Research on the Method to Recover Color of the Image Influenced by Atmospheric Light Curtains

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Abstract. Color of the image is affected by the atmospheric light curtain and results in the decrease of color contrast on high optical reconnaissance to collect images. Depending on the physical reason that far distance air curtain brightness has an effect on the image color, we propose that by compensating for radiation attenuation and removing the effects of atmospheric light curtains in the XYZ color space to achieve the restoration of the loss of image color information. The color difference between the image color and the natural scene color indicates the effect of color recovery, the experimental results show that the algorithm proposed is more realistic for the image color and is helpful for further image feature extraction.

Introduction

With the development of digital image processing techniques to extract image features for image interpretation has been applied in many fields, the color features [1] is one of the important features for image interpretation. The image is susceptible to weather conditions [2] that lead to image quality degradation such as color information loss [3], which is extremely unfavorable to the image interpretation.

High optical reconnaissance to collect the image with the distance increases, the color of the image is affected by the atmospheric light curtain [4] results in the decrease of color contrast. Reference the fog image recovery technology [5], the image is converted to XYZ color space for color restoration to reduce the color distortion according to the physical reason that far distance air curtain brightness has an effect on the image color.

Image Color Feature Recovery

The atmosphere will produce scattering and absorption attenuation when light from objects to receiver in the transmission process, while attached to the air curtain brightness related to the atmospheric transmission distance in the transmission direction, making the visible light brightness and color characteristics change [6].

The Color Distortion Characteristics

As shown in Fig.1 and Fig.2, the image information received by the imaging device sensor is the together result of atmospheric environment on the optical radiation attenuation and air curtain brightness participate in the imaging.
The image acquired by the CCD imaging device can be expressed as:

\[ M'(x, y) = M(x, y) \times e^{\alpha_l} + L_H \times (1 - e^{-\alpha_l}) \]  

(1)

In the Eq. 1, \( M(x, y) \) is the images received by the imaging device sensor, \( M(x, y) \) is the real objects image, \( L_H \) is the brightness of the sky at the infinity, \( \alpha \) is the atmospheric extinction index and \( l \) is the distance of observation.

From the Eq.1 we can see, the image received by the imaging device is associated with the distance of the objects. The farther observation distance, the attenuation of radiation energy in the atmospheric environment is more serious, and the increase in the proportion of the air curtain brightness involved in imaging process [7] causes the contrast of the image changes, making the image saturation reduced and the color degradation, which has a visual color distortion.

Color Space

The color features of the images in RGB color space recovery is on the R, G, B component image processing, respectively, and then linear combination of the three processed component image. RGB trichromatic is the vision of red, green and blue, but there is a strong relationship between the three kinds of color. This method will lead to the color of the whole image distortion.

The X, Y, and Z channels of the CIE-XYZ color space are independent of each other, separating the chromaticity of the color space from the brightness and independent of the imaging equipment [8-9]. It is more in line with the human visual system and more easily describe the color information. In this paper, RGB color space images are converted to XYZ color space to avoid the problem of color characteristics of the recovery images in RGB color space.

Image Color Feature Restoration Model

The algorithm flowchart of the image color recovery shown in Fig.3 is established, the sRGB image acquired by the CCD imaging device is converted into the RGB image, and then the RGB image is converted into the XYZ image, and in the XYZ color space respectively to recover the brightness of
the image color and chrominance. The brightness and the chrominance recovery image are independent of each other, so that can be linearly combined to obtain the color restoration image.

Parameter Calculation of Image Color Recovery

By Eq. (1) can get calculation formula for the restored image:

\[ M(x, y) = \frac{M'(x, y) \cdot L_H \times (1 - e^{-\alpha})}{e^{\alpha}} \]  

It can be seen from the Eq.2, color recovery image is related to the sky air curtain brightness, the atmospheric extinction index and the distance of observation.

(1) Sky air curtain brightness \( L_H \)

\( L_H \) is the brightness of the sky at the infinity. Due to the brightness values of RGB color space distribution in the three color channels, the error of using the average of the three-channel approximation of the air curtain brightness is relatively large. In order to reduce the image color hue offsets and brightness changes, this paper uses the maximum brightness value in brightness component image at XYZ color space approximation of the sky air curtain brightness, and the chromaticity image will not have an impact.

(2) Atmospheric extinction index \( \alpha \)

Atmospheric extinction index related to meteorological visibility \( S \), the relationship between the two as show in the Eq.3:

\[ S = 3.912/\alpha \]  

Meteorological visibility is measured by specialized instruments in the process of collecting images outdoors.

Experiments and Analysis

Collecting far and near images in the visibility of 20km sunny weather as shown in Fig.4(a) and Fig.4(b), and field spectrometer is used to measure the spectral reflectance curve marked points. The color restoration of the far distance image is shown in Fig.4(c), calculating the color difference between the color of the three image marked and the color measured by field spectrometer as shown in Table 1.
Figure 4. The color change of the far and near image.

Table 1. Color difference between the image color and true color.

<table>
<thead>
<tr>
<th>Picture</th>
<th>(a)</th>
<th>(b)</th>
<th>(c)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1)</td>
<td>20.5</td>
<td>18.6</td>
<td>17.3</td>
</tr>
<tr>
<td>(2)</td>
<td>35.4</td>
<td>32.6</td>
<td>28.5</td>
</tr>
</tbody>
</table>

As shown in Fig.4(a), because of the air curtain brightness in the imaging lead to the decrease of image brightness contrast and color offset, which has a color distortion on the visual sense. The color restoration of the image in the distance by the algorithm in this paper, the color contrast is improved and become clear and realistic. The results of the color difference calculation in Table 1 show that the color difference between the restored image marked and the true color is the smallest, that is, the color of the image is closer to the true after eliminate the effect of air curtain brightness and consistent with the subjective visual perception.

Collecting the target image at the remote as shown in Fig.5, by using the He algorithm, MSN algorithm and the algorithm to recover the color of original image, compare the three algorithms on the image color recovery effect.
Compared with the 3 algorithms for the color of the image recovery effect in Fig.5, we can see that
the color contrast enhancement of the MSN algorithm results in serious distortion of image color. He
algorithm removes more thoroughly for air curtain, but the leaves of the tree, trunk and other edges
appears the phenomenon of different degrees of white edge effect and color contrast excessive
enhancement as show in Fig.5(3). This paper algorithm completely removes the air curtain, the image
clarity improved and no color distortion phenomenon, and the color is more real and natural.

In order to make objective evaluation the algorithm in this paper, the clarity [10] and histogram
similarity [11] are calculated for the images processed by the three algorithms in Fig.5. The
calculation results as shown in Table 2.

<table>
<thead>
<tr>
<th>Picture</th>
<th>Picture (1)</th>
<th>Picture (2)</th>
<th>Picture (3)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Clarity</td>
<td>Histogram similarity</td>
<td>Clarity</td>
</tr>
<tr>
<td>Original image</td>
<td>0.2292</td>
<td>1.0000</td>
<td>0.1589</td>
</tr>
<tr>
<td>MSN algorithm</td>
<td>0.8603</td>
<td>0.2013</td>
<td>0.9502</td>
</tr>
<tr>
<td>He algorithm</td>
<td>0.4705</td>
<td>0.3147</td>
<td>0.5512</td>
</tr>
<tr>
<td>Modified algorithm</td>
<td>0.6930</td>
<td>0.7127</td>
<td>0.5674</td>
</tr>
</tbody>
</table>

As can be seen from Table 2, the image quality after processing by the various algorithms has been
improved. Increased clarity of the image after He algorithm and this algorithm show that the image
becomes clear and rich information, but the clarity value of the MSN algorithm is the highest because
of the excessive color enhancement. The histogram similarity value indicates that the algorithm has
the highest degree of hue reduction, and the color of the He algorithm and the MSN algorithm are
seriously distorted so that the similarity of the color histogram is the lowest. Therefore, this algorithm
on the color of the image recovery is the most realistic in the visual
Summary

Due to the atmospheric light curtains participate in imaging results in the color contrast changes and color distortion of the image. The image restoration algorithms at present enhanced shortfalls or too saturated for color intensity lead to color distortion, and have great color difference between the image color and true. In order to solve the problems, this paper transforms the RGB color space image acquired by the CCD imaging device into the XYZ color space, and establishes the image color restoration model to reduce the influence of the brightness of air curtain on the image color to realize the color restoration of the image. The experimental results show that the color of the image is more closer to the true, the visual perception is more realistic, and the clarity of the image is improved.

References


