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COLOR IMAGE ENHANCEMENT ALGORITHM BASED ON WEIGHTED GUIDED IMAGE FILTERING UNDER LOW AND NON- UNIFORM ILLUMINATION

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Abstract :

Image enhancement plays a crucial role in improving the visual quality of images captured under poor lighting conditions. Traditional methods applied to RGB images often cause color distortion and artifacts such as halo effects and blurring. To overcome these limitations, this paper proposes a color image enhancement method based on Weighted Guided Image Filtering (WGIF). The proposed method converts the RGB image into the HSI color model and enhances only the intensity component, preserving the original color information. WGIF is used to estimate illumination and reduce noise while maintaining edge details. The enhanced intensity is then reconstructed back into the RGB model using a linear color restoration method. Experimental results demonstrate that the proposed method effectively improves brightness, contrast, and clarity under low and non-uniform illumination conditions while preserving natural color appearance. Image enhancement plays a crucial role in improving the visual quality of images captured under poor lighting conditions. Traditional methods applied to RGB images often cause color distortion and artifacts such as halo effects and blurring.

Index Terms — Image Enhancement, WGIF, Weighted Guided Image Filtering, HSI Color Model, RGB to HSI Conversion, Noise Reduction.

I. INTRODUCTION

Image enhancement is a fundamental area in digital image processing that focuses on improving the visual quality and interpretability of images. Images captured underlow-light or non-uniform illumination conditions often suffer from several

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degradations such as poor brightness, low contrast, noise, and loss of details. These issues reduce the effectiveness of images in applications like surveillance systems, medical imaging, remote sensing, and computer vision tasks.

Traditional image enhancement techniques, such as histogram equalization and Retinex-based methods, are widely used to improve image visibility. However, these methods often lead to problems such as over-enhancement, halo artifacts, color distortion, and loss of fine details. In many cases, applying enhancement directly to RGB channels independently results in imbalance among color components, which affects the natural appearance of the image. To overcome these limitations, advanced filtering-based approaches have been introduced. Among them, Guided Image Filtering (GIF) is known for its edge-preserving smoothing capability. However, GIF may still struggle in handling images with complex illumination variations. Therefore, an improved approach called Weighted Guided Image Filtering (WGIF) is proposed, which introduces adaptive weighting to better preserve edges and improve enhancement performance under challenging lighting conditions. In this work, the input image is first converted from the RGB color space to the HSI color model, where brightness information is separated from color components. By enhancing only the intensity channel, the method avoids color distortion while improving brightness and contrast. The WGIF technique is then applied to effectively reduce noise, enhance illumination, and preserve important structural details such as edges and textures.

Furthermore, adaptive gamma correction is incorporated to improve brightness in darker regions without over-amplifying already bright areas. The separation of illumination and reflection components allows the system to enhance lighting conditions while maintaining the natural structure of the image. This combination of techniques ensures a balanced enhancement process that improves both visual quality and detail preservation. generates immediate alerts through notification mechanisms, enabling proactive stress management.

II. LITERATURE REVIEW

Image enhancement under low-light and non-uniform illumination conditions has been widely studied in the field of digital image processing. Various techniques have been proposed to improve image brightness, contrast, and visibility while preserving important features such as edges and textures. However, each method has its own advantages and limitations

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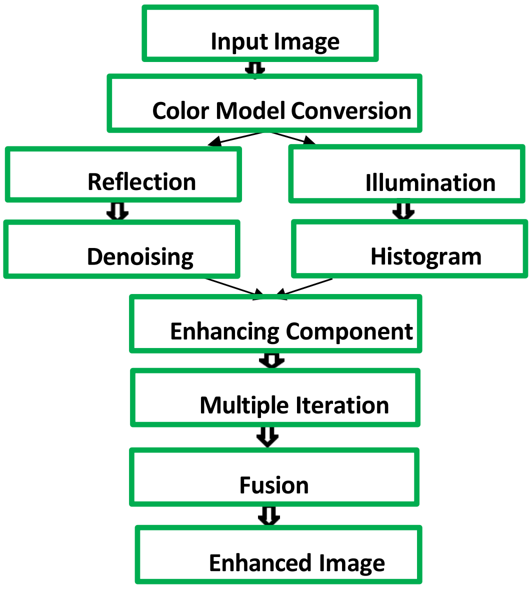
depending on the nature of the input image and lighting conditions.

One of the earliest and commonly used techniques is Histogram Equalization (HE), which enhances image contrast by redistributing pixel intensity values. Although HE improves global contrast, it often fails to preserve local details and may lead to over-enhancement or unnatural appearance in images with complex illumination. To overcome this, Adaptive Histogram Equalization (AHE) and Contrast Limited Adaptive Histogram Equalization (CLAHE) were introduced. These methods improve local contrast but may amplify noise in low-light regions.

Filtering techniques are also widely used for image enhancement and noise reduction. The Hybrid Median Filter (HMF) is effective in removing impulse noise while preserving edges. However, it does not significantly improve brightness or contrast in images captured under poor lighting conditions. Similarly, linear filtering methods may smooth the image but often result in loss of important structural details. The Guided Image Filtering (GIF) technique has gained attention due to its ability to perform edge-preserving smoothing. It uses a guidance image to control the filtering process, which helps maintain structural information. However, GIF may not perform effectively in regions with strong illumination variations and may require careful parameter tuning.

III. PROPOSED SYSTEM

The proposed method aims to enhance images captured under low-light and non-uniform illumination conditions using Weighted Guided Image Filtering (WGIF).



The main objective is to improve brightness and contrast while preserving important image features such as edges, textures, and color information. The method follows a structured approach consisting of multiple stages, including preprocessing, color space conversion, intensity enhancement, filtering, and reconstruction.

The proposed system begins with an input RGB image, which may contain

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issues such as low brightness, uneven illumination, and noise.

The system processes the image through several stages to enhance its visual quality. Each stage is designed to perform a specific function, such as noise reduction, brightness enhancement, or edge preservation. The final output is a visually improved image with better clarity and natural color appearance. Preprocessing is the initial step in the proposed method. In this stage, the input image is prepared for further processing by removing unwanted noise and normalizing intensity values. Low-light images often contain noise due to poor lighting and sensor limitations.

To address this, noise reduction techniques such as the Hybrid Median Filter (HMF) are applied. This helps in removing impulse noise while preserving important edges. Preprocessing improves the stability and effectiveness of the subsequent enhancement stages.

A. Image Enhancement

Image enhancement is the primary step used to improve the visual quality of an image captured under low-light or non-uniform illumination conditions. This process increases brightness, contrast, and clarity so that important details become visible.

In the proposed method, enhancement is mainly applied to the intensity component of the image using WGIF.

This helps improve illumination while preserving edges and textures, resulting in a clearer and more visually appealing image.

B. Image Fusion

Image fusion is the process of combining multiple images or processed versions of the same image into a single enhanced image. This technique helps integrate useful information from different sources to improve overall image quality.

In this project, fusion combines the enhanced image with filtered outputs to achieve better brightness, contrast, and detail preservation. It helps balance

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different features such as illumination and texture.

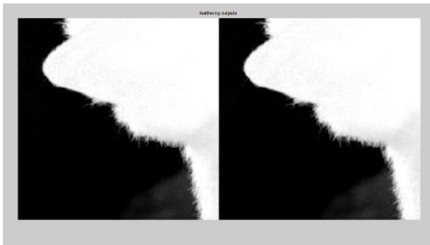
C. Image Dehazing

Image dehazing is used to remove haze or fog-like effects present in images captured under poor visibility conditions. It improves clarity by enhancing contrast and restoring scene details.

In low-light images, haze-like effects may occur due to uneven illumination. Dehazing helps improve visibility in such regions and makes hidden details more noticeable.

D. Image Feathering

Image feathering is used to smooth the boundaries between different regions of an image. It helps blend transitions gradually to avoid sharp edges or abrupt changes.



This technique is important after fusion, where multiple processed images are combined. Feathering ensures that the final image looks natural and free from visible seams or discontinuities.

E. Image Smoothing

Image smoothing is used to reduce noise and minor intensity variations in an image. It helps produce a cleaner and more visually consistent output.

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In the proposed method, smoothing is performed using filtering techniques such as WGIF, which reduces noise while preserving important edges. This ensures that the image does not appear blurred while improving overall quality.

F. Flash Effect

The flash effect refers to enhancing the brightness of an image as if it were captured using a camera flash. This helps improve visibility in dark regions and highlights important features.

In this project, the flash-like effect is achieved through intensity enhancement and adaptive gamma correction. It ensures balanced brightness across the image without overexposure.

VI. RESULTS

The proposed image enhancement method based on Weighted Guided Image Filtering (WGIF) was implemented and tested using MATLAB. Various images captured under low-light and non-uniform illumination conditions were used as input to evaluate the performance of the system.The results demonstrate significant improvement in image quality compared to the original images.

Dark regions in the input images become more visible, and hidden details are revealed effectively.Unlike traditional methods, the proposed approach avoids over-enhancement and preserves the natural appearance of the image.

The method also ensures that the enhanced image does not appear washed out or artificially bright. The use of intensity-based enhancement helps maintain balanced illumination across the entire image.

The proposed method effectively reduces noise present in low-light images. By applying filtering techniques such as Hybrid Median Filter (HMF) and WGIF, unwanted noise is minimized without affecting important image structures.

The results show that noise reduction is achieved while preserving edges and textures, which is a major

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improvement over traditional smoothing techniques that often blur the image One of the key advantages of the proposed method is its ability to preserve edges. Edges represent important structural information in an image, and their preservation is essential for maintaining image quality.

WGIF ensures that edges remain sharp and well-defined even after enhancement. This makes the enhanced images more suitable for further image analysis and computer vision applications.

The conversion of the image from RGB to HSI color space allows enhancement to be applied only to the intensity component. As a result, the original color information is preserved, and no color distortion is observed in the enhanced images.

The final output maintains a natural and realistic appearance, which is often not achieved by methods that directly process RGB channels.

VII. CONCLUSION

In this paper, an effective image enhancement method based on Weighted Guided Image Filtering (WGIF) has been proposed to improve images captured under low-light and non-uniform illumination conditions. The proposed method focuses on enhancing brightness and contrast while preserving important image features such as edges, textures, and color information. By converting the input image from the RGB color space to the HSI model, the enhancement process is applied only to the intensity component, which helps prevent color distortion and maintain the natural appearance of the image.

The integration of preprocessing techniques, noise reduction using Hybrid Median Filter, and edge-preserving smoothing using WGIF ensures that the enhanced image is clear and visually appealing. The use of adaptive gamma correction further improves brightness in darker regions while maintaining balance in brighter areas. Additionally, the separation of illumination and reflection components allows the method to effectively enhance lighting conditions without affecting structural details.

Experimental results demonstrate that the proposed method significantly improves image quality by increasing brightness, enhancing contrast, reducing noise, and preserving edges. Compared to traditional image enhancement techniques such as Histogram Equalization and Retinex-based methods, the WGIF-based approach produces better visual results with minimal artifacts such as halo effects and over-enhancement.

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Furthermore, the proposed method is computationally efficient and suitable for practical applications such as surveillance systems, medical imaging, remote sensing, and computer vision. The enhanced images provide better clarity and visibility, making them more useful for further analysis and interpretation.

However, the method may still face challenges in extremely dark or highly degraded images, where some details may not be fully recoverable. In addition, proper parameter selection is required to achieve optimal results for different types of images.

Overall, the proposed WGIF-based image enhancement method provides a reliable, efficient, and robust solution for improving image quality under challenging illumination conditions, making it suitable for a wide range of real-world applications.

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