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Artificial Neural Network in Medical Diagnosis

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ABSTRACT

Artificial Neural Network is a branch of Artificial Intelligence, has been accepted as a new technology in computer science. Neural Networks are currently a "hot" research area in medicine. People are too busy these days and also consultation with an expert is either unavailable or not available in a timely fashion. Medical professionals are not available everywhere. Many emergency situations may arise in places where medical consultation is not easily available A computer aided diagnosis system can be developed using Neural Networks that simulates medical reasoning. Medical reasoning can be implemented using Neural Networks People can consult this system for common problems. The Patients input the symptoms and the system then recognizes the disease based on the set of symptoms selected. The system also gives first aid suggestion for medical emergencies. The basic aim of the system is to recognize disease based on the symptoms observed by the patient. This paper is basically a medical diagnosis system which tells the user about the disease he/she is having on the basis of his/her symptoms.

Keywords : Neural Network, Medical Diagnosis, Disease, symptoms, Pattern Analysis

I. INTRODUCTION

The simplest definition of a neural network, more properly referred to as an 'artificial' neural network (ANN), is provided by the inventor of one of the first neurocomputers, Dr. Robert Hecht-Nielsen. He defines a neural network as:

”A computing system made up of a number of simple, highly interconnected processing elements, which process information by their dynamic state response to external inputs.”

People are too busy these days and also consultation with an expert is either unavailable or not available in a timely fashion. Medical professionals are not available everywhere. Many emergency situations may arise in places where medical consultation is not easily available A computer aided diagnosis system can be developed using Neural Networks that simulates medical reasoning. Medical reasoning can be implemented using Neural Networks People can consult this system for common problems. The Patients input the symptoms and the system then recognizes the disease based on the set of symptoms selected. The system also gives first aid suggestion for medical emergencies. The basic aim of the system is to recognize disease based on the symptoms observed by the patient. The patient need not consult a doctor and can have doctor in their Smartphone. In recent years machine learning methods have been widely used in prediction, especially in medical diagnosis. Medical diagnosis is one of major problem in medical application. Several research groups are working

world wide on the development of neural networks in medical diagnosis. Neural networks are used to increase the accuracy and objectivity of medical diagnosis. 'Neural networks' research and application have been studied for a half of hundred years.

An Artificial Neural Network (ANN) is an information processing paradigm that is inspired by the way biological nervous systems, such as the brain, process information. The key element of this paradigm is the novel structure of the information processing system (Eric Davalo and Patrick Naim, 1986). It is composed of a large number of highly interconnected processing elements (neurones) working to solve specific problems. ANNs, like people, learn by example. An ANN is configured for a specific application, such as pattern recognition or data classification, through a learning process. Learning in biological systems involves adjustments to the synaptic connections that exist between the neurones. This is true of ANNs as well. Artificial neural networks provide a powerful tool to help doctors to analyse, model and make sense of complex clinical data across a broad range of medical applications. In recent years machine learning methods have been widely used in prediction, especially in medical diagnosis. Medical diagnosis is one of major problem in medical application. Several research groups are working world wide on the development of neural networks in medical diagnosis. Neural networks are used to increase the accuracy and objectivity of medical diagnosis.

II. ARTIFICIAL NEURAL NETWORK

Before knowing about Artificial Neural Networks, at first we need to know what are neural networks and also about Structure of Neuron.

A. Structure of Neuron:

Neurons, also known as nerve cells, Cells within the nervous system, called neurons, communicate with each other in unique ways. The neuron is the basic working unit of the brain, a specialized cell designed to transmit information to other nerve cells, muscle, or gland cells.

Neurons or Nerve Cells are the basic building blocks of brains which are the biological neural networks. The structure of Neuron is as show below:

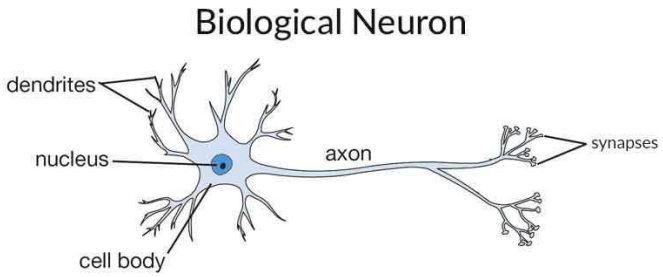

Fig.1. Structure of Neuron

Function of:

i) Dendrite: It receives signals from other neurons. Soma (cell body): It sums all the incoming signals to generate input.
ii) Axon Structure: When the sum reaches threshold value, neuron fires and the signal travels down the axon to the other neurons.
iii) Synapses Working: The point of interconnection of one neuron with other neurons. The amount of signal transmitted depend upon the strength (synaptic weights) of the connections.

B. Definition of ANN:

Artificial Neural Networks are the computational tools which were modeled after brains. It is made up of an interconnected structure of artificially produced neurons that function as pathways for data transfer. Or we can say Artificial Neural Network is a

mathematical representation of human neural architecture.

Artificial neural networks have been described as the second best way to form interconnected neurons. These artificial neural networks are used to model brains and also to perform specific computational tasks. A successful ANN application will have the capability of character recognition.

C. Architecture of ANN:

A Neural Network is formed by a series of "Neurons" or "Nodes" that are organized in layers and each node contain "activation function". Each neuron in a layer is connected with each neuron in the next layer through a weighted connection. Structure of Artificial Neural Network contains three layers.

i) Input Layer
ii) Hidden Layer
iii) Output Layer

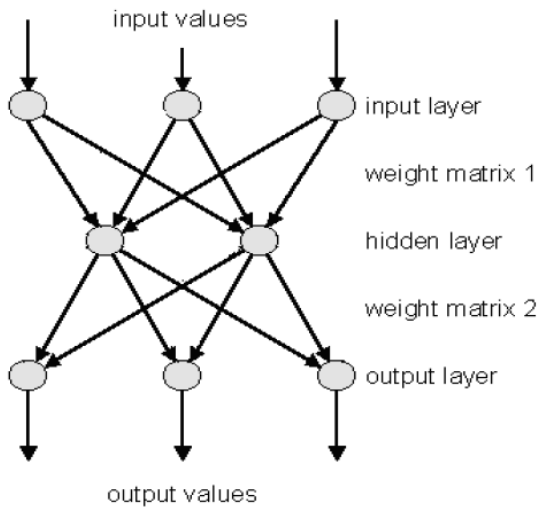

Fig.2. Real and Artificial Neural Network

1. Input Layer:

The Input layer communicates with the external environment. Its job is to deal with all the inputs only. The neurons in the input layer receives the data and transfer them to neurons in the hidden layer through the weighted links. Every input neuron should represent some independent variable that has an influence over the output of the neural network

2. Hidden Layer:

The hidden layer is the collection of neurons which has activation function applied on it and it is an intermediate layer found between the input layer and the output layer. Its job is to process the inputs obtained by its previous layer. So it is the layer which is responsible for extracting the required features from the input data.

Many researches has been made in evaluating the number of neurons in the hidden layer but still none of them was successful in finding the accurate result. Also there can be multiple hidden layers in a Neural Network. Suppose that if we have a data which can be separated linearly, then there is no need to use hidden layer as the activation function can be implemented to input layer which can solve the problem. But in case of problems which deals with complex decisions, we can use 3 to 5 hidden layers based on the degree of complexity of the problem or the degree of accuracy required. That certainly not means that if we keep on increasing the number of layers, the neural network will give high accuracy! A stage comes when the accuracy becomes constant or falls if we add an extra layer! Also, we should also calculate the number of neurons in each network. If the number of neurons are less as compared to the complexity of the problem data then there will be very few neurons in the hidden layers to adequately detect the signals in a

complicated data set. If unnecessary more neurons are present in the network then Over fitting may occur. Several methods are used till now which do not provide the exact formula for calculating the number of hidden layer as well as number of neurons in each hidden layer.

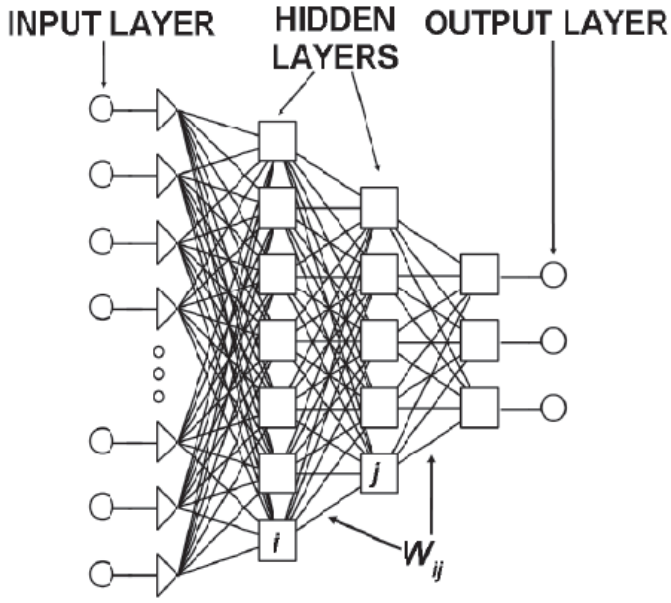

Fig 3. General structure of a neural network with two hidden layers.

- The neurons in the last layer provide the network's output. The j-th neuron in a hidden layer processes the incoming data (xi) by: (i) calculating the weighted sum and adding a "bias" term (θj)

$$net_j = \sum_{i=1}^{m} x_i \times w_{ij} + \theta_j \quad (j = 1, 2, \ldots, n)$$

The wij is the weight of the connection between the i-th and the j-th node.

- Various transfer functions are available (Zupan and Gasteiger 1999); however, the most commonly used is the sigmoid one:

$$f(x) = \frac{1}{1 + e^{-x}}$$

3. Output Layer:

The output layer of the neural network collects and transmits the information accordingly in way it has been designed to give. The pattern presented by the output layer can be directly traced back to the input layer. The number of neurons in output layer should be directly related to the type of work that the neural network was performing.

B. Types of ANN:

Some types of Artificial Neural Networks are discussed below :

i. Feedback ANN
ii. Feed Forward ANN

i. Feedback ANN –

In these type of ANN, the output goes back into the network to achieve the best-evolved results internally. The feedback network feeds information back into itself and is well suited to solve optimization problems, according to the University of Massachusetts, Lowell Center for Atmospheric Research. Feedback ANNs are used by the Internal system error corrections.

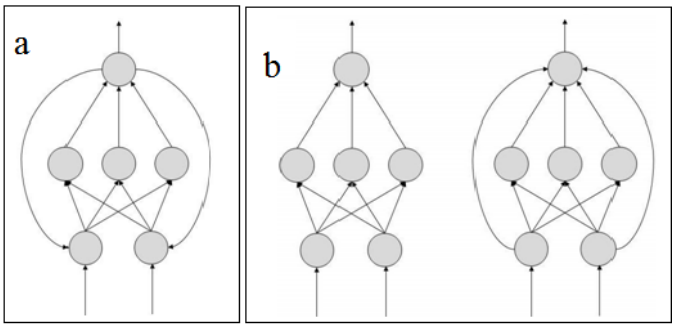

Fig.4 a) Feed Back ANN b) Feed Forward ANN

ii. Feed Forward ANN –

A feed-forward network is a simple neural network consisting of an input layer, an output layer and one or more layers of neurons. Through evaluation of its output by reviewing its input, the power of the network can be noticed base on group behavior of the connected neurons and the output is decided. The main advantage of this network is that it learns to evaluate and recognize input patterns.

III. PROPOSED SYSTEM

The system proposed is a system for diagnosis of diseases. All diseases have a set of associated symptoms. The patient needs to enter the observed symptoms and the system can recognize the disease. Whenever someone has some disease the human body responds to it by by giving symptoms. These symptoms can point towards a particular disease. Suppose a patient has the symptoms as fever and difficulty in micturation, the patient might have an urinary tract infection, if this is further enhanced by vomiting, the patient might have appendicitis. The System matches the set of symptoms to the disease. The patient needs to input the set of symptoms and the system calculates a score of symptoms based on the symptoms and gives a ranking to the diseases, and the selects the best scoring disease that is the most probable disease.

The system is works on the principle of artificial neural networks which simulate human thinking and reasoning. These networks work like the neurons in our brain and simulate medical reasoning.

The input nodes are the set of symptoms and the output nodes are the diseases as recognized by the system based on the set of symptoms. The system gives a value to the diseases and calculates the total a score to all the symptoms and gives a ranking to all the diseases and selects the best ranking disease based on the set of symptoms. The system will help those people living in areas where medical facilities and not available or not available as required. The system will help people recognize diseases as soon as possible so that it's not late and does not lead to a bigger problem later. The patients can then consult a doctor if it's really a big issue.

The system works as follows:

Programs can be written to simulate medical reasoning. Such programs are typically written in the form of complex "if ... then..." rules. The input goes as the set of symptoms and the output is the set of diseases based on the set of symptoms. The complex "if ... then..." statements select a disease based on the set of symptoms and the disease is recognized. The programs use complex "if ... then..." statements to implement the input of the symptoms. The inputs are then matched by the statements to find an associated disease. The complex statements help the system select the particular disease which the symptoms correspond to. The disease is thus selected based on the inputs using the complex statements.

Suppose there are n symptoms.

When the user enters the first symptom, the system goes in the loop and checks for corresponding (n-1)

symptoms which are further compared with (n-2) symptoms and so on until the user finishes entering symptoms.

The system thus matches the set of symptoms using complex statements to a disease. All diseases are given a score based on the number of symptoms, the highest ranking disease based on the score is selected and given as output.

IV. ALGORITHM

1. For each diagnosis determine the set of symptoms to be expected.
2. Give a score to each diagnosis by the number of symptoms resulting to the diagnosis.
3. Rank the diagnosis according to the scores obtained.
4. Select the highest score and check whether any one feature of the disease is present or absent.
5. Check for all features and then move to the next scoring diagnosis.
6. If a new diagnosis is found, begin with step 1 or otherwise stop and give the diagnosis as the result.

The above algorithm works as follows:

For each disease, we have a set of associated symptoms. When the patient inputs the observed symptoms the system calculates a score based on the number of observed symptoms. Like for a disease, let's take Gastroenteritis, the count of the number of symptoms is three (which are vomiting, diarrhoea and pain in abdomen), so the system knows that disease Gastroenteritis. Among these symptoms, if the diarrhoea is replaced by constipation, the system will recognize that the disease in not Gastroenteritis but it may be case of Intestinal Obstruction. If any subset of these symptoms is observed, the count is less than three, the system than ranks the diseases based on the count of the symptoms and then selects the highest scoring disease based on the set of symptoms observed.

TABLE I
SET OF SOME SYMPTOMS AND THEIR DIAGNOSIS RESULTS

No.	Symptoms	Diagnosis Result
1	Vomiting, Diarrhoea, Pain in abdomen	Gastroenteritis
2	Vomiting, Constipation, Pain in Abdomen	Intestinal Obstruction
3	Fever, Pain in Abdomen, Difficulty in Micturition	Urinary Tract Infection
4	Pain in Abdomen, Lump Abdomen	Hernia
5	Fever, Dry Cough, Difficulty in Respiration	Bronchial Asthma

V. FUNDAMENTAL STEPS IN ANNs-BASED MEDICAL DIAGNOSIS

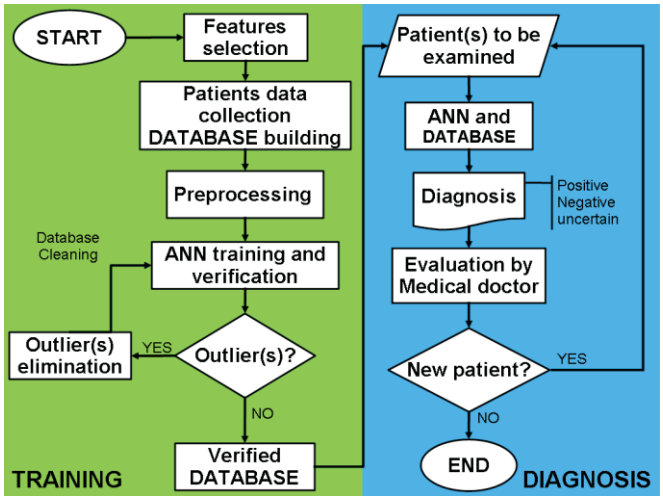

Fig. 5. **Diagram of fundamental steps in ANNs-based medical diagnosis.**

Building of the database and "learning" represents the left half (green) and its application for the diagnosis is the right part (blue).

The workflow of ANN analysis arising from the outlined clinical situations is shown in Fig. which provides a brief overview of the fundamental steps that should be followed to apply ANNs for the purposes of medical diagnosis with sufficient confidence.

For the reasons discussed above, the network receives patient's data to predict the diagnosis of a certain disease. After the target disease is established, the next step is to properly select the features (e.g., symptoms, laboratory, and instrumental data) that provide the information needed to discriminate the different health conditions of the patient. This can be done in various ways. Tools used in chemo metrics allow the elimination of factors that provide only redundant information or those that contribute only to the noise. Therefore, careful selection of suitable features must be carried out in the first stage. In the next step, the database is built, validated and "cleaned" of outliers. After training and verification, the network can be used in practice to predict the diagnosis. Finally, the predicted diagnosis is evaluated by a clinical specialist. The major steps can be summarized as:

a. Features selection
b. Building the database
    i. Data cleaning and pre-processing
c. Training and verification of database using ANN
    i. Network type and architecture
    ii. Training algorithm
    iii. Verification
d. Testing in medical practice

The individual steps listed above will be shortly commented below.

a. Features selection:

Correct diagnosis of any disease is based on various, and usually incoherent, data (features): for example, clinic pathologic evaluation, laboratory and instrumental data, subjective anamnesis of the patient, and considerations of the clinician. Clinician are trained to extract the relevant information from each type of data to identify possible diagnoses. In artificial neural network application such data are called "features". Features can be symptoms, biochemical analysis data and/or whichever other relevant information helping in diagnosis.

b. Building the database:

The neural network is trained using a suitable database of "example" cases. An "example" is provided by one patient whose values for the selected features have been collected and evaluated. The quality of training and the resultant generalization, and therefore the prediction ability of the network, strongly depend on the database used for the training. The database should contain a sufficient number of reliable "examples" (for which the diagnosis is known) to allow the network to learn by extracting the structure hidden in the dataset and then use this "knowledge" to "generalize" the rule to new cases. In addition, clinical laboratory data should be in a form that is readily transferable to program s for computer-aided diagnosis (Strike et al. 1986).

i. Data cleaning and pre-processing:

Data in the training database must be pre-processed before evaluation by the neural network. Several approaches are available for this purpose. It has been demonstrated that cases for which some data are missing should be removed from the database to improve the classification performance of the network (Gannous and Elhaddad 2011). A decrease in the classification performance of the network is observed for imbalanced databases (those with a

different number of cases for each class) (Mazurowski et al. 2008).

c. Training and verification of database using ANN

i. Network type and architecture:

Although multilayer feed-forward neural networks are most often used, there are a large variety of other networks including Bayesian, stochastic, recurrent, or fuzzy. The best possible neural network architecture must be selected in the first stage. This is usually done testing networks with different number of hidden layers and nodes therein. The optimal architecture is that for which the minimum value of E (Eq. 4) for both training and verification is obtained.

ii. Training algorithm:

The main property of an ANN is its ability of learning. Training or learning is a procedure of parameter tuning by which a neural network adapts itself to a stimulus and then desired output is produced. Broadly, there are two types of learning:

a. Supervised learning: Supervised learning is performed in the presence of a teacher. In this type of training, a supervisor or teacher is required for error minimization. Some supervised learning networks are:
   - Adaptive linear neuron (Adaline)
   - Back-Propagation network
   - Time delay neural network
   - Functional link network
   - Tree Neural Networks

b. Unsupervised learning: Unsupervised leaning is performed without the help of instructor. In this situation, the network itself find features, categories, patterns or regularities from the input data and relations for the input data over the output. Some unsupervised learning networks are:

- Kohonen Self-Organizing Feature Maps
- Learning vector Quantization(LVQ)

iii. Verification:

ANNs-based medical diagnosis should be verified by means of a dataset different from that one used for training. If outliers found it will sent back for the elimination of ouliers. Once the outliers has been removed the dataset will be ready for the diagnosis.

d. Testing in medical practice:

As the final step in ANN-aided diagnosis should be testing in medical practice. For each new patient the network's outcome is to be carefully examined by a clinician. Medical data of patients for which the predicted diagnosis is correct can be eventually included in the training database. However, wide and extensive evaluation of ANN aided diagnosis applications in clinical setting is necessary even throughout different institutions. Verified ANN-aided medical diagnosis support applications in clinical setting are necessary condition for further expansion in medicine.

VI. APLLICATIONS OF ARTIFICIAL NEURAL NETWORKS

i. Aerospace – Autopilot aircrafts, aircraft fault detection.
ii. Military – Weapon orientation and steering, target tracking, object discrimination, facial recognition, signal/image identification.

iii. Electronics – Code sequence prediction, IC chip layout, chip failure analysis, machine vision, voice synthesis.
iv. Industrial – Manufacturing process control, product design and analysis, quality inspection systems, welding quality analysis, paper quality prediction, chemical product design analysis, dynamic modeling of chemical process systems, machine maintenance analysis, project bidding, planning, and management.
v. Medical – Cancer cell analysis, EEG and ECG analysis, prosthetic design, transplant time optimizer.
vii. Speech – Speech recognition, speech classification, text to speech conversion.
vii.Telecommunications – Image and data compression, automated information services, real-time spoken language translation.
viii. Transportation – Truck Brake system diagnosis, vehicle scheduling, routing systems.

VII. ADVANTAGES

1. Adaptive learning: An ANN has the ability to learn how to do tasks based on the data given for training or initial experience.
2. Self-organization: After receiving the information in learning time an ANN can create its own organization.
3. Real-time operation: Many neural network computations can be carried out parallel. Specific hardware devices are being designed to take benefit of this ability of neural networks.
4. Fault-tolerance using unnecessary information coding: Partial damage of a neural network structures leads to the degradation of performance. Though, some network abilities may be recollected even after major network damage.

VIII. DISADVANTAGES

1. The Neural Network requires training to operate.
2. It requires high processing time for large Neural Network.
3. Training time is very large.
4. The architecture of Neural Network is different from the architecture and history of microprocessors so they have to be emulated.

IX. CONCLUSION

ANNs represent a powerful tool to help physicians Perform diagnosis and other enforcements. In this regard, ANNs have several advantages including:

(i) The ability to process large amount of data
(ii) Reduction of diagnosis time

ANNs have proven suitable for satisfactory diagnosis of various diseases. In addition, their use makes the diagnosis more reliable and therefore increases patient satisfaction. However, despite their wide application in modern diagnosis, they must be considered only as a tool to facilitate the final decision of a clinician, who is ultimately responsible for critical evaluation of the ANN output. Methods of summarizing and elaborating on informative and intelligent data are continuously improving and can contribute greatly to effective, precise, and swift medical diagnosis.

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