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Sand Dust Image Enhancement Using Modified Multiscale Retinex Algorithm

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Abstract: Images or videos captured in sandstorm scenes usually have low contrast, poor visibility and yellowish tones. This is because sand dust particles scatter and absorb specific spectra of light between the imaging devices and the observed objects. These degraded sand dust images will lose their quality and degrade the performance during unpleasant weather conditions. Image enhancement is one of the image processing applications to improve the quality and information content of original image.

Index Terms: Sand-Dust Images, Image Enhancement, Modified Multi-Scale Retinex

1. Introduction

The photographs or images of sand that has been clicked up into the air, this is often called sand or dust images.Sand dust in images can often make them appear dull and hazy, affecting their overall visual appeal and clarity. These images occur in a regions where the ground is dry and winds are strong. They can cause reduced visibility. Images or videos captured in sandstorm scenes usually have low contrast, poor visibility and yellowish tones. Sand-dust images occur due to sand dust particles scatter and absorb specific spectra of light between the imaging devices and the observed objects.

To enhance the degraded sand dust images several restoration algorithms are available in literature to improve the performance of computer vision systems and restore the visibility of degraded images. Few techniques such as Contrast-Limited Adaptive Histogram Equalization(CLAHE) [1], Atmospheric Scattering Model (ASM) [2], Dark Channel Prior (DCP) [3] , Image restoration-based approach [4] and Visibility enhancement method [5].

Contrast-Limited Adaptive Histogram Equalization (CLAHE) is an image processing technique that enhances the contrast and brightness of digital images. This helps to limit the noise.The Atmospheric Scattering Model(ASM) can beused to improve the quality and visibility of images affected by atmosphere.Dark Channel Prior(DCP) is used for image enhancement and restoration. Image restoration-based approach helps in estimating the clean, original image by taking the corrupt / noisy image (motion blur, camera mis-focus).Visibility Image Enhancement is used for images taken in poor environmental conditions decrease the visibility. It can be used to estimate the haze or atmospheric scattering in the image.

2.Literature Survey

The presence of sand and dust particles can reduce image quality and clarity, making it difficult to extract useful information from these images. Sand dust image enhancement is therefore an important area of research. In this literature survey, we will review some of the existing techniques and methods that have been used to enhance the quality of sand dust affected images.

Sand-Dust image Enhancement using Coincident Chromatic Histogram is an existing method[6].Outdoor images and videos captured in dusty weather conditions have poor contrast, color cast, low visibility and darkness. The problem of sand-dust images is severe color shifts or casts. Images can be degraded due to various causes, such as lighting condition, weather, and atmospheric changes. An input image is taken and extracted into RGB components and then a color correction method based on the mean and standard deviation of color histograms will be done. Green mean preserving color normlaization will be done. However, this process could result in an undesirable output .To rectify this problem, histogram shifting method is applied that makes the red and blue histograms overlap the green histogram as much as possible. This method is fast and generates reasonable enhancement results in a wide variety of sand-dust images . The performance was compared with those of existing sand-dust image enhancement.

Degraded Image is captured in a dusty environment, it can lead to degradation in image quality due to the presence of dust particles in the air. To enhance such degraded images, various methods can be employed.One of the most common approaches is to use image filtering techniques. In this method [7], the image is passed through a filter that is designed to remove the effects of the dust particles. For instance, a median filter can be used to remove the noise caused by the dust particles. Alternatively, a Wiener filter can be employed to remove the blur caused by the dust particles.

A Fast Single Image Haze Removal Algorithm Using Color Attenuation Prior [8] is a computer vision algorithm designed to remove the effects of haze or fog from a single image. Haze or fog can significantly reduce the visibility of objects in an image, making it difficult to interpret and analyze. This algorithm works by estimating the transmission map of the hazy image, which represents the amount of haze or fog at each pixel.The algorithm uses a color attenuation prior to estimate the transmission map. The algorithm first calculates the color attenuation calculated by comparing the color of the pixel with the average color of its local neighbourhood. Next, the algorithm applies a soft matting technique to smooth the estimated transmission map and reduce artifacts. This is done by dehazing the image using a dark channel prior and the estimated transmission map. The dark channel prior is a method for estimating the amount of haze or fog present in an image based on the dark pixels in the image.Overall, the "A Fast Single Image Haze Removal Algorithm Using Color Attenuation Prior" is an effective and efficient algorithm for removing the effects of haze or fog from single images. It is particularly useful for applications such as autonomous driving, surveillance, and outdoor photography.

Color Balance and Fusion for Underwater Image Enhancement [9] is a computer vision algorithm designed to enhance the visual quality of underwater images. Underwater images suffer from various degradations such as color cast, low contrast, and blurriness due to the scattering and absorption of light in water.The algorithm is based on a two-stage approach for enhancing underwater images. In the first stage, the algorithm performs color balance to remove the color cast from the underwater image. The color balance is done by estimating the color shift caused by water and compensating for it. The estimation is based on the fact that the color of the water depends on the depth and the type of water. In the second stage, the algorithm performs image fusion to combine the color-balanced image[10] with the original image to preserve the details and textures of the original image. The fusion process is done by blending the two images based on their saliency map, which highlights the important regions in the image.

3. Proposed Methodology

Aim of Sandstorm image enhancement based on YUV space using modified multiscale retinex where retinex improve the dynamic range and color balance of images.. According to Retinex theory, the brightness and color of the objects perceived by humans are determinedby the illumination of the environment and the reflection of the light on the surface of the object.

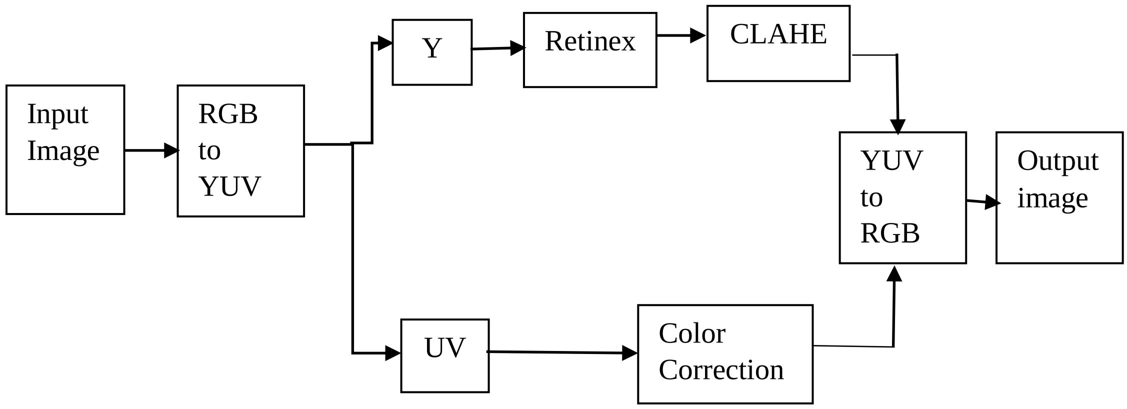

Fig-1 Block Diagram of Sand dust image enhancement using YUV space

3.1RGB to YUV:

To reduce the yellowish or reddish tones in the sand-dust images, the input image is converted into YUV space from RGB where YUV stands for Luminance (Y), Blue-difference (U), and Red-difference (V) and is a color space used to separate image intensity and color information.Converting an RGB image to a YUV image can be useful for various image processing tasks, such as compression, color correction, and filtering.To convert an RGB image to a YUV image, the RGB values for each pixel are first transformed into YUV values using a mathematical transformation.

The transformation matrix for converting an RGB image to a YUV image is as follows:

The formula to convert RGB space to YUV space is as follows:

$$Y = 2.099 * R + 0.58 * G + 0.11 * B \quad (1)$$

$$U = 0.147 * R - 0.289 * G + 0.436 * B \quad (2)$$

$$V = 0.615 * R - 0.515 * G - 0.110 * B \quad (3)$$

3.2Modified Retinex:

Modified Multiscale retinex is used to remove the influence of atmospheric light on image scattering and improve the image clarity, the guided filter improved Retinex is used.The goal of Multi-Scale Retinex is to improve the overall image quality by analyzing different image scales and enhancing the image details and colors. Multi-Scale Retinex algorithm involves breaking down the image into multiple scales, each containing different levels of detail. The algorithm then applies retinex algorithm to each scale, enhancing details and colors of image. The resulting enhanced scales are then combined to form the final image. The advantage of using Multi-Scale Retinex algorithm is that it can improve the image's overall appearance and quality by enhancing the details at different scales. Modified Multi-Scale Retinex involves Gaussian filters and Gamma transformation. The mathematical representation of modified retinex as follows,

First apply Gaussian filters to the Y component i.e, F1,F2 and F3.Then the reflection layers R1,R2 and R3 are calculated by using

$$R1 = \log(Y) - \log(F1) \quad (4)$$

$$R2 = \log(Y) - \log(F2) \quad (5)$$

$$R3 = \log(Y) - \log(F3) \quad (6)$$

By using R1,R2 and R3 Multi-Scale retinex is implemented using

$$MSR = \frac{1}{3} * (R1 + R2 + R3) \quad (7)$$

3.3 Color Correction:

Color correction is used to adjust the colors of an image to achieve a more visually pleasing or accurate result.In the YUV color space, the U and V components represent the color information of an image. Color correction of an image can be performed by adjusting these U and V components.

$$u' = W^{*}\{U(x,y) - \frac{1}{M*N}\sum V(x,y)\} \quad (8)$$

$$v' = W^{*}\{V(x,y) - \frac{1}{M*N}\sum V(x,y)\} \quad (9)$$

Where W is a Saturation adjustment factor.

3.4 YUV to RGB:

To convert an image from YUV to RGB color space, a set of mathematical formulas is used where RGB indicates Red(R), Green(G) and Blue(B) channels. YUV to RGB conversion is to obtain the R, G, and B values of each pixel from the Y, U, and V values. This is done using the following equations:

$$R = Y + 1.14 * U \quad (10)$$

$$G = Y - 0.39 * U - 0.58 * V \quad (11)$$

$$B = Y + 2.03 * U \quad (12)$$

4. Experimental Results

A quantitative analysis is conducted to further evaluate the enhanced images obtained from the three methods. This analysis is performed using image quality metrics, including Naturalness Image Quality

Evaluator(NIQE),No reference Image Quality Metric for Contrast Distortion(NIQMC), Entropy(e), and universal image quality Measure (UIQM), to assess the quality of the output enhanced images.

4.1 QualitativeAnalysis

A qualitative analysis is performed on the output enhanced images obtained from three different enhancement methods on a dataset consisting of 10 pairs of Sand-Dust images.The enhanced method is compared with red and blue channel technique based on at ion es nt and image enhancement based

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Image-8

Image-9

Image-10

(a) (b) (c) (d)

Fig 4: (a) Sand dust image, (b) retinex image (c) red and blue channel image (d) coincident histogram images

4.2 QuantitativeAnalysis

To compare the effectiveness for our proposed enhancement method with other approaches, we used four different metrics to quantitatively evaluate the quality of the resulting images. These metrics include naturalness Image Quality Evaluator(NIQE)[11],No reference Image Quality Metric for Contrast Distortion(NIQMC)[12], Entropy[13], and universal image quality Measure (UIQM)[14].

The NIQE metric is a tool for assessing the naturalness of an image based on a model of the human visual system's response to natural images.NIQE estimates naturalness of an image by comparing its statistical properties with natural images.

NIQE can be mathematically defined as

$$NIQE = W1 * f1 + W2 * f2 + \cdots + Wn * fn \quad (13)$$

Where W1,W2..Wn are the weights assisted to each feature.

$$fi = E[g_i] + \beta * \sigma_i (14)$$

Where $E[g_i]$ is the expected value of feature in normal images,β is a Scaling factor,σ_i is the Standard deviation.

NIQMC[] uses a feature-based approach to calculate the quality score of an image. It first extracts a set of features from the image using a combination of natural image statistics and local image contrast information. These features are then used to train a support vector regression model to predict the image quality score.

NIQMC can be evaluated mathematically as follows

$$NIQMC = NIQE(grayimage) \quad (15)$$

Entropy measures the amount of uncertainty or randomness in a system. In the context of digital signal processing and image analysis, entropy is commonly used to quantify the amount of information present in an image.

The entropy of an image can be calculated using the following formula:

$$H(I) = \sum P(I) * \log_2(P(I)) \quad (16)$$

where I is the input image, p(i) is the probability of occurrence of intensity level i in the image. The entropy value H(I) is a measure of the amount of information content in the image. Images with high entropy contain more information and are typically more complex or less predictable.

The Underwater Image Quality Measure (UIQM) is a no-reference metric used to evaluate the quality of underwater images. It is based on a combination of image features, including sharpness, colorfulness, and naturalness.

The UIQM metric is defined by the following formula:

$$UIQM = \alpha * C + \beta * S + \gamma * E + \delta * D \quad (17)$$

where I is the input image, w_i are the weights assigned to each feature, and f_i(I) are the individual feature measures.

TABLE 1: Quantitative analysis comparison of different enhance methods

Metric/Method	**Coincident Chromatic Histogram**	**Red and Blue channels**	**Modified Multi Scale Retinex**
NIQMC	6.41573	3.901905	**6.62591**
NIQE	6.41573	4.1468	**6.6232**
Entropy	**6.4171**	5.6436	4.4215
UIQM	4.64678	3.36781	**6.19136**

5. CONCLUSION

In conclusion, the successive color balance technique using coincident chromatic histogram is a promising approach for enhancing sand dust images. By analyzing the chromaticity distribution of the image, this method effectively adjusts the color balance of the image to improve its visibility and overall quality. The technique involves an iterative process of histogram stretching and color correction, which allows for precise adjustments and fine-tuning of the image. Additionally, the use of a coincident chromatic histogram ensures that the color balance is consistent across different regions of the image, resulting in a natural and visually appealing output. Overall, this technique has shown great potential for enhancing images in various applications, particularly in the field of remote sensing and environmental monitoring.

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