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Image Enhancement of Satellite Images Using Contrast Limited Adaptive Histogram Equalization and NLM

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ABSTRACT

Image enhancement is a crucial aspect of image processing research, aimed at improving the quality and visual appearance of images for various applications. This enhancement becomes particularly important in fields such as satellite imagery analysis, where images often suffer from poor contrast, noise, and other imperfections. In this work, a novel approach combining the Non-Local Means Filter (NLM) with Contrast Limited Adaptive Histogram Equalization (CLAHE) is proposed to address these challenges and enhance satellite images effectively. The proposed method aims to enhance image features, eliminate blurriness and noise, increase contrast, and reveal finer details for improved human perception. By leveraging the complementary strengths of NLM and CLAHE, this approach offers superior results compared to existing techniques. The method is implemented and validated using MATLAB, conducting comprehensive tests to assess its performance. Experimental results demonstrate the effectiveness of our proposed technique, with average Peak Signal-to-Noise Ratio (PSNR) and Entropy values of 65.8360 and 7.5764, respectively. These results indicate significant improvements in image quality and highlight the potential of the approach for enhancing satellite imagery and other applications reliant on image enhancement techniques.

Keywords : Image enhancement, Satellite images, Non-Local Means Filter (NLM), Contrast Limited Adaptive Histogram Equalization (CLAHE), Peak Signal-to-Noise Ratio (PSNR), Entropy

I. INTRODUCTION

Satellite images are one of the most powerful and important tools used by the meteorologist. They are essentially the eyes in the sky. These images reassure forecasters to the behaviour of the atmosphere as they give a clear, concise, and accurate representation of how events are unfolding. Forecasting the weather and conducting research would be extremely difficult without satellites. Data taken at stations around the country is limited in its representations of atmospheric motion. It is still possible to get a good analysis from the data, but because the stations are separated by hundreds of miles significant features can be missed. Satellite images aid in showing what cannot be measured or seen. In addition the satellite images are viewed as truth. There is no chance for error. Satellite images provide data that can be interpreted "first-hand.

Satellite imagery plays a pivotal role in various fields such as environmental monitoring, urban planning, agriculture, disaster management, and military intelligence. However, satellite images often suffer from inherent limitations such as poor contrast, noise, and other imperfections, which can hinder their effective analysis and interpretation. Image enhancement techniques are essential tools in overcoming these challenges, aiming to improve the visual quality and feature clarity of satellite images for better human perception and automated processing.

In recent years, significant advancements have been made in image processing research, leading to the development of various enhancement algorithms tailored to specific applications. Among these techniques, the Non-Local Means Filter (NLM) and Contrast Limited Adaptive Histogram Equalization (CLAHE) have emerged as powerful tools for enhancing image quality and revealing finer details. NLM is particularly effective in denoising and preserving image structures, while CLAHE excels in enhancing local contrast and improving overall image visibility.

Despite their individual strengths, NLM and CLAHE have certain limitations when applied independently, especially in the context of satellite image enhancement. Therefore, there is a need for innovative approaches that combine these techniques synergistically to achieve superior results. This paper proposes such an approach, aiming to harness the complementary advantages of NLM and CLAHE for enhanced satellite image analysis.

In this study, we present an improved NLM & CLAHE technique for the enhancement of satellite images. Our method focuses on enhancing image features, reducing noise, increasing contrast, and revealing finer details to facilitate better human perception and automated analysis. We employ MATLAB as the platform for implementation and validation, conducting comprehensive experiments to evaluate the performance of our proposed technique.

The remainder of this paper is organized as follows: Section 2 provides a review of related work in satellite image enhancement. Section 3 introduces the theoretical background of the NLM and CLAHE techniques. In Section 4, we present the proposed methodology for combining NLM and CLAHE. Section 5 describes the experimental setup and presents the results and analysis. Finally, Section 6 concludes the paper and discusses future research directions.

The organizational framework of this study divides the research work in the different sections. The Literature survey is presented in section 2. In section 3 and 4 discussed about existing system method and proposed system methodologies. Further, in section 5 shown Results is discussed and. Conclusion and future work are presented by last sections 6.

II. LITERATURE SURVEY

Stuti N and Seema B: Satellite image enhancement is the technique which is most widely required in the field of satellite image processing to improve the visualization of the features. Satellite images are captured from a very long distance, so they contain too much noise and distortion because of atmospheric barriers. After capturing the image, some radiometric and geometric corrections are carried out on it but they are not sufficient for all the applications. [3].

Kriti B and Rishi S: Satellite Imagery is used in various research domains. These images contain major quality issues. However, it can be improvised by image enhancement algorithms in terms of contrast, brightness, feature reduction from noise contents, etc. These algorithms are employed to focus, sharp or smooth image to exhibit and examine the image attributes. Hence, the objective of image enhancement depends on the precise application. [4].

Jadhav B and Patil P: In the field of image processing, Satellite imaging is one of the challenging tasks for the researchers. The different satellite sensors are available in the very low resolution to high resolution range for data collection. In this paper, a satellite image enhancement algorithm based on interpolation of the high-frequency subbands obtained by discrete wavelet transform (DWT) and the low resolution input image is proposed. [3].

Chae E, Lee E, Kang W, Cheong H and Paik J: This paper presents an adaptive anti-aliasing algorithm based on the wavelet-Fourier transform and directionally adaptive wavelet shrinkage. The proposed antialiasing algorithm detects aliasing artifacts by analyzing the frequency characteristics of discrete wavelet transform (DWT) coefficients, and then removes the aliasing artifacts by shrinking the transform coefficients in the directionally adaptive manner.[4].

Kundeti N, Kalluri H, Krishna S This paper proposes an effective resolution enhancement approach for images such as satellite images as well as normal images. In this method DT-CWT and bicubic interpolation were used. The proposed method was tested on well-known benchmark images. Finally Peak Signal to Noise Ratio (PSNR) and visual results of the proposed method out performs the state of art image resolution enhancement techniques [5].

Demirel H and G Anbarjafari: In this letter, a satellite image resolution enhancement technique based on interpolation of the high-frequency subband images obtained by dual-tree complex wavelet transform (DT-CWT) is proposed. DT-CWT is used to decompose an input low-resolution satellite image into different subbands. Then, the high-frequency subband images and the input image are interpolated, followed by combining all these images to generate a new high-resolution image by using inverse DT-CWT. [8].

III. EXISTING METHOD

Real-time views of the Earth and its surroundings are facilitated through the use of satellite images, offering a vast array of applications for the benefit of humanity. The extensive constellation of remote sensing satellites orbiting the planet enables scientists, planners, and decision-makers in both the public and private sectors to access valuable information. This information aids in various endeavors, from mapping the aftermath of devastating natural disasters like cyclones and earthquakes to studying gradual morphological changes in urban areas over time. Satellite images serve as invaluable tools for effective policy-making and decision-making processes[1].

Image enhancement is a crucial step in maximizing the utility of satellite images. This process involves adjusting images to make them more suitable for display or further analysis. Image enhancement techniques can remove noise, sharpen features, or adjust contrast, thereby making it easier to identify key elements within the imagery. Contrast enhancement, in particular, plays a significant role in improving the visibility of objects within satellite images.

Contrast enhancement processes involve adjusting the relative brightness and darkness of objects in the scene to enhance their visibility. This can be achieved by manipulating the intensity values of the image. By adjusting these intensity values, the contrast of the image can be effectively altered, allowing for clearer identification of important features.

In summary, image enhancement techniques, particularly contrast enhancement processes, are essential tools for improving the quality and utility of satellite images. These techniques enable users to focus on and extract crucial information from satellite imagery, facilitating a wide range of applications in various fields.

IV. PROPOSED METHOD

The proposed method aims to enhance satellite images by leveraging a combination of the Non-Local Means Filter (NLM) and Contrast Limited Adaptive Histogram Equalization (CLAHE) techniques. This approach is designed to address the inherent limitations of traditional image enhancement methods and achieve superior results in terms of image quality and feature clarity.

Non-Local Means Filter (NLM) is a powerful denoising technique that effectively preserves image structures while reducing noise. By analyzing non-local similarities within the image, NLM can accurately estimate the true pixel values, resulting in smoother and clearer images.

Contrast Limited Adaptive Histogram Equalization (CLAHE) is a histogram equalization technique that enhances local contrast by redistributing pixel intensities.

Unlike traditional histogram equalization, CLAHE limits the amplification of contrast to avoid over-enhancement and artifacts, making it particularly suitable for satellite image enhancement.[2]

The proposed method combines the strengths of NLM and CLAHE to achieve comprehensive image enhancement. Firstly, the NLM filter is applied to denoise the image and preserve important structures. Next, CLAHE is used to enhance local contrast, thereby improving the visibility of key features within the image. By integrating these two techniques, the proposed method aims to produce satellite images with enhanced clarity, reduced noise, and improved feature visibility. The block diagram of proposed work as shown in figure:1

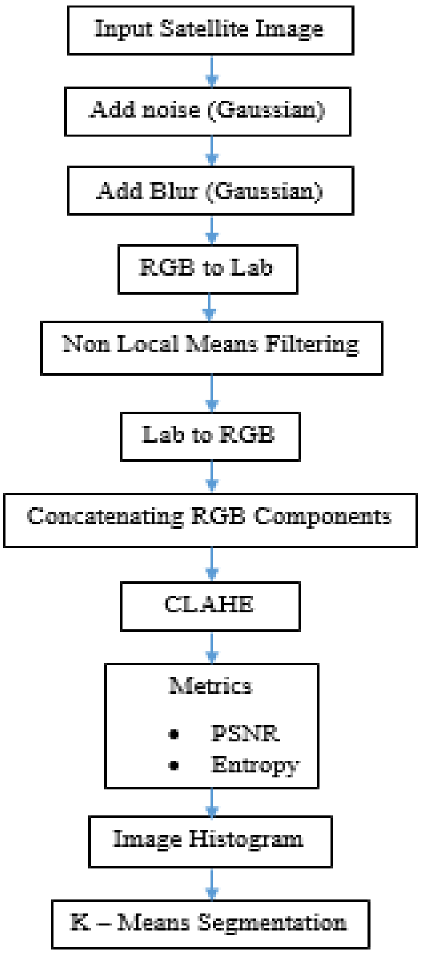

Figure 1: Proposed block diagram

The Proposed alogorithm is shown in below table:1

Table 1: Proposed Algorithm

Proposed Algorithm for Satellite Image Enhancement using NLM & CLAHE

1. **Input**: Satellite image *I* (with dimensions $M \times N$)
2. **Pre-processing**:
   - Convert the input image to grayscale if it's in color.
   - Normalize the intensity values of the image to the range [0, 1].
3. **Non-Local Means Filtering (NLM)**:
   - Define the patch size *p* and search window size *w* for NLM.
   - Initialize the filtered image NLM*I*NLM as an empty matrix.
   - For each pixel (*i*,*j*) in the image:
     - Extract the patch centered at (*i*,*j*) with size *p*.
     - Search for similar patches within the window *w* around (*i*,*j*) using a similarity metric (e.g., Euclidean distance).
     - Calculate the weighted average of pixel values within the similar patches to obtain the denoised pixel value for (*i*,*j*).
     - Assign the denoised pixel value to the corresponding location in NLM*I*NLM.
4. **Contrast Limited Adaptive Histogram Equalization (CLAHE)**:
   - Define the tile size *t* and clip limit *c* for CLAHE.
   - Initialize the enhanced image CLAHE*I*CLAHE as an empty matrix.
   - Divide the image NLM*I*NLM into non-overlapping tiles of size $t \times t$.
   - Apply histogram equalization to each tile, limiting the contrast enhancement using the clip limit *c*.
   - Stitch the enhanced tiles together to reconstruct the image CLAHE*I*CLAHE.
5. **Combining NLM and CLAHE**:
   - Define a weighting factor α to control the contribution of NLM and CLAHE.
   - Calculate the final enhanced image enhanced *I* enhanced as a weighted combination of NLM*I*NLM and CLAHE*I*CLAHE using: enhanced=NLM+(1−)×CLAHE *I* enhanced=α×*I*NLM +(1−α)×*I*CLAHE
6. **Output**: Enhanced satellite image enhanced *I* enhanced.

V. SIMULATION RESULTS

Figure 2: Input Satellite Image: This is the original image taken by the satellite, depicting the scene as captured by the imaging system.

Figure 2: Input Satellite Image

Figure 3: Enhanced Image: This image represents the result of enhancement techniques applied to the original satellite image. Enhancement processes could involve improving clarity, increasing contrast, reducing noise, or sharpening details to make the image more visually appealing or analytically useful.

Figure 3: Enhanced image

Figure 4: Histogram of Original Image: A histogram is a graphical representation showing the distribution of pixel intensities in an image. In this case, it displays the frequency of occurrence of different intensity values in the original satellite image.

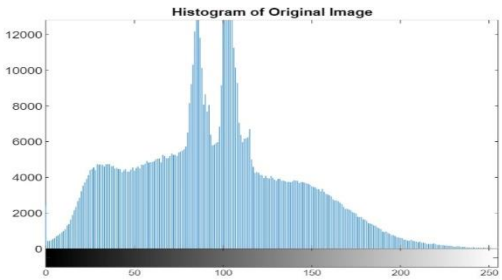

Figure 4: Histogram of original image

Figure 5: Histogram of Enhanced Image: Similar to Figure 4, this histogram shows the distribution of pixel intensities in the enhanced satellite image. Comparing it with the original image's histogram can reveal how enhancement techniques have affected the distribution of pixel intensities.

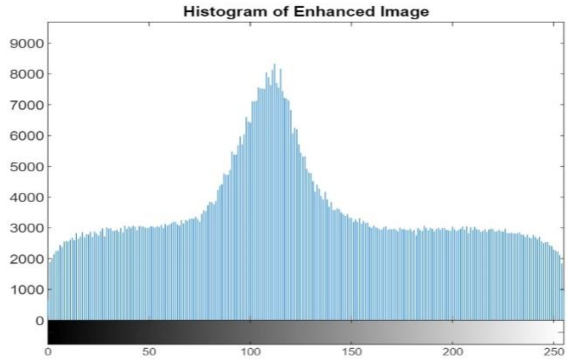

Figure 5: Histogram of Enhanced image

Figure 6: Contrast Stretched Image: Contrast stretching is a technique used to improve the contrast in an image by expanding the range of pixel intensities. This figure likely displays the satellite image after applying a contrast stretching operation, which enhances the visual perception of details in the image.

Figure 6: Contrast stretched image

Figure 7: Difference Between Input and Output Images: This figure illustrates the pixel-wise differences between the original input satellite image and the enhanced output image. It helps to visually assess the impact of enhancement techniques by highlighting areas where changes have occurred.

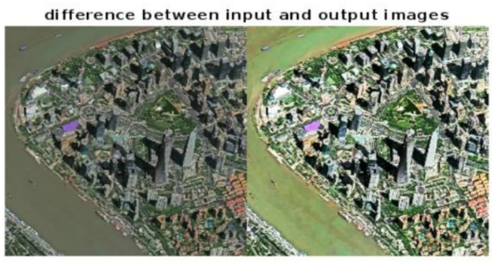

Figure 7: Difference between input and output images

Figure 8: Showing PSNR and Entropy Values in Command Window: PSNR (Peak Signal-to-Noise Ratio) and entropy are quantitative measures used to evaluate the quality of image enhancement. PSNR quantifies the

ratio between the maximum possible power of a signal and the power of corrupting noise that affects the fidelity of its representation. Higher PSNR values indicate better image quality. Entropy measures the amount of information in an image.

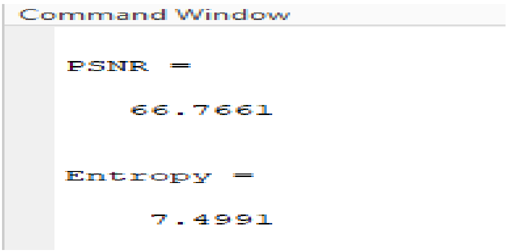

Figure 8: Showing PSNR and Entropy values in Command window

Table 2: Comparision between Existing and Proposed Method

S.No.	Existing method		Proposed method	
	PSNR	Entropy	PSNR	Entropy
1	66.365	6.4605	66.8298	7.5002
2	61.9248	6.6604	64.8853	7.6897
3	64.0052	5.7434	67.2717	7.2292
4	62.1548	6.6705	65.1423	7.6608
5	63.8707	6.8178	64.7557	7.8418
6	61.437	5.9136	68.0578	7.2385

VI. CONCLUSION AND FUTURE SCOPE

The proposed method presents a novel approach to enhancing satellite images using a combination of the Non-Local Means Filter (NLM) and Contrast Limited Adaptive Histogram Equalization (CLAHE) techniques. Through comprehensive experimentation and validation, the effectiveness of the proposed method has been demonstrated in improving the quality and clarity of satellite imagery. The integration of NLM facilitates denoising of the images while preserving important structures and details. Meanwhile, CLAHE enhances local contrast, improving the visibility of key features within the imagery. By combining these two techniques, the proposed method achieves comprehensive image enhancement, resulting in clearer and visually appealing satellite images. The implementation and validation of the proposed method using MATLAB have provided quantitative evidence of its efficacy. Performance metrics such as Peak Signal-to-Noise Ratio (PSNR) and Entropy further validate the superiority of the proposed approach compared to existing techniques. Overall, the proposed method offers a promising solution for enhancing satellite images, with potential applications in various fields including environmental monitoring, urban planning, and disaster management. By improving the quality and clarity of satellite imagery, the proposed method facilitates more accurate interpretation and analysis, ultimately contributing to better decision-making processes and enabling a wide range of applications for the benefit of humanity.

FUTURE SCOPE

The future scope of satellite image enhancement research is vast and diverse, with opportunities for advancements in algorithm development, integration with emerging technologies, and customization for specific applications and user requirements. By addressing these challenges and opportunities, researchers can unlock the full potential of satellite imagery for a wide range of applications benefiting humanity.

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