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An Improved Method for Reconstruction and Enhancing Dark Images based on CLAHE

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Abstract

The obtained images are frequently flawed because of a variety of environmental issues, particularly at night, such as inside illumination, cloudy weather, etc. The dark image has a compressed dynamic range that can be improved in order to see the finer details. This research effort proposes an improved lighting reflection model-based technique for improving extremely dim images. This improved method relies on reconstruction carried out via morphological processing with Top-hat transformation and Contrast Limited Adaptive Histogram Equalization (CLAHE). The HSV colour scheme is used to perceive the image, and the V component is estimated. The inverse of the intensity component (V) is calculated after normalising the intensity component. The negative image is then subjected to the CLAHE algorithm. The final step is to apply multiscale image enhancement to the obtained image. The brightness component of an image is adaptively adjusted via gamma enhancement. The outcomes of two gamma-enhanced photographs with various gamma values are produced after gamma enhancement. The significant information that can be used for image fusion is extracted from these images using principal component analysis. The weight value is adaptively determined during the PCA-based image fusion employing morphological Top-hat modification to enhance the image quality and highlight the erratic background pixels. The suggested technique emphasises edge and structural preservation while enhancing detail in extremely dim photos. Results from experimental validations demonstrate that the suggested strategy outperforms the current method in terms of both qualitative and quantitative measures.

1. Introduction

The majority of important information can be understood through visual data or visual images. They correlate to the largest amount of collected or perceived processed information that the human brain is capable of realising. Systems for image processing are widely employed in a variety of fields, including biomedical imaging, driver assistance systems, intelligent transportation, and the tracking of moving objects. The photographs captured are marred by several flaws brought on by a variety of unpredictable circumstances, like lighting inside, evening lighting, and gloomy weather. In these circumstances, noise makes colour unrecognisable and the tangent surface's reflection faint. By creating content blur and detail loss in dark areas, it consequently has a significant negative impact on the image quality (Guo, Li, and Ling). Low-light photos contain a compressed dynamic variation of the scene that can be upgraded to disclose hidden data. Compared to the original low illumination photos, the dark pixel values produced by the suggested method are brighter. One of the difficult study fields, poorly illuminated image enhancement or dark picture enhancement, has applications in forensics, night vision, and underwater enhancement. The brightness values in the extremely dark photos are uneven, which greatly lowers the image quality. The other difficulties include dealing with the noise during the intensification of the component. The proposed approach aims to enhance and improve the perception of extremely dim and dark images. The structure of the research paper is as follows. The literature and current work related to low and weak illumination images are briefly introduced in the second section. The third section outlines the main steps of the methodology suggested in this study, along with a thorough description of each module's role in the task. The experimental findings are in-depth examined and quantitatively and qualitatively assessed in section 4. Section 5 presents and summarises the conclusion.

2. Related Work

The CLAHE method, linear contrast adjustment, wiener filter noise removal, and other known methods are some of the different strategies for low light enhancement. A work based on picture contrast, colour improvement using adaptive gamma correction, and histogram equalisation was proposed by the author Veluchamy et al. (Veluchamy and Subramani). Although histogram equalisation is used to improve digital photos, in most circumstances it leads to saturation and over-illumination. The approach is based on the histogram distribution method and adaptive gamma correction for improving contrast. The contrast can be enhanced and adjusted using an adaptive gamma correction. The work's given weighted histogram distribution preserves colour and delivers precise details. Using the Gaussian feature, Yuen Peng Loh et al. (Loh, Liang, and Chan) discuss a CNN-based work on dark and weakly light image improvement. The scientists also presented a new model as a localised function based on Gaussian smoothing for enhancing the less lit photos. To comprehend the relationship between the pixels, the convolution neural network learns the brightness distribution of dark images. This method's primary flaw is overresult, which happens as a result of noise problems with camera sensors that occur when taking low-light pictures. A work on low light enhancement based on Guided Image Filtering in Gradient Domain was discussed by Xiankun Sun et al. in (Sun et al.). This method, which uses a guided image filter to retrieve the illumination component of the image, is based on the illumination reflection model. With the use of edge-aware restrictions in the gradient domain, this approach produces results with amazing edge preservation and details.

3. Proposed Work

A more effective technique for improving the structure reconstruction with Top-hat transformation and histogram equalisation (CLAHE)-based extremely dark image boosting or enhancement is suggested. The process is shown in fig. 1

3.1. *Conversion from RGB to Hue-Saturation-Value color model*

Brightness can be perceived by the human eye instead of colour. To maintain superior outcomes, the illuminance correction is carried out. It is impossible to guarantee that all channels are boosted in the proper ratio, which frequently results in distortion of the image colour after the correction process. Therefore, the illuminance correction must be conducted directly on RGB channels. All the hue, saturation, and intensity components are independent when a picture is transformed to the HSV model. Therefore, altering the intensity levels has no direct effect on the photographs' colour (Wang et al.). For this reason, the RGB colour model of the image is changed into the HSV colour model. The hue $I_h(x, y)$, saturation $I_s(x, y)$ value $I_v(x, y)$ components of the image is computed and displayed in fig. 2.

3.2. *Enhancement/ Improvement of illuminance component*

3.2.1. *Perform Normalization in intensity component*

The process of normalisation modifies the pixel intensity levels. 0 to 1 double precision (or single precision) numbers can be used to represent images. The intensity component's value in the suggested work varies from 0 to 255. As a result, keep the

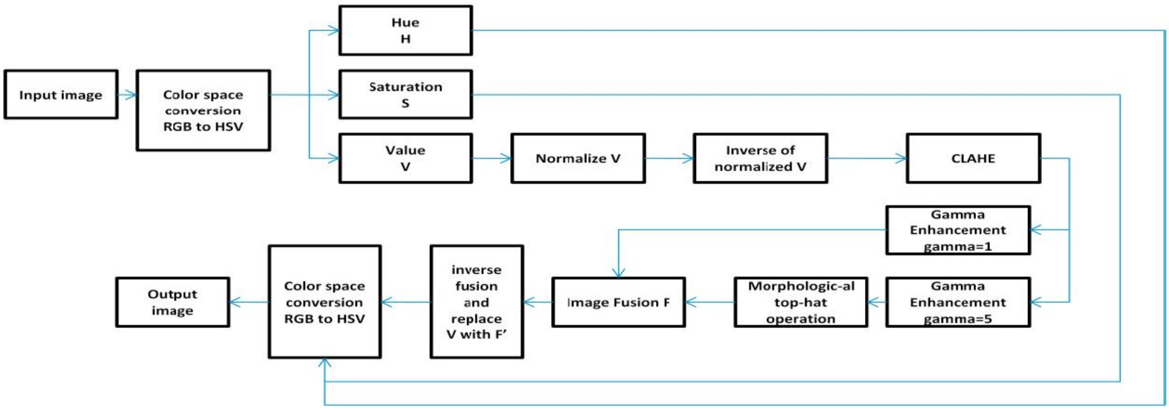

FIGURE 1. **Outline of the proposed method**

FIGURE 2. **Source Image**

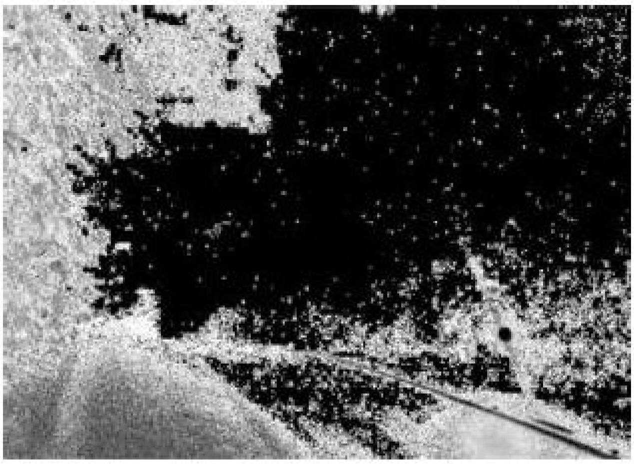

FIGURE 3. **Hue Component**

value between [0, 1].

3.2.2. Inverse of the normalized intensity component

Large pixel noise will be introduced when the intensity component is increased. To prevent noise enhancement of dark images, we take the intensity

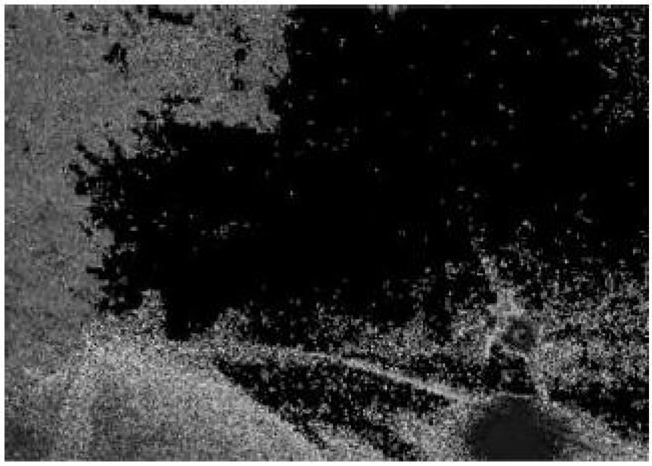

FIGURE 4. **Saturation Component**

FIGURE 5. **Value Component Conversion from RGB space to HSV space.**

component's inverse, i.e.

$$I = 1 - V \tag{1}$$

3.2.3. Contrast Limited Adaptive Histogram Equalization (CLAHE

CLAHE (Bai and Zhou), a histogram-based image enhancement technique, restricts amplification based on the histogram's clipping to a maximum level. The inverse of the intensity image is improved in the proposed study using the CLAHE approach. When CLAHE is applied to a negative image, the visual aspects of the image are enhanced, and the enhanced image has more details. The resulting image, as shown in Figure 3, is the inverse of the normalised intensity component after applying contrast-limited adaptive histogram equalisation.

FIGURE 6. Example of CLAHE applied to the inverse of intensity image.

3.3. Gamma Enhancement

As demonstrated in Figs. 4 and 5, the illumination value of overlit areas will drop and the illumination value of underlit areas will rise. Gamma enhancement is carried out based on the empirically determined gamma value, which has been determined to be between 1 and 5. The usual image is produced when gamma enhancement is applied with gamma value 1. The gamma output value can be increased to make an image appear brighter or more enhanced. Here, we conveniently utilise the gamma value of 5. Gamma identifies the contour of the curve that depicts how the input and output images are related. The power law equation is used to numerically express the gamma enhancement.

$$V = U^{\gamma} \tag{2}$$

where V is the enhanced output image, U indicates the input image and the value γ is denoted as gamma value.

3.4. Morphological Top-hat transform

By utilising morphological Top-hat modification, an extremely dark image with an uneven distribution of intensity values can be efficiently corrected. For example, gamma enhancement with a gamma value of 1 results in a normal image, whereas gamma enhancement with a gamma value of 5 results in a darker image. The image with unequal lighting components is the fused output image. The suggested method fixes this issue by introducing a technique known as the morphological Top-hat transform, which may be utilised to improve contrast in low-light images by adaptively computing the weight values in PCA fusion. A disc structuring element with a radius of three is used to conduct the top-hat transform (Pavan and Somashekara). The weight value for the PCA fusion is calculated using this resultant value.

FIGURE 7. CLAHE applied to the inverse image

FIGURE 8. Enhanced image with gamma value 1

CLAHE enhancement and gamma enhanced images with multiscale gamma values.

FIGURE 9. Enhanced image with gamma value 5

3.5. Image fusion

The fused images just calculate the weighted sum of the source image i.e.

$$F = \sum_{i=1}^{N} \omega_i \, \mathrm{S}_i \tag{3}$$

where F - fused result image, ω_i - weight coefficient and S_i- image to be fused. Image fusion is done with Principal Component Analysis (PCA) algorithm (Wang et al.) is used to determine weighting coefficients.

The picture fusion process is carried out according to (Wang et al.). The output of a gamma-enhanced image having a gamma value of one and the output of a gamma-enhanced image with a gamma value of five are combined in the suggested method to get the desired result.

3.6. Inverse image fusion

As shown in Fig 6 and Fig 7, after the fused image is obtained it is subtracted from one to get the inverse value of fused image i.e.

$$\mathrm{F}' = 1 - \mathrm{F} \tag{4}$$

After performing inverse fusion, the value of V component is replaced into F′ the value of inverse fusion.

$$V = \mathrm{F}' \tag{5}$$

3.7. HSV to RGB color space conversion

The HSV image is converted back to RGB space using formula (Gonzalez, Eddins, and Woods). The summary of the proposed dark image enhancement algorithm is given as follows.

Proposed Algorithm

Step 1: Load dark image I as input.

Step 2: Convert the image from RGB space to HSV color system.

Step 3: Normalize the intensity component and take the inverse of normalized intensity component.

Step 4: Perform the Contrast Limited Adaptive Histogram Equalization (CLAHE) into the Resultant image obtained from step 3.

Step 5: Let γ=1 and γ=5 and obtain the gamma enhanced images.

Step 6: Calculate the weight values with morphological Top-hat transform.

Step 7: Obtain the resultant image after fusion.

Step 8: Obtain the inverse of the fused image.

Step 9: Use F’ as the V component to merge H and S component from HSV and convert image J into RGB.

Step 10: Output the enhanced color image J.

4. Results and Discussion

We put our method to the test on photographs taken indoors and at extremely dark times of night in order to confirm the performance of the suggested task.

4.1. Qualitative Analysis

Experimental findings on a variety of photographs demonstrate that the suggested method has a clear advantage in maintaining detail and can improve the image quality, particularly in the case of extremely dark images. Fig. 8 displays some of the experimental findings. The Exdark dataset is used for the experimental analysis. The dataset available in github https://github.com/cs-chan/Exclusively-Dark-Image-Dataset.

4.2. Performance metrics

In order to estimate the efficiency of this method, three approaches are used i.e. BRISQUE (Mittal, Moorthy, and Bovik), PIQE and NIQE (Mittal, Soundararajan, and Bovik). These techniques are used to assess the performances of low illuminated images by comparing the input image and the enhanced image. The lowest values indicate the higher perception quality of the images. The table 1 shows the average quantitative performance of ExDark dataset. The work compare the quantitative analysis with Wencheng Wang (Wang et al.)

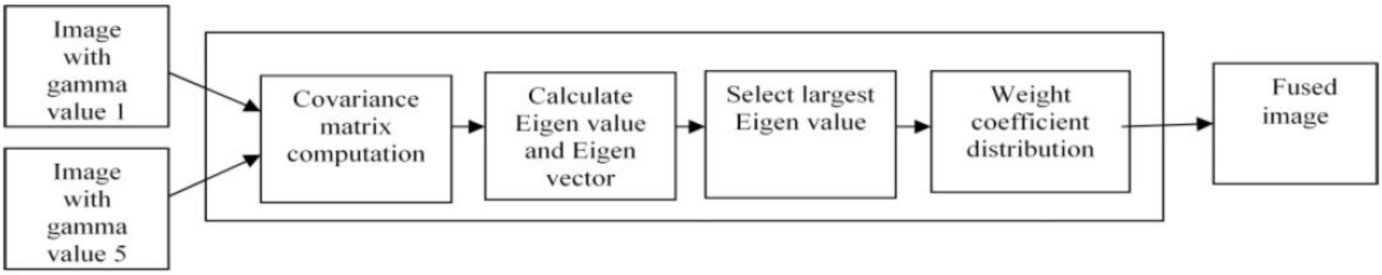

FIGURE 10. **Image fusion using PCA.**

TABLE 1. **Average quantitative performance of ExDark dataset**

Dataset	Current Work			Proposed Method		
	Niqe	**Pipe**	**Brisque**	**Niqe**	**Pipe**	**Brisque**
People	9.8564	99.0072	46.3867	3.9921	30.0680	28.8918
Dog	9.9864	99.1261	46.2956	4.0097	37.5215	30.0219
Car	9.9528	99.4420	46.7260	3.4314	35.6315	29.1532
Cycle	9.4255	98.8730	46.8923	3.7758	37.8515	26.8796
Bus	3.7698	99.4329	26.9319	3.6729	36.1322	26.5876
Cup	3.9446	98.4408	33.1276	3.5799	37.4407	29.5414

FIGURE 11. **Inverse of the fused image.**

FIGURE 12. **Image fusion based on PCA.**

.The proposed method shows better quality perception than Wencheng Wang (Wang et al.).

FIGURE 13. **(a) bottle image (b) current method (c) proposed method.**

FIGURE 14. **(a) Boy Image. (b) current method (c) proposed method.**

FIGURE 15. **(a) Bus image (b) current method (c) proposed method. Enhanced images with extremely low illumination.**

5. Conclusion

In this study, we offer a morphological operation-based contrast limited adaptive histogram equalisation technique for dark image improvement. The intensity component of the RGB image is recovered from and normalised after it has been translated into the HSV colour space. Extremely dark pixels make up the intensity component, and as the intensity value is increased, pixel sounds are added. Therefore, before eliminating the noise, we take the inverse of the intensity component. On the intensity component's inverse, the Contrast Limited Adaptive Histogram Equalization (CLAHE) is used. The image will be improved. Then multiscale gamma value gamma enhancement is carried out. PCA is used to combine images. To enhance the image quality during image fusion, adaptively calculate the weight value utilising morphological Top-hat transformation. Top-hat transform can be used to alter inconsistent background lighting. After that, the picture fusion's inverse is calculated. The final step is converting the image from the HSV colour model back to the RGB colour model. The experiment findings show that our method can accomplish higher edge preservation, detailed enhancement, and colour balance throughout the photos when compared to Wang et al. This technique may be effective for applications that enhance extremely dark images in real time.

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