Colour balance and contrast stretching for sand-dust image enhancement

Govind Bodhireddy
dept. Electrical Engineeering
IIT Kharagpur
Kharagpur,India
bodhireddygovind@kgpian.iitkgp.ac.in

Pavan Kalya Raju Kurichate
dept. Electrical Engineeering
IIT Kharagpur
Kharagpur,India
pavankalyanrajukurichate@kgpian.iitkgp.ac.in

Shashwat Singh
dept.Electrical Engineeering
IIT Kharagpur
Kharagpur,India
shashwat2715@kgpian.iitkgp.ac.in

***Abstract*—Inland areas increasingly frequent sand-dust weather seriously affects outdoor vision applications, especially autonomous vehicles and security monitoring. To moderate the image's colour cast and poor contrast caused by sand-dust weather, a practical approach is proposed in this study to enhance the sand-dust images. First, the original degraded image's colour cast is corrected by a new colour balance and compensation formula, compensating the blue and green channel information through numerous yellow channel information caused by sand-dust scattering before the white balance. Next, to avoid the new colour deviation, the corrected image is converted from the RGB colour space to the HSV colour space and use the CLAHE enhances the V component to improve the contrast. Finally, the S component is stretched to improve image saturation.**

***Index Terms*—Color compensation,White balance, HSV color space,CLAHE,Saturation stret.**

fig(a).Degraded Image.

fig(b).Enhanced Image.

I. INTRODUCTION

Unlike other severe weather, sand-dust weather brings plenty of large dust particles. Since the diameter of sand-dust granules is much longer than the visible light wavelength, the scattering feature is mainly non-selective scattering, that is, a large amount of reflection of the yellow part of the sand-dust itself, resulting in the overall scene image appearing yellowish tone. In addition, the suspended sand-dust particles in the air add noise to the idea, causing the image details to be blurred. Because the reflected light of the object undergoes the above scattering and absorption of the sand-dust particles during the propagation process, the light is seriously attenuated, resulting in the decline of image contrast and brightness.

To solve the above problems, such as colour cast, contrast reduction, and loss of details, many researchers have proposed complementary image enhancement schemes in adverse scenes such as haze, uneven lighting, and underwater. Still, these algorithms need to effectively and directly enhance sand-dust images. Although some algorithms that specifically enhance sand-dust images have been proposed in recent years, the results still suffer from halos, colour cast, blue artefacts, and saturation degradation. Computer vision applications such as feature point extraction and object detection in sand-dust environments require vivid colours, rich image details, and high contrast. The existing sand-dust image enhancement methods often pay attention to one and the other, which cannot meet these requirements simultaneously. Furthermore, only some scholars have studied sand-dust image enhancement from the perspective of the colour principle of the sand-dust image. Therefore, according to the requirements of computer vision applications and the principles of colour science, we propose a novel enhancement approach for sand-dust photos, which is mainly divided into colour balance and contrast enhancement. The enhancement effect is shown in the above Figure.

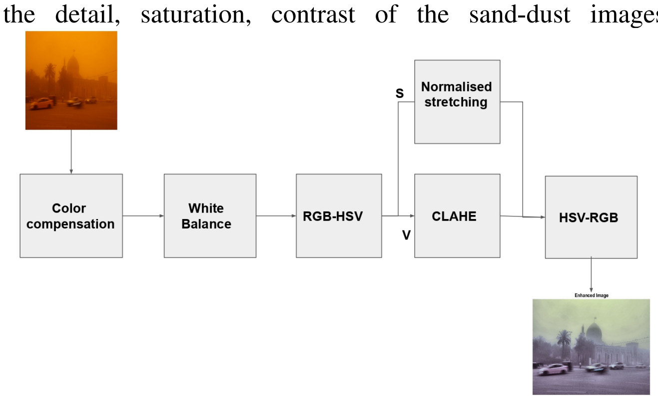
II. APPROACH

1) For the sand-dust images, we propose a new colour balance and compensation formula based on the colour principle of the sand-dust images, which compensates the blue and green channel information through a large number of yellow channel information caused by sand-dust scattering before white balance.
2) We put forward a contrast enhancement scheme based on HSV space. We define a nonlinear gain function to further adaptively sharpen the V component while suppressing noise and overshooting after enhancing the contrast of the sand-dust image by CLAHE on the V component. At the same time, the S component is stretched to improve image saturation.

The rest of the paper is structured as follows. The next section briefly introduces the related work of sand-dust image enhancement. In the next section, we present the details of our proposed method and show the comparison results between our new colour balance algorithm and other colour cast correction algorithms. Before the conclusion, we demonstrate and analyse the experimental results in detail through various image quality indicators and some typical outdoor computer vision applications, namely feature point extraction and target detection results.

III. PROPOSED METHOD

The figure illustrates the framework of our method, which consists mainly of colour balance and contrast stretching. We compensate the green and blue channels by the colour information of the yellow channel of the sand-dust images, then use the grey world algorithm on the compensated image to achieve colour cast correction. Next, we turn the corrected image into HSV space to separate the hue components to avoid the new colour deviation, then we use contrast limited adaptive histogram equalisation(CLAHE)and stretch the S component to enhance the detail, saturation, contrast of the sand-dust images.



A. Color compensation

In this section, we propose a method to remove the yellowish nature of the image. There are many classic white balance algorithms which cannot achieve good results in the colour balance of sand-dust images. In sand-dust weather, there is a large number of granules of sand-dust floating in the air. Since the diameter of sand-dust granules is much longer than the visible light wavelength, the scattering feature is mainly non-selective scattering. The main reason for the lack of blue channel information should be a large amount of reflection of sand-dust itself causes the overall scene image to be yellowish, rather than absorption of blue light by the sand-dust.

$$B_c = B + \frac{\frac{\bar{R}+\bar{B}}{2} - \bar{B}}{\bar{R}+\bar{G}+\bar{B}} * (R+G+B) \tag{1}$$

$$G_c = G + \frac{\bar{R}+\bar{G}}{\bar{R}+\bar{G}+\bar{B}} * (R+G+B) \tag{2}$$

where,$\bar{R}$,$\bar{B}$,$\bar{G}$ are mean of R,G,B channels.

B. White Balance

After the lack of the blue and green channels has been compensated, we resort to the conventional grey world algorithm to correct the colour cast, which has assumed that the average value of the average reflection of light from the natural scene is a fixed value as a whole. This fixed value is approximately "grey". That is to say, the mean value of the three components of red, green, and blue in a colour image tends to be the same grey value, K. The correction formula is

$$K = \frac{\bar{R}+\bar{G}+\bar{B}}{3} \tag{3}$$

$$R_c = \frac{K}{\bar{R}} * R \tag{4}$$

$$G_c = \frac{K}{\bar{G}} * G \tag{5}$$

$$B_c = \frac{K}{\bar{B}} * B \tag{6}$$

C. Contrast enhancement

To avoid the new colour cast and solve the problem of low saturation after enhancement, we convert the corrected sand-dust images from RGB colour space to HSV colour space and enhance the corresponding components. The HSV colour space was proposed by AR Smith in 1978 based on the intuitive characteristics of colours, also known as the Hexcone Model. The model can represent the colour information of the colour image through three channels: hue (H), saturation (S), and value (V), which do not interfere with each other. The conversion formula from RGB colour space to HSV colour space is as follows:

$$R^{'} = \frac{R}{255} \qquad G^{'} = \frac{G}{255} \qquad B^{'} = \frac{B}{255} \tag{7}$$

$$C_{max} = max(R^{'}, G^{'}, B^{'}) \quad C_{min} = min(R^{'}, G^{'}, B^{'}) \tag{8}$$

$$\Delta = C_{max} - C_{min} \tag{9}$$

$$H = \begin{cases} 60 * (\frac{G^{'}-B^{'}}{\Delta}), & C_{max} = R^{'} \\ 60 * (\frac{B^{'}-R^{'}}{\Delta} + 2), & C_{max} = G^{'} \\ 60 * (\frac{R^{'}-G^{'}}{\Delta} + 4), & C_{max} = B^{'} \end{cases}$$

(10)

Here 60 is in degrees

$$S = \begin{cases} 0, & C_{max} = 0 \\ \frac{\Delta}{C_{max}}, & C_{max} \neq 0 \end{cases} \tag{11}$$

$$V = C_{max} \tag{12}$$

where $R^{'}$, $G^{'}$,and $B^{'}$ represent the normalisation of each channel to the interval [0, 1]. H represents hue, and the value range is 0°to 360°, starting from red in the counterclockwise direction, red is 0°, green is 120°, and blue is 240°. S means saturation, ranging from 0 to 1, representing the ratio between the selected colour and the maximum purity of that colour. V represents the brightness of the colour, ranging from 0 to 1.

D. CLAHE

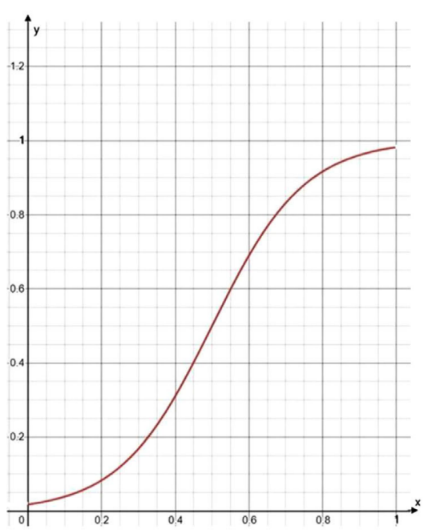
After the conversion, we apply the classic contrast limited adaptive histogram equalisation (CLAHE) to the V component to enhance the image contrast. CLAHE is very efficient and fast, which divides the image into several sub-blocks and sets a threshold. The part of each sub-block that exceeds the threshold is cropped and redistributed to achieve equalisation and control amplitude. Finally, each pixel passes and calculates the mapping value of the adjacent area to realise bilinear interpolation. The algorithm improves the enhancement effect of local contrast by segmenting and calculating the histogram of each sub-block, limits the amplification of noise and the excessive enhancement of difference by setting the threshold, and dramatically improves the calculation efficiency by introducing bilinear interpolation. In addition, the algorithm has strong adaptability and robustness in enhancing single-channel information, which is in line with the expected results of our method. The experimental threshold of this algorithm is 156, and the number of segmentation sub-graphs is 64 (8×8).

E. Saturation strecthing

Finally, to solve the problem of low saturation of the enhanced image, as shown in Figure , according to the experiment, we construct a non-linear function to stretch the S component. This function stretches the part with too low or too high saturation relatively smoothly, so it has high stability and will not cause an overshoot. The stretching formula is as follows:

$$S' = \frac{1}{1 + e^{4-8X_s}} * 255 \tag{13}$$

where s' represents the stretched saturation X_s means the normalised original saturation.



Stretching function

IV. SIMULATION RESULTS

The below figures are the simulation results obtained after implementation of the proposed method in MATLAB environment.

V. CONCLUSION

In summary, we propose a simply efficient sand-dust image enhancement approach that does not require specialised hardware or training data, can eliminate the colour cast and blue artefacts and improves global contrast while maintaining good saturation and edge clarity. Specifically, there are two aspects of the contribution: For the sand-dust images, we propose a new colour balance and compensation formula based on the colour principle of the sand-dust images, which compensates the blue and green channel information through a large number of yellow channel information caused by sand-dust scattering, and then carry out white balance, which effectively eliminates the blue artefacts and corrects the colour cast of the sand-dust images. We put forward a contrast enhancement scheme based on HSV space to separate the hue components to avoid the new colour cast, and CLAHE is used to enhance the V component, which can improve the contrast of the sand dust image. Then, to enhance the details, we define a nonlinear gain function to sharpen the V component further adaptively. Finally, the S component is stretched non-linearly to improve image saturation. The experimental results show that the proposed method is superior to comparison algorithms through quantitative and qualitative analysis, demonstrating our approach's superiority. In addition, our proposed method has further been verified to significantly improve the results of computer vision applications such as target detection and feature point matching.

VI. REFERENCES

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