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Image Enhancement Based on Histogram Equalization with Linear Perception Neural Network Method

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Abstract— Image enhancement poses a formidable challenge in low-level image processing. While various strategies, such as histogram equalisation, multipoint histogram equalisations, and picture element-dependent contrast preservation, have been employed, the efficacy of these approaches has not consistently met expectations. In response, this paper proposes a novel image enhancement method based on a linear perception neural network, demonstrating superior results in contrast improvement with brightness preservation. The proposed method leverages the interdependence of image components through a linear perceptron network, incorporating curvelet transform for image transformation into a multi-resolution mode. This transformative approach identifies component differences in picture elements, establishing a dependency characteristic matrix as a weight vector for the perceptron network. The perceptron network dynamically adjusts the weights of input image values, enhancing contrast while preserving brightness. Extensive testing of the image interdependence linear perception neural network method for contrast improvement has been conducted on multiple images. To quantify brightness preservation, comparative analysis with existing image enhancement strategies, such as histogram equalisation, was performed using Absolute Mean Brightness Error (AMBE) metrics. A smaller AMBE value indicates better preservation, while the Peak signal-to-noise ratio (PSNR) was employed to measure contrast improvement, with higher PSNR values indicating superior results. The proposed method (LPNNM) was rigorously evaluated against the conventional histogram equalisation (HE) technique for image enhancement. The results demonstrated that the LPNNM method outperforms HE in terms of both brightness preservation (as indicated by AMBE) and contrast improvement (as indicated by PSNR). This research contributes a robust and effective solution to the challenge of image enhancement, offering a more advanced alternative to existing methodologies.

Keywords: Contrast Enhancement, Histogram Equalisation, Brightness Preserving, AMBE, PSNR, LPNNM

I. INTRODUCTION

Enhancing contrast is a pivotal factor in elevating the visual quality of images. With the constant proliferation of image capture by individuals daily, the need for enhancement becomes apparent due to noise, cloud interference, and variations in the quality of image-capturing devices. The digital image processing domain is expansive, often involving sophisticated mathematical procedures. However, at its core, the fundamental concept is straightforward. The overarching objective of image processing is to leverage the information embedded within an image to facilitate the understanding, recognition, and interpretation of processed data inherent in the image pattern [1]. Image enhancement techniques are crucial in refining a picture's perceived quality for human observers. Typically, these techniques are employed to unveil obscured details or accentuate specific features of interest within an image. The image enhancement process entails modifying one or more attributes of an image and finding applications across various fields of science and engineering. In addition to challenges posed by varying illumination conditions, the quality of images is often impacted by external noises and environmental disturbances, such as atmospheric pressure and temperature fluctuations. Therefore, the significance of image enhancement cannot be overstated. This study explores contrast-limited image enhancement by stretching histograms over a reasonable dynamic range and multi-scale adaptive histogram equalisations. An adaptive algorithm is tailored to the distribution of image intensity either globally or locally. By distinguishing between smooth and detailed areas within an image, the algorithm is applied selectively to avoid excessive noise enhancement. The need for image enhancement becomes even more apparent because atmospheric and water mediums can affect image quality, especially in scientific and engineering applications [2]. The primary objective of image enhancement is to enhance the interpretability or perception of information in images for human viewers or to provide a 'better' input for other automated image processing techniques. While various methods exist for image processing, digital computers are the most common due to their speed, flexibility, and precision. In the context of application-specific image enhancement techniques, the system is directed towards specific procedures outlined in the block diagram of Figure 1 to achieve an improved output image.

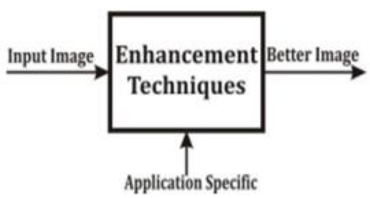

Figure 1 Application-specific image enhancement

Image enhancement operations are pivotal in refining digital images, encompassing tasks such as removing blur and noise, augmenting contrast, and revealing finer details [1]. Contrast Enhancement: Image contrast, defined as the disparity in appearance between different parts of an image observed simultaneously, is crucial for visual perception. Contrast enhancement is employed to accentuate these differences, utilising globally recognised algorithms. Two specific methods, brightness contrast and colour contrast, are discussed herein. Adequate brightness contrast is essential for proper vision, as low contrast impedes clear object differentiation. Auto-correction of image contrast involves three methods, with the first employing linear stretching of the histogram across the entire range, mapping intensities to new values and stretching data comprehensively.

- Removing Noise: Digital images are susceptible to diverse types of noise resulting from errors in the image acquisition process, leading to pixel values that do not accurately reflect the true intensities of the real scene. Noise can stem from scanning photographs, damaged film, issues with the scanning mechanism, low light, high shutter speed, or electronic transmission. Linear filtering is a commonly employed technique for noise removal in digital image processing, especially through averaging and Gaussian filters. However, it is important to be aware that this method may have the drawback of blurring the edges of the image. Median filtering, an alternative, determines pixel output values based on the median of neighbouring pixels, exhibiting less sensitivity to extreme values. Adaptive filtering, especially using the Wiener filter, often produces superior results by preserving edges and high-frequency information.
- Blur Reduction: Image deblurring is essential for achieving sharp and faithful representations of scenes recorded with a camera. Blurring is inherent due to the unavoidable spillage of scene information to neighbouring pixels during image recording. While recovery of the exact original image is not possible due to various errors in the recording process, image deblurring employs mathematical models to enhance sharpness, addressing fluctuations and approximation errors.
- Histogram Image Improvement Applications: Image improvement contributes significantly to advancements in various fields. In atmospheric sciences, astrophotography, satellite imagery, bioscience, and machine learning, where images often suffer from poor contrast due to noise, enhancing contrast without introducing artefacts is imperative [6]. Histograms, a popular tool for real-time processing, are easy to calculate in software and lend themselves to cost-effective hardware implementations. In forensics, image enhancement aids in identification, proof gathering, and police work, particularly in fingerprint detection, security video analysis, and crime scene investigations. Histograms are instrumental in image analysis, allowing predictions of image properties based on histogram details. In atmospherical sciences, histograms reduce the effects of haze, fog, mist, and turbulent weather in meteoric observations, aiding in investigating the form and structure of remote objects in environmental sensing. Satellite images undergo restoration and improvement to eliminate noise and enhance overall quality.

II. Literature Survey

The literature survey reveals several notable advancements in image processing techniques, particularly in image enhancement. Kim et al. [7] proposed the RSWHE method, an improved version of HE comprising three modules: histogram segmentation, weighting, and equalisation. While the approach shows promise in infrequent grey levels, the potential loss of statistical information post-histogram transformation raises concerns about achieving desired enhancements. In a different approach, Ch. Ganapathy Reddy et al. [8] employed DWT to decompose images into sub-bands, calculating log-average luminance in the LL sub-band for dominant brightness. An adaptive transfer function is applied for high-quality contrast enhancement, yielding enhanced images through the inverse DWT. Huang et al. [9] explored AGCWD, incorporating gamma correction and luminance pixel probability distribution. Despite improving image brightness, challenges arise when the input lacks sufficiently bright pixels. Li-Yu Chang et al. [10] introduced a fuzzy-based approach for contrast enhancement in remote sensing images, involving Fuzzy c-means clustering and the construction of stretch models for each cluster. Q. Chen et al. [11] addressed limitations in BBHE with the DSIHE method, where the histogram is split into two sub-images based on the median. However, issues with preserving mean brightness and potential artefact creation pose challenges. D. K. Pandey et al. [12] proposed a technique employing Kernel Padding, DWT, and Image Fusion for contrast enhancement, particularly in satellite images. The approach includes edge-guided image fusion, Canny edge detection, and intensity transformation functions.

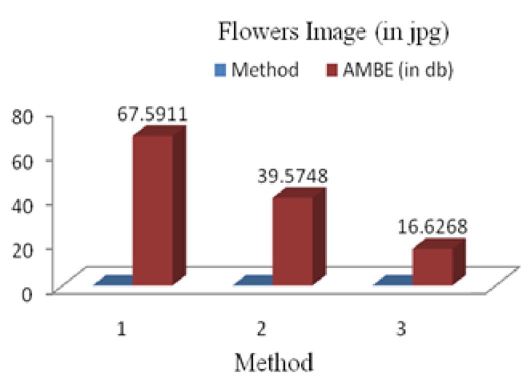

Figure 2 Performance Analysis Based AMBE in Flowers Image

Cagri Ozcinar et al. [13] utilised DWT and singular-value decomposition to enhance satellite image contrast, surpassing conventional methods. W. Kang et al. [14] decomposed images into three layers based on dominant brightness levels, using these layers to derive an adaptive intensity transfer function. Qiuqi Ruan et al. [15] introduced a robust inverse diffusion equation method, employing Laplacian sharpening and gradient magnitude to enhance image details effectively without introducing noise magnification. The literature survey provides a comprehensive overview of diverse image processing techniques, each with unique strengths and limitations, contributing to the ongoing pursuit of optimal image enhancement solutions.

III. IMPLEMENTATION AND RESULT ANALYSIS

In digital image processing, numerous techniques have been proposed to enhance image quality, with histogram equalisation being one such method. This study introduces a novel approach called the Image Linear Perception Neural Network Method (LPNNM) for image security improvement, aiming to provide superior results in terms of image security enhancement while preserving brightness. The proposed LPNNM method combines a Gaussian filter, curvelet transform, and perceptron network for effective image enhancement. The initial image under consideration is a grayscale image of flowers, denoted as If(i, j), with MxM and a file size of 26KB. The authors have employed histogram equalisation to enhance the security of the image, visualising the corresponding histogram. In the original state of the flower image, the security level is observed to be low, particularly when applying Histogram Equalization, as evidenced by the corresponding histogram.

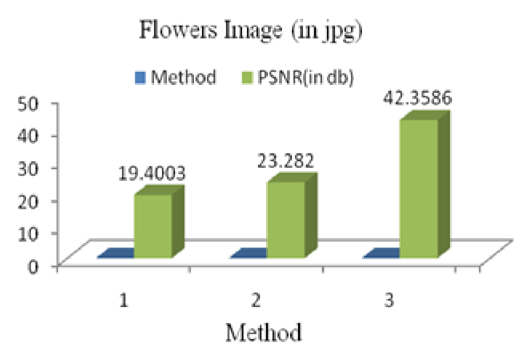

Figure 3 Performance Analysis Based PSNR in Flowers Image

To quantitatively assess the performance of the proposed method, a performance analysis is conducted based on the Peak Signal-to-Noise Ratio

(PSNR) in the flower image If(i, j) with an initial grayscale image size of MxM and a file size of 26KB. The authors compare the PSNR values of their proposed method against those of Histogram Equalization (HE) and another method denoted as BHEP. The findings indicate that the proposed LPNNM method yields higher PSNR values than HE and BHEP, providing a superior visual representation and enhanced image security.

IV. CONCLUSION

In conclusion, the field of image security improvement has witnessed the introduction of various techniques aimed at enhancing image quality, including histogram equalisation, multi-histogram equalisation, and pixel-dependent image security preservation. This study has presented the Image Linear Perception Neural Network Method (LPNNM) as an effective approach for image enhancement, demonstrating superior results in contrast improvement while preserving brightness. LPNNM leverages the curvelet transform and perceptron network to achieve image improvement. The curvelet transform facilitates multi-resolution mode transformation of the image while the perceptron network adjusts the weights of input image values. The proposed method for image security improvement has been applied to several images, and its results have been compared with those obtained from other image security improvement methods. The evaluation metrics used in this comparison include parameters such as AMBE (Average Mean Brightness Error) and PSNR (Peak Signal-to-Noise Ratio). Our findings indicate that the proposed method outperforms existing methods, such as Histogram Equalization (HE), as mathematically demonstrated. It substantiates the effectiveness of the LPNNM in achieving superior image security improvement, making it a promising and valuable contribution to the field of digital image processing.

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