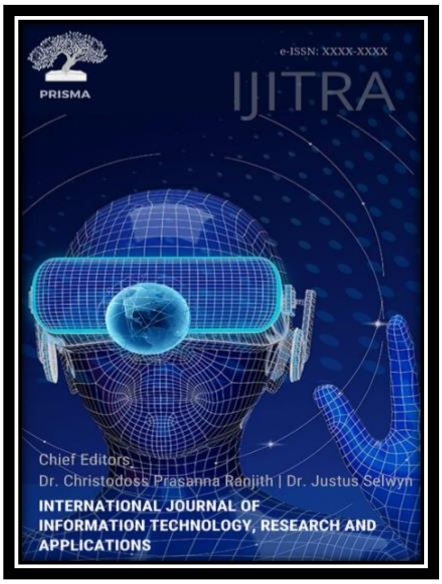

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A Fast Sand-dust Image Enhancement Algorithm by Blue Channel Compensation and Guided Image Filtering

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ABSTRACT

Computer vision systems are significantly impacted by the color variation and low visibility of images taken under sand-dust conditions To address the aforementioned issues, we provide a quick and efficient algorithm to improve photos taken under sand-dust situations. The loss value in the blue channel is first adjusted for. Subsequently, the image deteriorated by sand and dust is color corrected using white balance technology. Lastly, the picture contrast and edge correctness are improved using guided image filtering, and the image detail information is improved by using an adaptive method to determine the detail layer's magnification factor. The approach can successfully restore the fading features of sand-dust-deteriorated photos, according to the experimental results on a sizable number of degraded images by the dust in a brief amount of time, and enhance image sharpness. The suggested method may greatly improve the photos taken during sand-dust weather conditions, as shown by experimental findings via qualitative and quantitative assessments, and the outcomes are superior to those of other ways.

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1. INTRODUCTION

Low contrast, color divergence, and blur are features of photos taken in sand-dust conditions that significantly impair image clarity. The primary cause of this phenomenon is light being scattered and absorbed by sand-dust particles. As a result, the processing power of automated driving, remote sensing, and monitoring systems has been directly lowered by the sand-dust-degraded images [2].

As covered in Section II, some visibility restoration methods have been proposed by researchers to enhance the processing power of computer vision systems in sand-dust situations. Three classes can be identified from the earlier work done to enhance the clarity of sand-dust photographs.

Although some issues still exist, the sand-dust-degraded image-enhancing algorithms that are currently in use may correct color aberrations, boost contrast, and sharpen images. First, blue artifacts appear in the photos and lower the image quality when processing the sand-dust-degraded images with current color-correcting techniques. Secondly, the existing techniques for improving images degraded by sand and dust have a significant time complexity.

As a result, we present in this work a quick and efficient technique that can enhance the chroma and contrast of the photos deteriorated by sand and dust. The suggested method's primary steps are as follows. Initially, an algorithm for recovering the blue channel is suggested, which makes up for the lost value. An adaptive approach is proposed to determine the magnification coefficient for the detail layer to enhance the image

detail information. Secondly, guided image filtering is utilized to improve the contrast and edge accuracy of the image.
The experimental results, as determined by qualitative and quantitative evaluations, demonstrate that this method is superior to other methods in producing better outcomes and improving photographs recorded in a short amount of time under sand-dust weather circumstances.

2. LITERATURE SURVEY

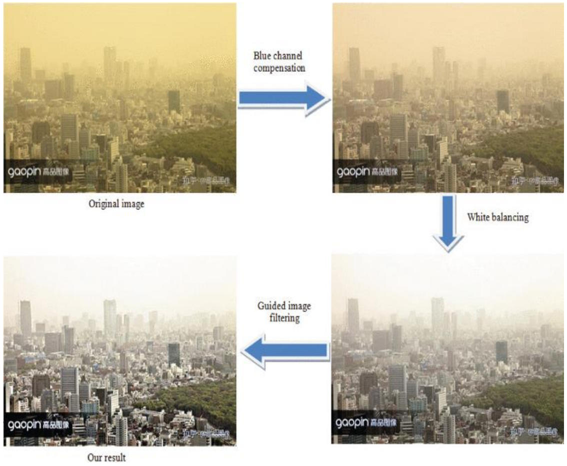
- Vision in bad weather (1999), Developing computer vision systems capable of operating effectively in adverse weather conditions involves studying atmospheric optics, identifying weather effects, exploiting atmospheric modulation, and developing models to recover scene properties from degraded images.
- An Advanced Single-Image Visibility Restoration Algorithm for Real-World Hazy Scenes(2015), The paper presents a Laplacian-based method to restore visibility and alleviate color cast issues in images captured during sandstorms, outperforming traditional approaches in both qualitative and quantitative evaluations.
- A fusion-based enhancing approach for single sandstorm image (2014), The paper introduces a fusion-based method to enhance single sandstorm images, improving visibility and color accuracy while preserving naturalness, suitable for real-time use.
- An Efficient Visibility Enhancement Algorithm for Road Scenes Captured by Intelligent Transportation Systems (2014), The paper proposes an efficient haze removal method for road scene images captured during inclement weather, surpassing traditional techniques in restoring scene radiance with reduced computational costs.
- Let You See in Sand Dust Weather: A Method Based on Halo-Reduced Dark Channel Prior Dehazing for Sand-Dust Image Enhancement (2019), The paper presents a method for enhancing images captured in sandstorms, utilizing color correction, dust removal, and contrast stretching techniques to improve visual clarity and color accuracy.

3. PROBLEM STATEMENT

Sand-dust image enhancement is crucial for various applications such as environmental monitoring, remote sensing, and surveillance. However, existing enhancement algorithms often suffer from slow processing speeds and insufficient preservation of image details.
The problem lies in achieving fast yet effective enhancement of sand-dust images while maintaining high image quality. Conventional methods may fail to adequately compensate for blue channel [10] deficiencies and preserve important image features during enhancement [4].
To address this, a novel algorithm leveraging blue channel compensation and guided image filtering is proposed. This algorithm aims to enhance sand-dust images efficiently while preserving fine details and reducing computational complexity.
The problem statement thus revolves around developing an algorithm that can rapidly enhance sand-dust images, compensating for deficiencies in the blue channel and employing guided image filtering to maintain image fidelity and quality.

4. ARCHITECTURE

The study mainly aims to achieve the following goals:
To propose a fast and effective method that can improve the contrast and chroma of the sand-dust [7] degraded images.
To decrease the time complexity of the system.



5. PROPOSED SOLUTION

To improve the deteriorated photographs taken during sand-dust weather [1] conditions, we present in this paper a visibility restoration algorithm based on guided image filtering and blue channel compensation [11]. White balancing based on blue channel compensation and guided image filtering make up the two components of the suggested approach. We first make up for the lost blue value and process the compensated image with white balancing to restore the fading characteristics of the degraded images and successfully fix the blue artifacts. Secondly, an adaptive approach is employed to determine the detail layer's magnification factor, thereby improving the detail information of the degraded image, and guided image filtering is used to increase the contrast [14] and edge accuracy of the sand-dust-spoiled image.

White Balancing Based on Blue Channel Compensation

The processed sand-dust image will have blue artifacts, which lowers the image quality even though the goal of white balancing is to improve the image quality. As a result, we suggest a blue channel compensation-based white balancing color correcting technique. The goal is to make up for the lost blue value to restore the blue channel. This technique can successfully remove blue artifacts and correct the color cast of photos damaged by sand and dust [7].

A. Blue Channel Compensation

The majority of blue light is scattered and absorbed in sand-dust environments, giving photographs taken in these situations an overall yellow look and color distortion. We use white balancing, gray world, the optical correction technique (OCM), and color balance to adjust the yellow look and process the photos damaged by sand and dust. The results are shown in Fig. 1.

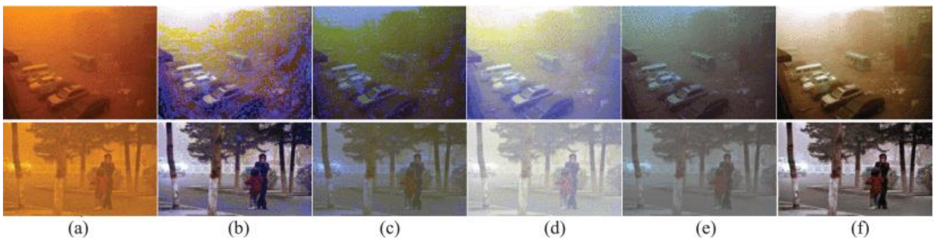


FIGURE 1.
a) Input sand-dust image. The remaining five images are the restoration results of (b) white balancing, (c) gray world, (d) the OCM, (e) color balance, and (f) our white balancing.

The conventional gray world and white balancing algorithms perform poorly on sand-dust-degraded [7] photos, and blue artifacts show up in degraded images (Fig. 1(b)–(c)). As a result, these approaches are unable to resolve the color cast issue. The processed image still has blue artifacts, as seen in Fig. 1(d), and a coating of mist has formed on its surface. The algorithm used proposes the compensating approach. Fig. 1 (e) displays the processing outcome that was achieved by compensating the blue channel using this approach. The image in this figure is black overall, with blue artifacts visible on the margins of the cars and white items on the ground. The processed sand-dust-degraded image appears light blue overall. Therefore, we improve the algorithm presented and propose a blue channel compensation [11] method for sand-dust-degraded images.

We compensate for the missing blue channel through the following three observations.

First, most of the blue light in the sand-dust weather conditions is scattered and absorbed; therefore, an image captured in sand-dust weather appears yellow overall. Hence, if we want to better handle the sand-dust images, we need to restore the blue channel.

Second, the gray world assumes that the average reflection of the natural scenery of the light is the same in general, and all channels have the same mean value in a zero-depth scene; therefore, we can use this hypothesis to restore the blue channel by compensating for the lost value.

Third, in sand-dust-degraded image processing, we assume that the mean values of the green channel and the red channel are unchanged to carry out blue channel recovery experiments. Through these experiments, we find that the effect of blue channel recovery is better if the mean value of the green channel is unchanged. Therefore, we ensure that the green channel’s mean is unchanged to compensate for the blue channel.

Through the above three observations, we obtain the blue channel compensation formula as follows:

$$I_{\mathrm{bc}}(\mathrm{x}) = I_{\mathrm{b}}(\mathrm{x}) + \frac{\overline{I}_g - \overline{I}_b}{\overline{I}_r + \overline{I}_g + \overline{I}_b} * I_g(x) \qquad (1)$$

where Ibc is the compensated blue channel; Ig and Ib are the green channels and blue channels of image I, respectively; Ir, Ig, and Ib are the mean values of the red channel, green channel, and blue channel in image I, respectively; and x represents the pixel position. As shown in Fig. 1 (f), the improved blue channel compensated white balancing algorithm can solve the problem of sand-dust color deviation, can effectively eliminate the blue artifacts in sand-dust images, and can improve the quality of sand-dust images.

B. White Balancing

After blue channel compensation [11], color divergence persisted, hence the white balancing [12] algorithm was chosen to adjust the compensated image's color. To ensure color constancy, the majority of white balancing techniques typically divide each color channel by the appropriate normalized light source intensity after estimating the color of the light source based on predetermined assumptions. The gray-world algorithm is one of those techniques that assumes that the average RGB component value of a picture with color changes tends toward the same gray value. Thus, by individually averaging each channel, the color distribution of the light source can be approximated. According to the Retinex theory, the white block is what causes each channel's maximum response, and each color channel's maximum response can be applied to determine the light source's color. The gray edge of computes the color of the scene illumination by applying the Minkowski p-norm to the derivative structure of the picture channels rather than the zero-order pixel structure, assuming that the average edge difference in the scene is achromatic. Despite having a straightforward computation, this method has been shown to produce results that are on par with the most sophisticated color constancy techniques.
Following a thorough comparison, we corrected the sand-dust image's color deviance using Robust-AWB. The retrieved image's gray color points were utilized by the algorithm to determine the color temperature. The slight color discrepancy between the gray color and the color temperature of the light source was used to estimate.

Guided Image Filtering

The key assumption of guided image filtering [16] is that the filter output q is a linear transform of a guided image I in a window wk centered at pixel k. The linear model is as follows:

$$q_i = a_k I_i + b_k, \quad \forall i \in w_k \tag{2}$$

where a_k and b_k are constants in a window w_k and i and k are indices. This linear model only ensures that q has an edge when I have an edge, because ∇q = a¯∇ I . a_k and b_k are obtained by minimizing the cost function, and the cost function is as follows:

$$E(a_k, b_k) = \sum_{i \in w_k} ((a_k I_i + b_k - p_i)^2 + \varepsilon a_k^2) \tag{3}$$

where p is the input image, and ε is a regularization parameter preventing a_k from being too large. Through the linear ridge regression model (3), a_k and b_k can be obtained as follows:

$$a_k = \frac{\frac{1}{|\omega|}\sum_{i \in w_k} I_i p_i - \mu_k \bar{p}_k}{\sigma_k^2 + \varepsilon} \tag{4}$$

$$b_k = \bar{p}_k - a_k \mu_k \tag{5}$$

where μ_k and σ^2_k are the mean and variance of I in w_k, respectively, and |ω| is the number of pixels in w_k. The filter output image qi can be calculated by taking the obtained coefficients a_k and b_k into equation (2). It can be written as follows:

$$q_i = \bar{a}_i I_i + \bar{b}_i \tag{6}$$

where $\bar{a}_i = \frac{1}{|\omega|}\sum_{k \in w_k} a_k$ and $\bar{b}_i = \frac{1}{|\omega|}\sum_{k \in w_k} b_k$.

As shown in Fig. 2 (c), the sand-dust-degraded image after using guided image filtering has noise because the magnification of the detail layer is generally a fixed value, which magnifies the details and amplifies the noise. Therefore, we improve the magnification of the detail layer and propose an adaptive magnification calculation method.

The following is our main method to obtain the adaptive magnification. The input image p is given, and its edge-preserving smoothed output is used as a base layer q. The difference between the input image and the base layer is the detail layer, which can be written as follows :

$$d = p - q \tag{7}$$

where d is the detail layer, p is the input image, and q is the base layer. The detailed information can be improved by increasing the magnification factor of the details, and the formula is as follows:

$$d_m = \beta d = \beta(\mathrm{p} - \mathrm{q}) \tag{8}$$

where β is the magnification, and d_m is the boosted detail layer. The output image is a combination of the boosted detail layer d_m and the base layer q, and the formula is as follows:

$$p = d_m + q \tag{9}$$

FIGURE 2.

(a) Input the sand-dust image and its license plate image. (b) Our white balancing enhanced the sand-dust image and its license plate image. The remaining two images are the result of processing (b) using the methods of (c) guided Image filtering [30] and (d) the proposed guided Image filtering.

The gradient relation between p and q is $\nabla q = \overline{a} \nabla p$. We considered that the gradient relation of the base layer should be equal to the detail layer; otherwise, the noise will increase. Therefore, we obtain the following equation

$$d_m = \beta(\mathrm{p} - \mathrm{q}) = \beta(\mathrm{p} - \overline{a}\mathrm{p} - \overline{\mathrm{b}}) \tag{10}$$

$$\nabla d_m = \nabla q = \overline{a} \nabla p \tag{11}$$

By solving the above equation, we can obtain the adaptive amplification coefficient β. The results are asfollows:

$$\beta = \frac{\overline{a}}{1 - \overline{a}} \tag{12}$$

where $\overline{a}_i = \frac{1}{|\omega|} \sum_{k \in w_k} a_k$.

To better illustrate the effectiveness of the algorithm, we perform color correction on the sand-dust-degraded images, and then conduct guided image filtering [16] and modified guided image filtering on the processed images. The results are shown in Fig. 2. By comparing Fig. 2 (c) and (d), we found that the modified guided image filter can effectively eliminate the noise [15] in the image and enhance [4] the contrast, edge accuracy, and detail information of the sand-dust-degraded image. As shown in Fig. 2, we found that the proposed algorithm can effectively enhance the clarity of the sand-dust-degraded image. The proposed algorithm can also enhance the license plate information in sand-dust environment conditions [9] and provide services for license plate recognition under surveillance video.

6. RESULTS AND DISCUSSION

Fig 1: Original Image

Fig 2: Image after Blue Channel Compensation

Fig 3: Image After White Balancing

Fig 4: Image after Guided Image Filtration

BRISQUE

The BRISQUE (Blind/Referenceless Image Spatial Quality Evaluator) method is a popular algorithm used to measure the perceived quality of digital images without requiring a reference image for comparison. It operates on the premise that distortions in images introduce statistical artifacts that are perceptually relevant. BRISQUE computes a quality score based on analyzing natural scene statistics (NSS) features extracted from the image.
BRISQUE values of an image represent the quality assessment score generated by the algorithm. A lower BRISQUE score typically indicates higher image quality, while a higher score suggests lower quality or the presence of artifacts, distortions, or impairments that may degrade the visual perception of the image.
The BRISQUE algorithm considers various spatial and spectral features of the image to assess its quality, including statistics related to contrast, sharpness, noise, and texture. By analyzing these features, BRISQUE aims to emulate human perception and provide a quantitative measure of image quality

BRISQUE RESULT

SNO	Image	BRISQUE SCORE
1	Original Image	51.48633239176806
2	White Balancing Image	47.15941094890624
3	Guided Filtration Image	40.294302025582255

EDGE DETECTION

Edge detection is a fundamental image processing technique used to identify boundaries within an image, where abrupt changes in intensity or color occur. These boundaries typically represent important features in the image, such as object boundaries, transitions between different textures, or significant changes in the underlying scene.

The process of edge detection involves analyzing the gradient or derivative of pixel intensities across the image to locate areas of rapid change. This is often achieved using convolution operations with specific kernels or filters designed to highlight edges.

Fig 5: Edge Detection for Original Image

Fig 6: Edge Detection for Final Output

We can see both the figures Fig 9 and Fig 10 show the edge detection of both images. Fig 9 shows the edge detection for the original image and Fig 10 shows the edge detection for the final output. We can observe both images the edges are more clearly visible in Fig 10 so we can assume that the noise is reduced from the original image and get a better image after doing white balancing using blue channel compensation and guided image filtration.

7. CONCLUSION

In this work, we present a novel approach to restore vision to sand-dust-degraded photos by guided image filtering and blue channel compensation. First, we restored the lost value in the blue channel using blue channel compensation technology. Subsequently, we employed white balancing technology to address the color deviation issue and integrated it with blue channel compensation technology to successfully address the blue artifact appearance. Ultimately, an adaptive approach was employed to determine the detail layer's magnification factor to improve the picture detail information. Guided image filtering was then used to improve the contrast and edge accuracy of the image. The experimental findings demonstrate the significant superiority of the suggested method over previous methods, which are based on guided image filtering and blue channel compensation.

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