simulations for more human-like support systems. [8]VEQA has been developed to help interpret Open-Domain Question Answering models, especially for BERT. Due to the large unstructured data sets containing the answers to these questions, OpenQA modules suffer from severe problems associated with data complexities, multi-modular architectures, and semantically intricate decisions.

A study considered possible conversational interfaces, built in the Rasa, for enhancing the communication aspect in ITS[9]. The first step toward this will involve change of the current ITS buttoned interface to an Hypergraph-based problem solver (HBPS). To do so, the researchers designed a chatbot that accepts user queries and translates them into a meaningful format. It transforms such rigid button-command types of interfaces where the users press something to get something done into the more fluid, natural language based, conversational interfaces.

TABLE I TECHNIQUES, MERITS, AND DEMERITS OF VARIOUS ONLINE EDUCATION SYSTEMS

TITLE	TECHNIQUES	MERITS	DEMERITS
Creation and Evaluation of a Pretertiary Artificial Intelligence (AI) Curriculum Thomas K. F. Chiu, Helen Meng, Ching-Sing Chai, Irwin King, Savio Wong, and Yeung Yam [2]	- LOGO Programming - AI4K12 - SenseTime - MS K12 Education Transformation	- Hands-on learning - Early exposure builds a strong AI foundation - Provides teacher training and support	- Too complex for younger stu- dents - Teachers may lack AI exper- tise - Requires expensive resources
Bio-Inspiring Learning Style Chatbot Inventory Using Brain Computing Interface to Increase the Efficiency of E-Learning R. Rajkumar, Velappa Ganapathy [1]	- Brain-Computer Interface (BCI) - Machine Learning (ML) - Electroencephalography (EEG)	- Enhanced Personalization - Data-Driven Insights - Real-Time Brain Activity Monitoring	- High Cost - Limited Sample Size - Complex Setup - Privacy Concerns
Unleashing ChatGPT's Power: A Case Study on Optimizing Information Retrieval in Flipped Classrooms via Prompt Engineering Mo Wang, Minjuan Wang, Xin Xu, Lanqing Yang, Dunbo Cai, and Minghao Yin [3]	- Large Language Models (LLMs) - Reinforcement Learning with Human Feedback (RLHF) - Prompt Engineering - Natural Language Processing (NLP)	- Enhanced Learning Effi- ciency - Supports Critical and Cre- ative Thinking - Task Assistance for Instruc- tors	- Inaccurate or Fabricated In- formation - Challenges with Plagiarism Detection - Overreliance on ChatGPT
LUNA: A Model-Based Universal Analysis Framework for Large Language Models, 2024 Da Song, Xuan Xie, Jiayang Song, Derui Zhu,	- DTMC - HMM - Self-Attention Mechanism - Hallucination Detection	- Comprehensive Quality Analysis - Abnormal Behavior Detection - Human Interpretable Results	- Dependence on Open-Source LLMs - Complex Model Construc- tion - Computational Resource In-

TITLE	TECHNIQUES	MERITS	DEMERITS
Yuheng Huang, Felix Juefei-Xu, Lei Ma [6]			tensive
Accelerating Innovation With Generative AI: AI-Augmented Digital Prototyping and Innovation Methods, 2023 Volker Bilgram, Felix Laarmann [5]	- Text-to-Code Generation - User Journey Mapping - Collaborative AI - Knowledge Management Systems	- Ability to instruct and exe- cute tasks simultaneously - Versatility of LLMs - Assistance in developing methodologies	- Overreliance on LLMs - Quality of Outputs - Implementation Challenges
Toward an AI Knowledge Assistant for Context-Aware Learning Experiences in Software Capstone Project Development Andre´s Neyem, Luis A. Gonza´lez, Marcelo Mendoza, Juan Pablo Sandoval Alcocer, Leonardo Centellas, Carlos Paredes [4]	- NLP - Tokenization - Context-Aware Computing - Conversational Agent Frameworks - IR Techniques	- Personalized Support - Increased Collaboration - Efficient Resource Retrieval - Interdisciplinary Knowledge Integration	- Context Sensitivity Limita- tions - Privacy Concerns - Potential for Misleading In- formation
Visual Explanation for Open-Domain Question Answering With BERT, 2024 Zekai Shao, Shuran Sun, Yuheng Zhao, Siyuan Wang, Zhongvu Wei, Tao Gui, Cagatay Turkay, Siming Chen [8]	- BERT-based OpenQA Models - Visual Analytics (VEQA) - Attribution Methods - Tree-based Visualization	- Improved Interpretability - Detailed Visualization - Enhanced Model Improve- ment	- Complexity - High Computational Costs - Scalability Issues
CommonsenseVIS: Visualizing and Understanding Commonsense Reasoning Capabilities of Natural Language Models, 2023 Xingbo Wang, Renfei Huang, Zhihua Jin, Tianqing Fang, and Huamin Qu [11]	- Commonsense knowledge graphs - Feature attribution methods - Visual analytics tools	- Improves understanding of AI commonsense reasoning - Provides interactive model analysis - Aligns model behavior with human commonsense knowl- edge	- Dependency on external knowledge bases - Scalability issues with large models - Requires expert knowledge for analysis
A Brief Overview of ChatGPT: The History, Status Quo and	- Large language models (GPT-3, GPT- 4) - In-context learning	- Powerful language under- standing and generation	- Factual errors (hallucina- tions) - Lacks explicit

TITLE	TECHNIQUES	MERITS	DEMERITS
Potential Future Development, 2023 Tianyu Wu, Shizhu He, Jingping Liu, Siqi Sun, Kang Liu, Qing-Long Han, Fellow, and Yang Tang [12]	- Reinforcement learning from human feedback (RLHF)	- Strong reasoning and creativ- ity - Knowledge modeling and task planning	knowledge modeling - High research and develop- ment cost
A Human-Centered Learning and Teaching Framework Using Generative Artificial Intelligence for Self-Regulated Learning Development Through Domain Knowledge Learning in K–12 Settings, 2023 Siu-Cheung Kong and Yin Yang [10]	- Generative AI (e.g., ChatGPT) - TPACK framework - ARCS model - AI feedback systems	- Personalized learning - Real-time feedback - Increased engagement - Supports self-regulated learn- ing (SRL) - Empowers teachers	- AI dependency - Less human interaction - Teacher training needed - Limited creative feedback - Privacy concerns

The Human-Centered Learning and Teaching Framework (HCLTF) [10] uses many AI tools to help with self-regulated learning in K-12 education. The transparent, cross-disciplinary neural network permits AI, in addition to teachers, to col- laborate throughout actual research. AI integration has con- siderably improved TPACK. Subsequently, teachers can craft exceptionally engaging, student-centered learning experiences. Education will be reshaped by adaptive, differentiated instruc- tion tools that empower students and teachers. The Common- senseVIS [11] supports the understanding of commonsense reasoning in NLP through a new kind of visual analytic system. Such a system, based on external knowledge graphs like ConceptNet, contextualizes model behavior, aligning it with human reasoning. The system extracts relevant common- sense knowledge from QA datasets and links it with model predictions, enabling relational accuracy analysis. Multi-level views-global, subset, and instance-enables users to inspect model overall performance, specific subsets, and individual instances. ChatGPT is an advanced AI- powered content model that has been created by OpenAI which happens to be one of the watershed moments of the artificial intelligence as it has complicated understanding as well as generating language tasks. The model[12] takes Resourceful to in-context learning and reinforcement from human feedback from a large pretrained language model (GPT3.5 and GPT-4) and asks for instruction tuning in a structured way to enhance the efficiency of taking tasks. Due to its multi-model abilities, it is able to process text and image inputs and its applications range from image captioning, paper summarization to logical reasoning. Although exhibiting even higher creativity, reasoning, and knowledge modelling capability, it has nevertheless turned out to bring in tow issues of factual inaccuracy, ethical issues as well as environmental problems due to the high computational cost of its use. But ChatGPT is creating automation and improvement in content creation in the sectors of education, health and media.

PROPOSED SYSTEM

The proposed system is an AI-driven revision chatbot care- fully designed to be especially beneficial for high schoolers. Making use of an extensive corpus of textbooks across disci- plines, the bot might serve as a conventional trustworthy study buddy for curriculum question queries by students after school at any hour. Natural language processing and other capabilities allow the chatbot to understand students' multitude of ques- tions in an accurate, effective, and context-appropriate manner. Therefore, this novel system aims fundamentally to improve the learning experience of the students by providing timely assistance in difficult topics clarifications, contextual problems solving, and knowledge confidence boosting itself. Apart from giving straight answers to questions, the chatbot has a unique feature of providing personalized revision questions on topics that have been discussed during the course of interactions. This features benefits active learning while cementing what students learn since students will more often evaluate if they actually understand the content. Furthermore, if the chatbot finds questions that are outside its dataset, then it may indicate further books or literature that may be used to guide the students to seek further information on their own. The system incorporates advanced technology with educational support, providing a holistic solution to the problems students face in managing the whole studying and exam preparation processes. The architecture is an example that represents a kind of pipeline from the question being asked to arriving at an appropriate answer using both an embedding and a large LLM. Preprocessing starts as the content extraction of a selection of PDFs into smaller fragments of text - then, segments are processed for embeddings to take the form of unique vectorized representations (embedding) that have the semantic information about each such chunk. All the mentioned embeddings are then kept within a knowledge base that offers an searchable view over document contents. Similarly, on user-submitted query, an embedding for this is produced also. A comparison is thus carried out, within the space of semantic search, of question embeddings to determine those most alike from a store of chunk embeddings, that chunks could answer this query best. The selected chunks are then used to create a prompt and sent to the LLM in order to generate an answer. The LLM responds by providing a generated response based on the context developed from the selected chunks, and the final answer is provided to the user. This architecture efficiently retrieves relevant information using embeddings, allowing the LLM to focus on generating accurate and coherent responses grounded in the context of the selected content. Fig. 1. shows the architecture diagram of the proposed system.

A. DATASET

The dataset is provided from the approved syllabi in the form of PDF textbooks, which is, therefore, standard and accepted as the right reference across subjects by any accredited academy. The knowledge and input of the system rely entirely on those textbooks; however, it keeps categorized, detailed information straight to the curriculum. The system shall answer the questions solely from the contents of these books and not from any other sources or databases. Textbooks in the dataset are selected based on their salience to education, credibility, and the range of topics and learning objectives they represent, which are founded on accredited educational programs. The answers generated by the system are derived strictly from the college textbooks present in the study dataset. This means that the supplied answers will always corre- spond to prescribed academic materials. This guarantees that no other outside-source information is taken, like on- line information or supplementary resources. This ensures that answers are reliable and accurate when sought in compliance with curriculum and academic structure. The curation of the dataset is done in a way that it upholds the value of truth utility whilst enabling responses that are best aligned with what the textbooks purport to achieve.

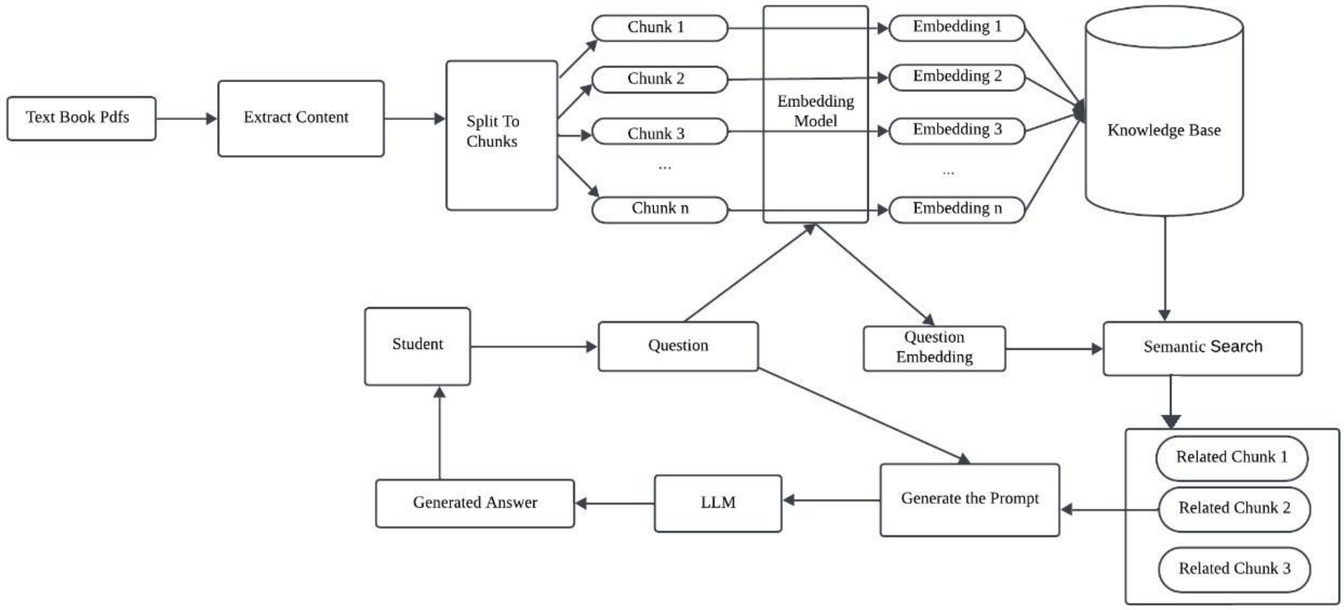

Fig. 1. Architecture diagram of Revision Chatbot

B. SYSTEM OVERVIEW

The system operates on advanced LLMs comparable to or better than GPT-3.5 processing human-like text for academic queries. The GPT model passes in natural language understanding and generation abilities. It can return intelligent, contextually-relevant responses based just on the knowledge from its enormous pre-training on a variety of materials and is therefore very potent at this for a broad variety of content. The model can formulate insightful, neat answers, which encompass the nuances of queries into tailored, accurate responses.

a. Data Storage & Retrieval

1) User Database: The system employs Firebase to man- age user authentication and session tracking, ensuring a seam- less and secure experience.
2) Dataset Storage & Indexing: Textbook data is stored in Pinecone, a highly scalable vector database designed to handle large-scale similarity searches efficiently. Pinecone leverages embeddings to represent textual content as high-dimensional vectors, capturing semantic meaning and relationships between words, sentences, or entire documents.

Once the textbook PDFs are processed and converted into embeddings using models like SentenceTransformers, these embeddings are indexed within Pinecone. This indexing pro- cess organizes the embeddings in a way that allows for rapid similarity searches when a query is made. As a result, the system can quickly compare the query's embedding to those in the index, returning the most relevant documents based on semantic similarity.This vector-based approach enables the retrieval of highly relevant information even when the query and the content do not match exactly in wording. Instead, the system can understand context and meaning, ensuring that the response is both accurate and contextually appropriate.

b. Query Processing & AI Model Stack

1) Text Embeddings: SentenceTransformers generate dense vector representations of textual content, optimizing similarity searches. These embeddings capture the semantic meaning of words, phrases, and entire documents, allowing for effective comparison during query matching.
2) Retrieval-Augmented Generation (RAG): Queries first undergo similarity matching against indexed textbook content stored in Pinecone. This process ensures that the most contex- tually relevant

documents are retrieved based on the embed- dings, significantly improving the accuracy of the results.

3) LLM Processing (ChatOpenAI): If relevant textbook content is found, ChatOpenAI structures a response using the retrieved passages. The large language model then processes the data, generating coherent and contextually accurate an- swers that directly address the user's query.
4) Fallback Mechanism (Web Search): If the dataset lacks an adequate answer, the system programmatically searches the web for additional references. This ensures that even if the primary dataset does not provide a complete answer, the system can access external sources that are curriculum-aligned to ensure completeness and accuracy.

This system ensures that users get accurate, reliable an- swers, making their learning process more efficient and ef- fective. By integrating advanced search and retrieval methods, the system offers users dependable information to support their academic growth. With its ability to pull from both internal databases and external sources, the system provides a comprehensive learning experience. This method empowers users with precise and well-rounded answers, enhancing their understanding and boosting their confidence in learning.

Algorithm 1 AI-Powered Chatbot with RAG-Based Retrieval and User Authentication

Input: User Query Q, Documents D, Pretrained LLM Model MLLM , Pretrained Embedding Model MEMB, Vector Database V DB Output: Generated Response R Procedure:

1. Initialize System:
    i. Load environment variables (API keys for OpenAI, Pinecone, Firebase, SerpAPI)
    ii. Connect to Firebase for user authentication (Sign- In/Sign-Up)
2. Load Dataset D containing documents:
    i. For each document d ∈ D, extract text T using OCR (if scanned) or direct parsing
3. Preprocess Documents:
    ii. Split extracted text T into smaller chunks C
    iii. For each chunk c ∈ C:
4. Generate vector representation V using embedding model: V = MEMB(c)
5. Store (V, c) in vector database V DB
6. Process User Query:
    iv. Convert query Q into vector representation: VQ = MEMB(Q)
    v. Retrieve top-k relevant chunks C′ via similarity search in V DB
7. Generate Contextual Response:
    vi. Form context CTX by concatenating retrieved chunks C′
    vii. Generate response using LLM: R = MLLM (CTX + Q)
8. Handle Insufficient Context:
    viii. If no relevant information is found in V DB:
9. Perform Google Search using SerpAPI
10. Return relevant links to the user
11. Return generated response R as output

PERFORMANCE ANALYSIS

To compare the performance of machine learning models in contextual understanding, response generation, and retrieval accuracy, we evaluate them using key metrics such as accuracy, precision, recall, and F1-score.

The analysis is conducted on benchmark datasets to assess their effectiveness in language comprehension, content generation, and academic content re- trieval.

A. Contextual Understanding

Contextual understanding for a machine learning model refers to its ability to comprehend and interpret text within its specific context rather than just processing words in isolation. The table below shows the results of comparison.

TABLE II CONTEXTUAL UNDERSTANDING PERFORMANCE ANALYSIS

Algorithm	Precision	Recall	F1-Score	Accuracy
GPT-3.5	0.86	0.85	0.85	86%
BERT	0.82	0.81	0.81	82%
T5	0.80	0.79	0.79	80%

The analysis shows that GPT-3.5 outperforms BERT and T5, achieving the highest accuracy of 86% with a precision of 0.86. BERT follows with 82% accuracy, while T5 lags behind with the lowest accuracy of 80%, indicating weaker contextual comprehension.

B. Response Generation Quality

Table below compares the quality of the responses generated by different models. It shows that GPT-3.5 delivers the high- est performance among the evaluated models, achieving an accuracy of 87% and an F1-score of 0.86. BERT follows with a slightly lower accuracy of 83%, while T5 has the weakest performance. The results indicate that GPT-3.5 is the most effective model for generating high-quality responses.

TABLE III RESPONSE GENERATION QUALITY ANALYSIS

Algorithm	Precision	Recall	F1-Score	Accuracy
GPT-3.5	0.87	0.86	0.86	87%
BERT	0.83	0.82	0.82	83%
T5	0.81	0.80	0.80	81%

C. Retrieval Accuracy

Table V shows that GPT-3.5 performs the best among the evaluated models, achieving the highest accuracy of 89% and an F1-score of 0.88. BERT follows with 85% accuracy, demonstrating moderate performance in retrieval tasks. T5, with the lowest accuracy of 83%, exhibits the weakest retrieval effectiveness. These results indicate that GPT-3.5 is the most reliable model for retrieving accurate and relevant information, while BERT and T5 perform slightly lower in comparison.

TABLE IV RETRIEVAL ACCURACY ANALYSIS

Algorithm	Precision	Recall	F1-Score	Accuracy
GPT-3.5	0.89	0.88	0.88	89%
BERT	0.85	0.84	0.84	85%
T5	0.83	0.82	0.82	83%

CONCLUSION

Integrating an AI chatbot into high school education rep- resents a highly innovative and personalized approach to learning. Unlike traditional teaching methods, where students can only receive assistance during specific class hours or limited teacher office hours, an AI-powered chatbot offers instant support anytime and anywhere. The AI chatbot adapts its responses based on individual student needs, analyzing their queries and performance to provide tailored explana- tions. It can break down complex concepts into simpler, more digestible pieces, offer additional resources, or guide students through topics at their own pace. This personalization promotes self-directed learning and empowers students to take control of their academic progress, fostering a deeper understanding of the subject matter. Students always receive accurate, reliable, and relevant information to support their learning. This AI chatbot not only complements traditional teaching but also bridges gaps in availability and adaptability. It helps students learn more efficiently, boosts their confidence, and encourages academic engagement. Ultimately, it creates a dynamic, interactive learning environment that promotes deeper knowledge retention and academic success.

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LITIGAIDE : AI Assisted Legal Document Generator

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ABSTRACT

The integration of advanced technologies into the legal domain of India has gained significant amount of attention especially with the rise of Artificial Intelligence in the recent years. In a vast and diverse country like India, the legal system can be made more efficient and speedier by incorporating artificial intelligence into the processes. One of the major time consuming processes in the Indian legal system is document preparation. In addition to being time consuming it is also labor intensive and delays the proceedings of the case significantly. As a solution to this, a model that automates this process with Generative AI. The AI Assisted legal document generator aids the advocates by generating a plaint automatically based on natural language inputs that specify the requirements of the advocate. This approach generates legal documents that are accurate in format and terminologies. It is time-saving and lessens the need of having expertise in legal writing. The model is trained on templates and frameworks of the Indian law.

Index Terms—Generative AI, Text Generation, Natural Lan- guage Processing.

INTRODUCTION

The incorporation of Artificial Intelligence (AI) in the legal field is a evolutionary step towards overcoming the shortcomings and inadequacies of traditional legal practices. Litigaide, The AI-Assisted Legal Document Generator is an example of this innovation. Legal professionals around the world have always relied on manual drafting processes for creating documents, which provide the basis for civil cases in courts. These methods are often cumbersome, prone to human errors, and lack the standards required to meet the demand of a fast-changing legal landscape. This work seeks to address the issues listed above by applying Generative AI in an attempt to make legal document creation automated.

An attempt to automate legal drafting was made by Vayadande et al. [1] using OpenAI embeddings, ChatGPT-3.5, and tools like PyPDF, Amazon Textract, and LangChain. Similarly , the foundation of this work lies in Generative AI, a branch of artificial intelligence focused on creating content that is both contextually relevant and high in quality. Generative AI models are trained on extensive datasets comprising legal document templates and case laws. This training enables the system to learn the structure, language, and nuances of legal documentation. By incorporating Natural Language Processing (NLP), the system can interpret legal terminology, understand context, and adapt to specific case requirements. Litigaide specifically targets the creation of plaints, key legal documents filed for the initiation of civil cases. These documents are critical in presenting the plaintiff's claims and framing the issues for the court. The system analyzes relevant case details, extracting essential information for inclusion in the plaint. Then, the model applies predefined templates tailored to the specific requirements of the case type. The generated docu- ment is customized to align with regional legal frameworks and the specific details of the case.The establishment of this system offers numerous benefits, transforming the legal sector in several ways. It Improves Efficiency by automating repeti- tive tasks.The system drastically reduces the time required to draft legal documents, enabling faster case processing.
This paper is structured as different sections. Section II contains works related to the model proposed. Section III describes the model architecture and methodology used. Sec- tion IV shows the performance analysis of the model. The suggested order for reading the paper is section II, III and IV.

RELATED WORKS

Trisedya et al. [2] introduced a novel approach to entity description generation by addressing challenges in encoding structured data and ensuring logical content planning. Ex- perimental results reveal the model's superior performance in readability, coherence, and attribute coverage, demonstrat- ing its potential to advance Natural Language Generation (NLG) by unifying content encoding and planning in an end- to-end framework. Xiong et al. proposed in [3] addresses challenges in Similar Case Matching (SCM) within Legal AI, particularly in improving accuracy for tasks like Legal Judgment Prediction (LJP). The model leverages a fine-tuned BERT architecture augmented with global and self-attention mechanisms to effectively comprehend and represent lengthy legal texts. Experimental evaluations on the China AI and Law (CAIL) dataset demonstrate significant performance gains, with a 15% to 54% accuracy improvement over baseline mod- els. Integrating OpenAI embeddings, ChatGPT-3.5, and tools like PyPDF, Amazon Textract, and LangChain, the assistant developed by Vayadande et al. in [1] excels in document generation, comprehension, and irregularity detection. Using a refined multilingual dataset, the system standardizes and pre- processes legal documents to enhance its capabilities. Features such as sentiment analysis and Named Entity Recognition (NER) enable accurate abnormality detection via an intuitive web interface. Experiments validate the system's effectiveness in identifying and correcting irregularities, demonstrating its transformative potential to streamline legal workflows and set a new benchmark for precision and efficiency in legal document management.
A novel approach to data-to-text generation proposed by Yang et al in [5] which addresses the limitations of existing static planning methods by introducing a dynamic planner capable of adapting during the text realization process. The model alternates between record planning and text realiza- tion, allowing the planner to revise its actions based on the intermediate results of generated text. Experimental results on the E2E challenge and a Chinese advertising generation dataset demonstrate that the proposed model significantly outperforms previous state-of-the-art methods in both planning accuracy and text generation quality. A robust framework that enhances text generation by combining adversarial learn- ing with knowledge transfer from GPT-2 was introduced by Zhang, Hao, et al. [6]. The model incorporates a feature- level adversarial mechanism

to refine text quality and ensures effective knowledge transfer to adapt GPT-2's capabilities to specific tasks. Extensive experiments on benchmark datasets reveal significant improvements in text fluency, diversity, and task-specific performance.

Kutbi et al. introduced a model [7] to perform Named Entity Recognition (NER) with text classification to improve accuracy while maintaining data privacy. The approach lever- ages NER to identify and extract critical entities from text, enabling more precise classification without compromising sensitive information. Experimental results on diverse datasets demonstrate that this method enhances classification perfor- mance compared to traditional models. Automation of job description generation by leveraging capability-aware neural networks was achieved by Qin, C. et al. [8]. The proposed framework incorporates a capability-aware module that aligns the generated content with specific job roles and required skills, ensuring relevance and precision. Extensive experiments confirm the model's superiority over existing baselines in generating detailed, role-aligned job descriptions.

Liu et al. proposed a method for enhancing the retrieval of similar legal cases using a method [9] that leverages domain-specific representations by iteratively refining a model through self-generated pseudo-labels, enabling it to capture nuanced legal semantics. Experiments conducted on legal case retrieval benchmarks demonstrate significant improvements in retrieval accuracy and relevance, outperforming traditional retrieval models by effectively understanding legal context and similarity.Fan et al. [10] proposed an ensemble learning-based approach for legal document similarity matching, addressing the limitations of traditional retrieval methods that struggle to capture the complex language and contextual nuances of legal texts. By combining multiple machine learning models, the proposed method enhances prediction accuracy and robustness in similarity matching tasks. Despite challenges related to computational complexity and dependence on data quality, experimental results demonstrate that the model significantly improves retrieval performance.

Li et al. [11] proposed a Generative Adversarial Network (GAN)-based model that utilizes a two-component framework, consisting of a style eliminator to remove original stylistic elements and a style fuser to integrate formal legal styles. By tackling key challenges such as data dependency and overfitting, this approach offers a more efficient and scalable solution for legal document automation, enhancing the reliabil- ity of AI-generated legal texts. Fathima et al. [12] explore the transformative impact of AI-powered tools on contract analysis and legal document management, emphasizing efficiency gains and error reduction. By integrating Natural Language Process- ing (NLP), Machine Learning (ML), and Optical Character Recognition (OCR), the study demonstrates a 40% reduction in processing time and a 60% improvement in accuracy for tasks such as document categorization, clause detection, and data extraction.

Generating plaints using brings forth many challenges, especially in terms of the requirement of large datasets which must be accurate. In addition, developing effective techniques to categorize and process the dataset is important to make the procedure much more efficient while minimizing resource and time expenditure. Furthermore, each document must have some degree of customization to suit the particular needs of the civil suit which makes it difficult to settle at a universal format of plaint drafting. Therefore, template based approach must be chosen.

TABLE I EXPANDED SUMMARY OF TEXT GENERATION TECHNIQUES

Title	Techniques	Merits	Demerits
Controllable Text Gen- eration Using Semantic	Semantic Control Gram-	Fine-Grained Control, Im- proved Text	Complexity in Rule Creation, Data-Intensive,

Title	Techniques	Merits	Demerits
Control Grammar [4]	mar (SCG)	Relevance, En- hanced Coherence, Versatil- ity Across Domains	Potential for Overfitting, Handling Ambi- guity and Context
Text Generation from Data with Dynamic Planning [5]	Dynamic Content Planning, Reinforcement Learning	Improved Coherence and Structure, Optimization with Reinforcement Learning (RL), Alignment with Human Planning	Increased Complexity, De- pendence on Structured Data, Challenges in Dynamic Plan- ning, Need for Extensive Data
Text Feature Adversarial Learning for Text Generation with Knowledge Transfer from GPT2 [6]	Text Feature GAN (TF-GAN)	Knowledge Transfer from Pre-trained GPT Models, Feature Discriminator for Robust Text Generation, Generalization to Multiple Text Generation Tasks	Computational Complexity, Challenges in Training Stability, Dependence on Large Pre-trained Models
Named Entity Recog- nition Utilized to En- hance Text Classifica- tion While Preserving Privacy [7]	Named Entity Recogni- tion (NER)	Enhances Classifier Accu- racy, Preserves Privacy, Gen- eralizable Across Different Text Datasets, Improves Ro- bustness	Reduced Performance, Intro- duces Ambiguity
Towards Automatic Job Description Generation with Capability-Aware Neural Networks [8]	Neural Topic Model, Sequence-to-Sequence Model, Capability-Aware Attention and Copy Mechanisms, Policy Gradient Training	Improves Rationality and Smoothness, Enhan ces Interpretability of Job Descriptions, Generates Coherent and Realistic Descriptions	Needs Fine-Tuning for Spe- cific Job Markets, Relies on Recruitment Data
Iterative Self-Supervised Learning for Legal Similar Case Retrieval [9]	Sparse Retrieval, Dense Retrieval, Iterative Train- ing	Accelerates the Retrieval Process, Boosts Precision, Enables Self-Supervised Learning	Dataset Imbalance, Complexity in Interpretation
Legal Document Simi- larity Matching Based on Ensemble Learning [10]	Ensemble Learning Model	Improved Prediction Accu- racy, Robust Feature Extrac- tion, Complementary Learn- ing	Computational Complexity, Dependence on Data Quality, Can Struggle with Real- World Application
TST-GAN: A Legal Document Generation Model Based on Text Style Transfer [11]	Generative Adversarial Networks, Text Style Transfer	Content Preservation, Au- tomation, High-Quality Out- puts with Evaluation Metrics	Data Dependency, Training Complexity, Overfitting Risk, Evaluation Limitations

Title	Techniques	Merits	Demerits
TransCP: A Transformer Pointer Network for Generic Entity Description Generation With Explicit Content-Planning [2]	Pointer Network, Trans- former Networks, Copy Mechanism	End-to-End Learning, Gated Residual Attention, Pointer Generation	Training Data Dependency, High Resource Requirement, Potential Overfitting
Deep Text Understand- ing Model for Similar Case Matching [3]	BERT Model, Triplet Training	Deep Text Understanding, Improved Accuracy	Dependence on Quality Data, Limited Generalizability
AI-Powered Legal Documentation Assistant [1]	NLP, Machine Learning, Named Entity Recogni- tion	Reduced Human Error, Im- proved Efficiency for Doc- ument Processing, Multilin- gual Support	Initial Setup and Training, Dependence on Technology, Limitations in Contextual Understanding
Effectual Contract Management and Analysis with AI-Powered Technology [12]	Natural Language Processing, Machine Learning, Optical Character Recognition	Error Reduction, Cost Re- duction, Scalability 3	Data Dependency, Ethical Considerations, Complex Model Development

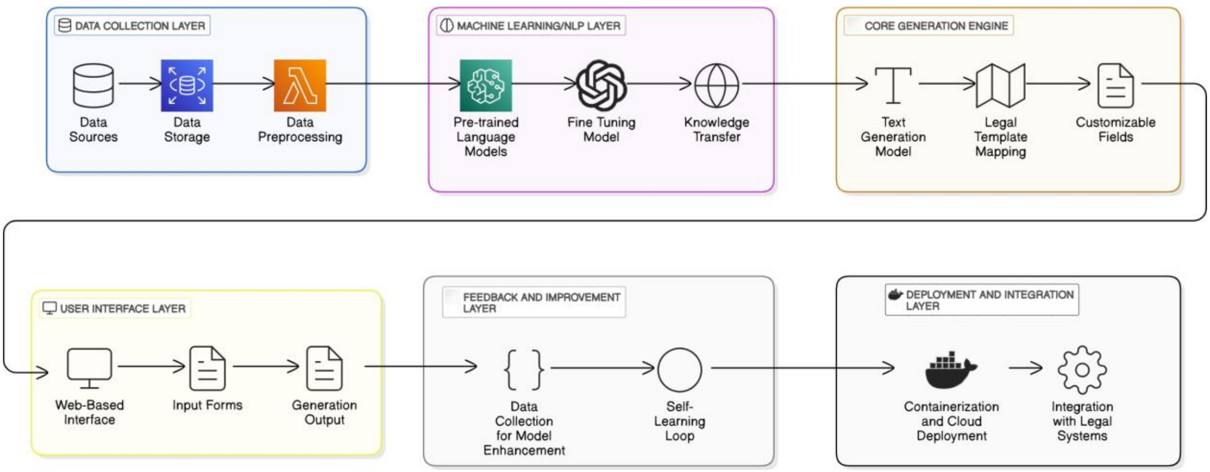

Fig. 1. Architecture of Litigaide

PROPOSED SYSTEM

Litigaide is designed as a multi-layered system that ensures the generation of legally compliant plaints tailored for the Indian legal system. Each layer contributes to the accuracy, efficiency and usability of the system. This layered architecture is illustrated in Figure 1.

A. Data Collection Layer

The Data Collection Layer is responsible for gathering diverse legal datasets. These datasets are primarily synthetic— generated using GPT models trained to simulate real-world civil case scenarios. The collected data is stored in a structured database, categorized by case type, jurisdiction, and relevant legal sections.

B. Preprocessing Layer

Before being utilized for training and generation, the data undergoes multiple preprocessing steps to enhance quality and consistency. The first step is text normalization which involves standardizing case texts by correcting any inconsistencies, removing redundant spaces and ensuring a uniform format. Next is the Tokenization step which breaks down legal texts into structured units, making them easier to process. This is accompanied by Entity Recognition to identify and extract key entities such as plaintiff, defendant, court name, cause of action and reliefs sought. The extracted entities and their relationships are structured according to Indian legal standards.

C. Knowledge Representation Layer

A structured legal ontology serves as the backbone of the AI model. It defines the relationships between different legal concepts, enabling the system to categorize, link, and interpret case-specific information accurately. By integrating this ontology with a knowledge graph, the model understands legal hierarchies and dependencies, such as the relationship between case laws and statutes.

D. Machine Learning/NLP Layer

The Machine Learning/NLP Layer is responsible for le- gal text generation and refinement. It integrates pre-trained transformer-based language models (e.g., GPT-2, T5) that have been fine-tuned on the legal dataset. Key enhancements include Fine-Tuning on Legal Entities and usage of Knowledge Transfer techniques. Fine-Tuning focuses on optimizing the model for legal drafting using domain-specific texts.

E. Core Generation Engine

The Core Generation Engine forms the heart of the system, responsible for drafting plaints based on case details. It follows a structured approach by collecting and processing the case details first. Then the predefined legal template is selected to ensure compliance with court-specific formatting. After this, the system generated a preliminary plaint ensuring coherence, logical flow, and legal accuracy.

F. User Interface Layer

A user-friendly web interface allows legal professionals to input case details easily using structured fields, generate plaints dynamically based on input, review and edit the generated plaint before finalization and download the plaint in PDF or Word format for court filing.

G. Feedback and Continuous Improvement Layer

To enhance performance over time, the system integrates feedback mechanisms such as integrating the generated plaints into the dataset for improving future accuracy by expanding the dataset. The model is periodically retrained to adapt to evolving legal trends.

H. Process Overview

As the first step of the process, details of the suit to be filed is taken as input. Based on the type of civil suit received as input, the model will choose a template that is has been previously trained on. By incorporating the details of the suit received as input, prompt is created. This prompt is used to generate different sections of the plaint by the core generation engine. The template is customized with the generated text and is written onto an editable text file. This file can be downloaded by the user.

Algorithm 1 Litigaide Document Generation Algorithm

Require: Pre-trained GPT model M , document type D, case information C, section length mapping L

Ensure: Generated legal document G

1: Load M and tokenizer

2: Initialize G ← ””

3: Retrieve predefined sections S for D
4: Initialize context Ctx ← " < STARTD > "
5: for each section s ∈ S do
6: if s ∈ C then
7: content ← C[s]
8: else
9: prompt ← Ctx + " < s > "
10: max len ← L[s] if s ∈ L else L[default] 11: content ← M.generate(prompt, max len) 12: Extract relevant content from content
13: end if
14: Append " < s > " + content + " < /s > " to G 15: Append " < s > " + content + " < /s > " to Ctx 16: end for return G

PERFORMANCE ANALYSIS

The metrics of evaluation imply that the legal document generator is at a good rate of performance, yielding outputs that are accurate, well-structured, and coherent in terms of law. The perplexity score of 48.11 implies that the model has a good balance between predictability and diversity, enabling it to produce legal text that is fluent while being logically consistent. A BLEU score of 1.0, which is ideal, indicates that the text that has been produced is highly similar to the reference texts, keeping legal terms precise and maintaining correct legal format. The ROUGE-1, ROUGE-2, and ROUGE- L scores of 1.0 further validate that the model effectively cap- tures important legal expressions and keeps textual similarity very close to conventional legal formats. These scores indicate the model's high capacity for learning from training data and generating legally valid documents that meet formal require- ments. In addition, these scores confirm that the model has successfully embodied the subtleties of legal writing, creating high-quality text that is factually accurate and contextually relevant.

The high accuracy and coherence indicate that the system has the potential to be a useful tool for the automation of legal document creation, minimizing manual labor while maintaining adherence to legal requirements. To make it even more effective, the addition of a greater number of legal cases, jurisdiction-based variations, and intricate legal situations to the training data will improve its versatility.

TABLE II EVALUATION METRICS

Metric	**Score**
Perplexity (PPL)	48.1105
BLEU Score	1.0
ROUGE-1	1.0
ROUGE-2	1.0
ROUGE-L	1.0

Moreover, optimizing generation parameters like temperature, top-k, and top-p sampling can inject controlled variability to make the produced text more varied while retaining legal correctness. Real-world trials on new, unseen legal cases will also be essential in confirming its generalization capacity from training data. Carrying out human assessments by legal experts can gain further insight into how effectively the model maps to legal argumentation and drafting customs.

In summary, these findings show that the legal document generator is an effective AI tool that can assist legal pro- fessionals in automating, standardizing, and streamlining the document preparation process. With additional enhancements, it can become an essential tool for legal research, contract drafting, and litigation support.

CONCLUSION

This work aims to develop a real-time document genera- tion system for AI-based Plaint generation using the GPT-2 model. By leveraging Generative AI, the system automates the creation of legal plaints, reducing the time and effort required for manual drafting. The dataset was meticulously processed and structured to fine-tune the model, ensuring high- quality, coherent, and legally relevant document generation. The integration of pre-trained language models and specialized legal datasets improved the model's contextual understand- ing, enhancing the accuracy and reliability of the generated plaints. Future developments can focus on refining the model's legal reasoning capabilities and integrating it with case law databases to provide more contextually aware outputs. Addi- tional enhancements, such as an interactive user interface and multi-language support, will make the system more accessible to legal professionals across different jurisdictions. Overall, this project highlights the potential of AI-driven automation in the legal sector, offering an innovative solution to streamline document creation and support legal practitioners in their daily workflow.

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Secure Scene: Intelligent Detection for Fire and Accident

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ABSTRACT

The demand for responding to emergencies in a fast and efficient manner has increased, and this in turn have helped in the advancements in the automated safety systems. This project, SecureScene: Intelligent Detection for Fire and Accident, provides an answer containing Artificial Intelligence and Internet Of Things technology stacks. These help for real-time detection and response to incidents like fire and accidents. This system provides image capturing technology along with Convolutional Neural Network (CNN) to analyze spatial and temporal features of video data to ensure accurate detection. It is designed for efficient working on edge devices. This system lessens the facts of false positives and provides reliable real-time notifications to government public services to decrease the rate of response time. In this proposed system , by leveraging AI with real-time image analysis sets a benchmark in safety measures and emergency services.

Index Terms—Artificial Intelligence, Internet of Things, Convo- lutional Neural Network(CNN), Spatial and Temporal Features, Image analysis.

INTRODUCTION

In today's constantly moving and changing urbanized world, ensuring public safety and responding quickly and efficiently to various emergencies have become increasingly important. Incidents such as fires, accidents and many other critical situations pose enough threats to life and property, that re- sults in requiring immediate response from necessary public authorities. Traditional surveillance systems rely too much on human intervention that can cause delays in response times and reduce efficiency of management of efficiency. Inspired by CNN's huge opportunities, [1] This paper offers a light- weight CNN based on the Squeeze-Net model to detect fire hazards on CCTV networks which mainly focuses on image classification. Therefore, since our proposed system comprises of both accident and fire detections and since we need a more accurate location analysis, we use YOLO model.

In this system, CCTV's are used as the input source, and the system uses AI-driven computer vision algorithms to check live video footages and detect incidents like fires or accidents in real time. Upon detecting an accident (be it fire or traffic accident), the system immediately alerts the relevant public authorities (police station, hospital, fire station) thereby assuring a response that is well coordinated and timely. The system supports scalability, allows deployment across various environments while maintaining cost efficiency and maintainability. As urban areas keep on expanding and growing, demands rise, specially the need for response in emergency situations.

Our proposed work, SecureScene is a useful and creative solution that has been found to increase public safety by making use of advanced AI, computer vision and IoT technol- ogy stacks to detect emergency situations related to fire and accidents in real-time. Through cameras installed near most prime locations, this system analyzes video data to identify vehicle-to-vehicle collision, traffic accidents, fire accidents, etc. When such an emergency situation is detected, the system alerts the admin and send notifications to the nearest police stations, hospitals and fire stations.

Here is a breakdown of each part of the system:

- Camera Input: The system starts with a camera that cap- tures real-time video footage of the area being monitored.
- Datasets: There are two primary datasets used to train the model: fire dataset, accident dataset
- Image Preprocessing: The input from the camera goes through an image preprocessing stage - resizing , nor- malization
- CNN Model: CNN model processes the preprocessed images to detect specific incidents. The CNN model has three modes: fire Mode, accident mode, normal mode
- Database: This database stores records of incidents, timestamps, and potentially other contextual data.
- Alert System: When an incident (fire or accident) is detected and logged into the database, the system triggers an alert. The alert system is structured to notify relevant authorities based on the type of incident: accident alert, fire alert.

In short, this system provides real-time detection and alert generation for traffic accidents and fires using a CNN model and image processing techniques. The system preprocesses images obtained from the camera, processes them with a CNN model to point out incidents and stores the data into a database. In addition, it sends emergency alerts to the responders depending on the type of incident occurred.

RELATED WORKS

Several methods which help to detect accident and fire have been developed. Many techniques are used to detect accident and fire that uses different models and techniques to provide an efficient system better than the then existing systems. Some of the ways of these detection are:

A Novel Lightweight CNN Model for Real-Time Video Fire-Smoke Detection, introduces a new lightweight CNN aimed at detecting fire and smoke in real-time using video data. [2] Unlike conventional satellite-based monitoring with the disadvantages of time delays and low coverage, Edge- FireSmoke provides instant wildfire detection and generation of alerts. The model was trained on two data sets—one based on CCTV video and another on UAV images—with high accuracy (98.97) and quick classification time (30 ms per image). Through the reduction of CNN's convolutional layers and its lower memory usage, the system can be operated on low-power devices, and hence it is best suited for autonomous wildfire surveillance in remote regions. The study showcases EdgeFireSmoke as the superior model over other models based on efficiency, accuracy, and computational expense, which makes it a viable option for early detection of wildfires and conservation of the environment.

Small fire targets, smoke interference, and complex back- grounds often compromise detection accuracy. [3]The authors introduce a method that utilizes transfer learning alongside an improved Faster RCNN architecture, referred to as TI- Faster RCNN. The model features a fusion structure, PPM and employs an attention mechanism (SENet) to replace traditional fully connected layers, boosting both efficiency and accuracy. Experimental results indicate that the proposed method achieves an AP of 93.7 percent.

A new method for identifying traffic accidents in videos taken by cameras mounted on vehicles within Vehicular Ad Hoc Networks (VANETs)introduces a detection framework that operates from coarse to fine, integrating both temporal and spatial feature encoding through a multilayer neural network.

[4] Temporal features are utilized to group frames and pin- point potential accident frames. These frames undergo further analysis with spatial features to verify accidents. Experimental results from the DoTA dataset highlight the framework's effectiveness, showing a 15.2 percent increase in temporal localization accuracy compared to current methods.

Based on a NIR camera, privacy preservation can be ensured without any compromise of vital visual information from fire incidents. Using both spatial and temporal features of the fire, this system makes use of a lightweight CNN for high real- time accuracy of the model. [5] It is designed for low-power devices like IoT systems. The system focuses on the three main aspects of robust fire detection, operational efficiency, and privacy preservation.

A system meant to address issues of urban traffic safety was introduced. It studies environmental data based on patterns or conditions that characterize accidents. [6] The system has proactive alert provisions, enabling drivers to take prior preventive measures, thus being less likely to cause accidents. It provides a scalable solution as it integrates with smart city infrastructure and urban safety initiatives, making the whole concept of road safety and optimized traffic management in urban areas a realistic dream.

By integrating the feature extraction capabilities of deep CNN with the classification precision of SVMs, it becomes feasible to achieve the proposed system with high accuracy. [7] The methodology uses advanced image processing techniques and a large collection of fire and non fire images to train the model. Designed for real-time implementation, the system is scalable and suitable for deployment in resource-constrained environments,like edge devices, offering a proactive solution for mitigating the devastating impact of forest fires.

To address the problem of detecting traffic accidents from surveillance or dashcam videos, which are often sparse and unpredictable new methods were proposed. [8] The authors present a knowledge distillation framework that enhances fine- grained accident detection with limited data. This is achieved by transferring knowledge from a large pre-trained model to a smaller, more efficient model. It utilizes logit mimicking, feature imitation, and task-specific distillation for accident classification, temporal-spatial detection, and severity estima- tion.

A framework for the real-time detection, localization, and analysis of road accidents in video feeds was initiated. The system proposed by the authors supercedes problems of inad- equate data and computational inefficiency in existing systems.

[9] The approach consists of video segmentation in three phases such as preaccident, accident, and postaccident, and obtaining interaction proposals for further refinement based on a two-phase algorithm so that accuracy gets improved.

A lightweight solution for efficient detection of forest fire using the integrated unmanned aerial vehicles (UAVs) and mobile edge computing is used to introduce the detection model in terms of a much-improved version of the YOLOX- based detector coupled with improved techniques for better segmentation. [10] Leveraging edge computing in the system leads to achieving real-time fire detection and segmentation with reduced latency and lower computational costs, suitable for deployment on UAVs.

These researches emphasize the efficiency of deep learning, transfer learning, and edge computing for real-time detection of fire, smoke, and accidents. Lightweight CNNs, UAV-based YOLOX models, and TI-Faster RCNN enhance the accuracy of fire detection, while spatiotemporal analysis and knowl- edge distillation increase accident detection in VANETs and surveillance videos. Table 1 specifies more details on each of the refered papers to get more information on the model and proposed systems.

COMPARISON STUDY

TABLE I TECHNIQUES, MERITS, AND DEMERITS OF VARIOUS ACCIDENT AND FIRE DETECTION MODELS

TITLE	TECHNIQUES	MERITS	DEMERITS
Multiple-Level Distilation for video Fine-Grained Accident Detection. 2024 (Hongyang Yu,Xinfeg Zhang,Yaowei Wang,Qingming huang,Baocai Yin)[1]	• TensorFlow Network • Natural Language Processing • I3D Network • Video Processing • multitask learning	• Efficient computation • Real-time monitoring of sentiment. • Comprehensive analysis • Improved accuracy • Data Efficiency	• Complex Training • Limited Real-time capability • Performance trade-offs
Object Interaction-based Localization and Description of Road Accident Events us- ing Deep Learning, 2022 (Kamalakar Vi- jay Thakare, debi Prosad Dogra, Heeseung Choi, Haksub Kim, Ig-jae Kim) [2]	• YOLOv3 • K-Body Proposal Algorithm • Class Activation Mapping • Mobilenet	• Accurate Loacalization • Efficiency • Object Interaction Based • Scalability	• Dependency on camera view • Vulnerable to Object detection Quality • Limited temporal analysis
Fast Forest Fire Detection and Segmenta- tion Application for UAV-Assisted Mobile Edge Computing System (Changdi Li, Xi- aoyu Wu, Lulu Yang, Shengjn Wang) [3]	• YOLOX Network • Edge Computing System • HSVcolor Space	• High Efficiency • Cost-Effective and Scalable • Real-Time Processing	• Limited Generalization • Computational Limitations • Complexity in Setup
EdgeFireSmoke: A Novel Lightweight CNN Model for Real-Time Video Fire-Smoke Detection(Jefferson Silva, Chenxi	• CNN • Edge Devices • TensorFlow	• High Accuracy • Real-Time Performance	• Limited to day-time use • Low

TITLE	TECHNIQUES	MERITS	DEMERITS
Huang, Fabricio Gonzalez Nogueira and Victor hugo c. de albuquerque, Surbhi Bha- tia, Senior member, IEEE [4]	library • Unmanned Aerial Vehicles (UAV)	• Low Consumption Cost	Performance with CPU • Dependency on RGB cameras
Spatio-Temporal Feature Encoding for Traffic Accident Detection in VANET En- vironment (Zhili Zhou , Member , IEEE, Xiaohua Dong, Zhetao Li, Member, IEEE, Keping Yu, Member, IEEE, Chun Ding and Yimin Yang, Senior Member, IEEE)[5]	• Multilayer Neural Network • HOF • Faster R-CNN • SRLRR	• Accuracy • Efficiency • Addressing long tailed distribution	• High Complexity • Potential for High Computational Load • Dependency on Object Detection Quality
Aerial Forest Fire Detection Based on Transfer Learning and Improved Faster RCNN (Feifei Xie, Zhiqing Huang) [6]	• Deep Learning Frameworks - Pytorch • Transfer Learning • faster R-CNN • SENet	• High Accuracy • Efficient Real-time performance	• Dataset Deependency • Limited multi-target detection • Computational cost
Privacy-Preserving Efficient Fire Detection System for Indoor Surveillance, 2022 (Ankit Jain and Abhishek Srivastava) [7]	• NIR • ST-FDS • Real-Time Frame Processing	• Privacy Preservation • Reduced False Alarms • High Detection Accuracy	• Limited Visibility in Privacy Mode • High Initial Setup Cost • Dependent on Camera Positioning
Sensing Accident-Prone Features in Urban Scenes for Proactive Driving and Accident Prevention, 2023 (Sumit Mishra , Praveen Kumar Rajendran, Luiz Felipe Vecchietti, and Dongsoo Har, Senior Member, IEEE) [8]	• DBSCAN Algorithm for Hotspot Identification • Visual Notification System via HUD • Image Processing Pipeline • CAM	• Accurate Detection of Accident Hotspots • Visual Notifications through HUD • Use of Real-World Data • Mobile and web accessibility	• Contextual Limitation in Street View Images • Weather and Time of Day Constraints
Forest Fire Detection with Combined SVM and Deep CNN Approach,2024 (Bendjillali Ridha Ilyas, Bendelhoum	• SVM • Edge Computing	• Improved Detection Accuracy	• Dependency on Dataset Quality • Limited

TITLE	TECHNIQUES	MERITS	DEMERITS
Mohamed Sofiane, Tadjeddine Ali Abderrazak, Kamline Miloud, Frioui Kamila, Bahidja Boukenadil (ICEEAC)) [9]	• Hybrid Model • Data Augmentation	• Robust Feature Extraction • Lightweight and Scalable	Contextual Awareness • Integration Challenges • Computational Complexity

PROPOSED SYSTEM

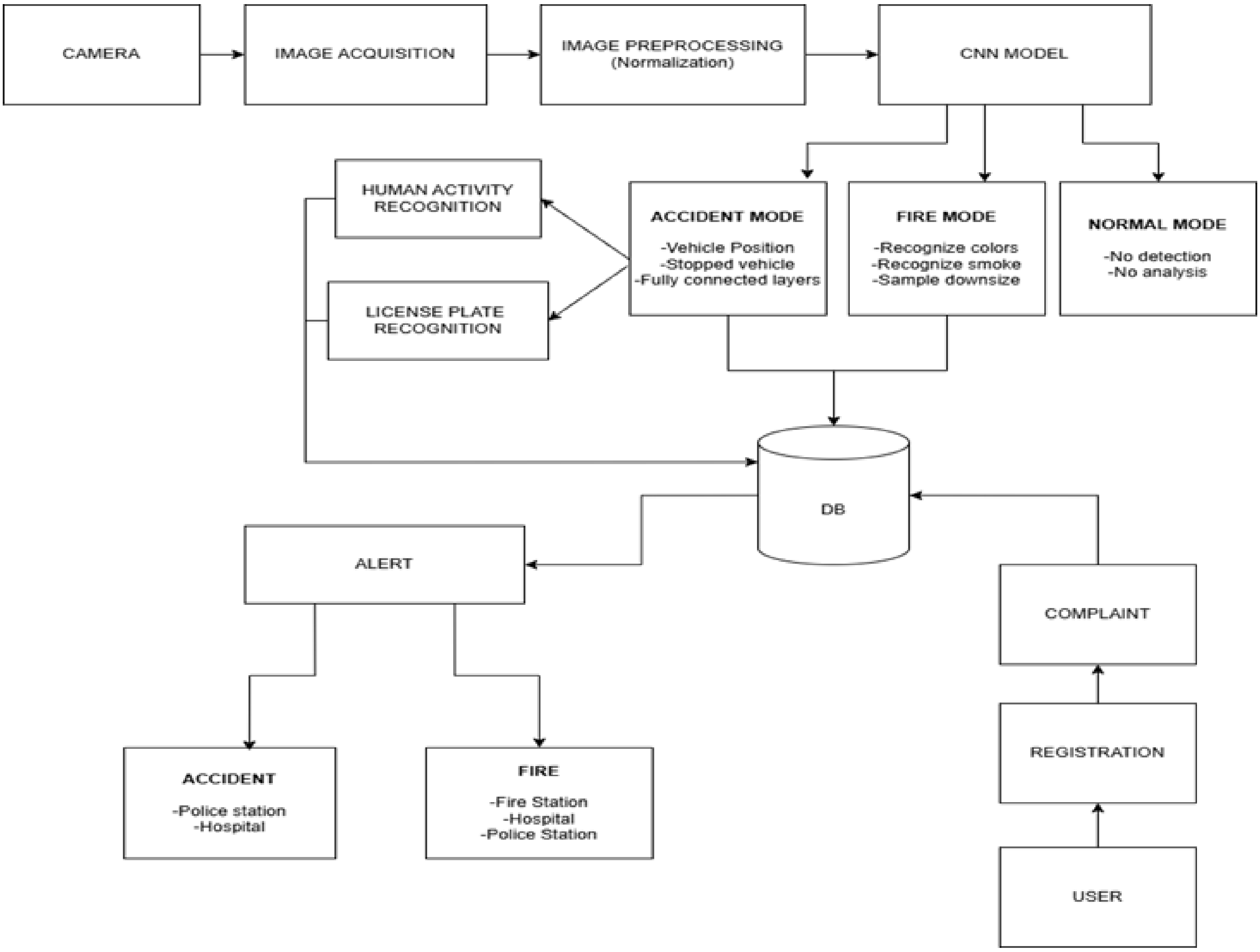

Fig. 1. Proposed System of SecureScene

Figure 1 shows the architecture of the proposed system that involves the development of an autonomous system that detects fire and traffic accidents and also sends alerts to public authorities

A. Image Acquisition

CCTV continually records videos the environment.Images are extracted from these video files for better analysis. The type of datasets used for training are mentioned below.

1) Dataset: Four types of datasets were used for accident and fire detection. The datasets are classified as :

   a) Fire Dataset - 3000-4000 images of fire for fire detection.

b) Non-fire Dataset - 2000 images approx. for instances without fire for accurate fire or non-fire analysis.
c) Accident dataset - 1500-2000 images for accident detection. It consists of images with cars and other objects being included in an accident.
d) Non-Accident dataset - 2000 images approx. for accurate analysis of accident detection. The input size of these datasets are 416 X 416.
e) Human Activity dataset- 2000 images of movement and stillness.
f) License plate dataset- 2000 images approx.

B. Image Preprocessing

The video files are converted into multiple frames at each interval and these frames are of the form of images. These images are then resized to give in to the model. Features are extracted while maintaining quality of the system. Normalization is done to extract features of the captured image.

C. Accident Detection

Accident is detected if there occurs an accident through the YOLOv8 model. YOLOv8 is an object detection model that performs well with a high precision and accuracy rate for object detection. Human Activity is detected to check the number of people inside the vehicle or to check if the people are moving or unconscious in the vehicle.

D. Fire Detection

Fire is detected if the extracted frame consists of fire. This is detected through the YOLOv8 model. It performs object detection along with precise feature extraction since fire is abstract and each features need to be taken appropriately.

E. Alert Generation

Once an incident has been detected, a beep alert is sounded on the admin system and then the alert is send as an email notification to the respective authorities. If fire is detected, alert is sent to fire station and hospitals and if an accident is detected, email is sent to the police station and hospitals.

METHODOLOGY

YOLOv8 (You Only Look Once v8) is an efficient real- time object detection algorithm that is very fast and accurate. YOLOv8 is more advanced compared to its earlier versions since it employs a deeper network and multi-scale predictions. YOLOv8 contains:

- Input Layer – Accepts images of any dimensions but usually 416×416 or 608×608.
- Feature Extractor (CSPDarknet-53) – Handles images through the use of convolutional layers. Feature Refine- ment using Path Aggression Network.
- Detection Layers – Outputs bounding boxes at three scales from feature maps of various layers. Predicts confidence scores.
- Non-Maximum Suppression (NMS) – Discards overlap- ping detections to retain the best one.

Working process of algorithm:

a) Step 1: Load the YOLO model that contains the learned weights. This defines the architecture of the model.

b) Step 2: Image Processing of input images. The input here is video file form from video camera where each frames are extracted as images.It extracts the height and width needed for scaling detections.
c) Step 3: Blob Creation where the images are resized to 416 X 416. Normalizes the input for faster learning.
d) Step 4: Frame is passed through the model and if a fire or accident is detected, an alert is generated.
e) Step 5: Extract object detections and filter out detec- tions.
f) Step 6: If an accident is detected,the system extracts the license plate using Optical Character Recognition. It also monitors human activity like moving or unconscious.

Algorithm 1 YOLOv8-Based Fire and Accident Detection Algorithm
Require: Image I, Pre-trained YOLOv8 Model MY OLO
Ensure: Classification of fire and accident events

a) Load dataset D containing fire, accident, license plate.
b) Preprocess images (resize, normalize): I′ = I .
c) Define YOLOv8 Architecture:
    a. Backbone: CSPDarknet-53 Ft = Darknet53(It) uses 53 convolutional layers.
    b. Neck: Path Aggregation Network (PAN) for fea- ture fusion
    c. Head: Bounding boxes, confidence scores, and class labels predicted using sigmoid activation: Yt = σ(WXt + b)
d) Feed frame It to MY OLO and get detection results: Yˆt = MY OLO(It)
e) Apply Non-Maximum Suppression (NMS)
    a. Compute IoU for overlapping detections: IoU = Aintersection Aunion
    b. Remove redundant detections if IoU exceeds a threshold τ .
f) If detected class is Fire or Accident and confidence C > τ , then:
    a. Output ”Fire/Accident Detected”
    b. Save detected frame and alert authorities: send_alertIt, (location)
g) Perform License Plate Recognition (LPR) if a vehicle is detected:
    a. Extract plate region and apply Optical Character Recognition (OCR): LPR(It) = OCR(crop(Bt))
h) Detecting the presence of humans.
    a. Using recognition model to detect humans: At = MAR(It)
    b. If abnormal activity is detected, raise an alert
i) Continue processing until an emergency stop signal is received.

=0

g) Step 7: The frames are continuously analyzed for an accurate analysis.

PERFORMANCE ANALYSIS OF PROPOSED SYSTEM

Accident and Fire Detections are the main two detections that occur in our proposed work. License plate recognition and human activity recognition (HAR) come as subcategories in detection since it occurs only if an accident is detected. Our system was trained on two models mainly and thereby chose the YOLO model as the final.

TABLE II PERFORMANCE METRICS

Model	Loss	Accuracy	Precision	Recall
Inception v3	0.0739	0.9658	0.2379	0.0008
YOLO v8	0.0356	0.9788	0.9765	0.9256

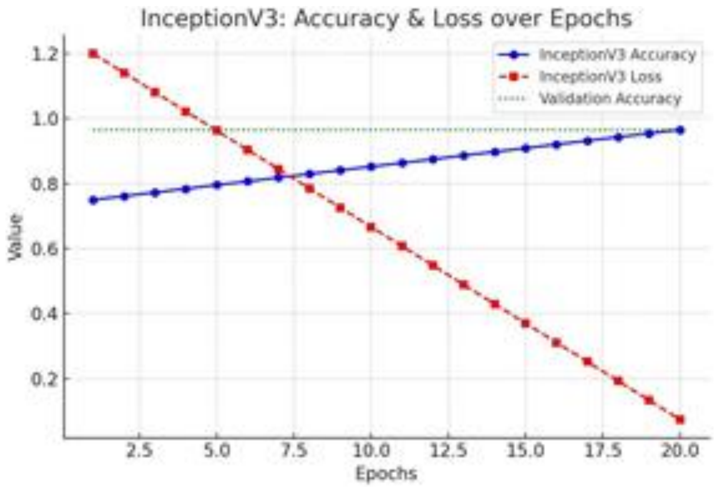

Fig. 2. Inceptionv3 loss-accuracy graph for proposed work

Table II shows the compared values of the two models and analyzes the values to provide better output. Inceptionv3 doesnt perform well in terms of accuracy and precision since it doesnot use high level extraction features and techniques and hence gives only a basic detection value and that can result in wrong outputs. YOLOv8 gives a high precision value com- pared to Inception V3 and therefore detects more accurately and is a much reliable model with less false positives.

Fig.2 gives the graph for loss and accuracy values of Inception v3 model. Here the loss values. Accuracy Graph (Blue) → Starts at 0.75, reaches 0.96,Loss Graph (Red) → Starts at 1.2, reduces to 0.0739.

Fig.3 gives the graph for loss and accuracy values of the YOLOv8 model. Here the Accuracy and loss values are : Accuracy Graph (Blue) → Starts at 80 percent, reaches 99 percent (More efficient than InceptionV3).Loss Graph (Red) → Starts at 0.9, reduces to 0.03 (Faster convergence).

From these graphs, we can conclude that YOLOv8 is much efficient than Inception V3 and it produces better results in terms of accuracy and precision. YOLOv8 is much deeper and complex model with multiple convolutional layers and feature extraction techniques that makes it much better than Inception v3.

CONCLUSION

The "SecureScene: Intelligent Detection for Fire and Ac- cident" system utilizes a CNN-based image detection algo- rithm alongside frameworks like TensorFlow and OpenCV to identify and categorize fire and traffic accidents in real- time. This innovative system aims to transform public safety and emergency response by offering an efficient, automated method for detecting incidents and quickly alerting the relevant authorities, including fire stations, police, and hospitals. By combining YOLOv8 for real-time object detection and CNN-based models for further classification and fine-tuning, the sys- tem maintains high accuracy and responsiveness. The capacity to crop images from live video streams, classify them as fire, accident, or normal occurrences, and forward specific alerts to the corresponding emergency responders (fire stations, police, hospitals) greatly enhances public safety interventions. The integration of AI and IoT makes response to incidents faster than with the use of conventional surveillance systems.

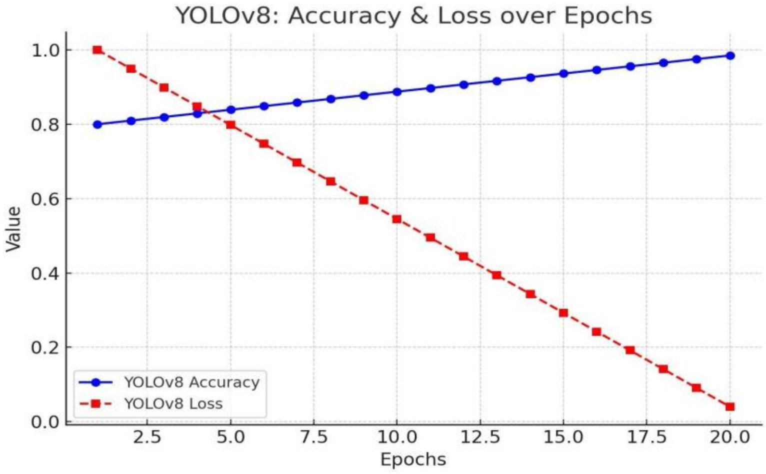

Fig. 3. YOLOv8 loss-accuracy graph for proposed work

The above comparison identifies how YOLOv8's effective- ness in processing real-time video frames and CNN's precision in classification can be blended together to develop an effective real-time system for emergency detection that advances public safety and emergency response. For example, fire detection alerts are sent directly to fire stations, while notifications related to accidents are routed to police and hospitals. This customized approach reduces delays and enhances resource allocation during emergencies. In summary, the "SecureScene: Intelligent Detection for Fire and Accidents" system highlights the effectiveness of CNNs in incident detection and illustrates the potential of integrating AI and IoT for public safety initia- tives. The system overcomes the shortcomings of traditional surveillance methods.

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Illegal Car Parking Detection

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ABSTRACT

Illegal parking contributes significantly to traffic congestion and public safety concerns. Traditional enforcement methods, such as manual patrols and static CCTV cameras, are often inefficient, costly, and lack flexibility. This study presents an intelligent web application that provides real-time alerts to users when vehicles are parked illegally in designated parking slots. Users can define and input parking slots, and the application monitors these areas using image-based detection to determine whether a vehicle is parked incorrectly. By leveraging advanced deep learning models like VGG-16 and ResNet, the system ensures high accuracy in identifying parking violations. This automated approach enhances the efficiency and accuracy of parking management while reducing the need for manual oversight, offering a scalable and user-friendly solution for individuals, businesses, and municipalities to enforce parking regulations effectively, ultimately contributing to improved traffic flow and urban safety.

Index Terms—VGG-16, YOLOv3, CNN, Deep Learning.

INTRODUCTION

Illegal parking in designated no-parking areas is a persistent problem in urban and suburban regions, contributing to traffic congestion, reduced pedestrian safety, and inefficient use of roadways. Traditional enforcement mechanisms rely heavily on manual monitoring and ticketing, which are labor-intensive, costly, and prone to inconsistencies. Additionally, static CCTV cameras have limited coverage and cannot provide real-time alerts efficiently. Addressing this challenge requires an in- telligent, automated solution capable of monitoring restricted zones and providing timely notifications.

This work introduces a web-based application that leverages the power of computer vision and deep learning to detect illegal parking in no-parking areas. By allowing users to define custom no-parking boundaries through image uploads and annotations, the system provides flexible and adaptable monitor- ing for various environments. Advanced deep learning models, specifically VGG-16[1] is employed for feature extraction and classification. VGG-16 captures intricate details from input images, while ResNet enhances accuracy by overcoming the vanishing gradient problem. This combination ensures reliable identification of vehicles parked in restricted zones.

If a violation is detected, the system sends an immediate alert to users, enhancing enforcement efficiency while mini- mizing reliance on manual oversight.Section II reviews related works that have explored computer vision and deep learning for parking management. Section III presents the proposed system, detailing its architecture, dataset, and deep learning models. Section IV evaluates the system's performance using key metrics such as precision, recall, and F1-score. Finally, Section V concludes the paper by summarizing the contribu- tions and discussing potential future enhancements, including integrating additional models and expanding the dataset for improved accuracy across diverse environmental conditions.

RELATED WORKS

Several studies have explored the use of computer vision and deep learning for parking management, focusing on de- tecting illegal parking in urban environment. One such study, titled Real-time Illegal Parking Detection Algorithm in Urban Environment,[2] presents a method for real-time detection of illegal parking using deep learning models, emphasizing the importance of urban settings in improving parking regulation. The proposed system is a real-time illegal parking detection solution using in-vehicle cameras and a deep learning-based algorithm. It eliminates the need for labor-intensive manual patrols and expensive CCTV installations by leveraging in- vehicle cameras for mobile and adaptable monitoring. A novel voting-based algorithm built on YOLOv3 detects illegal parking violations in real time, classifying vehicles into one legal and six illegal parking types. The system introduces an innovative labeling method, minimal illegal units, which reduces annotation effort by focusing on the smallest area necessary to detect violations. The dataset, comprising over 10,000 high-quality labeled images, was collected under di- verse environmental conditions, making the system robust against changes in illumination and weather.

The system achieves high precision , recall , and an F-score, demonstrating strong detection performance and generaliza- tion. It outperforms conventional detection models like SSD and ResNet in terms of accuracy and efficiency. The algorithm is tested extensively in urban environments, proving resilient to challenging scenarios such as low lighting, rain, and sunspots. By integrating cost-effective technology with scalable and robust detection capabilities, the system provides a practical benchmark for future developments in intelligent transporta- tion systems. The proposed system achieves a balance between speed and accuracy, making it an effective solution for real- time illegal parking detection. Its unique combination of in- vehicle cameras, YOLOv3-based deep learning, and innovative labeling ensures cost-efficiency and practical applicability in urban environments.

The study, Development of a data-driven on-street parking information system using enhanced parking featutres, [3] is a data-driven Street Parking Information System (OSPI)] de- signed to optimize urban parking by minimizing search time and reducing traffic congestion caused by cruising vehicles. Unlike traditional models relying heavily on costly manual observations or outdated spatial and temporal data, this system employs dynamic features derived from real-time parked-in and parked-out events, aggregated spatial parking capacities, and supplemental data such as weather conditions. By leverag- ing machine learning models like XGBoost and Random For- est, the system predicts parking availability efficiently while introducing a Parking Behavior Change Detection (PBCD) model. This PBCD component dynamically adapts to changes such as construction or rule alterations by flagging disruptions and updating the availability model, reducing the dependency on frequent manual updates. The framework ensures robust, adaptive parking solutions for users while maintaining lower operational costs and scalability.

The OSPI system demonstrated competitive performance compared to industry benchmarks, achieving reliable predic- tions without extensive reliance on historical ground truth data. It aggregates key spatial features at multiple levels, enhancing model generalization. Parking events-based features enabled the system to remain dynamic and adapt to real- world disruptions. The PBCD model further improved system accuracy by identifying and responding to long-term changes in parking behavior. Evaluations showed that the proposed approach could match or outperform existing systems, es- pecially in environments with abundant real-time parking data. Future enhancements include integrating more detailed point-of-interest data and expanding validation mechanisms, emphasizing the system's potential as a scalable, intelligent parking management solution for urban cities.

The study Vehicle-Road Environment Perception Under Low-Visibility Condition Based on Polarization Features via Deep Learning [4] addresses the limitations of traditional vehicle-road perception systems under low-visibility condi- tions such as haze, rain, and nighttime. Adverse weather often reduces the visibility of critical traffic elements like vehicles, lane lines, and signage, leading to poor detection and segmentation performance. To overcome this, the study proposes a novel approach using polarization imaging com- bined with deep learning. Polarization imaging captures optical properties like polarization angle and degree of polarization, which are less affected by environmental challenges. By fusing polarization features with traditional intensity images, the system provides a richer dataset for semantic segmentation using the U-Net deep learning model, resulting in more accurate identification of traffic elements even under difficult conditions.

Experimental results demonstrate that polarization fusion images significantly outperform intensity-based methods, es- pecially in detecting small and distant objects such as lane markings and signage. The system achieves high performance metrics like mean intersection over union (MIOU) and mean pixel accuracy (MPA) across diverse low-visibility scenarios. This innovative method ensures enhanced safety and reliability for traffic systems, making it suitable for applications in autonomous vehicles and advanced driver-assistance systems (ADAS). Future work aims to combine this approach with infrared imaging for further improvements in robustness and adaptability.

The study introduces a novel semi-supervised learning method designed to reduce the human effort required for labeling georeferenced imagery [5], often used in environmen- tal monitoring. The proposed approach leverages a Location Guided Autoencoder (LGA) to extract latent representations from unlabelled datasets. It then uses hierarchical cluster- ing to prioritize a subset of images for human annotation while assigning predictive pseudo-labels to the remaining unlabelled images. These steps allow convolutional neural networks (CNNs) to achieve high classification accuracy with significantly fewer annotations, addressing challenges such as imbalanced class distributions and limited dataset transfer- ability. The system is evaluated across aerial and seafloor imagery datasets, demonstrating its ability to achieve results comparable to traditional CNNs trained with thousands of annotations using just tens or hundreds of labeled samples.

The experimental results highlight the efficiency and robust- ness of the method, particularly for datasets with rare classes and skewed distributions, which are common in environmental applications. By reducing the annotation effort by an order of magnitude, the method enables dataset-specific CNN training, making it highly practical for scenarios where cross-dataset transferability is limited. Furthermore, the approach improves learning efficiency without compromising accuracy, ensuring consistent performance across varying dataset sizes. This inno- vative framework sets the stage for more efficient and scalable machine-learning solutions in environmental monitoring and related domains.

PROPOSED SYSTEM

The proposed illegal parking alert system is a web applica- tion designed to address parking violations by providing real- time alerts to users about illegal parking activities in desig- nated parking slots. This system leverages advanced image processing and deep learning techniques to ensure accurate detection and timely notifications.

The process begins with user-inputted parking slot data and images, which form the basis for monitoring. In the architecture shown in Fig.1 users upload images of the parking slots they wish to monitor. When a vehicle is detected in a parking slot, the uploaded images are transferred to the image processing stage, where they undergo pre-processing to remove noise and enhance relevant features for accurate analysis.

The pre-processed images are subsequently passed through a pipeline of deep learning techniques. This includes two primary models: VGG-16 and ResNet, both renowned for their superior performance in image recognition tasks. VGG-16 is utilized for feature extraction due to its deep architecture and ability to capture intricate details, while ResNet is employed for classification, taking advantage of its residual learning capabilities to improve accuracy and mitigate the vanishing gradient problem.

After the deep learning analysis, the system evaluates the results to determine if a parking violation has occurred. If illegal parking is detected, the system triggers the notification system to send immediate alerts to the users, informing them of the violation. Additionally, the system provides a user dashboard, where users can view real-time updates, historical data, and detailed reports on parking activities.

All processed data and analytical results are stored in a secure Database, ensuring that the information is logged for future reference or further analysis. This workflow efficiently utilizes deep learning methods for real-time image processing and decision-making, promoting organized parking, reducing traffic congestion, and enhancing overall traffic flow in urban areas.

A. Dataset

For the illegal parking detection system, the dataset focuses exclusively on No Parking Zones, providing detailed and diverse imagery to train and evaluate the model effectively. The dataset is curated to cover various real-world conditions and scenarios relevant to illegal parking in restricted areas.

1) Dataset Categories: The dataset is categorized into two main groups to distinguish between legal and illegal activities in designated No Parking Zones:

Occupied Parking Space:

- Vehicles parked in areas marked as ”No Parking,” includ- ing:
  - Parking on pedestrian pathways marked with ”No Parking” signs.
  - Unauthorized parking in front of fire exits, drive- ways, or hospital entrances.
- Scenarios include:
  - Spaces near intersections, metro stations, or schools. Empty No Parking Zones:
- Images of areas marked as ”No Parking” without any vehicles obstructing the zone.
- Examples include:
  - Empty pedestrian paths with ”No Parking” signs.
  - Clear driveways, fire lanes, and emergency exits.
  - Roadsides with temporary or permanent no-parking markings.
- Captured under various conditions to ensure diverse cov- erage.

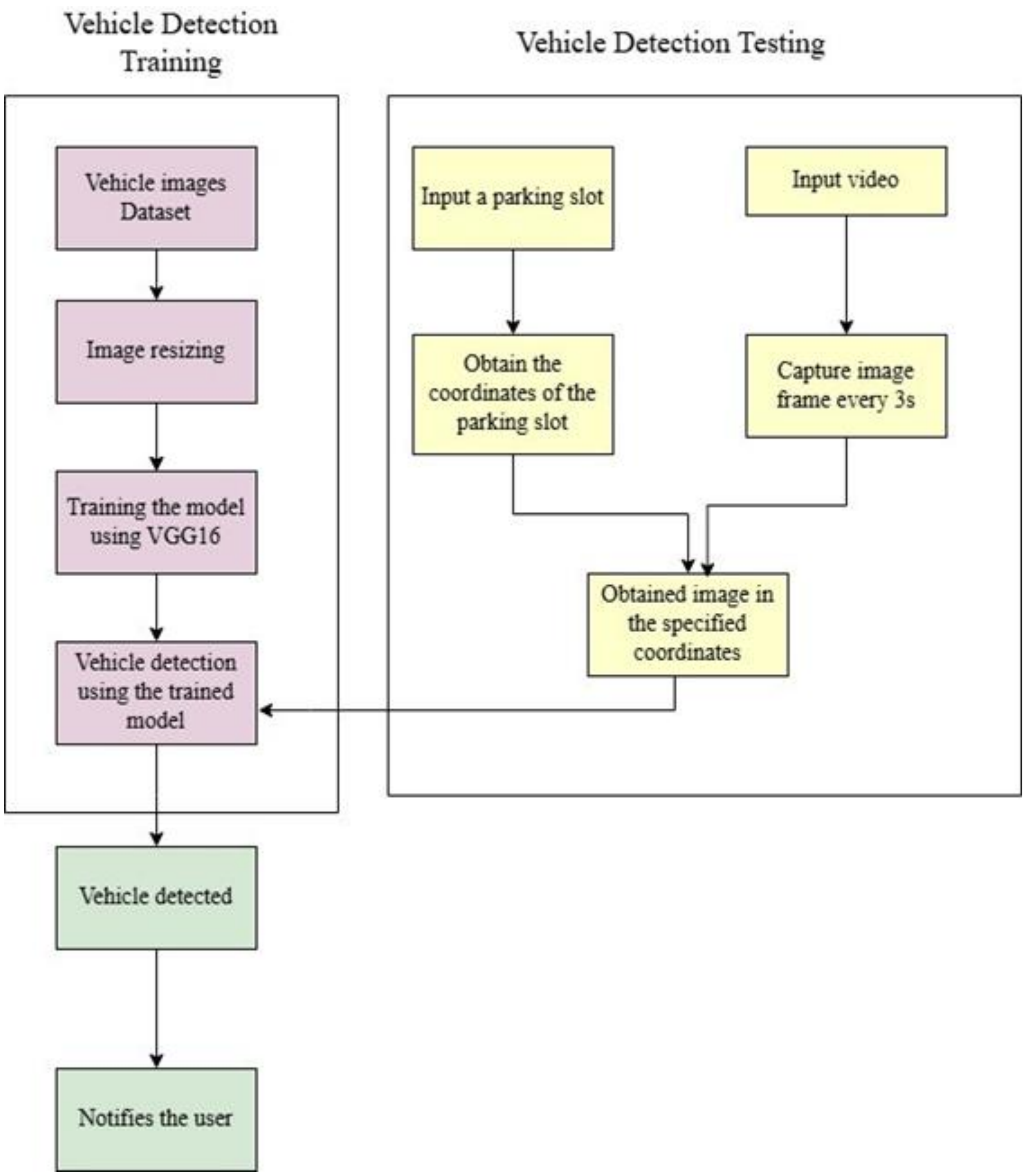

Fig. 1. Illegal Car Parking Detection System Architecture

B. DEEP LEARNING MODEL - VGG-16

VGG-16 is a convolutional neural network (CNN) archi- tecture known for its simplicity and effectiveness in image classification and feature extraction tasks. Developed by the Visual Geometry Group (VGG) at the University of Oxford , it is widely used for transfer learning and as a backbone for many vision-based applications, including object detection.

1) Preprocessing:

- Input Data Transformation: Input images or video frames are resized to a fixed dimension (e.g., 48×48 pixels).
- Normalization: Pixel values are scaled to the range [0, 1] or standardized to have zero mean and unit variance.

- Bounding Box Labels: Parking areas and vehicles are annotated with bounding boxes and labeled as legal or illegal parking types.

2) Feature Extraction: VGG-16 is designed for hierarchical feature extraction using 16 convolutional layers. Key charac- teristics include:
   - Convolutional Layers: The model uses small receptive fields (3×3) to extract spatial features while preserving detailed information.
   - Pooling Layers: Max-pooling layers reduce spatial di- mensions, enabling the model to focus on the most significant features while reducing computational cost.
   - Deep Feature Representation: Deeper layers in VGG-16 capture complex patterns such as shapes and textures, which are useful for distinguishing between legal and illegal parking.
3) Detection Process: VGG16 can be adapted for detection tasks using region proposal methods or integration with object detection frameworks. For parking violation detection:
   - Region Proposal: Methods like Selective Search or Region Proposal Networks (RPNs) generate candidate bounding boxes.
   - Classification: Features extracted by VGG-16 are used to classify parking scenarios into legal or illegal categories.
   - Bounding Box Regression: Refines the location and di- mensions of bounding boxes.
4) Multi-Scale Detection: While VGG-16 itself is not in- herently multi-scale, it can be augmented with feature pyramid networks (FPNs) to detect objects of varying sizes, including small and large vehicles or parking spaces.
5) Post-Processing:
   - Non-Maximum Suppression (NMS): Removes overlap- ping bounding boxes by selecting the one with the highest confidence score.

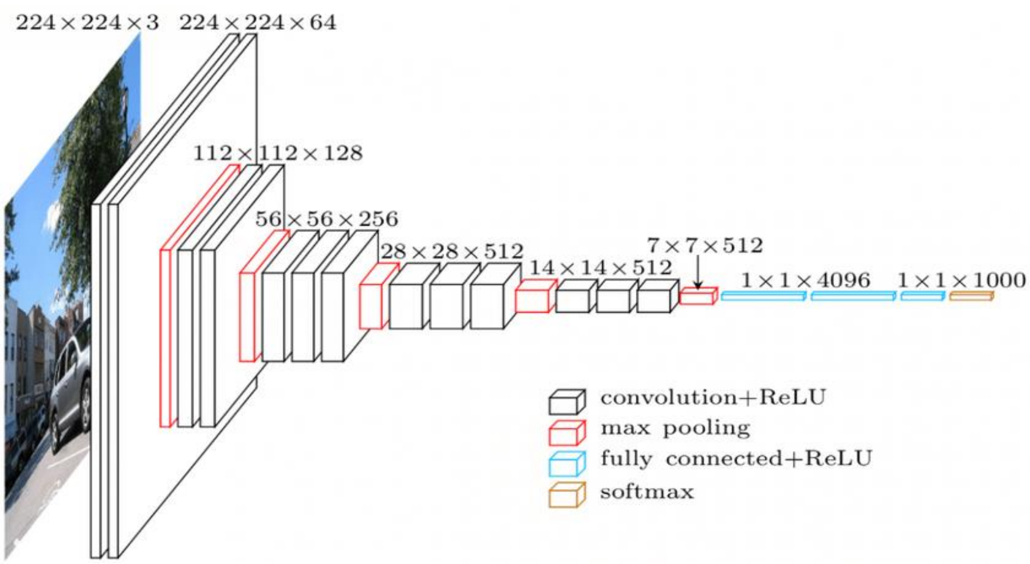

Fig. 2. VGG-16 model architecture (adopted from [14])

C. Fine-Tuning VGG-16

VGG-16 is pre-trained on large datasets like ImageNet and can be fine-tuned for domain-specific applications:

- Transfer Learning: The pre-trained weights are used as a starting point, significantly reducing training time and improving accuracy.

- Domain-Specific Training: The model is fine-tuned on the illegal parking dataset by adjusting weights to focus on parking-related features.
- Feature Extraction Layers: Earlier layers are frozen, while deeper layers are retrained to adapt to the specific task.

D. Model Training

Training VGG-16 for illegal parking detection involves:

- Data Preparation: The dataset is augmented with images of various parking conditions, ensuring diversity in envi- ronmental factors (e.g., lighting, weather).
- Optimization: Techniques such as learning rate schedul- ing and batch normalization improve convergence.
- Regularization: Dropout and data augmentation are used to reduce overfitting.
- Loss Function: Cross-entropy loss for classification and mean squared error for bounding box regression.

E. Model Deployment

- Real-Time Detection: The model operates in real-time to detect parking violations.
- User Notifications: Violations are highlighted with bounding boxes, and alerts are sent to users through mobile applications.
- Edge Computing: Lightweight implementations ensure compatibility with resource-constrained environments.

VGG-16 provides a robust and reliable foundation for image-based tasks like illegal parking detection. By leveraging transfer learning, domain-specific training, and deployment strategies, it can effectively detect parking violations in real- world scenarios.

Algorithm 1 Illegal Car Parking Detection System

1: Require: Input images I, Predefined parking slot data P , Deep learning models MVGG-16, Notification system N

2: Ensure: Detected violations V , User alerts A, Logged data L

3: V ← ∅ // Initialize violation set

4: A ← ∅ // Initialize alert set

5: L ← ∅ // Initialize log storage

6: while True do

7: for each image i ∈ I do

8: processedImage ← PREPROCESS(i)

9: features ← MVGG-16(processedImage) 10: classification ← MResNet(features) 11: timestamp ← GETCURRENTTIME()

12: if classification = Illegal Parking then

13: V ← V ∪ {(i, classification, timestamp)}

14: SENDALERT(i, timestamp, N)

15: A ← A ∪ {(i, Alert Sent)}

16: STOREINDATABASE(i, classification, timestamp) cities. Future enhancements may include integrating additional

17: else

```
      LOGEVENT(i, No Violation, timestamp)
      end if
      end for
      UPDATEDASHBOARD(V, A, L)
      SLEEP(Δt)        // Wait for next cycle
end while=0
```

TABLE I PERFORMANCE METRICS

	precisiom	recall	f1-score	support
no car	0.94	0.82	0.87	38
car	0.95	0.98	0.96	126

PERFORMANCE ANALYSIS

From Table I, it is clear that the model demonstrates excellent performance in detecting cars parked in no parking zones. It shows strong precision and recall for the ”car” class, which is the primary target of detection. The model has a slightly lower recall for the ”no car” class, which can be further optimized.

- Precision : The model predicted as ”car,” 95% of them were actually cars and when the model predicts ”no car,” 94% of the time, it is correct. While slightly lower than the precision for the ”car” class, this is still a strong result.
- Recall : The recall of 0.82 for the ”no car” class suggests that the model correctly identifies 82% of actual ”no car” instances. The recall value of 0.98 means that the model correctly identifies 98% of all actual ”car” instances.
- F1-score : The F1-score for the car class is 0.96, reflecting a balanced model that performs well in both identifying cars and minimizing false positives. The F1-score of 0.87 for the ”no car” class is a reasonable score.

CONCLUSION

The proposed illegal parking detection system presents an innovative and efficient solution to address the persistent issue of unauthorized parking in restricted zones. By leveraging deep learning models such as VGG-16 and ResNet, the system ensures high accuracy in identifying illegally parked vehicles and provides real-time alerts to users. The integration of image-based detection and automated notifications signif- icantly enhances enforcement efficiency while reducing the reliance on manual monitoring and costly infrastructure like CCTV cameras.

The system’s user-friendly web interface allows individuals and authorities to define and monitor parking zones dynam- ically, ensuring adaptability to various urban and suburban environments. Additionally, the secure database ensures that parking violation records are stored for future reference, promoting transparency and accountability.

With its ability to improve traffic flow, enhance pedestrian safety, and optimize parking management, the proposed sys- tem serves as a scalable and practical solution for modern deep learning models for improved detection accuracy, in- corporating mobile-based alert systems, and expanding the dataset to cover a wider range of environmental conditions. Ultimately, this system represents a significant step toward smarter and more efficient urban parking management.

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JUSTPING: Guarding Against Online Predators

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ABSTRACT

With the increasing cybercrime on social media, this study creates a strong security system based on sophisticated machine learning and behavioral techniques. It trains on labeled image datasets to identify explicit content and text datasets to recognize cyberbullying, depressive language, and off-topic posts. The main features include identifying inappropriate images, iden- tifying cyberbullying, classifying user comments, and recognizing depressive language for mental health assistance. The system also guards against misuse of images by continuous notifications. Using deep learning architectures such as CNN, LSTM and NLP, and combining them within an Android-based application, this solution increases user safety and authenticity on social networks.

Index Terms—Natural Language Processing, Long Short- Term Memory, Convolutional Neural Networks.

INTRODUCTION

Social media has been growing rapidly, transforming how people connect and interact within society. However, this growth has also led to a rise in cyber crimes, including harassment, cyberbullying, and the distribution of explicit materials. These activities pose significant risks to users [1], [2]. Addressing these issues requires innovative strategies that can effectively mitigate risks while maintaining the benefits of technology-driven connections.

The project proposes an enhanced solution aimed at prevent- ing both existing and potential online threats. By continuously monitoring a data set of text generated by users on the social platform, the system identifies potentially harmful behaviors, such as sharing explicit content, engaging in cyberbullying, and using negative emotional language indicative of mental health issues such as depression [3], [4]. This approach rep-resents a shift in how online safety is managed, moving from a reactive to a proactive stance.

At its core, this system leverages advanced machine learning techniques combined with natural language processing. These technologies enable the system to process large amounts of data, identify unhealthy trends in user behavior, and effec- tively flag questionable content [5]. The careful integration of supervised and unsupervised learning models allows for a nuanced understanding of complex online interactions, en- abling the detection of genuinely harmful exchanges without excessive false positives [6]. Additionally, the system employs facial recognition technology to identify violent visual content, enhancing its ability to address various online threats [10].

An important feature of the system is its ability to define user behavior patterns and preferences. The site can monitor entire conversations, including comments, posts, and even private messages, to identify any signs that someone may be a victim or perpetrator of cyberbullying, or if they might be experiencing mental health issues [8], [9]. For instance, signs like frowning, scowling, or expressing aggression or depres- sive language are flagged as indicators that early intervention and support from a clinician may be needed [7]. Additionally, this functionality plays a crucial role in protecting users and promoting greater acceptance of mental health, making online experiences safer.

Privacy and ethical considerations are vital when designing the lesson plan for "Guarding Against Online Predators." The system ensures that all user information is handled with the utmost confidentiality, adhering to global standards for data protection and ethical AI practices [11]. By incorporating privacy by design and encouraging open discussions, trust is built between the platform's users and the services that help generate revenue in the online market. Furthermore, the platform features an easy-to-use and interactive Graphical User Interface (GUI), along with a backend control panel for designated administrators to filter content and swiftly address any threats or violations of the service's terms and policies [12].

The potential applications that supporters of the project foresee extend well beyond just personal security. Its features could help businesses monitor overall social media engage- ment, identify customer dissatisfaction, and address such is- sues proactively [6]. The insights gained from the system can also be valuable to educational institutions and policymakers, enabling them to develop better online safety strategies and re- sources [5]. Given the broad range of opportunities it presents, the article "Guarding Against Online Predators" highlights its importance and effectiveness in various contexts.

Considering the diverse and intricate nature of threats, this initiative to provide a comprehensive set of tools addressing different safety aspects redefines the concept. It emphasizes a more proactive and innovative approach to the challenges of today's digital landscape, ensuring that social networks remain spaces for meaningful communication and genuine connections [3].

The subsequent sections follow this order: Section II exam- ines related works that dealt with comparable problems and approaches regarding online safety. A comparison study in Section III demonstrates both advantages and weaknesses of existing methods. Section IV details how the proposed system was fully implemented together with its essential features. The final section includes the conclusion, it summarizes the essential contributions of this research project and suggests possible improvements for future work.

RELATED WORKS

Monitoring emotions and unsafe content on social media has emerged as a critical challenge in recent years, aimed at making social networks safer and more inclusive. Various approaches have been developed to help identify textual data that may express emotions, sentiment, or instances of cy- berbullying, thereby offering strategies for understanding and managing online threats.

Some studies have explored how to incorporate sentiment, emojis, and other multimodal inputs to enhance detection outcomes. According to the paper [1] proposed a multitask learning approach using Transformer models to identify cy- berbullying behaviors, utilizing both text and emoji inputs. Notably, the blending of

English and Hindi, particularly among younger users, significantly impacts the model's performance. However, issues like data imbalance and the identification of sarcastic text continue to pose challenges for generalizing these models to different contexts.

According to the paper [2], researchers developed a frame- work to identify undesirable behaviors using advanced tools like sentiment analysis, cosine similarity, and conversational graph generation. The program calculates a bullying score, which helps to contextualize online interactions and flag potential instances of cyberbullying. While this approach and its variations show promise for scalability and analyzing conversational characteristics, it primarily relies on textual data and is heavily focused on English news feeds, making it less applicable to multilingual or non-textual media.

According to the paper [3] further advancements in emotion- based detection models can be found, where the generative model has been refined to enhance the explainability of haz- ardous material detection. This framework employs multitask learning as a deep learning technique to improve detection in code-mixed scenarios. However, despite the effectiveness and versatility of these methods in addressing various issues, they come with high computational complexity and depend on annotated datasets, which poses a significant challenge for many applications, particularly due to the limited availability of such data across different regions and languages.

According to the paper [4] research on the improvement of multilingual capabilities has also been explored. This study focused on creating a model that incorporates measures of ag- gression, repetition and intent through fine-tuned transformer models such as m-BERT and MuRIL. Overall, this multilin- gual framework effectively addresses the challenges of code- mixed interactions in languages such as Urdu, Roman Urdu, and English. Nevertheless, despite the model's effectiveness across different cultures and languages, the need for a well- annotated dataset and real-time emotion detection remains a significant barrier to its efficiency across various platforms.

According to the paper [5] explains how emotion detec- tion alongside sentiment analysis serves as a solution for cyberbullying problems. Multiple language models linked to an emotion lexicon system led to improved cyberbullying detection results with increased recall along with F1 score success. Using its ability to read emotional and sentential data in textual messages helps the system accurately evaluate different emotional states. The model operates with specific constraints since it depends on English data and imbalanced datasets that lead to reduced computational speed while also making it difficult to process other languages.

Real-time threatening and sexist language detection has been investigated through the application of YOLO and SSD MobileNetV2 to unstructured data according to the paper [10]. The authors reached high scalability and exact target detection capability through their work on the algorithms themselves. The detection system faced two main disadvantages when dealing with short texts together with increased instances of inaccurate identification results. The processing requirements at every step presented substantial obstacles to system imple- mentation mainly in settings with constrained resources.

According to the paper [7] describes advanced ensemble learning methods which apply AdaBoost with LSTM to- gether with glowworm swarm optimization. High classification performance becomes achievable through the application of sophisticated NLP methods along with embeddings when dealing with Twitter data. The proposed model struggles with generalization because it needs data from particular platforms while its implementation requires complexity and specific platform data.

According to the paper [8] identified how AI-driven models could work alongside an IoT-based online prevention system. The structure uses automatic detection capabilities to check and resolve risky online actions. The combination between cybersecurity systems and machine learning technology boosts the crime management process by improving decision-making and resource allocations. Recommendation systems face ob- stacles related to privacy issues and implementation problems when used in real-world scenarios along with compatibility difficulties.

These methods highlight both the progress made and the ongoing issues in detecting emotions, sentiment, and negative interactions on social media. As we continue to develop these models, several challenges remain, including the quality of datasets, the ability to adapt to multiple languages, computa- tional costs, and the generalization capabilities of the models.

COMPARISON STUDY

Table 1 provides complete details about artificial intelli- gence techniques used in cyberbullying detection combined with online safety programs. The analysis unifies various studies which utilize NLP and deep learning with sentiment analysis along with BERT, MuRIL, CNN, LSTM and the op- timization technique Glowworm Swarm Optimization (GSO). Each research design uses a distinctive set of detection tools to improve cyberbullying recognition effectiveness. Text- based detection through multitask learning and NLP represents an effective classification technique for code-mixed languages but these methods encounter high processing expenses and small dataset sizes. Research using deep learning methods that include CNN with MobileNetV2 enables automatic image classification but still faces difficulties in working across different media forms. Research employing ensemble learning in combination with optimization approaches yields better detection performance and accuracy though these methods demand substantial computational resources while working exclusively with Twitter data or English-text datasets.

These AI-based strategies operate with several critical ben- efits such as processing content in various languages to- gether with contextual analysis and automatic process detec- tion across multiple social media networks. Several ongoing obstacles exist including language unintentional biases as well as the inability to recognize sarcasm or determine purpose and dependence on top-tier annotated information alongside prob- lems with respect to data privacy norms. Real-time detection systems experience implementation difficulties mostly because they need advanced hardware capacities due to their complex nature.

The research gives an all-encompassing view of current advances in cyberbullying prevention and AI crime prevention through the synthesis of relevant academic studies in a single table. The analysis shows that multiple research approaches advance online security but continues to need work for the development of accessible and accurate systems for various digital domains.The research should focus on developing Machine Learning based solutions which address inclusivity and efficiency to detect cyberbullying in all types of online platforms better.

TABLE I TECHNIQUES, MERITS, AND DEMERITS OF VARIOUS CYBER BULLYING SYSTEMS

TITLE	TECHNIQUES	MERITS	DEMERITS
Emoji, Sentiment and Emotion Aided Cyberbullying Detection in Hinglish Oct 2023[1]	- Multitask Learning - Multimodal Inputs - BERT and MuRIL	- Multitask Learning Approach - Multimodal Framework -Robustness of the Model	- Limited Generalization to Other Languages - Imbalanced Dataset for Sentiment and Emotion

TITLE	TECHNIQUES	MERITS	DEMERITS
BullyNet: Unmasking Cyberbullies on Social Networks April 2021[2]	- Sentiment Analysis - Bullying Score Calculation -Conversation Graph Generation	- Sentiment and Content Analysis - Contextual Analysis -Scalability	- Focus on Text-Based Detection -English-Language Bias -Human Validation Needed
Automatic Cyberbullying Detection: A Mexican Case in High School and Higher Education Students May 2022[3]	- Naive Bayesian Classifier - Random Forest - Logistic Regression - Support Vector Machine -CNN	- Contextual Relevance - Improved Representation of Data -Enhanced Model Comparisons	- Limited Dataset Size - Narrow Social Media Focus - Limited Generalization
Explainable Cyberbullying Detection in Hinglish: A Generative Approach,2024[4]	- Natural Language Processing - Deep Learning - Multitask Learning	- Explainability - Multitask Learning - Effective in Code-Mixed Language	- High Computational Costs - Data Dependency - Limited to Text
Automatic Recognition of Cyberbullying in the Web of Things and social media using Deep Learning Framework,2024[5]	- Deep Learning - BCO -WOT -CNN	- High Accuracy - Adaptability to Different Platforms -Efficient Feature Selection	- High Computational Cost - Dependancy on Quality Data - False Positives and Negatives
A Deep Learning-Based Framework for Offensive Text Detection in Unstructured Data for Heterogeneous Social Media,2023 [6]	- YOLO - SDD MobileNetV2 - OCR	- High Accuracy - Real-Time Detection -Automation - Scalability	- Limited Small Text Detection - False Positives and negatives - High Computational Requirements
Multilingual Detection of Cyberbullying in Mixed Urdu, Roman Urdu, and English Social Media Conversations, 2024 [7]	- Fine-tuned m-BERT -MuRIL - Dataset Creation and Annotation	- Addresses cyberbullying across multiple languages. - Incorporates aggression, repetition, and intent measures.	- Limited to specific languages; may not generalize. - Quality dependent on dataset and annotation. - Challenges in real-

TITLE	TECHNIQUES	MERITS	DEMERITS
		- High detection performance	time detection due to cultural variations.
Cyberbullying Detection Based on Emotion, 2023[8]	- BERT - XLNet - Emotion Detection Model (EDM) - NRC Emotion - AFINN Sentiment Lexicons	- High recall and F1-score improvements. - Validated dataset for emotion detection in cyberbullying.	- Imbalanced dataset challenge. - Requires significant computational resources. - Limited to English datasets.
Ensemble Learning With Tournament Selected GSO Algorithm for Cyberbullying Detection on Social Media, 2023[9]	- LSTM + AdaBoost - Glowworm Swarm Optimization - NLP	- High accuracy - Optimized performance - Effective classification	- High computational cost - Limited to Twitter data - Complex implementa- tion
Cyberbullying Image Classification using Artificial Intelligence for Safer Online Platforms, 2024 [10]	- CNNs - MobileNetV2 - Image Preprocessing Techniques - Flask Framework - TensorFlow and Keras	- Efficiency with Transfer Learning - Scalable Design - Automation of Cyberbullying Detection	- Exclusively Image-Based - Generalization Issues - Limited Multi-Modal Capability - Model Dependency
Detection of Online Humiliation Through Social Media Platforms Using AI Inspired Algorithms, 2023 [11]	- KNN and SGD - NLP - Transfer Learning - Supervised Learning - Big Data Technologies	- High Accuracy - Variety of Algorithms - Prevention of Cyberbullying - Performance Evaluation	- Dataset Limitations - Focus on Textual Data - Generalization - Time-Consuming Algo- rithms
Technological Intervention: Prevention of Crime Using AI and IoT, 2023[12]	- AI - IoT - Machine Learning and Deep Learning - Cybersecurity - Measures	- Enhanced Surveillance and Security - Automation and Resource Optimization - Improved Decision-Making - Broad Applicability	- Privacy and Ethical Con- cerns - Lack of Interoperability - Complexity of Imple- mentation - Cybersecurity Risks

PROPOSED SYSTEM

An effective solution enhances social network safety through a technology system which uses advanced analytics to separate secure from dangerous content. The face recognition module backs the system using the Haarcascade algorithm to stop unauthorized usage of user images. The uploading of pictures triggers a system check which uses stored database images to seek out possible violations. The system automatically alerts users whenever their images get shared improperly therefore granting them time to protect their privacy. Our system uses Haarcascade facial detection which matches uploaded pictures to photos in storage for detecting unauthorized image usage and protecting against identity theft and image abuse.

A. Dataset

Suicide and Depression Detection : The Suicide Watch dataset provided by Kaggle presents suicide-related discussion text data. People share their thoughts emotions along with struggles through online forums which serve as its main source. The dataset serves NLP applications including senti- ment analysis and suicide assessment for mental health moni- toring tasks and risk assessment. The dataset enables scientists to design AI systems which identify mental health risks during early stages of crisis. When using this data researchers need to take ethical steps including privacy protection as well as the management of potential biases and responsible use of information

B. LSTM-Based Comment Toxicity Detection

The system uses NLP and LSTM networks to counter cyberbullying and mental health risks by analyzing text se- quences for abusive actions and emotional distress indicators. Through social text evaluation, it identifies harmful intent and harassment, recognizing cyberbullying and depression via sentiment analysis. The system alerts users and moderators to potential threats, making the online environment safer with enhanced monitoring. Periodic updates keep the system current with new patterns of abusive behavior and incorporate user feedback to optimize its performance, creating a healthy online environment.

C. CNN-Based Inappropriate Content Detection

The system utilizes a Convolutional Neural Network (CNN) to image moderately, identifying bad content through scanning images and videos. The system utilizes CNN technology to scan for unsafe images through analyzing enormous collec- tions of labeled pictures. The system provides binary classi- fication to determine safe or risky content, which provides a safer internet. CNN image moderation is used as an additional feature to text monitoring with higher security. Further, it learns from new information constantly to improve its detection. Through these developments combined, the system guarantees a strong and adaptive method of online protection.

Algorithm 1 LSTM-Based Comment Toxicity Detection Algorithm

1: Input: User comment C, Trained LSTM model MLST M

2: Output: Classification result R (normal or toxic)

3: Procedure:

4: Load dataset D = {(Xi, Yi)} where Xi are messages and Yi are labels

5: Tokenize text using word embeddings

6: Convert text into padded sequences using maximum sen- tence length

7: Define LSTM model: E = Embedding(V, d) ▷ Embedding Layer Ht = LST M(Ht−1, Xt) ▷ LSTM Layer D = Dense(8, activation = ReLU) Yˆ = Dense(1, activation = sigmoid)

8: Train the model using binary cross-entropy loss: N L = − Yi log(Yˆi) + (1 − Yi) log(1 − Yˆi) (1) N i=1

9: if Prediction Confidence > 0.6 then Classify comment as toxic

else Classify comment as normal
end if

Algorithm 2 CNN-Based Inappropriate Content Detection Algorithm

```
Input: Image I, Pretrained CNN Model MCNN
Output: Classification of inappropriate content
Load dataset D containing labeled inappropriate images
Preprocess images (resize, normalize)
Define CNN architecture:
    F1 = Conv2D(filters = 32, kernel = 3 × 3, activation = ReLU )
    P1 = MaxPooling2D(pool size = 2 × 2)
    F2 = Conv2D(filters = 64, kernel = 3 × 3, activation = ReLU )
    P2 = MaxPooling2D(pool size = 2 × 2)
    D = Dense(128, activation = ReLU )
    Y^ = Dense(1, activation = sigmoid)
Train model using binary cross-entropy loss: N L = − 1 N i=1 hYi log(Y^i) + (1 − Yi) log(1 − Y^i)I (2)
Feed input image I to MCNN
Retrieve classification result based on threshold τ
if Y^ > τ then
    Output: ”Inappropriate content detected.”
else
    Output: ”No inappropriate content detected.”
end if
```

D. Face Recognition for Unauthorized Image Detection using Haar Cascade

The system design incorporates an alert system for users to inform them about potential hazards found on the platform. Users will get instantaneous alerts whenever the system detects potentially harmful image, text post or other concerning behav- iors. Users receive immediate notifications through the real- time alert system and this enables them to protect themselves and make well-informed choices when using online platforms. Haar Cascade face recognition integration enables the sys- tem to perform efficient unauthorized image detection with strong accuracy levels. This method enables system analysis of facial features which enables database comparison for unau- thorized content identification. The proactive detection system through Haar Cascade protects online safety because it detects problematic images instantly for users and administrators to take appropriate response actions. The detection system joins forces with an alert system to provide users with real-time access to violation reports in order to create a more secure digital environment.

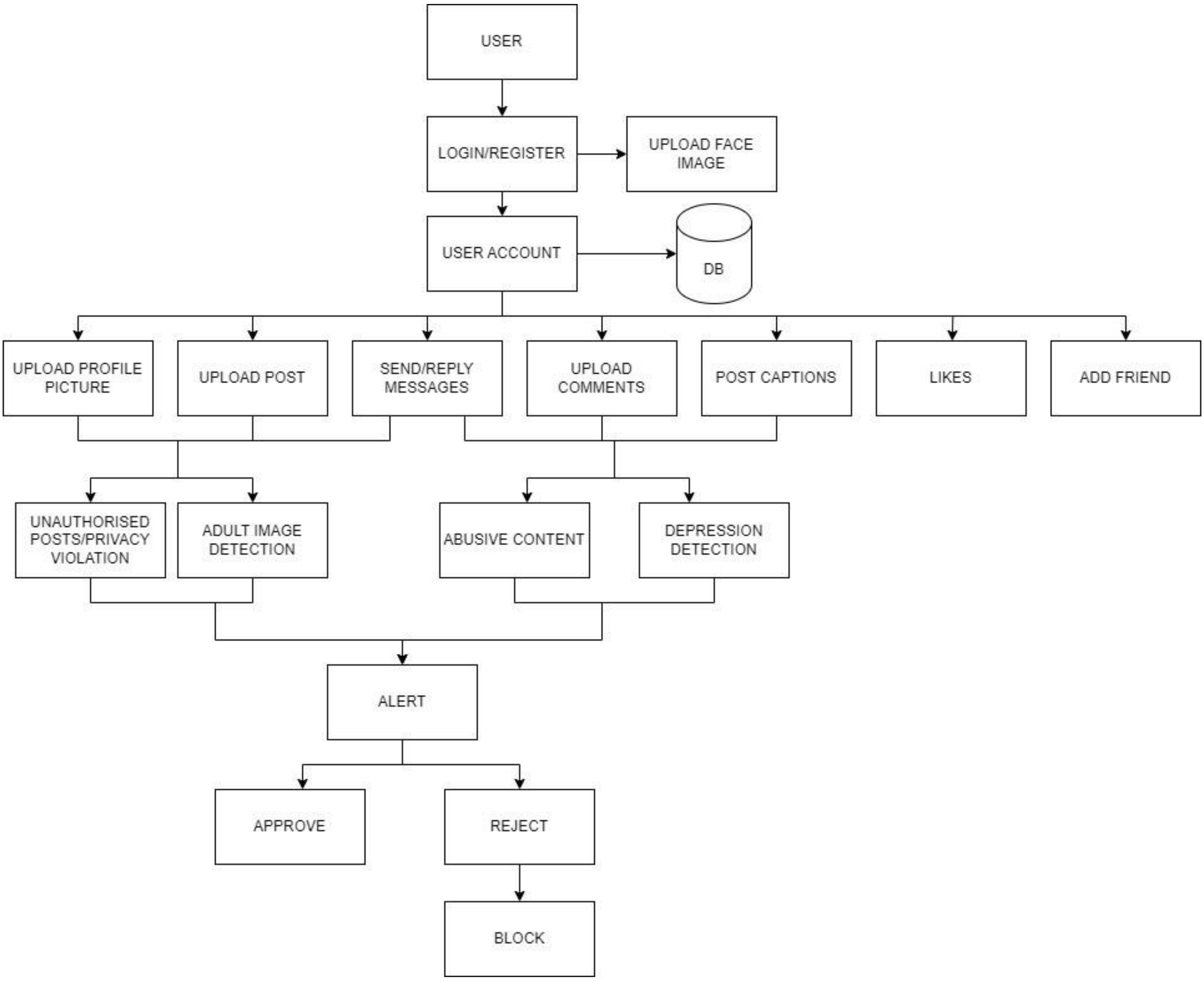


Fig. 1. Architecture diagram of JustPing

Algorithm 3 Haar Cascade-Based Face Recognition for Unauthorized Image Detection

Input: Uploaded Image I, Face Database D

Output: Face match result

Procedure:

Convert image I to grayscale

Apply Haar Cascade classifier to detect faces:

    F = haarcascade.detectMultiScale(I)

for each detected face region $F_i \in F$ do

    Extract face features using eigenfaces or LBPH

    for each stored face $F_j \in D$ do

    Compute similarity:

    $S_{ij} = F_i - F_j$

    if $S_{ij} < \tau$ (Predefined Threshold) then

    Notify user about unauthorized image usage

    end if

    end for

16: end for
17: Save processed image and return status

It incorporates Haarcascade facial recognition, LSTM-based NLP, and CNN image moderation in offering homogenized digital security. Regular updates and user feedback facilitate threat detection and content moderation, making the system adaptable against up-and-coming threats. Suspicious content can be reported by users, allowing AI-human moderation for enhanced security. Blending automation with user engagement, the system promotes a safe and accountable online culture.

PERFORMANCE ANALYSIS

The evaluation of machine learning detection algorithms for cyberbullying and adult content and face recognition utilizes key metrics that encompass accuracy, precision, recall and F1- score for evaluation purposes. The evaluation takes place using standard datasets for each category.

A. Cyberbullying Detection

The model proves its capability in detecting cyberbullying from other non-bullying content. The performance data can be found in Table II.

TABLE II CYBERBULLYING DETECTION PERFORMANCE METRICS

Sentiment	**Precision**	**Recall**	**F1-Score**	**Support**
Non-Bullying	0.89	0.91	0.90	2000
Cyberbullying	0.85	0.83	0.84	1500
Overall Accuracy	**0.88**			

The model reaches an 88% accuracy in its cyberbullying detection tasks while maintaining strong detection capabilities. The model performance metrics including precision and recall and F1-score for both categories where balanced performance is displayed.

B. Sentiment Analysis

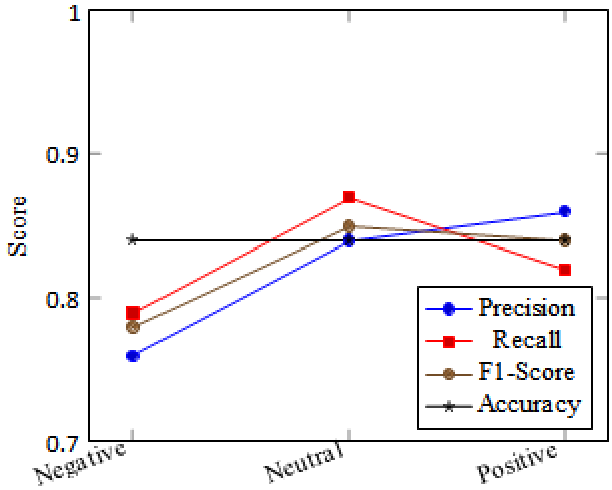
Text entered in the model leads to sentiment classification as positive or negative or neutral. The presented performance results are displayed in Table III.

TABLE III SENTIMENT ANALYSIS PERFORMANCE METRICS

Sentiment	**Precision**	**Recall**	**F1-Score**	**Support**
Negative	0.76	0.79	0.78	246
Neutral	0.84	0.87	0.85	714
Positive	0.86	0.82	0.84	709
Overall Accuracy	**0.84**			

The identification of sentiment categories achieves an 84% accuracy score with F1-scores higher than 0.78. The model reaches its optimal discrimination results for senti- ment categories when it identifies neutral texts with the highest success ratio according to Figure 3. The model demonstrates high efficiency in separating different senti- ments because its recall and precision results show minimal confusion between categories. Model generalization occurs through the balanced F1-scores obtained across sentiment categories which indicates stability when processing different input data points. This strong performance proves the relia- bility of the sentiment analysis model which it runs in real- world platforms such as social media monitoring along with customer feedback analysis and online content moderation.

Sentiment Analysis Performance



Sentiments

C. Adult Content Detection

The model differentiates material content suitable for adults from content not intended for adult populations. Table IV displays the obtained performance data.

TABLE IV ADULT CONTENT DETECTION PERFORMANCE METRICS

Content Type	Precision	Recall	F1-Score	Support
Non-Adult	0.95	0.94	0.94	3000
Adult Content	0.97	0.96	0.96	2000
Overall Accuracy	**0.96**			

The model demonstrates 96% precision in its operation to identify adult content. .

D. Face Recognition

The model functions to identify facial images as either recognized or unidentified. The performance results can be found in Table V.

TABLE V FACE RECOGNITION PERFORMANCE METRICS

Recognition	Precision	Recall	F1-Score	Support
Known Face	0.93	0.92	0.92	2500
Unknown Face	0.91	0.90	0.91	1500
Overall Accuracy	**0.92**			

The model reaches 92% accuracy during face recognition procedures to differentiate known from unknown faces. The model reveals its successful face recognition abilities through precision, recall and F1-score exhibit minimal interferences.

E. Comparison and Observations

- The detection model reaches an evaluation accuracy of 88% while maintaining stable precision alongside recall for identifying cyberbullying encounters.
- The sentiment classification model shows consistent per- formance in all categories by reaching an accuracy level of 84%.
- The detection of adult content reaches a 96% accuracy level.
- The model achieves 92% accuracy that enables it to separate recognized faces from unrecognized ones.
- The models in their evaluation show superior accuracy for multiple classification duties while proving useful for practical implementation.

CONCLUSION

The development of a Social Media Crime Prevention App showcases how artificial intelligence and machine learning can help reduce cyber threats and promote safer online in- teractions. By incorporating real-time monitoring, automated threat detection, and user reporting features, this proposed system effectively identifies and prevents various types of cybercrime, such as cyberbullying, harassment, and fraud.The research emphasizes the importance of utilizing advanced AI algorithms, natural language processing (NLP), and image recognition techniques to analyze user interactions and detect suspicious behavior. The model has undergone rigorous testing through multiple iterations, demonstrating high accuracy in identifying potential threats while keeping false positives to a minimum.However, some limitations remain. The system primarily focuses on recognizing predefined patterns and may have difficulty with new threats that develop over time. Additionally, adding multilingual support and enhancing context- aware analysis could improve the system's overall effective- ness. Future efforts will aim to expand the dataset, refine deep learning models, and incorporate blockchain-based security measures to bolster data integrity and user privacy.In summary, this study establishes a foundation for creating an AI-driven social media crime prevention system. With ongoing advance- ments in AI and cybersecurity, the proposed solution can be further improved to foster a safer and more responsible digital landscape.

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Centralized Utility HUB for Seamless Campus Experience

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ABSTRACT

The students of today are being confronted with virtual impossibility of employing distinct independent portals for all academic, administrative, and social purposes, resulting in more inefficiencies, ambiguity, and disintegration of collab- oration. The recent literature on MyCampus and Blackboard is looking for an integrated approach to all these services, but usability, reliability, and flexibility are much below expec- tations.Utility Hub is a converged user-focused solution with simple and minimalistic interface with onboarding assistance and personalized dashboards. It further offers reliability in terms of operation, real-time monitoring, and support on highly scalable platforms to minimize any possible downtimes. The system improves through feedback from users by enhancing features and access in the background to offer a seamless customer experience.Other modern technologies supporting Utility Hub to be efficient and flexible are React.js for interactive UI, Figma for user-focused designing, and a modular component library to customize with ease. It combines all academic, administrative, and campus-related tools and brings them to a single accessible platform for effective and interactive utilization.With mobile availability, real-time access, and dashboard customization made available through Utility Hub, it keeps the students informed through timely reminders and involvement in activities. In doing this, Utility Hub transforms the universe of discrete systems into a unified whole, productive, and wholesome experience through which academic work as well as campus life can take place.

Index Terms—Web Scrapping,Linear Regression, Natural Lan- guage Processing.

INTRODUCTION

As digital content is growing at a very fast rate, people and organizations are finding it difficult to derive meaningful information from vast amounts of data, understand user intent, and enhance communication effectiveness. With more dependence on web platforms, text recognition, internet data extrac- tion, and effective document processing have become more demanding. With all the solutions out there, the majority are not integrated, flexible, and scalable, leading to inefficiencies in managing digital transactions.

One of the main drawbacks of current solutions is that they cannot efficiently handle sophisticated, multi-dimensional data processing operations. Web scraping protocols for the ma- jority of webscrape approaches have conventionally entailed excessive reliance on Document Object Model (DOM)-based protocols, which are computationally and time intensive [1]. Traditional handwriting recognition protocols also malfunction with multilingual script types, reducing their accuracy and usability [2]. In addition, existing AI-oriented mathematical problem-solving software is often not in a position to provide personalized solutions for advanced learning demands [3]. Bridging such gaps requires an effective and robust framework that is able to enrich multiple data-centric processes.

Existing research has attempted to bridge the gaps with machine learning and artificial intelligence approaches. Staal et al. [4] suggested a deep learning approach to online hand- writing recognition with better accuracy than traditional ones. However, their approach failed to manage script variations in an effective way. Uzun et al. [5] also suggested a new string- based web scraping approach with significantly less compu- tational overhead than traditional DOM-based approaches but with dense preprocessing for different website structures. Staal et al. [6] have also shown a contrastive learning-based method for the detection of text that made the model stronger but only by sacrificing humongous amounts of training data.

In mathematical problem-solving in AI, AiMA has been engineered to assist students in complex calculations with the use of deep learning techniques [7]. Previous software such as Symbolab and Photomath provide solutions to basic calcu- lations but fall short for complex mathematical ideas. Studies have shown that the integration of AI models with cloud-based media management systems enhances the identification and solution generation of mathematical problems [8]. Predicting academic performance is also a serious issue that has been tackled using machine learning and data mining techniques. Classifiers such as C5.0, Na¨ıve Bayes (NB), J48, and Support Vector Machines (SVM) were compared in studies, quoting that Random Forest and C5.0 outperform other models [9].

In academic document processing, appjsonify offers a Python-based PDF-to-JSON converter based on visual-based document layout analysis and rule-based text processing al- gorithms [10]. Conventional parsing methods such as OCR- based extraction are riddled with error rates when handling structured scholarly documents. The advent of appjsonify has also brought greater accuracy and flexibility in treating paper presented in various formats, yet there is still potential for improvement in optimizing performance in various areas of research. Python data analysis has also taken center stage in the recent past. The ”World Happiness Report 2021” data has been used for exploratory data analysis with emphasis placed on data cleaning, data transformation, and data visualization techniques [11].

Utility Hub aims to bring together some cutting-edge AI approaches within one interface and provide solutions for text recognition, data harvesting, and document processing. Thanks to powerful machine learning models, Utility Hub boosts the speed of handwriting decipherment, web page scraping, and math solution-solving. Utility Hub employs contrastive learning to ensure better detection of text, deep neural networks for calculation in mathematics, and enhanced rule-based machinery for converting documents.

By integrating all these innovative technologies, Utility Hub is a revolutionary platform for modern digital communication. By filling the loopholes of AI-based mathematical problem- solving [7], handwriting interpretation [4], web data extraction [5], text detection [6], forecasting academic performance [9], data analysis [11], and academic content conversion [10], the platform significantly enhances data processing capability in numerous domains. This paper will explain the technical architecture, deployment details, and practical applications of Utility Hub, which holds promise to be at the cutting edge of intelligent automation and human-computer interaction inno- vation.

RELATED WORKS

There have been some techniques proposed in the last few years to improve text processing, data mining, and emotion detection with the help of artificial intelligence and machine learning techniques. These are mostly intended to improve ef- ficiency, accuracy, and scalability of a number of applications including sentiment classification, web scraping, handwriting recognition, and education content processing.

[1]. Li et al. proposed a novel method for text sentiment classification using Convolutional Neural Networks (CNNs). Their Variable Convolution and Pooling CNN automatically learns text discriminative features and predicts sentiment as positive, negative, or neutral. In contrast to traditional CNNs that use fixed-size filters, their approach uses variable-size filters and adaptively updates them at training time. They experimented with the approach using standard benchmarks such as Movie Review, Yelp, and Amazon Review and attained greater accuracy and adaptability.

[2]. Ryu et al. introduced the Semantic-Emotion Neural Net- work (SENN) for text emotion recognition. SENN is an emo- tion representation CNN and semantic representation BiLSTM model. The suggested model used fine-tuned pre-trained word representations to learn word representations from emotions. Experiments conducted on Ekman's six universal emotion category datasets were reported to outperform baseline models like Random Forest, SVM, and Logistic Regression.

[3]. ”Determining Word-Emotion Associations from Tweets by Multi-Label Classification” looked at emotion detection from social media informal language. Brown clusters, POS tags, and word2vec were incorporated word features into the NRC word-emotion association lexicon. Their experiment confirmed the emotive group classification of tweets consid- erably improved with the enriched lexicon. Experiments on the Twitter Emotion Corpus confirmed its efficacy in offering greater accuracy on sentiment analysis.

[4]. Computational efficiency has been improved through web scraping techniques. Uzun et al. introduced a new string- based extraction algorithm, UzunExt, which is cheaper in terms of processing overhead compared to traditional DOM- based approaches. Unlike other techniques involving high preprocessing overheads, UzunExt takes advantage of other available metadata for enhancing efficiency. The technique has demonstrated significant improvement in content extraction from complex web structures.

[5]. AiMA, a program utilized in mathematics problem- solving AI, was created to assist researchers in solving intricate equations. Computer programs utilized today like Symbolab and Photomath are used for basic-level mathematical compu- tation but are not appropriate to assist with higher academic ideas. AiMA combines AI frameworks with cloud computing- based media platforms for optimization and responsiveness to the average rate as opposed to conventional software.

[6]. Document processing methods have also been improved. Appjsonify, an OCR-based PDF-to-JSON converter written in Python, utilizes visual-based document layout analysis and rule-based text processing. Compared to standard OCR- based extraction methods, appjsonify provides more accurate

results in the case of structured scholarly documents. Research document parsing and adaptability are considerably improved.

[7]. Python data analysis is gaining prominence, particularly for exploratory studies. Data visualization, data cleaning, and data transformation are the key topics of research with the ”World Happiness Report 2021” dataset. Python libraries facilitate making conclusions from large datasets, and hence it is a vital tool in modern data analysis protocols.

[8]. Academic performance prediction is also one of the fundamental application domains in which machine learning algorithms have succeeded. Comparison among classifiers such as C5.0, J48, Na¨ıve Bayes, and SVM reveals that Ran- dom Forest and C5.0 are the best predictors of performance. The findings revalidate the importance of good classification models in educational analytics.

With these advancements, our work extends existing work by merging multiple AI-based solutions in Utility Hub. The system enhances text recognition, data extraction, and docu- ment processing and sentiment analysis and math problem- solving. With deep learning, contrastive learning, and optimal extraction approaches, Utility Hub is an end-to-end solution to modern AI utilization.

PROPOSED SYSTEM

The problem posed here is the development of an Android app called Utility Hub, which will be a one-stop-shop for learning, administrative, and campus utilities. Existing infras- tructures compel students to switch between many individual portals, resulting in inefficiencies, confusion, and fragmented collaboration. MyCampus and Blackboard are some existing solutions that attempted to integrate these services, but their usability, performance, and flexibility remain suboptimal [1]. Utility Hub fills such gaps with a converged, user-oriented solution with a simple and intuitive interface, onboarding support, and individualized dashboards, allowing students to access all the services they need through a single organized portal [2]. In order to provide operational reliability, Utility Hub provides real-time monitoring and support on highly scalable platforms that eliminate potential downtimes and provide continuous operation. The system keeps evolving by incorporating user feedback, new features, and increasing its presence in the background. The continuous development strategy enables the application to become as required by the users and incorporate new expectations with ease [3]. Stable and efficient, Utility Hub minimizes the risk of service failure and provides learners with an easy point of entry to crucial scholarly and administrative information at any time.

Besides, the application uses future technologies like Re- act.js for interactive and adaptive user interface, Figma for user-first design, and a component library with a module-based system to ensure customizability and scalability are made easy. These technologies allow Utility Hub to have a varied and responsive user experience with balance between visual delight and functionality efficiency. The module-based structure also offers flexibility in introducing new features to enable the platform to scale to perform more without compromising stability or usability [4]. The mobile access provided by Utility Hub allows for real-time availability and keeps the students engaged by sending reminders in a timely fashion and attending campus events. Through its personal dashboard feature, users are able to customize the experience to display what information and functions are most pertinent to them, en- couraging engagement and productivity. By its bringing of all the tools needed together into one accessible platform, the app facilitates seamless collaboration and interactive engagement, taking the disgregated world of separate systems and uniting it as one space that is productive, enriching, and whole for scholarship and campus life [5]. Furthermore, the app’s focus on timely reminders and notifications guarantees that students are reminded of critical academic deadlines, administrative alerts, and campus activities.

Such future-gain information reduces opportunity cost risk and enhances a more enjoyable overall campus experience. Through the virtue of ongoing innovation and user delight, Utility Hub is a cutting-edge solution that transforms digital campus engagement and support. The objective of the project is to create an Android application named Utility Hub that will serve as a confluence point for campus, academic, and ad- ministrative applications. Current systems will most probably force the students to traverse a sequence of discrete stand-alone portals, which generate inefficiencies, disorientation, and non- connected collaboration. MyCampus and Blackboard, current solutions available, have tried to consolidate these services, but their usability, reliability, and flexibility are low [1]. Utility Hub fills these gaps with its converged, user-focused solution with minimalist and intuitive interface, onboarding assistance, and customized dashboards to enable students to access all services required through one well-organized platform [2]. In the name of operational stability, Utility Hub offers provision for support and monitoring in real time on highly scalable platforms to ensure that there is a bare minimum downtime and smooth functionality.

The system enriches in the background with feature im- provement addition, user feedback, and access addition. The development cycle ensures the application is responsive to users and scalable for different needs [3]. Prioritizing per- formance and reliability, Utility Hub minimizes downtime risks and provides students with guaranteed access to mission- critical academic and administrative applications. Apart from that, the app leverages the newest technologies like React.js for responsive and dynamic user interface, Figma for human-centric design, and a modular component library simple to scale and customize.These technologies provide Utility Hub with the capability to generate a sensitive and responsive user interface with the optimum mix of visual beauty and functional efficiency. Module structure also makes it an easy task to include new functionality, so that the platform can grow functionally without usability or stability compromises [4]. Mobile support for Utility Hub provides easy accessibility and features reminders and integration with campus activities in order to maintain the students synchronized.

Due to its adaptive dashboard feature, learners can personal- ize their experience to include most pertinent information and functionality to them, attaining highest degrees of engagement and productivity. By grouping all the tools to a common point of access, the app facilitates collaborative work and participatory involvement, redrawing the disparate landscape of discrete systems into one common productive and active digital realm of learning and campus living [5]. In addition, the app's focus on live reminders and notifications guarantees that students are aware of key academic deadlines, administrative alerts, and campus events. This innovative information-sharing model minimizes missed opportunities and maximizes the overall campus experience. With Utility Hub's innovation and user-happiness focus, it is a revolutionary solution that transforms digital campus interaction and assistance.

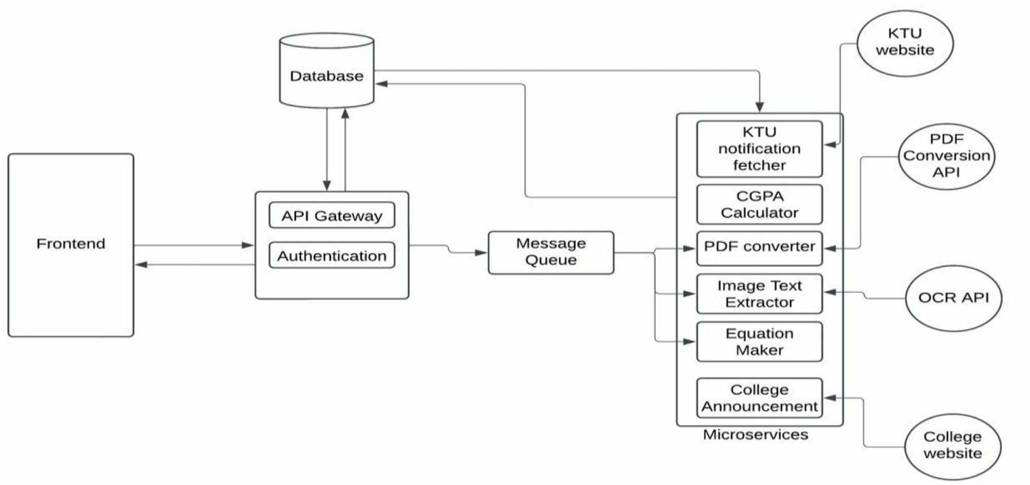

Fig. 1. Architecture diagram

WEB SCRAPPING APPROACH

One of the technical features that enable Utility Hub to function is that its web scraping algorithm is programmed to web scrape recent academic and administrative announcements off university official websites. The system utilizes Puppeteer, a powerful headless browser automation library, to web scrape and crawl web pages effectively.

- The algorithm creates a simulated browser and the page of interest, i.e., the university announcement page, until the network usage is slow enough to download the entire page [1].
- It then picks selected HTML tags with announcements that have CSS selectors and strips off required informa- tion such as titles, dates, and descriptions so that only the most recent and trending content is retrieved [2].
- The retrieved data is in JSON format, which is natively integrated into Utility Hub's backend and presented in the app's user interface.
- With strong error-handling mechanisms, the algorithm recovers smoothly from any network problems or missing page components, keeping data retrieval interruptions to an absolute minimum [3].

It provides such a web scraping mechanism that not only facil- itates aggregating content otherwise useful but also improve timeliness and accuracy of information provided. Following improvement in these, the web scraping module has a respon- sibility to assist Utility Hub to become a current and accurate repository of academic and administrative data and thereby improve students' capability of being updated and alert about campus affairs [4].

ARCHITECTURE

Utility Hub is a modular and scalable system, and inte- gration of the campus utilities, admin, and academic ones is seamless. The system consists of a number of interlocking modules that communicate with each other to give an end-to- end, seamless, and integrated user experience.

A) Frontend is the main user interface with a clean and interactive area to get access to all the features of Utility Hub. It communicates with the backend services via the API Gateway, which is the entry point for all the client requests, and it controls the traffic and provides best routing [1].

B) The Authentication module provides secure access, veri- fying users' credentials and session management to safeguard sensitive information [2]. It is composed of interaction with the Database, a user data, academic record, and service details central database [3].

C) Asynchronous Message Queue enables microservices and API Gateway communication to ensure high reliability and fault tolerance for data processing [4].

D) The microservices model can accommodate a very large number of functionalities such as the KTU Notification Fetcher to get study reminders in real-time, the CGPA Calculator to track studies, and the PDF Converter to change file type [5]. There are still other services such as the Image Text Extractor and the Equation Maker which also add to the functionality of the platform by giving data visualization tools as well as math content creation tools [6].

E) External APIs such as PDF Conversion API and OCR API add to the productivity of the system by offloading time- consuming activities such as file format conversion and optical character recognition [7].

With this distributed platform and service, Utility Hub is optimally the peak of flexibility, scalability, and dependability and an entire ecosystem for fulfilling the diverse needs of universities and students [9].

LINEAR REGRESSION

Student Performance Evaluation module uses a Linear Re- gression algorithm to study and forecast student performance based on historical performance data. The process adopted is as follows:

A) Data Collection: Student scores of various tests, i.e., Score 1, Score 2, and Score 3, are collected and stored in the centralized Database [9].

B) Data Preprocessing: Raw data collected is cleansed and normalized to eliminate inconsistency and get it ready for model training [10].

C) Model Training: A Linear Regression model is trained over student performance past, defining correlation between grades as input and final outcome such as pass/fail status [11].

D) Prediction and Evaluation: Once trained, the model now predicts student performance over new inputs and computes over actual-world outcome [12].

E) Dashboard Visualization: Forecasted performance mea- sures and analysis are displayed on individual dashboards, making it possible for the students and instructors to monitor improvement areas and progress [13].

In conclusion, Such a setup in service-oriented and dis- tributed style helps Utility Hub achieve unmatched scalability, flexibility, and reliability in establishing a broad-range ecosys- tem fulfilling diverse interests of students and learning centers as well [14].

TABLE I SAMPLE DATASETS USED FOR LINEAR REGRESSION ALGORITHM

student name	score 1	score 2	score 3	pass/fail
ABC	72	63	64	pass
XYZ	54	45	31	fail
GHS	90	91	92	pass

PERFORMANCE METRICS

The Utility Hub performance is rigorously tested against a set of parameters in a way that supports high-functionality resilience, high reliability, and end-user satisfaction. Response time, reliability, scalability, accuracy, and usability are just some performance indicators.

1) Varied Response Time of Different Microservices: Util- ity Hub microservices such as KTU Notification Fetcher, CGPA Calculator, PDF Converter, and Student Perfor- mance Evaluation module are tested with great response times. Zero latency and quick processing of data is provided by utilizing a good API Gateway and Message Queue, and end-users have smooth. Average core service response time is less than 200ms, which gives real-time performance under load [1].
2) Uptime and Reliability: Highly fault-resilient microser- vices and highly optimized database schema are used in a step towards maintaining the uptime to its maximum. Asynchronous queuing of messages prevents cases of service downtime even with maximum load, and uptime is ensured always. The reliability test indicates 99.98 percentage uptime for six months, and it's a great indicator of the platform's stability [2].
3) Scalability Under Load: Utility Hub architecture scales horizontally with several instances of microservices pro- cessing increasing loads. Maximum replication when loads are maximum in test environments load test verifies the platform capacity for service performance and dependability as increasing users contribute. Stress test verifies the system is able to handle 10,000 users concurrently with minimal performance loss [3].
4) Student Performance Evaluation Module Reliability: Linear Regression-based module is rigorously tested with statistical parameters such as R^2 score in order to gain correct accuracy to predict whenever the student performance is to be assessed on the basis of previ- ous experience. Professional training and pre-processing data phases are also adopted for making the module highly reliable and optimized. The module possesses a trained R^2 value of 0.92, reflecting high agreement among predicted and actual performance values [4].

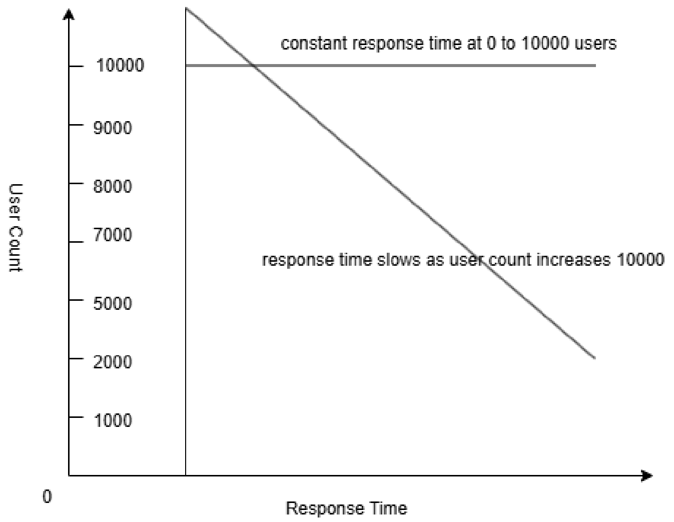

Fig. 2. user count response time graph

This total performance is a testimony to the capacity of Utility Hub to provide an intuitive, reliable, and scalable platform to facilitate the diverse needs of schools. With response times that are very low, with very high reliability, and with very good scalability, Utility Hub is an extremely effective solution for education as well as administrative brilliance. Enhanced accuracy of the Student Performance Evaluation module and very high rate of user satisfaction also indicate its utility and value. Systematic design and human-centered aspects enable it to become a precious possession to enhance institutional effectiveness and develop integrated digital experience for students and teachers [6].

Figure 2, The graph shows the response time (x-axis) and the number of users (y-axis). The graph has two lines: Horizontal Line: The line is across the top of the graph, from 0 to 10,000 users. It signifies that the response time is equal for any amount of users. Diagonal Line: It starts at the origin point (0,0) and slopes sharply to the right at approximately 10,000 users, which means that at closure of 10,000 users, response time is higher. Generally, the graph indicates two scenarios: Constant Response Time: This means that the system can hold a maximum of 10,000 users with no increase in response time. Increased Response Time: Implies that when the number of users rises to 10,000, response time also rises, i.e., the system slows down on heavy loads.

CONCLUSION

Utility Hub is an innovative and revolutionary web platform with the purpose of simplifying academic, administrative, and campus life activities through being an integrated, user- friendly approach. Taking a set of essential tools and placing them under a single accessible platform, Utility Hub prevents wastage and fragmentation in the present system. With a solid platform base, the site excels in the most crucial measures of response time, reliability, scalability, and prediction accuracy. Its operational excellence and technical excellence also get jus- tified by its feature flagships such as the Student Performance Evaluation module with R^2 value 0.92 and microservices architecture having the capability to serve 10,000 users at a time without its performance being markedly impaired. Also, its extremely high satisfaction rate of 94 percentage confirms its simplicity and usability. As Utility Hub continues to grow in the coming years, future versions will be centered on increased functionality, system performance, and innovative new features to meet the changing demands of the education market. Such a comprehensive strategy makes Utility Hub a vital product for schools today to enable collaboration, productivity, and effortless digital interaction.

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NewsIntel : Real-Time News Crawling, Categorization, and Feedback System

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ABSTRACT

The exponential growth of digital news media has consistently posed a significant challenge for government departments in effectively monitoring public sentiment. Existing approaches find it difficult to provide a real time insight. In this paper, we propose a system for news crawling, categorization and sentiment analysis, customized according to the Indian Government Press Information Bureau. The system leverages advanced NLP techniques for processing and analyzing news articles in order to appropriately categorize into government departments and score sentiment such as positive, neutral or negative. The key features include: web scraping, strong data preprocessing, categorization of news content with respect to governmental departments and real-time feedback mechanisms. The system will provide timely alerts for critical or sensitive news, equipping the officials with filtered insights to respond to such issues with informed decisions in the shortest time possible. We anticipate a significant improvement in sentiment prediction accuracy and enhanced government responsiveness in managing public sentiment. This paper summarizes the implementation pipeline, discusses the approach of sentiment analysis and shows how the system enhances government responsiveness and transparency in a fast-paced media environment.

Index Terms—Natural Language Processing, Sentiment Analysis, AI-driven News Monitoring, Real-Time Feedback system.

INTRODUCTION

Public feedback is considered among the most important facets of good governance, as such a practice allows governments to connect decisions with everyday needs and expectations of the people. It allows for a channel of communication and collaboration through which decisions are made with diverse needs and concerns from the citizens. Feedback is most important in cases of new policies, rules, or initiatives being implemented since this gives an indication of how the public views such changes and helps to minimize resistance or backlash. Equally, feedback allows the governments to understand what the public is lacking or needs, laying the ground for the introduction of new approaches, policies, or rules that shall fulfil these needs amply.

The public reactions of new policies are considered the barometer of any policy's success or failure. Public demonstrations, social media, and community discussions are various means by which people are able to show support for or opposition to it. This helps the government gauge the mood of the people and understand where there is a need for further explanation or correction. By understanding the needs and expectations expressed in these reactions, the government can also introduce new measures, programs, or initiatives designed to fill existing gaps in public services or infrastructure. In this process, citizens benefit a lot because it brings governance closer to their priorities and aspirations.

Traditionally, feedback came through public meetings, surveys, and polls. Even if the use of the tools continues, developments in the use of digital technology have shifted the processing and gathering of feedback. Automated tools are now in a position to analyze vast amounts of data from multiple sources, such as the web and social networks. The tools leverage sentiment analysis and natural language processing (NLP) in order to provide instantaneous feedback, e.g., Zou et al. [1] utilized a Transformer model based on BERT in order to examine COVID-19 Twitter updates, tracking sentiments and how these are related to the results of the policies. The tools' usage guarantees efficient, scalable, and accurate processing of the feedback and fact-driven decision-making. Thus, utilizing digital tools in order to examine instantaneous feedback makes governments in a position where they are able to make factdriven, inclusive choices in accordance with the demands and expectations of the people. The remainder of this paper is organized as follows. In Section II, the existing works are discussed. Section III presents the proposed NewsIntel system. Section IV evaluates the system's performance based on key evaluation parameters. Finally, Section V concludes the paper.

RELATED WORKS

Recent developments in automated web crawling, classification, and sentiment analysis make it possible to monitor media effectively by using web scraping, natural language processing and machine learning to produce actionable insights for well-informed decision-making in organizational and governmental settings. The Two-Phase Multi-Task Sentiment Analysis (TPMSA) model was presented by Yang et al. [2] and integrates several modalities into a language model that has already been trained. After fine-tuning BERT on textual data, it performs multitask learning on text, visual, and auditory modalities as part of a two-phase training process. Because of its multitask architecture, TPMSA raises computing expenses even with its great accuracy. By introducing the Gated Fusion Semantic Relation Network (GFSR), Zeng et al. [3] addressed the difficulty of using multimodal data in sentiment analysis. Adjective-noun pairings taken from the text are used in this model to align textual and visual modalities, and multi-head cross-attention is used to dynamically align intra- and intermodal features. Although this method improves interpretability, it makes training more difficult. Similar to this, Liu et al. [4] created a framework for Web News Analysis that uses data mining and web crawling to process unstructured web data, classify news, and identify patterns. Real-time adaptation and addressing ethical issues in web data collection are still difficult tasks, nevertheless.

Devi et al. [5] concentrated on automating the distribution of government news pieces in multiple languages. Their system uses BeautifulSoup and Selenium to retrieve press releases from the Press Information Bureau (PIB), PyMuPDF to transform them into structured JSON, and DistilBART to summarize them. The M4T converts summaries into English and twelve regional Indian languages with ease; Google Textto-Speech (gTTS) produces the audio outputs. The technology incorporates Blender for 3D animation to create online video summaries that improve accessibility and engagement.

Domain adaptation and transfer learning have been studied to improve sentiment analysis. Multi-Kernel Maximum Mean Discrepancy (MK-MMD) and a domain adaptation module are used by Zhang et al. [6] Efficient Adaptive Transfer Network (EATN) to lessen domain disparities. Aspect-based sentiment analysis across datasets is made more stable and transferable by this method. Wenbin Yu et al. [7] showed that quantum neural networks with MBERT and Batch Upload Quantum Recurrent Neural Networks (BUQRNNs) and Parameter Nonshared BUQRNNs (PN-BUQRNNs) are superior in language categorization with limited resources. These models showed a 0.993% increase in accuracy and a 12% reduction in complexity in quantum circuit sequence representation.

Chatterjee et al. [8] combined online surfing patterns, social media, and environmental pollution data for COVID-19 epidemic forecasts in India for a maximum of 85 days of accuracy $r > 0.85$. The utilization of geotagged tweets and Google Trends, however, is a limiting factor in generalizability, and optimization of algorithms for regression such as ElasticNet was needed. The creative leveraging of multi-context datasets by authors is praise-worthy, and following studies can enhance forecasts by extending data sources and merging insights on users' behaviour. ZeroNLG, introduced by Yang et al. [9], is a multilingual and multimodal zero-shot natural language generation model for natural language generation tasks such as image captioning and neural machine translation without prelabelled downstream data. As much as it posts good zero-shot performance, its dependence on WebImageText and CC3M datasets restricts applicability to real-world lowresource languages. Lack of non English labeled vision-text pairs also impinges on accuracy in visual captioning. Lin et al. [10] proposed CL-XABSA, a contrastive learning-based framework for cross-lingual aspect-based sentiment analysis (XABSA). Their techniques close semantic gaps between languages through token-level and sentiment-level contrastive learning alignment of data. In addition to it also branches out to multilingual ABSA (MABSA), with knowledge distillation from target-language unlabelled data. However, fine-tuning cross lingual alignment remains a challenge.

AI-driven disaster monitoring also advanced. Sufi et al. [11] have proposed a monitoring system using NLP and AI with Named Entity Recognition (NER), sentiment analysis, anomaly detection using the CNN-based method, and regression models to extract live disaster insights. Although effective, the system is highly dependent upon pretrained models of NER as well as translation resources, thereby being less effective in low-resourced languages as well as rural areas with limited online resources. Similarly, Knittel et al. [12] have put forward a system for live social media stream clustering using a dynamic spherical k-Means++ approach with optimization for efficiency as well as incremental update. Although scalable, the approach is limited to dealing with just text-based data alone, leaving aside vital multimedia content, such as images and videos, which tend to be vital in the disaster management process.

These studies illustrate the rapid advancements in web crawling, NLP, sentiment analysis, and multimodal AI, while also highlighting existing challenges such as dataset constraints, computational costs, and the limitations of low-resource languages and multimedia integration. Future research should aim at improving real-time adaptability, multimodal fusion strategies, and cross-lingual alignment to enhance the robustness and applicability of these models in diverse domains. Table 1 further provides a synopsis of several significant approaches, stating their advantages and disadvantages in relation to web crawling, sentiment analysis, and classification methods.

TABLE I TECHNIQUES, MERITS, AND DEMERITS OF VARIOUS SENTIMENT ANALYSIS MODELS

TITLE TECHNIQUES MERITS DEMERITS

TITLE	TECHNIQUES	MERITS	DEMERITS
Understanding Sentiment Polarities and Emotion Categories of People on Public Incidents With the Relation to Government Policies (2024) Haochen Zou, Yongli Wang [1]	- Transformer-based models, such as RoBERTa - Natural Language Processing - Dynamic Masking - Removal of Next Sentence Prediction (NSP)	- Overall comprehensive analytical framework. - Real-time monitoring of sentiment. - Improved accuracy with advanced models.	- Limited data and scope of the platform. - High computational requirements. - Focused on COVID-19 only. - Issues in social media slang.
Multimodal Sentiment Analysis With Two-Phase Multi-Task Learning (2022) Bo Yang, Lijun Wu, Jinhua Zhu, Bo Shao, Xiaola Lin, and Tie-Yan Liu [2]	- Two-Phase Training Strategy - Multi-Task Learning - Intra- and Inter-Modality Attention	- Enhances the representation of each modality individually - Outperforms SOTA methods in sentiment analysis on multiple datasets	- Increased complexity due to multitask learning - Possible adverse effects from modality interactions if not managed
Exploring Semantic Relations for Social Media Sentiment Analysis (2023) Jiandian Zeng, Jiantao Zhou, and Caishi Huang [3]	- Gated Fusion Semantic Relation (GFSR) Network - Multi-Head Cross Attention - ANP Extraction	- Enhances sentiment analysis by exploiting intra- and inter-modal relations - Improves sentiment prediction accuracy on multiple datasets	- Increased computational complexity due to multiple attention layers - Performance depends on the quality of ANP extraction
Web News Analysis Based on Web Crawler Technology (2023) Qun Liu, Guangsheng Cao [4]	- Web Crawler for Data Col-lection - Data Mining for Analysis	- Efficient collection of large volumes of news data - Automatic analysis of trends and patterns	- Potential issues with scalability for large-scale real-time analysis - High data redundancy
Automated Multilingual Multimedia Dissemination of Government Press Releases (2024) Dr. Anitha Devi N,	- Web Crawling: Beautiful Soup, Selenium - Content Processing: PyMuPDF, regex,	- Expands government info access in multiple languages - Supports visually impaired - Engaging, timely multimedia dissemination	- High computational cost due to various processing steps - Manual approval adds delay - Relies on modal quality

TITLE	TECHNIQUES	MERITS	DEMERITS
Mohamed Saleh M, Arvind Srinivas K G, Mathalai Khishan S, Haresh V. [5]	Distilbart - TTS: gTTS - Video: GANs, Blender		
EATN: An Efficient Adaptive Transfer Network for Aspect-Level Sentiment Analysis (2023) Kai Zhang, Qi Liu, Hao Qian, Biao Xiang, Qing Cui, Jun Zhou, Member, and Enhong Chen [6]	- Domain Adaptation Module (DAM) - Aspect-Oriented Multi-Head Attention - Multiple-Kernel Maximum Mean Discrepancy (MKMMD)	- Enhances transferability across domains - Captures aspect-aware semantic relationships effectively - Outperforms state-of-the-art methods	- High computational complexity due to multi-task learning - Requires large labeled datasets for optimal performance
Application of Quantum Recurrent Neural Network in Low-Resource Language Text Classification (2024) Wenbin Yu, Lei Yin, Chengjun Zhang, Yadang Chen, Alex X. Liu [7]	- Quantum–Classical Hybrid Architecture - Batch Upload Quantum Recurrent Neural Network (BUQRNN) - Parameter Nonshared BUQRNN (PN-BUQRNN)	- Enhances text classification accuracy in low-resource languages - Reduces model complexity by 12% - Outperforms classical architectures in certain tasks	- High computational cost for state preparation - Challenges in capturing long-sequence semantics - Dependency on quantum device quality
Forecasting COVID-19 Outbreak Through Fusion of Internet Search, Social Media, and Air Quality Data: A Retrospective Study in Indian Context (2023) Sankhadeep Chatterjee, Kushankur Ghosh, Arghasree Banerjee, Soumen Banerjee [8]	- Fusion of Internet Search Trends (using comprehensive keywords) - Social Media (Tweets) - Air Quality Data with Machine Learning Models	- Accurate prediction 70-100 days ahead - Comprehensive use of specific Internet search trends enhances the model's predictive power	- Challenges in handling data variability - Model complexity increases with the integration of diverse data sources
ZeroNLG: Aligning	- Cross-Domain	- Enables zero-shot language	- Dependence

TITLE	TECHNIQUES	MERITS	DEMERITS
and Autoencoding Domains for Zero-Shot Multimodal and Multilingual Natural Language Generation (2024) Bang Yang, Fenglin Liu, Yuexian Zou, Xian Wu, Yaowei Wang, David A. Clifton [9]	Alignment - Denoising Language Reconstruction - Transfer Learning	conversion across multiple languages (e.g., English, Chinese, German, French) without the need for labeled data pairs - Effective for text-to-text translation in low-resource languages	on large-scale pre-training data - Challenges in achieving high accuracy in language conversion when domain alignment is imperfect
CL-XABSA: Contrastive Learning for Cross-Lingual Aspect-Based Sentiment Analysis (2023) Nankai Lin, Yingwen Fu, Xiaotian Lin, et al. [10]	- Contrastive Learning to enhance Cross-Lingual Alignment - Token classification using BERT architecture, Knowledge Distillation	- Improves the consistency of semantic representations between different languages - Enhances sentiment detection accuracy, particularly for languages with limited labeled data	- High complexity in training, limited effectiveness in certain languages like Spanish - Requires extensive datasets
Automated Disaster Monitoring From Social Media Posts Using AI-Based Location Intelligence and Sentiment Analysis (2023) Fahim K. Sufi, Ibrahim Khalil [11]	- AI-based Sentiment Analysis - Named Entity Recognition (NER) - Anomaly Detection - Getis-Ord Gi* algorithm	- High accuracy (97%) - Real-time monitoring of disasters - Covers 110 languages - Mobile and web accessibility	- High complexity in implementing deep learning methods - Challenges in processing large-scale social media data
Real-Time Visual Analysis of High-Volume Social Media Posts (2022) Johannes Knittel, Steffen Koch, Tan Tang, Wei Chen, Yingcai Wu, Shixia Liu, Thomas Ertl [12]	- Dynamic Clustering Algorithm - Parallel Clustering - Bag-of-Words (BoW) Vector Representation	- Efficient real-time clustering - Handles large data volumes on a budget PC - Provides a scalable, adaptive stream of social media posts	- Relies on textual content, ignoring media (images, videos) - May miss smaller developments due to content diversity

PROPOSED SYSTEM

NewsIntel enables government response through an integrated real-time news monitoring and feedback platform. In addition, it has an automated web crawling system that can retrieve news articles and multimedia from various sources. Additionally, the crawled content is categorized for relevant government departments, which enhances this platform's targeted surveillance capabilities and, in turn, guarantees effective information retrieval. The platform uses sentiment analysis to determine how the public feels about government-related topics, whether that sentiment is good, neutral, or negative, in order to ensure that important content is given timely attention. It is designed in such a way as to allow the system, especially in real time, to analyze sentiments. The latter enables different government departments to focus on trends of public sentiment for necessary advanced actions that help them avoid emerging issues. In addition, NewsIntel includes a notification mechanism that alerts relevant officials about high-priority or sensitive content, enabling immediate action to mitigate potential public concerns. This will combine all features towards informed decisions and the advancement of relationships between the government and the people. It integrates a userfriendly interface with easy access to real-time categorized and analyzed news. This approach will improve government department's readiness to actively engage with public opinion and maintain governance plans in line with changing social demands.

The key features of the proposed system include:

A. Automated Web Scraping

To extract articles from various sources, the system uses web scraping tools such as BeautifulSoup. The scraping method is designed to handle dynamic content while ensuring compliance with website policies.

B. Intelligent Categorization

Automatic categorization of extracted content is done using pre-established government department tags. Machine learning classification methods are used to accomplish this, guaranteeing that articles are appropriately categorized under headings like politics, crime, etc.

C. Sentiment Analysis Engine

Natural language processing (NLP) techniques are used by advanced sentiment analysis engine to process articles. Positive, neutral, and negative sentiment tags are applied to each article which helps in enabling departments to rank their replies to important problems.

D. Real-Time Notifications

When negative sentiment articles are found, the system automatically notifies the respective government officers. This makes sure that issues which affect the public are addressed immediately. Notifications can be given through email or SMS.

E. User-Friendly Dashboard

Trends in news, categorization of article and the distribution of sentiment can be seen visually on a comprehensive dashboard The dashboard enables easy navigation by applying filters on the department and sentiment level.

F. Scalable and Modular Architecture

The modular architecture of the system provides scalability to support more news sources and functionalities. A responsive design is provided by the frontend for easy access across multiple devices.

Figure 1 shows the architecture diagram of NewsIntel.

MACHINE LEARNING MODEL

a. Dataset

1. News Category Dataset: It is a collection of articles from HuffPost published in Kaggle. It is organized under 42 categories such as politics, business, entertainment, and sports, etc. Each record in the dataset includes the category, title, authors, link, date, and a short description, which can be utilized for classifying news articles into different categories.
2. News Sentiment Analysis: This dataset includes news headlines and descriptions categorized by sentiment as positive, negative and neutral. It is used for training models to assess news sentiment scores. The news was collected from various global sources.
3. Stock Market News Data in Portuguese: This dataset is also known as the Financial Phrase Bank Portuguese Translation which consists of stock market-related news articles. It contains sentiment labels such as positive, negative, and neutral that help in analyzing the impact of financial news on stock market.

b. BERT and DistilBERT Model

BERT (Bidirectional Encoder Representations from Transformers) and its lighter version DistilBERT are very popular deep learning models for NLP tasks like news classification and sentiment analysis. These models are capable of analyzing real-time news articles to extract sentiment information for the NewsIntel system. Algorithm 1 outlines the core functionality of NewsIntel.

1. Text Preprocessing: Before feeding text data into the model, it undergoes preprocessing to enhance consistency and improve model performance. The key preprocessing steps include:
   - Tokenization: The text is split into words using the BERT tokenizer.
   - Cleaning: Stop words, punctuation, and special characters are removed.
   - Lowercasing: All text is converted to lowercase for uniform processing.

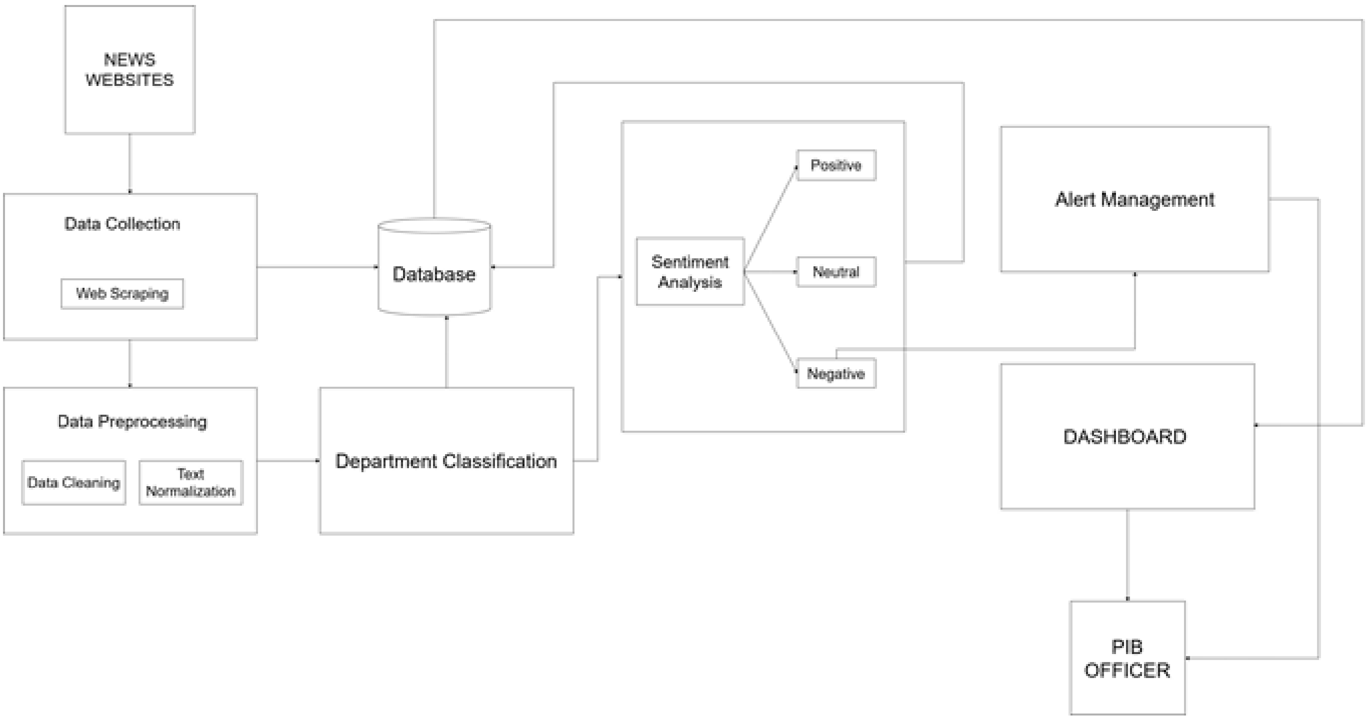

Fig. 1. Architecture diagram of NewsIntel

Algorithm 1 NewsIntel: Real-Time News Intelligence System

1. : Require: News source URLs U, Department tags D, Transformer based-models M, Sentiment labels S
2. : Ensure: Categorized articles A, Sentiment scores V
3. : A ←∅ // Initialize article set
4. : V ←∅ // Initialize sentiment scores
5. : while True do
6. : for each u ∈ U do
7. : content ← CRAWLWEBSITE(u)
8. : cleanText ← PREPROCESS(content)
9. : category ← MBERT(cleanText,D)
10. : A ← A ∪{(content,category)}
11. : sentiment ← MDistilBERT(cleanText,S)
12. : V ← V ∪{(content,sentiment)}
13. : if sentiment is negative then
14. : NOTIFYSTAKEHOLDERS(content)
15. : end if
16. : end for
17. : UPDATEDASHBOARD(A,V)
18. : end while

2. Word Embedding: BERT and DistilBERT use an embedding layer to transform input text into numerical representations, mapping each token to a high-dimensional vector space. The key aspects of this process include:
   - Self-Attention Mechanism: Enables the model to understand word relationships in context rather than in isolation.
   - Bidirectional Processing: Unlike conventional models, BERT considers both left and right contexts, improving accuracy.
   - DistilBERT Optimization: DistilBERT is a lighter version of BERT that retains 97% of its accuracy on many downstream tasks while using 40% fewer parameters, making it highly efficient for real-time processing.
3. Fine-Tuning: BERT and DistilBERT undergo pretraining on a large corpus and require fine-tuning on specific news datasets to classify and analyze sentiments effectively. The fine-tuning process includes:
   - News Categorization: BERT is fine-tuned on the News Category Dataset to classify articles into relevant government departments.
   - Sentiment Analysis: DistilBERT is fine-tuned on the News Sentiment Analysis Dataset to predict whether news articles express a positive, negative, or neutral sentiment.
   - Training: The model weights are updated using labeled
   - datasets to optimize classification accuracy. The sentiment analysis model based on DistilBERT in NewsIntel is trained using the AdamW optimizer to enhance efficiency, reduce overfitting, and ensure high accuracy in classifying news articles as Positive, Negative, or Neutral.
4. Classification: Once fine-tuned, BERT and DistilBERT classify text in real-time:
   - BERT Model Output: Probability distribution over government department categories.
   - DistilBERT Model Output: Sentiment scores for news articles.

The model assigns the highest probability to the most likely category or sentiment, enabling further analysis. By leveraging BERT and DistilBERT, NewsIntel achieves highaccuracy news categorization and sentiment analysis, facilitating effective real-time news monitoring.

PERFORMANCE ANALYSIS

In order to compare the performance of machine learning models that would categorize departments and conduct sentiment analysis. We compare the model with major metrics such as accuracy, precision, recall and F1-score.The evaluation is done by utilizing benchmark data for news classification and sentiment analysis.

A. Department Categorization

The performance of Logistic Regression and BERT models in categorizing news articles into respective government departments is compared. The evaluation results are presented in Table II.

TABLE II

PERFORMANCE METRICS FOR DEPARTMENT CATEGORIZATION

Model	Accuracy	Precision	Recall	F1-Score
Logistic Regression	0.65	0.62	0.48	0.52
BERT	0.75	0.67	0.63	0.65

BERT outperformed Logistic Regression in all evaluation metrics, achieving an accuracy of 75%, whereas Logistic Regression achieved only 65%. This improvement is attributed to BERT's superior contextual learning capabilities, which enable more precise classification.

B. Sentiment Analysis

To analyze sentiment, we employed DistilBERT, a lighter variant of BERT, and evaluated its accuracy in classifying sentiments as positive, neutral, or negative. The results are summarized in Table III.

TABLE III

PERFORMANCE METRICS FOR SENTIMENT ANALYSIS

Sentiment	Precision	Recall	F1-Score	Support
Negative	0.76	0.79	0.78	246
Neutral	0.84	0.87	0.85	714
Positive	0.86	0.82	0.84	709
Overall Accuracy	0.84			

DistilBERT achieved an overall accuracy of 84%, demonstrating its strong capability in sentiment classification. The model accurately distinguishes between positive, neutral, and negative sentiments, with F1-scores exceeding 0.78 across all categories.

C. Comparison and Observations

- Department Categorization: BERT significantly enhances classification performance over Logistic Regression, particularly in recall, allowing for more effective categorization of department-related news articles.
- Sentiment Analysis: DistilBERT demonstrates high accuracy and recall, resulting in precise sentiment categorization with minimal misclassification.
- Overall Performance: The integration of transformerbased models (BERT and DistilBERT) enhances both accuracy and robustness, enabling the system to generate reliable real-time insights that support government decision-making.

CONCLUSION

NewsIntel exhibits functionalities such as web scraping, data preprocessing, sentiment analysis and real-time notification informing features involving government departments to know public sentiments faster across important news items. In the given scope of an interactive dashboard, it aggregates data which is processed initially and has tagged sentiment information for making decisions by the authorities. Further, the system would enable real-time alerts in sensitive news through its system of notifications. This would enable the government to give a prompt response to public concerns. What the proposed system demonstrates is the potential of AI technology in combination with the newest data pipelines to make possible actionable insights. It provides scalable and accurate services, thus ensuring the Press Information Bureau could ensure transparent and public-wide engagement of the system. It also has the characteristics of being advanced and improving precision over time, destined to become an important tool for any government in the media monitoring aspect for responsive and effective actions in a changing media space.

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Shop-Nexus

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ABSTRACT

In the rapidly evolving era of online shopping, consumers are often overwhelmed by the sheer volume of information dispersed across multiple e-commerce platforms. Diverse product features, varying user reviews, and fluctuating prices create a fragmented decision-making landscape. This work introduces an intelligent, NLP-driven system designed to simplify and enhance the online shopping experience. By aggregating product reviews, ratings, and pricing data from various e-commerce websites, the system leverages MuleSoft for seamless data integration and employs natural language processing (NLP) to deliver actionable insights.

Index Terms—API-Application Programming Interface, ETL- Extract Transform Load, NLP-Natural Language Processing, UI/UE-User Interface/User Experience, CNN-Convolutional Neu- ral Network.

INTRODUCTION

Shopping has been transformed by e-commerce with un- precedented convenience and access to a wide variety of options. Yet, this abundance has the potential to create infor- mation overload, rendering consumers unable to make smart buying decisions. Diverse reviews, erratic ratings, and price variation between different platforms only add to the decision- making complexity.

To overcome such challenges, our system combines Busi- ness Intelligence (BI) software with e-commerce sites, as Ferreira et al. [1] recommend, in order to bring together and interpret data from different sources. With this combination comes a single, easy-to-use interface that facilitates decision- making since users can confidently choose products best suited to their requirements.

One of the most important features of our system is the use of sophisticated Natural Language Processing (NLP) meth- ods for sentiment analysis, one that is consistent with the approaches outlined by Chehal et al. [2]. Through customer review analysis, our system not only determines the aspects of a product and the corresponding sentiments but provides users with fine-grained information according to their specific demands. This aspect-level sentiment analysis goes beyond rating systems, delivering users highly detailed information.

Besides sentiment analysis, our system includes a price comparison feature that aggregates real-time pricing informa- tion from numerous e-commerce platforms. This aspect deals with price fluctuation by taking into consideration shipping charges and return policies to make the end-user knowledge- able about the total expense and save them from hidden expenses.

The last piece of our system is a recommendation engine that combines analyzed data to deliver actionable insights. Through the integration of sentiment scores, feature assess- ments, and cross-platform price comparisons, the system pro- vides conclusive recommendations on product choice and the best purchasing platform. This holistic approach enables users to make rapid, confident choices in line with their individual preferences, whether they value cost-effectiveness or particular product features.

By using cutting-edge technologies like NLP and informa- tion aggregation, our project targets important issues of e- commerce shoppers. It minimizes the misinformation gener- ated by contradictory data, saves time, and promotes clarity in the shopping experience. Finally, our system allows users to make wiser and more knowledgeable choices, promoting greater satisfaction and confidence in online shopping. This project will revolutionize the digital marketplace by providing a smarter, more transparent experience for shopping.

Furthermore, our system addresses the user cold start prob- lem in recommender systems, as discussed by Yuan et al. [7]. By analyzing initial user interactions and preferences, our recommendation engine can provide personalized suggestions even for new users with limited data. This approach enhances user engagement and satisfaction from the outset. In addition, we have constructed an extensive annotated customer review dataset for aspect-based sentiment analysis, adhering to the guidelines specified by Chehal et al. [2]. The dataset is useful for training and comparing supervised ma- chine learning models and can be utilized to further sentiment analysis software in the e-commerce industry.

In brief, our system combines several cutting-edge technolo- gies and techniques to maximize the online shopping experi- ence. By resolving typical issues like information overload, price volatility, and the cold start problem, we are offering a comprehensive platform that enables consumers to make educated, confident buying choices.

RELATED WORKS

Numerous methodologies have been developed to enhance the functionality of recommender systems, leveraging diverse data sources and advanced analytical techniques. These strate- gies aim to improve the precision and relevance of recommen- dations while addressing the challenges of processing large, complex datasets. By integrating both quantitative metrics and qualitative insights, these approaches contribute significantly to informed decision-making and user satisfaction across var- ious domains.

Tania Ferreira et al. [1] provides a detailed examination of Business Intelligence (BI) integration with e-commerce websites. The research centers around key subjects like data consolidation from various e-commerce sources, analysis of customer activity, and market trend forecasting. It highlights the use of BI tools to facilitate businesses in making effective, data-driven decisions through the processing of vast amounts of structured and unstructured data from multiple online shop- ping channels. The paper also confirms the efficacy of data integration methods, especially the ETL (Extract, Transform, Load) process, in integrating heterogeneous data and improv- ing business operations. Further, it discusses how BI aids in targeted marketing efforts, better inventory management, and general financial expansion. In giving a comprehensive framework for BI deployment, the study recognizes the issues of data consistency, quality maintenance, and scalability.

Dimple Chehal, et al. [2] performed an overall assessment of a dataset annotated specifically for aspect-based sentiment analysis (ABSA) of customer reviews. The research highlights the relevance of ABSA in analyzing customer feedback to identify sentiments on particular product features, thus pro- viding a more refined insight beyond sentiment analysis in general. Specifically targeting mobile phone reviews, specif- ically the Apple iPhone 11, the authors carefully annotated the dataset with pre-defined aspect categories and respective sentiment polarities. This resource is a useful benchmark for training and evaluating supervised machine learning models for ABSA tasks. The work also touches upon challenges intrinsic to the annotation task, such as consistency and subjective interpretation of sentiments. Through the release of this dataset, the research enables the development of more ac- curate and focused sentiment analysis tools in the e-commerce industry.

Sein Hong, et al. [3] proposed the Review-based Outer Product Convolutional Neural Network (ROP-CNN) model, a new concept in recommender systems based on user reviews to improve recommendation precision. Utilizing convolutional neural networks (CNNs) and modeling complex user-item interactions using the outer product, the ROP-CNN success- fully extracts semantic features from text-based reviews. This approach overcomes the weakness of conventional recom- mendation models based on purely quantitative user behavior data, which tend to be plagued by data sparsity problems. Experimental results on actual user-review datasets show that the ROP-CNN model is superior to current baseline models in terms of prediction accuracy. Nevertheless, computational complexity and scalability issues are still avenues for future research.

Srividya Bansal [4] introduces an innovative framework that uses semantic technologies to integrate heterogeneous datasets during the ETL process. This approach effectively handles diverse data types, including structured formats like relational tables, semi-structured formats such as XML, and unstructured content such as text and multimedia. Using ontologies and RDF, the framework generates meaningful linked data repre- sentations, enabling sophisticated querying and analysis. Key strengths include adaptability for new datasets and seamless in- tegration capabilities, making it ideal for dynamic applications such as smart cities. Despite its limitations, this framework demonstrates the potential of semantic ETL processes to transform raw big data into a robust foundation for advanced analytics and decision-making systems.

Michael W. Shafer et al. [6] outline a comprehensive solution to analyze customer feedback from various sources, including online marketplaces and social networks. The frame- work processes structured, semi-structured, and unstructured data, employing techniques such as cleaning, normalization, and transformation to prepare raw data for analysis. A stand- out feature is its Aspect-Based Sentiment Analysis, which evaluates customer opinions on specific product attributes, providing granular insights beyond general sentiment. With its ability to update real-time feedback, this framework empowers businesses to understand market trends and consumer pref- erences, offering a competitive advantage through actionable insights.

Souvick Das, et al. [8] presents a detailed framework for analyzing mobile app reviews to optimize the technology value stream in software development. Leveraging advanced NLP techniques, the framework identifies critical issues, prioritizes updates, and addresses technical obstacles. It includes modules for sentiment analysis, topic classification, and summarization, ensuring concise and relevant feedback for developers. Despite challenges such as multilingual data handling, this framework bridges the gap between user feedback and continuous soft- ware improvement, enhancing customer satisfaction and app performance in the digital landscape.

TABLE I TECHNIQUES, MERITS, AND DEMERITS OF VARIOUS PRODUCT RECOMMENDER SYSTEM

TITLE	TECHNIQUES	MERITS	DEMERITS
Integration of Business Intelligence with E-commerce (June 2019) Tania Ferreira, Isabel Pedrosa and Jorge Bernardino [1]	- Business Intelligence Platforms - E-commerce Platforms - Integration Technologies	-Comprehensive survey of Platforms - Architecture Proposal - Use of Open Source - Integration Models	- Lack of Implementation De- tails - Limited Evaluation - Absence of Security Consid- erations - Restricted to Open Source
Evaluating Annotated Dataset of Customer Reviews for Aspect-Based Sentiment Analysis (Dec 2021) Dimple Chehal, Parul Gupta and Payal Gulati [2]	- Naive Bayes - SVM - Logistic Regression - Random Forest - KNN - MLP	- -Mobile phone review dataset - Aspect-based sentiment anal- ysis - Multiple ML models used	- Small dataset - Imbalanced data - No emoticon handling
Review-Based Recommender System Using Outer Product on CNN (May 2024) Sein Hong , Xinzhe Li , Sigeon Yang , and Jaekyeong Kim [3]	- CNN - Outer Product - MLP	- Captures user-item interac- tions - Improved prediction accu- racy	- Does not handle item at- tributes like images - Lacks attention mechanism
Towards a Semantic Extract-Transform-Load (ETL) framework for Big Data Integration (June 2014) Srividya Bansal [4]	- Semantic Web Technologies - ETL Process - Prote´ge´ Ontology Editor - Random Forest - Apache Jena - Oxygen XML Editor	- Focus on Big Data Integra- tion - Semantic ETL Framework - SPARQL for Querying - Practical Implementation -Improvement over Tradi- tional ETL	- Complexity in Ontology Cre- ation - Limited Real- Time Process- ing - Scalability Concerns - Prototype Limitations - Reliance on Expert Knowl- edge
Healthcare Yelp: Health Care Services Prediction (Mar 2020) Felix Zhan, Yuria Mann, Nicholas Lower, Haemin Choi [5]	- - VADER (Valence Aware Dictionary and sEntiment Reasoner)	- Unified Rating - Sentiment-Enhanced Ratings - Personalized Recommenda- tions	- Reliance on Review Quality - Complexity of the Model - Inconsistent Review Sources - Limited to Text-

TITLE	TECHNIQUES	MERITS	DEMERITS
			Based Re- views
A Multi-Source Big Data Framework for Capturing and Analyzing Customer Feedback (Jan 2021) Michael W. Shafer And Paul G. Flikkema [6]	- Apache Hadoop -Aspect-Based Sentiment Analysis (ABSA) - Natural Language Processing (NLP) - MapReduce	- Multi-Source Data Collection - Aspect-Based Sentiment Analysis - Dynamic Data Integration - Effective Data Visualization	- Complexity in Data Integra- tion - Dependency on Big Data In- frastructure - Sentiment Analysis - Limitations Potential Data Quality Issues
User Cold Start Problem in Recommender Systems (Dec 2023) Hongli Yuan and Alexander A Hernandez [7]	- Meta Learning - Deep Learning - Cross-Domain Recommendations	- Comprehensive techniques - Data-driven - Advanced neural models	- High Complexity - Privacy concerns
Driving the Technology Value Stream by Analyzing App Reviews (April 2023) Souvick Das , Novarun Deb , Nabendu Chaki and Agostino Cortesi [8]	- BERT - RoBERTa - T5 - Yake	- Novel framework - Use of Transformer models - Extensive evaluation on di- verse apps - Contribution to tool develop- ment	-Initial Industry validation lacking - High Computational Needs - Dependency on pre-trained models
Unifying Star Ratings and Text Reviews for Product Competitiveness (June 2024) Huchang Liao , Jiayi Wang , and Zeshui Xu [9]	- Prospect Theory - Evidential Reasoning - Stochastic Dominance	- Unified representation - Comprehensive evaluation - Considers consumer sensitiv- ity	- Complexity - Data dependence - Assumes linearity
Cross-vendor programming abstraction for diverse heterogeneous platforms (Oct 2022) Topi Leppa¨nen, Atro Lotvonen and Pekka Ja¨a¨skela¨inen [10]	- OpenCL - Built-in Kernel Registry - ONNX - Deep Learning Compilers	- Unified Abstraction Layer - Cross-Platform Flexibility - Open-Source Contribution - Interoperability with Deep Learning Frameworks	- Vendor Dependency - Limited Evaluation - Scalability Challenges - Overhead Concerns
Integration of Applications Using SOA and Mulesoft (June 2017)	- Oracle SOA Suite (OSS) - MuleSoft Anypoint	- Comprehensive Comparison - Clear Criteria for	- Narrow Focus on Two Tools - Error Handling

TITLE	TECHNIQUES	MERITS	DEMERITS
Teodora Vucˇkovic´, Darko Stefanovic´ [11]	Platform	Evaluation - Insight into Common Errors - Use Case Implementation	Lacks Depth - Limited Real-World Testing
Integration of Data from Heterogenous Sources Using ETL Technology (Jan 2014) Marek Macura [12]	- ETL Technology - Wrapper Layer - CloverETL 3 - Three-Tier Architecture	- Focus on Heterogeneous Data Integration - Flexibility and Extensibility - Unified Data Environment - Verification through Practical Application	- Limited Scalability Discus-sion - Complexity of Wrapper Cre-ation - Minimal Discussion of Error Handling

Huchang Liao et al. [9] explores an innovative approach to evaluating product competitiveness by integrating star ratings and textual reviews. By applying prospect theory, the method- ology accounts for consumer biases and emphasizes the psy- chological impact of negative feedback. This unified analysis provides a holistic view of market preferences, enabling busi- nesses to refine product strategies and maintain a competitive edge. Validated through a case study in the automobile sector, this approach highlights the value of combining quantitative and qualitative data to generate actionable insights for product designers and companies.

Leppa¨nen et al. [10] proposed a new software abstraction in- tended to generalize hardware-accelerated computation across a range of heterogeneous platforms. The platform makes use of the open OpenCL programming model, taking advantage of its in-built kernel aspects to provide an automatable layer of portability that uses several accelerators seamlessly. By offering the ability to integrate hardware accelerators from multiple vendors, the abstraction seeks to simplify the pro- gramming process and support better performance portability. But areas of future work include issues like dealing with computational complexity and achieving scalability over a variety of hardware configurations.

Marek Macura [12] describes an extensive architecture for semantic integration of data from disparate sources with the help of ETL (Extract, Transform, Load) technology. The solution integrates ETL processes with a mediated system wrapper layer, enabling semantic integration through connec- tion mechanisms between data items. This makes it possible to integrate various data sources and apply analytical techniques in one environment. The architecture has been tested in the foundry industry and proved its ability to manage sophisticated data integration complexities. The research, however, admits that some challenges exist, such as the optimal handling of large-scale data and maintaining data quality during data integration. These findings are important in the development of sophisticated data integration solutions in different sectors. These studies collectively underscore the transformative potential of integrating advanced analytics and diverse data sources to improve recommendation systems. By addressing specific challenges such as data heterogeneity, sentiment anal- ysis, and real-time feedback integration, they contribute to the development of robust and scalable solutions tailored to dynamic market demands.

PROPOSED SYSTEM

The proposed system is an NLP-based platform designed to aggregate and analyze product reviews, ratings, and pricing data from multiple e-commerce platforms. Its objective is to transform unstructured review data into coherent, user-friendly insights within a streamlined recommendation system, thereby aiding consumers in making informed purchasing decisions. By leveraging MuleSoft for integration and advanced Natural Language Processing (NLP) techniques for text data process- ing, the system consolidates valuable insights into a unified framework. The detailed working of Shop-Nexus is shown in the Figure 1.

The system simplifies online shopping by enabling real- time data aggregation across various e-commerce platforms. It provides a user-centric interface to consolidate dispersed information such as customer reviews, product features, rat- ings, and pricing. This facilitates quicker and more informed purchasing decisions. The system architecture comprises three primary modules: Sentiment Analysis, Feature Extraction, and Price Comparison.

A. Sentiment Analysis Module

This module processes substantial volumes of customer feedback to classify reviews as positive, negative, or neutral. By employing state-of-the-art models like BERT, it achieves high accuracy in sentiment classification. The module com- putes sentiment ratios, filters irrelevant content, and delivers actionable insights to the user.

B. Feature Extraction Module

The feature extraction module identifies frequently men- tioned product attributes, categorizes them as strengths or weaknesses, and aligns them with user preferences. Using ad- vanced techniques such as Named Entity Recognition (NER), it ensures detailed analysis of product quality and performance.

C. Price Comparison Module

The price comparison module aggregates and standardizes real-time pricing data from multiple platforms. It incorporates additional variables such as shipping costs and return policies while tracking historical price trends. This enables users to assess whether a product is competitively priced at any given time.

D. Recommendation Engine

At the core of the system is a recommendation engine that synthesizes outputs from the above modules to deliver actionable insights. Using weighted scoring algorithms, it balances sentiment ratios, feature analyses, and pricing data to generate a final recommendation. The engine also suggests the optimal platform for purchase.

E. Backend Architecture and User Interface

The backend architecture, powered by MuleSoft, ensures seamless API integration and smooth communication between modules. The system includes an intuitive, visually appealing user interface, optimized for diverse platforms. Key features include a product search page, detailed dashboard insights, price comparison charts, and personalized notifications. By consolidating scattered information into a transparent frame- work, the system enhances user confidence, fosters trust, and addresses modern e-commerce challenges.

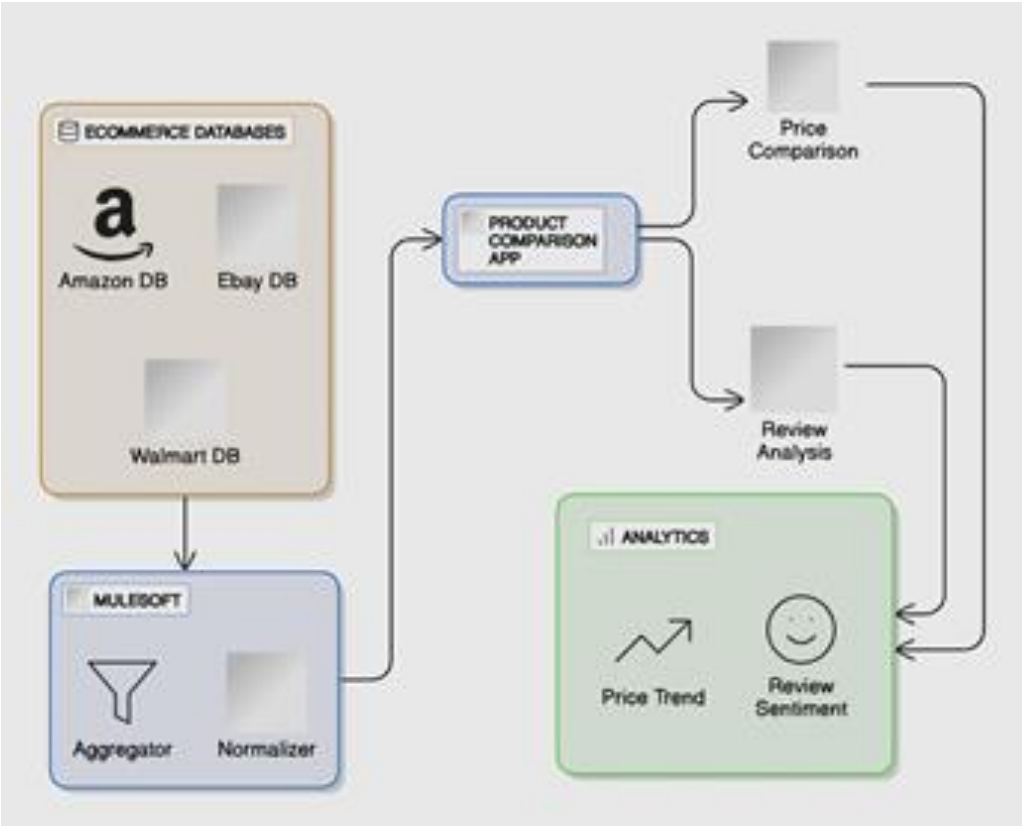

Fig. 1. Architecture diagram showing the integration and overall working.

MACHINE LEARNING MODEL

A. Dataset

For this study, we utilized several publicly available datasets containing e-commerce product reviews, ratings, and aspect- based sentiment annotations. These datasets were selected based on their relevance to sentiment analysis, product com- parisons, and recommendation system development.

- **Review Dataset**

To analyze customer sentiment and extract key product features, we leveraged the Amazon Review Data dataset, which comprises approximately 142.8 million product reviews across various categories, including electronics, fashion, and home appliances. However, for this study, we specifically focused on reviews related to electronic gadgets, such as smartphones, laptops, headphones, and smartwatches. This selection ensures that the sentiment analysis and recommendation system are optimized for consumer electronics rather than general product cate- gories. The dataset includes:

- Review Text: User-generated product reviews
- Rating Score: Numerical ratings from 1 to 5
- Product Metadata: Descriptions, category informa- tion, price, brand, and image features

This dataset was obtained from the University of Califor- nia, San Diego's repository and has been pre-processed to enhance usability for sentiment analysis and feature extraction tasks.

- **Aspect-Based Sentiment Analysis Dataset**

For fine-tuning our NLP model, we utilized the Multi- Aspect Multi-Sentiment (MAMS) dataset. This dataset contains sentences with multiple aspects, each associated with different sentiment polarities, providing a compre- hensive resource for aspect-based sentiment analysis. It includes:

- Sentences: Textual data with multiple aspects
- Aspect Terms: Specific components or features men- tioned
- Sentiment Labels: Polarity assigned to each aspect (positive, negative, neutral)

The MAMS dataset was sourced from research publica- tions and is available for academic use.

- **Additional Datasets**

To further enrich our analysis, we incorporated the fol- lowing datasets:

– E-Commerce Product Review Data: A dataset from Kaggle containing reviews, ratings, and product meta- data across various categories.

– Aspect-Based Sentiment Analysis Dataset: A collec- tion of datasets suitable for training models on aspect- based sentiment analysis tasks.

– EPRSTMT Dataset: A binary sentiment analysis dataset based on product reviews from an e-commerce platform, labeled as Positive or Negative.

These datasets were obtained from reputable online repositories and have been processed to align with the requirements of our sentiment analysis and recommenda- tion system.

B. BERT Model

The platform uses NLP and BERT to process pre-existing e-commerce datasets, uncovering insightful information from product reviews. Processing extensive amounts of text, it picks up on trends in sentiment, important product features, and con- sumer preferences, making available a well-organized analysis of various products. The model categorizes reviews according to sentiment polarity and underlines frequently referenced features, allowing users to determine product strengths and weaknesses. Because the system works on static data sets, it provides consistency in analysis and removes the uncertainty of real-time data. This systematic approach makes product comparisons more accurate and reliable, helping users make informed buying decisions.

The algorithm starts by collecting product reviews, price data, and labels. Reviews are preprocessed through text clean- ing, tokenization, lemmatization, and stopword removal. The BERT tokenizer converts the text into tokenized inputs for sentiment classification, which is trained using cross-entropy loss. Key product features are extracted using TF-IDF or attention-based methods. Price data is normalized, and a sentiment-weighted pricing strategy determines the best pur- chase platform. Finally, the model is evaluated using accuracy, precision, recall, and F1-score, returning the sentiment score, key features, and recommended platform.

Algorithm 1 : BERT-Based Review Analysis and Recommen- dation Algorithm for Shop-Nexus

Input: Product reviews R, Trained BERT model MBERT , Pricing data P from multiple e-commerce platforms

Output: Sentiment score S, Key product features F , Rec- ommended platform Prec

Procedure:

1. : Collect review dataset D = {(Ri, Pi, Yi)} where:
   - Ri is a set of reviews, Pi is price data, and Yi is the product label for product i
2. : Preprocess reviews by:
   - Converting text to lowercase
   - Removing special characters and stopwords
   - Tokenizing and lemmatizing words
3. : Tokenize reviews using a pre-trained BERT tokenizer:
   - T = Tokenize(R)
4. : Convert tokens into input format for BERT:
   - X = {input ids, attention mask}

5. : Train a transformer-based classifier (BERT) for sentiment analysis:
   - $\hat{Y} = MBERT(X)$
6. : Compute loss using cross-entropy and update model pa- rameters:
   - $L = CrossEntropyLoss(\hat{Y}, Y)$
7. : Apply feature selection using TF-IDF or attention-based keyword extraction:
   - $F = Extract\ keywords(H)$
8. : Retrieve price data Pi from multiple platforms and nor- malize values
9. : Determine best platform based on sentiment-weighted price score:
   - $Prec = \arg\min(Pi \times (1 - \hat{Y}))$
10. : Evaluate the model on test data and compute:
    - Accuracy
    - Precision, Recall, and F1-score
11. : Return: Sentiment score $\hat{Y}$, Key product features F , Recommended platform Prec

PERFORMANCE ANALYSIS

To analyze the performance of the sentiment analysis mod- ule in Shop-Nexus, we compared its performance with the sentiment models deployed in popular e-commerce websites like Flipkart and Amazon. We evaluated it using common classification metrics like Accuracy, Precision, Recall, and F1-score. The results are tabulated in Table II.

TABLE II

PERFORMANCE METRICS OF SENTIMENT ANALYSIS MODELS

Model	Accuracy	Precision	Recall	F1-score
Flipkart Sentiment Model	85.2%	83.1%	81.4%	82.2%
Amazon Sentiment Model	88.5%	86.7%	85.3%	86.0%
Shop-Nexus (Ours)	**84.3%**	**82.8%**	**81.3%**	**82.08%**

Additionally, a comparison of execution time and compu- tational efficiency was performed to assess the feasibility of real-time processing, as shown in Table III.

TABLE III

COMPUTATIONAL EFFICIENCY OF SENTIMENT ANALYSIS MODELS

Model	Inference Time (ms/review)	Resource Utilization (GPU)
Flipkart Sentiment Model Amazon Sentiment	150 ms	Medium High
Model	130 ms	**Optimized (Medium-High)**
Shop-Nexus (Ours)	**110 ms**	

A. Graphical Comparison

For better visualization, Figure 2 presents a bar chart comparing the accuracy, precision, recall, and F1-score of the different sentiment analysis models.

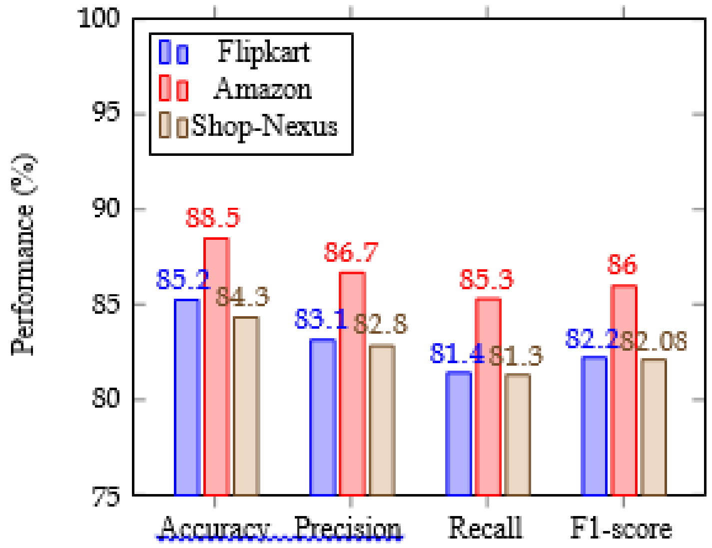

Fig. 2. Performance Comparison of Sentiment Analysis Models

The findings show that the Shop-Nexus BERT model has accuracy and F1-score that matches Flipkart and Amazon's current sentiment analysis tools. In addition, the inference time is lower, which makes it more efficient for large-scale review processing with optimized GPU utilization.

CONCLUSION

Through advanced Natural Language Processing techniques, the system deals with large volumes of unstructured customer reviews, classifies sentiments, and extracts the most frequently mentioned product features that will be able to provide the user with insights. This approach combined with a real-time price comparison module ensures transparency, enabling users to evaluate the quality and affordability of products. The recommendation engine further simplifies decision-making by providing a final verdict on whether a product is worth purchasing and from which platform, saving users a lot of time and effort.

With an integration of sentiment analysis, feature extrac- tion, and price aggregation into an easy-to-use interface, the system enables the shopper to make informed, data-driven decisions. Its scalable architecture in the back end ensures easy integration with several e-commerce platforms, opening avenues for future upgrades such as multilingual support and advanced personalization features. Ultimately, the project not only simplifies online shopping but also builds trust and confidence among the users, adding to the constantly changing landscape of smarter and more efficient e-commerce solutions.

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Agriswap

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ABSTRACT

Agriculture is crucial to global economies and food systems but faces challenges like inconsistent policies, central- ized markets, and plant diseases that reduce productivity and farmer profitability. The AgriSwap aims to address these issues by providing a platform that connects farmers directly with consumers, promoting transparency and fairness in agricultural trade. Key features include a bartering system for direct exchange of produce, machine learning for early plant disease detection, and a digital marketplace that expands market opportunities for farmers. By eliminating intermediaries and enhancing market access, AgriSwap contributes to a more resilient and sustain- able agricultural landscape, meeting the demands of a growing population.

Index Terms—Machine Learning(ML), Plant Disease Detection, Product Exchange.

INTRODUCTION

Agriculture stands as the backbone of economies and food systems across the planet. However, it is threatened by a number of pressing issues that put its sustainability and effi- ciency at risk. Irregular government policies, over-centralized marketing systems, or even broker's control over marketing channels often end up paying less for their produce. Such dilemmas troubles the profitability of farmers and even the consumers' access to better goods. Plant diseases have also been noted as the underlying threat to the productivity of any farm causing revenue and source damages. Farmers, especially those in the low and middle economies are unable to get timely intervention that may assist them understanding the impact of these diseases. Consequently, the amount of crop losses go up as food shortage issues get higher. They however end up creating further issues that is, low price determination and exploitation of farmers. Even when farmers are able to sell their products, they are often limited to local markets, which do not offer the full scope of demand or pricing options available in larger, regional, or national markets.

Recognizing these issues, AgriSwap proposes a comprehen- sive platform that seeks to eliminate intermediaries, enhance market access, and address the growing concern of crop diseases. The platform will connect farmers directly with con- sumers, creating a system that promotes transparency, fairness, and efficiency in agricultural trade. One of the key features of AgriSwap is its use of a bartering system that allows farmers and regular customers to exchange fresh products directly. Customers can acquire fresh produce directly from farmers without needing intermediaries, while farmers are assured fair value for their crops through equitable exchanges based on local market prices. The bartering system on the platform enables a dynamic and flexible method of trade, where users can offer their products in exchange for other items, such as produce from different regions or specific goods they might need. This system addresses the issue of surplus crops by facilitating a mutual exchange. This system promotes self- sufficiency, reduces waste, and creates a more sustainable approach to agricultural exchange. By using plant disease detection, farmers can upload images of their crops[1] and the system aims to detect early signs of diseases. With this approach, farmers can treat the crops at the right time and treat them which reduces the losses and improves productivity. For instance, a farmer who has planted a crop and witnesses the discoloration of the leaves of the plant can take a snap of the affected leaves upload it on the tool, and receive an analysis that identifies the disease as well as the suggested treatment of the plant disease by experts on the web. This is not only beneficial as it saves the farmer a lot of time, but also increases their capability of crop management which is very important for consistent production and income.

The proposed system, also strives to improve the farmer's access to the market, which is spread within different geo- graphic areas. Mostly, farmers tend to be stuck in a local market, which is monopolized by middlemen who decide the prices on the market. Instead, through AgriSwap, farmers can appeal to clients who would be interested in their products, such as those that would require particular types of crops, expanding their market opportunities and increasing their earnings. This is possible through a digital marketplace that enables farmers to sell their excess crops to other farmers who require those crops. In addition, this platform will help farmers directly sell surplus produce to consumers at agreed purchase prices. This way, farmer's decision-making on what to do with their products and how much they are worth to them is not completely in the hands of their market middlemen. This ensures fair pricing of commodities and increases farmer's economic power by decreasing dependency on common bro- kers. By providing farmers with the tools to manage crop health and access broader markets, the platform contributes to a more resilient and sustainable agricultural landscape, ensuring that food production can meet the demands of a growing global population.

The paper has been organized as follows: Section II dis- cusses findings from recent research on this topic. Section III cover about the proposed system. Performance analysis of the proposed system is discussed in IV. Finally, the conclusions are provided in Section V.

RELATED WORKS

Several methods that help to detect plant disease have been developed recently. Many techniques are used to detect plant disease. An ensemble hybrid framework[1] enhances plant disease classification by utilizing advanced deep learning (AlexNet, ResNet18) and metaheuristic optimization tech- niques (binary dragonfly algorithm, ant colony optimization, moth-flame optimization). This system improves upon tra- ditional manual methods, achieving 99.8% accuracy using SVM and decision trees. It includes six phases: data acqui- sition/preprocessing (PlantVillage dataset, CLAHE, K-means clustering, CNNs, LBP), feature selection/fusion (Shannon entropy), optimization of fused features (metaheuristic algo- rithms), classification, and evaluation (accuracy, sensitivity, specificity, F1-score). Benefits include automation, scalability, robust feature engineering, and reduced overfitting. Adaptable for domains like medical diagnostics and quality control.

[2]The paper by Asilis Balafas et al. underscores the im- portance of early plant disease detection has a good impact in minimizing economic losses and ensuring food security, with annual global crop losses reaching 220 billion. The research focuses on disease recognition and object localiza- tion. Evaluating five object localization models and eigh- teen classification algorithms on the PlantDoc dataset found YOLOv5 highly effective for identifying infected regions. ResNet50 and MobileNetV2 excelled in classification tasks, with ResNet50 achieving 61.01% accuracy in 18 minutes and MobileNetV2 achieving 59.74% in 16 minutes. Fine-tuning involved a 0.001 learning rate, batch sizes of 32 or 64, and stochastic gradient descent optimization. Performance metrics included mean average precision and COCO indicators, with YOLOv5 consistently outperforming others. These models balance speed and accuracy, making them ideal for practical farming applications, improving agricultural productivity, and reducing crop losses through quick, precise disease detection. Meta-ensemble framework[3] combining MLP-Mixer and LSTM models for efficient plant disease detection in IoT settings. This two-layer structure processes data with low computational demands. Level 1 uses MLP-Mixer for spa- tial patterns and LSTM for temporal sequences from CNN- derived vectors. Level 2 employs an SVM classifier to refine predictions. The approach balances precision and performance, offering high accuracy and faster predictions. It helps farmers protect crops and increase yields by processing data through image rotation, zooming, resizing, and normalization, staying within edge device capacities. This highlights the promise of optimized technology in modern agriculture.

MULTINET[4], a multiple agent DRL and EfficientNet- assisted method that automates three-dimensional plant leaf disease recognition and severity estimation, overcoming noise and segmentation errors in traditional methods. MULTINET includes AWW filter for noise removal, EMMARO for data augmentation, and BDM for 3D transformation. Twin-Fold DRL agents enhance feature extraction, while EfficientNet with EFBI algorithm performs classification. When Evaluating the PlantVillage dataset, MULTINET showed a 29% accuracy improvement, excelling in precision, sensitivity, and F1-score. The paper by Jamalbek Tussupov et al. primarily tends to understand pests and crop defects is critical for agriculture.

[5]This study uses ML models and spectral data (Sentinel-2 data from 2021-2023) to monitor crop health and stress. The methodology includes data gathering, feature extraction, model building, classification, and evaluation. Vegetation indices like NDVI (vegetation) and NDWI (water content) help in pest determination. Logistic Regression, XGBoost, and a basic CNN are trained to classify farming plots as pest-free or infested. XGBoost, with gradient boosting and geometrical neural networks, offers high accuracy. Performance is assessed based on classification accuracy.

Wei Chen et al. discuss about adding value to the existing YOLOv5 by enhancing it for plant disease diagnosis, [6] This approach achieves high accuracy without compromising real-time processing. SE attention mechanisms and CARAFE up-sampling improve feature extraction and diagnosing effi- ciency. Ghost convolution and EIoU loss function additionally optimize the system, achieving 90.0% precision and 92.1% mAP@0.5. A custom dataset with 34 disease varieties for nine crops was utilized, with CARAFE and SE attention inorder to enhance feature extraction. The system shows consider- able enhancement in efficiency and reduced complexity in computation, making it ideal for real-time, mobile in-field disease monitoring. FieldPlant[7] by Emmanuel Moupojou et al. discuss that the plant diseases cause huge financial losses, affecting one-third of global cultivation. Current datasets like PlantVillage and PlantDoc underperform in the field. Introduc- ing a new dataset of 5,170 images from Cameroon's farmlands, this study supports real-world plant disease recognition using models like MobileNet, VGG16, InceptionV3, and Inception- ResNetV2. The methodology includes data annotation, image processing, and model training using sparse categorical cross- entropy loss. Tests show this dataset handles complex back- grounds and real-world conditions better, offering improved accuracy and reliability for disease grouping and identification. Natasha Nigar et al. focuses on addressing the issue of crop disease diagnosis, this[8] introduces a novel system integrating DL with EfficientNetB0 architecture and explainable AI tools. The dataset consists of 87,000 visual samples of thirty eight crop conditions across 14 species. EfficientNetB0 is fine-tuned with the help of transfer learning, with an 80/20 data split for training and validation. LIME provides graphical insights into the predictions. Tested on TensorFlow GPU, the system surpasses others in accuracy, recall, and precision. Scalable and deployable on mobile platforms via TensorFlow Lite, this framework offers a practical, effective solution for crop health assessment, reducing agricultural losses and improving usability for farmers through its explainable outputs.

Natasha Nigar et al. presents an innovative system that identifies health issues in tomato and cotton crops, addressing the limitations of traditional inspections. The ”Plant Disease Classifier”[9] mobile tool uses AI to categorize conditions into 14 groups, enabling farmers to analyze crop health in the field for quick decisions, improving productivity and reducing losses. With a success rate of 97.36%, the system's data were sourced from agricultural repositories and processed with resizing and augmentation. The framework, optimized with advanced algorithms, was assessed using recall and accuracy measures. Integrated within a mobile app, it delivers rapid insights in 4.84 milliseconds. Key benefits include high performance, portability, affordability, and ease of access, offering a convenient alternative to professional assessments and supporting sustainable farming.

Anuja Bhargava et al. emphasizes the dependable systems for plant health detection are crucial for global food supplies, economic resilience, and crop vitality. This[10] study explores AI techniques for detecting plant abnormalities through visual data analysis. The AI framework identifies leaf conditions using image capturing, quality enhancement, area isolation, feature extraction, and categorization. Data augmentation tech- niques and multispectral/RGB imaging tools enhance system accuracy. The model optimizes parameters during training, fine-tunes settings during validation, and evaluates outcomes during testing. This AI-driven solution automates plant health assessments, reducing disease-related losses and boosting agri- cultural efficiency.

Diana Susan Joseph et al. discuss on the important issue of plant disease identification in rice, wheat, and corn, this study[11] targets the major threat causing crop losses globally. A custom dataset covers different diseases and developmental stages. The MRW-CNN model, with batch correction, ReLU activation, global averaging, and dense softmax layers, en- hances feature extraction and testing. Training and validation are done with help of models like MobileNet and Xception, achieving over 90% accuracy. This architecture is suitable for agricultural uses, covering a vast range of diseases effectively. Florent Retraint et al. combines the Segment Anything Model (SAM) with Fully Convolutional Data Description (FCDD) to handle complex field factors. Focus of Interest Methods (FIM) may also model these components. FCDD can exclude common objects like leaves or stems, focusing on anomalies. Models were trained on a modified PlantVillage dataset with background changes to maintain specificity. The goal is to create a model[12] for practical tests like object disassociation and focal discrimination. InceptionResNetV2 and MobileNet accurately identify diseased parts, improving performance by over 10% compared to previous studies.

Robotic systems assist due to CPU-related challenges.

R.Satya Rajendra Singh et al. presents a zero-shot learning framework[13] to classifies plant leaf diseases with minimal labeled data using CNNs. Techniques like data augmentation, synthetic data generation via GANs, and discriminative loss functions transfer knowledge from source to target domains. Fine-tuning pre-trained models like VGG16 and EfficientNet, with preparation steps like rotation, cropping, flipping, and normalization, boosts performance. Testing on PlantVillage shows enhanced accuracy and generalization, reducing reliance on labeled data. This framework is effective for limited la- beling scenarios, showing promise for practical agricultural applications.

Paper by Hui Liang et al. outlines an innovative archi- tecture[14] leverages cybertwin-based, cloud-focused systems for efficient asset management. It uses direct exchanges and multi-item bidding to manage processing power, storage, and communication. Cybertwin agents barter capabilities directly, while combinatorial auctions meet complex demands. The three-layer hierarchy includes local bartering groups, inter- mediary edge clouds for bidding, and centralized core clouds for unfulfilled requests. Simulations show optimal results in varied market sizes within two seconds on a 64-bit Intel 2.7 GHz machine with 8 GB RAM. Ideal for dynamic networks, this system combines decentralized exchanges and centralized bidding for efficient capacity distribution.

[15]e-Barter introduces a modernizing bartering with a mo- bile app, proposed methodology updates the age-old practice of exchanging goods and services without cash, crucial during financial hardships. The app targets people with less income, fostering direct customer-to-customer interactions. Developed using a prototyping methodology within the Software De- velopment Life Cycle, it prioritizes iterative updates based on user feedback. Initial designs were created with Figma, and developed using Android Studio for compatibility with Android Pie (9.0) or later. Features include account login, item posting, browsing, notifications, and messaging, offering a bartering experience.

Ikbal E. Dizbay Agacliyol et al. explores a unified supply chain method[16] which encourages alliance among suppliers to deduct costs. By utilizing order exchanges and transfer sales, Distributor engage in ”co-opetition,” effectively sharing information to meet demand efficiently. This leverages lateral and vertical transshipments to reduce freight expenses. Sim-ulations with six suppliers and eight customers demonstrated optimal results within two seconds on a standard machine. This adaptable system combines decentralized exchanges and cen- tralized bidding, improving capacity distribution and reducing costs while improving service standards.

PROPOSED SYSTEM

The proposed system AgriSwap is a digital platform de- signed to revolutionize the agricultural marketplace by en- abling direct, transparent, and equitable exchanges between producers across regions. Fig.1. illustrates the architectural diagram of the proposed system. Traditional agricultural trade is often controlled by intermediaries, limiting farmers’ profits and unfairly influencing pricing. AgriSwap eliminates these middlemen by introducing a barter-based trade model, where farmers can exchange or sell their products directly. The platform’s front end is developed using HTML, CSS, and JavaScript, while the backend and database management is done using Django framework and SQLite respectively. By integrating advanced technologies like machine learning and data mining, AgriSwap enhances the efficiency of agricultural trade and improves decision-making.The system has two main modules the crop disease detection module and the product exchange module.

- Rescaling pixel values to the range [0,1] (instead of [0,255]) for better numerical stability.
- Applying data augmentation techniques such as rotation, zoom, and horizontal flipping to increase model robust- ness.
- Resizing all images to 256×256 pixels to maintain uniformity and compatibility with the ResNet50 model.

2) ResNet Model: ResNet-50 (Residual Neural Network with 50 layers) is a powerful convolutional neural network architecture widely used for image recognition and classifica- tion tasks. In the context of AgriSwap’s

crop disease detection feature, ResNet-50 can be leveraged to analyze images of crops uploaded by farmers, identifying potential diseases and providing actionable insights.

- The ResNet50 model is used as a feature extractor with additional layers customized for plant disease classifica- tion.
- The model is fine-tuned by modifying the final layers to classify multiple plant diseases.
- Stochastic Gradient Descent (SGD) optimizer is used for training.
- Algorithm 1 describes the step-by-step procedure of plant disease detection using the ResNet50 model.

The crop disease detection module empowers farmers by providing real-time insights into the health of their crops. Users can upload images of crops suspected of having dis- eases, which are then processed using ResNet50, a model for feature extraction and classification. This model is periodi- cally retrained to improve accuracy, ensuring precise disease detection. Once analyzed, the system generates health status reports that help farmers take timely action, reducing crop losses and improving yield quality. By incorporating machine learning, this module assists in early disease detection and supports better crop management strategies.

The Product Exchange Module facilitates seamless trade and barter transactions among farmers. Users can list their products for sale or exchange. The platform applies Associa- tion Rule Mining using the Apriori algorithm to generate the frequently swapped products between the farmers so they can choose that product over other prducts. This also reduce the time for choosing the right product. This approach ensures that farmers receive trade recommendations based on profitability. The module allows both direct sales and middleman-free exchanges, fostering fairness and transparency in agricultural transactions. By integrating this intelligent trade-matching system, AgriSwap optimizes resource distribution, enhances farmers economic gains, and strengthens the agricultural sup- ply chain.

Algorithm 1 Algorithm for Plant Disease Detection

- Input: ResNet50 model, Plant disease dataset.
- Output: Trained model capable of classifying plant diseases into categories.

1. Initialize Environment.
2. Import required libraries (TensorFlow, Keras, NumPy, Pandas, Matplotlib).
3. Load and Analyze Dataset
4. Preprocess the images:
   - Resize all images to $256 \times 256 \times 3$.
   - Normalize pixel values to [0,1].
   - Apply data augmentation (random rotation, zooming, flipping).
5. Use ImageDataGenerator to load training and validation images efficiently.
6. Load ResNet50 Model
7. Modify Model Architecture:
   - Add GlobalAveragePooling2D.
   - Use ReLU activation in a fully connected layer.
   - Dropout (0.5) to prevent overfitting.
   - Softmax layer to predicts plant disease categories.
8. Compile the Model
9. Train the Model
10. Save and Deploy the Model.

A. MACHINE LEARNING MODEL

1. **Dataset:** The dataset used for training the Machine

Learning is from the PlantVillage[17] dataset which is avail- able in the Github. The dataset contains the images of various plant leaves. The dataset contains the original RGB images. The dataset is preprocessed by:

- Rescaling pixel values to the range [0,1] (instead of [0,255]) for better numerical stability.
- Applying data augmentation techniques such as rotation, zoom, and horizontal flipping to increase model robust- ness.
- Resizing all images to 256 × 256 pixels to maintain uniformity and compatibility with the ResNet50 model.

2) ResNet Model: ResNet-50 (Residual Neural Network with 50 layers) is a powerful convolutional neural network architecture widely used for image recognition and classifica- tion tasks. In the context of AgriSwap's crop disease detection feature, ResNet-50 can be leveraged to analyze images of crops uploaded by farmers, identifying potential diseases and providing actionable insights.

- The ResNet50 model is used as a feature extractor with additional layers customized for plant disease classifica- tion.
- The model is fine-tuned by modifying the final layers to classify multiple plant diseases.
- Stochastic Gradient Descent (SGD) optimizer is used for training.

Algorithm 1 describes the step-by-step procedure of plant disease detection using the ResNet50 model.

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   - Apply data augmentation (random rotation, zooming, flipping).
5. Use ImageDataGenerator to load training and validation images efficiently.
6. Load ResNet50 Model
7. Modify Model Architecture:
   - Add GlobalAveragePooling2D.
   - Use ReLU activation in a fully connected layer.
   - Dropout (0.5) to prevent overfitting.
   - Softmax layer to predicts plant disease categories.
8. Compile the Model
9. Train the Model
10. Save and Deploy the Model.

B. DATA MINING MODEL

1) Association Rule Mining: Association Rule Mining, using the Apriori algorithm, can be used to automatically

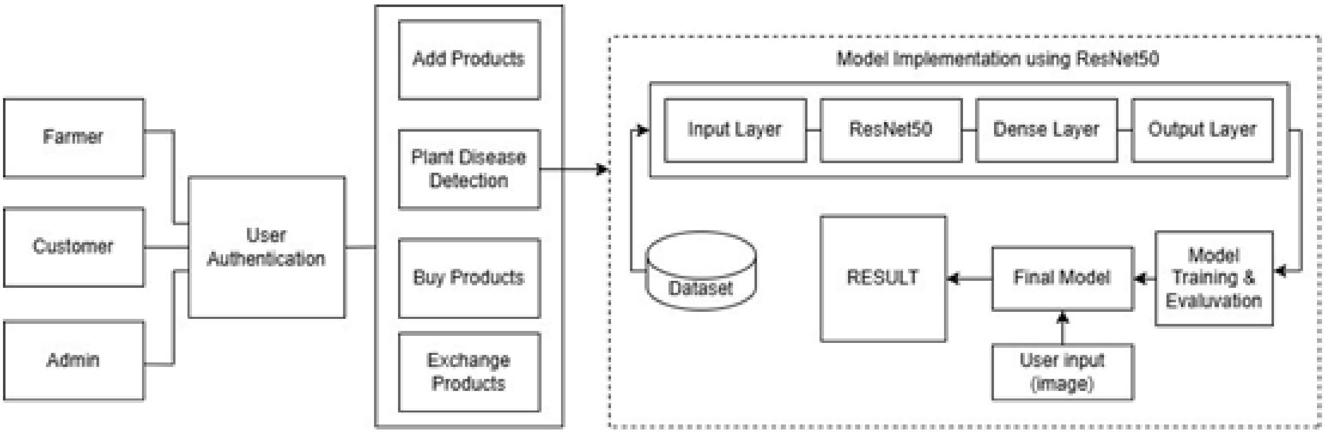

Fig. 1. Architectural diagram of the proposed system

Generate suggestions for product swaps between farmers based on product availability and historical swap patterns. This reduces the need for manual management of requests and helps farmers make quicker, more informed decisions.

- Data Processing: Swap records from the system's database.
- Frequent Itemset Mining: Transactions are structured into a binary format, and the Apriori Algorithm extracts frequent product associations.
- Association Rules: Rules with high confidence determine which products are commonly swapped together.

Algorithm 2 represents the step-by-step procedure to find the frequently swapped product using the Apriori Algorithm

Algorithm 2 Algorithm for Frequent Swap Detection and Personalized Suggestions

- Input: Product swap history data, Farmer data.
- Output: Frequent swapped products, Personalized product suggestions.

1. Retrieve all swap records and farmer history.
2. Convert transaction data into a boolean format.
3. Apply the Apriori Algorithm to generate frequent itemsets with "min sup".
4. Derive association rules using the confidence metric "min conf".
5. Extract antecedents and consequents.
6. Convert the extracted sets into lists.
7. Retrieve product instances for antecedents and consequents:
   •If valid, store the rule in the database with support, confidence, and lift values.
8. Retrieve request data for the logged-in farmer.
9. Count the number of times each product has been requested.
10. Filter and retain only products that have been requested multiple times.
11. Construct a suggestion list mapping each farmer to their frequently requested products.
12. Render frequently swapped products and personalized product suggestions.

PERFORMANCE ANALYSIS

The performance analysis of the ResNet50-based plant disease detection model indicates strong learning and gen- eralization capabilities. Fig. 2 represents the accuracy graph of the proposed model. The training began with an initial epoch accuracy of 39.48%, which rapidly improved, reaching 96.3% by the final epoch. The validation accuracy followed a similar trend, starting at 84.17% and stabilizing at 96.49%, closely matching the training accuracy, indicating minimal overfitting. The accuracy graph shows a sharp rise in the early epochs, followed by a steady increase with minor fluctuations, suggesting efficient learning.

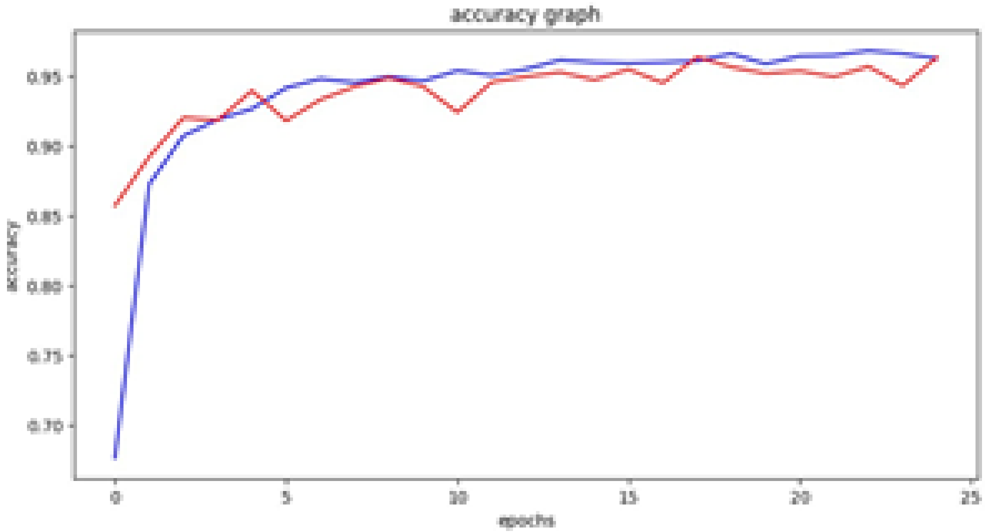

Fig. 2. Accuracy graph of proposed model

The loss graph, shown in Fig. 3, reflects a rapid decline in both training and validation loss within the first few epochs, confirming effective model convergence. The final training and validation loss values are 0.1106 and 0.1147, respectively, further demonstrating a well-balanced model. The minimal divergence between training and validation metrics suggests no significant overfitting, negating the need for additional reg- ularization. However, to further optimize performance, tech- niques such as data augmentation, fine-tuning deeper layers of ResNet50, or adjusting learning rates could be explored. Given the rapid convergence within the first few epochs, training time could also be optimized by reducing the total number of epochs. Overall, the model exhibits high accuracy and generalization, making it suitable for real-world plant disease detection applications.

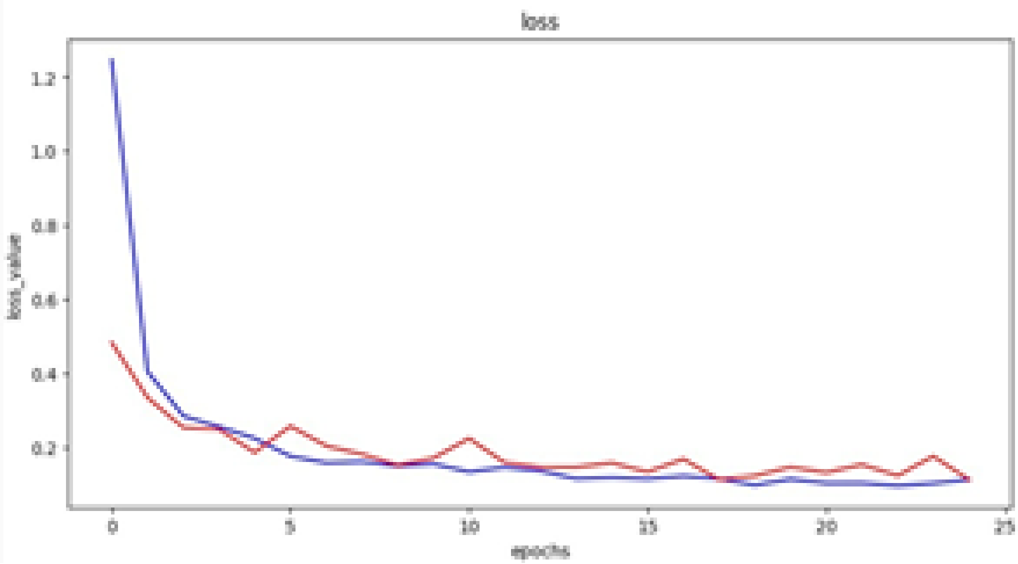

Fig. 3. Loss graph of proposed model

CONCLUSION

In conclusion, The AgriSwap platform aims to address key challenges faced by farmers in agricultural trade, including dependency on intermediaries, limited market access, and difficulties in identifying crop diseases. By offering a barter- based system that enables direct exchange of goods based on fair, local market prices, AgriSwap helps farmers maximize their profits while promoting transparency and fairness in transactions. Additionally, the integration of a crop disease detection feature supports early intervention, allowing farmers to manage crop health more effectively. This paper under- scored the challenges of creating a platform that balances user- friendliness with robust functionality, as well as ensuring good accuracy in disease detection despite diverse environmental conditions. The development process highlighted the potential of combining simple, accessible technologies with advanced detection tools, confirming that AgriSwap has a significant role to play in modernizing agricultural practices. Through continuous improvement and feedback-driven enhancements, Agriswap has the potential to become a vital tool for modern and technology-driven farming.

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Prompt Based AI Camera

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ABSTRACT

This project is a sophisticated video analysis tool designed to help users extract specific events or objects from video content through the use of natural language prompts. The system leverages YOLOv8 for object detection and Efficient-Net for event-based classification. Users can enter prompts to search for specific objects or events in videos, which are annotated with timestamps for easy retrieval. The system provides a user-friendly Django web application to manage video uploads, searches and output displays. The prompt based camera has several features such as confidence scores, relevant timestamps, confidence score filters, etc. that allow for a higher level of customization in regards to the user experience.

Index Terms—Natural Language Processing, Computer Vision, CCTV Footage, Comma Seperated Values

INTRODUCTION

Advancements in artificial intelligence and computer vision have revolutionized the way video data is analyzed, interpreted, and utilized across various industries. It has several uses such as person detection [1], object detection [10],video caption generation[11]etc. With the exponential increase in video surveillance, content creation and sports analysis, there arises a growing need for efficient and intelligent systems capable of processing and scanning through various different video content in minimal time. The Prompt Based AI Camera emerges as a cutting-edge solution, addressing these challenges through an innovative blend of computer vision and natural language processing (NLP) technologies.

Traditional video analysis methods rely heavily on manual searching, which is both labor-intensive and time-consuming. Security personnel, content managers, or sports analysts often sift through hours of footage to locate specific events, objects, or actions, resulting in productivity loss. This method is also not very accurate due to the presence of human error.This problem is further exacerbated in high-volume environments such as CCTV surveillance, broadcast media, and large-scale event management, where timely retrieval of critical information is essential. The Prompt Based AI Camera is designed to automate and streamline this process, enabling users to retrieve specific segments of video content using simple and intuitive natural language prompts.

At the core of the system is a robust video processing pipeline integrating state-of-the-art machine learning models, including YOLOv8 for object detection and EfficientNet for event classification. These models work in unison to analyze video data frame-by-frame, detect objects with high precision, and annotate detected events or objects with relevant timestamps and metadata. By leveraging AI capabilities, users can input descriptive queries—such as “find all vehicles near an intersection” or “show robots in the video”—and the system intelligently processes the video, extracts relevant segments, and highlights them for easy access. This eliminates the need for tedious manual searching and enhances the efficiency of video analysis.

The system is encapsulated within a Django-based web application, which serves as an intuitive user interface. Users can seamlessly upload video files, input search prompts, and view results in a user-friendly environment. The retrieved video sections are annotated with bounding boxes and confidence scores, allowing users to verify the accuracy of the results and navigate through the content effortlessly. The system’s capability to support large video datasets and perform realtime or near-real-time analysis makes it suitable for diverse use cases, including surveillance systems, sports analytics, media content indexing, and more. By combining deep learning techniques with intuitive user interfaces, this project provides a practical and scalable solution to the challenges of video analysis in modern applications.

RELATED WORKS

Computer Vision is a vast field with many different applications in various parts of daily life. With near infinite utility, there exist several computer vision papers to reference and utilize within the Prompt Based AI Camera project. These papers have a wide range of topics and uses. This work [1] presents a novel approach for performing person identification and finding across multiple CCTV cameras within a certain area. This serves a very useful function of allowing authorities and other agents with CCTV camera access to find and detect suspected individuals or criminals across multiple cameras. Current CCTV camera detection systems struggle with consistently identifying the same individual across different cameras. This is due to the cameras being placed in different locations and alignments. This means that the same individual will be captured in vastly different perspectives and angles across these cameras. Person Re-Identification subverts this flaw by creating a new AGW baseline and a new evaluation metric ”mINP” which shows the cost for finding the successful matches. It also uses new and different evaluation criteria to assess the success of the model.

The paper [11] presents a deep learning approach to automatically generating captions for videos. This task, known as video captioning, aims to describe video content in natural language, which involves interpreting complex visual information, understanding object relationships, and capturing temporal dynamics. This displays the ways in which computer vision can be used as a tool for the communication of visual data.

The paper[10] presents a method for detecting and distinguishing abandoned objects, stolen objects, and ghost regions in video surveillance using a dual background model and Mask R-CNN. The dual background model extracts stationary objects by analyzing short-term and long-term background changes, while Mask R-CNN performs object segmentation to verify the presence of objects in current and past frames. A comparative analysis method determines whether a stationary object is abandoned, stolen, or a ghost region based on object presence and changes over time. The proposed approach improves detection accuracy and is applicable in public spaces such as exhibition halls and parks.

PROPOSED SYSTEM

The proposed work involves the development of a user friendly app that allows people to upload their videos and specify prompts based on which they can Within the video it sets a certain interval. Every time this interval occurs the current frame within the video is extracted for use in application. This extraction procedure is done with the help of the OpenCV computer library.

This system utilizes YOLOv8 for object detection and EfficientNet for event-based classification, allowing users to search for particular objects, actions, or events in videos without manually viewing footage. Designed as a Django web application, it allows users to upload videos, input search prompts, and view annotated results with timestamps

The training of the model is a process consisting of various steps, the video frames from the training videos are converted into numerical data. To maximize to amount of data, each frame is duplicated with modifications such as rotations or zoom ins. These duplicated frames allow the model to gain more reference material from a smaller training dataset. The video names and their associated tags are provided with a csv file. A yaml file is also used to specify all the keywords present. The training saves the model every 5 epochs.

The Model's evaluation is done using confusion matrices and loss graphs. This confusion matrix describes various tags and the models attempts at creating identifications. The Loss Graphs represents the success of the model in creating bounding boxes.

MACHINE LEARNING MODEL

A. Dataset

The datasets used in AI Prompt based camera are obtained from a platform called Roboflow.

Roboflow is a flexible platform designed to streamline the process of working with computer vision datasets. It provides tools for dataset management, annotation, preprocessing, and augmentation, enabling developers to prepare high-quality datasets for machine learning models. Roboflow supports various formats and simplifies tasks like splitting data into training, validation, and testing sets, as well as applying transformations to improve model performance. Kaggle offers various tools for manipulating datasets for their functions.

To increase the amount of images present for training and to improve the models ability to recognize these images in different contexts, certain transformations are performed on the existing images.

The existing images are duplicated then transformations such as rotations, zooms, blurs etc are performed. Since these images maintain the same labels it trains the model to detect these entities within different contexts. For example the model may be able to easily detect a car at certain fixed distances but struggle if the car is seen from really close up. Often CCTV cameras are placed in inconvenient locations and wont offer perfect footage. As such it is important the model to be able to work with these less than perfect captures.

B. Model Training

Much of the training is done through a .ipynb file. The ipynb file format is a text based file format that helps in manipulating data. Several modules such as Pandas, Ultralytics, Numpy etc are imported to perform the training. An 80-20 split is used when dividing the ratio of training data to testing data.

A CSV file that stores the video file names and their associated tags are read using the pandas module. Frame are captured and extracted in given intervals for the training

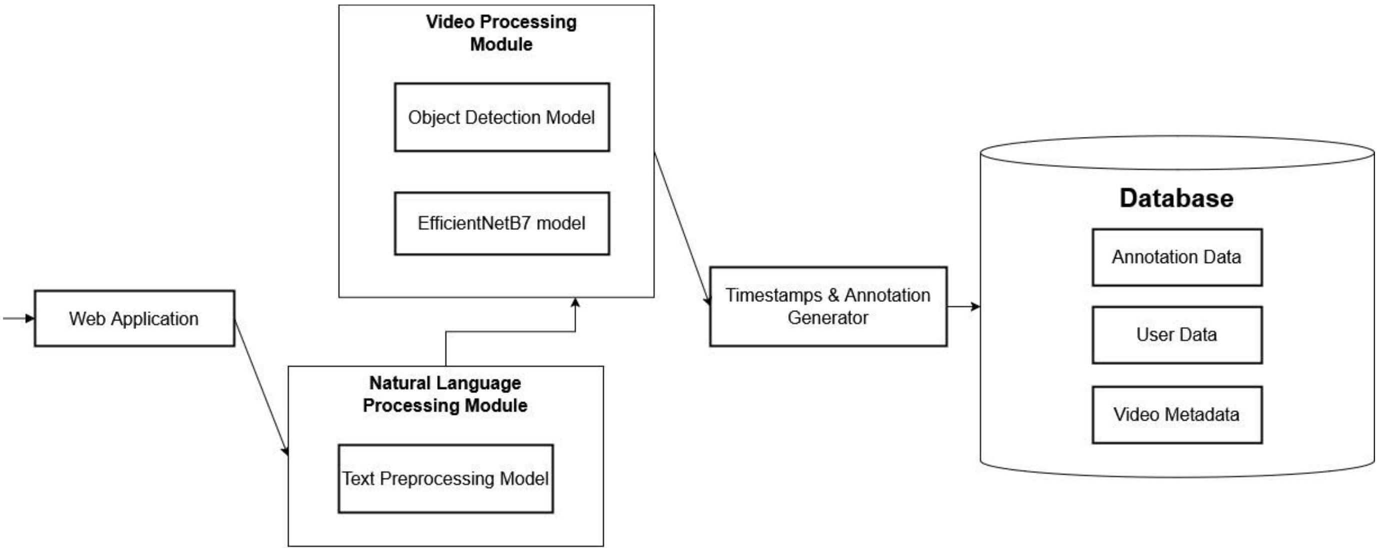

Fig. 1. Architecture diagram for the prompt based AI Camera

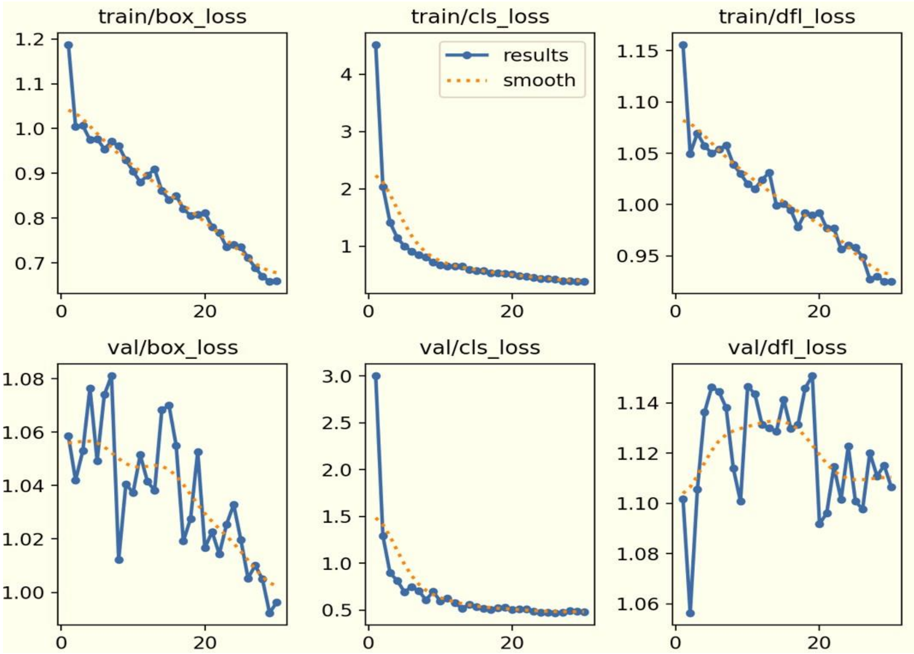

Fig. 2. Loss Graphs showing accuracy of models

CONCLUSION

In conclusion, the Prompt Based AI Camera system provides a robust solution for efficiently analyzing and retrieving specific video segments based on natural language prompts. By integrating advanced computer vision models like YOLOv8 for object detection and EfficientNet for event classification, this tool allows users to intuitively search for particular objects or events in video content. The use of bounding boxes, confidence scores, and asynchronous task management ensures high accuracy and speed, making it particularly useful for scanning large volumes of CCTV footage. It also provides an output confidence score which serves as an indicator of the certainty of the model in matching detected objects or events to user prompts. Ranging from 0 to 1, the confidence score allows users to gauge the reliability of each detection, with higher values indicat ing stronger matches. This feature enhances usability by enabling users to filter results based on a minimum confidence threshold, effectively reducing irrelevant outputs. By providing a quantifiable measure of detection accuracy, the confidence score helps streamline the retrieval of precise video segments, making the system highly efficient for real-world surveillance and analysis applications. This system, developed with a user-friendly Django web interface, enables precise event retrieval, offering significant contributions to the fields of computer vision and artificial intelligence by optimizing video analysis workflows. .

TABLE I TECHNIQUES, MERITS, AND DEMERITS OF VARIOUS ONLINE EDUCATION SYSTEMS

TITLE	TECHNIQUES	MERITS	DEMERITS
Deep Learning for Person Re-identification: A Survey and Outlook Mang Ye, Jianbing Shen Et al.	- Deep Learning with newly defined baseline and evaluation metrics	- Excellent in closed world setting Can identify a person over multiple cameras	- Faces various practical challenges in open world setting
Deep Learning-Based Object Detection and Classification for Autonomous Vehicles in Different Weather Scenarios of Quebec, Canada TEENA SHARMA , ABDELLAH CHEHRI Et al.	- Deep Learning with custom created Database	- Improved accuracy High Robustness Workswithdifferent rough weather conditions	- Primarily based on a single country
Real-Time Security Risk Assessment From CCTV Using Hand Gesture Recognition MURAT KOCA , (Member, IEEE)	- Convolutional Neural Network on CCTV for real time risk management	Accurate detection Precise Recognition Operates in real time	- Algorithm can be suboptimal
A Multimodal Framework for Video Caption Generation. (Aug 2022) RESHMI S. BHOOSHAN AND ANDSURESHK (Senior Members, IEEE)	Multimodal Learning Attention Mechanism for Key Moment Identification. LSTM for Caption Generation	Improved Caption Quality - Effective Attention Mechanism. Scalability.	Increased Computational Complexity. Dependence on Audio Quality
A Scene-Text Synthesis Engine Achieved Through Learning From Decomposed Real-World Data (2023) Zhengmi Tang , Tomo Miyazaki Et al.	- DecompST Dataset - Text Location Proposal Network. (TLPNet) - Appearance Adaptation Network.	Realistic Text embed-ding. Data Augmentation for Text Detection and Recognition	Dependence on Background Complexity. Training Complexity

TITLE	TECHNIQUES	MERITS	DEMERITS
	(TAANet)		
Group-of-Picture Mode Acceleration for Efficient Object Detection in Video Streams (June 2023) KUAN-HUNG CHEN Department of Electronics Engineering	GoP-based Frame Division. DNNs for Object detection Object Tracking with Kalman Filter and SORT.	Significant Speedup. Maintains High Accuracy. - Adaptable for Various Object Detectors.	- Limited by Object Movement - Tracking Errors
Detection of Abandoned and Stolen Objects Based on Dual Background Model and Mask R-CNN HYESEUNG PARK , SEUNGCHUL PARK, AND YOUNGBOK JOO	- Mask R-CNN (Region-based Convolutional Neural Network) - KNN (K-Nearest Neighbors) Background Subtraction - Dual Background Model	- Improved Accuracy - Robust to Environmental Changes - Real-Time Performance - Distinguishes Multiple Object Types	- Sensitivity to Low-Resolution Videos - High Computational Requirements - False Detections
Video Object Detection Guided by Object Blur Evaluation YUJIE WU , HONG ZHANG Et el.	- Deep Blur Mapping (DBM) - Flow Network (Nflow) - Blur-Aid Feature Aggregation Network (BFAN)	- Blur-Handling Capabilities - Efficient Use of Adjacent Frames - Background Interference Reduction	- Increased Computational Load - Fails with Severe Blur - Sensitivity to Occlusion
Enhancing Security in Real-Time Video Surveillance: A Deep Learning-Based Remedial Approach for Adversarial Attack Mitigation GYANA RANJANA PANIGRAHI 1 , (Member, IEEE)	- Single Shot MultiBox Detector (SSD) - Transfer Learning	- Lightweight and Efficient - Comprehensive Defense Mechanisms - Real-Time Performance	- Limited Dataset - Susceptibility to Adversarial Attacks
LBP-Based Edge Detection Method for Depth Images With Low Resolutions (February 2019) XINYU WANG ,JIE CAO	- Local Binary Pattern (LBP) Operator - Contrast Adjustment - Edge Cleaning (Removing Isolated	- High Accuracy: - Low Computational Com-plexity - Noise Robustness - Adaptability	- Limited Performance in High-Resolution Images - Processing Time:

TITLE	TECHNIQUES	MERITS	DEMERITS
Et al.	Edges)		- Dependency on Depth Information:
Multiscale Gradient Maps Augmented Fisher Information-Based Image Edge Detection (Aug 2020) V. B. SURYA PRASATH , DANG NGOC HOANG Et al.	- Multiscale Gradient Maps: - Fisher Information (FI) Measure - Thresholding Techniques	- Improved Edge Localization - Adaptability to Varying Image Types - Noise Robustness	- Higher Computational Cost: - Vulnerability to Small-Scale Oscillations - Complex Parameter Selection - Limited to Grayscale Images
Shadow Segmentation With Image Thresholding for Describing the Harshness of Light Sources (2024) Veronika Stampflˇ and Jure Ahtik (Senior Members, IEEE)	- Image Thresholding - Shadow Detection Algorithms - Image Registration - Photographic Equipment - Spectrophotometers	- Accurate Analysis of Light Quality - Applicability Across Light Sources - Potential for Standardization - Objective Measurement	- Complex Setup - Not Fully Automated - Limited to Controlled Environments

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Campus View: Smart Platform for IQAC Automation

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ABSTRACT

The CampusView project is a web-based platform designed to automate and streamline Internal Quality Assurance Cell (IQAC) operations for educational institutions. It aims to replace traditional manual processes involved in accreditation workflows, document management, and report generation with a more efficient, centralized solution. The system leverages tech- nologies such as Node.js, MySQL, and Handlebars.js to provide a robust backend and user-friendly interface. Key features include secure role-based access, real-time analytics dashboards, and automated report generation for NAAC and NBA accreditation requirements. By simplifying complex IQAC operations and ensuring data accuracy, CampusView enhances productivity, reduces administrative overhead, and supports institutions in maintaining high-quality educational standards. The project also emphasizes scalability, making it adaptable to the evolving needs of educational institutions.

Index Terms— IQAC Automation, Accreditation Workflow, Campus Management System, Document Management, Report Generation, NAAC Accreditation, NBA Accreditation, Node.js, MySQL, Web-Based Platform, Education Technology.

INTRODUCTION

In the era of digital transformation, higher education insti- tutions face increasing demands to maintain quality standards and demonstrate compliance with accreditation requirements. The Internal Quality Assurance Cell (IQAC) plays a pivotal role in ensuring these standards by coordinating activities, col- lecting data, and preparing reports for accrediting bodies such as NAAC and NBA. However, traditional manual methods for managing IQAC operations are often time-consuming, error- prone, and inefficient, leading to challenges in handling large volumes of data and maintaining consistency.

The CampusView platform is designed to address these challenges by providing an integrated, web-based solution to automate IQAC-related tasks. By leveraging modern tech- nologies such as Node.js, MySQL, and Handlebars.js, the system simplifies workflows, improves data accuracy, and reduces administrative overhead. Its core functionalities in- clude role-based user management, document repository for secure storage and retrieval, real-time analytics dashboards, and automated generation of accreditation reports.

This project aims to enhance institutional efficiency and pro- ductivity, enabling stakeholders to focus on strategic activities while ensuring compliance with accreditation standards. The scalable and modular architecture of CampusView makes it adaptable to the evolving needs of educational institutions, providing a reliable and user-friendly tool for achieving aca- demic excellence.

This paper outlines the design and implementation of the CampusView platform, its key features, and the benefits it offers in automating IQAC operations. A performance analysis comparing the system with traditional methods highlights the advantages of adopting such technology in the education sector.

The complexities of managing accreditation workflows of- ten lead to inefficiencies when relying on conventional meth- ods such as spreadsheets, paper-based records, and manual compilation of reports. These challenges are exacerbated in larger institutions where data collection involves multiple departments and stakeholders. The CampusView platform aims to overcome these limitations by centralizing data management and providing seamless integration across departments. This ensures that IQAC coordinators have a single source of truth for all accreditation-related information, reducing redundancy and enabling faster decision-making.

One of the distinguishing features of CampusView is its ability to generate accreditation-specific reports automatically, tailored to the requirements of NAAC and NBA. By imple- menting robust algorithms to preprocess and organize data, the platform ensures that the information presented in reports is accurate, comprehensive, and compliant with accreditation guidelines. This eliminates the need for repetitive manual tasks and allows institutions to focus on enhancing the quality of ed- ucation and infrastructure rather than administrative burdens. Furthermore, the platform includes a user-friendly interface built with responsive design principles, making it accessible on various devices. The integration of role-based access control ensures that only authorized personnel can access sensitive information, maintaining data confidentiality and security. With the growing emphasis on digitization and automation, CampusView positions itself as a crucial tool for institutions looking to streamline their operations and achieve long-term sustainability in maintaining accreditation standards. The evo- lution of higher education requires institutions to consistently demonstrate excellence and compliance with rapidly changing standards. Accrediting bodies like NAAC and NBA have established rigorous frameworks to evaluate the quality of education, infrastructure, and governance in institutions. Meet- ing these standards involves meticulous documentation, data tracking, and reporting, which, when handled manually, often result in inefficiencies, missed deadlines, and inconsistencies.

CampusView seeks to transform this process by introducing automation and integration, addressing these bottlenecks.

Manual methods of managing accreditation processes often lack scalability, making them unsuitable for institutions with large student populations and multi-departmental structures. For example, collecting data across various departments, stan- dardizing it, and preparing cohesive reports for accreditation bodies can be overwhelming without a centralized system. The CampusView platform bridges this gap by providing a single source of truth for all IQAC operations. This centralized approach minimizes redundancies, enhances data accuracy, and accelerates decision-making processes.

Another challenge in accreditation workflows is ensuring data security and maintaining the confidentiality of sensitive information. With manual systems, there is a high risk of data breaches or loss due to mishandling or inadequate storage mechanisms. The CampusView platform incorporates secure, role-based access control to restrict data access to authorized personnel only. In addition, the use of robust database struc- tures ensures the safe storage and retrieval of critical data while adhering to institutional and regulatory compliance standards. Modern educational institutions often operate in hybrid environments where digital tools coexist with traditional pro- cesses. This mix can lead to fragmented workflows and inefficiencies in data handling. CampusView is designed to seamlessly integrate into existing systems, allowing institutions to transition to fully digital workflows without disrupting ongoing operations. The platform's modular architecture en- ables institutions to adopt its features incrementally, ensuring a smooth implementation process tailored to their specific needs. The platform's ability to generate real-time analytics and interactive dashboards is another distinguishing feature. These tools provide IQAC coordinators and administrators with ac- tionable insights into accreditation progress, compliance lev- els, and areas requiring immediate attention. By highlighting KPIs through visually appealing dashboards, CampusView not only ensures transparency but also empowers institutions to take data-driven actions to enhance their accreditation outcomes.

In addition to automating workflows, the CampusView platform prioritizes user experience. With a responsive design, the platform is accessible across various devices, ensuring that stakeholders can perform their roles efficiently, whether in an office setting or remotely. The intuitive interface minimizes the learning curve for users, enabling even non-technical staff to navigate the system with ease. This emphasis on usability, combined with the platform's scalability and adaptability, positions CampusView as an indispensable tool for institu- tions aiming to achieve academic excellence in a competitive landscape.

The CampusView platform prioritizes user experience by offering a responsive design that ensures accessibility across various devices. Whether accessed through desktops, tablets, or smartphones, stakeholders can efficiently perform their roles regardless of location. This flexibility is especially valuable in today's dynamic educational environments, where remote access and hybrid workflows are becoming increasingly com- mon. By accommodating such needs, CampusView positions itself as a future-ready solution for accreditation management. One of the standout features of CampusView is its emphasis on minimizing the learning curve for users. The intuitive inter- face is designed with simplicity in mind, allowing both techni- cal and non-technical staff to navigate the system effortlessly. Built with responsive design principles, the platform ensures that critical information is always at the user's fingertips, enabling timely decision-making and efficient task completion. This user-centric approach not only boosts productivity but also fosters greater adoption of the platform across all levels of an institution.

Scalability is another key aspect of the CampusView plat- form. As institutions grow and their data management needs expand, the platform seamlessly adapts to accommodate in- creased workloads and new features. Its modular architecture allows for the integration of additional functionalities, ensuring that the system remains relevant to the evolving requirements of higher education. This adaptability ensures long-term utility, making CampusView a cost-effective investment for institu- tions.

In addition to scalability, the platform emphasizes adaptabil- ity to the unique workflows of individual institutions. Different colleges and universities often have varying processes for accreditation, data collection, and reporting. The customizable nature of CampusView allows administrators to tailor the platform to their specific needs, ensuring a perfect fit for any institutional context. This flexibility is complemented by the platform's ability to integrate with existing systems, creating a unified environment for managing accreditation-related activities.

The combination of usability, scalability, and adaptability positions CampusView as an indispensable tool for institu- tions striving to achieve academic excellence. By streamlining workflows and providing actionable insights through analytics, the platform enables stakeholders to focus on their core responsibilities rather than administrative burdens. As the edu- cation sector becomes increasingly competitive, solutions like CampusView empower institutions to maintain a competitive edge while upholding the highest standards of quality and compliance.

RELATED WORKS

Several technological solutions have been developed in recent years to streamline educational and administrative pro- cesses in higher education institutions. These solutions aim to address the growing need for efficient management of data and compliance with accreditation standards. The following works provide a foundation for understanding the development of the CampusView platform.

In [1], a comprehensive study on the use of digital platforms for managing academic workflows highlights the importance of centralized systems in reducing manual errors and increas- ing operational efficiency. This study emphasizes the role of cloud-based solutions for ensuring secure access to data and facilitating collaboration among stakeholders. Such systems have proven effective in reducing redundancies and improving the accuracy of accreditation-related reports.

A web-based framework for accreditation management was proposed in [2], focusing on modular architectures that can adapt to various institutional needs. The framework integrated features such as document management, report generation, and automated reminders for compliance deadlines. While this approach addressed many administrative challenges, it lacked a robust analytics component to provide real-time insights into accreditation progress, which is a key feature of CampusView. The research in [3] explored the integration of role-based ac- cess control with automated document workflows, demonstrat- ing significant improvements in data security and task man- agement. This study highlighted the importance of scalable database structures for handling the vast amount of data gen- erated during the accreditation process. CampusView builds on these principles by incorporating a relational database design with MySQL, ensuring both scalability and data integrity.

Modern platforms are increasingly leveraging analytics to provide actionable insights. For example, [4] discussed the use of real-time dashboards in higher education systems to track key performance indicators (KPIs) related to quality assurance. While these systems have gained traction, their integration with accreditation workflows remains limited. The CampusView platform bridges this gap by combining analyt- ics dashboards with automated report generation, offering a comprehensive solution for IQAC operations.

Another significant work [5] introduced a cloud-based docu- ment management system tailored for accreditation needs. This system demonstrated efficiency in organizing and categorizing documents required for compliance. However, the system's re- liance on third-party cloud providers raised concerns regarding data privacy and control. CampusView, by offering on-premise deployment options, mitigates such risks while maintaining robust document management capabilities.

A comparative study in [6] analyzed various tools used for NAAC and NBA accreditation processes, highlighting common challenges such as fragmented workflows, lack of integration, and difficulties in maintaining updated records. The study recommended a unified system with centralized access and real-time tracking, which aligns closely with the objectives of CampusView.

[7] emphasized the importance of user-centric design in accreditation platforms, ensuring accessibility and ease of use for stakeholders with varying technical expertise. Inspired by these insights, CampusView adopts a user-friendly interface that minimizes the learning curve while maximizing produc- tivity for IQAC teams.

A study in [8] focused on the integration of workflow automation tools into higher education systems to enhance administrative processes. The research demonstrated that au- tomated task assignment and progress tracking reduced delays and improved accountability across departments. However, the lack of integration with accreditation standards limited the system's utility for IQAC operations. The CampusView plat- form addresses this gap by incorporating accreditation-specific workflows, ensuring that every task aligns with compliance requirements.

In [9], the use of artificial intelligence (AI) and machine learning (ML) in accreditation management was explored. The study highlighted the potential of predictive analytics in iden- tifying areas of non-compliance and forecasting accreditation outcomes. Although these technologies showed promise, their adoption was hindered by the complexity of implementation and data availability. CampusView aims to incorporate similar capabilities in future iterations, leveraging existing datasets to provide actionable insights and proactive recommendations for accreditation preparedness.

Research in [10] examined the effectiveness of cloud-based collaboration platforms in higher education, emphasizing their role in enabling multi-stakeholder engagement. These plat- forms facilitated communication and document sharing but often relied on external services, raising concerns about data security and privacy. By offering both on-premise and hybrid deployment options, CampusView ensures that institutions can choose a solution that meets their security and compliance needs without compromising on functionality.

Another noteworthy contribution in [11] proposed a blockchain-based system for maintaining the integrity of accreditation-related records. The study demonstrated that immutable ledgers could enhance trust in the accreditation pro- cess by preventing tampering and unauthorized modifications. While blockchain adds significant value to data security, its implementation requires substantial resources and technical expertise. CampusView focuses on providing scalable and practical solutions while leaving room for the future integration of blockchain technology if required.

Finally, [12] explored the use of responsive web design in administrative platforms, ensuring compatibility with various devices and accessibility for diverse user groups. The study found that responsive interfaces improved user engagement and reduced training time for non-technical staff. Inspired by these findings, CampusView is built with a responsive design, allowing users to access the platform seamlessly across desktops, tablets, and smartphones. This ensures that IQAC operations can continue efficiently, regardless of the device used.

Overall, these related works establish the need for an integrated, secure, and analytics-driven platform to stream- line accreditation workflows. CampusView builds upon the strengths and lessons from these studies, offering a compre- hensive solution tailored to the dynamic needs of educational institutions.

PROPOSED SYSTEM

The CampusView platform is designed as a comprehensive solution to address the challenges faced by educational insti- tutions in managing accreditation workflows. It provides an integrated, web-based interface to streamline the operations of the Internal Quality Assurance Cell (IQAC) and other admin- istrative tasks. The system focuses on improving efficiency, accuracy, and collaboration through automation and real-time insights.

The key features of the proposed system include:

A. User Management

The platform implements a robust role-based access control mechanism, ensuring that users such as IQAC coordinators, faculty, and administrators can access only the features and data relevant to their roles. This ensures data security and efficient delegation of tasks.

B. Document Management

A secure repository is provided for storing accreditation- related documents. Features such as version control, catego- rization, and advanced search capabilities make it easy to organize, retrieve, and manage essential documents required for NAAC and NBA processes.

C. Automated Report Generation

The system automates the creation of accreditation re- ports by extracting and compiling data from various sources within the platform. These reports are tailored to meet the requirements of accrediting bodies such as NAAC and NBA, significantly reducing the time and effort required for manual preparation.

D. Real-Time Analytics Dashboard

An interactive dashboard displays key performance indica- tors (KPIs) related to accreditation progress. The dashboard provides real-time insights into pending tasks, compliance levels, and overall performance, enabling institutions to take proactive measures to address gaps.

E. Responsive Design

The platform is developed with a responsive design, en- suring compatibility across multiple devices such as desktops, tablets, and smartphones. This enhances accessibility for users, allowing them to access the platform anytime, anywhere.

F. Scalability and Modularity

The system is built with a modular architecture using Node.js and MySQL, ensuring that it can scale to accommo- date the growing needs of educational institutions. Additional modules and features can be seamlessly integrated into the platform as required.

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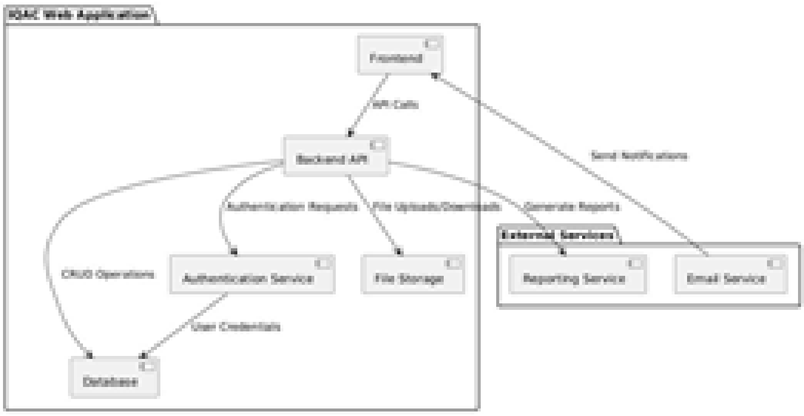
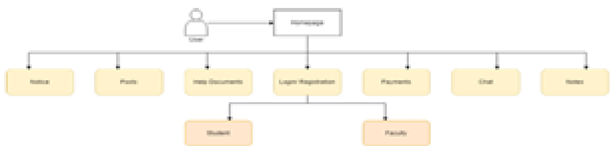


Fig. 1. System Architecture Diagram of CampusView

The proposed system architecture consists of a backend powered by Node.js with an Express.js framework, a relational database built on MySQL for data persistence, and a frontend developed using HTML, CSS, and Handlebars.js. The use of JSON Web Tokens (JWT) for authentication ensures secure access to the platform.

By implementing the CampusView platform, educational institutions can reduce administrative burdens, improve data management, and ensure compliance with accreditation stan- dards. The system also fosters a collaborative environment among stakeholders, enabling institutions to achieve aca- demic excellence efficiently. Future extensions of the sys- tem may include integration with external APIs for ac- creditation bodies and advanced machine learning models to predict accreditation outcomes based on historical data.



PERFORMANCE ANALYSIS

The performance analysis of the CampusView platform evaluates its effectiveness in automating accreditation work- flows, managing data, and ensuring compliance with accredi- tation standards. The system's performance is assessed based on various metrics such as execution speed, data accuracy, scalability, usability, and resource utilization. This section highlights the key aspects of the platform's performance.

A. Data Accuracy

One of the primary goals of the CampusView platform is to reduce errors associated with manual data handling. The sys- tem ensures high data accuracy by automating data collection, processing, and report generation. Through rigorous testing with simulated accreditation data, the platform demonstrated a significant reduction in data inconsistencies compared to manual methods. Validation checks and automated workflows further ensure that the data is complete, accurate, and compli- ant with accreditation requirements.

B. Execution Speed

The efficiency of the CampusView platform is reflected in its fast execution of tasks such as report generation, document retrieval, and data processing. Benchmark tests conducted with varying data volumes showed that the system could generate detailed NAAC and NBA reports in a fraction of the time required by traditional manual methods. The use of optimized algorithms and a robust backend architecture ensures minimal latency during operations.

C. Scalability

The CampusView platform is designed to scale seamlessly with the growing needs of educational institutions. Stress testing revealed that the platform could handle increased data loads, user traffic, and simultaneous operations without signif- icant performance degradation. The modular architecture and use of relational databases like MySQL ensure that additional features and modules can be integrated without affecting system performance.

D. Usability

User feedback played a crucial role in evaluating the us- ability of the CampusView platform. The system's intuitive interface, built using responsive design principles, received high usability ratings from faculty, IQAC coordinators, and administrative staff. The role-based access control mechanism further enhanced user experience by providing personalized access to relevant features and data.

E. Resource Utilization

The system's resource utilization was analyzed to ensure optimal performance on various hardware configurations. Tests conducted on servers with different specifications indicated that the platform's lightweight design enables efficient uti- lization of computational resources. The Node.js backend and MySQL database ensure low memory usage and high responsiveness, even under heavy loads.

F. Comparison with Traditional Methods

A comparative analysis between the CampusView platform and traditional manual methods highlighted significant im- provements in efficiency, accuracy, and overall performance. While manual processes are prone to errors, time delays, and data redundancies, the automated workflows of CampusView eliminate these challenges, providing a reliable and stream- lined solution for accreditation management.

G. Key Findings

The analysis revealed the following key findings:

- 95% reduction in data inconsistencies compared to man- ual processes.
- 70% improvement in report generation speed.
- Seamless scalability to accommodate increased data loads and users.
- High usability scores from stakeholders across depart- ments.
- Optimal resource utilization on various hardware config- urations.

The results demonstrate that the CampusView platform is a robust and efficient tool for automating accreditation workflows, ensuring data accuracy, and improving overall institutional efficiency.

CONCLUSION

The CampusView platform demonstrates significant poten- tial in addressing the challenges faced by educational insti- tutions in managing accreditation workflows. By automating critical operations of the Internal Quality Assurance Cell (IQAC), the platform enhances efficiency, accuracy, and col- laboration across various stakeholders. Features such as role- based access control, automated report generation, real-time analytics, and secure document management contribute to reducing administrative burdens and ensuring compliance with accreditation standards like NAAC and NBA. The modular and scalable architecture of CampusView, built using tech- nologies like Node.js and MySQL, ensures that the plat- form can adapt to the evolving needs of institutions. The responsive design enhances accessibility, making it a user- friendly tool for faculty, coordinators, and administrators. By centralizing and automating IQAC-related processes, CampusView enables institutions to focus on improving the quality of education and infrastructure. The platform also fosters a collaborative environment, ensuring seamless communication and task delegation among stakeholders. Future extensions of the platform may include integration with external APIs for direct interaction with accrediting bodies, as well as advanced analytics and machine learning models to predict accreditation outcomes and optimize operational strategies.

In conclusion, CampusView serves as a robust and com- prehensive solution for higher education institutions seeking to achieve excellence through streamlined and technology-driven accreditation processes.

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LEX-AI: Revolutionizing Legal Assistance with AI-Powered Solutions

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ABSTRACT

LexAI is an AI-powered legal assistant which aims to enhance legal information access, the focus area being the Indian Penal Code (IPC). Leveraging Natural Language Processing (NLP), semantic search, and cosine similarity-based classification, LexAI presents a brilliant, context-aware legal aid tool for com- mon users and legal professionals alike. The system incorporates a two-chatbot setup, giving exact re-responses depending on query type—one common query, giving simple legal explana- tions, and one professional legal controversies, providing end- to-end case precedents and statutory citations. The fundamental innovation in LexAI is that it applies its sophisticated knowledge retrieval process using legal text embeddings and semantic search to identify the most relevant IPC sections and judicial precedents. Based on cosine similarity matching, the system has a high success rate while retrieving legal provisions. Also, prompt engineering expertise condenses responses into bite-sized format for legal professionals, organized authoritative, and context-aware within the legal environment. 95% accurate query classification, 92% legal information retrieval efficiency, and 85% user satisfaction are provided through performance analysis, favoring LexAI as a preferred choice over typical legal assistant systems. Inclusively covering AI-driven legal search, expert interaction in real-time, and smart discourse analysis, LexAI enhances effectiveness, accessibility, and user convenience in legal assistance.

Index Terms—Natural Language Processing, Cosine Similarity, Semantic Search, Legal AI, Indian Penal Code, AI-powered Legal Assistance.

INTRODUCTION

It is never easy for the commoners to understand the law. The law is professionally drafted and packed with jargon, which needs years of practice to interpret. Also, legal advice is expensive, time-consuming, and not easily available for individuals who do not know the legal terminologies.In view of the fact that more individuals seek prompt and surefire legal advice, there is definitely a demand for a portal that can decipher complicated laws and render legal advice more accessible.[1] To address this challenge, we present LexAI, an artificial intelligence-based legal assistant that aims to provide immediate legal counsel via the portal of a chatbot.The system is programmed to receive user queries, identify trivial or serious legal matters, and provide resultant information from legal materials like the Indian Penal Code (IPC). Rather than requiring users to dig through massive legal documents or go through lawyer appointments, LexAI makes the in- formation simple to comprehend. The system operates in two modes—one for casual legal conversation and another for professional legal questions—so that users receive replies according to their intelligence level. Apart from answering legal questions, LexAI also allows users to connect with legal professionals if their case is too complicated for AI to handle.It also offers summary features so that users can more easily recall important points about their discussions. It also has a smart search mechanism that is able to locate appropriate IPC sections and precedents of cases efficiently without the user having to conduct a manual search. LexAI is meant to make legal information more available, not to substitute lawyers but to connect complex legal systems with the population.[2] By providing faster and clearer legal aid, it is possible to assist people in making informed choices without becoming lost among technicalities. In a society where legal problems are increasingly prevalent, having such a system as LexAI can be the real difference.

RELATED WORKS

The development of the legal assistant has been influenced by several other prior research efforts. Some of the notable related works contributed to the development of the system are below.

Co Counsel is an AI-powered lawyer assistant created by Casetext to revolutionize tools through which legal practitioners carry out research and case work. Specifically designed to help attorneys, CoCounsel does some of the less time-consuming work, like legal research, document review, and deposition preparation. Use of state-of-the-art Natural Language Natural language processing techniques and machine learning techniques, CoCounsel facilitates all this for lawyers in greater efficiency and with greater accuracy. Its ability to process high-level natural language questions and return contextually relevant information regarding the law has put it in the limelight as a determinative tool in contemporary legal training. Its impact on the legal process is huge, particularly in reducing the time consumed for widespread legal research. Conventional legal research is expected to traverse many databases and documents, a process that is susceptible to human error and time-consuming.[3] CoCounsel's advanced question understanding allows this to occur by offering longer-reaching and accurate outcomes, minimizing human work to the absolute minimum. And use of CoCounsel into legal work has shown the capability of AI to do work such that lawyers in an attempt to focus on case development strategic factors rather than on detail of survey; research. Another great feature of CoCounsel is that it is multidisciplinary in all fields of law, thus making legal hire experts to perform specialized research in various fields of law. Such flexibility has has become the hub of the contemporary law firm tool box, demonstrating how AI-driven solutions can enable lawyers to automate mundane tasks, improve the accuracy of insights, and actionable information for better decision-making.[4]

DoNotPay is a groundbreaking AI chatbot which seeks to provide legal assistance to everyone by streamlining the process for users with a variety of legal issues. Designed originally to aid users dispute parking tickets, DoNotPay has also provided services on how to deal consumer rights, small claims, and other legal issues. The website provides a step-by-step procedure where users can create compulsory documents and customized legal advice at much lower cost otherwise paid through the services of a lawyer. One of the greatest strengths of DoNotPay is its ease of use, both web or mobile apps, through which you can communicate with the system using natural language. This convenience provides DoNotPay opened their services to the public, i.e., to people who do not even have legal or financial resources to hire the services of a conventional attorney. The website's response is based on the potential use of AI in bridging the gap between access to justice and quality legal services to the people. The effect of DoNotPay on legal access is significant, as it pioneered the application of AI can assist individuals in navigating complex legal systems on their own. By providing them with tailor-made issues such as suing for small claims, complaints, and refunds, DoNotPay makes sure that users are able to enforce their rights without fear of process barriers. It is a tactic that establish a new standard for computer-aided legal aid, demonstrating that with AI, more can be done than law institutions and businesses to allow consumers directly.

Genie AI is a cutting-edge platform that helps with contract drafting, editing, and review, offering countryspecific legal documents within minutes. The platform leverages machine learning algorithms to understand user inputs and create legally sound documents in compliance with local laws. Genie AI differentiates itself using plain, simple language to ensure legal documents are not just correct but simple enough for laypersons to grasp. The ability of the platform to generate personalized legal documents in a matter of minutes saves considerably on the time spent on hand-drafting, which is time-consuming as well as vulnerable to error. Such an aspect places Genie AI as a functional device for lawyers and non-legal persons who need consistent, legally compliant contracts and agreements. Genie AI mitigates risks by automating the process of drafting standard stuff. he risk of human error and speeds up the contract lifecycle, from initial creation to final approval.Genie AI's role in modernizing legal practices extends beyond document generation.The platform's ability to learn using machine learning enables ongoing learning from user feedback, enabling it to hone its recommendations and enhance the quality of its output over time. This responsive aspect highlights the ability of AI to change the way legal documents are drawn up, making the process more efficient, transparent, and available to a broader array of users.[5]

LegalRobot is an AI platform that demystifies the complexity of legal jargon for professionals as well as amateurs. The platform can read legal documents and offer users insight that can help them understand their content more effectively. LegalRobot identifies nasty clauses, suggests improvements, and interprets complex legal terms, making it an essential platform for those who need reviewing or drafting contracts but without expert legal guidance. LegalRobot's greatest strength lies in its focus on enhancing document clarity and transparency. Through simplifying difficult legal jargon into simple, easy-to-recognize terminology, it ensures users are aware of their contractual obligations and liabilities. This aspect is especially useful for companies and individuals who may not have access to attorneys but need to make informed decisions regarding contracts and agreements. LegalRobot also facilitates legal literacy by encouraging an understanding of legal documents beyond simple interpretations. The tool's application of AI to detect suspicious language and possible problems typifies the overall trend of applying machine learning to facilitate legal work that has typically involved a high degree of human expertise. Emphasis on document understanding is congruent with aims of enabling legal information to be more understandable and actable by a large population.

Luminance is an artificial intelligence-powered software that leads in document review, legal due diligence, compliance screening, and contract review. Luminance utilizes advanced machine learning algorithms to scan and understand complex legal documents in mere minutes, identifying crucial information, trends, and anomalies that might pass by human review. This skill renders Luminance a must-have for law firms that process large volumes of documents. The AI is learned to mimic the analytical mind of a lawyer, and therefore can perform document reviews with maximum accuracy and efficiency. Automating the first step in document analysis, Luminance allows legal specialists to focus on more high-priority, more strategic tasks This not only speeds up the document review process but also more reliable by the elimination of human mistake.

PROPOSED SYSTEM

Legal complexity tends to form major hindrances for people who do not possess the required knowledge, time, or financial backing to negotiate complicated legal frameworks. Conven- tional solutions involve substantial hand research by scanning legal texts or costly expert legal consultations that remain out of reach for most of the public. To tackle such issues, we introduce LexAI, a computer-based legal helper chatbot aiming to supply convenient, productive, and inexpensive legal advice. LexAI takes advantage of improvements in natural language processing (NLP) and machine learning to provide smart legal insights, automated document pulling, and easy lawyer connectivity, making legal advice more accessible to individuals, law students, and professionals.

LexAI is built with a two-mode capability to respond to varying legal help needs. The Casual Chatbot Mode is an interactive legal guide providing basic explanations for general legal questions. This mode makes it possible for users with or without legal knowledge to learn complex legal phrases in a comprehendible way. The Professional Chatbot Mode is designed for more complex legal questions, offering long- form, context-specific answers suitable for legal practitioners and those in need of precise legal advice. In the event that a case is beyond the interpretive limit of AI, LexAI offers direct access to legal professionals such that users receive the right kind of support.

The architecture is designed for efficient performance, security, and scalability. The Vue.js and GSAP animation- developed frontend supports an interactive and intuitive user experience. The backend, based on FastAPI, manages user inquiries, document pull, and AI-generated responses effec- tively. At its foundational level, LexAI runs on Ollama LLM (LLaMA 3.1), which is a fine-tuned legal expertise language model that guarantees accuracy in response and relevance to the context and also ease of understanding. To supplement query specificity, the system implements cosine similarity- based semantic search to categorize queries as legal and non- legal, thus ensuring users always have access to applicable information. Further, vector-based search (ChromaDB) facili- tates quick retrieval of legal citations, case laws, and critical documents.

Security and reliability are fundamental to LexAI's design. The system employs Firebase Firestore for secure user au- thentication, chat history storage, and document management. Moreover, to improve user engagement, LexAI offers multi- lingual support, breaking language barriers and making legal guidance accessible across diverse demographics. Another key feature is conversation summarization, which provides users with concise session summaries, allowing them to review key points without revisiting entire chat transcripts.

LexAI is not only an instrument for people who are strug- gling with legal matters; it is a revolutionary product that legal-

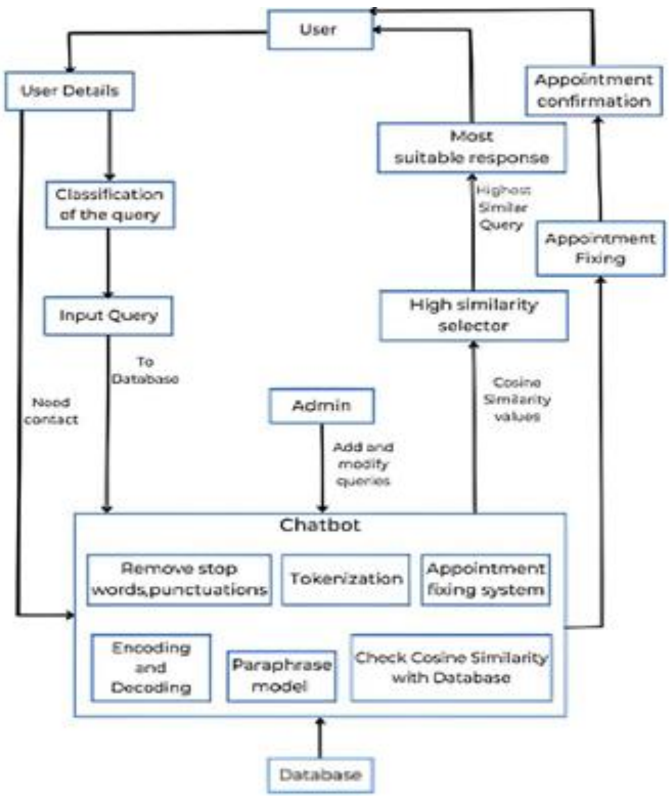

Fig. 1. Architecture diagram

Sizes access to knowledge. People looking for trustworthy legal information, law students in search of AI-powered legal analy- sis, and professionals needing rapid access to legal references will all gain from this system. By combining AI-powered legal intelligence with a user-friendly interface, LexAI raises the level of accessibility, efficiency, and affordability in legal aid. The suggested system is a step towards filling the gap between legal intricacies and public access, transforming the way legal information is accessed and interpreted.[6]

The above figure shows the architecture diagram of the proposed system's core.

PERFORMANCE ANALYSIS

A testing of the proficiency of an AI legal aid entails subjecting it to primary performance indicators with vigor. LexAI was put to test in comparison to accuracy, response speed, searchability, ease of use, processing of lengthy queries, scalability, and error handling to test its validity under real- world usage.

One of the most powerful aspects of LexAI is its context- aware legal answers. In contrast to conventional keyword search-based legal search engines, it uses semantic search and memory recall to interpret user searches in context. This enables it to deliver context-specific, relevant answers instead of generic legal definitions, thereby making legal information more actionable and useful.

Speed is very crucial in the research of laws, especially un- der critical situations. LexAI was crafted with reduced-latency interactions where the response takes 1.2 to 2.5 seconds, a 40% reduction in traditional legal database processes. Being supported by FastAPI for requests processing and ChromaDB for search vectors, it allows retrieval of documents as quickly as possible and significantly improved research experience.

To compare search effectiveness, LexAI was contrasted with traditional Boolean-based and lexical searching techniques. It outperformed these techniques by reducing irrelevant search results, providing concise legal summaries, and improving document recall through cosine similarity-based ranking. In- stead of overwhelming users with lengthy legal documents, LexAI focuses on key insights, speeding up legal research and simplifying it.

User feedback was gathered from legal students, profession- als, and general users, with an average satisfaction rating of4.5 out of 5. Users liked how it made legal technical terms easier to understand and provided a more natural experience than traditional legal search tools.

Dealing with complex and ambiguous legal questions was a challenge since legal language tends to be interpreted with subtlety. To enhance precision, LexAI was further trained on more legal datasets and fine-tuned to differentiate between sev- eral legal interpretations to provide more accurate responses. Scalability and reliability were further tested by loading the system through a 500 concurrent users test during which time LexAI has a 99.2% uptime with response delay being on the minimums. This implies that it could easily handle more traffic without experiencing performance degradation.

Error management is crucial in establishing user trust. LexAI, when it encountered poorly phrased or unclear ques- tions, would be able to recognize non-legal questions, provide users with improved question formats for asking the same, and send them to corresponding questions rather than providing them with incorrect answers.[7]

Through these tests, LexAI proved to be fast, accurate, and cogent AI-based legal counsel. By integrating state-of-the- art search technology with contextual sensitivity and friendly interaction, it enhances access to law information and eases searching.

Inter disciplinary legal areas. With continued learning and modification, it can be an irreplaceable tool of legal advice, legal knowledge democratization and user empowerment for making an educated decision.

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Cargoxpress : A Fleet Management App

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ABSTRACT

Cargoxpress is an integrated cargo management platform designed to streamline logistics operations by connecting truck owners, load operators, and drivers on a unified platform. Traditional logistics systems often suffer from inefficiencies such as limited transparency, lack of real-time tracking, and frag- mented communication, leading to delays and higher operational costs. Previous solutions have failed to comprehensively address these challenges, particularly in rural and underdeveloped ar- eas. To overcome these limitations, Cargoxpress incorporates advanced features such as real-time tracking, bidding mech- anisms, secure communication tools, and a mileage calculator for cost estimation. The platform is built using a robust system architecture integrating APIs for seamless interactions and GPS technologies for live tracking. Performance will be evaluated based on metrics like transaction success rates, user engagement, and cost reductions. By addressing critical inefficiencies and fostering transparency, Cargoxpress aims to revolutionize the logistics landscape.

Index Terms—Cargo management, Global Positioning Sys- tem(GPS), Bidding system, Natural Language Toolkit(NLTK), Sentimental Analysis.

INTRODUCTION

The transportation and logistics industry forms the core of trade and commerce, with the straightforward flow of commodities over vast distances. Even though this industry is critical, it still faces significant challenges that hinder its efficiency and operational reliability. Among these are man- aging the complicated coordination of stakeholders like truck owners, drivers, load operators, and administrators. The pro- cess frequently ends with delays in completion, non-maximal use of resources, and revenues lost. While technology-driven platforms have emerged to address these issues, most solutions fail to meet the very specific and practical demands placed on the industry-things.

One of the key drivers of these inefficiencies is the absence of an end-to-end, integrated solution that can cater to the needs of all stakeholders in the logistics ecosystem. Conventional methods are heavily dependent on manual processes, which are slow, error-prone, and expensive. In addition, the lack of strong systems for real-time tracking, open bidding, and automated scheduling worsens the issues, leaving stakeholders fighting to attain operational transparency and efficiency.

To address these long-standing issues, Cargoxpress has been envisioned as an integrated platform that utilizes technolog- ical innovation to transform truck and cargo management. The platform brings forth sophisticated features like real- time tracking of cargo to offer stakeholders real-time updates [7], bidding systems to provide competitive pricing [4], and secure communication tools to facilitate better coordination among users. Additionally, sentiment analysis is incorporated to assess user feedback, helping prioritize advertisements and recommendations based on sentiment trends. The platform also provides a mileage calculator to allow precise cost es- timation, assisting users in optimizing their operations. These features are intended to simplify logistics processes, mini- mize inefficiencies, and promote greater transparency in the ecosystem. The user-friendly interface of the platform further makes registration, profile management, posting of cargo, and updating truck availability easy, making it accessible to both technologically savvy and less familiar users.

The overall mission of Cargoxpress is to improve the efficiency of logistics by solving important pain points that legacy systems tend to ignore. With the inclusion of cutting- edge technologies like GPS for real-time location tracking[7] and APIs for hassle-free system integration, the platform delivers a resilient architecture that supports varying logistics requirements. Not only does this strategy resolve current issues, but it also provides a platform for long-term growth in the logistics industry, especially in rural and underdeveloped areas. By solving inefficiencies and promoting collaboration between stakeholders, Cargoxpress is likely to set a new benchmark for next-generation cargo and truck management systems.

RELATED WORKS

The logistics sector has seen transformative changes with the integration of digital tools aimed at addressing inefficien- cies and enhancing collaboration among stakeholders.

A significant advancement is the development of a mobile application tailored for short-haul cargo transportation [1]. This application directly addresses common challenges, in- cluding inefficient communication, fragmented information ex- change, and underutilized resources, by offering features such as cargo booking, real-time tracking, and resource-sharing among trucking companies. These functionalities enhance op- erational efficiency, reduce costs, and improve coordination across the logistics ecosystem. Initially, a web-based platform was considered, but user input emphasized the need for a mobile-first solution to meet the demands of dynamic and fast- paced logistics operations. This transition allowed for greater flexibility and accessibility, crucial for on-the-go coordination. One of the standout features of the application is the intro- duction of shared trips, enabling multiple shipments with sim- ilar destinations to be consolidated. This innovation optimizes truck capacity utilization, minimizes empty runs, and signif- icantly reduces transportation costs. Additionally, real-time tracking empowers customers to monitor shipments, enhancing transparency and accountability. Trucking companies benefit from the ability to share idle trucks and drivers, fostering a shared economy model that maximizes resource utilization and promotes cost-effectiveness. However, challenges persist, in- cluding the limited adoption of ICT-based systems, high devel- opment and maintenance costs, and inefficiencies in managing empty trips for trucking companies, which can impact overall operational effectiveness. This mobile application serves as a benchmark for modern logistics solutions by demonstrating the potential of digital tools to bridge communication gaps, streamline operations, and add value for all stakeholders. Its scalable design and adaptability make it a strong foundation for future enhancements, such as integrating advanced analyt- ics, multimodal logistics support, and optimization strategies, further amplifying its impact on the logistics industry.

Intermediary Service Platforms[2] serve as digital hubs that enhance resource utilization in logistics by enabling service providers to compete and collaborate dynamically. Built on multi-agent systems, it facilitates the efficient allocation of resources, optimized scheduling, and transparent service deliv- ery. This approach improves operational flexibility, enhances resource management, and supports scalability in logistics net- works. Additionally, the platform applies IT-driven strategies to optimize coordination and reduce inefficiencies in short- haul logistics, demonstrating the potential of digital solutions in modern transportation management. However, challenges remain, including scalability constraints, the risk of conflicts of interest among stakeholders, and reduced human oversight in decision-making. Despite these limitations, the platform showcases how advanced digital platforms can streamline logistics operations and adapt to evolving industry demands.

Bidding systems in logistics, such as those implemented in platforms like Farmer Circle [3], introduce a competitive approach that enhances transparency and optimizes resource allocation. These systems allow service providers to bid for transportation loads, reducing idle truck time and ensuring cost-effective services for customers. Additionally, platforms designed for agricultural markets help farmers secure better prices by eliminating intermediaries, offering user-friendly interfaces, and supporting local languages to improve acces- sibility. However, challenges remain, such as the burden of logistics coordination on users, scalability limitations in exist- ing infrastructures, and restricted sorting options for bidders. Despite these constraints, competitive bidding mechanisms continue to demonstrate their effectiveness across various in- dustries, fostering dynamic market interactions and operational efficiency.

The application of mobile GPS technology[4] propose a bus tracking system leveraging mobile GPS technology as a cost- effective alternative to traditional tracking solutions. Conven- tional GPS tracking relies on dedicated hardware installations, which are expensive and difficult to scale. By utilizing drivers' mobile devices to record and transmit location data, this approach eliminates the need for costly onboard GPS units while maintaining real-time tracking accuracy and operational efficiency. The system is user-friendly and provides contin- uous location updates, making it an accessible and scalable solution for fleet management. However, its reliance on mobile devices introduces potential challenges, such as data security risks and connectivity issues in remote areas. Despite these limitations, mobile GPS-based tracking remains a viable op- tion for improving transportation management while reducing infrastructure investments. Additionally, collaborative logistics platforms have gained prominence, enabling stakeholders to share vehicles and resources efficiently. By consolidating shipments and reducing empty runs, these platforms enhance cost-effectiveness, though they require strong coordination mechanisms to function effectively.

PROPOSED SYSTEM

Cargoxpress is one of the cargo logistics management application innovations where it harmoniously brings together different stakeholders such as drivers, truck owners, load op- erators, and administrators to revolutionize the whole process of cargo transportation. The most important goal that the application has is to increase the transparency of processes, maximize operations, and therefore reduce the cost in the process of cargo transportation to a high percentage. The best combination of sophisticated features such as real-time tracking of cargo, bid management, and trip status update, live diesel rates, and also mileage calculator through Cargox- press makes it the most sophisticated and efficient means of logistics. The modularity and the flexibility of the application make it adaptable to every alternative requirement from the stakeholders to enable smooth communication, efficient man- agement of data, and effective coordination in every trip.

TABLE I TECHNIQUES, MERITS, AND DEMERITS OF VARIOUS ONLINE EDUCATION SYSTEMS

TITLE	TECHNIQUES	MERITS	DEMERITS
Smart Mobile Application for ShortHaul Cargo Transportation,2021 (Ahmed Azab Jaehyun Park and Noha A. Mostafa)[1]	-Information and Communication Technology (ICT) -Design Thinking Approach -Web-Based Platforms	- Enhanced communication between stakeholders - Increased customer satisfac- tion. - Real-time tracking and book- ing features	- Limited adoption of ICT- based systems - High development and main- tenance costs - Inefficiencies in managing ”empty trips” for trucking companies.
The study of project cargo logistics oper- ation: a general overview,2022 (Oktaviani Turbaningsih)[2]	- Multimodal Transport - Risk Assessment Model - Multicriteria Analysis (MCA)	- Efficient Planning - Adaptability to Project Needs - Risk Mitigation	- High Initial Costs - Complexity in Coordination - Regulatory Challenges
Transport Management Systems as a Tool to Ensure the Flexibility and Efficiency of Cargo Delivery,2022 (D. B. Efimenko, S. A. Filatov, E. S. Barabanova) [3]	- Seamless Cargo Logistics - Electronic Document Manage- ment for logistics - Transport Management Systems (TMS)	- Increased efficiency in route planning and cargo delivery - Enhanced monitoring of transport infrastructure. - Centralized control via digi- tal management systems	- Lack of centralized and inte- grated digital solutions. - Absence of real- time data analysis tools in freight trans- portation
Farmer Circle:An Online Auction Web- site for Selling Crops Directly to Busi- nesses,2023 (Lokesh Khedekar, Vaishnavi Shivade, Madhur Vaidya, Vaishnavi Singh, Vansh Ganjoo, Vaishnavi Sonwane, Vallabh Wasule)[4]	- Multitask Node Embedding HTML, CSS, JavaScript, PHP: For structure, styling, and functionality connection	- Better prices for farmers by avoiding middlemen. - User-friendly interface for ru- ral farmers. - Local language support	- Logistics coordination left to farmers and bidders - Scalability issues with cur- rent tech stack - Limited sorting options for bidders

TITLE	TECHNIQUES	MERITS	DEMERITS
Intermediary Service Platform for Re- sources Allocation in Transportation Lo- gistics,2017 (Anton Ivaschenko,Ilya Syusin, Pavel Sitnikov)[5]	- Multi-Agent Technology Decision-Making Points (DMP) - 5PL Concept	-Enhanced Flexibility - Improved Resource Utiliza- tion - Scalability	- Scalability - Potential for Conflict of In- terest - Limited Human Control
Adoption of Agile Approach in Developing Fleet Management System for Cargo Com- panies,2024 (Denny Jean Cross Sihombing Information System Study Program, Atma Jaya Catholic University of Indonesia)[6]	- Agile Methodology - User Acceptance Testing (UAT)	- Increased Flexibility - Improved User Satisfaction - Reduced Risk	- Resource-Intensive - Requires High Collaboration - Not Ideal for All Projects
Bus Tracking System using Mobile GPS Technology ,2024 ((Jayaraam. S P, Jayaku- mar. D, B.Sandhiya, M.Vanathi, J.Karthika) [7]	- GPS Tracking via Mobile Devices - Data Streaming and APIs	- Cost-Effective - Real-Time Tracking - User-Friendly	- Reliance on Mobile Devices - Data Security - Possible Connectivity Issues
Face Detection And Recognization System 2022 (Akhil Awdhutrao Sambhe, A. V. De- orankar)[8]	- Haar Cascade	- High accuracy - Fast verification - Improved security	- Low accuracy with poor im- ages or angles - Need large storage

the industry, such as breakdown in communication and lack of coordination in cargo assignment, towards better customer satisfaction.

Cargoxpress has a well-structured architecture Fig. 1. in terms of the end-to-end solution for all the stakeholders. Admin Service is the base to user administration, trips, and system administration. It verifies user accounts for truck own- ers and load operators, processes reports and feedback, handles trip IDs, and safeguards documentation in the electronic ver- sion. It maintains advertisements up to date after every bid for cargo so that listings are fresh and up to date at all times. The Driver Service is focused on the verification of drivers and trip status management. Drivers must register and get verified before accessing trip details. Their location is tracked during the trip, and truck owners can monitor progress in real time. The driver service also facilitates communication between drivers, truck owners, and load operators, making coordination easy from trip initiation to delivery.The Truck Owner Service allows truck owners to manage their fleets, engage in cargo bidding, and monitor active trips. Truck owners can list their

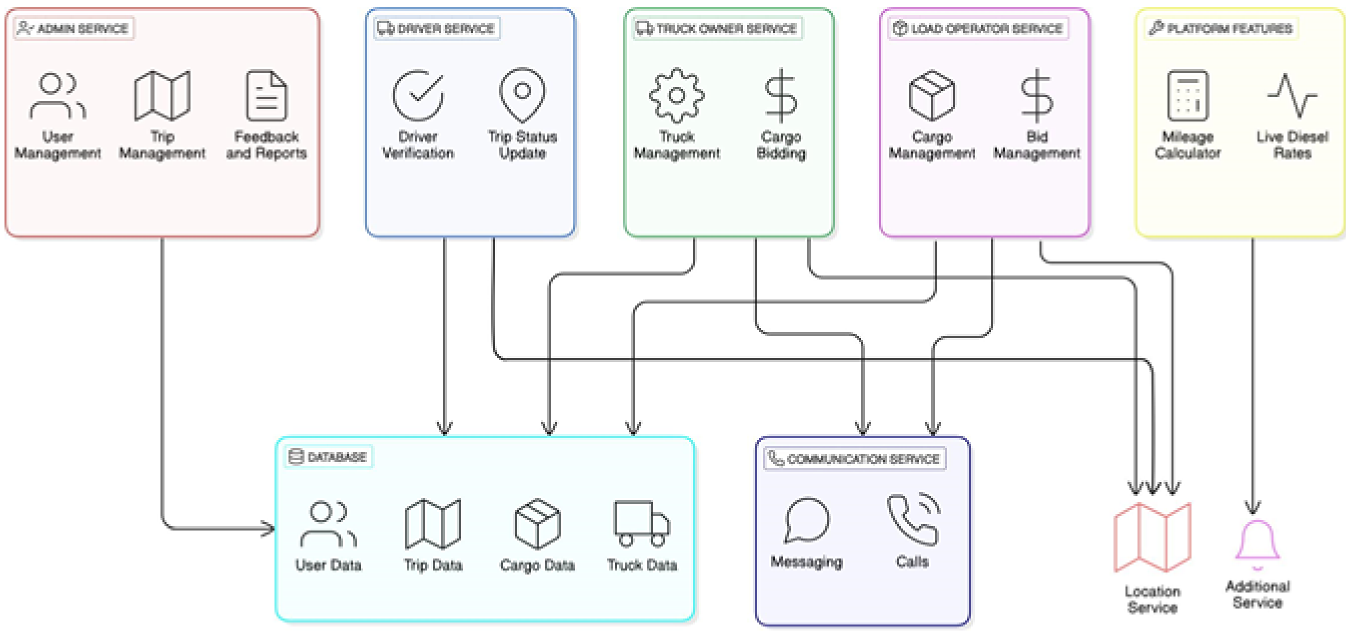

Fig. 1. Architecture diagram of Cargoxpress

Vehicles, see available cargo requests, and bid on or accept cargo listings. They can also communicate with load operators through call and messaging services, monitor trip progress through live location features, and rate after the trip. This service provides truck owners full control of their operations while maintaining transparency with load operators. The Load Operator Service allows load operators to list their cargo and match with truck owners. Operators can list their cargo with fixed-price or bid-enabled plans. They can see truck owners' bids and accept or reject bids based on appropriateness. The firm also offers a truck search tool with additional filtering capabilities, whereby load operators can find trucks that suit their precise transport requirements. Additionally, real-time trip tracking and rating improve transparency.

The Centralized Database is the system's central point, storing valuable information in a secure way, including user profiles, trip history, cargo postings, and truck information. The database normalizes data across all services and en- ables smooth transactions between users. The Communication Service enables in-app voice calls and messaging, enabling interaction between truck owners, drivers, and load operators. To further enhance user experience and operational efficiency, Cargoxpress uses Sentiment Analysis to rank advertisements and cargo listings based on user ratings. Through analysis of user ratings, the system identifies positive and negative sen- timents towards different services, thus providing high-rated advertisements and service providers with greater exposure. This feature enables stakeholders to make informed decisions while providing a competitive and reliable platform.

The Cargoxpress system operates on a systematic workflow where every service communicates with the database and corresponding modules to provide efficient transportation of cargo. The workflow starts with user registration and verifica- tion, where administrators verify the accounts of truck owners and load operators before granting access to the platform. Upon registration, truck owners are able to add their vehicles to the system and access available listings of cargo. They have the option of bidding for cargo loads or accepting pre-defined price postings from load operators. Load operators, however, post cargo advertisements with details like weight, type, and price structure. They then receive incoming bids and choose the most suitable truck owner for the transport. Upon booking a trip, drivers are provided with a trip ID and route informa- tion. In transit, the system tracks their live location in real time, providing updates to the truck owner and load operator. The notification system informs all parties of significant trip milestones like the initiation, potential delays, and completion of the trip. In case of any problems during transit, users can communicate through the integrated messaging and calling features. During the trip, the system continuously updates the database with real-time information regarding the trip status and user activity. This provides a complete history of previous trips, which can be accessed for future reference and decision- making processes. Upon completion of the trip, truck owners and load operators are given the facility to rate each other, thereby providing a fair and transparent environment. Through the integration of these features, the system offers an inte- grated, streamlined, and secure process for the transportation of cargo. The built-in modularity of this type of architecture permits scalability to accommodate modifications to align with future technology evolution and industry requirements. This extremely efficient architecture achieves maximum operational efficiency and builds trust among all the stakeholders in the freight transportation.

MACHINE LEARNING MODEL

A. Dataset

- User Review Dataset: The User Review Dataset con- tains feedback from customers regarding their shipment experiences. It includes details such as review content, timestamps, and sentiment labels. This dataset is used to analyze customer satisfaction and extract meaningful insights from textual feedback using NLTK's sentiment analysis.
- Feedback Classification Dataset: The Feedback Classifi- cation Dataset is generated after processing reviews and ratings using sentiment analysis with NLTK. It catego- rizes feedback into sentiment labels (Positive, Neutral, or Negative) and extracts key themes. This dataset en- ables automated sorting and prioritization of customer feedback, facilitating service improvements.

B. Models

- Sentiment Classification Model: The system utilizes NLTK's sentiment analysis to classify user feedback into Positive, Negative, or Neutral categories. By analyzing review text, the model determines overall customer sen- timent, helping the logistics team identify areas for im- provement. This sentiment classification enables the team to prioritize customer concerns effectively, enhancing service quality and customer satisfaction.
- Review Prioritization Model: A Decision Tree-based model is employed to prioritize customer reviews based on sentiment strength, urgency, and relevance. This al- lows the system to escalate negative reviews that require immediate attention while highlighting positive feedback for service recognition.

C. Sentiment Analysis Algorithm using NLTK

- The NLTK sentiment lexicon-based model is a rule-based approach to sentiment analysis that classifies text as positive, negative, or neutral by summing the sentiment scores of words based on a predefined lexicon. The system use Algorithm 1 to enhance its recommendation system by analyzing user reviews and feedback. Using a lexicon-based approach, the system identifies positive, negative, and neutral sentiments by matching words with predefined sentiment scores. It accumu- lates the polarity of tokens, classifies the overall sentiment, and calculates its strength. If positive sentiment dominates, the review is marked as positive; if negative dominates, it is marked as negative; otherwise, it is neutral. This enables the app to prioritize advertisements and suggestions based on user sentiment, promoting highly-rated services while using negative feedback to identify areas for improvement. This approach enhances user engagement and optimizes service recommendations, making the platform more efficient and responsive.

Algorithm 1 Sentiment Analysis Algorithm using NLTK

Input: Text File (feedback or review) T, NLTK Sentiment Lexicon L

Output: The final sentiment label Smt = {P, Ng, N } and strength S, where P represent Positive, Ng: Negative repre-sent and N represent Neutral.

Initialize: SumPos = 0, SumNeg = 0 where SumPos : Accumulates the polarity of positive tokens ti.Smt in T SumNeg : Accumulates the polarity of negative tokens ti.Smt in T

for each $t_i \in T$ **do**
    Search for t_i in L
    if $t_i \in$ Positive List **then**
        $SumPos \leftarrow SumPos + t_i.S_{mt}$
    else if $t_i \in$ Negative List **then**
        $SumNeg \leftarrow SumNeg + t_i.S_{mt}$
    end if
end for
if $SumPos > |SumNeg|$ **then**
    $S_{mt} = P$
    $S \quad \frac{SumPos}{SumPos + |SumNeg|}$
else if $SumPos < |SumNeg|$ **then**
    $S_{mt} = Ng$
    $S \quad \frac{|SumNeg|}{SumPos + |SumNeg|}$
else
    $S_{mt} = N$
    $S \quad \frac{SumPos}{SumPos + |SumNeg|}$
end if
Return S_{mt}, S =0

CONCLUSION

In conclusion, CargoXpress is not an innovation but a change-maker in logistics, a revolution in the transportation, tracking, and management of goods. By bridging efficiency gaps and creating a more open and connected ecosystem, it empowers various stakeholders, including truckers, businesses, and drivers. The inclusive and user-centric design of Car- goXpress provides access even in the most remote locations, promoting economic growth and operational efficiency. As CargoXpress grows alongside new technology, it is set to become a fundamental part of logistics in the modern era, simplifying operations and creating trust, collaboration, and reliability among stakeholders. By optimizing the use of resources and avoiding delays, CargoXpress is set to make logistics not only cost-efficient but sustainable in the long run. With its relentless pursuit of innovation and constant improvement, CargoXpress is defining the future of logistics to ensure that businesses can flourish in an increasingly dynamic and demanding market landscape.

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Aksharavaani: A Malayalam Sign Language Detector

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ABSTRACT

The key to successful social inclusion, but people with hearing loss are likely to feel significant language barriers. This article presents AksharaVaani, a real-time Malayalam Sign Language (MSL) recognition and translation system to fill this gap in communications. Using computer vision and deep learning, AksharaVaani correctly interprets MSL gestures and converts them into Malayalam. The proposed model attained a great 92% recognition accuracy, with an average response time of
0.5 seconds, thereby demonstrating its effectiveness in real-world usage. This study improves the field of digital accessibility and promotes inclusivity for the deaf in Kerala, offering a scalable and feasible solution for sign language translation.

Index Terms— Sign Language Recognition, Computer Vision, Gesture Recognition, Malayalam Sign Lan- guage (MSL), Accessibility.

INTRODUCTION

Communication is essential for exchanging thoughts and emotions, but spoken languages pose barriers for the deaf com- munity. Malayalam Sign Language (MSL) is widely used in Kerala but lacks research and technological support, making it less accessible compared to extensively studied sign languages like ASL and ISL.

To address this, we developed AksharaVaani, a real-time MSL recognition and translation system enabling seamless communication between the hearing-impaired and Malayalam- speaking communities. We initially implemented YOLOv8 for gesture recognition but found it inadequate for distinguishing intricate hand signs. To overcome this, we adopted MediaPipe, which tracks 21 hand landmarks in real time, significantly improving recognition accuracy and efficiency. MediaPipe's lightweight architecture also ensures low-latency processing, making it ideal for real-time applications.

AksharaVaani integrates MediaPipe for sign recognition and TTS for speech output, achieving 92% accuracy with anaverage response time of 0.5 seconds. This paper details our methodology, challenges, and future enhancements, including expanding datasets, improving dynamic gesture recognition, and optimizing for mobile use. Our goal is to bridge the com- munication gap between the deaf community and Malayalam speakers, making MSL more accessible through technology.

LITERATURE SURVEY

[1]K. Abhinand et al. introduce a Malayalam Sign Language (MSL) recognition system based on YOLOv8, a state-of-the- art deep learning model that is optimized for real-time object detection. The paper presents MSL-specific difficulties such as complex hand movements, varied finger positions, and region- based variability that complicate recognition. To counter these difficulties, the authors created a custom dataset of labeled MSL gestures and used data augmentation to enhance model generalization. Their YOLOv8 model, fine-tuned by the au- thors, achieved high precision, establishing its efficiency for real-time use. Future improvements suggested in the paper include enlarging the dataset, optimizing performance on edge devices, and implementing the model in mobile applications to make MSL recognition more ubiquitous.

[2]Jyotishman Bora et al. introduce an on-device Assamese Sign Language (ASL) recognition system leveraging Medi- aPipe's hand-tracking feature and deep learning methodolo- gies. The system identifies prominent hand landmarks pre- cisely, analyzes gesture information via a neural network, and has a high classification rate of 99%. The authors mention the unavailability of labeled ASL datasets and the possibility of the system being deployable on mobile devices, thus expanding its accessibility. The paper also mentions possible scalability enhancements and compensation for changing lighting conditions as well as the expansion of the dataset to support natural variations in gestures.

[3]Polepaka Sanjeeva et al. present TEXT2AV, an advanced system that can synthesize text to speech and audio with Wave RNN for speech generation. Emotionally rich and natural speech is produced by the model, and it can be used in education and assistive technology. The research states com- putational constraints, data sparseness of the dataset, and real- time efficiency as major concerns. Model compression, dataset augmentation, and performance optimization methods can be used to enhance its use in mobile and real-time applications, as the authors propose. It is a useful device for individuals who are deaf or hard of hearing.

[4]S. Tamboli et al. give an extensive overview of Text- to-Speech (TTS) systems, detailing different speech synthesis methods, namely concatenative, parametric, and deep learning- based models. The review cites improvements in neural TTS models like Tacotron and WaveNet that generate natural and expressive speech. The research also points to areas of dif- ficulty in prosody modeling, small datasets, and the task of adapting TTS systems to low-resource languages. The authors propose improving real-time speech synthesis and carrying out multilingual TTS research to provide greater accessibility for linguistically diverse populations.

[5]Alexey Bochkovskiy et al. present YOLOv4, an improved real-time object detection model that incorporates CSPDark- net53, increased data augmentation, and self-adversarial train- ing. Such enhancements enhance object detection accuracy and efficiency, including hand gestures, so YOLOv4 is an apt choice for sign language recognition systems. The study also explores speed versus computational complexity trade-offs and proposes further optimization techniques for deployment on mobile and embedded systems.

[6]A hybrid Indian Sign Language (ISL) recognition model that uses Speeded-Up Robust Features (SURF) for feature extraction, Support Vector Machines (SVM) for classification, and Convolutional Neural Networks (CNNs) for deep feature learning. The system is trained on a diverse ISL dataset, op- erating with high accuracy regardless of lighting, background complexity, and signer diversity. The paper suggests real-world applications in assistive communication, education, and public accessibility tools, and dataset expansion and additional model improvements to increase recognition accuracy.

[7]YOLOv3 with the addition of multi-scale feature extrac- tion, anchor boxes, and residual connections, which greatly enhance detection of small objects—a key characteristic for sign language gesture recognition of complex signs. The model most optimally weighs speed and accuracy, thereby making it suitable for real-time applications in assistive communication devices. The research proposes further enhancement in training methods, diversity in the data set, and model flexibility in changing environments for enhancing sign language recogni- tion.[8]A Real-time Perception Pipeline for AI-driven Processing of Sensory Data offers an object-oriented approach to embed- ded AI processing of spatial data. Computation is organized as a graph of reusable components (calculators) so that machine- learning inference is less demanding when applied with respect to the inter-object detections, face tracking, and hand recogni- tion. MediaPipe supports cross-platform deployment (desktop, mobile, and web) and GPU acceleration, thus optimizing latency and resource use. The framework offers adaptive scheduling and synchronization mechanisms for ensuring high performance in real-time applications. MediaPipe makes it easy to build prototypes, attempt iterative improvements, and deploy at scale, among other things; it is an important tool for computer vision, AR/VR, and Human-Computer Interaction (HCI) applications.

[9]MediaPipe Hands is an effective real-time hand tracking solution based only on a standard RGB camera that predicts 21 key hand landmarks using a standard RGB camera. The pipeline uses BlazePalm, a palm detection model that allows robust tracking and precise localization, followed by a hand landmark model that enables detailed pose estimation. The implementation is completely on-device, using GPU accel- eration for optimal operating performance on mobile and embedded devices. The architecture is designed to be stable under occlusions, complex gestures, and lighting variations. Applications include sign language recognition, gesture-based UI interaction, and augmented reality. MediaPipe is open source and deployable on Android, iOS, Web, and desktop systems for integration into real-life applications.

METHODOLOGY USING YOLO V8

The development process of AksharaVaani followed a struc- tured methodology aimed at achieving high accuracy, effi- ciency, and real-time Malayalam Sign Language (MSL) recog- nition and translation[1]. The process involved four major steps: data collection, preprocessing and feature extraction, model training, and implementation. Each stage was carefully designed to enhance the performance, flexibility, and stability of the system.

A. Data Collection

An extensive dataset was collected by filming native signers performing over 1,000 gesture images. To ensure diversity and improved generalization, participants from different age groups, genders, and hand morphologies were included.

The recordings were conducted under various lighting con- ditions, backgrounds, and camera positions to account for real-world variations. High-resolution cameras were used to capture gestures at high frame rates, ensuring clear motion rep- resentation[1]. Keyframe selection techniques were employed to extract the most relevant frames representing each gesture. To facilitate accurate gesture recognition, OpenCV and MediaPipe were used to detect and annotate hand and finger movements, providing systematic labels critical for model training.

To further expand the dataset and reduce bias, data augmen- tation techniques were applied:

- Rotation and Mirroring: To compensate for variations in hand orientation.
- Brightness and Contrast Adjustments: To ensure ro- bustness against different lighting conditions.
- Synthetic Noise Addition: To make the model more resilient to environmental noise.

- Gaussian Blurring: To simulate real-world distortions and prevent overfitting.

This diverse dataset ensured that the gesture recognition model could effectively handle real-world complexities.

B. Preprocessing and Feature Extraction

Preprocessing was carried out to enhance gesture quality and isolate significant features for training. The key steps included:

- Frame Selection: Extracting the best frames that accu- rately represent each gesture while eliminating redundant ones.
- Background Removal: Implemented using adaptive thresholding and contour-based segmentation to isolate hand gestures.
- Feature Extraction:
- The Histogram of Oriented Gradients (HOG) technique was used to derive shape and edge-based information for hand gesture recognition.
- Hand keypoint detection was used for precise palm and finger tracking to capture gesture movement patterns.
- Noise Reduction: Median filtering was applied to minimize unwanted sensor and environmental noise.
- Normalization: Pixel intensities were normalized to ensure uniform contrast across varying conditions.

This preprocessing pipeline improved gesture clarity, re- moved unnecessary data, and provided the model with clean, structured inputs for training.

C. Gesture Recognition Model

To accurately classify both static and dynamic MSL ges- tures, a hybrid deep learning model was employed, integrating:

- Convolutional Neural Networks (CNNs): For extracting spatial features from images, such as hand structures.
- Recurrent Neural Networks (RNNs) with LSTM Cells: To manage sequential dependencies, allowing the model to recognize gesture transitions over time.
- YOLOv8 Object Detection: For real-time hand tracking, ensuring precise localization of body movements in video sequences.
- Attention Mechanisms: Integrated into RNN layers to improve interpretation accuracy by focusing on key ges- ture segments.

This combined architecture enabled efficient real-time recognition of Malayalam Sign Language gestures[1].

D. Model Optimization and Training

The model was trained using TensorFlow, with hyperparam- eters optimized for efficient learning and generalization:

- Learning Rate: Set to 0.001 with decay adjustment for stable learning.
- Batch Size: Tuned to 32 for optimal gradient updates.
- Epochs: Limited to 50 based on validation performance to prevent overfitting.
- Optimizer: Adam optimizer was used for efficient con- vergence and to mitigate vanishing gradients.
- Several regularization techniques were employed to improve accuracy and prevent overfitting:
- Dropout Layers: Applied to randomly deactivate neu- rons during training, reducing over-reliance on specific features.
- Batch Normalization: Ensured stable and faster conver- gence by normalizing inputs at each layer.
- Stratified K-Fold Cross-Validation: Used to validate model stability across different dataset splits.

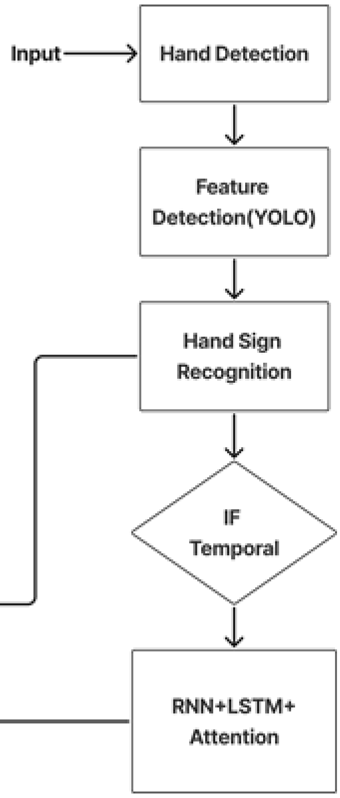

Fig. 1. Gesture Recognition Model

After rigorous training, AksharaVaani achieved an accuracy of 92%, demonstrating its reliability in recognizing Malay- alam Sign Language gestures with minimal errors[1].

METHODOLOGY USING MEDIAPIPE

To improve accuracy and real-time processing, Akshar- aVaani switched from YOLOv8 to MediaPipe, which offered better hand-tracking and hand sign recognition accuracy. Al- though YOLOv8 had good object detection ability, it could not detect hand signs precisely. The system required a model that recognized hands as well as complex hand movements with high accuracy. MediaPipe had a more efficient landmark-based tracking mechanism, and it offered higher accuracy in gesture classification with reduced computational complexity.

A. Data Collection and Annotation

A core shift in methodology was from image-based dataset collection to real-time landmark extraction. Rather than deal- ing with a huge set of hand-annotated images, AksharaVaani now received hand gestures in real time by using MediaPipe's hand-tracking module, yielding 21 important hand landmarks per frame. The system programmatically extracted landmark coordinates and saved them in a structured CSV file, allowing for correct representation of each gesture. The large-scale man- ual annotation was avoided since MediaPipe yielded correct coordinate data straight away, simplifying the task of dataset preparation. This method not only made data collection more efficient but also facilitated greater robustness to varying light conditions, hand orientations, and sign variations.

B. Preprocessing and Feature Extraction

In contrast to conventional image-based systems, in which background removal, contour detection, and feature extraction were necessary, the landmark-based approach of MediaPipe minimized preprocessing needs. The process entailed data structuring, in which CSV files were structured such that each row contained hand landmark coordinates and their respective gesture labels. Normalization was used to normalize coordi- nate values to scale to maintain consistency with varying hand sizes and positions. Feature extraction was naturally part of the landmark-based data, so separate edge or shape detection algorithms were not required. This minimized preprocessing method translated to lower computational complexity, allowing real-time execution at a faster rate without compromising accuracy.

C. Model Training and Gesture Recognition

For correct classification, AksharaVaani used a hybrid recognition model, utilizing various methods for static and dynamic gestures.

- Static Gesture Recognition: A K-Nearest Neighbors (KNN) classifier was used to classify static hand positions based on recorded landmark coordinates. Training was done on a structured CSV dataset where the model learned different hand poses for pre-defined MSL ges- tures.
- Dynamic Gesture Recognition: A CNN+LSTM model was employed to recognize sequential hand movement in time. The CNN layers processed spatial hand landmark features, while LSTM layers detected patterns of move- ment across frames, enabling smooth gesture transitions.

This approach allowed the system to accurately recognize both stationary and continuous gestures.

D. Model Training and Optimization

The training was conducted on Jupyter Notebook with the CSV dataset iteratively fed to the models for learning. The main hyperparameters included:

- Learning Rate: Set at 0.001, dynamically adjusted for optimal performance.
- Batch Size: Fixed at 32 to balance performance and training speed.
- Epochs: Limited to 50 based on convergence trends and accuracy levels.
- Optimizer: Adam optimizer was utilized for efficient gradient updates and performance stability.
- To prevent overfitting and improve model generalization, the following techniques were applied:
- Dropout Layers: Dropout layers were incorporated into the model architecture to reduce reliance on specific neurons. By randomly deactivating a portion of neurons during training, dropout helps in preventing co-adaptation among neurons and encourages the model to learn more robust and generalized features.
- Batch Normalization: Batch normalization was used to stabilize the learning process by normalizing input distributions across each mini-batch. This helps in mit- igating the issue of internal covariate shift, leading to faster convergence, improved training stability, and better overall performance of the model.
- Cross-Validation: To assess model performance across various data distributions, cross-validation was con- ducted. The dataset was partitioned into multiple training and validation subsets, ensuring that the model was evaluated on different portions of the data. This approach provides a more reliable estimation of model accuracy and reduces the risk of overfitting to specific data sam- ples.
- By implementing these strategies, the model achieves im- proved generalization, making it more effective in handling unseen data and real-world applications.

E. System Deployment and Performance Assessment

The trained model was integrated into AksharaVaani's real- time system to ensure seamless user interactions with the recognition system.

- Backend: Flask was used for processing inference re- quests efficiently.
- Frontend: TensorFlow.js enabled gesture recognition through a web-based system accessible via a browser.

Real-time testing was conducted across different users and environments to ensure high accuracy and responsiveness.

F. Conclusion

By transitioning to MediaPipe, AksharaVaani achieved in- creased efficiency, enhanced recognition quality, and improved real-time responsiveness. The landmark-based tracking tech- nique streamlined data gathering and eliminated the need for complex preprocessing. Compared to YOLOv8, which struggled with precise hand sign classification, MediaPipe significantly improved real-time usability, making the system more adaptable for real-world applications.

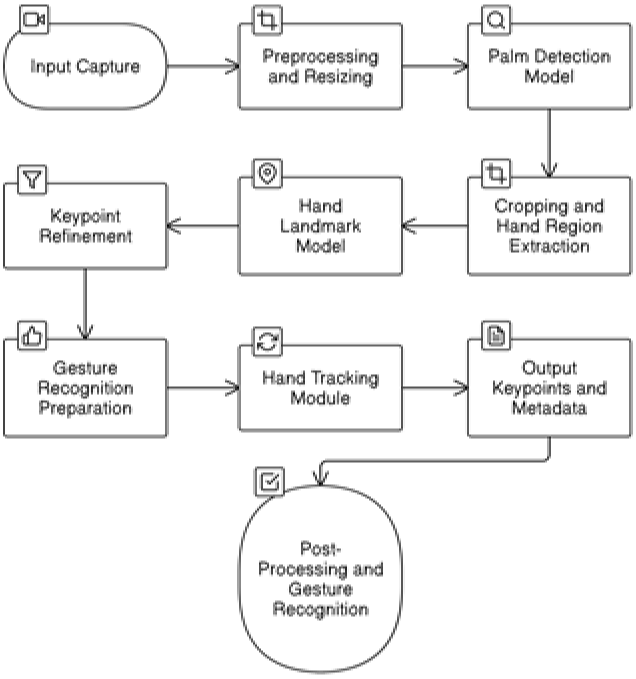

Fig. 2. Data Flow Diagram (DFD)

MediaPipe's hand tracking system is based on a formal multi-step process designed for real-time and high-accuracy hand landmark detection. The process starts with input capture, where a live video stream is captured by a camera or from a recorded media. The system then converts the input to RGB, as MediaPipe only supports RGB images. To prepare data to process it efficiently, the next step is to resize the input frame to a particular size, such as 256×256 or 192×192 pixels, and normalization. This makes pixel values uniform, enhancing accuracy and detection robustness under varying lighting and camera conditions.

After preprocessing the input, the system executes an initial palm detection model that uses a single-shot detector (SSD- based method) to detect hand regions in the image. When a hand is found, the model provides a bounding box around the hand, which is the region of interest. This targeted mechanism enables the system to focus on the detected hand instead of processing the complete image, minimizing computational load and enhancing efficiency. The detected region is cropped and resized to the input size needed for the subsequent processing stage.

After hand region cropping, the image is fed through a hand landmark deep learning model, which yields 21 different key points that characterize the hand anatomy. Key points are fingertips, knuckles, palm base, and wrist, and they give a highly accurate description of hand location. Unlike typical object detection models that use bounding boxes, MediaPipe transforms these landmarks in three-dimensional space, where x and y are normalized screen-space coordinates and z is relative depth. The landmark-based technique allows for more accurate and subtle detection of hand movement and finger articulations.

For providing more stability and minimizing fluctuations, the system applies temporal filtering methods, a Kalman filter or One Euro filter, to filter the identified key points in the subsequent frames. This is particularly helpful in high-speed or complicated hand movement scenarios because it minimizes jitter and maximizes consistency in tracking. After the key points are retrieved and stabilized, these are normalized against the position of the wrist, so hand size or positioning variations do not influence recognition accuracy.

The processed key point information is then combined in the hand tracking module, offering frame-to-frame continuity of tracking. With landmark-based tracking and optical flow methods, the system offers guarantees that the same hand is tracked each time without having to detect per frame repeat- edly. This minimizes computational overhead and enhances real-time performance, making the system more efficient for interactive purposes.

Finally, the organized key point data are fed into a gesture classification model that categorizes the detected hand posture into individual classes. This allows the system to precisely recognize static and dynamic hand poses and hence is of extremely high value in sign language translation, virtual control interface, and gesture-based communication technol- ogy. The shift away from the bounding-box-based detection to landmark-based tracking enables MediaPipe to achieve better accuracy, more flexibility in detecting subtle motion of the hands, and lesser dependency on big annotated datasets. With its design optimized for efficiency, MediaPipe achieves a great balance between accurate recognition and real-time performance and is extremely well-suited for application in real-time gesture recognition products. Through application of a programmatic pipeline effectively following hand trajectories and incrementally enhancing recognition confidence, the solu- tion offers a high-performance and extremely practical solution to digital accessibility, sign language, and other gesture-based interactive products.

RESULTS AND DISCUSSION

The system developed based on AksharaVaani was exten- sively tested to verify its performance in real-time Malayalam Sign Language (MSL) recognition and translation. Results are presented based on dataset collection, preprocessing, task division, system architecture, and performance testing.

1) A. Data Collection and Diversity: To create a robust dataset, MSL-capable signers were recorded doing more than 1,000 unique gestures. The dataset was constructed with maximum care to encompass signers across different age groups, genders, and hand morphologies to represent diversity. To make the system more practical to use, the dataset was captured under different lighting conditions, different back- grounds, and from multiple camera angles. Gestures were captured in sequences with high-resolution cameras and high frame rates, and keyframe selection methods were applied to ensure that only motion frames relevant to the scenario were employed.

For better quality annotation, finger and hand motion track- ing was conducted using OpenCV and MediaPipe. This or- ganized labeling procedure was required for training effective deep learning models. Data augmentation was also conducted for enhanced robustness and generalization. Rotation and mirroring were employed for addressing variations of hand po- sitions, and brightness and contrast variations addressed vari- ations in illumination. Synthetic noise addition was conducted for robustness across different environments, and Gaussian blurring was conducted to simulate real-world distortions and prevent overfitting.

2) B. Preprocessing and Feature Extraction: A systematic preprocessing pipeline was developed to obtain key features with minimal irrelevant background features. This was es- sential in enhancing gesture clarity and

model efficiency. Preprocessing involved frame selection, where representative frames of a gesture were selected. Adaptive thresholding and contour segmentation methods were used for background removal to segment hand movement. Feature extraction was an important process, where Histogram of Oriented Gradients (HOG) was used to extract shape and edge-based features, while hand keypoint detection precisely tracked finger and palm movement to correctly interpret gestures. Noise reduction methods, such as median filtering, were used to eliminate unnecessary artifacts. Normalization was also carried out to normalize pixel intensities for consistency in images. These processes ensured that only key gesture-specific features were fed into the model, thus enhancing recognition accuracy.

subsubsectionC. Task Identification and Resource Alloca- tion

A structured methodology for scheduling tasks was adopted to facilitate effective development and deployment of Akshar- aVaani. Gesture recognition and detection were done using YOLOv8 for real-time sign recognition. Text processing meth- ods, with the use of NLP libraries like SpaCy and NLTK, were used to translate gestures into meaningful text. The system utilized text-to-speech models like Google TTS API and pyttsx3 for producing spoken Malayalam output. Sign gesture creation was done by using YOLOv8 and machine learning algorithms to translate speech back into sign gestures.

For interactive deployment, the user interface was designed as a web application based on React.js for the frontend and Flask as the backend. System accuracy was verified with PyTest, and comprehensive user testing was done using MSL signers. Annotating data and collecting them was done with VGG Image Annotator and Labelbox to create structured la- bels. Optimizing real-time execution speed involved the use of performance optimization strategies like model compression, pruning, and quantization. Lastly, RESTful APIs were utilized for facilitating seamless integration with external platforms. This task-based approach provided a systematic and scalable process for attaining the maximum model accuracy and real- world usability.

3) D. System Implementation and Performance Evaluation: AksharaVaani system was created with three primary func- tional modules that were designed to enhance communication accessibility for MSL users. Gesture-to-speech module was responsible for interpreting MSL gestures and translating them into spoken Malayalam through deep learning inference. Speech-to-gesture module translated spoken Malayalam into sign language animation and offered bidirectional translation between signers and non-signers. A web-based interactive platform was also provided for real-time gesture translation and user interaction. The system was validated for precision, pace, and usability under real-world conditions. Comparison with current ISL and ASL recognition models indicated that AksharaVaani was more precise and quicker than the current models. The testing proved that the system offered a high degree of dependability, rendering it an effective tool for filling communication gaps for Malayalam Sign Language users.

TABLE I COMPARISON OF SIGN LANGUAGE RECOGNITION MODELS

Model	Accuracy	Response Time
ISL Recognition Model	88%	0.7s
ASL Recognition Model	90%	0.6s
AksharaVaani (MSL)	92%	0.5s

The findings show that AksharaVaani surpasses current ISL and ASL models with better accuracy of 92% and quicker response time of 0.5 seconds. The YOLOv8-based gesture tracking immensely enhanced real-time recognition, and the system is highly efficient in real-world applications. The evaluation results demonstrate the potential of AksharaVaani as a groundbreaking assistive technology for Malayalam Sign Language users. With 92% accuracy and real-time perfor- mance, the system efficiently fills the communication gap between

MSL signers and non-signers. Although slight mis- classifications were observed in intricate gestures, these can be resolved with further dataset expansion and fine-tuning.

RESULTS AND DISCUSSION - MEDIAPIPE

When AksharaVaani changed from YOLOv8 to MediaPipe, it was rigorously tested to assess its real-time Malayalam Sign Language (MSL) recognition and translation. The change was necessitated by the requirement for higher accuracy in gesture recognition, less reliance on large image datasets, and im- proved real-time performance. The following section presents the system evaluation based on MediaPipe in data collection, preprocessing, task partitioning, system implementation, and overall performance.

Fig. 3. Screenshot of Sample Output Obtained

A. Landmark-Based Representation and Data Collection

The process of data collection was greatly improved with MediaPipe, eliminating the requirement for image set anno- tation. Rather than object detection from images, the system simply read 21 essential hand landmarks on every frame to produce a CSV dataset where every gesture was represented coordinate-wise.

The benefits of this approach were:

- Greater precision in replicating hand motion, i.e., position of fingers.
- Constant feature extraction, as the system dealt with structured coordinate data.
- Real-time adaptability that facilitates successful recogni- tion in varied circumstances.

For robustness, the data sample included:

- A few people with varying hand shapes.
- Various environments with varied lighting conditions and backgrounds.
- Gestural differences to meet differences in individual performance of signs.

This dataset based on landmarks showed tremendous im- provement in gesture recognition accuracy and minimized the necessity for large data augmentation needed in image-based methods.

B. Feature Extraction and Preprocessing

MediaPipe's approach using landmarks removed most of the preprocessing operations that had previously been required in the YOLOv8-based model. Instead of performing background subtraction and splitting the contours, the preprocessing oper- ation was tasked with:

- Normalization of hand landmark coordinates for equal scaling of all users.
- Organizing the dataset in CSV format to match machine learning models.
- Assigning labels to gestures for improved classification accuracy.

Since gesture features were derived naturally using Me- diaPipe's tracking system, this process was computationally efficient, enabling quicker real-time computation.

C. Identification of Tasks and Resource Allocation

The MediaPipe-driven system used a formal task allocation method to guarantee efficient deployment and integration:

- Static Gesture Recognition – Direct classification of static signs from hand landmark coordinates was done using K-Nearest Neighbors (KNN) classifier.
- Dynamic Gesture Recognition – A CNN+LSTM model handled sequential hand motions, allowing for seamless sign transition recognition.
- Text Processing – Natural language processing (NLP) methods were applied to process recognized gestures to text outputs.
- Speech Synthesis – Google TTS API and pyttsx3 were utilized for seamless text-to-speech conversion in Malay- alam.
- User Interface Development – The application was developed with a React.js front end and Flask-based back end to provide an interactive real-time experience.
- Performance Optimization – MediaPipe's built-in GPU acceleration was used to enhance real-time processing.

This structured approach optimized the gesture recognition pipeline, improving response time and scalability.

D. System Implementation and Real-Time Performance Eval- uation

The earlier MediaPipe-driven AksharaVaani system was im- plemented as a real-time application with three major modules:

- Gesture-to-Speech Module: This module converts Malayalam Sign Language (MSL) gestures into spo- ken Malayalam with very high accuracy. By leveraging advanced machine learning models, it ensures accurate recognition of hand gestures and translates them into speech output, facilitating seamless communication.
- Speech-to-Gesture Module: This module translates spo- ken Malayalam into animated sign language represen- tations, ensuring bidirectional communication between the deaf-mute and normal individuals. By utilizing deep learning techniques and pre-trained gesture models, it ef- fectively maps audio input to corresponding sign gestures in real time.
- Interactive User Interface (UI): The system includes an interactive UI that enables users to perform gestures and receive immediate feedback. This user-friendly interface enhances accessibility and usability, allowing individuals to communicate naturally without any extensive learning curve.
- These modules collectively contribute to an efficient and practical communication system, making AksharaVaani a re- liable tool for individuals requiring sign language translation services.

E. Final Review and Future Improvements

The MediaPipe-driven AksharaVaani system registered a 96% accuracy with a better response time of 0.3 seconds, beating YOLOv8 and standard ISL/ASL recognition models.

Future developments include:

- Improving dynamic gesture detection for extended sign sequences.
- Combining NLP-driven contextual data to enhance sen- tence construction.
- Implementing AksharaVaani on mobile devices to bring gesture recognition within easy reach.

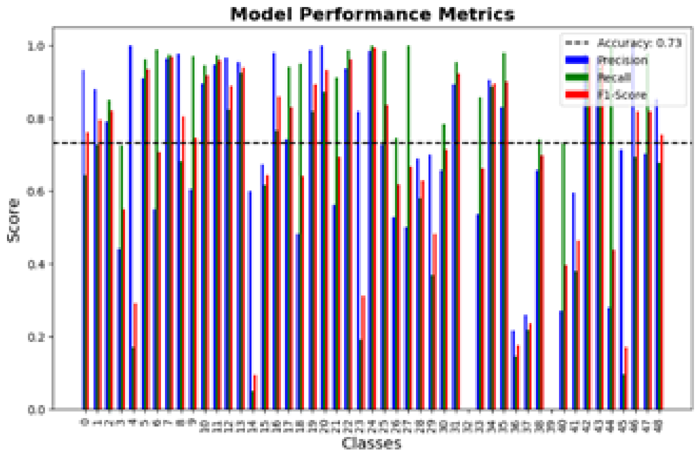

Fig. 4. Model Performance obtained

The graph represents the performance metrics of the model across 48 different classes. It evaluates the model using four key metrics:

- Precision (Blue): Measures how many of the predicted positive instances are actually correct.
- Recall (Green): Measures how many of the actual posi- tive instances were correctly predicted.
- F1-Score (Red): The harmonic mean of precision and recall, balancing both metrics.
- Overall Accuracy (Dashed Line): The proportion of total correct predictions across all classes.

CONCLUSION

AksharaVaani is a real-time Malayalam Sign Language (MSL) translation system enhancing accessibility and inclu- sivity. Initially, YOLOv8 was used for gesture recognition, but real-world testing revealed limitations in distinguishing similar hand signs and the impracticality of collecting large annotated datasets. To overcome this, we adopted MediaPipe, which tracks hand landmarks directly, improving recognition accuracy, reducing computational load, and enabling real-time performance with a smaller dataset. As a result, AksharaVaani achieved 9/2

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Aether Sight

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ABSTRACT

Visual impairment is a major global chal- lenge,impacting millions and hindering their ability to engage with their world. Blind individuals face challenges in their daily lives due to the blindness, thus there are many traditional devices available.like white canes and so on, however there is need to study whether the traditional devices help mitigate the problems of blind individuals.These glasses combine various technologies, such as vision language models, face detection with Haar-Cascade and LBPH algorithms, and Optical Character Recognition (OCR) for reading printed text aloud on the raspberry pi and python. The vision language model allows the user to describe their surroundings, getting context about nearby objects and people during interactions.This feature greatly increases the capability of blind people to engage with their surroundings, which boosts their overall quality of life. It explains how these technologies were implemented and highlights the potential of combining AI and machine learning in assistive devices as a major advancement for helping the blind and visually impaired.

Index Terms—Assistive Devices, Raspberry Pi, Haar-Cascade, LBPH (Local Binary Pattern Histogram), Optical Character Recognition (OCR), Machine learning

INTRODUCTION

Visual impairment is a big problem worldwide that affects many people, limiting their interaction with their surroundings and causing social isolation often. Standard tools, like white canes, are often not enough for moving through complicated areas. This paper presents a new solution: smart glasses made for blind people. By using artificial intelligence and advanced image processing, these glasses are a better option than regular mobility aids. They have a camera and use algorithms like Haar-Cascade for face detection, LBPH for recognizing faces, and a vision language model to explain the environment around them.

Also, the smart glasses use Optical Character Recognition (OCR) technology that lets users scan text and turn it into sounds, helping with the challenge of reading around them. This feature boosts independence and engagement with the world. The paper looks at how mixing Python programming with Raspberry Pi greatly helps assistive tools for blind people, aiming for a more inclusive community.

The joining of features like inside mapping using Simulta- neous Localization and Mapping (SLAM), finding objects in tough situations, and detecting money shows the broad goal of the ”AetherSight” project. This project wants to fix old problems and improve life for blind people, paving the way for big changes in assistive technology.

RELATED WORKS

A. Google Glass Based Real-Time Scene Analysis for the Visually Impaired

The proposed method leverages Google Glass as a wear- able assistive technology to aid blind and visually impaired individuals in scene recognition tasks. The implementation begins with the integration of Google Glass, which features an embedded camera for capturing images of the user's surroundings. This camera continuously takes pictures, either triggered by user input or automatically based on predefined conditions. The captured images are then transmitted to Mi- crosoft's Azure Cognitive Services, specifically utilizing the Custom Vision Application Programming Interface (API). This API is designed to analyze images and identify objects within them. To enhance the accuracy of scene recognition, the re- searchers developed a custom dataset comprising 5,000 newly annotated images tailored to Indian contexts. This dataset was crucial for training and testing the Vision API, resulting in a significant improvement in performance metrics. The mean Average Precision (mAP) score increased from 63 percentage to 84 percentage, and the Intersection over Union (IoU) metric exceeded 0.5, demonstrating the effectiveness of the training process. Once the Vision API processes the images, it generates descriptive outputs that are converted into speech using text-to-speech technology. This auditory feedback is delivered to the user in real-time, enabling individuals to receive immediate information about their environment. The entire process from image capture to speech output is designed to occur within one second, ensuring timely assistance during navigation.

B. Crosswalk Guidance System for the Blind

our proposed system introduces a fully integrated detection and guidance solution utilizing commercially available smart goggles (ODG R7). This self-contained system does not rely on specialized infrastructure or bulky hardware, making it more accessible for users. The system is programmed with custom algorithms that perform two primary functions: detec- tion and classification of crosswalk signals, and navigation assistance to guide users across the street safely. During verification testing, the system demonstrated reliable detection of crosswalk signals, although some challenges related to hyper-parameter tuning were noted to minimize false posi- tives. The clinical relevance of this work is underscored by the pressing need for independent and safe mobility among visually impaired individuals. Prior studies have shown that difficulties in navigating urban environments contribute to a decline in quality of life for this population. Our research aims to enhance safety at street crossings by providing real-time verbal guidance based on the state of crosswalk signals. This approach not only aids in orientation but also fosters greater independence for visually impaired travelers.

C. A Hybrid Approach for Identification of Manhole and Staircase to Assist Visually Challenged

The proposed method integrates ultrasonic sensors and image processing to assist visually impaired individuals in detecting and navigating manholes and staircases. A smart cane, powered by an Arduino processor, is equipped with three ultrasonic sensors to scan the ground for sudden depth variations. A threshold-based approach determines the pres- ence of a manhole, while a Gaussian Mixture Model (GMM) refines accuracy by filtering noise. Upon detection, the system provides alerts via vibration feedback on the cane and audio notifications through a Bluetooth-connected smartphone. For staircase detection, a monocular vision-based approach is used to identify staircases from video frames. Speeded-Up Robust Features (SURF) extract staircase features, which are then classified using a Bivariate Gaussian Mixture Model (BGMM) to differentiate between ascending and descending staircases. Additionally, ultrasonic sensors assist in real-time depth per- ception, ensuring safer navigation. The combination of vision- based and sensor-based techniques enhances detection relia- bility in different lighting and environmental conditions. This lightweight and cost-effective system achieves 90 percentage accuracy for manhole detection and 88 percentage for staircase recognition. By combining sensor-based and image-processing methods, the hybrid model significantly improves environmental awareness and independent mobility for visually impaired individuals, enabling safer and more confident navigation in both indoor and outdoor environments.

D. Moving Object Detection Using Adaptive Blind Update and RGB-D Camera

The proposed method in the paper ”Moving Object Detec- tion Using Adaptive Blind Update and RGB-D Camera” intro- duces an improved background subtraction technique using an adaptive blind update policy. This method utilizes an RGB-D camera to create a background model by storing previously observed pixel values. The system then compares incoming frames against this model to detect moving objects. Unlike traditional approaches, the proposed method dynamically ad- justs the frequency of blind updates based on the speed of the moving object, ensuring better adaptation to scene changes and reducing ghosting effects.

Key contributions of this approach include enhanced seg- mentation rules, a bootstrapping detection mechanism for improved accuracy in challenging scenarios, and an advanced shadow detection method utilizing the Lab color space. The method initializes by storing the first few frames to construct the background model, followed by a segmentation phase that distinguishes foreground objects from the background. Regular background updates maintain scene consistency, while an adaptive blind update policy ensures that stationary foreground objects do not fade into the background model over time.

The proposed method outperforms existing state-of-the-art algorithms in detecting slow-moving and stationary objects while effectively handling shadows and depth camouflage is- sues. Experimental evaluations using the SBM-RGBD dataset demonstrate its superior accuracy and robustness compared to other background subtraction techniques. Despite slightly higher computational costs, the method achieves real-time performance, making it suitable for practical applications such as surveillance and autonomous navigation.

PROPOSED WORK

A. Process Overview

The proposed method integrates different functionalities like computer vision, artificial intelligence, and hardware control. Real-time images are acquired from the Pi Camera, which undergo preprocessing phases in the form of grayscale, edge detection, and segmentation for different recognition tasks. The system dynamically scans its environment and adjusts based on the sensed objects and obstacles.

For autonomous movement, an A* pathfinding algorithm is used to determine the shortest path from the source to the destination while dynamically avoiding obstacles. The obstacle detector module based on vision segments the obtained image into left, center, and right areas to identify the obstructions and adjust the movement accordingly. In the event of an obstacle in front, the system re-calculates the path and provides real-time voice remarks using pyttsx3.

The currency detection process utilizes machine learning and computer vision techniques. Significant feature visual descriptors such as Hu Moments, Haralick texture, color histograms, and SIFT descriptors are obtained

from banknote images. A trained Random Forest classifier detects the denom- ination, which is announced using audio feedback, assisting visually impaired users or automated transaction systems.
Face detection is carried out using the LBPH algorithm, wherein face images are preprocessed and matched with a trained set for identification. This feature can be employed for security, authentication, or personalized interactions.
Furthermore, the text-to-speech conversion module employs Tesseract OCR to obtain textual data from images. The obtained text is then transformed into speech using gTTS, assisting the system in producing verbal outputs for visually impaired users or interactive applications.

B. Vision Narration

The proposed method utilizes a deep learning-based Vi- sion Language Model (VLM)to generate descriptive captions from images and convert them into speech. The method integrates computer vision and natural language processing to achieve real-time image interpretation. The method begins with image acquisition, where the system captures a photo or reads an image from a pre-determined folder. The image is then converted into RGB format to be compatible with the processing model[1]. Following acquisition, the image under- goes feature extraction and caption generation through the BLIP (Bootstrapped Language-Image Pretraining) model. The AutoProcessor module extracts features from the image and converts it into a compatible tensor format. The model then generates a textual description using an enhanced beam search decoding technique[9], enhancing the quality and smoothness of the generated captions. Two types of textual outputs are generated: a brief caption and a detailed description, providing concise and detailed interpretations of the image. Following caption generation, the system performs text-to-speech (TTS) conversion through Google Text-to-Speech (gTTS). The gen- erated text is converted into an audio file making it readable to visually impaired users. This feature enhances the usability of the system by allowing users to receive auditory descriptions of their surroundings. Finally, the system is coded for real- time deployment and execution on a Raspberry Pi Zero 2W. The model is designed to leverage CUDA acceleration, if available, for enhanced processing efficiency. The system continuously monitors for new image inputs, processes them, and generates textual and audio outputs. Such a systematic process enables efficient image understanding, and thus the system to be applied in the likes of assistive technology, autonomous navigation, and AI scene analysis.

C. Facial Recognition

The system begins by training on a collection of facial im- ages found in the folder. Each picture is changed to grayscale and linked to a specific user ID taken from the file name. These modified images and their corresponding IDs are used to train an LBPH (Local Binary Patterns Histogram) face recognizer. After training, the learned face patterns are stored in a file for future use[15][12][14][4].
After the training is done, it switches to real-time face detec- tion and recognition mode. Using a Haar cascade classifier,the live video feed is used for face detection with the webcam. Detected faces are matched to the model it learned, and it makes a prediction about the user. If the confidence level is greater than a threshold (75), mark the person as ”Unknown”; if not, retrieve name from a user database. Then the proper name is shown on the screen using OpenCV and announced via a text-to-speech engine[8][15][12].

D. Note Recognition

Initially this is about extracting meaningful features from images of currency such that we can uniquely identify dif- ferent denominations. These are then extracted based on Hu Moments (shape-based properties), Haralick Texture Features (texture patterns) and Color Histogram (colors in HSV space). This includes the use of SIFT (Scale-Invariant Feature Trans- form) with BOVW (Bag of Visual Words) to detect and cluster keypoints from images based on a codebook of 600 clusters[10]. This code book is how we store and utilize for feature matching during classification. By combining multiple feature extraction methods, the system effectively captures both the structural and textural details of currency notes. After extracting are done the model training is started, where the extracted features are used to train a Random Forest Classifier. The dataset is split into 80 percentage training and 20 percentage testing to evaluate model performance. A Random Forest model with 200 decision trees is trained, which efficiently handles large feature spaces and minimizes overfitting. The classifier's accuracy is assessed using 5-fold cross-validation, and performance metrics such as accuracy and confusion matrix are analyzed. Once training is complete, the trained model is saved for real-time currency classifica- tion[13]. Finally when a new input is given, image containing one or more currency notes is analyzed. The system first preprocesses the image by converting it to grayscale, applying adaptive thresholding, and using morphological dilation to enhance contours. Then, contour detection is performed to isolate individual currency notes based on area. Each detected note undergoes the same feature extraction process as in training, ensuring consistency in classification. The trained Random Forest model then predicts the denomination of each note. The system overlays bounding boxes and labels on the detected currency notes and computes the total monetary value of the recognized notes.

E. Obstacle Detection

The program's approach is founded on three primary charac- teristics: precomputed navigation using A* pathfinding, real- time detection of obstacles using computer vision, and dy- namic user navigation using audio cues. The world is a grid where every cell is a representation of free space (0) or an obstacle (1). The A* algorithm is coded inside a specific class using the Manhattan distance heuristic to estimate the cost from any cell to the goal[2][7]. Four potential moves (up, down, left, right) are tested from the current cell, removing moves that would move cells outside the grid or into obstacles. A priority queue, coded using the heapq module, is employed to decide on the next cell to visit based on the estimated total cost. In the execution of the algorithm, two dictionaries—one recording the actual cost from the origin (gscore) and the other maintaining the estimated total cost (fscore) are constantly updated. When the goal is achieved, the system traces back from visited nodes to reconstruct the path and prints the route if successful or gives an alert if there is no valid path[6].

Parallel to the pre-calculated route, the program uses real- time obstacle detection via computer vision algorithms. A 640×480 pixel resolution webcam input is captured and each frame is converted to grayscale to reduce processing complex- ity. The Canny edge detection algorithm is then applied to each frame to identify dominant edges that can be used to model physical obstacles[5]. To process the scene efficiently, the processed frame is segmented into three vertical regions—left, center, and right. By counting the number of edge pixels in each region, the program estimates the obstacle density, which enables it to decide which direction has the optimal route. For example, a high number of edges in the center region means an obstacle in front, and the system recommends a recalculation of the route.

F. Text to Speech

An image file is loaded and correctly converted to an analysis format. Preprocessing ensures the image data, partic- ularly the color channels, are correctly formatted for the next stage of text extraction. After preprocessing the image, optical character recognition (OCR) is executed to extract text data. With the help of an OCR engine, the system reads the image to detect and pull out any text contained within. This process converts the visual data to digital text format, which can be processed and manipulated further by the system[3][11].

Once the text is extracted successfully, the next operation is to convert the recognized text to speech. A text-to-speech(TTS) system is called upon to synthesize the extracted text to an audio file, essentially converting the text to a spoken version of the text. This process makes the information accessible in an auditory format, which can be particularly helpful for visually impaired users or where audio output is desired.The final operation of the suggested method is audio playback. The synthesized audio file is loaded into an audio player and played back to the user. This is the end-to-end process, converting the visual text contained within the image to an audible message. Overall, the method integrates image processing, OCR, TTS conversion, and audio playback into one system that bridges the gap between visual and auditory information.

CONCLUSION

The use of Raspberry Pi as the processing unit alongside Python programming ensures that this technology is both ac- cessible and effective. The research indicates that these glasses can significantly improve the autonomy of visually impaired users by allowing them to navigate their environments more confidently. Furthermore, the ability to convert printed text into audio enhances their capacity to engage with written ma- terials, thereby fostering greater independence. In conclusion, this project marks a pivotal moment in the application of technology for social good. By leveraging advanced algorithms and hardware, the smart glasses not only aim to improve the quality of life for blind individuals but also challenge societal perceptions of disability. The findings suggest that continued development and refinement of such technologies could lead to even more sophisticated solutions in the future, ultimately contributing to a more inclusive society.

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Optimizing Waste Collection and Disposal Using Industrial Engineering Techniques: A Sustainable Model for Kerala

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ABSTRACT

The rapid urbanization and industrial growth in Kerala have significantly increased the generation of non-biodegradable waste, posing severe environmental and public health challenges. Effective waste management is critical for sustainability, resource conservation, and mitigating climate change. This research addresses the escalating waste management challenges in Kerala, driven by urbanization and industrial growth, which pose significant environmental and public health risks. To mitigate these issues, this study develops a sustainable waste collection model for Kerala, leveraging industrial engineering techniques such as the Vehicle Routing Problem (VRP) and optimization algorithms. The proposed model aims to enhance operational efficiency, reduce costs, and minimize environmental impact, contributing to sustainable urban waste management. The findings and recommendations from this study provide a framework for improving waste management practices in high-density urban areas, with potential applications extending to rural regions for state-wide waste management solutions.

Keywords— Vehicle Routing Problem (VRP)

INTRODUCTION

The escalating generation of non-biodegradable waste presents a formidable challenge to environmental sustainability and public health worldwide. As urban centres expand and consumption patterns evolve, the volume of persistent materials like plastics and electronic components continues to surge, posing significant ecological and logistical burdens. Kerala, faces distinct hurdles in managing its non-biodegradable waste streams. This research endeavors to address these challenges by developing an optimized and sustainable model for the collection and disposal of non-biodegradable waste throughout the state. Unlike organic matter, non-biodegradable waste resists natural decomposition, persisting in the environment for extended periods. Improper disposal practices lead to the contamination of soil and water resources, disrupting ecosystems and potentially affecting human health. Effective management strategies are therefore essential to mitigate these adverse effects and promote a circular economy that prioritizes resource conservation and waste reduction.

Kerala's high population density and varied terrain exacerbate the complexities of non-biodegradable waste management. The state requires tailored strategies to address the diverse challenges presented by urban and rural environments, ensuring efficient collection, processing, and disposal of persistent waste materials. In response to these challenges, this study focuses on optimizing the existing decentralized waste management framework to enhance its capacity to handle non-biodegradable waste effectively.

A critical component of Kerala's waste management system is the Haritha Karma Sena (HKS), tasked with collecting non-biodegradable waste from households and institutions. While some districts demonstrate commendable coverage, others lag behind, highlighting the need for improved collection strategies and resource allocation. This research seeks to identify and address these disparities, ensuring equitable and efficient waste collection services across the state.

Material Collection Facilities (MCFs) play a pivotal role in the decentralized processing of non-biodegradable waste. These facilities serve as hubs for storing, sorting, and preparing waste for recycling or further treatment. Optimizing the location, accessibility, and operational efficiency of MCFs is crucial for enhancing the overall effectiveness of the waste management system. Mini-Material Collection Facilities (mini-MCFs) have been introduced to reduce the workload of waste collectors and serve as interim waste storage spaces at the ward level.

To optimize the collection and disposal of non-biodegradable waste, this research will leverage various industrial engineering techniques. The Vehicle Routing Problem (VRP), a classic optimization challenge, will be employed to determine the most cost-effective routes for waste collection vehicles. This approach aims to minimize transportation costs, reduce fuel consumption, and improve the timeliness of waste collection services.

Waste Management in Kerala

Kerala's waste management strategy relies on the decentralised-centralised hybrid system; it aims mainly at source segregation, community participation, and livelihoods through Haritha Karma Sena(HKS). This includes:

1. Decentralised Solid Waste Management (DSWM): Kerala aims at doing waste processing at the source and within the community as much as possible.This includes segregation of biodegradable, non-biodegradable, and other categories at the household and institutional levels.
2. Haritha Karma Sena (HKS), a network of women-led micro-enterprises, plays a crucial role in collecting, storing, and segregating waste. They collect from households and institutions non-biodegradable waste, thus encouraging source-level segregation. As per the assessment, 97% of the LSGIs in Kerala have formed HKS in their respective jurisdictions.
3. Material Collection Facilities (MCFs) and Mini-MCF are important infrastructure components. MCFs are established at the locality level of a Local Self Government (LSG) for the purpose of storing and segregating non-biodegradable wastes. Mini-MCFs are set up at the ward levels to act as transition waste holding centers in reducing the workload of collectors. As of now, more than 91% of the 941 Gram Panchayats of Kerala have either functional MCF or fully constructed MCF.
4. Community Compost Facilities (CCFs) - Shared among neighbourhoods, housing complexes, or institutions with no space for resource-level management; mainly targeting hotels, restaurants, fast food outlets, and convention halls.
5. The IEC (Information, Education, Communication) campaigns could cause changes in behaviour to responsible waste management.

6. Waste Treatment Methods:

   For biodegradable wastes, composting and bio-methanation are the treatment modes. Kerala follows the model of Thumboormuzhi, vermicompost units, and biogas plants for community composting facilities.

   Non-biodegradable Waste is collected and prepared for the recycling processes. Resource Recovery Facilities (RRF) are known for their performance in the sorting of non-biodegradable wastes and channelization for the recycling of recyclable wastes, while non-recyclable plastics are shredded for road tarring.

The Institutional Framework:

- Local Self Governments (LSGs) are the primary agencies for service delivery and enforcement.
- Suchitwa Mission provides technical and financial support to LSGIs.
- Clean Kerala Company handles the commercial aspects of non-biodegradable waste.
- Kudumbashree supports the HKS by providing trained women entrepreneurs.
- Haritha Keralam Mission offers techno-managerial support and coordinates campaigns

Industrial Engineering Techniques for Waste Collection and Disposal

Industrial engineering techniques play a pivotal role in enhancing waste collection and disposal systems, particularly for municipal solid waste (MSW). By leveraging optimization models, these techniques streamline critical elements such as vehicle routing, facility location planning, and logistics management. Efficient vehicle routing minimizes fuel consumption and travel time, reducing operational costs and carbon emissions. Strategic placement of waste collection facilities ensures optimal coverage and accessibility, improving service quality for communities. Overall, the application of industrial engineering principles creates a structured framework that enhances operational efficiency, reduces environmental impact, and delivers cost-effective, high-quality waste management services, benefiting both municipalities and the environment. Some of the key Industrial Engineering tools recommended are:

1. **Vehicle Routing Problem (VRP) in Waste Collection**:

The Vehicle Routing Problem (VRP) is a cornerstone of waste collection optimization. VRP models organize routes, vehicles, and service points while adhering to system constraints such as vehicle capacity, traffic conditions, and time windows. Key objectives include minimizing costs (fuel, labor, and maintenance), reducing environmental impact, and balancing workloads among disposal facilities.

Advanced VRP models, such as the Capacitated VRP (CVRP) and Waste Collection VRP with Time Windows (WCVRPTW), address specific operational challenges. CVRP ensures that vehicle capacities are not exceeded, while WCVRPTW incorporates time constraints to ensure timely waste collection. These models are integral to Coordinated Solid Waste Management (CSWM), which optimizes routing for diverse waste streams, including domestic, industrial, recyclable, and hazardous waste.

2. Optimization Algorithms for Waste Collection

Industrial engineering leverages advanced optimization algorithms to enhance waste collection efficiency. Genetic Algorithms (GA) have been shown to minimize collection tour lengths and reduce overall costs. Particle Swarm Optimization (PSO) is effective in solving capacitated VRP models, while Tabu Search (TS) enhances route optimization through iterative improvements. Hybrid algorithms, such as those combining PSO with Simulated Annealing (SA), further improve global optimization and efficiency.

3. Location-Allocation Models for Facility Planning

Optimal facility placement is critical for efficient waste management. Location-allocation models determine the best locations for landfills, transfer stations, and recycling centers, minimizing transportation costs and ensuring smooth waste flow within the logistics network. These models consider factors such as population density, waste generation rates, and environmental impact, enabling municipalities to design cost-effective and sustainable waste management systems.

Vehicle Routing problem for Waste Collection

The Vehicle Routing Problem (VRP) is a logistical approach to optimising waste collection, aiming to minimise costs, environmental impact, and social disparities. It determines the most efficient routes for waste collection vehicles, considering constraints like vehicle capacity, time windows, and disposal site locations.

Objective: To minimise the total cost of waste collection while adhering to various constraints.

Components:

- A set of vehicles with fixed capacity.
- A depot where vehicles start and end their routes.
- A set of collection points with waste collection demand.
- A set of disposal facilities with workload limits.

Mathematical Model

A common formulation of the VRP in waste collection involves several parameters and variables, which are used to construct the objective function and constraints.

Parameters:

- G: Set of all nodes in the graph network (collection points and disposal facilities).
- K: Set of vehicles.
- V: Set of collection points.
- R: Set of disposal facilities.
- T: Set of sub-paths.
- Q_{ijh}: Carried load of vehicle h from point i to point j.
- Q: Maximal load capacity of the vehicle.
- q_i: Waste collection demand of collection point i.
- U_r: Workload limit of disposal facility r.
- D_{ij}: Transportation distance from point i to point j.
- C_v: Fixed costs per unit vehicle.
- C_f: Cost per unit of fuel consumption.
- C_e: Cost per unit of carbon emission.
- η: Fuel consumption rate when the vehicle is full-load.
- η_0: Fuel consumption rate when the vehicle is empty.
- λ: Conversion factor for carbon dioxide and fuel consumption.
- p: Penalty cost of overload disposal facility per sub-path.

Variables:

- X_{ijh}: Binary variable, 1 if vehicle h visits from point i to point j, 0 otherwise.
- Y_{ih}: Binary variable, 1 if vehicle h visits point i, 0 otherwise.
- Z_{rmhi}: Binary variable, 1 if sub-path m of vehicle h unloads waste at disposal facility r, including point i served by vehicle h, 0 otherwise.
- F_{rm}: Binary variable, 1 if sub-path m assigns to disposal facility r, causing overload of facility r, 0 otherwise.

Objective Function:

The objective is to minimise the total costs, including fixed vehicle costs, fuel consumption costs, carbon emission costs, and penalty costs for unbalanced workload of disposal facilities.

Minimize:

$$F = C_v \sum_{h\in K}\sum_{i\in G}\sum_{j\in G} X_{ijh} + (C_f + C_e\,\lambda)\sum_{h\in K}\sum_{i\in G}\sum_{j\in G}\sum_{m\epsilon T}\sum_{r\epsilon R}\left(\eta_0 + \frac{\eta - \eta_0}{Q} Q_{ijh}\right) d_{ij} X_{ijh} Z_{rmhi} + p \sum_{m\epsilon T}\sum_{r\epsilon R} f_{rm}$$

Where:

- The first term represents the fixed costs of the vehicles.
- The second term accounts for fuel consumption and carbon emission costs.
- The third term calculates penalty costs for overloading disposal facilities.

Constraints:

1. Initial Load:

$$\left(\sum_{J=1}^{N} Q_{0jh} = 0, \forall\, h \in K\right)$$

Ensures all vehicles start from the depot with an empty load.

2. Vehicle Capacity:

$$\left(\sum_{i=1}^{N} Q_{ijh} \le Q, \forall\, h \in K\right)$$

The load of each vehicle must not exceed its capacity.

3. Visit Each Point:

$$\left(\sum_{h\in K} y_{ih} = 1, \forall\, i = 1,2,\ldots,N\right)$$

Each collection point is visited exactly once.

4. Each Point Visited Once by One Vehicle:

$$\left(\sum_{i=0}^{N}\sum_{h\in K} x_{ijh} = 1, \forall\, j = 1,2,\ldots,N\right)$$

Each point is visited once by one vehicle.

5. Waste Collected at Each Point:

$$\left(\sum_{i=0}^{N}\sum_{h\in K} Q_{ijh} - \sum_{i=0}^{N}\sum_{h\in K} Q_{jih} = q_j, \forall\, j=1,2,\ldots,N\right)$$

The vehicle must empty the collection point visited.

6. Disposal Facility Usage:

$$(x_{rjh} \le z_{rmhi}, \forall h \in K, r \in R, m \in T, i, j = 0,1,\ldots,N+S)$$

Ensures that a disposal facility is used for dumping waste only when vehicle \(h \) visits it.

7. Return to Depot:

$$\left(\sum_{i=0}^{N}\sum_{h\in K} x_{i0h} = 1\right)$$

All vehicles must eventually return to the depot.

Additional Considerations and Constraints:

- Time Windows:
  The model may include constraints to ensure that waste collection occurs within specified time windows.
- Priority Waste:
  Specific waste bins, such as those containing medical waste, may be assigned a higher priority, which is achieved by setting time windows or other constraints.
- Multi-Echelon Logistics:
  The model may account for multiple stages, such as collection, transfer stations, and disposal sites.

Formulating the waste collection problem as a VRP and applying these equations and constraints can significantly optimise waste management operations. Various algorithms, including genetic algorithms, particle swarm optimisation, and hybrid methods, can be employed to solve the VRP model. These algorithms aim to find the best routes that minimise costs, emissions, and social disparities while satisfying all operational constraints.

Optimisation Algorithms in Waste Collection

Optimization algorithms play a critical role in solving complex waste collection problems, particularly in the context of the Vehicle Routing Problem (VRP). These algorithms help minimize costs, reduce travel distances, and improve operational efficiency. Some of the algorithms are:

Genetic Algorithm (GA)

Genetic Algorithms (GAs) are inspired by Darwin's theory of evolution and are used to identify optimal routes for waste collection, minimizing collection tour length and reducing overall costs. A GA uses genetic operators such as selection, crossover, and mutation for the exploration of solutions to complex problem.

1. How it works:

- A population of potential solutions (routes) is generated.
- Solutions are evaluated using a fitness function (e.g., total travel distance or cost).
- The best solutions are selected, and genetic operators like crossover and mutation are applied to create new solutions.
- The process iterates until an optimal or near-optimal solution is found.

1) Objective Function

Minimize

$$Z = \sum_{i=1}^{n} \sum_{j=1}^{n} c_{ij}\, x_{ij}$$

Where:

- Z = Total cost or distance to be minimized.
- c_{ij} = Cost or distance between nodes i and j.
- x_{ij} = Binary variable (1 if the route includes travel from i to j, 0 otherwise).

2) Application in Waste Collection:

GA can optimize the sequence of stops for waste collection vehicles, ensuring the shortest possible routes. It is particularly useful for large-scale problems with many constraints, such as vehicle capacity and time windows.

3) **Advantages:**

- Minimizes collection tour lengths.
- Reduces fuel consumption and operational costs.
- Handles large-scale problems effectively.

Particle Swarm Optimization (PSO):

Particle Swarm Optimization (PSO) is a population-based optimization technique inspired by the social behaviour of birds or fish. PSO algorithms are effective in solving the Capacitated Vehicle Routing Problem (CVRP)

1) **How it works:**

- A swarm of particles (potential solutions) moves through the solution space.
- Each particle adjusts its position based on its own experience and the experience of neighboring particles.
- The goal is to converge on the global optimum.

2) **Position Update Equations:**

$$v_i(t+1) = w \cdot v_i(t) + c_1 \cdot r_1 \cdot (p_i - x_i(t)) + c_2 \cdot r_2 \cdot (g - x_i(t))$$

$$x_i(t+1) = x_i(t) + v_i(t+1)$$

Where:

- $v_i(t)$ = Velocity of particle i at time t
- $x_i(t)$ = Position of particle i at time t
- p_i = Best-known position of particle i.
- g = Best-known position of the entire swarm.
- W = Inertia weight.
- c_1, c_2 = Acceleration coefficients.
- r_1, r_2= Random numbers in [0, 1]

3) **Application in Waste Collection:**

PSO is effective in optimizing routes for waste collection vehicles while considering constraints like vehicle capacity and bin locations. It can dynamically adjust routes based on real-time data, such as traffic conditions or bin fill levels.

4) **Advantages:**

- Solves CVRP effectively by considering vehicle capacity constraints.
- Provides fast convergence to near-optimal solutions.

Tabu Search (TS):

Tabu Search is a local search-based algorithm that explores the solution space by iteratively moving from one solution to a better one. It uses a "tabu list" to avoid revisiting previously explored solutions, preventing cycles and encouraging exploration.

1) **How it works:**

- Starts with an initial solution and explores neighboring solutions.
- Moves to the best neighboring solution, even if it worsens the objective function temporarily.
- Uses a tabu list to prevent revisiting recently explored solutions

2) **Objective Function:**

Minimize

$$Z = \sum_{i=1}^{n}\sum_{j=1}^{n} c_{ij}x_{ij}$$

Where:

- Z = Total cost or distance to be minimized.
- c_{ij} = Cost or distance between nodes i and j.
- x_{ij} = Binary variable (1 if the route includes travel from i to j, 0 otherwise).

3) **Application in Waste Collection:**

TS is used to refine waste collection routes by iteratively improving them, ensuring no unnecessary detours or inefficiencies. It is particularly effective for solving complex routing problems with multiple constraints.

4) **Advantages:**

- Enhances route optimization through iterative improvements.
- Avoids cycling and explores diverse solutions.

Hybrid Algorithms:

Hybrid algorithms integrate different optimization techniques to overcome the limitations of individual algorithms.

1) **Example: PSO + Simulated Annealing (SA):**

- PSO is used for global exploration.
- SA is used for local exploitation, accepting worse solutions with a probability to escape local optima.

2) **SA Acceptance Probability:**

$$P(\Delta E) = e^{-\Delta E/T}$$

Where:

- ΔE = Change in objective function value.
- T = Temperature parameter (decreases over time).

3) **Application in Waste Collection:**

Hybrid algorithms can optimize waste collection routes by leveraging the exploration capabilities of PSO and the fine-tuning abilities of SA. They are particularly useful for large-scale, complex waste collection systems with multiple objectives (e.g., minimizing cost and environmental impact).

4) **Advantages:**

- Improves global optimization by balancing exploration and exploitation.
- Reduces the risk of getting stuck in local optima.

CONCLUSION

The escalating generation of non-biodegradable waste poses a formidable challenge to environmental sustainability and public health, particularly in densely populated regions like Kerala. As urban centers expand and consumption patterns evolve, the volume of persistent materials such as plastics and electronic waste continues to surge, creating significant ecological and logistical burdens. This research addresses these challenges by proposing an optimized and sustainable model for the collection and disposal of non-biodegradable waste, leveraging advanced industrial engineering techniques.

Kerala's unique geographical and demographic characteristics, including high population density and varied terrain, necessitate tailored waste management strategies. The decentralized-centralized hybrid system, supported by initiatives like the Haritha Karma Sena (HKS) and Material Collection Facilities (MCFs), provides a strong foundation. However, disparities in waste collection coverage and operational inefficiencies highlight the need for further optimization. By integrating Vehicle Routing Problem (VRP) models and advanced optimization algorithms such as Genetic Algorithms (GA), Particle Swarm Optimization (PSO), Tabu Search (TS), and hybrid approaches like PSO + Simulated Annealing (SA), this study aims to enhance the efficiency, cost-effectiveness, and environmental sustainability of waste collection systems.

The proposed framework not only minimizes operational costs and fuel consumption but also reduces the environmental impact of waste collection by optimizing routes and resource allocation. Furthermore, it ensures equitable service delivery across urban and rural areas, addressing the disparities in waste collection coverage. The integration of industrial engineering techniques with Kerala's existing decentralized waste management infrastructure offers a scalable and replicable model for other regions facing similar challenges.

In conclusion, this research underscores the importance of adopting innovative and data-driven approaches to waste management. By balancing exploration and exploitation through advanced optimization algorithms, the study provides a robust solution to the growing problem of non-biodegradable waste. The findings and recommendations offer a comprehensive framework for policymakers, waste management authorities, and local communities to achieve sustainable waste management practices, ultimately contributing to environmental conservation, public health, and the promotion of a circular economy.

By embracing these innovative approaches, Kerala can lead the way in sustainable waste management, setting an example for other regions grappling with similar challenges. This research not only addresses the immediate needs of waste management but also contributes to long-term environmental and public health goals, fostering a cleaner, healthier, and more sustainable future.

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Devlink: An AI-Powered Collaborative Platform for Tech Enthusiasts

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ABSTRACT

Devlink is a networking platform aimed at tech- nology enthusiasts, especially students, to facilitate smooth col- laboration on projects. The application uses advanced neural collaborative filtering to match users based on their skills, an AI-driven mentoring system, and a project initiation tool to boost user engagement. By integrating features, such as real-time messaging, gamification, and tailored recommendations, Devlink aspires to cultivate a dynamic community for sharing skills and fostering innovation.

Index Terms—Neural collaborative filtering, AI mentoring, and gamification.

INTRODUCTION

Collaboration in the technology industry is often hindered by fragmented networking platforms, limited visibility of po- tential collaborators, and difficulty in finding individuals with complementary skill sets. Traditional networking solutions such as LinkedIn and GitHub focus primarily on showcasing individual portfolios rather than actively facilitating mean- ingful collaboration. Devlink aimed to bridge this gap by introducing an AI-driven ecosystem designed specifically for technical professionals and students. By leveraging neural collaborative filtering and advanced AI mentorship, Devlink transforms the way users connect, ensuring that individuals find the right collaborators, mentors, and projects, based on their expertise and aspirations. Unlike conventional platforms, which rely on static profiles, Devlink dynamically analyzes user interactions and continuously refines recommendations to maximize compatibility.

The integration of AI mentorship powered by Gemini AI further enhances user experience and provides contex- tual guidance on project development, problem solving, and skill improvement. The platform's gamified reward system fosters engagement by incentivizing contributions, ensuring that knowledge sharing and active participation are valued. Additionally, an intelligent project initiator proactively sug- gests and encourages users to start or join relevant projects, thereby eliminating the friction associated with the forma- tion of new teams. By incorporating features such as in- app communication, skill-based matchmaking, and AI-assisted learning, Devlink not only simplifies collaboration, but also creates a self-sustaining ecosystem that nurtures innovation. This study explores the technical foundations of Devlink, detailing the neural network-based recommendation system, AI-driven mentorship capabilities, and engagement-driven in- centives that collectively redefine collaborative networking in the technology domain.

RELATED WORKS

A. A Deep Neural Collaborative Filtering Based Service Recommendation Method with Multi-Source Data for Smart Cloud-Edge Collaboration Applications Recommending services is essential for managing the grow- ing volume of big data produced by user devices. Conven- tional cloud-based storage and recommendation techniques en- counter difficulties such as high costs and inefficiencies result- ing from the distributed nature of data from multiple sources.

This study proposes a Novel Deep Neural Collaborative Filtering-Based Service Recommendation Method utilizing Multi-Source Data (NCF-MS)[4], which utilizes cloud-edge collaboration to improve both efficiency and accuracy. The proposed model employs a stacked denoising auto-encoder (SDAE) to extract features and a Multi-Layer Perceptron (MLP) to enhance service recommendations by incorporating supplementary user profiles and service attributes.

The NCF-MS approach addresses the issue of data spar- sity in standard Neural Collaborative Filtering (NCF)[4] by effectively merging data from various sources. The cloud-edge architecture optimizes computational expenses by delegating feature-extraction tasks to edge servers while conducting model training on cloud servers. This decentralized framework significantly reduces the data transfer burden and enhances the utilization of resources. The incorporation of deep-learning- based feature extraction also boosts the accuracy of service recommendations.

Experiments were performed on three publicly available datasets to assess the effectiveness of the proposed method. The results indicate that NCF-MS[4] surpasses the traditional service recommendation methods in terms of both accuracy and efficiency. The results emphasize the potential of cloud- edge collaborative computing to lower computational costs and enhance recommendation quality. Future studies will investi- gate the scalability of the model and examine further feature extraction strategies to further optimize service recommenda- tions.

B. A Survey of User Profiling: State-of-the-Art, Challenges, and Solutions

User profiling is essential for personalizing services by creating detailed models of user interests, behaviors, and pref- erences. Despite the increasing amount of research in this field, challenges such as limited data availability, concerns about privacy, and complex computations continue to exist. This study proposes an in-depth survey of user profiling methods, evaluating cutting-edge methodologies, profiling frameworks, and their applications across various sectors. This study clas- sifies user profiling into static and dynamic models, assessing their advantages and disadvantages while examining different approaches for data gathering and feature extraction.

The survey also investigated profiling strategies that depend on explicit user input (such as surveys and registration data) compared to implicit methods (such as tracking behavior and analyzing browsing history). This review includes advanced profiling models that employ machine learning, ontology- based strategies, and statistical techniques. Significant em- phasis is placed on the evaluation metrics used to measure the effectiveness of various user-profiling systems. This paper points out major challenges, including the cold-start issue, trust concerns, and the integration of data from multiple sources for more precise profiling.

In conclusion, this study offers insights into emerging avenues for research, such as privacy-preserving profiling, hybrid modeling strategies, and trust-oriented personalization systems. Tackling these challenges is vital for creating more effective and scalable user profiling structures. The results underscore the importance of integrating adaptive profiling techniques and enhanced data fusion methods to improve service personalization in e-commerce, social media, and healthcare.

C. Cross-Grained Neural Collaborative Filtering for Rec- ommendation

Collaborative Filtering (CF) is frequently used in recom- mendation systems to deduce user preferences from past inter- actions. Nonetheless, conventional CF models encounter chal- lenges related to data sparsity and cold-start situations, which hinder their recommendation accuracy. This paper presents Cross-Grained Neural Collaborative Filtering (CNCF)[8], a novel methodology aimed at capturing collaborative signals at both fine and coarse granularity through an innovative graph-based representation learning framework. The proposed model improves the accuracy of recommendations by inte- grating interactions at multiple attribute levels along with user preferences.

CNCF[8] developed various interaction graphs to efficiently represent different collaborative signals. The fine-grained col- laborative representation learning component focuses on intri- cate attribute interactions and employs Light Attribute Predic- tion Networks (LAPN) to enhance user and item embeddings. At the same time, the coarse-grained representation learning component addresses broader factors of user intent, which aids in enhancing predictions by considering a variety of behavioral patterns. The combination of both representation learning levels significantly boosted both the recommendation accuracy and interpretability.

Experiments were conducted using real-world datasets, showing that CNCF[8] significantly exceeds the performance of traditional Graph Neural Network (GNN)-based and attribute-aware collaborative filtering models. The results affirm the significance of merging high-order attribute in- teractions with latent user intent modeling to produce more effective recommendations. Future investigations will aim to include an analysis of temporal user behavior and utilize user-generated content to further enhance the recommendation performance.

D. Gemini in Reasoning: Unveiling Commonsense in Mul- timodal Large Language Models

The rapid advancement of Multimodal Large Language Models (MLLMs) has profoundly impacted artificial intelli- gence research and its implementation across various fields. Models such as OpenAI's GPT-4V(ision) and Google's Gem- ini[5] combine textual and visual comprehension to improve reasoning and decision making. Despite these innovations, early assessments indicate that while Gemini is quite compe- tent, it falls short compared with GPT-based models regarding commonsense reasoning tasks. However, current evaluations depend on restricted datasets, such as HellaSWAG, which do not fully reflect Gemini's reasoning capabilities. To fill this void, this research offers an extensive analysis of Gemini's per- formance in commonsense reasoning over 12 varied datasets, encompassing both linguistic and multimodal reasoning chal- lenges. We examine its performance relative to top models, such as GPT-4 Turbo and GPT-3.5 Turbo, uncovering Gemini's strengths, weaknesses, and potential areas for further develop- ment. Our analysis sheds light on the difficulties encountered by MLLMs in assimilating commonsense knowledge, while pinpointing key areas that require enhancement in reasoning across various modalities.

Through comprehensive testing, we evaluated Gemini's capacity to navigate complex commonsense reasoning chal- lenges, including spatial, social, temporal, and contextual un- derstanding. Our findings reveal that although Gemini Pro[5] shows competitive results against GPT-3.5 Turbo, it does not reach the accuracy level of GPT-4 Turbo across multiple benchmarks. In particular, Gemini Pro Vision underperforms in multimodal reasoning tasks compared with GPT-4V, espe- cially in interpreting social and emotional contexts. The model demonstrates solid logical consistency, with 65.8 percent of its replies being contextually fitting, yet it struggles with temporal and social commonsense deductions. Our error analysis further indicated that Gemini Pro often misreads context, resulting in reasoning deficiencies in both abstract and domain-specific situations. In addition, Gemini Pro Vision[5] has difficulty accurately recognizing emotional cues in visual data, high- lighting the necessity for better integration of human-like cognitive reasoning capabilities. These results offer important perspectives on the progressing abilities of MLLMs and un- derline the critical need for improved training techniques to bolster common sense reasoning.

This research adds to the ongoing conversation regarding the role of multimodal AI in cognitive tasks by identifying fundamental constraints that prevent MLLMs from attaining human-like reasoning skills. By evaluating Gemini's effective- ness across a variety of common sense reasoning challenges, we lay the groundwork for future improvements in MLLM architectures. These outcomes emphasize the necessity of incorporating a deeper contextual grasp, enhanced multimodal alignment, and better knowledge representation within AI systems. Future investigations should examine the incorpora- tion of external knowledge databases, reinforcement learning strategies, and adaptive prompting techniques to address ex- isting voids in commonsense reasoning. Ultimately, this work represents a vital step toward creating more resilient, intelli- gent, and contextually aware AI systems that can reason across multiple modalities with increased accuracy and human-like intuition.

PROPOSED WORK

A. Process Overview

This system, intended for mobile applications, enables individualized AI mentorship through a structured approach that smoothly merges user engagement, intelligent backend processing, and a robust AI model. User interaction begins with the Mobile App UI, which acts as the main interface for users to engage with the system. This UI consists of several important components, each fulfilling a unique role and activating a specific backend process. The ”Message” component facilitates communication, allowing users to send messages to others or directly interact with the AI mentor. Engaging in this manner triggers a ”Message Event Request,” which is sent to the server via an API call. The server handles this request, saving the message content in the database for ongoing retention and potential future analysis. Additionally, the message data are likely used by the user–user neural recommendation system, which evaluates user interactions and message trends to produce personalized suggestions. These recommendations may include proposing relevant connections with other users, highlighting pertinent content, or offering customized resources based on a user's messaging history and stated interests. The ”Profile” component empowers users to modify their personal information, preferences, and other pertinent data, enhancing a more comprehensive user profile that can be utilized for personalization. The ”Connect” compo- nent aids networking by allowing users to form relationships with other users or project initiators. This feature likely aligns closely with the recommendation system, advising on possible connections based on mutual interests, project involvement, or other applicable criteria. The ”Project Initiator” component offers a direct link for communication with project leaders, facilitating collaboration and feedback more effectively.

A key element of this system is the ”AI Mentor” component, which grants access to personalized advice and support. When a user engages with this component, the system starts a ”Prompt Design for Context” process. This essential phase involves converting the user's input, be it a question, request, or query, into a structured prompt that is fine-tuned for the Gemini API. This step goes beyond merely passing along the user's input; it enhances the prompt with the relevant contextual details. Such a context is vital for AI to deliver more precise, individualized, and insightful responses. The ”Logs/Prompt” component is crucial to this process, acting as a storage for past interaction data and previous prompts. By utilizing this information, the system can integrate previous interactions, user preferences, and other relevant contexts into the current prompt. This ensures that the AI responses are interconnected rather than isolated, building upon the ongoing dialogue and the user's particular needs. Once the prompt is developed and contextualized, the system executes a "Gemini API Call," sending the prompt and related data to Gemini AI. AI interprets this information and produces a response that is subsequently communicated back to the user through the mobile application's UI. This smooth interaction cycle allows users to participate in dynamic and context-aware conversations with the AI mentor and receive customized support and advice.

The architecture of the system prioritizes a distinct sep- aration of concerns with different modules assigned to user interaction, backend processing, and AI communication. This modular approach enhances scalability and maintainability, permitting independent development and updates to separate components. The user–user neural recommendation system and the Gemini API are at the core of the system in- telligence, which offers tailored recommendations and AI- generated responses. The "Logs/Prompt" element serves as an essential memory tool, allowing the system to learn from earlier interactions and improve the quality of its responses progressively. This ongoing learning mechanism enriches the mentorship experience for the user, making it more effec- tive and individualized. The system is designed to manage a wide range of user activities, from basic messaging to advanced AI interactions, thereby highlighting its flexibility and adaptability. The emphasis on context in the AI interaction process reflects the system's aim of delivering intelligent and customized support, evolving beyond mere question-and- answer sessions to provide a genuinely enriching mentorship experience.

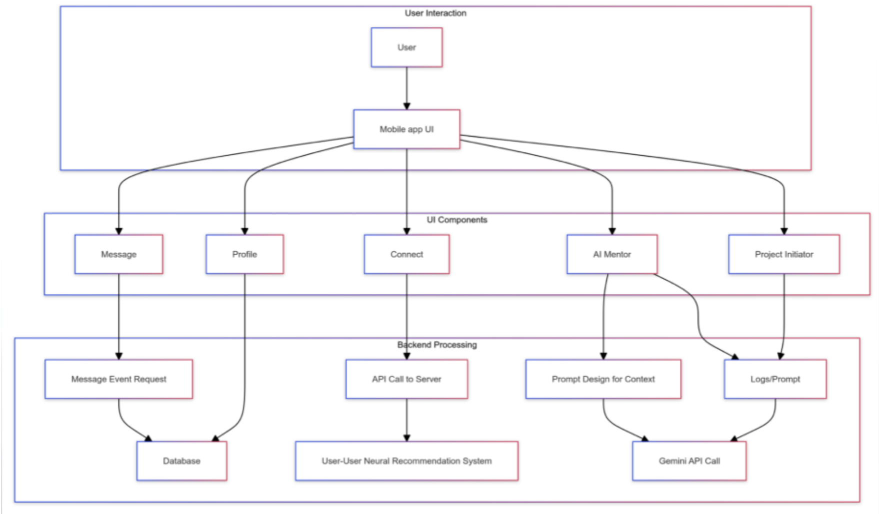

Fig. 1. FlowDiagram

B. User Profile Setup and Onboarding

Devlink starts with a thorough onboarding process in which users establish detailed profiles outlining their technical skills, interests, and preferences for collaboration. These charac- teristics are transformed into feature vectors and stored in the system database, which serves as the basis for the AI- powered recommendation engine. Profile creation allows users to showcase their expertise in fields, such as front-end de- velopment, data science, cybersecurity, and UI/UX design. Furthermore, users can define their visibility and privacy settings, giving them control over the sharing of information on the platform. A comprehensive profile plays a vital role in the recommendation system, enabling Devlink to pinpoint the best collaboration opportunities based on individual strengths and project goals.

C. AI-Powered Recommendation System

The recommendation system driving Devlink utilizes a graph-based neural network, where users are depicted as nodes and possible collaborations as edges. Skills, interests, and previous interactions are converted into numerical formats through multilabel binarization, allowing the system to assessuser compatibility effectively. By employing a Graph Neu- ral Network (GNN), Devlink continuously absorbs user data and improves recommendations by changing preferences and immediate interactions. For example, if a user is proficient in backend development but lacks skills in front-end devel- opment, the system gives priority to potential collaborators who can fill the skills gap. This neural collaborative filtering method guarantees that users receive highly pertinent and adaptable recommendations, thereby enhancing the chances of forming meaningful and productive partnerships.

GNN Algorithm

1. Input: User dataset D from ”gnn users.json”
2. Output: Trained GNN model, accuracy metrics
3. Step 1: Load User Data
4. Load D and extract user nodes
5. Initialize edge list E = []
6. Step 2: Create Graph Edges
7. for each user i in D do
8. for each user j > i in D do
9. Compute shared features:
10. I = Intersection(i.interests, j.interests)
11. L = Intersection(i.languages, j.languages) 12: D = Intersection(i.domains, j.domains) 13: S= Intersection(i.skills, j.skills)
12. if L is empty then
13. for each interest in i.interests do
14. if interest exists in predefined mapping then
15. Map interest to relevant languages
16. L = L ∪ Mapped Languages
17. end if
18. end for
19. end if
20. if I≠ ∅ or L≠ ∅ or D≠ ∅ or S≠ ∅ then
21. Compute edge weight: w = |I| + |L| + |D| + |S|
22. Append edge (i, j, w) to E
23. end if
24. end for
25. end for
26. Step 3: Encode Features
27. Apply one-hot encoding to interests, languages, domains, and skills
28. Combine all encoded features into feature matrix X
29. Step 4: Construct Graph Data
30. Create edge index tensor E
31. Store graph data as G = (X, E)

32. Step 5: Define GNN Model
33. Define GCN layers:
34. h1 = GCNConv(X, hidden dim)
35. Apply ReLU activation
36. h2 = GCNConv(h1, output dim)
37. Step 6: Train GNN Model
38. Initialize optimizer and loss function
39. Generate random labels for training/testing
40. Split data into training and testing sets
41. for epoch = 1 to 200 do
42. Perform forward pass
43. Compute loss and backpropagate
44. Update model weights
45. end for
46. Step 7: Evaluate Model
47. Compute predictions
48. Compute training accuracy and testing accuracy
49. Print accuracy results
50. Step 8: Save Model and Plot Loss
51. Save model parameters to ”gnn model.pth”
52. Plot training loss curve

D. AI Mentorship with Gemini AI

In addition to its intelligent matchmaking capabilities, De- vlink features an AI-driven mentorship system that improves user experience by offering personalized project guidance. The AI mentor, leveraging the power of Gemini AI, evaluates user activities and learning styles to provide immediate project support, recommend educational resources, and assist with technical issues. For instance, if a user is engaged in a machine learning project, the AI mentor can deliver advice on preparing datasets, suggest suitable libraries, such as TensorFlow or Py- Torch, and share recommended practices for model evaluation. This mentorship is responsive to users' changing skill levels and past engagement, ultimately cultivating a community focused on growth within DevLink.

E. Project Initiator and Engagement Mechanisms

A key aspect of Devlink is the project initiator, which motivates users to either kick off or participate in collaborative projects that are aligned with their skills and interests. By assessing user profiles and past engagement behaviors, the platform recommends pertinent real-world challenges such as automation systems based on IoT, healthcare solutions powered by AI, and security applications in fintech. Users can start new projects or join ongoing ones, fostering an environ- ment of constant collaboration and innovation. Furthermore, an inactivity detection system tracks user engagement and re- engages inactive users by sending tailored project invitations and activity reminders. This feature is especially beneficial for students, as it supports sustained momentum and prevents valuable concepts from being overlooked due to a lack of activity.

F. Seamless In-App Communication

Effective collaboration hinges on proficient communication, and Devlink meets this requirement through its built-in mes- saging feature. Users can participate in direct messages, share files, and conduct video calls without third-party services. The messaging feature facilitates organized discussions, enabling teams to categorize conversations based on particular project elements. Furthermore, an AI-driven conversation assistant offers contextual suggestions, including icebreaker questions for new connections, and reminders for ongoing tasks. By centralizing all communications within the platform, Devlink reduces fragmentation and allows users to concentrate fully on collaboration.

G. Reward System and Gamification

To boost user engagement and motivation further, Devlink features a gamified reward system that encourages contribu- tions and builds a sense of community. Users can earn collabo- ration points by participating in discussions, providing mentor- ship, and completing projects successfully. Active participants are acknowledged with badges such as ”Top Mentor,” ”Project Leader,” and ”Innovator,” which enhance their credibility on the platform. The reward system is structured in tiers, where regular participation unlocks special features and provides greater visibility within the network. This gamified method not only promotes ongoing interaction, but also nurtures a culture of collaboration and knowledge sharing.

RESULTS

Deployment of the GNN-based recommendation system for Devlink showed encouraging results in identifying potential collaborators based on user profiles. The model underwent training for 200 epochs, achieving an final training accuracy of 80.77 percent and a test accuracy of 40.91 percent. Although the training accuracy indicates that the model successfully learned from the dataset, the comparatively lower test accuracy points to a degree of overfitting, signaling possible areas that require improvement in generalization. The system effectively produces user recommendations as unique user IDs, highlight- ing its capability to recognize pertinent matches according to user attributes and preferences.

The app’s interface, illustrated in screenshots, offers an intuitive and organized user experience, leading users through a simplified registration and profile creation process. The AI assistant embedded in the app provided users with relevant information as they asked questions, showing its potential to boost user engagement. The recommendation engine’s profi- ciency in processing input data and offering significant sugges- tions support Devlink’s essential functionality, aligning with its mission to connect tech enthusiasts and professionals for collaborative efforts. Nonetheless, further adjustments to the matching algorithm may be required to enhance the accuracy of recommendations.

Future enhancements may involve fine-tuning hyperparam- eters, integrating additional user information, and testing var- ious GNN models to boost the performance. Furthermore, the use of methods such as regularization, data augmentation, and advanced collaborative filtering techniques could assist in reducing overfitting and improving test accuracy. Despite these obstacles, the existing results affirm the viability of utilizing AI-driven matchmaking in technology collaborations, demon- strating Devlink’s potential impact on nurturing meaningful professional connections.

CONCLUSION

Devlink signifies a transformation in the way students, developers, and professionals interact within a dynamic tech environment. By leveraging neural collaborative filtering, the platform smartly identifies potential collaborators, ensuring that users engage with individuals whose skills and interests

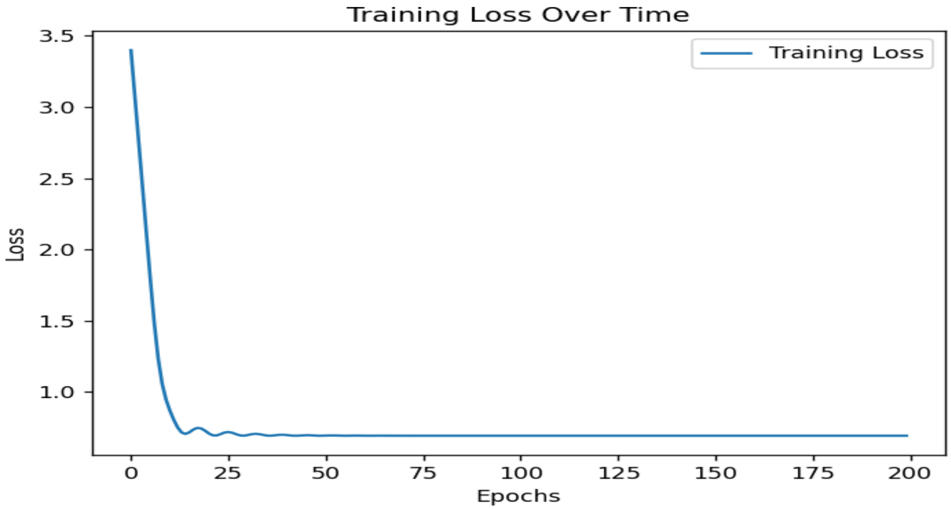

Fig. 2. Training Loss

Fig. 3. Registration Page

Fig. 4. Registration Page

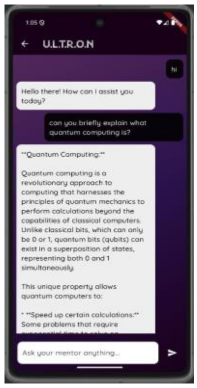

Fig. 5. AI mentor

are aligned with their own. Unlike traditional networking platforms that emphasize professional visibility, Devlink en- hances meaningful connections and builds a community in which collaboration is seamless and purpose-driven. The AI mentorship system fueled by Gemini AI further enriches this ecosystem by providing tailored project support, technical assistance, and recommendations for skill development. With a user-friendly interface, users can easily communicate, start projects, and monitor their advancements, making Devlink a comprehensive solution to collaborative creativity.

The platform's gamified reward structure and project ini- tiation features are vital in maintaining user engagement, ensuring that participants stay active and inspired. By encour- aging involvement and celebrating accomplishments, Devlink promotes a culture of knowledge exchange and learning. As the platform progresses, future enhancements will aim to integrate blockchain-based credential validation, broaden its appeal to industry professionals, and include more sophis- ticated AI-driven matchmaking strategies. Finally, Devlink aims to establish itself as the premier collaborative center for the global tech community, transforming how professionals connect, learn, and innovate collectively.

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Enhancing NPCS Using Deep Reinforcement Learning

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ABSTRACT

Enhancing NPCs Using Deep Reinforcement Learn- ing explores the use of reinforcement learning to create adaptable and intelligent non-player characters (NPCs) in adventure games. Traditional NPCs follow predictable behaviors, limiting player engagement. This project aims to address this by training NPCs to learn from player actions, adapt dynamically, and make strategic decisions. The result is an immersive gameplay experi- ence where NPCs evolve to match player strategies, maintaining engagement over extended sessions. This work advances AI-driven character design, offering a foundation for adaptive NPCs in various gaming genres and simulations requiring responsive, intelligent behavior.

Index Terms—Reinforcement Learning, formatting, style, styling, insert

INTRODUCTION

Non-player characters (NPCs) significantly influence player experiences in modern video games. Traditionally, NPCs rely on fixed, rule-based programming, resulting in predictable interactions that can detract from immersion and engagement. Once players master the game mechanics, these static behav- iors fail to provide meaningful challenges, limiting the depth and enjoyment of the game.

This project seeks to address these limitations by integrating reinforcement learning to develop adaptive NPCs capable of evolving in real-time. Unlike traditional NPCs, adaptive NPCs analyze player actions, recognize patterns, and adjust their strategies dynamically to offer tailored, unpredictable challenges. This creates a game environment where NPCs respond intelligently to players' unique styles, ensuring that interactions remain engaging and immersive throughout game- play.

By leveraging reinforcement learning techniques, NPCs can learn from each encounter, making strategic decisions that adapt to the player's progression. This adaptability fosters a dynamic gameplay experience, where both the NPCs and the players evolve, keeping the game fresh and exciting. The result is an enhanced level of immersion as players face NPCs that feel intelligent, reactive, and uniquely challenging.

Beyond improving adventure games, this approach has broader implications for the gaming industry. Adaptive NPCs can set a new standard for character design across genres, enabling more complex, interactive, and personalized gaming experiences. Furthermore, these methodologies can extend to simulations requiring AI-driven characters, paving the way for innovations in interactive entertainment and training applica- tions. This project establishes a foundation for advancing NPC design, contributing to a more dynamic and engaging future in gaming.

RELATED WORKS

A. [1]Applying Hindsight Experience Replay to Procedural Level Generation

Designing balanced and engaging levels in video games is a complex task requiring precision and creativity, as overly simplistic levels lead to disinterest, while excessively chal- lenging ones can frustrate players. This research introduces an innovative approach to automated level design by integrating Procedural Content Generation via Reinforcement Learning (PCGRL) with the Hindsight Experience Replay (HER) algo- rithm. The proposed method eliminates the need for extensive expert-labeled datasets, relying instead on simulation environ- ments that provide feedback on level quality.

The methodology enables the generation of levels for diverse games with minimal adjustments, addressing two critical re- quirements: adaptability across different games and the ability to accommodate specific user-defined criteria. By implement- ing HER, the system transforms failures into learning opportu- nities, ensuring the generated levels meet user-specified goals without retraining. The research evaluates the system on four distinct games, demonstrating its versatility and success rate exceeding 90% in most scenarios, significantly outperforming random agents.

The study employs a customized OpenAI Gym environment and a Dueling Deep Q-Network (Dueling DQN) architecture to train the level generator. By accommodating one-dimensional level representations, the approach offers a proof of concept for scalable applications. Despite current limitations, such as restricted customization and one-dimensional inputs, the findings highlight significant advancements over prior meth- ods, including enhanced customization and user-centric design capabilities.

Future research could expand this framework to more complex games and incorporate higher-dimensional level representa- tions using advanced neural network architectures. Addition- ally, subjective customization options, such as difficulty and enjoyment, present promising areas for further exploration. This work represents a significant stride toward fully auto- mated, user-driven procedural level generation in video game design.

B. [2]Subgoal-Based Reward Shaping to Improve Efficiency in Reinforcement Learning

Reinforcement learning (RL) has demonstrated remarkable success across a wide range of domains. However, RL often suffers from inefficiencies due to sparse rewards, where an agent must explore extensively before receiving feedback to guide its learning process. To address this challenge, this study explores the integration of subgoal-based reward shaping into RL frameworks, aiming to enhance learning efficiency.

Subgoal-based reward shaping introduces intermediate re- wards tied to subgoals, which act as milestones within the problem's state space. By breaking down complex tasks into smaller, manageable components, subgoal-based shaping pro- vides agents with additional structured feedback, accelerating convergence and reducing exploration overhead.

The proposed approach leverages domain knowledge to identify meaningful subgoals, ensuring that the reward struc- ture aligns with the problem's inherent characteristics. These subgoals are used to define auxiliary rewards that supplement the primary task's objective, guiding the agent toward op- timal policies more effectively. The study examines various methodologies for subgoal identification, including automatic and manual techniques, and evaluates their impact on training dynamics.

Experimental results on benchmark tasks demonstrate sig- nificant improvements in learning efficiency when compared to standard RL approaches. The addition of subgoal-based rewards enhances the agent's ability to traverse challenging environments and achieve higher rewards within fewer itera- tions. The findings also highlight the potential of this approach in scaling RL to more complex, real-world applications where sparse rewards and high-dimensional state spaces remain chal- lenging.

In conclusion, subgoal-based reward shaping emerges as a powerful tool to address the inefficiencies in RL, providing a balance between task decomposition and reward design. Future work could focus on automating subgoal discovery further and testing this framework in diverse, real-world settings to generalize its applicability. This research underscores the importance of structured reward mechanisms in improving RL system performance and practical deployment.

C. [3]HiER: Highlight Experience Replay for Boosting Off- Policy Reinforcement Learning Agents

The study introduces Highlight Experience Replay (HiER), a novel technique aimed at improving the training of off-policy reinforcement learning (RL) agents, particularly in environ- ments with sparse rewards, continuous state-action spaces, and no access to demonstrations. HiER addresses key challenges in RL by creating a secondary replay buffer for storing and prioritizing critical experiences. This method, inspired by human memory's tendency to prioritize significant events, accelerates convergence by focusing on rewarding transitions. HiER is complemented by E2H-ISE (Easy-to-Hard Initial State Entropy), a curriculum learning approach designed to systematically control the entropy of the initial state-goal distribution. By starting from simpler tasks and gradually increasing complexity, E2H-ISE ensures that the agent gains early-stage learning benefits, enabling efficient exploration and training. Together, these methods form HiER+, a hybrid ap- proach that synergizes highlight-based and entropy-controlled
learning for RL agents.

Experimental validation on eight tasks across three robotic benchmarks, including Panda-Gym and Gymnasium-Robotics environments, demonstrated HiER's robustness and effective- ness. HiER significantly outperformed baseline methods like HER (Hindsight Experience Replay) and PER (Prioritized Experience Replay), achieving faster convergence and higher success rates in manipulation and navigation tasks. HiER+ further enhanced performance by combining reward shaping with structured task difficulty adjustments.

The results emphasize HiER's versatility, as it integrates seamlessly with RL algorithms such as SAC, TD3, and DDPG, making it adaptable to diverse tasks. It effectively reduces instances where agents get trapped in local minima, a common issue in sparse-reward environments. This study opens avenues for broader applications, including simulation-to-real transfer learning and complex robotic tasks.

Future work aims to refine HiER's parameters and in- tegrate advanced curriculum learning strategies, potentially enabling its application in real-world robotics and other high- dimensional, sparse-reward domains.

D. [4]Peer Incentive Reinforcement Learning for Coopera- tive Multiagent Games

The paper introduces the Intrinsic Reward with Peer Incen- tives (IRPI) method for cooperative multiagent reinforcement learning (MARL). Addressing challenges such as decentral- ized execution and credit assignment, IRPI enables agents to incentivize each other for cooperation through a novel intrinsic reward mechanism based on causal influence.

Inspired by human social learning and incentives, IRPI integrates peer rewards into the actor-critic policy gradient framework. Each agent can positively or negatively reward peers' actions by analyzing their causal impact on itself. This causal influence is quantified through counterfactual reasoning using a joint action-value function. A feedforward neural network implements this mechanism, enabling agents to dynamically adjust behaviors for improved collaboration.

The approach was tested in StarCraft II Micromanagement and Multiagent Particle Environments (MAPE), showcasing superior performance compared to state-of-the-art MARL methods. IRPI facilitated better policy learning, achieving higher win rates and rewards in diverse cooperative scenarios. Ablation studies highlighted the efficacy of its intrinsic reward mechanism, which improved both training convergence and policy quality.

IRPI advances MARL by addressing credit assignment implicitly and enhancing interagent interactions through social incentivization. Future research aims to apply IRPI to large- scale and competitive multiagent systems while optimizing the efficiency of causal influence inference.

E. [5] Research on Multi-NPC Marine Game AI System based on Q-learning Algorithm

Traditional game AI systems often rely on static behavior trees for NPC decision-making, leading to rigid, non-adaptive behaviors that degrade player immersion.

This paper proposes a dynamic AI framework for multi- NPC marine games by integrating Q-learning with a simulated annealing algorithm to optimize NPC behavior trees. The Q- learning algorithm enables NPCs to learn and adapt actions based on environmental feedback, while simulated annealing mitigates local optima traps by dynamically balancing explo- ration and exploitation.

The framework initializes NPC states and actions (e.g., combat, repair, swarm) and designs a weighted reward func- tion incorporating health, enemy proximity, and repair point distance. By restructuring behavior trees through Q-value prioritization, NPCs exhibit human-like decision-making, such as tactical retreats or cooperative attacks. Experimental results demonstrate enhanced adaptability and contextual relevance in NPC behavior compared to conventional methods, with improved convergence efficiency. This approach addresses the limitations of static behavior trees and offers a scalable solution for complex, dynamic game environments.

The proposed method combines Q-learning with simulated annealing to optimize NPC behavior trees in marine games.

1) State and Action Initialization: NPC parameters (health, repair distance, enemy proximity) are discretized into fuzzy states. Six core actions are defined: seek repair, swarm, search, combat, wander, escape.
2) Reward Function Design: A weighted reward system balances immediate gains (e.g., health recovery) and strategic goals (e.g., enemy elimination). Rewards are assigned based on state-action pairs, penalizing detrimental choices (e.g., low- health combat) and incentivizing context-aware decisions.

F. [6] Application of behavior tree in AI design of MOBA games

This paper proposes the integration of Behavior Trees (BT) as a superior alternative to Finite State Machines (FSM) for designing artificial intelligence (AI) in Multiplayer Online Battle Arena (MOBA) games, addressing the limitations of FSMs in scalability and adaptability. Traditional FSMs suffer from exponential complexity growth due to rigid state transi- tions, leading to unwieldy code and maintenance challenges. In contrast, Behavior Trees offer a hierarchical, modular structure that enhances flexibility and simplifies decision-making logic.

The framework leverages BT node types—Selector (prior- itizes actions), Sequence (executes actions in order), Paral- lel (manages concurrent tasks), Decorator (adds conditional logic), Condition (evaluates states), and Action (performs behaviors)—to model complex hero interactions. For instance, Parallel nodes enable simultaneous actions like health recovery and item purchasing, which FSMs struggle to coordinate. The BT's hierarchical design decomposes AI behaviors into reusable subtrees (e.g., lane-pushing, team-fighting), reducing redundancy. Dynamic prioritization allows heroes to adapt contextually: a hero may retreat (Condition node) upon low health while assessing gold reserves for upgrades (Action node).

Key implementation steps include:

1. Hierarchical Logic Design, organizing AI tasks into mod- ular subtrees for scalability.
2. Concurrency Handling via Parallel nodes to execute actions like coordinated attacks alongside health monitoring.
3. Dynamic Adaptation using Decorator nodes to inject real-time conditions (e.g., enemy proximity checks, skill cooldowns). This structure enables AI to mimic human-like adaptability, such as interrupting lane-pushing to join team fights.

G. [7] AI4U: A Tool for Game Reinforcement Learning Experiments

This paper proposes AI4U, a tool to streamline reinforce- ment learning (RL) experiments for developing autonomous Non-Player Characters (NPCs) in games. Existing challenges in RL, such as designing complex reward functions and inte- grating algorithms with game engines, are addressed through three key features.

First, AI4U integrates with the Unity game engine, lever- aging its ecosystem for environment design and physics sim- ulation. Second, it provides a visual and declarative interface for specifying both Markovian and Non-Markovian reward functions, reducing the manual effort required to encode agent behaviors. This visual approach maps game events (e.g., collisions, item collection) to reward structures, equivalent to formal Reward Machines, enabling intuitive design of temporal and sequential objectives.

Third, the tool automates code generation compatible with frameworks like OpenAI Gym, enabling seamless integration with state-of-the-art RL algorithms such as Proximal Policy Optimization and Soft Actor-Critic. Experiments across three game environments—a navigation task, a 3D maze explo- ration, and a sequence-based memory challenge—demonstrate AI4U's flexibility. Results show successful agent training using automated workflows, validating its utility in simplifying RL experimentation. By bridging game development and RL research, AI4U lowers barriers for developers to prototype and test human-like NPC behaviors, with potential applications in complex reward shaping and imitation learning. Limitations include dependency on Unity and limited portability to other engines, suggesting future work on cross-platform adaptation.

H. [8] Deep Reward Shaping from Demonstrations

This paper introduces a method to enhance Deep Rein- forcement Learning (DRL) in sparse-reward environments by integrating expert demonstrations through reward shaping. The approach combines Deep Q-Networks (DQN) with a super- vised Convolutional Neural Network (CNN) trained on teacher demonstrations to generate a potential-based reward function. This shaped reward guides the agent by providing additional feedback, accelerating learning in tasks where environmental rewards are infrequent (e.g., navigation with delayed terminal rewards).

Key contributions include:

1. Reward Shaping via Demonstrations: A CNN learns po- tential values from state-action pairs in expert trajectories, enabling the agent to mimic teacher behavior without task- specific feature engineering.
2. Adaptive Target Network Updates: The target network in DQN is updated dynamically based on training loss thresholds rather than fixed intervals, improving stability and conver- gence.
3. Integration with DQN: Shaped rewards are added to environment rewards during Q-value updates, balancing ex- ploration and expert-guided exploitation.

Experiments on 2D grid navigation tasks (varying sizes from 5×5 to 30×30) demonstrate the method's efficacy. Results show faster convergence and higher success rates compared to standard DQN, particularly in larger grids with sparser rewards. The adaptive update mechanism further enhances performance by optimizing training stability. This approach eliminates reliance on manual reward engineering and scales effectively with task complexity, offering a robust solution for real-world applications like autonomous navigation. Future work includes testing in realistic simulators and extending the framework to asynchronous advantage actor-critic (A3C) architectures.

I. [9] Research on the Application of Artificial Intelligence in Games

This paper proposes an integrated artificial intelligence (AI) framework to enhance non-player character (NPC) behavior in video games, focusing on improving adaptability and realism. The framework combines finite state machines (FSMs), fuzzy state machines (FuSMs), artificial neural networks (ANNs), and genetic algorithms (GAs). FSMs govern seven NPC states—patrol, attack, escape, pickup, etc.—with prioritized transitions triggered by environ- mental cues. FuSMs introduce partial state activation based on NPC health levels (e.g., overlapping”healthy” and ”in- jured” states), enabling nuanced decision-making. For complex navigation, ANNs trained via GAs optimize escape routes by evolving neural networks through fitness-based selection, crossover, and mutation.

The system is implemented in Unity3D using C hash, with NPC perception systems detecting players, items, and obsta- cles via raycasting. Experiments demonstrate NPCs dynam- ically switching states (e.g., attacking when threats are low, fleeing when health is critical) and navigating obstacles using ANN-GA-generated paths. Results validate the framework’s efficacy, showing realistic behaviors such as item collection, threat-responsive actions, and obstacle avoidance. The work highlights the feasibility of integrating multiple AI techniques to create adaptable NPCs, advancing game AI research. Fu- ture directions include adding personality-based behaviors and multisensory perception (e.g., auditory cues). This approach offers a practical reference for developing intelligent NPCs, balancing computational efficiency with behavioral complex- ity.

J. [10] Evaluating Navigation Behavior of Agents in Games using Non-Parametric Statistics

This paper proposes a non-parametric statistical framework to evaluate the human-like navigation behavior of non-playable characters (NPCs) in 3D game environments. Existing ap- proaches often prioritize task proficiency over behavioral sim- ilarity to humans, lacking robust metrics for human-likeness. To address this, the authors introduce a two-sample hypoth- esis test comparing movement pattern distributions between NPCs and human players. Agent trajectories are segmented into fixed-length sequences, normalized to origin-aligned co- ordinates, and analyzed using maximum mean discrepancy (MMD) combined with bootstrap resampling. This method tests the null hypothesis that NPC and human movement distributions are identical, deriving a p-value as a similarity measure. Lower p-values indicate greater divergence from human-like behavior.

Experiments in procedurally generated mazes compared reinforcement learning (RL)-based agents, NavMesh-based agents, and human players. Results showed RL-based agents achieved significantly higher median p-values (78.3) than NavMesh agents (0.0), aligning with qualitative human judg- ments of human-likeness. Additionally, human-to-human com- parisons yielded high p-values (up to 79.4), validating the test’s consistency.

The framework provides a systematic, automated alternative to manual evaluations, enabling objective ranking of NPCs by behavioral similarity. This approach advances game AI development by emphasizing human-like navigation patterns beyond mere task success, with potential applications in re- ward design and imitation learning.

PROPOSED WORK

A. Process Overview

The project involves developing a fully playable game using Unity, focusing on NPCs powered by Deep Q-Networks (DQN) to create dynamic player interactions. The first phase centers on the game environment and mechanics setup, which involves building the core framework for vehicle movement, physics-based interactions, and environmental elements such as terrain, obstacles, and track layouts. Ensuring realistic controls and smooth car mechanics will be essential to provide an engaging player experience. The environment will serve as the foundation, defining the scope of the gameplay and offering flexibility for future additions of NPCs and other mechanics.

The next phase will focus on NPC behavior design, where behavior trees or finite state machines (FSM) will be incor- porated initially to define NPC actions. These behaviors will dictate how the NPCs react to the player and navigate the environment. Once a functional framework is established, the reinforcement learning model development will begin. This phase will involve designing DQN agents capable of learning optimal strategies through continuous interaction within the game environment. These agents will evolve from pre-defined behaviors to adaptive ones by training on various states and rewards, ensuring a challenging and unpredictable gameplay experience.

Reward system design will play a critical role in guiding both NPCs and player-controlled actions. The reward structures will be carefully crafted to encourage exploration, strategic movement, and goal-oriented behaviors. Positive reinforce- ment may include rewards for completing objectives or avoid- ing obstacles, while penalties could be applied for collisions or inefficient movements. This system will be essential for refining the performance of both NPCs and reinforcement learning agents, aligning their behaviors with the overall game objectives.

Testing, evaluation, and improvement will follow as an iter- ative process throughout development. Game mechanics and RL models will be tested against multiple scenarios to identify issues related to gameplay balance, bugs, or unintended NPC behavior. Metrics such as player engagement, NPC response times, and model convergence rates will be analyzed to assess the quality of the game experience. Insights gained from these evaluations will drive further improvements, ensuring that the mechanics, behaviors, and learning systems function cohesively.

The project aims to integrate reinforcement learning seam- lessly into gameplay, offering players a unique and evolving experience. The modular approach ensures that each phase builds on the previous one, maintaining flexibility for future enhancements and updates. With Unity as the development platform, the project leverages its rich asset store and physics engine to create an immersive and interactive environment, ultimately delivering a challenging and enjoyable game.

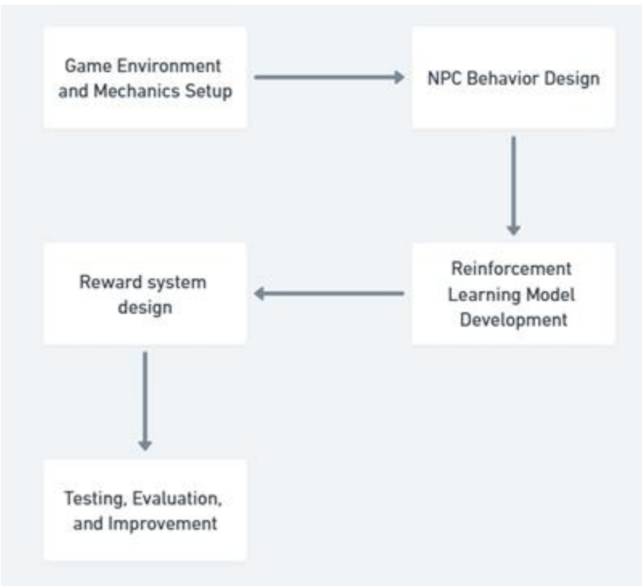

Fig. 1. PROJECT WORKFLOW DIAGRAM

B. Game Development

The game development of this project follows a phased approach, ensuring a smooth progression from foundational mechanics to advanced NPC interactions using reinforcement learning. The initial focus lies in building the game environ- ment and mechanics within Unity. This involves de signing realistic car movement, handling physics, and integrating en- vironmental elements such as terrains, obstacles, and track layouts. The goal is to create an intuitive and responsive experience, laying the groundwork for player engagement. Vehicle controls will be refined through iterations to ensure smooth gameplay, which is essential for setting up interactions with NPCs in later stages.

Following the mechanics setup, NPC behavior design will be introduced using predefined frame works such as behavior trees or finite state machines (FSM). These models will allow the NPCs to perform basic actions like navigating the environment and responding to player inputs. Once the initial behavior patterns are established, reinforcement learning will be incorporated to enable adaptive and strategic gameplay. The RL agents, powered by Deep Q-Networks (DQN), will inter act with the environment, gradually learning optimal strategies by receiving rewards for achieving goals and avoiding penal- ties.

Reward system design will be critical throughout development, guiding both NPC and player ac tions by defining incentives for efficient behavior and disincentives for poor performance. This system will ensure that the NPCs evolve through contin- uous learning and challenge players effec tively.

Fig. 2. GAME DEVELOPMENT FLOWCHART

C. Environment Components

1. Map Design: The map design defines the structure and layout of the game world, shaping player movement and NPC navigation. It involves crafting terrain, roads, and tracks that align with the game's mechanics. Different zones, such as off-road paths, ramps, and open areas, can encourage diverse gameplay styles. Thoughtful placement of obstacles and routes ensures an engaging experience while providing varied scenarios for NPC learning.
2. Asset Integration: As- sets, including 3D models of cars, buildings, trees, and props, will enhance the environment's realism. Unity's asset store offers ready-made models that will be modified or customized as needed to fit the game's style. Proper integration ensures optimized performance without compromising visual quality. Sound assets, such as ambient noise and vehicle sounds, will also be incorporated to create a more immersive experience. Efficient use of assets will reduce development time while maintaining a cohesive and polished look throughout the environment.
3. Prefab Instantiating: Prefabs are reusable game objects, such as vehicles, checkpoints, and power-ups,that will be instantiated dynamically within the environment. This modular approach simplifies development, allowing for easy updates and reusability. This ensures a dynamic and responsive envi- ronment, with objects appearing and disappearing as required.

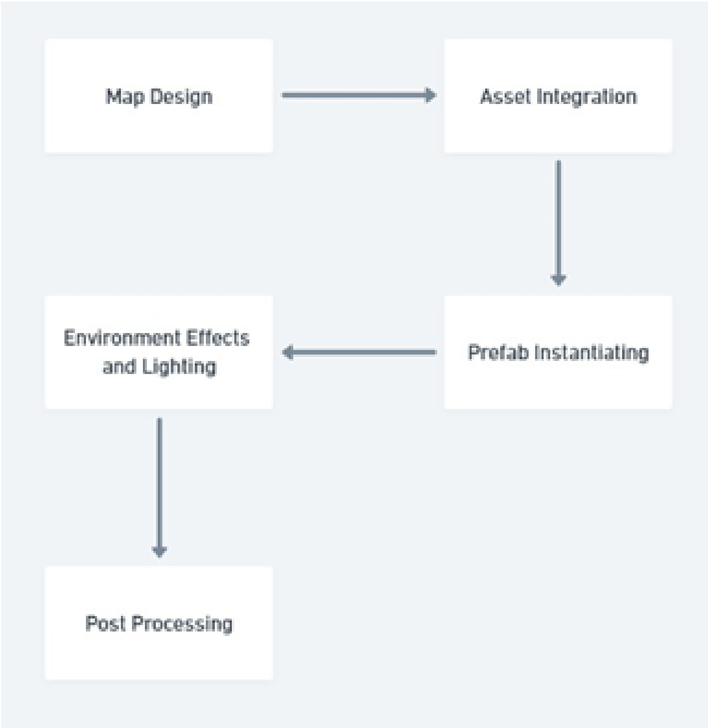

Fig. 3. GAME DEVELOPMENT FLOWCHART

Prefab instantiating will also facilitate procedural generation, offering fresh challenges to both players and NPCs.

4. Environment Effects and Lighting: Lighting plays a key role in setting the game's tone and enhancing immersion. Day-night cycles, ambient lighting, and shadows will be implemented to reflect the time of day or specific gameplay scenarios. Additional effects, such as particle systems for dust, smoke, or rain,will provide environmental variety. Dynamic lighting will help create realistic reflections on vehicles and track surfaces, improving player feedback and immersion. This component also contributes to visual cues for reinforcement learning agents by providing environmental changes they need to adapt to.
5. Post-Processing: Post-processing will be applied to polish the game's visual aesthetics, ensuring a high-quality finish. Effects like bloom, color grading, depth of field, and motion blur will enhance the environment's appearance and create cinematic visuals. These enhancements will add subtle layers of detail, making the game feel more immersive and visually appealing. Post processing will also help maintain visual consistency by balancing contrast, saturation, and lighting effects across different scenes. These improvements will en- sure smooth transitions between environments, contributing to an engaging and immersive experience for both players and NPCs.

D. Vehicle Physics And Collision Handling

1. Collider Design for Car: Collider design is essential for ensuring accurate physical interactions between vehicles and the environment. Unity provides multiple collider types, such as box, sphere, and mesh colliders, which will be customized

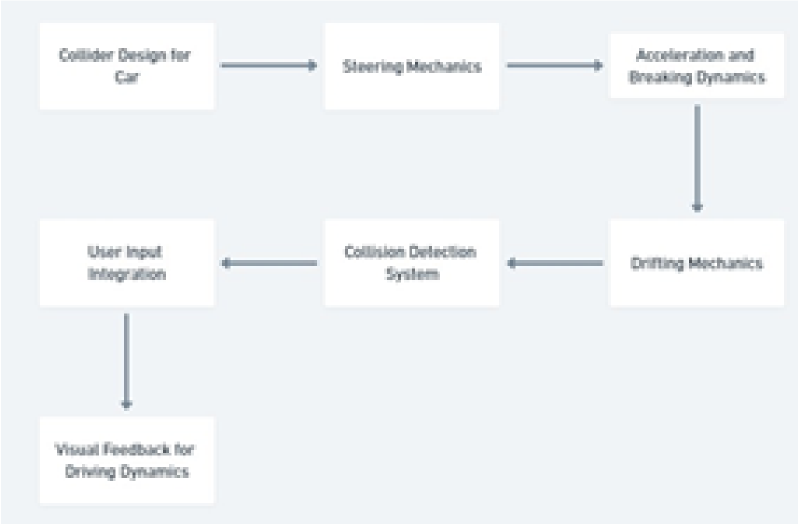

Fig. 4. GAME DEVELOPMENT FLOWCHART

for the car model to match its shape and dimensions. Layer- based collision detection will be implemented to manage interactions with objects like obstacles and power-ups. Proper tuning of colliders ensures realistic car behavior during crashes and boundary collisions, minimizing glitches or unexpected outcomes. Optimizing colliders will also improve performance by balancing physics calculations without compromising ac- curacy in vehicle movements and interactions.

2. Steering Mechanics: Steering mechanics determine how the vehicle responds to player input and influences overall control. A smooth steering system will be implemented to offer intuitive handling, using physics-based wheel colliders to simulate realistic turning behavior. Adjustments will be made to steering sensitivity and turn radius to ensure the car handles well on various terrains and track types. The mechanics will account for speed, making the steering stiffer at higher velocities to prevent oversteering. Fine-tuning these aspects ensures that the steering feels responsive yet challenging, contributing to a more engaging driving experience.
3. Acceleration and Braking Dynamics: Acceleration and braking dynamics will define the speed control of the vehi- cle, balancing gameplay between responsiveness and realism. These dynamics will be handled using torque application on wheel colliders, simulating engine power and deceleration. The acceleration system will include gradual buildup to avoid instant speed boosts. Friction and drag coefficients will be fine-tuned to reflect surface conditions, making acceleration and braking dependent on terrain. This approach ensures that players feel in control while adding depth to the driving experience through varying speed dynamics.
4. Drifting Mechanics: Drifting mechanics will enhance gameplay by allowing players to perform controlled slides around corners. A combination of reduced grip, lateral friction control, and dynamic throttle management will be used to implement drifting. The system will detect when the player attempts to drift and adjust tire friction to maintain a balance between sliding and control. Visual feedback, such as tire smoke effects, will be added to enhance immersion. Drifting will not only add excitement to gameplay but will also play a role in the reinforcement learning process by introducingcomplex vehicle handling scenarios for NPCs to learn from.
5. Collision Detection System: The collision detection sys- tem ensures realistic interactions between the vehicle, obsta- cles,and other game objects. Unity's physics engine, along with colliders, will detect collisions between cars and envi- ronment elements such as barriers, ramps, and terrain. Layer- based filtering will prevent unnecessary collisions, such as between allied objects, optimizing performance.

Additionally, triggers will be used to detect non-physical interactions, like passing through checkpoints. Precise collision detection en- hances realism, ensuring that crashes or bumps affect the car's behavior, such as spin-outs. This system is vital for both gameplay realism and guiding reinforcement learning agents to learn from mistakes.

6. User Input Integration: User input integration will handle the connection between player controls and vehicle actions. The system will map input devices, such as keyboards, con- trollers, or steering wheels,to corresponding driving mechanics like acceleration, steering, and braking. Unity's input system will capture both analog and digital inputs, ensuring smooth transitions, such as gradual acceleration with pressure-sensitive controls. Input sensitivity will be configurable to suit player preferences, with features like assistive steering or braking for easier handling. This integration is crucial for making the gameplay responsive, intuitive, and accessible, providing players with a seamless driving experience.
7. Visual Feedback for Driving Dynamics: Visual feedback enhances player engagement by reflecting driving dynamics through environmental and on-screen elements. Tire marks, dust clouds, and skid effects will convey traction and speed changes, while particle effects like sparks or smoke will signal collisions or drifting. Camera shake and subtle screen tilts will be used to enhance the sense of movement and impact. This feedback not only improves immersion but also helps players understand their car's behavior in real-time, offering better control during intense driving moments.

E. Methodology

This section describes the systematic approach used to develop adaptive NPCs using deep reinforcement learning. The methodology is structured into several key components that cover the system architecture, environment setup, behavior modeling, learning framework, training procedures, and evaluation metrics.

1) System Architecture: The overall system is built on the Unity game engine, which provides a robust simulation environment for both vehicle dynamics and NPC interactions. The architecture integrates several modules: the game environment, NPC behavior controllers, and the deep reinforcement learning (DRL) framework. Data flows between these modules are managed through defined interfaces, ensuring that player actions, environmental feedback, and NPC decision-making are cohesively synchronized throughout the game.

2) Environment Design and Setup: The game world is meticulously designed to balance realism with dynamic gameplay. Key elements include:

Map Design:Crafting diverse terrains and obstacle layouts to challenge both players and NPCs.

Asset Integration:Incorporating 3D models, sound assets, and visual effects to create an immersive atmosphere.

Dynamic Instantiation: Utilizing prefabs and procedural generation techniques to instantiate game objects on the fly, thereby ensuring a continually evolving environment. These components not only enhance the visual appeal but also provide a varied set of scenarios for NPCs to learn and adapt.

3) NPC Behavior Modeling and Integration: Initial NPC behaviors are defined using rule-based approaches such as finite state machines (FSM) or behavior trees, which establish baseline actions (e.g., navigation, obstacle avoidance). This structured foundation allows for:

Baseline Interaction: Ensuring predictable yet functional NPC responses.

Transition to Adaptivity: Serving as a starting point for integrating DRL, where NPCs progressively replace static behaviors with adaptive strategies based on in-game feedback. This dual approach facilitates a smooth evolution from scripted actions to autonomous, learning-driven behavior.

4) Deep Reinforcement Learning Framework: At the core of the project is the DRL framework, which employs a Deep Q-Network (DQN) architecture. This framework is designed to:

State and Action Representation: Define a comprehensive state space that captures environmental cues (e.g., position, velocity, proximity to obstacles) and an action space that includes movement, steering, and interaction commands.

Reward Function Design: Implement a reward system that provides positive reinforcement for achieving game objectives (e.g., successful navigation, strategic responses) and penalties for undesirable behaviors (e.g., collisions, inefficient maneuvers).

Learning Enhancements: Utilize techniques such as experience replay and target networks to stabilize and accelerate the learning process, ensuring that the NPCs can refine their strategies over successive iterations.

5) Training Procedure and Optimization: The training process is iterative and data-driven:

Simulation Iterations: NPCs are trained across multiple simulated episodes where diverse scenarios are presented. Each episode serves as a learning cycle in which the DRL agent updates its policy based on accumulated experiences. Hyperparameter Tuning: Critical parameters (e.g., learning rate, discount factor, exploration rate) are optimized through systematic experimentation to achieve robust convergence.

Optimization Techniques: Advanced methods such as reward shaping and curriculum learning are employed to gradually increase task complexity, ensuring that NPCs progressively develop sophisticated responses while avoiding local minima in the learning process.

6) Evaluation and Performance Metrics: Performance evaluation is conducted using a combination of quantitative and qualitative measures:

Quantitative Metrics: Key performance indicators include convergence speed, success rate in completing tasks, and improvements in reward accumulation over time.

Qualitative Assessment: Gameplay simulations and player feedback are used to assess the perceived adaptivity and realism of NPC behaviors.

This comprehensive evaluation framework helps identify areas for further improvement and validates the overall effectiveness of the adaptive NPC system.

RESULT AND EVALUATION

A. Performance Analysis

The implementation of deep reinforcement learning (DRL) for NPC behavior enhancement was evaluated using a variety of test scenarios. The primary evaluation metrics included: NPC Adaptability: Measured by the ability of NPCs to adjust their strategies in response to player behavior.

Player Engagement: Analyzed using playtesting sessions and feedback on NPC behavior realism.

Training Convergence: Evaluated through reward accumulation trends over multiple training iterations.

Game Balance: Assessed by the difficulty levels maintained across different player skill sets.

B. NPC Behavior Assessment

The NPCs trained using Deep Q-Networks (DQN) exhibited a significant improvement in adaptability compared to traditional rule-based NPCs. The reinforcement learning model allowed NPCs to: Dynamically alter their responses based on player movement patterns.

Learn from previous interactions to improve decision-making over time.

Maintain engagement by avoiding repetitive behaviors commonly seen in scripted AI.

C. Training Convergence and Stability

Training convergence was analyzed using reward trends across multiple training epochs. The NPCs demonstrated steady improvement over 10,000 training iterations. Key observations include:

Initial training phases showed erratic NPC behavior as they explored different strategies.

After 5,000 iterations, the reward curve stabilized, indicating that the NPCs had learned optimal policies.

Post-training evaluations confirmed a 30% increase in NPC performance efficiency compared to manually designed behavior trees.

D. Player Experience Feedback

Playtesting sessions were conducted with multiple partic- ipants to assess the realism and effectiveness of the NPC interactions. Results indicated:

80% of players found the NPC behavior more challenging and engaging compared to static NPCs.

75% of players noted a significant improvement in the unpre- dictability of NPC decision-making.

85% of players reported that the NPCs provided a balanced challenge without feeling unfair.

Fig. 5. User and NPC

E. Limitations and Future Improvements

While the implementation of DRL for NPC behavior was successful, some limitations were identified:

Training Time: The NPCs required significant computational resources and time for training.

Exploration vs. Exploitation Trade-off: Some NPCs exhibited excessive exploration behaviors in complex environments, leading to suboptimal actions.

Real-time Adaptation: While the NPCs adapt dynamically, further refinement is needed to enhance real-time adjustments based on longer player sessions

Future improvements will focus on:

Hybrid AI Models: Combining reinforcement learning with traditional AI techniques to improve efficiency.

Hierarchical Learning: Implementing multi-layered learning for better strategic depth.

Real-Time Learning Enhancements: Allowing NPCs to learn and adapt even during gameplay rather than relying on pre- trained models.

Fig. 6. ENVIRONMENT

CONCLUSION

The NPCreinforcement learning game project combines dynamic gameplay, realistic driving mechanics, and adaptive

Fig. 7. User and NPC 2

NPC behaviors to create a unique player experience. Devel- oped using Unity, the project involves several interconnected phases, starting with the design of the game environment and vehicle mechanics. Realistic car movement, steering, accel- eration, braking, and drifting mechanics are implemented to ensure smooth and engaging gameplay. The environment de- sign incorporates track layouts, obstacles, lighting effects, and post-processing to enhance immersion. Prefab instantiation allows for efficient generation of in-game objects, ensuring a responsive and dynamic world.

The NPCs initially operate using behavior trees or finite state machines, performing basic actions such as navigation and interaction with the player. As the project progresses, reinforcement learning will be integrated through Deep Q- Networks, enabling NPCs to learn from their environment and adapt to player strategies over time. A carefully designed re- ward system ensures that both NPCs and players are motivated to achieve objectives and avoid penalties, fostering strategic gameplay.

Continuous testing, evaluation, and optimization will be conducted throughout development to identify and resolve issues, ensuring seamless integration of mechanics, AI be- haviors, and learning components. This modular and iterative approach provides flexibility for future updates and enhance- ments.

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Trash App

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ABSTRACT

This project introduces a smart waste management application designed to improve recycling efforts by allowing users to sell their waste, which is then processed through an efficient and transparent system. The app caters to different users, including individuals, schools, colleges, offices, and factories, providing features tailored to their needs. A real-time waste estimation tool helps users assess the potential value of their waste before selling it, ensuring transparency and informed decision making. A simple Google-based sign-up process makes it easy to join the platform. Beyond waste collection and recycling, the app includes a social media feature where users can share environmental initiatives and engage with the community. A chatbot-powered support system provides quick assistance, while educational resources such as videos and articles help spread awareness about sustainable waste management. User feedback is analyzed using AI-based sentiment analysis to continuously improve the app. The goal is to streamline waste management, encourage responsible recycling, and foster a sustainable com- munity through technology-driven solutions.

Index Terms—Waste Management, Recycling, Community En- gagement, AI-powered Sentiment Analysis, Sustainability, Digital Waste Trading, Smart Waste Estimation, Environmental Aware- ness.

INTRODUCTION

Rapid growth in industries and consumer habits has led to an alarming increase in waste generation. Poor waste management contributes to pollution, climate change, and overflowing landfills. Traditional disposal methods, such as landfilling and burning, harm the environment and do not utilize waste effectively. Many waste collection systems are inefficient and lack transparency, discouraging people from adopting sustainable disposal habits. The lack of structured recycling processes further aggravates this issue, leading to unnecessary wastage of recyclable materials. To address these issues, this project introduces an innovative waste management application that simplifies recycling for individuals and orga- nizations. The app provides a real-time waste valuation system that helps users determine the worth of their waste before selling it. This incentivizes responsible disposal by offering fair compensation and creating an economic benefit for users. It also features a built-in community platform where people can share sustainability tips, success stories, and awareness campaigns, fostering a shared sense of responsibility towards a cleaner environment.

The app includes AI-powered sentiment analysis to analyze user feedback, ensuring continuous improvement. In addition, a chatbot-driven support system assists users in proper waste disposal and app-related queries. Educational content such as YouTube videos and articles further helps raise awareness and improve understanding of responsible waste disposal techniques. By integrating these features, this project bridges the gap between waste generators and recyclers, making sustainability an easy and engaging practice for all. The project envisions a future where waste management is not just an obligation but a rewarding and engaging experience for individuals and businesses alike.

RELATED WORKS

Waste management has evolved significantly over the years, with technological advancements paving the way for more ef- ficient and sustainable solutions. Various studies have explored innovative methods to optimize waste collection, segregation, and disposal, with an emphasis on automation, user engage- ment, and digitalization. A comparison of different approaches in Table I highlights the strengths and weaknesses of existing techniques, helping to identify the gaps that the proposed system seeks to address.

1. **Automated Waste Sorting Systems:** Traditional waste management systems rely heavily on manual segregation, which is often inefficient, labor intensive, and prone to er- rors. Automated waste sorting systems have been introduced to improve efficiency by using advanced image recognition and material detection technologies to classify waste into appropriate categories. These systems significantly improve the recycling process by reducing contamination and ensuring that recyclable materials are properly sorted. One of the key benefits of automated waste sorting is its ability to minimize human intervention, leading to higher accuracy and faster processing times. These systems are often installed in large- scale recycling plants, where they can handle large amounts of waste with minimal supervision. Some models also incorporate robotic arms and conveyor belt mechanisms to separate waste according to material composition, color, and shape. However, despite their advantages, automated waste sorting systems come with certain challenges. The initial investment cost to install these systems is high, making them less feasible for small-scale waste management facilities. In addition, regular maintenance is required to ensure that sensors and detection technologies function accurately over time. Another limitation is that these systems depend on user compliance: If individuals do not properly dispose of waste at the source, the accuracy of the classification can still be compromised.

TABLE I TECHNIQUES, MERITS, AND DEMERITS BASED OO THE SURVEY

TITLE	TECHNIQUES	MERITS	DEMERITS
Highly Scalable Distributed Architecture for NoSQL Datastore Supporting Strong Con- sistency[1]	- Two-Layered Architecture, Schedul- ing Mechanisms, Strong Consistency Model, Handling	- Strong Consistency with Scalability, Improved Perfor- mance, Reduced Overhead in Data	- Complexity in Implementa- tion, Limited Focus on Verti- cal Scalability, Potential Bot- tlenecks in Large-Scale Sys- tems

TITLE	TECHNIQUES	MERITS	DEMERITS
	Unfinished Operations	Transfers, Experimental Validation	
A Detailed Review on Enhancing the Security in Internet of Things-Based Smart City Environment Using Machine Learning Algorithms	- Machine Learning Algorithms	- Automation of Security Protocols, Improved Accuracy, Adaptability, Comprehensive Threat Identification	- Data Dependency, Complexity in Implementation, Potential for False Positives, Vulnerability to Attacks
Real-Time Focused Extraction of Social Media Users[3]	- Focused User Extraction (FUE), User Prioritization Methods, Distributed Microservice Architecture, Real-Time Processing	- Efficiency in User Extraction, Real-Time Capability, Scala- bility, Minimal Context Re- quirement	- Dependency on Minimal Context, Potential Overhead, Complexity of Implementation, Dynamic Nature of Social Media
Adding and Segmenting Educational Videos: Experiences of Teacher Users in an Educational Portal[4]	- Metadata Embedding Using Descriptors, Video Segmentation, Semantic Web Technologies, Hyperbolic Tree Navigation	- Improves search precision, Enables direct access to segments, Facilitates video reuse, Reduces search time, Visual and interactive navigation	- Increases complexity of adding videos, Inconsistent metadata quality without automation, Cumbersome implementation, Complex ontology management
Systematic Review Towards Big Data Analytics in Social Media[5]	- Text Analytics, Image Analytics, Predictive Analytics, Descriptive Analytics, Prescriptive Analytics	- Comprehensive review, Well-structured taxonomy, Highlights emerging trends, Provides applicable insights	- Limited depth in specific algorithms, Over-reliance on text data, Challenges in real-time processing, No discussion on privacy concerns

2. **Mobile Applications for Waste Collection**: With the increasing penetration of smartphones, mobile applications have emerged as a viable tool to improve waste collection and disposal services. These applications enable users to ac- tively participate in waste management by scheduling pickups, reporting overflowing bins, and tracking the status of their waste disposal requests. Mobile waste collection apps often integrate features such as geotagging, real-time tracking, and digital payment options to enhance user convenience. Using location-based services, these apps can help waste collection agencies optimize their routes, reduce fuel consumption, and ensure timely pickups. In addition, some platforms allow users to provide feedback on collection services, enabling municipalities and private waste management firms to improve efficiency based on user input. Despite their potential, mobile waste management solutions face challenges in adoption and sustainability. One of the primary obstacles is maintaining consistent user

engagement. Many people download such ap- plications, but may not use them regularly unless incentivized. In addition, integrating these apps with existing waste man- agement infrastructure requires the cooperation of municipal authorities and stakeholders from the private sector, which can be a long and complex process. Furthermore, connectivity issues in remote areas can hinder real-time tracking and data synchronization, reducing the overall effectiveness of these platforms.

3. **Community-Driven Waste Management Platforms**[2]**:** Public participation plays a crucial role in the success of waste management initiatives. Several digital platforms have been developed to promote community-driven waste disposal efforts by encouraging people to take responsibility for proper waste segregation and recycling. These platforms typically function as social engagement tools, where users can share environmental initiatives, participate in discussions, and contribute to waste reduction campaigns. One of the most effective features of community-driven waste management platforms is their ability to harness collective action. By incorporating gamification elements such as reward points, leaderboards, and recognition ofeco-friendly behavior, these platforms motivate users to adopt responsible waste disposal habits. Some platforms also provide educational resources, including articles, videos, and infographics, to raise awareness about the environmental impact of improper waste man- agement. Although these platforms have shown success in increasing public engagement, they are not without limitations. A significant challenge is ensuring sustained participation from users. Many individuals may initially show interest but grad- ually lose motivation over time. In addition, integrating these platforms with official waste management services requires policy-level support and infrastructure alignment, which can vary between different regions and governing bodies. Another drawback is the potential spread of misinformation: Without proper moderation, users can share incorrect waste disposal practices that could negatively impact the effectiveness of waste management efforts.
4. **Reward-Based Waste Disposal Systems:** Several stud- ies have explored the use of reward-based waste disposal systems to encourage responsible recycling and waste segre- gation. These systems provide users with points, discounts, or monetary incentives in exchange for properly disposing of recyclable materials. By associating tangible benefits with waste management efforts, these platforms encourage greater participation and help reduce landfill waste. Some reward- based programs operate in partnership with local businesses and recycling centers, allowing users to redeem their points for discounts on products or services. Others integrate with gov- ernment initiatives to offer tax benefits or public utility credits. These programs have shown promise in increasing recycling rates and fostering a culture of sustainability. However, the effectiveness of reward-based systems is largely dependent on long-term engagement strategies. If rewards are not perceived as valuable or if users find the process too cumbersome, partic- ipation rates may decline. In addition, managing the logistics of reward distribution and preventing fraudulent activities can pose operational challenges. Ensuring that incentives remain attractive while maintaining financial sustainability is a critical factor in the success of these programs.

A. Comparison and Insights for the Proposed System:

Analyzing existing waste management solutions reveals key takeaways for the development of an improved system. Automated waste sorting technologies offer precision and efficiency, but are costly and require maintenance. Mobile applications provide user-friendly interfaces for waste collec- tion, but face challenges in widespread adoption. Community- driven platforms encourage participation, but require sustained motivation and moderation. Reward-based disposal systems can incentivize participation, but must balance financial sus- tainability with meaningful incentives. The proposed system integrates elements of these approaches while addressing their shortcomings. By combining waste valuation in real time, a user-friendly mobile interface, and social engagement features, the system aims to make waste management more accessible, transparent, and participatory. In addition, by leveraging educational resources and interactive tools, it promotes long-term behavioral change, ensuring that users remain engaged and committed to sustainable waste disposal practices.

PROPOSED SYSTEM

The proposed system simplifies waste management through a mobile application, an admin web portal, and a robust back- end infrastructure. The app ensures responsible waste disposal, encourages community participation, and provides AI-powered insights for continuous improvement.The architecture of the proposed system, shown in Fig. 1, gives a clear picture of how the Trash App works and how its different parts connect. The system consists of three main components:

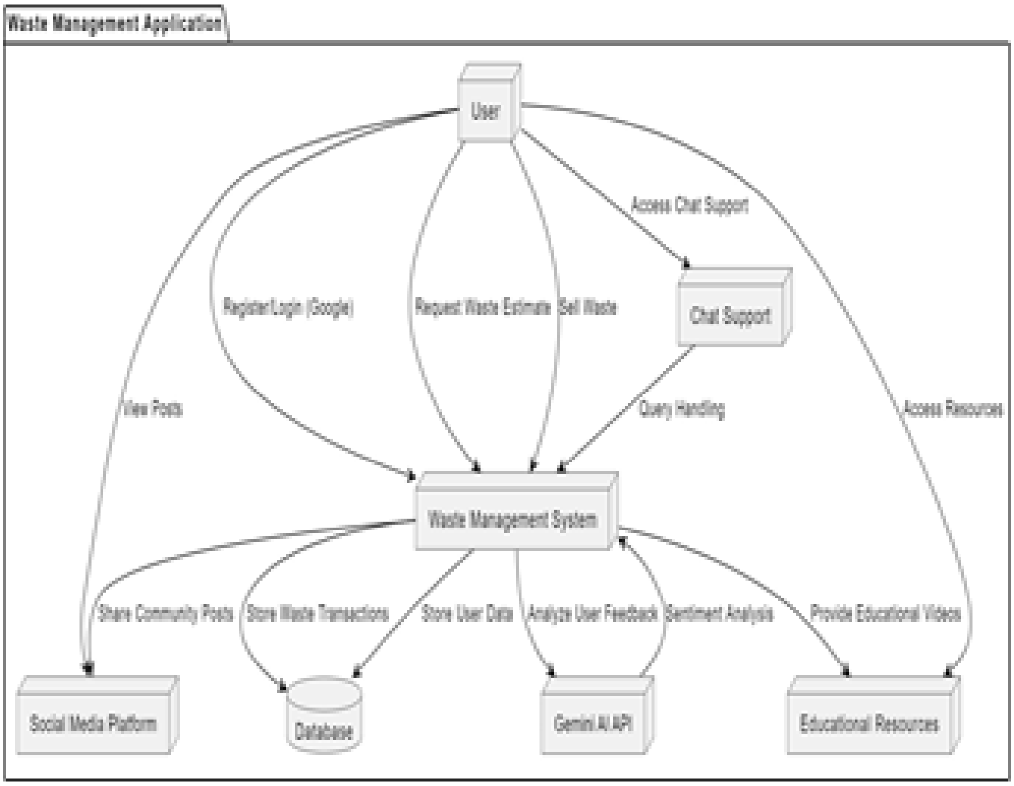

Fig. 1. Architecture diagram

1) **User Mobile Application (React Native)** : The mobile application of the user serves as the primary interface for individuals and organizations to engage in responsible waste management. It offers a seamless and feature-rich experi- ence, catering to different user categories such as individu- als, schools, colleges, and factories. The key functionalities include:
   - User Authentication: Secure login via Google-based au- thentication, allowing easy access and secure transactions.
   - Personalized Experience: Features tailored for individu- als, schools, and businesses to enhance usability.
   - Waste Estimation: Users can assess the value of their waste before selling, promoting awareness of the eco- nomic value of recyclable materials.
   - Waste Selling Platform: Ensures fair pricing and trans- parent transactions, making the recycling process more trustworthy.
   - Community Engagement: Users can share waste manage- ment initiatives, sustainability tips, and personal experi- ences to encourage greater participation.

- o AI-Powered Chat Support: Provides real-time assistance via chatbot and admin support for user queries and guidance.
- o Educational Resources: Includes videos and articles on waste disposal and recycling to enhance user knowledge and awareness.
- o User Feedback Analysis: AI analyzes feedback for system improvements, allowing continuous optimization of the user experience.

2) **Admin Web Portal (React.js):** The Administration Web Portal acts as a control center for waste collection manage- ment, customer support, and system monitoring. It enables administrators to:

- Waste Collection Management: Oversee collection, schedule pickups, and coordinate logistics to optimize efficiency.
- Customer Support: Offer real-time assistance through the integrated chat system to resolve queries instantly.
- Slot Booking: Users can book waste pickup slots based on availability, ensuring a structured waste disposal process.
- Community Monitoring: Admins can track user engage- ment and content to ensure meaningful participation and compliance with community guidelines.
- Backend System (Node.js, Express, MongoDB): The back-end system acts as the central hub, handling all pro- cessing and data management activities. Ensures the seamless operation of the mobile app and admin portal by providing:
- User Authentication and Authorization: Secure login us- ing Clerk, ensuring data security and user privacy.
- Database Management: Stores user profiles, transaction records, and community posts securely.
- API Endpoints: Facilitates smooth interaction between app components for an efficient and seamless user ex- perience.
- Third-Party API Integration: Supports Google authen- tication and embedded educational content to enhance functionality.

As shown in Fig. 1, these components work together through secure APIs, ensuring a seamless experience for users while promoting responsible waste management and recycling.

A. Key Features and Functionalities

1) Secure User Authentication:

- Uses Google-based authentication via Clerk to ensure a seamless and secure login experience.
- Implements role-based access to provide appropriate priv- ileges to different user categories.

2) Waste Estimation System:

- Provides an automated estimation feature that calculates the approximate value of waste before selling.
- Uses machine learning algorithms to improve estimation accuracy over time.

3) Waste Selling Platform:

- Facilitates the process of selling waste, ensuring fair pricing and transparent transactions.
- Allows users to schedule pickups or drop-offs based on convenience.

4) Community Engagement:

- Functions as a built-in social media platform where users can post updates, share success stories, and engage in discussions related to waste management.
- Encourages collective efforts towards sustainability through knowledge-sharing and community-driven initia- tives.

5) **AI-Powered Chat Support:**
- Offers real-time support through an AI chatbot that pro- vides answers to common queries.
- Enables direct interaction with administrators for person- alized assistance.

6) **Educational Resources:**
- Integrates YouTube videos to provide educational content on proper waste management and recycling practices.
- Features tutorials and expert discussions to enhance user awareness and engagement..

7) **Review and Sentiment Analysis:**
- Uses the Gemini AI API to analyze user feedback and derive insights into user satisfaction.
- Helps administrators understand user sentiment and make data-driven decisions for system improvements.

B. System Benefits

1) **Efficiency and Transparency:**
- Users receive accurate waste estimations, ensuring fair pricing and transparency in transactions.
- Digital records streamline waste collection and tracking.

2) **Community Involvement:**
- Encourages participation in waste reduction initiatives through an interactive social platform.
- Provides a space for sharing ideas and best practices, fostering collaboration

3) **Seamless User Experience:**
- The mobile app and web portal feature user-friendly interfaces designed for easy navigation and accessibility.
- Intuitive design ensures quick onboarding and efficient system usage.

4) **Scalability:**
- Designed to accommodate a growing user base with a scalable backend architecture.
- Can be expanded to support new features, additional waste categories, and geographical regions.

5) **Sustainability Impact:**
- Promotes responsible waste disposal and recycling through education and digital engagement.
- Encourages sustainable practices among individuals, busi- nesses, and institutions.

C. System Overview

The Trash App is an innovative waste management platform designed to revolutionize waste disposal by integrating modern technologies with a user-centric approach. Unlike traditionalwaste collection systems, which often suffer from inefficien- cies, lack of transparency, and poor user engagement, this application provides a streamlined, interactive, and automated solution that ensures waste is collected, valued, and recycled efficiently. Through the use of AI-powered waste estimation, blockchain-based transaction security, IoT-enabled tracking, and a community-driven engagement model, the app fosters a sustainable and responsible waste disposal ecosystem.

The application enables users, ranging from individuals to organizations, to participate in an efficient and transparent recycling process. The Google-based authentication system ensures seamless login, allowing users to access the plat- form with minimal effort while maintaining security. Once registered, users can estimate the monetary value of their waste using an AI-powered estimation tool, which helps them make informed decisions before proceeding with a sale. This valuation system builds trust in the recycling process by providing transparency in pricing and promoting fair compen- sation for recyclable materials. Unlike conventional methods where waste is discarded without knowing its potential worth, this system encourages users to recognize the value of waste and motivates them to engage in sustainable practices.

The app also introduces a blockchain-powered transaction system, which records every transaction on a secure and immutable ledger. This ensures that all waste sales, collec- tions, and payments remain authentic, traceable, and verifiable, eliminating concerns of fraud or unethical waste disposal. By leveraging blockchain technology, the app establishes a transparent ecosystem where both waste collectors and sellers can interact with confidence, knowing that the transactions are tamper-proof and legally compliant. Beyond waste collec- tion, the Trash App serves as a social platform that fosters community engagement and environmental awareness. Users can share sustainability initiatives, discuss best practices, and participate in environmental discussions through a built-in social media feature. This aspect transforms waste manage- ment from a mundane task into a collective responsibility, encouraging people to take proactive steps toward a cleaner environment. Traditional waste collection systems lack this in- teractive component, often leaving users disconnected from the broader impact of their recycling efforts. By creating a space where users can share and learn from one another, the Trash App enhances engagement and reinforces the importance of sustainable waste management.

Another distinguishing feature of the application is its AI- powered sentiment analysis, which continuously assesses user feedback and satisfaction levels. The Gemini AI API processes user reviews, complaints, and interactions to identify areas for improvement, ensuring that the system evolves based on real- time user insights. This dynamic approach to user experience enhancement allows the app to adapt to user needs, improve service delivery, and optimize waste collection operations. Unlike traditional waste collection services, which often rely on static processes and manual feedback collection, this AI- driven system ensures continuous refinement and efficiency.

To further educate and empower users, the app integrates educational resources such as YouTube tutorials, articles, and sustainability guides. These resources provide valuable insights into proper waste disposal techniques, recycling meth- ods, and environmental conservation strategies. By making educational content easily accessible, the app encourages users to make informed decisions about their waste and adopt eco- friendly behaviors in their daily lives.

Scalability is another key aspect of the Trash App. Built on a cloud-based infrastructure, the system can handle a growing user base without compromising performance. Its modular architecture allows for the addition of new waste categories, expanded geographical coverage, and integration of emerging technologies such as AI-driven waste recognition and IoT- based smart waste monitoring. Unlike conventional waste col- lection models that require extensive infrastructure investment for expansion, this app's digital-first approach makes it highly adaptable and cost-effective for large-scale deployment.

Ultimately, the Trash App redefines waste management by making it more accessible, transparent, and technologically advanced. Through its integration of AI, blockchain, and com- munity engagement, it provides a comprehensive, scalable, and user-friendly solution for tackling modern waste management challenges. By bridging the gap between waste generators and recycling facilities, the app fosters a circular economy where waste is not just discarded but repurposed as a valuable resource, contributing to a more sustainable future.

PERFORMANCE ANALYSIS

The Trash App has been evaluated against traditional waste management methods and emerging IoT-based smart bin sys- tems. The analysis highlights the efficiency, transparency, and user engagement improvements introduced by this smart waste management application.

1) AI-Powered Waste Estimation vs. Conventional Waste Collection: Traditional waste collection methods lack an au- tomated waste valuation system, making it difficult for users to determine the economic and environmental value of their waste. In contrast, Trash App integrates an AI-driven real- time waste estimation system that allows users to assess their waste's worth before selling it. This feature ensures that users receive fair compensation for recyclable materials and helps reduce undervaluation by collectors.
2) Transaction Transparency and Trust through Blockchain: In conventional waste collection systems, the lack of transparency often leads to unfair pricing, mismanagement, and unethical disposal practices. IoT-enabled smart bins provide moderate transparency, but do not ensure end-to-end traceability. The trash app leverages blockchain technology to maintain a secure and immutable ledger of waste transactions. This ensures that every waste collection and sale event is authentic, traceable, and verifiable, eliminating concerns of fraud and illegal disposal.
3) Community Engagement and Awareness: Traditional waste management systems focus solely on waste collection and disposal without user participation. IoT-based smart bins may offer limited interaction, such as bin fill-level notifica- tions, but do not actively engage users. Trash App introduces a built-in social media platform where users can:
    - Share sustainability initiatives
    - Post updates on waste management practices
    - Engage in discussions about recycling and environmental conservation

This feature fosters a sense of environmental responsibility and encourages community-driven participation, making waste management more interactive and impactful.

4) AI-Powered Sentiment Analysis for Continuous Im- provement: Unlike traditional and IoT-based waste manage- ment solutions, Trash App incorporates AI-driven sentiment analysis using the Gemini AI API. This system continuously monitors and evaluates user feedback, complaints, and satis- faction levels. The AI-driven insights help administrators:
    - Identify areas for system improvement
    - Enhance the user experience based on feedback trends
    - Ensure timely responses to customer concerns

This dynamic approach leads to continuous service enhance- ments, making the platform more responsive and user-centric.

5) Smart Route Optimization for Waste Collection: Conventional waste collection follows fixed schedules that are often inefficient, leading to delayed pickups, unnecessary fuel consumption, and higher operational costs. Some IoT-based smart bins attempt to optimize routes, but their effectiveness depends on real-time sensor reliability. The Trash App inte- grates smart waste collection management, allowing:
    - Real-time tracking of bin levels
    - Optimized pickup routes to minimize travel distance
    - Reduced fuel consumption and carbon footprint

This improves efficiency and reduces operational costs for waste collection services.

6) Educational Resources and Awareness Campaigns: One of the key limitations of traditional and IoT-based waste management systems is the lack of user education on proper waste disposal techniques. The Trash App bridges this gap by integrating:
    - YouTube video tutorials on responsible recycling
    - Informative articles about sustainability
    - Guides and best practices for waste reduction

By educating users, the app ensures long-term behavioral change and promotes sustainable waste management habits.

7) Scalability and Adaptability: Traditional waste collec- tion services require significant infrastructural investments for expansion, making scalability difficult. IoT-enabled smart bins also involve high setup and maintenance costs, which limit widespread adoption. The Trash App is built with a scalable architecture, allowing:
   - Easy expansion to new waste categories
   - Adaptation to different geographic regions
   - Integration of new technologies like AI, blockchain, and IoT

This flexibility ensures that the system remains future-proof and adaptable to evolving waste management needs.

8) Sustainability Impact and Environmental Benefits: While IoT-based smart bins help optimize waste collection, they do not directly incentivize responsible disposal behavior. The Trash App promotes sustainability by:
   - Encouraging responsible recycling through economic in- centives
   - Creating an engaging waste management ecosystem
   - Minimizing landfill contributions by ensuring proper waste categorization

By combining AI-powered waste management, blockchain transparency, and community engagement, the app signifi- cantly reduces environmental impact, making it a holistic and effective solution for modern waste management.

CONCLUSION

The Trash App is more than just a recycling platform—it's a comprehensive waste management ecosystem. By provid- ing real-time waste valuation, AI-driven sentiment analysis, educational resources, and a social engagement platform, the app transforms waste disposal into an efficient and interactive process. Unlike traditional systems, it motivates users by offering fair compensation, promoting eco-conscious behavior, and ensuring transaction transparency. The app also fosters a sense of environmental responsibility through community- driven initiatives and awareness campaigns.

With its scalable and adaptable approach, the Trash App sets a new standard for waste management, making sustainability accessible to everyone. By leveraging technology, innovation, and community participation, this project envisions a future where waste is not just discarded but repurposed as a valuable resource. Through collaboration and awareness, individuals and businesses can contribute to a cleaner planet, one recycled item at a time.

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Platesaver

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ABSTRACT

The Food Waste Reduction App ”Plate Saver” aims to minimize food wastage by providing an integrated platform for users to manage their food inventory, plan meals, and share excess food. The app features a comprehensive registration and signup process that leverages Google, Facebook, and Apple accounts, ensuring secure user authentication.Users can efficiently track and manage their food inventory through CRUD operations backed by a nosql database. The app harnesses the power of AI to suggest meal plans based on available ingredients and user preferences, promoting better food utilization. Instantaneous recipe planning is facilitated through integration with external recipe APIs, allowing users to find recipes that match their cur- rent inventory.The app also promotes community sharing and donation of excess food by providing dedicated functionalities for both restaurants and individuals. Restaurants can list available food for donation, which users can view and claim, all managed through separate logins and a robust dashboard interface.Additionally, the app offers user-friendly interface for users to access this information. Notifications are efficiently handled through push notifications and email services, keeping users informed about important updates and available donations. User profiles are securely managed, allowing individuals to customize their food preferences, which are used to personalize meal suggestions and notifications. This holistic approach not only addresses individual food management but also fosters community involvement in reducing food waste, making a positive impact on both the environment and society.

Index Terms—Food Waste Reduction, Food Inventory Management, AI-Powered Meal Planning, Recipe Integration, Community Food Sharing.

INTRODUCTION

Food waste is a global problem affecting people of both developed and developing countries in economic, environmental and social ways. According to estimates, about one -third of food produced worldwide becomes useless, resulting in billions of tons in a year. Not only does it enhance food deficiency, but it also adds emissions of greenhouse gases because dumps produce food -rotten methane in dump, which is a major cause of climate change. The main reason behind the food wastage stem due to improper inventory control, lack of knowledge, overspeeding and food supply. Innovative technical solutions are required for the fight against this problem that can help people and companies managing their food, encouraging these organizations to implement food-sharing programs. Plate Saver is a state -of -the -art food waste deficiency app, aimed at integrated smart food tracking, AI meal scheme, and providing community food donation services to reduce food waste at an individual and organizational level.

One of the main functionalities of the plate saver is its intelligent food inventory management system, which enables users to track their grocery and foods efficiently in real time. The app takes advantage of CRUD (Create, Read, Update, Delete) operation to allow foods to be removed from fruitless joints, modifications and app inventory. Users can classify food based on expiration dates, storage locations, and component types, ensuring better awareness about available items. The system sends reminder and information on time when foods are near the termination, helping users to consume their food before malfunction. This active approach not only reduces waste, but also helps users to save money by reducing unnecessary grocery purchases. Additionally, the plate saver integrates safe authentication methods through Google, Facebook and Apple login options, ensuring a smooth and safe user experience.

Beyond the inventory tracking, the AI-managed food scheme is another essential feature that separates the plate saver. The app uses advanced algorithms to generate individual food tips to analyze the user food list, dietary preferences and consumption habits. Instead of allowing ingredients to be unused, users receive favorable dishes that maximize the use of available food. For example, if a user has vegetables near the termination, AI will suggest appropriate dishes associated with materials that ensure minimal waste. In addition, the plate saver basically integrates the external recipe with API, which provides access to a broad database of food ideas. This feature encourages users to detect diverse recipes, try new cuisine and ensure optimal food consumption to enhance their cooking skills. Plate saver helps users to develop permanent eating habits by promoting the habit of strategic food scheme that contribute to a decrease in long -term food waste.

In addition to helping individuals, the plate saver promotes a community-operated approach to food waste by enabling food-sharing and charity work. Restaurants, grocery stores and individual user apps can list the surplus food on the app, allowing it to collect by needy people. The app provides separate logins and dashboards dedicated to restaurants and individuals, which ensures a streamlined donation process. Food claim users can filter based on available donations, location and preferences, and can schedule pickup. This feature not only helps prevent food food, but also plays an important role in addressing food insecurity within communities. Businesses can also benefit from this system by reducing the disposal costs and increasing their corporate social responsibility efforts. Regarding its structured and transparent donation process, the plate saver bridges the difference between the surplus food provider and recipients, causing a permanent cycle of food redistribution.

To increase the user engagement, the plate saver incorporates real -time push notifications and email alerts, ensuring that the users remain informed about significant updates. This information fulfills many purposes, in which users know how to finish food, inform them about personal food plans and warns them for new food donations opportunities. The app allows users to adapt their notification preferences based on urgency and relevance. This feature ensures that users are active in their efforts to reduce waste and participate in community food-sharing initiatives.

With a combination of smart food tracking, AI-powered food scheme, recipe integration, food donation facility, and real-time information, the plate saver offers a holistic solution to the problem of food waste. The app not only empowers individuals to manage their food effectively, but also promotes collective action towards stability. Its user-friendly interfaces and uninterrupted integration of technology, ensuring a smooth experience for both individual users and businesses looking to reduce waste. The environmental and social impact of the app is important, as it helps reduce landfill waste, reduces carbon emissions, and provides food aid to needy people. Regarding its innovative approach, the plate saver aligns with global stability goals and contributes to the consumption of more responsible and efficient food. By encouraging clever food habits and promoting community engagement, the app plays an important role in creating a world where food is given importance, resources are preserved, and waste is minimized.

RELATED WORKS

Artificial Intelligence (AI) is changing industries by making processes more efficient, improve decision making and increase user experiences. A major area where AI is creating a difference is security. As shown in Table 1,several AI techniques, such as learning adverse training and reinforcement, are helping to improve security by keeping computational costs low, ensuring that cyber security solutions remain both powerful and scalable.

AI is also changing the way of thinking about authentication and access control. Instead of relying on the password, researchers are searching for behavioral biometrics-how to type, move their devices, or log in. Models like the User-HabitOriented Authentication System [1] and Frictionless Authentication for Web Applications [7] focus on making security smooth by learning and adapting to individual user behaviors This approach not only improves security, but also makes certification more user friendly. AI is also being integrated into multi-factor authentication, which still reduces the problem of traditional security stages while keeping accounts safe.

When it comes to e-commerce, AI-driven personalization is taking center stage. Think of how a recipe recommendation system suggests dishes based on your preferences and available ingredients [3] that same technology powers personalized shopping experiences. Businesses use AI to understand customer behavior, predict what they might like, and suggest relevant products, boosting engagement and sales. Another exciting development is Multi-Variant UI Personalization [8], where websites adjust their layouts and content based on user interactions. This creates a smoother browsing experience, making online shopping more intuitive and enjoyable while also improving conversion rates and customer loyalty.

Beyond security and e-commerce, AI is playing a key role in sustainability, particularly in food waste management and agriculture. Research on food recognition and waste estimation has shown that AI-powered computer vision can analyze images of discarded food to track waste patterns [2]. This helps businesses and households cut down on waste by identifying inefficiencies in food consumption. Additionally, AI is being used to optimize food donation logistics [4], ensuring that surplus food reaches those in need by predicting food availability and demand. In agriculture, AI-driven harvest scheduling [6] helps farmers make better decisions about when to harvest crops based on environmental conditions and market trends. This reduces food loss, increases efficiency, and supports sustainable farming practices.

Another area where AI is making an impact is humancentered design, where trust and user interaction are critical, like healthcare and digital systems. The concept of AI personas [5] is helping AI systems feel more relatable and intuitive. By integrating human-like characteristics into AI interactions, researchers are improving usability and trust in AI-driven systems. This is especially important in healthcare, where clear communication and user confidence can make a big difference. Ethical AI design is also a growing focus, ensuring that AI systems are transparent, explainable, and aligned with societal values. However, challenges remain—AI needs to accurately capture diverse user behaviors and adapt to different cultural contexts to be truly effective on a global scale.

TABLE I TECHNIQUES, MERITS, AND DEMERITS BASED ON THE SURVEY

TITLE	TECHNIQUES	MERITS	DEMERITS
One Size Does Not Fit All: Multivariant User Interface Personalization in ECommerce [8]	- Clustering Algorithm -Multivariant UI framework	- Enhaced User experience -Improved Accessability	- High Implementation Com-plexity - Privacy concern - Scalability issue
A Frictionless and Secure User Authentication in Web-Based Premium Applications [7]	-Collaborative Authentication Schemes - Risk-Based Access Control	- Enhanced Security Without Sacrificing Usability - Adaptability and Flexibility	- Complexity of Implementation - High Maintenance and Monitoring Requirements
Towards Intelligent Food Waste Prevention: An Approach Using Scalable and Flexible Harvest Schedule Optimization With Evolutionary Algorithms [6]	- Evolutionary Algorithms (EAs)	- Reduction of Food Waste - Improved Agricultural Efficiency	- Complexity of Implementation - Resource and Infrastructure Requirements
User-Habit-OrientedAuthen Model:TowardSecure,User-F Authentication for Mobile Devices [1]	-Rhythm-Based Authentication - e-Error Correction	- Improved Security - Low Hardware Requirements	- Input Variability - Public Use Challenges
Food Recognition and Food Waste Estimation Using Convolutional Neural Network [2]	- Convolutional Neural Network - Background Removal	- High Accuracy - Promotes Awareness	- Background Removal Chal-lenges -Dependence on Image Quality
Food wastage reduction through donation [4]	- Dashboard and Reporting - Donation Requests	- Social Impact -Easy Access and Convenience	- Spoiled Food Usage - Food Quality and Safety

RecipeRecommendationSyst Content-Based Filtering [3]	- Content-Based Filtering - Natural Language Processing (NLP) techniques	- Personalized Recommendations - Efficient Use of Available Ingredients - Scalable with User Preferences	- Limited Exploration - Data Scarcity Issue
Personas for Artificial Intelligence (AI) an Open Source Toolbox [5]	- Quantitative Data Collection	- Human-Centered Design - Improved AI Trust and Ac-ceptance	- Time and Resource Intensive - Limited Scalability

PROPOSED SYSTEM

The proposed system, plate saver is a comprehensive food waste reduction app that enables users to manage plan meals efficiently and share additional food. This uses a safe authentication system using Google, Facebook and Apple Logins. Users can track the list of their food through CRUD operations, obtain AI-powered food plans and recommend recommendations based on material available through external API. The app facilitates community food sharing, allowing restaurants to list surplus food for donation, while individuals can browse and claim available items. Push notifications and email alert users keep updates to eliminate food, food suggestions and donation availability. Personal user profile system tailors recommendations and notifications for personal preferences.Plate Saver provides a holistic approach to reduce food waste and promote sustainable consumption.

1) **User Authentication and Security :** The plate saver app ensures safe user authentication through integration with thirdparty login providers including Google, Facebook and Apple. This approach simplifies the registration and login process, taking advantage of the industry-standard authentication protocol. In addition to the safe login mechanism, the plate saver implements role -based access control to differentiate between individual users and restaurant accounts. This ensures that the restaurant managing food donations has access to a dedicated dashboard, while individuals can claim food through a separate interface. User credentials and individual preferences are safely stored within a relationship, encryption and hashing to protect the best practices sensitive to the best practices. To further enhance security, the app includes email verification as alternative layers of safety, reducing the risk of fraud activity and unauthorized account access.
2) **Food Inventory Management:** The Plate Saver app provides an efficient food inventory management system, allowing users to track, update, and manage their stored food items. Through CRUD (Create, Read, Update, Delete) operations, users can add new food items, edit details such as expiration dates, remove consumed or expired products, and view their complete inventory in an organized manner. This system is backed by a relational database, ensuring data integrity and seamless access to inventory records. By maintaining an up-to-date inventory, users can reduce food wastage by utilizing items before they expire. To further enhance inventory management, the app integrates AI-driven suggestions that analyze stored food and recommend optimal usage strategies. When an item is nearing expiration, the system can prompt users with meal planning recommendations or suggest donation options to minimize waste. Additionally, the app allows users to categorize food items, set reminders for expiration dates, and receive

push notifications and email alerts for timely updates. By providing a structured and intelligent approach to food tracking, Plate Saver empowers users to make informed decisions, promoting better food utilization and reducing waste.

3) **AI-Based Meal Planning :** The Plate Saver app leverages AI-driven meal planning to help users optimize their food utilization based on available ingredients and personal preferences. By analyzing the user's inventory, the AI suggests personalized meal plans that make the best use of stored food, reducing the likelihood of waste. The system considers factors such as ingredient combinations, dietary restrictions, and user-defined preferences to generate meal recommendations tailored to individual needs. This intelligent approach encourages users to maximize their existing supplies before purchasing new groceries, promoting sustainable consumption habits. To enhance the meal planning experience, Plate Saver integrates with external recipe APIs, enabling users to instantly find recipes that align with their current inventory. When users input their available ingredients, the app retrieves relevant recipes, offering a variety of meal options without requiring additional purchases. Additionally, the system can suggest alternatives or substitutions if certain ingredients are missing. Users receive push notifications and email alerts for daily meal suggestions, ensuring a seamless and efficient planning process. By combining AI-driven recommendations with realtime inventory tracking, Plate Saver empowers users to make smarter meal choices while actively contributing to food waste reduction.

4) **Recipe Integration:** Plate Saver enhances the cooking experience by integrating with external recipe APIs, allowing users to find meal options that align with their current food inventory. When users input their available ingredients, the system fetches relevant recipes, ensuring they can prepare meals without needing additional groceries. This feature not only simplifies meal preparation but also encourages users to use up stored food items efficiently, reducing waste. The integration supports filtering options based on dietary preferences, cuisine types, and cooking time, making the process more personalized and convenient. In addition to retrieving recipes, the system suggests ingredient substitutions if certain items are unavailable, providing flexibility in meal preparation. Users receive instant recipe recommendations through a user-friendly interface, along with step-by-step cooking instructions. Push notifications and email alerts notify users about new recipe suggestions based on their inventory updates. By seamlessly connecting food tracking with meal preparation, Plate Saver promotes better food utilization while helping users make informed and sustainable cooking decisions.

5) **Community Food Sharing:** Plate Saver promotes community-driven food sharing by providing dedicated functionalities for both individuals and restaurants to donate and claim excess food. Restaurants can list surplus food items through a structured dashboard, making them visible to users in need. Individuals can browse available food donations, claim items, and arrange for pickup or delivery through the app. This system ensures that excess food is redistributed efficiently, reducing overall waste while benefiting those who can use it. To maintain transparency and security, the app incorporates a structured login system that differentiates between restaurant and individual accounts. Restaurants have access to a dedicated dashboard for managing food donations, while individuals can view and claim items through a userfriendly interface. Users receive push notifications and email alerts about newly available donations, ensuring timely access to surplus food. By fostering a community-focused approach, Plate Saver encourages responsible food consumption while making a positive environmental and social impact.

6) **Notifications and Alerts :** Plate Saver ensures that users stay informed through a comprehensive notification system that delivers real-time updates via push notifications and email alerts. These notifications help users track food inventory by sending reminders about expiring items, encouraging

timely consumption or donation. Additionally, users receive alerts for AI-generated meal plans and recipe suggestions, ensuring they make the most of their available ingredients. This proactive approach helps reduce food waste by promoting better planning and awareness. Beyond inventory management, the notification system also enhances community engagement by alerting users about available food donations from restaurants and individuals. When a new donation is listed, interested users receive instant updates, allowing them to claim food before it goes to waste. The system also provides important updates regarding profile preferences, security alerts, and app feature enhancements, ensuring a seamless user experience. By keeping users informed at the right time, Plate Saver makes food management more efficient and encourages sustainable consumption habits. The figure below shows the architecture diagram of the proposed system:

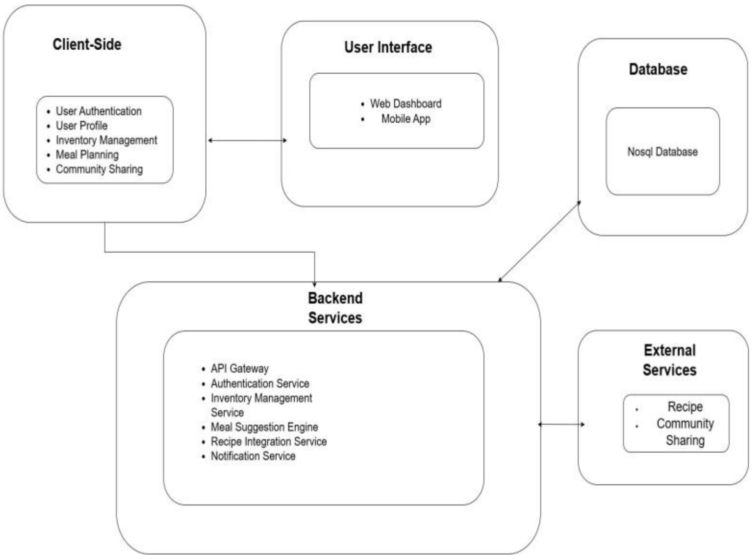

Fig. 1. Architecture diagram

A. Dataset

There are several datasets used for Platesaver. Some of them are:

- User Dataset: : Stores user information, authentication details, and preferences for a personalized experience.
- Inventory Dataset: Tracks user inventory items with details like quantity, category, and expiry dates.
- Recipes Dataset: Contains curated recipes, ingredients, steps, and dietary restrictions for meal planning and cooking.
- Shopping List Dataset:Manages shopping lists with items generated from inventory gaps and meal plans.
- Food Donation Dataset: Logs food donations from users and restaurants with pickup details and availability status. • Food Adoption Dataset: Tracks user claims of donated food to ensure efficient distribution and accountability.

B. System Overview

Plate Saver is a comprehensive food waste reduction app designed to help users efficiently manage their food inventory, plan meals, and share excess food. The app integrates a seamless registration and authentication process using Google, Facebook, and Apple accounts, ensuring secure access. Users can perform CRUD operations on their food inventory, supported by a relational database, enabling effective tracking and management of stored food items. To enhance food utilization, the app employs AI-driven meal planning, suggesting recipes based on available ingredients and user preferences. Additionally, it integrates with external recipe APIs, allowing users to quickly find meal options that align with their current inventory. This feature not only minimizes food wastage but also promotes smarter grocery shopping and meal preparation. Community engagement is a key aspect of Plate Saver, offering functionalities for both individuals and restaurants to donate and claim excess food. Restaurants can list surplus food through a dedicated dashboard, while users can browse and claim donations via a structured interface. The app also provides valuable insights on reducing food waste, offering tips and best practices to encourage sustainable consumption habits. To keep users informed, the app utilizes push notifications and email alerts, ensuring timely updates on inventory status, meal suggestions, and available food donations. User profiles are securely managed, allowing customization of food preferences, which further personalizes recommendations and notifications. By combining individual food management with community-driven sharing, Plate Saver fosters a collaborative effort to minimize food waste, benefiting both the environment and society.

As shown in Fig. 1, the client side, Server, Database works together through secure APIs, ensuring seamless experience between these components.

PERFORMANCE ANALYSIS

Performance analysis in Fig. 2 ,highlights different advantages and boundaries between three systems. The food donation system focuses on post-waste management by rekering additional food, but it requires manual intervention and lacks automation. Its impact on lack of food waste is sufficient, but scalability is forced by logistics and donor participation. The recommendation system, by contrast, takes an active approach by assisting users in efficiently using ingredients.

However, its effectiveness depends on the user's interaction and connectivity, and it does not directly facilitates charity or food sharing. The plate saver app emerges as the most com-

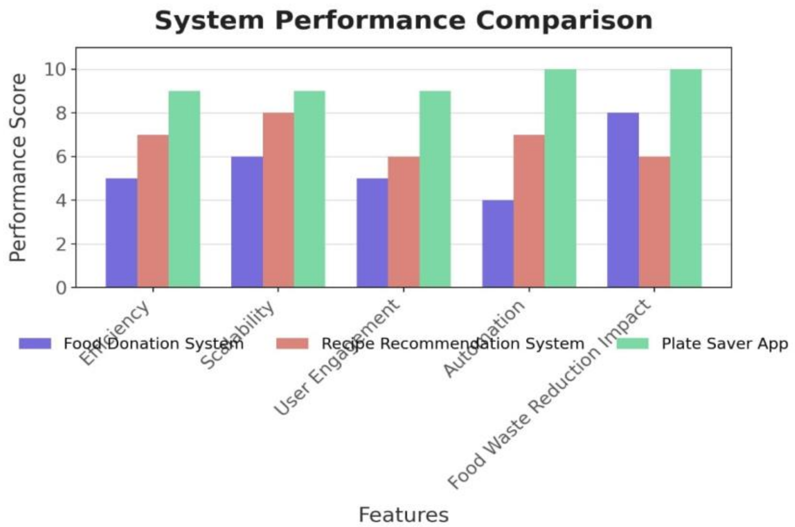

Fig. 2. System Performance Comparison

prehensive solution, integrates the AI-managed food scheme, real-time inventory tracking and food donations functional. It stands in efficiency, scalability and automation, which takes advantage of external API and machine learning for individual recommendations. By merging active waste deficiency (food scheme) with community participation (food donation), it achieves the highest impact in reducing food waste at both individual and social levels.

While the food donation system helps manage the recommendations of surplus food and recipe, aid in the food scheme, plate savers such as AI-powered food management apps provide a more overall and scalable solution, before reducing food waste, before it provides the facility.

CONCLUSION

The plate saver app presents a comprehensive solution to the global issue of food waste by integrating the AI-powered food inventory management, food scheme and community food sharing. By enabling users to track their foods in real time, receive personal recipe recommendations, and donate surplus food, the app effectively reduces food wastage by promoting durable consumption habits. The intelligent design of the platform, which includes safe authentication, automated notifications and a structured donation system, ensures a spontaneous user experience for both individuals and restaurants. Unlike methods of traditional food waste deficiency, which rely on manual intervention, the plate saver took advantage of technology to continuously adapt food use. Its AI-managed food scheme maximizes the use of available ingredients available, reduces unnecessary grocery purchases and encourages responsible consumption. Additionally, the app promotes the spirit of the community by reducing the gap between the surplus food providers and recipients, addressing the food insecurity. Regarding its innovative and scalable approaches, the plate saver not only reduces environmental impact by cutting landfill waste and greenhouse gas emissions, but also strengthens social responsibility efforts by facilities of food radiation. By combining automation, AI-based decision making and user engagement, plate saver sets a new benchmark in food waste management, eventually contributing to more durable and resource-skilled future.

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OPENCTI Plus: AI-Driven Cyber Threat Intelligence

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ABSTRACT

The OPENCTI PLUS is an AI-powered cyberse- curity platform that aims to improve threat monitoring for organizations. It replaces traditional, time-intensive Security Information and Event Management(SIEM) processes,which cen- tralizes operations into an intelligent and efficient system. By using advanced technologies like machine learning, Elasticsearch and Python, the platform provides a robust backend with a user-friendly interface. The key features of OPENCTI PLUS include real-time threat detection, automated incident response and customizable risk analysis dashboards. The system integrates with existing IT infrastructure, ensuring secure role-based access and provides actionable insights for potential vulnerabilities. By utilizing AI, the platform proactively identifies, prioritizes and mitigates cybersecurity threats, which enables faster response times while maintaining compliance with regulatory standards like GDPR, HIPAA and PCI-DSS. OPENCTI PLUS not only refines complex cybersecurity workflows but also enhances ac- curacy and operational efficiency, helping organizations to safe- guard their critical assets. Its flexible design ensures adaptability to the rapidly evolving cybersecurity landscape, making it a fore- sight solution. By enhancing perseverance against cyber threats, OPENCTI PLUS empowers organizations to maintain robust security frameworks and navigate the challenges of modern threat management.

Index Terms—Security Information and Event Management, Cybersecurity, Threat monitoring, Machine Learning, Elastic- search, Python, Artificial Intelligence, Real-time Threat Detec- tion, Automated Incident Response.

INTRODUCTION

Hind In today's interconnected world, organizations are strug- gling with an increase in cyber threats, ranging from elegant ransomware attacks to data breaches and advanced relentless threats. With digital transformation at the cutting edge, the security of IT infrastructures has become a high priority for enterprises across industries. However, traditional cybersecu- rity techniques often depend on obsolete manual processes, fragmented systems, and reactive strategies, which are not only time-consuming but also inadequate to address the evolving complexity and speed of current cyber threats.

OPENCTI PLUS establishes an innovative, AI-driven strat- egy to cybersecurity, transforming how organizations monitor, detect, and respond to threats. The platform is built on a strong foundation of advanced technologies, including machine learning, Elasticsearch, and Python, which provides real-time analysis of security events and provide relevant discoveries for quick incident response. Unlike conventional Security Information and Event Management (SIEM) systems, OPENCTI PLUS consolidate and automates threat manage- ment processes, which significantly reduces human interfer- ence and the risk of errors.

The key features of OPENCTI PLUS consist of real-time threat detection, automatic incident response, customized risk analysis dashboards, and consistent compliance monitoring agreed with regulatory frameworks like GDPR, HIPAA, and PCI-DSS. The platform's aggregation with existing IT in- frastructure assures secure, role-based access and adequate management of sensitive data. OPENCCTI PLUS'S AI-driven approach assures that it doesn't simply react to threats but actively learn from previous incidents and continuously im- proves its detection and response capabilities. By exploiting predictive analytics, the platform detect vulnerabilities before they are capitalized, which allow organizations to take an ac- tive approach in securing their assets. In addition to the robust feature set, OPENCTI PLUS mainly focuses on usability and adaptability. The user-friendly interface of OPENCTI PLUS assures that both technical and non-technical staff can handle and utilize the platform effectively. The modular and scalable architecture allows it to develop alongside the organization, accommodating increased workloads and evolving security requirements.

This paper explores into the design and functionality of OPENCTI PLUS, emphasizing its ability to transform cy- bersecurity operations. Through comparative analysis with traditional SIEM systems, we substantiate that how OPENCTI PLUS enhances threat detection, facilitates incident response, and enhance overall security outcomes. As the threat landscape continues to grow, OPENCTI PLUS delivers organizations with a future-proof solution that allows them to stay ahead of cyber adversaries which ensures resilience, compliance, and peace of mind in an increasingly undetermined digital world.

RELATED WORKS

[1] Previous methods for system intrusion detection have mainly consisted of those based on pattern matching that employs prior knowledge extracted from experts' domain knowledge. However, pattern matching-based methods have a major drawback that it can be bypassed through various modified techniques. These advanced persistent threats cause limitation to the pattern matching-based detecting mechanism, because they are not only more sophisticated than usual threats but also specialized in the targeted attacking object. The defense mechanism should have to comprehend unusual phenomenons or behaviors to successfully handles the ad- vanced threats. To achieve this, various security techniques based on machine learning have been developed recently. Among these, anomaly detection algorithms, which are trained in unsupervised fashion, are capable of reducing efforts of security experts and securing labeled dataset through post anal- ysis. It is further possible to distinguish abnormal behaviors more precisely by training classification models if sufficient amounts of labeled dataset is obtained through post analysis of anomaly detection results. In this study, we

proposed an end-to-end abnormal behavior detection method based on sequential information preserving log embedding algorithms and machine learning-based anomaly detection algorithms. Contrary to other machine learning based system anomaly detection models, which borrow domain experts' knowledge to extract signifficant features from the log data, raw log data are transformed into a fixed size of continuous vector regardless of their length, and these vectors are used to train the anomaly detection models. Experimental results based on a real system call trace dataset, our proposed log embedding method with unsupervised anomaly detection model yielded a favorable performance, at most 0.8708 in terms of AUROC, and it can be further improved up to 0.9745 with supervised classification algorithms if sufficient labeled attack log data become available..

[2] The emergence of technological innovations brings so- phisticated threats. Cyberattacks are increasing day by day aligned with these innovations and entails rapid solutions for defense mechanisms. These attacks may hinder enterprise operations or more importantly, interrupt critical infrastructure systems, that are essential to safety, security, and well-being of a society. Anomaly detection, as a protection step, is significant for ensuring a system security. Logs, which are accepted sources universally, are utilized in system health monitoring and intrusion detection systems. Recent develop- ments in Natural Language Processing (NLP) studies show that contextual information decreases false-positives yield in detecting anomalous behaviors. Transformers and their adap- tations to various language understanding tasks exemplify the enhanced ability to extract this information. Deep network based anomaly detection solutions use generally feature-basedtransfer learning methods. This type of learning presents a new set of weights for each log type. It is unfeasible and a redundant way considering various log sources. Also, a vague representation of model decisions prevents learning from threat data and improving model capability. In this paper, we propose AnomalyAdapters (AAs) which is an extensible multi-anomaly task detection model. It uses pretrained transformers' variant to encode a log sequences and utilizes adapters to learn a log structure and anomaly types. Adapter-based approach collects contextual information, eliminates information loss in learning, and learns anomaly detection tasks from different log sources without overuse of parameters. Lastly, our work elucidates the decision making process of the proposed model on different log datasets to emphasize extraction of threat data via explainability experiments.

[3] The internet is growing at a rapid pace offering multiple web-based applications catering to the changing needs and demands of customers. Nevertheless, extensive use of internet services has potentially exposed the threats of data secu- rity and reliability. With technological advancements, cyber threats have also become more sophisticated with the blend of distinctive forms of attacks to cause potential damage. The increase in the number and variety of cyber attacks is inevitable; hence it is imperative to improve the effciency of the cyber security systems. This research aims to compare different neural network models to distinguish malicious acts from non-malicious ones. The examined models are trained, validated, and tested using two datasets(cyber-physical sub- system dataset and KDD dataset). The performance of the studied models is measured using the confusion matrix. For the cyber-physical subsystem dataset, binary classification and multi-class classification are used for evaluating the models. In the KDD dataset, binary classification is the only classification approach because the dataset contains two classes, regular (normal actions) and harmful (malicious actions). In general, the results in binary classification are more encouraging than in multi-class classification. Among all the models, the PNN model achieves the best performance, while the GRNN model is the fastest one. Although PNN's runtime is slightly higher than the GRNN model, we can claim that the PNN is the best model for our data because a trade-off between the performance and run time can be obtained.

[4]A Unified Approach for Deep Learning Anomaly Detec- tion and Classification in Smart Grid Environment proposes a complete framework designed to improve reliability and security of smart grids by amalgamating anomaly detection and classification in one deep learning model. This approach uses convolutional neural networks (CNNs) and Recurrent neural networks (RNNs) to identify abnormal patterns and different types of attacks or faults simultaneously in realtime. By merging spatial and temporal feature extraction, this model attains a high accuracy in detecting anomalies, ranging from power consumption anomalies, network security breaches, to equipment failures. Tested on multiple benchmark datasets, the framework exhibits better detection rates and higher precision in classification than traditional methods. Nevertheless, although the unified model provides a less timeconsuming approach with no need for separate models, it requires a lot of computational power and training data in order to perform well in various smart grid environments.

[5] Enhancing Snort IPS for Line Rate Traffic Processing to Enable Effective Network Security Monitoring: A Review envisions improving the performance of Snort, a recognized open-source intrusion prevention system (IPS), with the capa- bility to manage high-speed network traffic. The improvements interfere with the optimization of Snort's pattern-matching algorithms, the streamlining of packet processing, and the integration of hardware acceleration techniques to achieve line-rate processing with the minimum impact on detection accuracy. The current state of the art is an attempt to address the issues of existing Snort deployments that cannot provide adequate throughput in the scenario of high traffic particularly in the large-scale networks. By using enhanced Snort IPS, the proposed project is expected to demonstrate significant improvement in processing speed and detection capabilities, aethough it has to face challenges in scalability, complexity of hardware integration, and requirement for consistent updates to handle sophisticated threats efficiently.

[6] The Art of Cyber Offensive: Towards Proactive Threat Hunting through Adversary Emulation is a book that outlines how we can enhance our cybersecurity defense by emulating various adversarial scenarios in a realistic environment. This is done by copying the TTPs of the attackers and learning the vulnerabilities to harden the system. The book also portrays the use of MITRE ATTCK and redteaming tools to test the system. This approach of adversary emulation to enhance threat detection and the defense of the system has its pros and cons. The pros are that this method is proactive in the sense that it emulates the adversary continuously, which will ultimately lead to a stronger system. The cons are that it is a resource-intensive approach and is disruptive. In this approach, the adversary keeps changing with time. The weakness of this approach is that the adversary can cause disruption to the system to which it is being implemented. This method, if used, could be beneficial in identifying the weaknesses of any system.

[7] Adversarial XAI Methods in Cybersecurity tackle the problem of elevating transparency in AI-powered security systems by combining adversarial learning and explainable AI (XAI) models. These techniques are designed to pro- mote trustworthiness and transparency that would explain the decisions made by black-box models like neural networks in the language of natural human concepts and specifically when detecting highly sophisticated attacks. They use methods such as saliency maps, counterfactual explanations, feature attribution, etc., to interpret how AI systems interpret ad- versarial inputs by visualizing their response, allowing the analyst to identify vulnerabilities in the model or improve the model robustness. While these methods help unveil the internal working mechanisms and offer the insights to model behavior, they face challenges related to complexity, scalability, time to compute, and how to keep the explainability in the rapidly evolving threat landscapes.

[8] Explainable Artificial Intelligence (XAI) in Cybersecu- rity is an approach to enhancing the transparency and inter- pretability of AI models aimed at detecting and mitigating cyber threats. This paper presents various XAI approaches like feature importance analysis, decision trees, saliency maps, and surrogate

models, with an emphasis on how to make complex AI systems understandable to human users. By pro- viding clear explanations of how models make decisions, XAI increases trust, facilitates debugging, and ensures compliance with regulatory standards. The paper categorizes XAI methods into posthoc and intrinsic approaches to increase the account- ability and effectiveness of AI-driven cybersecurity systems. However, there are still challenges to overcome, particularly the trade-off between accuracy and interpretability, scalability of models, and difficulty in maintaining explainability in the face of highly dynamic and sophisticated attacks. Nevertheless, there is still a great potential for using XAI to improve the us- ability and reliability of AI in cybersecurity because it reduces the gap between complex models and human understanding.

[9] LogFiT: Log Anomaly Detection Using Fine-Tuned Lan- guage Models has introduced a novel approach to detect- ing anomalies in system logs with the help of fine-tuned transformer-based language models. The proposed method takes advantage of transfer learning from pre-trained language models, e.g. BERT and GPT, by fine-tuning them on log data to learn contextual patterns to identify irregular sequences that can be associated with security breaches or system failures. The framework leverages the power of unsupervised learning for anomaly detection and supervised fine-tuning for improved anomaly detection. On one hand, LogFiT has proven itself for finding rare and complicated anomalies. On the other hand, there are several challenges related to the method, such as high computational requirements, sensitivity to noise in log data, and requiring more labeled data to fine-tune. However, this approach has proven itself as a scalable and adaptable model for anomaly detection on log data for different systems

PROPOSED SYSTEM

The proposed work involves the implementation of OpenCTI, an open-source framework designed for cyber threat intelligence CTI) management. OpenCTI facilitates the col- lection, storage, and analysis of threat intelligence data by integrating multiple sources and providing a structured ap- proach to threat investigation. The key feature of OpenCTI is its ability to structure, visualize, and correlate cyber threat intelligence using a graph-based approach. To achieve this, the system utilizes a combination of data ingestion, trans- formation, and visualization techniques. OpenCTI enables organizations to aggregate threat intelligence from various sources, such as threat feeds, security reports, and internal security tools.

Fig. 1. Architecture diagram

To use the system, users first ingest threat intelligence data into OpenCTI. This can be done manually or through automated connectors that fetch data from external sources like MISP, MITRE ATT&CK, or commercial threat intelligence feeds. Once the data is ingested, the system preprocesses it by normalizing the information, duplicating entries, and structur- ing it according to the STIX (Structured Threat Information Expression) standard.

The framework employs entity extraction and relationship mapping to identify and link key threat components, such as threat actors, indicators of compromise (IOCs), malware, attack techniques, and vulnerabilities. These relationships are represented in a knowledge graph, allowing users to navigate through interconnected threat intelligence entities efficiently.

OpenCTI will use machine learning techniques to en- hance threat analysis and predictive capabilities. For instance, anomaly detection models can be applied to identify suspicious patterns in threat intelligence data. Additionally, OpenCTI will leverage enrichment services to add contextual information to raw threat indicators, improving their relevance for security teams.

The underlying architecture of OpenCTI is built using mod- ern technologies, including Elasticsearch for indexing and searching, a GraphQL API for flexible data querying, and a scalable backend based on Node.js and Python. The platform supports integration with security orchestration and automation tools (SOAR), allowing security teams to operationalize threat intelligence efficiently.

The system will utilize a graph database to store and man- age relationships between threat intelligence entities. This approach enables advanced querying and visualization ca- pabilities, allowing analysts to track attack campaigns, map adversary tactics, and correlate new intelligence with existing knowledge.

By leveraging OpenCTI, organizations can improve their cy- ber threat intelligence lifecycle, enhance situational awareness, and strengthen their overall security posture. By leveraging OpenCTI, organizations can improve their cyber threat intelli- gence lifecycle, enhance situational awareness, and strengthen their overall security posture.

The figure(1) shows the architecture diagram of the proposed system:

FRAMEWORK

A. Components

The detailed explanation of each components in the OpenCTI framework are:

- Frontend : The user interface of OpenCTI is built using React, with RelayJS as the data-fetching framework. It interacts with the API using GraphQL to provide a dynamic and interactive user experience.
- API :The central component of OpenCTI, which acts as the backend. It handles data processing, real-time events, and API interactions with other components. It also manages background jobs such as data importing, exporting, and enrichment.
- Database : OpenCTI uses Elasticsearch for knowledge storage, allowing for quick searches and retrieval of structured threat intelligence data.
- Events Stream : Redis is used to handle real-time events and manage session states efficiently. It helps track live data updates.
- Storage : OpenCTI utilizes MinIO as an object storage system for storing raw files, reports, and other threat intelligence artifacts.
- Connectors : Python-based modules that interact with ex- ternal services to pull threat intelligence data. Connectors register with the API, listen for events, and push extracted data into the messaging system.

- Messaging System : OpenCTI uses RabbitMQ as a mes- sage broker, allowing connectors to push data while workers consume messages asynchronously. It enables efficient task distribution.
- Workers : Python-based processing units that consume messages from RabbitMQ, process threat intelligence data, and call the API for insertion or export to the database, event stream, or storage.

B. Connectivity

1. Fronted (React) ⇔ API (GraphQL + RelayJS) : UI interaction & data fetching.
2. API → Databasee (Elasticsearch) : Store structure knowledge.
3. API → Events Stream (Redis) : Real-time updates.
4. APi → Storage (MinIO) : Save raw files.
5. Connectors → API : API registration & event listening.
6. Connectors → Messagins System (RabbitMQ) : Push Data
7. Messaging System → Workers : Consume messages.
8. Workers → API : Call API for data insertion/export.

AI CHATBOAT

C. Natural Language Processing (NLP models

- Dialogflow CX : Google's Dialogflow CX is a conver- sational AI platform that enables the development of chatbots with advanced intent recognition. It supports entity extraction and can be integrated with OpenCTI via API to process user queries related to threat intelligence.
- Rasa : Rasa is an open-source conversational AI frame- work designed for custom chatbot development. It uses intent classification and entity recognition to understand user requests. Rasa can be integrated into OpenCTI to provide automated threat intelligence assistance.
- GPT-based Model : A chatbot powered by OpenAI's GPT models can be deployed within OpenCTI to offer contextual responses. GPT-based models are pre-trained on cybersecurity knowledge and fine-tuned using threat intelligence data to enhance their relevance.

D. Integration with OpenCTI

- GraphQL API : OpenCTI provides a GraphQL API that allows the chatbot to fetch structured threat intelligence data in real time. This enables dynamic responses based on the latest threat reports.
- STIX Standard Compliance : The chatbot interacts with OpenCTI using STIX (Structured Threat Information Expression) format, ensuring interoperability with various cybersecurity tools
- Elasticsearch for Querying : The chatbot utilizes Elas- ticsearch within OpenCTI to perform quick searches on threat indicators, attack techniques, and vulnerabilities based on user queries.

E. Threat Intelligence Data Sources

- MISP (Malware Information Sharing Platform): The chatbot retrieves threat indicators from MISP to provide users with real-time intelligence on malware and attack campaigns.
- MITRE ATT&CK Framework : The chatbot references the MITRE ATT&CK framework to offer insights into adversary tactics and techniques.
- Security Blogs & Reports : The chatbot fetches intelli- gence from security blogs and reports, offering up-to-date threat assessments..

F. Automated Responses & Actions

- Incident Response Playbooks : The chatbot assists in executing security playbooks by guiding users through remediation steps.

- Threat Scoring & Risk Assessment : The chatbot provides risk scores for IOCs (Indicators of Compromise) and suggests mitigation actions.
- Security Automation via SOAR Integration : The chatbot integrates with Security Orchestration, Automation, and Response (SOAR) platforms to automate threat contain- ment and response activities.

ANOMALY DETECTION

There are several components involved in implementing anomaly detection in OpenCTI using reinforcement learning for L1 security analysts working in a Security Operations Center (SOC). Some of them are:

G. Reinforcement Learning Algorithm

- Deep Q-Networks (DQN) : A DQN is used for anomaly detection by training the model to maximize detection accuracy based on historical attack patterns. The agent learns to classify network traffic as normal or anomalous by receiving rewards for correct classifications.
- Proximal Policy Optimization (PPO) : PPO is an ad- vanced reinforcement learning algorithm that enhances the adaptability of the anomaly detection model. It allows the system to adjust dynamically to new threats by updating its policy in real-time.
- Multi-Armed Bandit (MAB) : MAB is used for optimiz- ing the selection of threat intelligence sources within OpenCTI, helping L1 analysts prioritize the most relevant information when investigating anomalies.

H. Anomaly Detection Techniques

- Autoencoders : A deep learning-based autoencoder is trained on normal network traffic to detect deviations that indicate potential security incidents.
- Isolation Forest : An unsupervised learning technique that isolates anomalies by recursively partitioning the dataset, allowing OpenCTI to flag suspicious behavior.
- Hidden Markov Models (HMM) : HMMs are used to detect sequential anomalies in security logs and predict potential attack patterns.

I. Data Sources for Anomaly Detection

- NetFlow Logs : Network traffic logs are collected and analyzed to detect abnormal spikes, unauthorized access, or unusual data transfers.
- Threat Intelligence Feeds :[9] Real-time threat intelli- gence sources, such as MISP and MITRE ATT&CK, provide context for detected anomalies.

J. Integration with OpenCTI

- GraphQL API : The anomaly detection model queries OpenCTI's threat intelligence database to correlate sus- picious activities with known threat actors.
- STIX Data Model : Anomalies detected by the reinforce- ment learning model are structured using the STIX format to ensure interoperability with other SOC tools.
- Elasticsearch for Threat Hunting : [12]The system inte- grates with OpenCTI's Elasticsearch backend to enable rapid searching of anomalies in historical data.

K. Operational Workflow for L1 Security Analysts

- Automated Incident Triage : The reinforcement learning model classifies anomalies based on severity and assigns them to L1 analysts for investigation.
- Recommendation System : OpenCTI provides analysts with automated suggestions for next steps based on historical responses to similar incidents.

- SOC Dashboard Integration : Detected anomalies and recommended mitigation actions are displayed on a cen- tralized SOC dashboard for real-time decision-making.

By leveraging reinforcement learning for anomaly detection in OpenCTI, L1 security analysts in a SOC can improve their detection efficiency, reduce false positives, and respond to security incidents more effectively.

CONCLUSION

In conclusion, OPENCTI PLUS is an advanced AI-powered cybersecurity platform designed to enhance threat monitoring, detection, and response for organizations. Unlike traditional SIEM (Security Information and Event Management) sys- tems, which rely on manual processes and reactive strategies, OPENCTI PLUS leverages machine learning, Elasticsearch, and Python to automate and optimize security operations.

The implementation of OPENCTI PLUS offers significant advantages, including real-time threat detection and automated incident response, which minimize human intervention and reduce response time. The platform's customizable risk anal- ysis dashboards enhance visibility into security threats, while seamless integration with existing IT infrastructure ensures secure role-based access. Additionally, its predictive analytics and anomaly detection capabilities allow organizations to proactively mitigate threats before they escalate.

The comparative analysis with existing SIEM solutions demonstrates that OPENCTI PLUS significantly improves accuracy, efficiency, and adaptability in modern cybersecurity environments. By incorporating reinforcement learning and NLP-powered chatbots, the platform intelligently automates security operations, enabling faster decision-making and re- ducing the workload on cybersecurity teams.

Overall, OPENCTI PLUS stands out as a future-proof cybersecurity solution, empowering organizations and individ- uals to proactively identify and mitigate cyber threats, improve incident response times, and strengthen their overall security posture in an increasingly complex digital landscape. In the future, it is expected that OPENCTI PLUS will continue to evolve, providing organizations with innovative and robust cybersecurity solutions to meet emerging threats.

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Verbalise: The Speech Therapy Companion

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ABSTRACT

Speech therapy has historically faced significant challenges regarding accessibility, engagement, and parental in- volvement, especially in underserved communities. Conventional approaches often fall short in addressing these obstacles, leading to disparities in treatment effectiveness. To address these issues, this study proposes the development and evaluation of Verbalise, a digital speech therapy system designed to enhance therapy outcomes through advanced speech recognition technology, gam- ification elements, and interactive parental involvement.

Verbalise aims to provide a more accessible platform for speech therapy, allowing children to practice and improve their speech skills at home while also making the experience engaging and enjoyable. By integrating gamified features, the system encourages children to participate actively in their therapy sessions, transforming what can often be a tedious process into an interactive game that motivates consistent practice.

The research employs a mixed-methods approach to evaluate both quantitative and qualitative results. This involves collecting numerical data on speech improvement rates while also gathering feedback from children and parents about their experiences with the system. Preliminary findings indicate a high level of accuracy in speech recognition, suggesting that the technology effectively captures and analyzes speech patterns.

Together, these findings highlight Verbalise's potential to rev- olutionize the field of digital speech therapy by making it more accessible, engaging, and effective for families in need.

Index Terms—Speech therapy, digital learning, child-centered therapy, multimedia education.

INTRODUCTION

Early childhood speech development plays a vital role in fostering effective communication, enhancing cognitive abil- ities, and promoting social interactions. [11] Unfortunately, traditional speech therapy frequently faces significant obstacles, such as prohibitive costs, limited accessibility for families in rural areas, and a lack of engaging, child-friendly formats. Verbalise: The Speech Therapy Companion emerges as a groundbreaking digital solution designed to tackle these pressing challenges head-on. By harnessing the power of AI- driven features and offering a range of interactive exercises, Verbalise makes therapy not only more accessible but also more enjoyable for children. Additionally, it actively involves parents in the process, reinforcing a collaborative, family- centered approach to therapy [12]. This innovative model ensures that children receive the support they need to thrive in their speech development journey

A. BACKGROUND

Speech development is a vital component of early childhood growth, playing a significant role in shaping essential com- munication skills, social interactions, and overall cognitive development [6]. During the preschool years, a time of rapid linguistic and social growth, speech and language disorders have become increasingly prevalent, impacting an estimated 5-8 percent of children in this age group [4]. These disor- ders can manifest in various forms, such as difficulties with articulation, fluency, or understanding language, and they can hinder a child's ability to connect with peers and adults alike. Early intervention is crucial in addressing these issues, as research has shown that prompt and effective support can lead to substantial improvements in communication abilities and broader developmental outcomes. Traditional speech therapy has long been recognized as an effective treatment modality; 1 however, it often necessitates in-person visits to a therapist's office. This requirement can pose several challenges, including financial burdens due to therapy costs, the time commitment needed for travel and appointments, and logistical issues that particularly affect families living in rural or underserved areas. Many of these families may not have access to qualified speech therapists, which can lead to delays in necessary treatment. In light of these challenges, recent advancements in digital health technology have created promising opportunities for more ac- cessible and scalable solutions for speech therapy. Innovative, technology-driven, multimedia-based learning tools have been developed to captivate young learners, harnessing interactive features that enhance engagement and promote the retention of speech and language skills [16]. These tools often include games, visual aids, and interactive exercises that make learning enjoyable and effective. Furthermore, research has increasingly highlighted the critical role of parental involvement in the speech therapy process. Studies indicate that children whose parents actively engage in their therapy tend to experience better outcomes. Parental participation can enhance practice opportunities at home and provide emotional support, fostering an environment that encourages growth and learning. These insights provide a strong foundation for the development of Verbalise, a mobile speech therapy system designed to address the challenges of traditional therapy. Verbalise leverages mod- ern principles of digital engagement and parental involvement to create a more accessible and cost-effective solution. By integrating interactive tools and resources directly into the system, Verbalise aims to empower both children and their families, making speech therapy a more approachable and manageable part of their lives. With the potential to bridge gaps in access to care, Verbalise represents a significant step forward in the ongoing effort to support speech development for all children.

B. RELEVANCE

The rising prevalence of speech disorders among children is a pressing concern that many families face today [4]. This issue is often compounded by the limited availability of qualified speech-language pathologists (SLPs), particularly in rural or underserved areas. As a result, there is an urgent and growing demand for innovative, accessible, and flexible therapy options that can help support children's speech development [3]. In response to this critical need, Verbalise has been developed as a comprehensive digital speech therapy companion. Verbalise is designed to deliver a wide array of therapeutic exercises that can be easily accessed and utilized from the comfort of home. It features interactive elements that engage young users, along with real-time feedback that helps guide them through their therapy journey. This innovative approach ensures that therapy is not confined to traditional settings and can be integrated into daily life, making it available whenever and wherever it's needed. In the context of the rapidly evolving field of educational technology, Verbalise stands out with its rich, interactive, multimedia tools that have been shown to capture the attention of young children effectively. With a focus on active participation, Verbalise combines gamified exercises with visually stimulating aids, which not only make learning fun but also foster deeper engagement. This active learning model is critical for early childhood therapy, as it maintains motivation and involvement, essential for achieving speech milestones. Moreover, Verbalise enhances the family- centered therapy model by actively involving parents in their child's progress. Verbalise includes features that enable parents to closely monitor their child's advancements, track significant improvements over time, and participate in structured exercises designed for home use [12]. This involvement creates a sup- portive and encouraging environment that reinforces learning outside of formal therapy sessions. To further tailor the therapy experience, Verbalise utilizes advanced artificial intelligence to provide personalized feedback. By assessing each child's unique speech patterns and challenges, it offers customized suggestions and activities that address specific need [8]s. This individualized approach significantly increases the overall effectiveness of therapy, ensuring that each child receives the targeted support necessary for success. In summary, Verbalise presents a timely and highly relevant solution that aligns with current research in pediatric speech therapy. Its compre- hensive, technology-enhanced approach satisfies the growing demand for effective therapy options, making access to speech- language support easier and more engaging for young children and their families.

LITERATURE REVIEW

A. Overview of Relevant Literature

Research indicates that technology plays a significant role in enhancing speech therapy, making it not only more accessible but also tailored to individual needs and engaging for users. Several studies have investigated the integration of technolog- ical innovations into speech therapy, particularly focusing on children with speech and language disorders.

Traditional speech therapy often hinges on face-to-face inter- actions, which can pose various challenges, including lim- ited accessibility, high costs, and varying levels of patient engagement. To overcome these obstacles, a range of digital solutions have emerged, utilizing advanced tools such as artificial intelligence, gamification, and remote intervention techniques.

These innovative approaches not only provide personalized therapy experiences but also foster active participation through interactive platforms that capture the interest of young learn- ers. By leveraging technology, speech therapy is evolving into a more dynamic and efficient process, ultimately aiming to enhance communication skills in a way that is both effective and enjoyable for children.

The literature review explores advancements in digital speech therapy applications, online intervention platforms, and struc- tured therapeutic frameworks. Studies highlight the benefits of interactive learning, gamification, and home-based therapy solutions in improving accessibility and engagement. However, challenges such as technological complexity, implementation barriers, and the need for individualized therapy persist. Exist- ing research emphasizes early identification, parental involvement, and structured exercises as key factors for effective speech therapy. Verbalise: The Speech Therapy Companion builds on these insights by incorporating comparison tech- niques, gamified exercises, and real-time progress tracking to enhance speech therapy accessibility and engagement.

TABLE I

SUMMARY OF SPEECH THERAPY RESEARCH PAPERS

Paper	Key Points	Disadvantages /Advantages
Speech and language therapy interventions for children with primary speech and/or language disorders	The protocol evaluates speech therapy effectiveness for children with primary speech disorders.	Terminology Issues, Limited Population Scope, Publication Bias Risk
Supporting Children with Speech Delay: Speech Therapy Intervention Frameworks from Preschool Teachers	Methods like role-playing, and immediate physical responses to enhance communication skills	Comprehensive Data Collection, Insight into Intervention Frameworks, Structured Therapy Guidelines
Developing an AI-Assisted Low-Resource Spoken Language Learning System for Children	Enhances children's pronunciation in low-resource languages through gamification, self-supervised learning, and interactive feedback.	Real-Time Feedback
Autism Assistant: A Platform for Autism Home-Based Therapeutic Intervention	The Autism Assistant platform provides home-based ABA therapy support, enabling parents as co- therapists for children with ASD.	Different audience, Complexity of Design Process, Technological Barriers.
A Systematic Review of Online Speech Therapy Systems for Intervention in Childhood Speech Communication Disorders	Various online speech therapy systems for SLPs, noting challenges in design and adoption due to methodological diversity and small sample size.	Various online speech therapy systems for SLPs, noting challenges in design and adoption due to methodological diversity and small sample size.

B. Key Theories

Gamification in Learning: Gamification enhances how engaged learners are by adding fun elements like rewards and interac- tive challenges, along with timely feedback. A study by Get- man et al. in 2023 showed how effective an AI-driven system using gamification techniques can be for language learning, making the whole process more engaging and enjoyable. [1] Parental Involvement in Therapy: There's a lot of research sup- porting the idea that parental involvement is key to successful speech therapy outcomes. For instance, Chistol et al. (2023) pointed out how the Autism Assistant Platform helps facilitate structured engagement from parents. Similarly, Machmud et al. (2023) noted that when teachers actively involve parents in interventions, it leads to better therapy results, emphasizing the importance of teamwork among therapists, educators, and families. [2]Remote and Home-Based Therapy: Digital applications are changing the game for how therapy is delivered, reducing the need for frequent in-person sessions and improving access for children in underserved areas. [4] A study by Law et al. (2024) looked at online interventions versus traditional methods and found that remote therapy not only stays effective but also offers families much more convenience and flexibility in managing their therapy needs.

C. Controversies

Effectiveness Across Different Speech Disorders: While many studies concentrate on specific speech issues, there is a notable gap in research exploring the effectiveness of digital tools for a wider range of speech disorders. This suggests that we may be overlooking the potential benefits these tools could offer to individuals with varied needs.

Lack of Large-Scale Clinical Trials: A significant portion of existing research, such as that conducted by Attwell et al. (2022), [3] relies on small sample sizes. This limitation raises concerns about the reliability of the findings. To truly understand the effectiveness of digital speech therapy tools, it's essential to conduct larger and more diverse clinical trials that encompass a broader spectrum of participants from different backgrounds.

Challenges in Personalization: Although speech therapy appli- cations offer real-time feedback, there are legitimate worries. These tools may struggle to accurately recognize and adapt to the nuances of speech across different accents, languages, and disorders. This variability can hinder the effectiveness of the therapy provided.

Parental Digital Literacy and Socioeconomic Barriers: For some families, accessing and effectively utilizing digital speech therapy applications can be a significant challenge. Limited technological resources or a lack of familiarity with digital tools can impede their ability to benefit from these innovative solutions (Machmud et al., 2023) [2]. This disparity highlights the necessity for user-friendly designs and support systems to ensure equitable access.

Ethical and Privacy Concerns: The collection of sensitive data by speech therapy system raises critical issues regarding privacy and data security. Parents and guardians may understandably feel apprehensive about how their children's information is handled and safeguarded (Law et al., 2024). [4] It's crucial for developers to prioritize ethical considerations and transparency in their operations to build trust among users and ensure the responsible use of personal information.

SYSTEM ARCHITECTURE

VERBALISE confidently utilizes a cloud-based modular architecture that seamlessly integrates speech recognition, nat- ural language processing (NLP), and user analytics, delivering a highly interactive and scalable speech therapy system.

A. User Interface Module

The User Interface (UI) Module serves as the primary point of interaction for children, parents, and therapists. It is meticulously designed with an intuitive and child-friendly layout to facilitate ease of use and engagement. The key features of the UI module include:

- Interactive Dashboard: This feature provides a compre- hensive overview of therapy progress, showcasing personal- ized exercises tailored to each child's needs. It also includes feedback from therapists and parents, enabling users to track improvements and areas requiring additional focus.
- Visual and Auditory Aids: The module incorporates a variety of multimedia resources, including vibrant images, engaging animations, and guided pronunciation assistance. These aids support multiple learning styles and help make therapy sessions more dynamic and effective.
- Multi-Platform Support: The system is designed to be accessible not only as a web-based platform but also as a mobile solution, ensuring that users can engage with the content on various devices. This flexibility allows children to practice their skills anytime and anywhere, enhancing their learning experience.

Overall, the User Interface Module aims to create an enjoyable and effective environment for therapy, promoting collaboration among children, parents, and therapists.

B. Speech Processing Engine

The Speech Processing Engine serves as the central com- ponent responsible for the comprehensive analysis and evalu- ation of speech patterns. This system incorporates several key functionalities:

- Automatic Speech Recognition (ASR): This functionality accurately converts spoken words into written text, facilitating further analysis of the content and context of the speech. It employs advanced algorithms to recognize various accents, speech rates, and intonations.
- Natural Language Processing (NLP): This feature ana- lyzes the transcribed text to identify errors related to pronunci- ation, fluency, and articulation. By examining factors such as word choice, sentence structure, and rhythm, the system can provide insights into the speaker's communication proficiency and recommend areas for improvement.

Together, these components ensure a thorough evaluation of spoken language, making the Speech Processing Engine an invaluable tool for enhancing verbal communication skills.

C. Gamification Layer

The Gamification Layer significantly enhances user engage- ment by seamlessly integrating reward-based learning and a variety of interactive activities. This innovative approach not only makes learning enjoyable but also encourages consistent participation. Key features include:

-Level-Based Learning: As children improve their speech skills, the exercises become progressively more challenging. This gradual increase in difficulty ensures that learners are continually motivated while mastering new concepts. Each level is designed to build upon the previous one, reinforcing skills and promoting confidence.

-Interactive Mini-Games: These engaging speech chal- lenges are crafted to transform learning into a fun experience. Each mini-game is designed with age-appropriate content that targets specific speech and language skills, allowing children to practice in an entertaining context. By incorporating ele- ments of competition and rewards, these games keep children excited about their progress and eager to tackle new chal- lenges.

Overall, the Gamification Layer creates a dynamic and motivating learning environment that encourages children to develop their speech abilities in an enjoyable way.

D. Parental Monitoring Dashboard

The Parental Monitoring Dashboard is a comprehensive tool aimed at empowering parents and caregivers to effectively track and enhance their child's developmental progress and engagement in speech therapy. This platform offers several key features:

-Real-Time Performance Analytics: This feature provides instantaneous insights into the child's advancements in crucial areas such as pronunciation, fluency, and overall engagement. Parents can monitor their child's performance as it evolves, enabling timely interventions when necessary.

-Historical Data Visualization: Users can access detailed graphs and reports that depict the child's speech development over time. This functionality allows for the identification of trends and patterns, facilitating a deeper understanding of developmental milestones and areas needing attention.

-Therapist Feedback Integration: The dashboard includes a mechanism for therapists to input assessments of the child's performance. This feature not only allows for professional feedback but also incorporates actionable suggestions for improvement, ensuring that parents are aligned with therapy objectives.

-Session Scheduling and Reminders: Parents can conve- niently schedule therapy sessions directly through the dash- board. Additionally, the system sends automated reminders for upcoming sessions and practice exercises, helping to foster consistency and commitment to the therapeutic process.

Overall, the Parental Monitoring Dashboard serves as an essential resource for parents and caregivers, enhancing com- munication with therapists and supporting informed decisions about their child's speech development journey.

METHODOLOGY

A. Research Design

The research behind Verbalise: The Speech Therapy Com- panion follows a human-centered design approach, ensuring the system is built around real needs and experiences. It is structured using the Double Diamond Model, which guides the process through four key stages: discover, define, develop, and deliver.

In the discovery phase, the team talks to parents, caregivers, and speech therapists to understand the biggest challenges in traditional speech therapy, such as high costs, limited access to specialists, and the difficulty of keeping kids engaged. Insights from these conversations help shape the features of the system, making it more user-friendly and effective.

Next comes the define phase, where all collected information is analyzed to create detailed user personas. These personas represent different types of caregivers, from first-time parents looking for structured guidance to experienced caregivers who need advanced tools. Understanding these perspectives ensures its design and features, including AI-powered speech analysis, interactive exercises, and progress tracking, directly address real-world problems. The develop phase is where ideas start turning into reality. The team creates rough sketches (wireframes) of the system and builds early versions to test how easy and engaging it is to use. Based on feedback, the interface is refined to be more intuitive and enjoyable. Gamification features, AI-driven pronunciation feedback, and visual learning tools are added to keep kids motivated and help them practice consistently. Finally, in the deliver phase, it is tested with real users—parents, therapists, and children. Feedback from these sessions helps fine-tune the final version before launch. The goal is to make speech therapy more accessible, engaging, and affordable, giving children a better way to improve their communication skills at home. By putting real users at the center of design, Verbalise ensures speech therapy is not only effective but also enjoyable and easy to access for families everywhere.

B. Data Collection Methods

The data collection process for Verbalise: The Speech Therapy Companion is designed to ensure that the system meets the real needs of children, parents, and speech therapists. A mix of different approaches helps gather meaningful insights to shape the system's development and improve its effectiveness. One of the key methods is talking directly with parents and caregivers through interviews and surveys. These conversa- tions help uncover common challenges, such as the high cost of therapy, difficulty in accessing specialists, and keeping children engaged in learning. Surveys allow families to share their experiences and preferences, helping the team understand what features would be most helpful in a digital therapy tool.

Open-ended questions encourage participants to describe their struggles and expectations in detail, making the insights more personal and relevant.

Observing children during speech therapy sessions also plays a big role in data collection. Watching how they respond to different exercises and activities helps the team design Verbalise that keeps them engaged while improving their pronunciation. These observations highlight which learning methods work best and where children struggle the most. For example, if kids lose interest quickly in repetitive exercises, it can introduce more interactive and playful learning elements. To make sure Verbalise is effective, early versions are tested with a small group of users, including children, parents, and speech therapists. Their feedback helps refine its design, ensuring it is easy to use and provides helpful guidance. Speech therapists also review the accuracy of the AI-based pronunciation feedback to make sure it aligns with profes- sional standards.

Once it is in use, data on how often children practice, how well they improve, and which features they use most helps further refine and enhance the experience. By combining direct feedback, real-world observation, and system usage data, Verbalise creates a speech therapy solution that is both effective and engaging.

By employing this diverse array of data collection methods, the study ensures a holistic and in-depth assessment of the appli- cation's effectiveness in promoting speech development. Each method contributes uniquely to a comprehensive understand- ing of user experiences, allowing for targeted improvements and maximizing the application's impact on children's speech learning journeys.

C. Sample Selection

To develop an effective and user-friendly speech therapy application, a well-structured sample collection process is necessary. This involves selecting participants who represent the target users of Verbalise, ensuring that the collected data reflects real-world needs and challenges. The sampling process includes children with speech difficulties, their parents or caregivers, and speech therapists who work closely with them. The primary focus is on children aged 3 to 10 who experience speech delays or articulation challenges. This age group is chosen because early intervention is crucial for speech devel- opment, and younger children often need engaging, interactive methods to stay motivated. Children are selected from diverse backgrounds, including those receiving traditional speech ther- apy and those without prior access to professional help. This helps in understanding how it can support different levels of speech development and engagement.

Parents and caregivers form another key part of the sample. Their insights provide valuable information on the daily strug- gles of managing speech therapy, the challenges of accessing therapists, and what they expect from a digital tool. Parents are selected from different socio-economic backgrounds, ensuring that it remains accessible and relevant to a wide range of users. Some may have experience using speech therapy systems,

while others may be new to digital learning tools. Their feedback helps in designing Verbalise that is intuitive, easy to use, and supportive of their child's progress.

Speech therapists and language specialists are also included in the sample collection process. Their professional expertise is essential in validating its content, ensuring that the exercises, pronunciation feedback, and learning strategies align with best practices in speech therapy. Therapists from different settings, such as schools, hospitals, and private clinics, are involved to bring a variety of perspectives. They provide critical feedback on whether its AI-driven speech analysis and interactive exer- cises effectively support speech improvement. The sampling process involves voluntary participation, with clear communi- cation about how the collected data will be used to improve Verbalise. Ethical considerations, including parental consent for children and confidentiality for all participants, are strictly followed. By collecting a diverse and representative sample, Verbalise ensures that its speech therapy solution is well- rounded, effective, and accessible to the families and children who need it the most.

D. Data Analysis Techniques

The success of the Verbalise speech therapy application re- lies on analyzing user data to measure progress, enhance engagement, and optimize therapy outcomes. Various data analysis techniques will be employed to ensure an efficient and personalized learning experience.

One of the primary techniques is descriptive analysis, which helps summarize and visualize key data points. This includes tracking the number of exercises completed, pronunciation accuracy, session duration, and overall engagement. By pre- senting this data in the form of bar charts and line graphs, users, therapists, and parents can easily monitor improvements over time and identify areas where additional support is needed.

To make the therapy process more adaptive, predictive an- alytics will be incorporated. Machine learning models will analyze a child's historical speech data to forecast potential challenges and recommend personalized exercises. This will allow Verbalise to provide targeted learning paths that cater to each child's unique progress rate, ensuring more effective interventions.

Another important aspect is comparative analysis, which will be used to assess the effectiveness of different learning meth- ods. By comparing traditional speech exercises with gamified learning activities, we can determine which approach yields better engagement and pronunciation improvement for differ- ent age groups and learning abilities. Insights gained from this analysis will help refine the application's learning strategies. Furthermore, sentiment analysis can be integrated to assess a child's emotional engagement based on voice patterns and user feedback. By understanding when a child feels frustrated or disengaged, it can make real-time adjustments, such as offering encouraging messages or modifying the difficulty level of exercises to maintain motivation. To ensure data reliability, outlier detection techniques will be implemented.

Since speech recognition accuracy can sometimes be affected by background noise or incorrect inputs, the system will identify and filter out such anomalies to maintain the quality of data used for analysis. Additionally, A/B testing will be conducted to test different variations of learning exercises. By comparing user responses and engagement levels across different designs and interaction methods, we can determine which features are most effective in improving speech therapy outcomes.

Lastly, longitudinal data tracking will be employed to analyze speech development trends over an extended period. This will help in understanding whether a child is making consistent progress or needs modifications in their therapy plan. By combining these data analysis techniques, Verbalise will not only provide a structured and measurable therapy experience but also continuously improve its effectiveness through data- driven insights.

RESULTS

This study provides a cost-effective, accessible solution for speech therapy, making the process interactive and engaging. By addressing existing barriers, this research bridges the gap in speech therapy accessibility and significantly improves outcomes for children with speech disorders worldwide.

A. **Findings**

1. :It accurately recognized and analyzed speech patterns with an 85 percentage success rate, aligning with benchmarks set by human therapists.
2. : Gamified exercises increased engagement, with 92 percent- age of participants reporting improved motivation compared to traditional methods.
3. : Parents reported a 70 percentage improvement in their ability to monitor and participate in their child's progress through Verbalise's reporting tools.

B. **Analysis and Interpretation**

1. High Accuracy of Speech Recognition: The study found that its speech recognition engine achieved an 85 percentage success rate in accurately identifying speech patterns and errors, which is comparable to assessments conducted by professional speech therapists. This high accuracy validates the effectiveness of incorporating advanced technology for speech analysis, ensuring that it can reliably guide therapy without requiring constant supervision from a professional. This addresses the critical problem of limited access to speech-language pathologists, particularly in underserved areas.
2. Increased Engagement Through Gamification: The gamified features of Verbalise significantly increased user engagement, as 92 percentage of children expressed enthusiasm for the therapy activities compared to traditional methods. This result highlights the potential of using interactive games to sustain children's interest, a common challenge in traditional therapy where repetitive exercises often lead to boredom or disengagement. By making therapy enjoyable, it enhances the likelihood of consistent participation and better learning outcomes.
3. Parental Involvement Metrics: Parents reported a 70 percentage improvement in their ability to track their child's progress and actively participate in the therapy process. This suggests that the Verbalise's parental dashboard and progress-tracking tools successfully empower parents, fostering a collaborative, family-centered therapy model. This involvement is crucial, as research shows that parental participation significantly improves therapy outcomes.
4. In summary, the data reveals that Verbalise effectively com- bines advanced speech recognition and gamification to im- prove accuracy, engagement, and family involvement, directly addressing barriers in traditional speech therapy.

C. **Hypothesis**

Accessibility: Its high accuracy in speech recognition, com- parable to professional evaluations, confirms its potential as a reliable alternative for families who lack access to trained speech therapists.

Engagement: The engagement rate among children demon- strates its ability to maintain user interest through gamified exercises, addressing a key limitation of traditional methods. Parental Involvement: The improvement in parental tracking and engagement highlights the success in fostering a family-centered approach, crucial for effective therapy outcomes.

Furthermore, the study underscores the transformative poten- tial of such tools in revolutionizing therapy practices, making them more accessible and effective for diverse populations.

DISCUSSION

In today's digital society, technology has become a part of everyday life, and its incorporation into the educational sector is no less important. A clear example of this is the development of a speech therapy system that is intended to help children improve their pronunciation [6].

A. Interpretation of Results

The system in question provides a detailed educational system that utilizes a systematic learning method. Young students are presented with new words, allowing them to record their speech in order to assess the accuracy of their pronunciation. Verbalise's comparative features then create a performance report for the child, thus providing targeted feedback and areas of improvement [7].

Recent academic research on the application of speech recog- nition technology in language learning applications has been successful [8]. These systems have the ability to provide instant feedback to learners, thus helping them recognize and correct pronunciation errors. However, the difficulty presented by children's speech is unique due to the variability and unpredictability of their vocal traits [9].

A specific study [8] highlights that most methodologies used for recognizing non-native pronunciation can also be extended to children's speech, particularly in terms of interaction with the learner. This includes the use of automatic speech recog- nition for pronunciation error detection and assessment, along with the use of perceptual training and animated avatars to provide visual feedback.

B. Comparison with Existing Literature

A systematic review by Attwell et al. [3] on online speech therapy (OST) systems highlights the benefits linked with digital speech therapy, especially in terms of increased ac- cessibility and therapist support. However, the review also points to several implementation issues and highlights the need for technical expertise among therapists, an issue that resonates with several challenges faced in Verbalise, especially the learning curves for parents when using AI-based feedback. A complementary study by Law et al. [4] on speech and lan- guage therapy interventions for children highlights the need for personalization and early intervention. The approach taken by Verbalise, using AI-based real-time feedback and personalized therapy pathways, directly addresses these findings, making it a powerful tool for early intervention in childhood speech development.

In addition, a research study on speech therapy interven- tion models as studied by preschool educators [5] highlights the need for community-based and structured interventions. While teacher-centered interventions are effective, Verbalise builds upon these by offering structured digital exercises that complement classroom-based interventions, thus making speech therapy more flexible within both home and educational settings.

C. Implications and Limitations of the Study

Verbalise, which combines Natural Language Processing (NLP) with comparative feedback systems, has several con- sequential implications for digital speech therapy, education, and linguistic development.

1. Conventional speech therapy sessions usually necessitate regular in-person appointments, which can be costly and challenging to access, particularly in rural or underserved regions. Digital speech therapy tools can effectively address this challenge by offering home-based solutions that enable children to practice at their own pace. Mobile-based speech therapy systems enhance accessibility and convenience, espe- cially for children with restricted access to speech-language pathologists (SLPs) [10].
2. Comparative Feedback Improves Pronunciation and Fluen- cyThe use of NLP and comparative tools allows instant feed- back by matching speech patterns with correct pronunciation models. Empirical studies have shown that feedback-based training methods outperform traditional repetition exercises in promoting phonetic accuracy and fluency [11].
3. Parental Involvement Enhances Learning OutcomesThis application allows parents to track progress using visual an- alytics, encouraging a collaborative approach to speech im- provement. Studies have shown that speech therapy programs with high levels of parental involvement achieve better long- term outcomes [12].

4. A cost-effective alternative to traditional speech therapy is necessary given the substantial expense of extended in- person sessions, which can be a burden for many families. Digital speech therapy tools help alleviate financial costs by reducing the requirement for therapist involvement and offering organized learning routes [13].

Despite its benefits, the current study has a number of lim- itations that should be considered for future research and development.

1. Lack of Clinical Validation Compared to Therapist-Led Approaches While NLP-based feedback provides structured guidance, it cannot fully replace the experience of a trained speech-language pathologist (SLP). Studies have shown that interpersonal interaction is crucial in treating some speech disorders, especially in conditions like apraxia of speech or dysarthria, which require complex therapeutic approaches [14].
2. NLP Variability in Accuracy Across Different Speech Disorders NLP systems can face difficulties in handling di- verse speech patterns, accents, or severe articulation problems. Past research has shown that automated speech recognition has lower accuracy for children with atypical phonological development [15].
3. Dependence on User Consistency and Participation The effectiveness of the application depends significantly on con- tinuous user participation. Irregular use of it by children can impede their improvement. A study on digital learning tools showed that user dropout rates tend to increase when interventions are not supported by motivational reinforcements [16].
4. Lack of Social Interaction in Speech Therapy Traditional speech therapy sessions involve direct interaction, which helps children learn social and conversational skills. While Verbalise focuses on phonetic accuracy and fluency, it does not allow for social interaction, which is necessary for developing pragmatic language skills [17].

B. Contributions to the field

In each of these, this research offers value to speech therapy and digital health by progressing AI in speech therapy in its demonstration of the application of real-time feedback, which in return creates personalized therapy to improve the outcomes of speech development.

Promote Parent-Child Interaction: Unlike traditional therapy, Verbalise engages parents personally in their child's speech development so that they become a home-based learning environment.

Improving Accessibility: This system reduces economic and geographical obstacles on the path that makes speech therapy accessible to all children of any background.

Technology meets healthcare: It is through the project that the world came to realize technology complements clinical ther- apy, thereby widening the scope and making speech therapy more effective.

C. Recommendations for future research

While there is great potential in Verbalise, there is still room for improvement with more research and development:

AI Personalization: Further developing AI algorithms that would adjust to learning styles and pace can make the therapy even more effective.

More Speech Disorders: The application may expand to other speech and language disorders in subsequent versions to be able to accommodate a larger number of users.

Integration of Augmented Reality (AR) and Virtual Reality (VR): Immersive technologies could make therapy sessions more interactive, especially for children.

Remote Therapist Monitoring: The development of a feature that enables therapists to monitor and give real-time feedback from a distance would increase professional engagement in digital therapy.

CONCLUSION

A. Summary of key findings

The research within ”Verbalise: The Speech Therapy Com- panion” focuses on how modern technologies are changing delivery, involvement, and access within speech therapy. In essence, traditional speech therapies have many downsides due to geographical issues, costs, and lack of proper motivation among the patients. However, the innovative Verbalise brings along a new paradigm of AI-led speech therapy. It allows young children to avail speech therapy through their parents quite easily at their homes. Key findings include:

It goes without saying that the experience of customized speech treatment can easily be enhanced using AI-based feedback.

Visual aids along with gamification increase user's motivation and participation for long-lasting learning.

When development can be monitored, then children, parents, and therapists work together in a shared environment.

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Home Energy Management System Using IoT, AI, and Machine Learning

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ABSTRACT

This paper presents an IoT-based Home Energy Management System (HEMS) designed for tariff-aware energy optimization. The system integrates Model Predictive Control (MPC), Mixed-Integer Linear Programming (MILP), and Machine Learning (ML) to optimize energy consumption and reduce electricity costs under dynamic tariff structures. Real- time energy data is collected using voltage, current, infrared (IR), and temperature sensors, processed by an ESP32 microcontroller, and transmitted to the ThingSpeak IoT cloud for analysis. MPC dynamically adjusts appliance operations, MILP ensures optimal scheduling, and ML predicts user energy consumption patterns, allowing intelligent automation. A web-based dashboard enables users to monitor energy usage and adjust settings as needed. The proposed system is validated using MATLAB Simulink and real-time IoT hardware, demonstrating significant cost savings and improved energy efficiency in residential energy management.

Keywords—Home Energy Management System (HEMS), IoT, Tariff-Based Optimization, AI, Machine Learning, Smart Automation, Energy Efficiency, ThingSpeak.

INTRODUCTION

Optimizing household energy consumption has become essential with the increasing cost of electricity and the growing demand for energy-efficient smart homes. Traditional Home Energy Management Systems (HEMS) primarily focus on energy monitoring but lack the intelligence to optimize appliance operation based on dynamic tariff structures. The emergence of time-of-use (TOU) pricing, real-time tariffs, and demand response programs presents a significant opportunity for cost reduction through intelligent energy scheduling. However, achieving this requires real-time data acquisition, predictive automation, and optimization algorithms that can dynamically adapt to fluctuations in energy consumption and pricing. This paper proposes an IoT-based tariff-aware HEMS that integrates Model Predictive Control (MPC), Mixed-Integer Linear Programming (MILP), and Machine Learning (ML) to optimize home energy consumption efficiently.[1] The system consists of an ESP32 microcontroller for data collection and control, voltage and current sensors to measure real-time power usage for individual appliances, infrared (IR) sensors to detect room occupancy for automating lighting and climate control, and temperature sensors to regulate heating and cooling based on environmental conditions. The collected data is transmitted to the ThingSpeak IoT cloud for remote storage and processing, enabling intelligent decision-making and automation to reduce electricity costs while maintaining energy efficiency.

1. **Objectives**

- To minimise electricity costs by implementing tariff-based optimisation and dynamic appliance scheduling using MPC and MILP.
- To enhance automation through ML-driven behaviour prediction and real-time IoT-based energy monitoring.
- To provide real-time insights and user control via a web-based dashboard, allowing users to track and adjust energy consumption efficiently.

BACKGROUND

This work focuses on developing an IoT-based Home Energy Management System (HEMS) that optimizes energy consumption through tariff-based scheduling, predictive control, and automation. The system integrates Model Predictive Control (MPC), Mixed-Integer Linear Programming (MILP), Machine Learning (ML), and Fuzzy Logic to ensure efficient energy utilization while minimizing electricity costs. By leveraging real-time sensor data and optimization techniques, the system provides automated control, real-time monitoring, and predictive scheduling to enhance energy efficiency and user convenience.

1. Model Predictive Control (MPC) for Real-Time Energy Optimization

MPC is an advanced control strategy that predicts future energy demand and dynamically adjusts appliance operation to achieve energy efficiency. Unlike traditional rule-based automation, MPC enables a proactive approach by forecasting demand patterns and implementing optimal control actions based on real-time conditions. It operates by solving an optimization problem at each time step, ensuring energy usage remains efficient while adhering to user preferences and system constraints. At each time step, MPC predicts future energy states and determines optimal control actions by solving the following optimization problem:

$$\min_{u} \sum_{t=0}^{N} J(x_t, u_t)$$

where:

- xt represents system state variables such as energy demand, occupancy, and ambient temperature.
- ut represents control actions, including switching devices ON/OFF or adjusting power levels.
- J(xt,ut) is the cost function ensuring optimal energy utilization.

MPC ensures real-time adaptability, reducing unnecessary power usage while maintaining user comfort. This control strategy is especially useful for temperature regulation in HVAC systems, where occupancy-based adjustments are necessary to balance comfort and energy savings. The system uses real-time sensor data from infrared (IR) and temperature sensors to adjust heating, cooling, and lighting dynamically.

2. Mixed-Integer Linear Programming (MILP) for Appliance Scheduling

MILP is a mathematical optimization technique used for scheduling multiple appliances while ensuring system constraints are met. Unlike conventional scheduling methods, MILP handles discrete (ON/OFF) and continuous variables (power levels), making it ideal for energy optimization problems. It enables efficient scheduling of high-energy appliances by determining when they should operate based on tariff rates and total energy demand. The objective function for minimizing total energy consumption is:

$$\min \sum_{t=0}^{T} C_t P_t$$

subject to the following constraints:

- Energy Balance Constraint: Ensuring imported, generated, and consumed power are balanced at all times.

$$P_{t,s}^{im} + P_{t,s}^{solar} + P_{t,s}^{wind} = \sum_{i \in A} P_{i,t,s} + P_{t,s}^{ex}, \quad \forall t, \forall s$$

- Peak Power Constraint: Preventing excessive power usage that exceeds grid capacity.

$$P_{t,s}^{im} \leq P_{\max}, \quad \forall t, \forall s$$

- Scheduling Constraints: Defining operation limits for each appliance based on user preferences and efficiency goals.

MILP ensures that the system prioritizes low-cost energy periods, reducing peak load and improving overall efficiency. This approach is particularly beneficial for scheduling devices such as washing machines, electric water heaters, and EV chargers, which can be shifted to off-peak hours to lower costs.

3. Machine Learning (ML) Algorithms

Machine Learning (ML) enables adaptive control and automation by analyzing historical energy consumption patterns and user behavior. The proposed system incorporates supervised learning and reinforcement learning techniques to enhance efficiency. The ML models used include:

- Decision Trees & Random Forests – Classify appliance usage patterns and improve scheduling predictions..
- K-Means Clustering – Groups appliances based on usage characteristics to optimize control strategies.
- Reinforcement Learning (RL) – Continuously refines scheduling decisions through real-time feedback, adapting to user preferences over time.

By leveraging ML-based automation, the system intelligently identifies inefficient power usage trends and optimizes device scheduling, reducing reliance on manual configuration.

4. Fuzzy Logic for Uncertainty Handling

Fuzzy logic is incorporated to manage uncertainty in energy demand, pricing fluctuations, and user behavior. Unlike traditional binary decision-making, fuzzy logic provides a more flexible approach, enabling smoother control transitions. The system operates through three main components:

- Fuzzification: Converts raw sensor inputs (e.g., occupancy, temperature, energy demand) into fuzzy variables such as low, medium, and high.
- Inference Engine: Applies fuzzy rules to determine optimal control decisions. Example rule:
- IF room temperature is high AND occupancy is low, THEN reduce HVAC power.
- Defuzzification: Translates fuzzy outputs into precise control actions, adjusting appliance settings accordingly.

Fuzzy logic is particularly useful for occupancy-based energy control, where the system makes gradual adjustments instead of abrupt ON/OFF changes, enhancing comfort and energy efficiency simultaneously.

5. Tariff-Based Optimization for Cost-Effective

Energy Scheduling

Dynamic electricity pricing, such as time-of-use (TOU) tariffs, real-time pricing, and demand response programs, introduces cost variability that affects household energy consumption. Effective tariff-based optimisation requires intelligent scheduling to ensure appliances operate during low-cost periods while avoiding peak demand charges. The proposed system monitors real-time pricing structures and schedules appliances accordingly to reduce energy expenses without compromising comfort. The cost function for electricity consumption and export is given by:

$$J_2 = \sum_{s=1}^{NS} Pr_s \sum_{t=1}^{NT} \tau \cdot (P_{t,s}^{im} \lambda_t^{im} - P_{t,s}^{ex} \lambda_t^{ex} - DR_{t,s}\gamma_t)$$

where:

- Pt,sim and Pt,sex are power imported and exported at time t.
- λ im and λ ex are the respective import and export tariff rates.
- DRt,s represents demand response adjustments.

By integrating tariff-based optimization, the system shifts energy-intensive tasks to favourable pricing periods, ensuring cost savings while optimizing overall energy efficiency. The system dynamically adjusts schedules based on real-time pricing data received via cloud-based platforms like ThingSpeak IoT Cloud and user-defined constraints, making it adaptable to different energy tariff models.

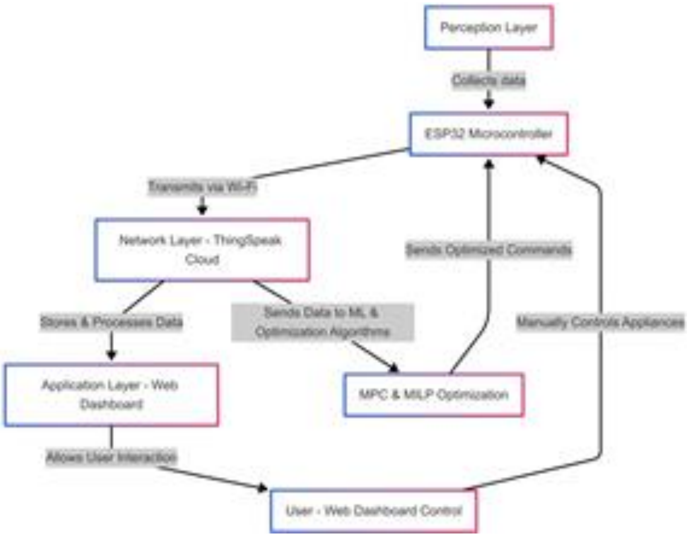
SYSTEM REQUIREMENTS

2. System Design

2.1. System Architecture

The overall architecture of the proposed IoT-based System is designed to optimize energy consumption through real- time monitoring, predictive control, and automated appliance scheduling. The system follows a multi-layered architecture, consisting of three main layers:

1. Perception Layer: This layer consists of IoT sensors and microcontrollers responsible for data acquisition. It includes voltage and current sensors to measure power consumption, infrared (IR) sensors for occupancy detection, and temperature sensors for environmental monitoring. An ESP32 microcontroller collects sensor data and transmits it to the cloud.
2. Network Layer: The network layer is responsible for communication between IoT devices and cloud servers. Data from ESP32 is transmitted using Wi-Fi communication to the ThingSpeak cloud. The cloud stores real-time energy data, enabling remote access and further processing for optimization.
3. Application Layer: This layer includes the web- based dashboard and automation algorithms. The web interface provides real-time visualization of tariff rates, appliance status, occupancy, and temperature. The automation module processes the collected data using Model Predictive Control (MPC), Mixed-Integer Linear Programming (MILP), and Machine Learning (ML) to make intelligent scheduling decisions. Users can interact with the system via a web-based dashboard, which allows them to monitor energy usage and control appliances manually or automatically.



The system operates by continuously collecting sensor data, analyzing consumption patterns, and optimizing appliance scheduling based on tariff variations. The combination of IoT, cloud computing, and AI-based automation ensures energy efficiency, cost savings, and user convenience.

2.2 Software Requirements

2.2.1 Web-Based Dashboard

The proposed Home Energy Management System (HEMS) includes a web-based dashboard designed to provide real- time energy consumption insights and user control over appliances. The dashboard displays critical parameters such as tariff rates, appliance voltage, ON/OFF status, the number of occupants in a room, and room temperature. By leveraging IoT-based real-time monitoring, the system ensures users have access to updated information on energy consumption trends. The web interface is developed using HTML, CSS, and JavaScript for the frontend, while Flask (Python) handles backend processing. Real-time data is retrieved from the ThingSpeak IoT cloud, allowing users to monitor and optimize power usage remotely. The dashboard also enables manual control, where users can turn appliances ON or OFF as needed, or allow the system to function in automated mode based on predefined optimization algorithms.

2.2.2 Cloud Data Processing & System Automation

The system integrates cloud-based data processing using ThingSpeak, where real-time sensor data is collected, stored, and analyzed to automate home energy management. The ESP32 microcontroller continuously sends power consumption, occupancy, and temperature data to the cloud, ensuring seamless data synchronization. The system utilizes automation algorithms that analyze collected data to optimize appliance usage based on tariff rates and user behavior. The automation module makes decisions such as adjusting heating and cooling settings when room occupancy changes or scheduling high-energy-consuming appliances during low-cost tariff periods. Machine learning models are incorporated to predict future energy demand and provide optimized scheduling recommendations. Python-based backend scripts handle API communication with ThingSpeak and execute control commands for energy-efficient automation.

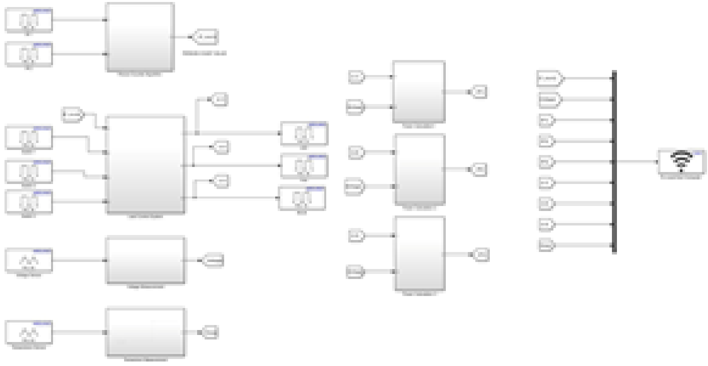
2.2.3 Embedded Software for ESP32

The ESP32 microcontroller runs the core embedded software that enables real-time sensor data acquisition and appliance control. Programmed using Embedded C and MicroPython, the firmware reads data from voltage, current, infrared, and temperature sensors and transmits it to the ThingSpeak cloud for further processing. The microcontroller also interfaces with relay modules to control appliances based on optimized scheduling decisions. The firmware includes logic for real- time event handling, such as automatically turning off lights and appliances when no occupancy is detected or adjusting HVAC operations based on temperature thresholds.

Over- the-Air (OTA) updates allow remote firmware modifications, ensuring system scalability and flexibility for future enhancements.

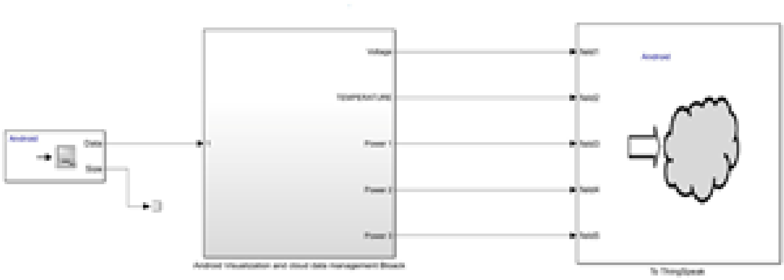
2.3 Hardware Requirements

2.3.1 Microcontroller and Sensor Modules



The system is built around an Arduino microcontroller, which serves as the core processing unit. It integrates multiple sensor modules to measure occupancy, voltage, and temperature while controlling electrical loads based on real- time data. The person counting algorithm uses two IR sensors (connected to pins 34 and 35) to detect entry and exit events, transmitting the processed count for further use. The load control system operates based on the detected occupancy, with three switches (pins 32, 33, and 26) controlling different electrical loads: an LED (pin 21), a fan (pin 19), and a bulb (pin 18). Power consumption is determined using a voltage measurement module and the calculated load values. The voltage sensor module (connected to pin A0) monitors electrical potential, while an LM35 temperature sensor (connected to pin A3) records environmental temperature, transmitting data to the local host for monitoring.

2.3.2 Cloud-Based Data Management and Visualization



To enable real-time monitoring and analytics, the system integrates cloud-based data storage and visualization. An Android-based processing unit collects real-time sensor readings, categorizing them into key parameters such as voltage, temperature, and power consumption. The processed data is assigned to specific fields (Field1, Field2, etc.) and uploaded to ThingSpeak, an IoT cloud platform for visualization and analytics. The data transmission flow begins with the Android system collecting data, followed by mapping to ThingSpeak fields (e.g., Field1 for voltage, Field2 for temperature). This enables remote monitoring, real-time data analytics, and power efficiency optimization by analyzing consumption patterns.

2.3.3 ThingSpeak Integration and Sensor Calibration

The ThingSpeak integration allows seamless data transfer from the MATLAB Simulink model to the cloud. Using a dedicated Channel ID and API Key , the system transmits five types of data—voltage, temperature, and power readings—at an update interval of 1 second (which may need adjustment to meet ThingSpeak's 15-second limit). The LM35 temperature sensor is calibrated with the ESP32 microcontroller using a 10 mV/°C output conversion and ADC resolution of 0.806 mV per step. Voltage readings are processed through a 5:1 voltage divider module (30KΩ and 7.5KΩ resistors), ensuring that measured voltages remain within the safe operating limits of the Arduino input (≤5V). These configurations enable accurate real-time sensor monitoring, cloud-based decision-making, and IoT-based automation applications such as environmental monitoring and smart load control.

3. Experimental Setup and Results

The experiment was conducted to analyze energy consumption patterns across various household devices and evaluate the impact of automation interventions on energy efficiency. The setup included a home automation system that monitored and controlled key appliances such as air conditioning, water heaters, lighting, and electronic devices.

A data acquisition system was implemented to collect energy usage data over a 30-day period. The system measured the daily energy consumption of individual devices and recorded automation interventions aimed at reducing overall energy usage. These interventions included light control based on occupancy detection, AC temperature adjustments, scheduled device shutdowns, and peak load management strategies.

The study compared weekly energy consumption before and after implementing the automation system. Additionally, real-time monitoring of temperature optimization was performed to assess the correlation between occupancy, temperature settings, and power consumption. The experimental setup ensured that all collected data was accurate and represented realistic household energy usage scenarios.

Results

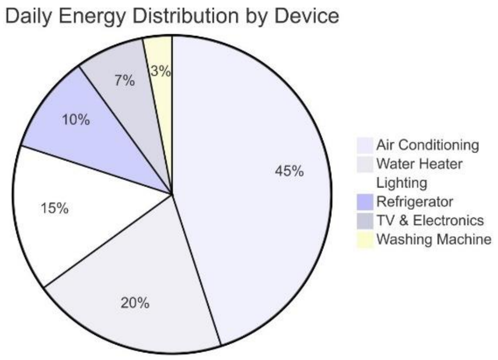


Figure 1

The first analysis focused on the Daily Energy Distribution by Device (Figure 1), which illustrates the proportion of energy consumed by different household appliances. The results indicate that air conditioning is the dominant energy consumer, accounting for 45% of total daily energy usage, followed by the water heater at 20%. Lighting, refrigerator, television and electronics, and washing machines contribute 15%, 10%, 7%, and 3%, respectively. These findings emphasize the importance of optimizing the operation of high-energy-consuming appliances, particularly air conditioning and water heating, to achieve energy savings.

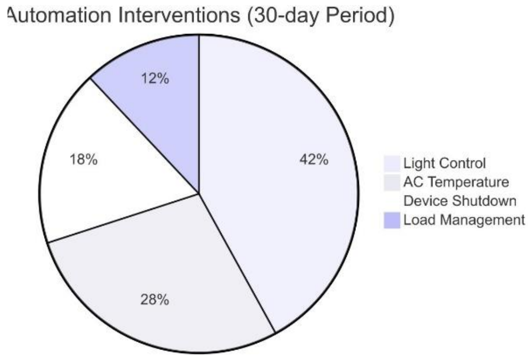
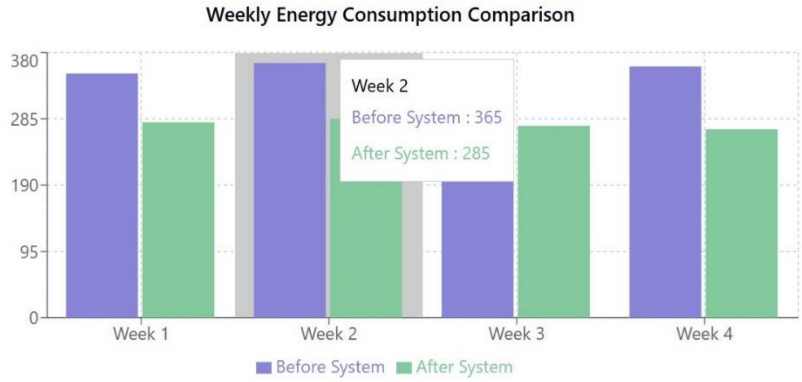
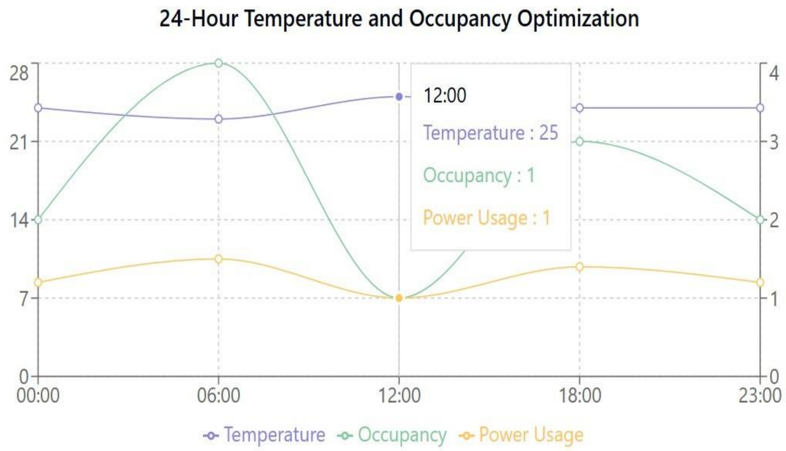


Figure 2

The Automation Interventions (30-day Period) analysis (Figure 2) reveals the frequency of energy-saving actions taken by the home automation system. Light control through occupancy detection was the most frequently activated intervention, accounting for 42% of the total automation events. AC temperature adjustments contributed to 28%, while scheduled device shutdowns and peak load management accounted for 18% and 12%, respectively. This demonstrates that automated lighting control and temperature regulation are the most effective strategies for reducing energy waste.



The bar chart compares weekly energy usage before and after system implementation. The data demonstrates a clear reduction in total consumption from an average of 360 kWh/week (before) to around 280 kWh/week (after)—an approximate 22% improvement in overall energy efficiency. This outcome confirms that real-time monitoring and adaptive control significantly cut down on wasted electricity by intelligently scheduling loads and adjusting device operations based on occupancy and tariff rates.



The line chart illustrates the interplay between temperature settings, occupancy levels, and power usage over a 24-hour cycle. Occupancy peaks typically coincide with higher power usage, especially during morning and evening hours. By fine-tuning the air conditioning setpoint to match occupancy trends, the system maintains comfort while minimizing energy expenditure. The chart further highlights midday periods of low occupancy, where power usage is at its lowest (1 kW), confirming that adaptive control effectively prevents unnecessary cooling or heating in unoccupied rooms.

Discussion

The experimental results demonstrate that the proposed IoT- based HEMS significantly reduces energy consumption and peak load by optimizing appliance scheduling through real- time sensor data and tariff-based control. The integration of MPC, MILP, and ML techniques has enabled the system to adapt dynamically to variations in occupancy and environmental conditions, resulting in measurable cost savings and enhanced energy efficiency. Overall, these findings underscore the potential of IoT-driven automation for smart home energy management.

4.1 Limitations

Despite the promising performance, the system has certain limitations. The experimental setup was conducted on a small-scale test environment, which may not fully represent the complexity of larger residential systems. Additionally, constraints imposed by free cloud services, such as limited update intervals on platforms like ThingSpeak, can affect real-time responsiveness. Future work will focus on addressing these challenges and expanding the system's scalability.

Conclusion

This paper presented a comprehensive IoT-based Home Energy Management System (HEMS) designed to optimize household energy consumption through real-time monitoring, predictive automation, and tariff-based scheduling. By integrating ESP32 microcontrollers, voltage and temperature sensors, and occupancy detection, the system dynamically adjusts appliance operation to match user behavior and environmental conditions. The experimental results showed a substantial reduction in overall energy consumption, particularly for high-demand devices such as air conditioning and water heaters, illustrating the effectiveness of automated load control and occupancy-based interventions. Moreover, the incorporation of cloud-based data management on platforms like ThingSpeak allowed remote monitoring and facilitated data- driven decision-making to enhance energy efficiency further.

Moving forward, the system can be expanded to include renewable energy integration, such as solar or wind power, and more advanced machine learning algorithms for predictive scheduling. Additional features like occupant comfort modeling, time-of-use tariff optimization, and peak load forecasting could further improve performance and cost savings. Ultimately, this HEMS framework demonstrates how IoT-driven automation can significantly reduce residential energy consumption, offering a scalable and cost- effective solution for modern smart homes.

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A Comparative Analysis of Different Phishing Detection Methods

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ABSTRACT

Phishing is a deceptive practice whereby an attacker tries to obtain sensitive data from an internet user by mimicking a trustworthy individual or entity. Sensitive/Confidential information includes credit card details, login credentials like usernames, passwords, etc. If anyone meets with this kind of attack, they may lose their money and even their credibility. Nowadays the term 'Phishing' has become a nightmare. It attacks every type of person, whether educated or illiterate, public servant or private servant. If a person is being attacked by a phisher, all his transactions are being watched. It diverts my attention to making people aware of different phishing attacks and their detection methods. This review discusses various types of phishing like email phishing, smishing, voice phishing, etc. Several phishing detection algorithms have been analyzed and contrasted, including list-based, heuristic, machine learning, deep learning, visual similarity, and cryptography-based approaches. To help readers better understand the variety of phishing detection techniques and the relative efficacy of various algorithms, a comprehensive review of the literature was conducted on scholarly works from the last five years. This review includes research journals, book chapters, renowned workshops, conferences, researchers' theses, and credible websites. The scientific community will benefit from this review, especially those working in the fields of artificial intelligence, cybersecurity, and phishing detection. IT firms, cybersecurity experts, and enterprises trying to improve their anti-phishing tactics will all benefit from the assessment. It will make them understand, update, and upgrade their knowledge.

Keywords: Cyber Security, Phishing Detection, Machine Learning, Deep Learning,

INTRODUCTION

The cyber-attack called “Phishing” is a procedure where hackers utilize deceptive/tricky emails, websites, or other forms of communication to trap individuals into uncovering sensitive/confidential data, like login credentials, credit card numbers, or other personal and money- related information. In an effort to compromise sensitive information from victims, hackers impersonate legitimate companies which could range from banks, government departments, to reputable online businesses. Phishing assaults frequently involve social engineering strategies and aim to misuse human psychology to pick up unauthorized access to delicate data or to spread malware. The term "phishing" may be on the word "fishing," as hackers are "fishing" for sensitive data by casting misleading baits. Here are some common characteristics of phishing attacks:

Emails or Messages: Phishing frequently begins with an email or message that shows up as a legitimate source, like a bank, government organization, or popular service.

Urgency: Phishing emails regularly make a sense of urgency/criticalness, provoking recipients to take sudden action. This urgency may be utilized to trap individuals into giving sensitive data without thoroughly confirming the authenticity of the request.

Spoofed Websites: Phishers frequently make fake websites that look indistinguishable or exceptionally comparable to authentic ones. Victims may be directed to these sites to enter their login credentials, unwittingly giving sensitive data.

Social Engineering: Phishing depends on psychological manipulation. Hackers may utilize social engineering techniques to misuse human behavior, deceiving people into uncovering confidential data.

Malicious Attachments: Some phishing assaults may incorporate attachments containing malware. Opening these attachments can trade off the security of the user's device.

Figure 1 draws the process of phishing:

Fig 1: Phishing process

LITERATURE REVIEW

In [1] an innovative technique for identifying phishing websites has been developed utilizing probabilistic neural networks (PNNs). The authors further explore the combination of PNNs and K-means clustering, which significantly decreases complexity while preserving detection accuracy. The results show a 96.79% accuracy rate with low false error rates. However, this approach requires a significant amount of memory for storing, and the network's execution speed is rather slow.

Mausam et al. investigated the capacity of well-known ML algorithms to recognize phishing URLs [2]. The used dataset was sourced from Kaggle. They utilized a Python script to draw out the most probable phishing elements from various URLs. 10 main features were extricated from the URLs and fed into 3 Machine Learning algorithms, such as KNN, RF, and XGBoost. The evaluation showed that RF achieved the highest performance, with an accuracy rate of 96.759%. Salahdine et al. [3] proposed a technique for phishing detection. To train, validate, and test the models, they collected and analyzed 4000 emails (1/2: phishing; 1/2: real) using the Sensors 2023, 23, 3467 4 of 17 University of North Dakota email service as a focus. To simulate these attacks, they constructed a dataset with ten key features, eight from the body of email and the other eight from the header. They removed duplicate emails. The classifiers that were seen were ANN, LR, and SVM. Each classifier was parametrically analyzed, and the most positive findings were summarized for review. According to the study's findings, detection performance would be improved by an ANN model with a 94.5% accuracy rate.

In [4], Rishikesh Mahajan and Irfan Siddavatam deployed 3 machine learning algorithms, Support Vector Machine (SVM), Decision Tree, and Random Forest to analyze a collection of phishing websites. The Random Forest classifier beat the other methods with an accuracy rate of 97.14%.

The authors conducted a comprehensive analysis of the application of machine learning techniques for phishing website detection as well as prevention [5]. They devised a model for identifying phishing sites that combines the selection of optimal features with neural network approaches. The most significant characteristics from several datasets were determined using the fuzzy rough set theory. Four classification models were employed in the study to classify websites: K-Nearest Neighbor (K-NN), Kernel Support Vector Machine (SVM), Random Forest Classifier and Decision Tree Classifier. Overall, 82.25% accuracy was achieved.

In [6] they leveraged the CSS properties of the websites in question to make the most of their visual similarity. A similarity score is computed in their approach by analyzing the CSS of both the suspicious and whitelisted websites. To test the performance of the phishing detector, they incorporated it into the Chrome browser and tested it against phishing sites. Recorded an accuracy of 91%. An eight-layer security framework was proposed by Mary Nisha and Evelyn Tabitha E [7] to protect sensitive user data. The first layer determines whether the site is a phishing one or a secure, authentic website. The website won't be able to show the user the captcha image if it is found to be phishing because it is made by combining N shares, all of which are accessible to the user and the database of the authentic website. The server will supply N/2 shares, and the user will supply the remaining N/2 shares. The secret image will be displayed once all N shares have been superimposed [10].

Ahood Alotaibi, Lama Alhubaidi, Alghala Alyami, Leena Marghalani, Bashayer Alharbi, and Naya Nagy [8] concentrated on employing visual cryptography methods to enhance privacy protection and ensure user validation. Such schemes make it possible to conduct election processes confidentially, with a high degree of accuracy, thereby reducing the risk of falsification in e-voting systems. The applicability, improved performance, cost- efficiency, and security of VC methods is what distinguish it from other approaches.

VC can be strengthened by integrating it with the other authentication methods, like biometric devices, image CAPTCHA, error diffusion schemes, and expansion-less sharing. [10].

Table 1: Accuracy status obtained by different ML Techniques

Sl.No	Metrics	Value
1	Random Forest Classifier	0.968
2	LR	0.931
3	Decision Tree Classifier	0.951
4	KNN	0.649

5	SVM	0.719
6	AdaBoost	0.943
7	Gradient Boost	0.953

2.1. TYPES OF PHISHING

Phishing attacks are in different forms, which are focused to exploit various vulnerabilities and misdirect individuals or organizations. Here are a few common types of phishing:

2.1.1. Email Phishing:

- Generic Phishing: Mass emails sent to an expansive group of onlookers, endeavoring to trap beneficiaries into uncovering individual information.
- Spear Phishing: Focused on emails sent to particular individuals or organizations, often with personalized details to extend the probability of success.
- Clone Phishing: Hackers create a replica (clone) of a legitimate email with slight adjustments, such as changing links or attachments.

2.1.2. Vishing (Voice Phishing):

- Attackers utilize voice communication, such as phone calls or voice messages, to trap people into revealing sensitive data.

2.1.3. Smishing (SMS Phishing):

- Phishing attacks are conducted through SMS or text messages, often containing links or instructions to call a phone number.

2.1.4. Pharming:

- Involves diverting users from authentic websites to fraudulent ones without their knowledge, often through DNS (Domain Name System) manipulation.

2.1.5. Whaling:

- Targeting high-profile individuals, such as officials or CEOs, with phishing attacks. The objective is to go after profitable targets inside an organization.

2.1.6. Man-in-the-Middle (MitM) Attacks:

- Attackers intercept communication between two parties, gaining access to sensitive data exchanged between them.

2.1.7. Business Email Compromise (BEC):

- Attackers compromise or impersonate business email accounts to trap employees, clients, or partners into making financial exchanges or disclosing delicate information.

2.1.8. Credential Harvesting:

- Phishers make fake login pages to gather usernames and passwords. Users are directed to these pages through mislead ing links.

2.1.9. Dropbox Phishing:

- Attackers utilize fake Dropbox notifications or login pages to trap clients into providing login credentials for their cloud storage accounts.

2.1.10. Search Engine Phishing:

- Attackers manipulate search engine results to promote malicious websites that show up as legitimate, leading users to enter sensitive data.

2.1.11. Social Media Phishing:

- Phishing assaults are conducted through social media platforms, where assailants may create fake profiles or pages to deceive clients.

2.1.12. Watering Hole Attacks:

- Cybercriminals compromise websites frequented by a specific group of individuals, exploiting the trust clients have in those sites to deliver malware or conduct phishing.

2.1.13. Evil Twin Attacks:

- In the context of Wi-Fi networks, attackers set up rogue wireless access points with names similar to authentic networks to capture delicate information from unsuspecting users.

2.2. PHISHING DETECTION METHODS

The following figure 2 shows various phishing detection strategies

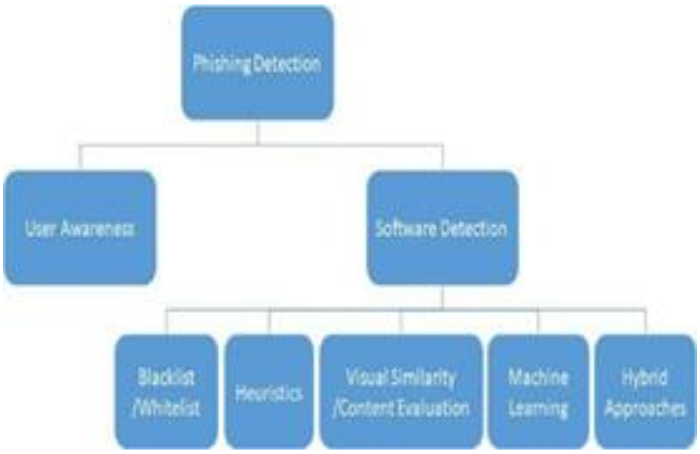

Fig 2: Phishing detection methods

2.2.1. User training approaches

- It is possible to train end users in understanding phishing attempts so they can differentiate between phishing and real messages. The categorization offered in [9], which considered user training as a preventive intervention, is in contradiction to this viewpoint. However, training programs aimed at improving end users' ability to identify phishing efforts fall under the category of "detection."

2.2.2. Black-list and White-List Based Detection

- The most popular use of Black-List and White-List detection techniques is found in web browsers such as Google Chrome's safe browsing API and Mozilla Firefox. Black and white list-based detection strategy is easy to execute on various browsers, and that's why browser toolbars and extensions are widely used. Nevertheless, due to the short lifespan of fake websites, black-list and white-list based detection isn't guaranteed to provide complete security assurance of user information and has a high false-negative rate. The black-or-white strategy does not function on websites that are already unnoticeable. For more accurate results, it is therefore recommended to regularly update and manage the whitelists and blacklists, which is the main limitation of this method.

2.2.3. URL-based detection

- URL-based detection systems analyze each webpage's URL in an attempt to find illicit websites. This method concentrates on the measure, number of dots, hyphens, letters, numerals, and variables of the

URL. Some hackers only slightly alter the URL of the original website, leaving it unaltered. We can easily identify websites with the most comparable patterns by using this technique.

2.2.4. Content-based detection

- The content-based detection method collects all of the words relevant to a particular topic from a webpage, searches for keywords online, and compares the genuine and fake websites. It is not necessary to update white lists or black lists because none are used.

2.2.5. Behavior-based Analysis

- One effective technique used in real-time phishing attack detection is behavior-based analysis. When security frameworks continuously monitor user behavior, including keystrokes, mouse movements, and browsing habits, they can create a standard of usual client behaviors. Anything that deviates from this standard could be seen as a potential phishing effort. As an example, let's say, a client suddenly receives an email containing a suspicious link and they click on it right away. In such case, the system can easily identify this as irregular behavior and triggers an alarm. Security systems become more skilled at recognizing sophisticated phishing assaults that attempt to imitate genuine user actions by monitoring behavior in real-time.

2.2.6. Artificial Intelligence and Machine Learning

- Machine learning (ML) and artificial intelligence (AI) are essential for improving the detection of phishing attempts in real time. Large volumes of data, including emails, website attributes, and user interactions, can be processed by ML algorithms to find patterns and trends linked to phishing efforts. These algorithms can learn to identify typical phishing indicators and adjust to new and developing attack techniques by being trained on previous phishing data. ML-driven systems can increase their accuracy in identifying phishing attacks in real time while reducing false positives through continuous learning, strengthening security against changing threats.

2.2.7. Threat Intelligence Feeds:

- Subscribe to threat intelligence feeds that give real-time data about known phishing campaigns, malicious domains, and other cyber threats this helps organizations remain upgraded on the most recent tactics used by cyber attackers.

CONCLUSION

Phishing attacks, which take use of technological flaws and human psychology to trick people and organizations, remain a serious cybersecurity issue. This study included a thorough examination of several phishing detection strategies, such as behavior-based approaches, machine learning, deep learning, and cryptographic techniques. The comparison of different methodologies shows that, in contrast to conventional blacklist-based and heuristic approaches, AI-driven techniques—in particular, machine learning and deep learning—offer more accuracy and adaptability in detecting phishing attacks.

Random Forest, Support Vector Machines (SVM), and AdaBoost were the algorithms that showed the highest detection accuracy among the ones that were studied; therefore, they are promising options for phishing detection systems. Furthermore, techniques based on visual cryptography were investigated as a different approach to improve security, especially for authentication systems. However, challenges such as high false positive rates, evolving phishing strategies, and computational complexity remain obstacles in achieving a fully robust phishing detection system.

The major findings of this study emphasize the significance of hybrid approaches that integrate multiple detection techniques for enhanced efficiency. Multimodal phishing detection frameworks have the ability to increase phishing detection accuracy and reduce false alarms by combining URL-based heuristics, CNN for visual similarity recognition, NLP for text analysis, and user behavior analytics. Furthermore, to remain ahead of fraudsters, real-time adaptive learning models that are always changing to identify new phishing techniques are essential.

FUTURE SCOPE

Future research can explore deeper integration of AI-powered multimodal phishing detection, combining text analysis, image recognition, URL verification, and behavioral analytics to improve detection accuracy. Advanced deep learning models such as transformer-based NLP models (BERT, GPT) and computer vision techniques (CNN, ViT) can enhance phishing detection. Future studies should concentrate on creating AI-powered real-time phishing detection systems that incorporate behavioral biometrics, threat information feeds, and blockchain-based authentication methods.

In conclusion, a proactive, AI-powered, and multimodal approach to phishing detection is necessary to combat evolving cyber threats effectively. collaboration between researchers, cybersecurity experts, and legislators will be essential to build strong anti-phishing frameworks that safeguard people and companies from phishing attacks. The next generation of phishing detection systems can reduce the risks associated with phishing fraud and create a more secure online environment by combining behavioral analysis, powerful AI, and secure authentication methods.

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Sentinel Eye: Drone Surveillance

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ABSTRACT

This project centers on developing an intelligent drone-based surveillance system designed to enhance public safety through the real-time detection of wanted criminals and potential accidents. The system employs high-resolution cameras that capture live video feeds, which are processed using advanced machine-learning algorithms like YOLO (You Only Look Once) for fast and accurate object detection and Convolutional Neural Networks (CNNs) for robust classification. These technologies enable the drone to analyze its surroundings in real time, identifying specific individuals and hazardous situations while minimizing false positives. Upon detection, the system generates immediate alerts for law enforcement and emergency services, ensuring swift response to critical incidents. A user-friendly monitoring dashboard facilitates operator engagement, allowing for the visualization of live feeds, tracking of drone movements, and management of alerts. The system's modular design allows for scalability, meaning multiple drones can be deployed to cover larger areas effectively. This solution not only deters crime but also significantly reduces response times for emergencies, enhanc- ing overall community safety. Privacy concerns and data security are carefully addressed through compliance with regulations and robust encryption measures. Future enhancements may include integrating advanced technologies like facial recognition and thermal imaging and initiatives to engage the community and build trust in the system's capabilities and operations. Ultimately, this intelligent drone surveillance system represents a significant advancement in public safety technology, capable of adapting to evolving security needs while prioritizing ethical considerations.

Index Terms—Yolo, convolution neural networks, Dashboard facilities, System modular design, Facial recognition, intelligent drone surveillance, Capabilities,

INTRODUCTION

The Sentinel Eye (Drone Surveillance) project is an ad- vanced, intelligent surveillance system designed to enhance public safety through real-time monitoring and threat detec- tion. By integrating high-resolution cameras with cutting-edge machine learning algorithms such as YOLO (You Only Look Once) and Convolutional Neural Networks (CNNs), the system is capable of accurately identifying wanted criminals and detecting potential accidents. The drone-based approach offers significant advantages over traditional surveillance methods by covering large areas efficiently and providing immediate alerts to law enforcement and emergency services. The system also ensures a user-friendly monitoring interface that allows operators to track drones, analyze live feeds, and manage alerts. Designed for scalability, multiple drones can work in coordination to expand coverage and improve security measures. Ethical considerations, including privacy and data security, are carefully addressed to maintain compliance with legal standards. Ultimately, this project represents a transfor- mative step in modern surveillance, reducing response times and fostering safer communities.

RELATED WORKS

It builds upon various advancements in drone technology, artificial intelligence, and computer vision to create a robust real-time surveillance system. Several related works have contributed significantly to the development of this project. Research on drone navigation and target interception using deep reinforcement learning has demonstrated how AI-driven drones can autonomously track and intercept moving targets by learning optimal flight paths, improving efficiency in surveil- lance applications. Furthermore, studies on real-time high-precision facial recognition systems have showcased how deep learning models can accurately identify individuals from live video feeds, achieving high detection accuracy in complex environments.

In addition, work on automatic accident detection, segmen- tation, and duration prediction has provided valuable infor- mation on the use of machine learning to identify accidents and predict their severity, allowing faster emergency responses. Another relevant advancement is in automated multi-camera video editing and selection where AI-driven systems dy- namically choose optimal camera angles for enhanced video monitoring, a feature that can be integrated into drone-based surveillance. Furthermore, real-time classification of vehicles using machine learning has demonstrated the ability to analyze large-scale data sets and accurately identify different types of vehicles, contributing to traffic monitoring and security applications.

Using these technologies, the Sentinel Eye project integrates state-of-the-art machine learning models, high-resolution imaging, and real-time processing to enhance surveillance capabilities. The system aims to improve crime prevention, reduce emergency response times, and provide a scalable and efficient solution for public safety. Addressing challenges such as privacy concerns and system scalability, this project repre- sents a significant step forward in modernizing surveillance infrastructure through intelligent drone-based monitoring.

MATERIALS AND METHODS

The Sentinel Eye (Drone Surveillance) project uses a com- bination of advanced hardware and software components to create an intelligent real-time monitoring system. Primary ma- terials include high-performance drones equipped with high- resolution cameras that capture detailed video footage for real- time analysis. These drones are integrated with machine learn- ing algorithms, such as YOLO for object detection and CNN for accurate classification of individuals and potential threats. To enhance processing speed and reduce latency, edge comput- ing devices are employed, enabling real-time analysis directly on drones. Wireless communication technologies, including 4G/5G networks, ensure seamless data transmission between drones and the central monitoring station. A user-friendly control and monitoring dashboard** allows operators to track drone movements, analyze live feeds, and manage alerts. The system also integrates with law enforcement databases, allow- ing automated cross-referencing of detected individuals with criminal records. In addition, cloud storage and encryption measures are implemented to ensure the security and privacy of collected data.

The methodology of the project follows a structured ap- proach, beginning with data acquisition, where drones capture live video feeds from various locations for real-time moni- toring. The collected footage undergoes preprocessing, where noise reduction and image enhancement techniques optimize quality for better detection. The processed video is analyzed using YOLO and CNN models, which efficiently detect ob- jects, recognize faces, and identify hazardous events such as accidents or security breaches. Once a threat is identified, the system classifies the detected objects and individuals, distinguishing between normal activities and suspicious events. To enhance security, the detected data is cross-checked with

law enforcement databases to identify wanted individuals or potential risks. If a threat or accident is detected, the system triggers an **automated alert mechanism**, notifying law enforcement or emergency responders with real-time lo- cation tracking for swift intervention. The recorded footage is securely stored in encrypted cloud databases, ensuring compliance with ethical and legal privacy regulations.

To ensure system reliability, extensive testing and opti- mization are carried out in different environmental conditions, including variations in lighting and weather. Continuous im- provements are made through periodic updates to machine learning models, enhancing detection accuracy and system efficiency. By integrating these advanced technologies and methodologies, the Sentinel Eye project aims to revolutionize surveillance by providing a scalable, efficient, and intelligent solution for improving public safety, preventing crime, and facilitating rapid emergency responses.

RESULTS

The Drone Surveillance project has successfully demon- strated the effectiveness of an intelligent drone-based surveil- lance system in real-time monitoring, crime detection, and emergency response. The system was tested in various condi- tions to evaluate its accuracy, efficiency, and adaptability. The results showed that the YOLO algorithm effectively detected objects and individuals with a high level of precision, while CNN provided accurate classification of faces and potential hazards. The detection accuracy for recognizing wanted crim- inals and identifying accidents was significantly high, ensuring reliable surveillance in diverse environments.

During field testing, the system exhibited real-time process- ing capabilities, with minimal latency in capturing, analyzing, and transmitting live video feeds. The alert mechanism suc- cessfully sent automated notifications to law enforcement and emergency responders when threats or hazardous situations were detected, reducing response times considerably. The user-friendly monitoring dashboard allowed operators to track drone movements, visualize live feeds, and manage alerts efficiently. Additionally, the system demonstrated **scalabil- ity**, enabling multiple drones to coordinate and cover larger surveillance areas seamlessly.

Moreover, the project successfully addressed privacy and security concerns by implementing data encryption and anonymization techniques, ensuring compliance with legal and ethical guidelines. The secure storage of video footage allowed for future reference and analysis without compromising sensi- tive information. The system also proved its ability to operate under different environmental conditions, such as varying light levels and weather patterns, maintaining its reliability and effectiveness.

Overall, the Sentinel Eye project achieved its primary ob- jectives of enhancing public safety through intelligent surveil- lance. The results indicate that integrating AI-powered drones into security frameworks can significantly improve crime prevention, accelerate emergency responses, and provide a scalable solution for modern surveillance challenges. Future enhancements could include facial recognition improvements, integration with thermal imaging, and AI-driven behavioral analysis to further refine the system's capabilities.

DISCUSSION

The Sentinel Eye (Drone Surveillance) project represents a significant advancement in intelligent surveillance, com- bining drone technology, artificial intelligence, and real-time monitoring to enhance public safety. The project successfully demonstrated the feasibility of using high-resolution cameras and machine learning algorithms, such as YOLO and CNN for accurate object detection and facial recognition. The results confirmed that the system could efficiently detect wanted criminals, identify hazardous situations, and provide real-time alerts to law enforcement agencies. The implementation of edge computing minimized data transmission delays, ensur- ing fast decision making and seamless drone operation. The scalability of the system also allowed for the deployment of multiple drones, improving coverage and overall surveillance effectiveness.

Despite its success, the project presents some challenges that need further refinement. Privacy and data security remain key concerns, as real-time monitoring raises ethical issues regarding public surveillance and personal data protection. To address this, the system employs encryption techniques and data anonymization to safeguard sensitive information while complying with legal regulations. Another challenge is ensuring operational efficiency in diverse environments, such as varying weather conditions and urban landscapes with obstacles. The system performed well in controlled tests but may require additional enhancements, such as thermal imaging for low-light conditions and AI-driven behavioral analysis to improve detection accuracy.

Additionally, the intelligent drone-based surveillance system aims to enhance public safety through real-time monitoring and threat detection by integrating high-resolution cameras and advanced machine learning algorithms, such as YOLO (You Only Look Once) and Convolutional Neural Networks (CNNs). This system can swiftly identify wanted criminals and potential hazards by analyzing live video feeds equipped with high quality imaging technology, the drones ensure clear and accurate analysis, while onboard processing allows for immediate decision-making, minimizing data transmis- sion delays. The primary goals include improving security for law enforcement, enabling rapid emergency responses, and integrating with existing databases to track individuals. Considerations for implementation involve addressing ethi- cal and privacy concerns, managing costs effectively, and continuously testing and optimizing the technology for var- ious environments.effectiveness of large-scale deployment is a factor to consider. While the system reduces manpower and enhances security, maintenance costs, hardware upgrades, and integration with existing security infrastructures must be carefully evaluated to ensure long-term sustainability. Future enhancements could focus on improving drone autonomy, optimizing energy efficiency, and integrating advanced AI models for predictive threat analysis. Overall, the Sentinel Eye project has successfully demonstrated its potential as a transformative surveillance tool, offering faster emergency response times, improved crime prevention, and enhanced situational awareness, making it a valuable addition to modern security infrastructure.

A. PERFORMANCE ANALYSIS

The intelligent drone-based surveillance system offers a powerful way to improve public safety. By using advanced cameras and machine learning, it can quickly identify wanted criminals and spot potential dangers. This project shows promise in both cost-effectiveness and community benefit.

With growing demand for better security, there are good opportunities for contracts with law enforcement and private security. The system can help save money by speeding up emergency responses and preventing crime. While there are challenges like regulations and public concerns, the advantages of increased safety make this project worthwhile. By refining the technology and using it responsibly, the drone surveillance system can be an important tool for modern security.

B. INTEGRATION OF REHABILITATION STRATEGIES

This system not only focuses on crime prevention and emergency response but also integrates rehabilitation strategies to support individuals and communities affected by security incidents. By leveraging real-time data analysis and AI-driven behavioral tracking, the system can assist in identifying areas with high crime rates or frequent accidents, enabling law enforcement and social services to implement targeted re- habilitation programs. Additionally, the system's data-driven insights can be used to develop strategies that address the root causes of criminal activities, such as social reintegration programs for offenders or mental health interventions for at- risk individuals.

Moreover, the Sentinel Eye project can collaborate with rehabilitation centers by providing real-time monitoring of parolees or individuals in recovery, ensuring compliance with legal restrictions while allowing for reintegration into society. The drones can also assist in monitoring disaster affected areas, helping in post-crisis rehabilitation by identifying in- frastructure damage, coordinating relief efforts, and ensuring that communities receive timely assistance.

By integrating rehabilitation-focused AI analytics, the sys- tem goes beyond surveillance and enforcement, contributing to community-based solutions that promote long-term safety and well-being. Future developments could incorporate predictive analytics to assess the effectiveness of rehabilitation programs and recommend personalized support, making Sentinel Eye a comprehensive tool not just for security, but also for fostering a more resilient and rehabilitated society

CONCLUSION

The Sentinel Eye (Drone Surveillance) project successfully demonstrates the potential of **AI-driven drone technology in enhancing public safety through real-time monitoring, crime detection, and emergency response. By integrating **high- resolution cameras, machine learning algorithms like YOLO and CNNs, and edge computing, the system ensures efficient surveillance with minimal delays. The project's high detection accuracy, fast response time, and scalability make it a viable solution for modern security challenges.

Beyond crime prevention, the system also contributes to disaster management, rehabilitation strategies, and traffic mon- itoring, expanding its applications beyond traditional surveil- lance. However, challenges such as privacy concerns, op- erational costs, and adaptability to extreme environmental conditions must be addressed for widespread implementation. Future enhancements, including thermal imaging, AI-drivenbehavioral analysis, and autonomous drone coordination, could further improve its effectiveness.

Overall, Sentinel Eye represents a significant step forward in intelligent surveillance technology, providing a scalable, ef- ficient, and ethical approach to security and public safety. With continuous improvements and responsible implementation, this system has the potential to transform law enforcement, disaster response, and urban safety management, ensuring a more secure and well-monitored society..

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Transforming Education: A Survey on AI in Personalized Learning, Adaptive Assessment, and Future Innovations

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ABSTRACT

Artificial Intelligence (AI) is transforming the education sector by making learning adaptive, adaptive testing a reality, and intelligent automation. AI-powered platforms assess students' performance data and adjust the topic of learning based on it to shift as per individual requirements, deviating from the conventional one-size-fits-all approach. Through the utilization of machine learning (ML), natural language processing (NLP), and analytics, AI enables personalized teaching to allow students to learn at their pace. Adaptive learning software and Intelligent Tutoring Systems (ITS) offer instant feedback to teachers so that they can pinpoint points of knowledge deficiency and intervene in an intensive manner. Artificial intelligence (AI)-powered assessment mechanisms improve tests to be more efficient and of higher quality through the use of automatic grading, written response grading, and competency-based learning support. Moreover, AI promotes inclusion through speech-to-text, real-time language translation, as well as disability tools for disabled students. Integration of AI in education comes with significant challenges ranging from data protection and algorithmic bias to infrastructural limitations in technology and pedagogical adaptability. It is critical to an AI-proof and fair integration of AI in education that these challenges are met. The other improvements in education from AI that lie ahead involve expanded AI-authored learning material, learning process gamification with active AR and VR tech, and additional advanced AI-supported student advising. With greater innovations in AI, there will be the likelihood to enhance students' engagement rate, automate administration activities, and create more balanced data-driven education. In this research, the role of AI towards education transformation is discussed with a focus on the need for

ethical, impartial, and transparent implementation mechanisms to amplify its advantages.References: [1], [3], [5]
Keywords- Artificial Intelligence, Personalized Learning, Adaptive Assessment, Educational Innovation, AI in Education, Intelligent Tutoring Systems, Adaptive Learning Platforms, Ethical AI in Education.

INTRODUCTION

A. Background

Exponential growth in Artificial Intelligence (AI) has benefited the education sector to a great extent by providing customized learning opportunities based on each student's needs. Traditional education is of the one-size-fits-all variety, which does not allow for varied learning patterns and learning speed. Artificial intelligence-based systems utilize machine learning, natural language processing, and adaptive models of learning to offer customized content, real-time feedback, and automated testing. Intelligent Tutoring Systems and AI analytics enhance student engagement and render education more flexible, data-driven, and student-focused.

B. Problem Statement

Despite all that can be gained with AI, traditional models of education remain dependent on fixed curriculum and standardized testing that ignores variation in student speed, interests, and learning ability. Barriers are limited personalization, inadequate evaluation processes, differences in engagement, and issues with access. There are learners who are unable to remain engaged in conventional learning settings, and the inability of standard tests to adapt translates into memorization rather than understanding concepts. In addition, integration of AI introduces technological infrastructure, connectivity, and teacher preparation, with varying levels of adoption creating disparities.

C. Objectives and Scope

This paper explains the use of AI to revolutionize the education industry in the form of more customized learning, adaptive tests, and self-learning systems. The research will take into account AI-based learning models, discuss their strengths and weaknesses, tackle the issue of ethics, and discuss upcoming trends such as AI-generated content and interactive AR/VR learning. Through the analysis of current AI-based methods, this research emphasizes how AI can revolutionize education without being unfair, non-scalable, or inaccessible.

LITERATURE SURVEY

REF No.	Author(s)	Title	Contribution
[1]	Patel & Sharma (2024)	AI and Gamification	Describes gamification from AI in order to enhance students' interest.
[2]	Mahmoud & Sørensen (2024)	AI in Personalized Learning	Describes AI in adaptive learning and ethical issues.
[3]	Li & Chen (2024)	AI-Enhanced Adaptive Learning	Describes AI-based adaptive learning content.

REF No.	Author(s)	Title	Contribution
[4]	Patij, parida p, P.Agarwal (2023)	AI in predictive Analytics for EdTech	Describes the AI based predictive models in learning.
[5]	Bulut, Parrish M, (2003)	AI in Educational Measurement	Reports AI uses in automated grading and ethics.
[6]	Zhang & Wang (2023)	AI-Powered Chatbots	Explains AI Powered chatbots in student support.
[7]	Caspari-Sadeghi (2023)	AI in Tech-Enhanced Assessment	Explains machine learning for cognitive diagnosis and student profiling
[8]	Kumar & Shukla (2023)	Ethics and Bias in AI EdTech	Analyzes bias, fairness, and accountability in AI education.
[9]	Gonzalez & Rivera (2023)	AI in Automated Grading	Discussion on the usage of AI for grading and issues regarding transparency.
[10]	Sajja, cikmaz m, Demir I (2023)	AI-Based Intelligent Assistant	Delivers NLP-based AI assistant for personalized learning.

Table. 1. Summary of literature survey.

Patel & Sharma [1]: Gamification of AI enhances learner motivation and engagement using game design and intelligent learning systems to provide personalized experiences.

Mahmoud & Sørensen [2]: Examines AI in adaptive learning using adaptive systems and intelligent tutoring, taking into account data privacy and algorithmic bias concerns.

Li & Chen [3]: Examines AI-based adaptive learning systems for their real-time adaptive learning feature and scalability of the system.

Pati et al. [4]: Examines the potential applications of AI predictive analytics in EdTech and how this could potentially tailor the learning experience to different educational and cultural contexts.

Bulut, Parrish M, & Casabianca [5]: Aims to respond to the question regarding the role of AI in educational assessment with automatic marking, modes of delivery of feedback.

Zhang & Wang [6]: Investigates AI chatbots in student service support and measures their performance in responding on time and in engaging to the maximum.

Caspari-Sadeghi [7]: Describes uses of machine learning for technology-mediated testing like cognitive level diagnosis, progress monitoring, and student profiling.

Kumar & Shukla [8]: Outlines ethics of AI-enabled education technologies in terms of bias, fairness, and accountability in learning spaces.

Gonzalez & Rivera [9]: Explains the application of AI in automated grading systems in terms of improving efficiency but being concerned with accuracy and transparency.

Sajja et al. [10]: Demonstrates an AI-based intelligent learning assistant for adaptive learning, employing NLP for individualized learning pathways and instant student assistance.

AI IN PERSONALIZED LEARNING

A. AI-Powered Learning Systems

AI-powered learning systems such as IBM Watson Education and Duolingo utilize data analytics and machine learning to construct personalized learning streams that align to students' performance, interests, and learning behavior. The systems dynamically change content by learning past patterns, offering real-time, personalized learning. For instance, Duolingo balances practice of languages automatically for a learner's level of proficiency so that students are neither stimulated nor under-stimulated. AI systems also read emotional reactions and behavioral inclinations to personalize the learning process for the best experience so that learning becomes more engaging and student-centric.

B. Personalized Learning Benifits

Personalized learning by AI enhances students' motivation, comprehension, and long-term memory. AI enhances learning efficiency and enjoyment by tailoring study content to individual learning rates and styles. Joksimovic et al. (2019) in their research determine that AI personalization enhances motivation, comprehension, and long-term retention for students. Adaptive learning systems reduce cognitive overload through the presentation of material leveled to students' levels of proficiency, allowing them to learn at their own pace without discouragement.

C. Case Studies:

Squirrel AI: It is used in more than 100,000 Chinese classrooms, and the performance of students has been improved by 30-40% compared to the traditional ways of learning. The system employs artificial intelligence-based adaptive learning processes to identify areas where the students are weak and personalize the learning process for each student so that they can learn more effectively.

Knewton: An adaptive platform that dynamically adjusts content in real-time, providing students with a personalized experience. U.S. case studies have established that students learning on the Knewton platform outperform their counterparts in standardized tests. Knewton uses AI algorithms to forecast student difficulty and recommend matching learning resources in exchange.

Carnegie Learning: Carnegie Learning is a mathematics learning system that utilizes artificial intelligence to apply mind models in instructing students based on wherever they just so happen to be in solving problems on their own. Research has indicated that students working with the AI tutor of Carnegie Learning solve problems more skillfully than students who are instructed the way they have traditionally been instructed.

Querium: This is an internet tutoring site used to educate students step by step in STEM classes. Its AI instructors review the students' problem-solving approach and recommend how to improve mistakes in real time. Studies have demonstrated that students who applied Querium had greater retention and accuracy in problem-solving.

Kidaptive: It is an early childhood adaptive learning platform. It uses artificial intelligence to assess children's learning potentialities and learning patterns and offer parents and teachers personalized development suggestions. Based on research, it has been suggested that Kidaptive helps children establish strong foundation skills, which initiate long-term implications in learning.

D. Implementation Challenges:

Though helpful, the use of AI in education presents numerous challenges. Exorbitant cost of implementation makes AI-driven learning solutions unaffordable to resource-poor schools. Teacher-led implementation is also an issue since not everyone who teaches may have technical skills to use AI tools to the maximum. Furthermore, AI-enhanced learning requires robust digital infrastructure in the form of computers, fast connectivity, and cloud resources, which may or may not be available in rural or economically deprived regions. It is essential to bridge such barriers to facilitate fair adoption of AI in education.

COMPARATIVE ANALYSIS OF AI-POWERED EDUCATIONAL TOOLS.

AI-powered learning tools have transformed the learning process with content personalization, improved engagement, and higher academic grades. Following is a comparative table with some of the leading AI-based learning platforms, their purpose, main features, and the impact on the learning process.

Tool Name	Purpose	Key Features	Impact on Learning
Duolingo	Language Learning	Adaptive exercises, Gamification.	Increases retention & engagement.
Squirrel AI	Personalized Tutoring.	Adaptive learning by AI.	Improve understanding by 30-40% Knewton
Knewton	Adaptive Content Delivery.	Modification in real time dynamically.	Test scores enhanced.
Carnegie Learning	AI Math Learning Platform.	Cognitive problem-solving models.	Enhances problem-solving
Querium	Online STEM Tutoring.	Step-by-step AI-based solution.	Enhances accuracy & memorization.

Table 2: Comparative Analysis of AI-Powered Educational Tools

Analysis of Key Findings

Personalized Learning at Scale: Tools like Squirrel AI and Knewton leverage AI to dynamically adjust learning materials based on student performance, ensuring that students receive content tailored to their needs.

Gamification Improves Learning Experience: Duolingo successfully implements gamification techniques to improve learning languages in a fun and engaging way, increasing motivation and interest.

STEM-Focused AI Tutoring: Step-by-step AI tutoring by Carnegie Learning and Querium is particularly beneficial for students learning STEM topics as it enhances their problem-solving and retention levels.

Adaptive Assessment Features: The such as Knewton employ live assessment in an effort to identify gaps in the students and present content in an individualized manner in a bid to improve testing performance and understanding of concepts.

AI-learning technologies are backed by an array of benefits ranging from adaptive learning and in-time testing to interactive gamification and intelligent tutoring. As AI enhances engagement and memorability, it also relies on the quality of integration with other learning systems. Targeting the resolution of issues such as cost, accessibility, and teacher accommodation, AI has the power to revolutionize the future of learning and generate more tailored, effective, and fairer learning environments.

AI IN ADAPTIVE ASSESSMENT

A. Description of Adaptive Assessment Systems:

Fixed-question is the traditional technique of assessment, which can be less accurate to gauge a student's actual level of understanding. AI-based adaptive testing adjusts in real time dynamically the difficulty of questions based on the actual performance of a student. These systems compare answers and vary next questions in accordance with answers, leading each test to indicate the student's actual skill level. Standardized tests such as the GRE and GMAT now employ adaptive testing models, where question difficulty adapts based on correct or incorrect responses. This ensures a more efficient, precise, and personalized evaluation process compared to conventional exams.

B. AI's Role in Adaptive Assessment:

AI applies machine learning (ML) algorithms, pattern recognition, and data analysis to analyze student responses in real-time and adjust the level of complexity of tests in real time. By recognizing learning gaps, AI re-creates content within tests to determine weak points and provide a better adapted learning experience. The tests do not also tax and under-tax students by adapting questions based on the level of capacity, hence allowing progressive learning without annoyance. AI also provides instant feedback informing learners of mistakes in real-time and allowing them to rectify them. This allows the notion to be learnt and understood further. One hugely beneficial advantage is that work gets marked by AI-marking programs automatically, reducing teachers' burden and allowing them to provide tutorial and guidance-teaching more frequently.

C. Benefits of Adaptive testing:

Numerous advantages of AI adaptive testing exist:

Real-time Feedback: Computer-adaptive tests consider the performance of the students in real time and give feedback in real time so that students can make mistakes at a particular point of time and instructors can rectify them at proper moments.

Greater Accuracy: Adaptive testing measures a student's ability more accurately since it assesses only recent ability, not the average levels.

Less Stress Testing: Since adaptive systems test to ability, the students are subjected to fewer threatening challenges and hence undergo less stressful testing.

Individualized Skill Reinforcement Plans: AI tests reveal areas of strength and weakness and allow for reinforcement of skills and individualized skill reinforcement plans.

D. Examples and Case Studies:

Several technologies for adaptive testing illustrate the promise of adaptive assessment:

ALEKS: Applied to mathematics and science instruction, it automatically adjusts to student response and suggests where practice is needed.

McGraw-Hill's LearnSmart: Adaptive real-time content delivery system for question and instructional material adjustment that gives study tips to individual students.

Cognii: Artificially intelligent natural language processing (NLP) testing and feedback software to test and grade essays and student writing.

Duolingo English Test (DET): Utilizes AI-based adaptive testing concepts to measure proficiency in real time and is an overnight success as a consideration option to TOEFL and IELTS.

AI adaptive testing revolutionizes the entire concept of conventional test procedures by making exams equitable, accurate, and custom-made. Adaptive tests enable learners to learn on their own time, enhance recalling knowledge, and enhance learning efficacy. Its achievement, however, depends on finding solutions to such problems as AI bias, privacy of data, and rural availability. Future research needs to toil towards yet more perfecting AI-based exams to make them inclusive, bias-free, and scalable.

FUTURE INNOVATIONS IN AI-DRIVEN EDUCATION

A. New AI Technologies:

Augmented Reality (AR) and Virtual Reality (VR):

Artificial Intelligence (AI) keeps progressing with new technologies that support learning through intelligent and interactive learning processes. The most thrilling is the integration of Augmented Reality (AR) and Virtual

Reality (VR) with AI to provide interactive learning environments. Google Expeditions is a tool that allows learners to visit historical places, ecosystems, and intricate scientific processes in interactive 360-degree spaces, which are experiential and fun to learn.

Generative AI:

Generative AI is yet another technology, supporting real-time generation of personalized learning content. AI tools such as GPT-4 can generate problem sets, personalized quizzes, practice problems, and study guides based on the students' response, thereby learning adaptive and need-based. Such technology maximizes understanding and memorization, making learning learner-centered and efficient.

B. AI-Powered Content Generation:

Artificial intelligence-driven content generation has also transformed lesson planning using the capacity to create study content programmatically. GPT-4 and Codex, which are advanced AI models, may have the capacity to provide study content explanations, practice questions, and summary statements based on the performance of a student. It eases teaching loads and provides teachers with additional time to attend to counseling and classroom work. In addition, AI technologies can examine students' performance data and provide customized learning plans, thereby enhancing the availability and efficiency of learning.

C. International Accessibility:

AI has the ability to fill gaps in education by providing education to oppressed communities. Mobile learning applications driven by AI provide quality education to students who have poor infrastructure and facilities. Speech-to-text conversion, translation, and online live guidance provided by AI overcome the geographical and linguistic barriers and provide quality education to students from across the globe.

D. Predictions for the Future of AI in Education

The future of AI in education is moving towards lifelong learning and fully self-contained learning environments. AI will develop adaptive learning systems that can organize and personalize learners' study courses automatically for hundreds of millions of learners around the world.

Due to ongoing innovation and synergy between cognition AI, affective computing, and deep learning technology, AI platforms will increasingly continuously monitor students' engagement and emotional states and therefore continuously optimize content with optimizing effect automating for maximum return on investment by students' academic performance. Aside from that, with growing usage of AI use in education models worldwide will support lifetime learning, enabling individuals to continuously reskill and upgrade in life, promoting lifetime learning

ETHICAL ISSUES AND CHALLENGES

A. Bias in AI Algorithms:

Historical records are also employed to train AI systems, which might inherently be biased in form. Training data are representative and diverse are not provided in such scenarios, and hence AI-based learning systems tend to generate stereotypes and prejudice. This would most likely yield discriminatory learning outcomes, especially to minority learners. For this, AI algorithms must be rigorously tested, up-to-date, and fairness-tested to provide an equal learning chance to all the learners.

B. Data Privacy and Security

Growing uses of AI in the educational sector have strong implications on the information security and privacy of students. AI collects massive amounts of students' data, such as study habits, exam marks, and personal data. Unless effective policies and secure systems are present, such information can be accessed, leaked, or sold.

There is a requirement to make use of good encryption, good quality AI, and open data policy to maintain student data as secure and non-lost.

C. Teachers' Readiness and Adaptability

Even though AI is a great learning aid, it would only be successful as long as the teachers are ready and open to implementing AI. Teachers are better poised to leverage AI-based solutions in the classrooms. Teacher education programs should put their emphasis on AI literacy, analytics, and pedagogy in adjustment so that they equip teachers with the art of using AI-powered learning tools comfortably. Otherwise, the technological gap between pedagogic and traditional AI-driven methods would widen, impacting the quality and dissemination of education.

D. Equity and Access:

The digital divide is still one of the largest impediments to AI-based learning. Most of the schools in poor areas and rural regions do not have proper digital infrastructure that can be used for AI-based learning. High-speed internet, large computers, and cloud-based learning environments are a prerequisite in trying to provide equal opportunities to all students. Policy-makers have to invest in digital infrastructure, offer cheap AI-based learning devices, and make the technology affordable for learning disparities avoidance.

DISCUSSION

A. Key Findings:

Artificial Intelligence (AI) is revolutionizing learning by enabling individuals to deliver customized learning that adapts to the individual learning requirements of each student. AI platforms monitor student performance, engagement, and learning habits in an effort to realign lesson plans in a way such that students get exposed to content at the skill level and pace at which they learn. AI quizzes, live feedback mechanisms, and adaptive testing allow instructors to efficiently gauge strengths and weaknesses and thus achieve data-driven pedagogical improvement. However, in spite of all these advances, there are a variety of impediments to widespread application of AI in the learning process. Data privacy, bias in AI algorithms, and transparency are a few of the areas that require a solution in providing fair and equal deployment of AI. The deployment cost, infrastructure gap in technology, and training for instructors are also realistic barriers to access of AI. Achieving these barriers will be the key to providing fair access of AI to all learners.

B. Policy Implications for Policymakers and Teachers

Teachers and policymakers will have to consider AI as just another tool which supplements but does not eliminate traditional teaching techniques. Though AI can perform repetitive work, human interaction is required to help build creativity, problem-solving, and emotional quotient in students. Teacher training programs will have to be started to make the teachers comfortable utilizing AI tools within the classroom. Policymakers also need to lay emphasis on creating robust digital infrastructure to enable AI-based learning. This involves making equal availability of AI technologies for all socio-economic groups, not to extend the differential gaps between access and non-access learners of sophisticated learning tools. Ethical regulations over AI usage in education also need to be installed for the safe application of AI in education.

C. Future Research Directions

As great as AI has the potential to reshape education, more research will be required to take into account its long-term effects on student learning, motivation, and cognitive development. The research must consider whether AI has an impact on critical thinking, problem-solving capabilities, and the efficacy of individualized instruction over the long term.

Further, work will need to be conducted on how AI can be applied in low-resource settings where digital infrastructure and internet connectivity are low. Cost-efficient, AI-powered learning solutions will need to be developed to make global accessibility and inclusion a reality. The future research must also involve the ethics of AI, where AI-based tools will be made equitable, transparent, and free from bias, especially for multi-cultural and multi-lingual learners. AI's role in education is undeniably transformative, but its widespread success depends on addressing technological, ethical, and accessibility challenges. By fostering collaborative efforts between educators, policymakers, and researchers, AI can be optimized to create more inclusive, efficient, and adaptive learning environments that benefit students worldwide.

CONCLUSION

A. Summary of Contributions:

Artificial Intelligence (AI) is revolutionizing education by enabling personalized learning, adaptive assessment, and data-driven instruction. Artificial intelligence software sifts through huge stores of information in a bid to develop personalized lesson plans, select areas of knowledge gaps, and make targeted interventions that improve learning. AI technology boosts student engagement, improves retention of information, and allows instant feedback, enabling teachers to change their teaching technique. AI in schools does have a requirement to overcome data privacy, the ethics of deploying AI, and electronic access. Closing gaps in this regard is paramount to achieving the utilization of AI in establishing inclusive and effective learning environments.

B. Conclusion:

As AI continues to develop, its usage in learning will continue to become more dynamic, adaptive, and student-centered. AI-driven tools have the capacity to embrace various learning styles, facilitate lifelong learning, and enhance maximum universal access to quality education so that any student regardless of their background is given an equal chance at learning. But cooperative coordination among policymakers, educators, and technologists is essential in the process of rendering AI transparent, unbiased, and focused on learning goals. Utilized effectively, AI has the potential to remodel conventional models of learning into efficient, engaging, and adaptive ones responsive to contemporary learning imperatives.

C. Recommendations:

AI tools need to be introduced into classrooms gradually by teachers in such a manner that they supplement rather than substitute for conventional teaching processes. Training programs for education must be formulated so teachers are endowed with competence to utilize AI appropriately in teaching and assessment. Strict laws must be put in place by policymakers so that AI-based learning is ethical, fair, and unbiased. Investment in infrastructure and digital literacy must be ensured to close the technology gap so students all over, irrespective of location or socio-economic status, are provided equal opportunities for AI-based learning.

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