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# A Novel Gabor Filtering and Adaptive Histogram Equalization Method for Improving Images

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**Abstract**— The correct information may only sometimes be effectively conveyed by images due to various factors, such as excessively bright or dark lighting and low or high contrast. As a result, picture improvement has become an essential part of digital image processing. This proposed method aims to develop an algorithm for improving photos captured in dark environments. This letter presents a new picture-enhancing approach that combines median and Gabor filtering using the wavelet domain with histogram equalization working over a spatial domain. The proposed method in this paper combines spatial and transformed domains for image enhancement and has been simulated using MATLAB. The simulation results of two different photos show that the suggested approach extends the histogram over a wide range of grayscale, offering a superior improvement to the original image. The novel proposed algorithm aims to improve image quality and visibility, making identifying essential details within the image easier. Further, the proposed technique's success is manifested by examining the produced photos' contrast and brightness. The findings reveal that the suggested technique beats the other strategies for improving low-contrast photos.

**Keywords**- Gabor filter, adaptive histogram equalization, spatial domain.

## I. INTRODUCTION

The observer's interpretation of the data appropriately displays an imaging system's output to a person. This entails considering the features of human visual perception, which differ from person to person. Brightness and contrast are two essential elements to consider. As seen by the viewer, a picture's overall blackness or lightness is considered brightness. Because visual perception is subjective, what one person perceives as bright may be perceived as dim by the other. Contrastingly, it measures the difference in grey level between distinct picture portions. It is determined as the difference between a picture's highest and lowest pixel intensities. The visibility of the essential elements in a photo is improved by accentuating these disparities

The character of a picture may be described by its brightness and contrast, which can be determined visually or by studying its histogram. Dark photographs have a histogram grouped towards the bottom of the grey scale, whereas bright images have a histogram crowded near the top. Low-contrast photos have a narrow histogram focused around the grayscale's center, whereas high-contrast photographs have a histogram that spans a wide range of gray-level values. Sometimes, images may be too dark or too bright due to under or overexposure during capture or may have low contrast due to poor lighting or incorrect camera settings. As a result, image enhancement techniques may be necessary to bring out all the information in the image.

The organization of this article, which suggests a technique for brightening darkish photos, is as follows. Section II presents a literature analysis of the most recent cutting-edge picture-enhancing approaches. Section III discusses the proposed strategy for improving dark photos. And section IV includes the results and comments, while section V concludes the study.

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## II. LITERATURE SURVEY

Image enhancement is a process that modifies digital images to make them more suitable for display or further analysis. Its primary goal is to enhance the visibility of images, particularly poor-quality ones. In this regard, specific approaches have been considered to improve the quality of digital photographs, and these methods are further sorted as spatial domain approaches and transform domain approaches. One of the most widely used techniques for improving the contrast of an image is Histogram Equalization (HE). It is particularly effective for improvising image's global contrast, but it may produce abnormal artifacts and over-enhancement in some cases. Another method is the adaptive histogram equalization (AHE) which is more robust in nature for enhancing the image's local contrast, but it may also over-enhance contrast in specific regions and amplify noise in low-contrast areas.

Current advances in image improvement include a linear image combinations approach, a morphological transform-based filter for medical pictures, an efficient wavelet-based adaptive image improvement technique for handwritten documents, a homomorphic filter-based strategy for improving x-ray images, and a new approach that weighs the total of the singular values in low contrast and general histogram equalized photos. A unique wavelet-based medical picture-enhancing algorithm has also been suggested. This approach adds information from huge -frequency sub-images and decomposes the picture using an anti-symmetric biorthogonal wavelet, leading to improved feature extraction and quicker processing performance. It also overcomes classic wavelet constraints, making it appropriate for real-time edge identification.

Furthermore, the highlights of some recent advancements in the field of image enhancement are reviewed. For instance, in paper [1], various techniques for enhancing MRI brain medical images are proposed. Meanwhile, the method for improving the contrast and quality of medical images using morphological transform techniques is presented in [2]. A novel approach to eliminate interference in old handwritten documents based on directional wavelets is suggested in [3]. The appearance of the original documents is greatly improved by this method. The essential key points of suspected rib fractures in X-ray images using an image improvement technique are extracted and highlighted in [4]. Wavelet denoising and picture contrast enhancement were combined to reduce noise, making the images easier to interpret. Different decomposition wavelet levels were examined with numerous thresholds of horizontal,diagonal, and vertical coefficients for Daubechies (db),Symlets(sym), Coiflets (coif), and Biorthogonal (bior) wavelets.

Researchers in [5] revealed a new approach for automatically improving medical photographs. The suggested approach could promote adjuvant therapy, curative impact diagnosis, and clinical medical diagnosis. Moreover, the specified technique uses the contrast-limited adaptive histogram equalization (CLAHE) approach in the F-shift transformation domain. A instantaneous contrast improvement technique on digital video real applications is suggested in [6]. This approach, known as ACE, is based on a modified histogram equalization process that adjusts to the input video data. Several filters with the Hex-Gabor Filter (HBF) are employed to improve the fingerprint picture and to carry out the necessary two fundamental processes namely, image improvement preprocessing and interpolation [7].

A circular Gabor filter-based approach for improving fingerprint images is put forward in [8-9]. Numerous primary picture-enhancing techniques and their comparison analyses of the implied methodologies are briefed [10-20]. The other studies [21-24] presents a transfer learning method based on convolution neural networks to improve mammographic picture contrast. The findings reveal that the suggested technique beats the other strategies for enhancing low-contrast photos on various real time applications.

## III. PROPOSED METHODOLOGY

The proposed method for enhancing dark images is described in this section. It includes an approach that combines several techniques, such as median filtering, Gabor filtering, and adaptive histogram equalization (AHE).

The Gabor and median filters are exploited in the wavelet domain, while the AHE is employed in the spatial domain. With various strategies, the method efficiently improves dim photos and reveals hidden features. The AHE technique enhances the image's contrast by redistributing the pixel intensities to cover a broader grayscale range. Gabor filtering uses wavelet functions to extract different features from the image, while median filtering removes noise and smoothes the image.

Overall, the proposed method is a multi-stage process that leverages the strengths of each technique to enhance dark images. By performing AHE, Gabor filtering, and median filtering in combination, the method can provide high-quality enhancement of dark images and is a promising approach for improving the visibility and quality of images in low-light conditions.

A grayscale image I with Row x Column pixels is considered, where each pixel is represented by the intensity value f(a, b)

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ranging from 0 to 255 for an 8-bit image. However, it is common for images to have unsuitable brightness or limited dynamic range, making it challenging to discern image details. For instance, if the image is captured under low-light conditions, it might be too dark to clearly see the information.

The goal of this work is the development of an algorithm for improving photos that are captured in dark environments. The proposed algorithm aims is to enhance image's quality and visibility, highlights the essential details within the image easier. Applying this algorithm to underexposed images significantly improves the overall image quality that is adaptable for various applications.

AHE (Adaptive Histogram Equalization) is a robust method for improving the contrast of both natural and medical photographs. Nevertheless, AHE has two significant drawbacks: slow processing speed and over-enhancement of picture noise. The suggested approach combines AHE with Gabor and median filtering to overcome these constraints and generate a better-enhanced image with less noise.

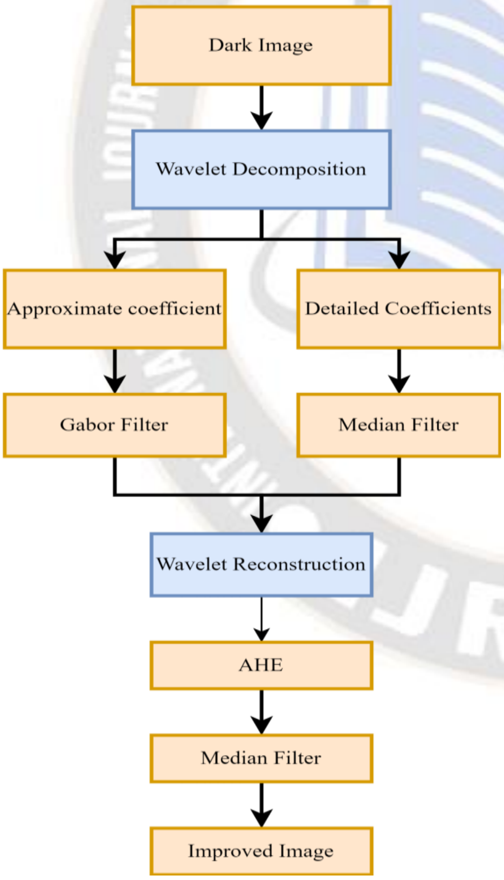


Figure 1: Suggested methodology that combines Gabor and Median filtering using the wavelet and AHE over a spatial domain

The proposed work employs a multi-stage process, as shown in Figure 1. First, AHE is applied to the image to improve its contrast. Next, Gabor filtering is implied on the image to extract different features from it. Finally, median filtering is used to remove noise and smooth the appearance. With these techniques, the proposed method can effectively enhance dark images while minimizing noise and preserving important details. Overall, the novel method is robust and much effective for enhancing the quality and visibility of dark images, making them more useful for various applications.

Our proposed method for enhancing dark images involves several steps. First, we decompose the input image using Haar wavelet into approximation (LL) and detail (LH, HL, HH) coefficients, the simplest and shortest among different wavelet families. Because the Haar wavelet creates a tiny buffer around the edge, which is suited for edge growing, it reduces the influence of relationship disturbance among components.

$$X(a,b,\varphi,f) = exp\left\{-\frac{1}{2}\left[\frac{a_\varphi^2}{\sigma_a^2}+\frac{b_\varphi^2}{\sigma_b^2}\right]\right\}\cos\left(2\pi f a_\varphi\right) \qquad (1)$$

Where $a_\varphi = asin\varphi - bcos\varphi$ and $b_\varphi = asin\varphi + bcos\varphi$ , $\varphi$ is the direction of orientation, $f$ is the frequency of cosine wave, $\sigma_a$, and $\sigma_b$ is a fixed distance on the x and y axes from the Gaussian characteristics.

A median filter is a type of non-linear filter in which the original value of the pixel is replaced by the median of its neighborhood pixels. Specifically, the median filter calculates the median value of the pixels within the area specified by Zab for the corrupted image g(a,b). At any given point (a,b), the filtered image f is assigned the median value of the pixels in the area specified by Zab. This procedure can be described using the equation (2).

$$f\ (a,b)^{\wedge} = median\ \{g(z,t)\}, (z,t) \in Z_{a\ b} \qquad (2)$$

Then, we use a median filter for the detail (LH, HL, HH) components, and for the approximation component (LL), we use a Gabor filter. Gabor filter is an orientation-specific sinusoidal plane wave that modulates the Gaussian kernel function. The median filter just replaces the pixel value with the median pixel value that comes under vicinity. We employ the median filter to retain edges and decrease blurring induced by the mean filter.

After filtering, the image is rebuilt by exploiting the inverse discrete wavelet transform (IDWT) to retrieve the picture in the spatial domain. The picture is then enhanced using AHE, a practical approach for enhancing contrast but needs more speed and over-enhancement of noise. We use median filtering again to decrease noise. Overall, Figure 1's block diagram depicts the processes of our suggested strategy.

## IV. RESULTS AND DISCUSSION

Image enhancement is a crucial aspect of image processing, as captured images may only sometimes be suitable for directly

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applying picture analysis algorithms. Images may sometimes lack appropriate brightness or contrast, necessitating image improvement before applying different image processing techniques. This work proposes a picture improvement method that combines spatial and transformed domains and is simulated using MATLAB. Simulation results for two different images are shown in Figures 2 and 3.

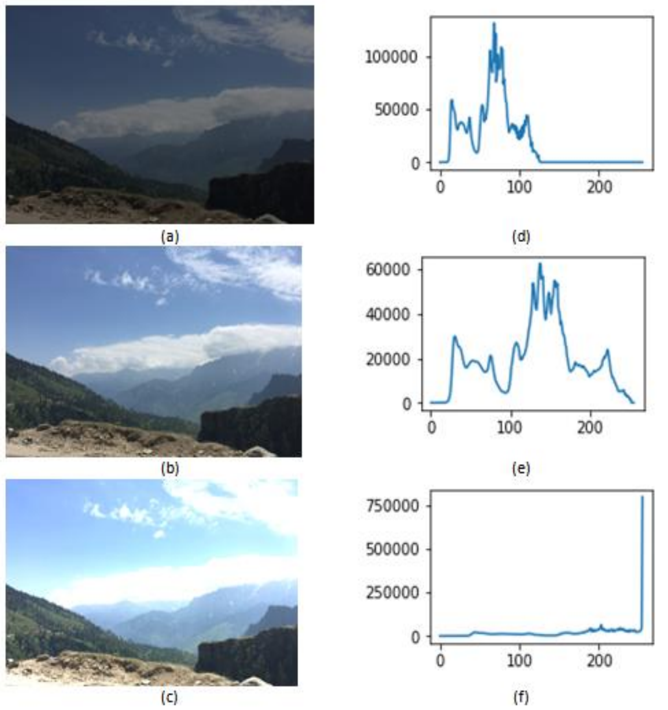


Figure 2: (a) Dark picture, (b) Adaptive Histogram Equalization-improved image, (c) Suggested method improvement, (d) Dark image histogram, (e) AHE image histogram, (f) Proposed technique picture histogram.

Figures 2(d) and 3(c) demonstrate how the histogram of dark images is concentrated on low grey-level values. Still, Figures 2(f) and 3(d) explain how the histogram of the photos is spread across a wider range of grey scales after using the suggested approach. The histogram analysis shows that the proposed strategy delivers superior improvement.

The recommended method's performance is assessed using brightness and contrast metrics. Brightness is a visual perception factor that indicates the brightness of a visual target. The image intensity and the brightness of every pixel in the grey level value are determined as the mean of the grey level values. Equation (3) is employed to calculate brightness (Br).

$$Br = \frac{1}{ab}\sum_{m=1}^{a}\sum_{n=1}^{b} I(m,n) \tag{3}$$

Contrast measures the variation in grey-level values within a picture, typically quantified as the difference between the highest and lowest pixel values. Thereafter, the performance of the image processing approach is evaluated via the key parameters such as the Root Mean Square (RMS) contrast, as shown in equation (4). RMS contrast measures the average contrast within an image by calculating the square root of the mean of the squared differences between the grey level values and the mean grey level value of the picture.

$$Contrast = \sqrt{\frac{1}{ab}\sum_{m=1}^{a}\sum_{n=1}^{b}[I(m,n) - Br]^2} \tag{4}$$

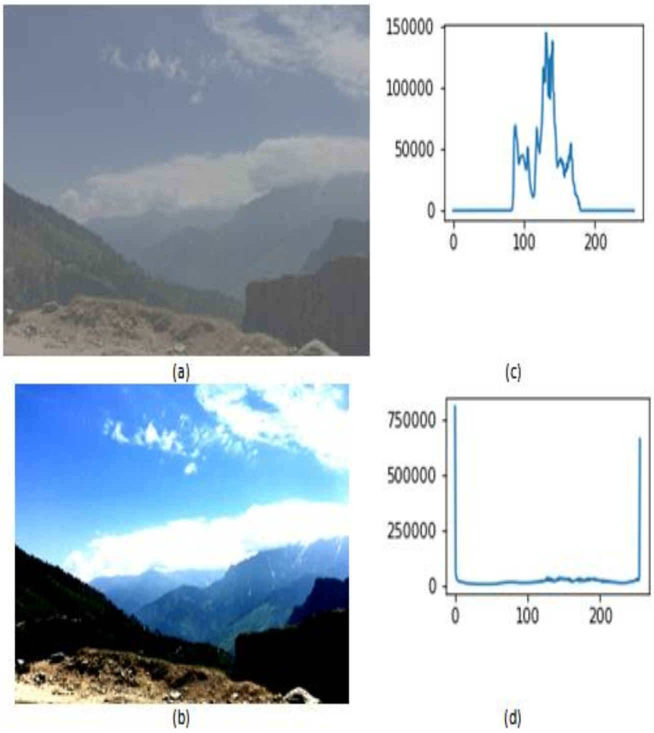


Figure 3: (a) Dark picture, (b) Adaptive Histogram Equalization improved picture, (c) Dark picture histogram, (d) Histogram of an improved picture using the suggested method

Image improvement is vital in image processing as captured pictures may only sometimes have good brightness or contrast. The proposed method in this paper combines spatial and transformed domains for image enhancement and has been simulated using MATLAB. The simulation results of two different photos (Figures 2 and 3) show that the suggested approach extends the histogram over a wide range of greyscale, offering a superior improvement to the original image. The proposed method's performance was evaluated using the brightness and contrast parameters derived from equations (3) and (4). Brightness for Dark images, AHE enhanced images and Enhanced images using the proposed method is calculated using equation (3) and comparative analysis is shown in Figure 4.From the Figure4 it is clear that proposed technique outperforms AHE

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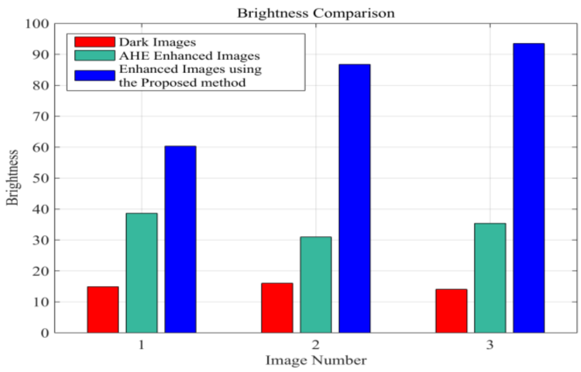


Figure 4: Brightness comparison of Dark images, AHE enhanced images and Enhanced images using the proposed method

The comparison of the results for several photos, as shown in Table 1, demonstrates that the suggested technique outperforms AHE in brightness and contrast. Contrast for Dark images, AHE enhanced images and an Enhanced image using the proposed method is calculated using equation (4) and comparative analysis is shown in Figure5. From the Figure5 it is clear that proposed technique outperforms AHE.

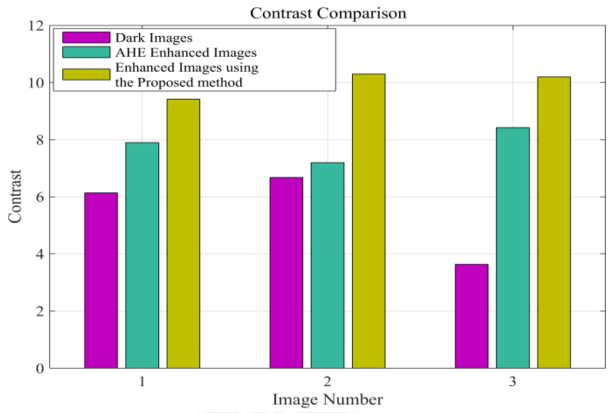


Figure 5: Contrast comparison of Dark images, AHE enhanced images and Enhanced images using the proposed method

The comparison of the results for several photos, as shown in Table 1, demonstrates that the suggested technique outperforms AHE in brightness and contrast.

Table1: Comparison of the proposed method's Contrast and Brightness with Adaptive Histogram Equalization and original dark images

| Test images | Dark images | | AHE enhanced images | | Enhanced images using the proposed method | |
|---|---|---|---|---|---|---|
| | Contrast | Brightness | Contrast | Brightness | Contrast | Brightness |
| **Image1** | 6.14 | 14.92 | 7.90 | 38.65 | **9.42** | **60.36** |
| **Image2** | 6.68 | 16.02 | 7.20 | 30.95 | **10.3** | **86.78** |
| **Image3** | 3.64 | 14.04 | 8.42 | 35.38 | **10.2** | **93.5** |

## V. CONCLUSION

Image enhancement techniques modify the images to better interpret the information they contain. The spatial domain and the wavelet domain are combined in this research to suggest a picture-enhancing approach. The approach is divided into two stages: first, Gabor and median filtering are conducted using the wavelet domain. Then, the filtered image is translated to the time domain for adaptive histogram equalization (AHE) in the second step. The suggested method is tested using quantitative analysis and visual inspection, and the findings show that the proposed strategy delivers superior enhancement to existing ways.

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