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Enhancement MSRCR Algorithm of Color Fog Image Based on the Adaptive Scale

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ABSTRACT

To deal with the image hue and saturation distortion problems in the traditional Retinex algorithm with color restoration coefficient, enhancement MSRCR algorithm of color fog image based on the adaptive scale is proposed. In the RGB color space, the color restoration coefficient is confirmed firstly. Then according to the each channel pixel values, the local weight correction function is introduced and the Gaussian kernel of the required scale is calculated. Doing local correction for the reflection component estimation and obtaining the multi-scale image by weighting. At last, the obtained image is used to contrast stretching and global Gamma correction in order to enhance the image. Through the subjective observation and objective evaluation, the algorithm is better than the traditional MSRCR algorithm in the overall and details.

Key words: Image enhancement; Adaptive scale; Local weighting factor; Gamma correction

1. INTRODUCTION

With the development of modern industry, due to the large number of emissions, the haze weather days caused by the environmental pollution continues to increase in recent years, to the intelligent transportation systems, visual surveillance system with a lot of interference [1], namely the contrast and color of recorded images are change and degradation, many features of image become blurred due to being covered with. Therefore, the fog image enhancement is more extra attention. Right now, the common fog image processing methods are mainly histogram equalization, bilateral filtering theory, wavelet transform theory, dark channel prior theory, Retinex theory [2]. Histogram equalization is the most common method of theory, to make the contrast and the detail of image enhancement, but the drawback is the gray level image reduction and color prone to distortion after treatment. Bilateral filtering theory is concern for keeping the image edge features better, but the deals only had a significant effect on the mist and have greater limitations. Wavelet transform theory have the characteristics of multi-resolution and the ability to the local signal in time-domain and frequency-domain, in which has been widely used in the image enhancement, but because of its two-dimensional image processing with isotropic, it means that it has limitation when representing the current characteristics and boundaries [3]. Dark channel prior theory is one of the latest theory to defog the image, but it takes a long time in the use of sparse matrix processing images and takes up a lot of calculation memory when processing high-resolution image, and cannot be applied in general computer. Retinex theory is a new idea in the image processing development [4]-[6], which is based on color constancy, the full name is the retina double cortex theory that the human eye's perception of color depends on the surface reflection characteristics of the object, and is irrelevant to the incident. More common are the single-scale Retinex(SSR), multi-scale Retinex (MSR) and multi-scale Retinex with color restoration (MSRCR) algorithms. The MSRCR is better in these types of Retinex because of using color restoration. Its enhancement is better, but not maintaining a constant tone, there is still a small color distortion.

In view of the above processing method, it proposes enhancement MSRCR algorithm of color fog image based on the adaptive scale from the perspective of machine vision in the RGB color space.

2. MULTI-SCALE RETINEX WITH COLOR RESTITUTION (MSRCR)

According to the Retinex theory, it is a single scale Retinex algorithm, the color of the object is determined by the light reflection ability objects on long wave, medium wave and short wave, rather than by the reflection intensity, which is not affected by non-uniform illumination and has a consistency. The human eye perceiving the brightness depends on the ambient lighting and the irradiation light of surface reflection, its mathematical expression is:

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$$I(x,y) = R(x,y) \times S(x,y) \tag{1}$$

where $I(x,y)$ is the image from observing or the camera receiving, $R(x,y)$ is the reflected component of the target object, $S(x,y)$ expresses the incident component of the ambient light [7].

Taking the logarithm on both sides of equation (1), it is given such that:

$$\log I(x,y) = \log R(x,y) + \log S(x,y) \tag{2}$$

Then using the Gaussian filter to estimate the incidence of component $S(x,y)$ of the image，after Retinex algorithm processing，the output image is $R(x,y)^{'}$,which is given such that:

$$R(x,y)^{'} = \log I(x,y) - \log[F(x,y) * S(x,y)] \tag{3}$$

where $R(x,y)^{'}$ is the logarithmic of $R(x,y)$, and $*$ denotes convolution, $F(x,y)$ expresses the surround function, here uses Gaussian function, which is defined as:

$$F(x,y) = K \times \exp(-\frac{x^2 + y^2}{\sigma^2}) \tag{4}$$

where σ represents the standard deviation, which is also the scale constant of Gaussian surround function. According to the surround function，size of scale σ depends on the scope of the convolution kernel. the smaller a scale is, the greater the dynamic range compression is , the local details of the image is more prominent; the larger a scale is, the better the overall image is, the color is more natural and is close to the original color, but its local details is not clear. K is a normalization factor and is now given by:

$$\iint F(x,y)dxdy = 1 \tag{5}$$

Single scale is difficult to achieve a large dynamic range compression and better color constancy at the same time. Therefore, it needs to adopt the MSR algorithm, which takes a plurality of single-scale (SSR) to weight the processing results. The formula is given by:

$$R_{MSR}(x,y)^{'} = \sum_{i=1}^{n} \lambda_i \left\{ \log I(x,y) - \log[F(x,y) * S(x,y)] \right\} \tag{6}$$

Where n is a number of scales, the value is generally 3; λ_i represents a weight, and meets the equation, $\sum_{i=1}^{n} \lambda_i = 1$, the weight value is 1/3 under normal circumstances.

Multi-scale Retinex with color restitution [8] is based on the results of color from consideration such that introduces a color restitution factor. Mathematically,

$$R_{MSRCR}(x,y)^{'} = \mathrm{C}_i(x,y) \times R_{MSR}(x,y)^{'} \tag{7}$$

$$\mathrm{C}_i(x,y) = \Gamma[\mathrm{I}_i(\mathrm{x,y})] = \Gamma[\frac{\mathrm{I}_i(\mathrm{x,y})}{\sum_{j=1}^{n} \mathrm{I}_j(\mathrm{x,y})}] \tag{8}$$

where $\mathrm{C}_i(x,y)$ is the color restitution factor ,and is used to adjust the proportion of three-channel color; $\Gamma[\mathrm{I}_i(\mathrm{x,y})]$ represents the i channel of the color mapping function, n value is 1,2,3.

3. ENHANCEMENT MSRCR ALGORITHM OF COLOR FOG IMAGE BASED ON THE ADAPTIVE SCALE

When the traditional multi-scale Retinex algorithm with color recovery factor processes a strong contrast edge region, it will appear the halo phenomenon. For darker image brightness, brightness still cannot be effectively improved after processing. The scales are in a fixed number, it is not free to determine the threshold value according to the features of fog image. For different pixel size, there will be large differences in the effect of the treatment, and is not effectively improved in the overall and details. In view of the above situation, this paper studies the relationship between the image pixels and the size on the base of the MSRCR algorithm, and proposes enhancement MSRCR algorithm of color fog image based on the adaptive scale. The chief flow chart is figure 1.

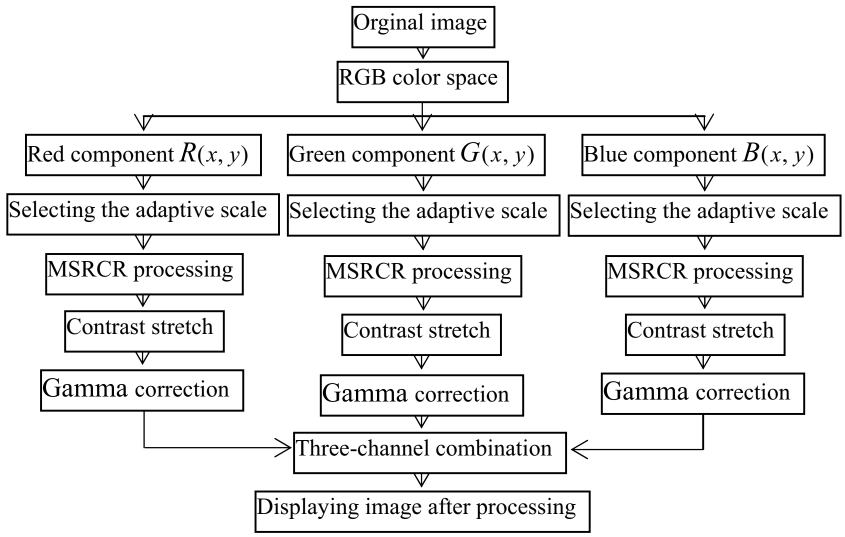

Figure1: the chief flow chart

The specific steps are as follows.

3.1 Original image conversion in RGB color space

Given the color recovery factor choosing, it needs to transform the original image to the RGB color space. Furthermore, due to the nature of the color fog image, although a single for a channel to deal with save the processing time, but to a certain extent, it leads to the brightness, saturation and hue distortion. In view of the above, this paper draws lessons from traditional MSRCR algorithm and uses the three-channel simultaneous processing, the image of the scene is closer to the natural color, and avoid image distortion to the maximum extent.

3.2 Selecting the adaptive scale

With modern equipments diversification, people's choices have begun to tend to diversify, so the dimensions of the image pixel also begin to have more choices. To this end, it proposes enhancement algorithm of color fog image based on the adaptive scale and s-cosine curve.

With regard to the classical Retinex algorithm, it mostly uses the Gaussian center surround function to process. From equation (4), if the selected size is fixed to some value, choosing different scales for different image pixel size, there is a large difference in processing effect. Therefore, the paper uses an algorithm which can be adaptive the size of the image pixel, and meet the details and overall requirements. The adaptive scales are chosen as follows:

①. When the rows and columns of image pixel are even, it can directly obtain the Gaussian kernel from the above experiments: a small-scale is 2.5% of the image pixel size, a meso-scale is 12.5% of the image pixel size, a large-scale is 40 % of the image pixel size;

②. When the rows of image pixel are even and the columns of image pixel are odd, the value of row does not change, and the value of column is decremented by one. The obtained is used as a new image size and gets a new Gaussian kernel: a small-scale is 2.5% of the new image pixel size, a meso-scale is 12.5% of the new image pixel size, a new large-scale is 40% of the new image pixel size;

③. When the rows of image pixel are odd and the columns of image pixel are even, the value of row is decremented by 1, the value of column remains unchanged, The obtained is as the new size of the image and can gain a new Gaussian kernel: a small-scale is 2.5% of the new image pixel size, a meso-scale is 12.5% of the new image pixel size, a large-scale is 40% of the new image pixel size;

④. When the rows and columns of image pixel are odd, the value of row and column minus one is as the new size of the image and obtains a new Gaussian kernel: a small-scale is 2.5% of the new image pixel size, a meso-scale is 12.5% of the new image pixel size, a large-scale is 40% of the new image pixel size.

Given the choice above the value of row and column, it is mainly based on the Gaussian kernel structure matching. When it choose some values which cannot satisfy the Gaussian surround function, the match will occurs an error, but when the selecting the Gaussian kernel is a size of a processed image pixel which is a fixed proportion value, the mismatch can be avoided.

3.3 In the RGB space, setting the local weight factors and MSRCR processing

The traditional Retinex algorithm suggests that the illumination is gentle change, which leads to the halo phenomenon in the large contrast of the edge. Given all of the above, it introduces a local weight correction factor function $\mathrm{W}\left(\mathrm{x},\mathrm{y}\right)$ [9], its expression is given such that:

$$W(x,y)=1-\frac{1}{1+\exp(-I(x,y)-0.5)} \tag{9}$$

where $I(x,y)$ is the original image pixel value of three-channel; $\mathrm{W}\left(\mathrm{x},\mathrm{y}\right)$ is the weight factor in the point of the pixel. The weight function is a modified form of sigmoid function, which can effectively suppress flare. After adding a weight factor, the multi-scale Retinex of enhancement algorithm formula is given such that:

$$R_{MSR}(x,y)'=\sum_{i=1}^{n}\lambda_i\left\{\log I(x,y)-W(x,y)\times\log[F(x,y)*S(x,y)]\right\} \tag{10}$$

where $W(x,y)$ is the weight factor in the point of the pixel, its expression is such as formulation (9), each other parameters are consistent with the meaning of the above.

The MSRCR algorithm with color recovery coefficient, its color recovery coefficient mainly depends on the original three-channel in each pixel value representing the sum of the three-channel pixel ratio. The processed image pixel color is matched by the ratio so as to achieve the color fidelity.

3.4 Contrast stretch processing and global Gamma correction for the image of three-channel

After the MSRCR algorithm processing, to some extent, the brightness of image is dim, especially for some dark video image, details and overall will be larger deviation. In view of the above, the new algorithm introduces the contrast stretching and global Gamma correction after the MSRCR algorithm processing.

Due to the traditional Retinex algorithm processing, the pixel value is beyond the scope of the [0 255], hence the need for these pixel contrast stretching [10], it can be well distributed within the display range, while in contrast there improved to some extent. But for some number of contrasting images after processing appears too saturated or color distortion. In view of this, the new algorithm make a global Gamma correction simultaneously on three channels [11], for the part of the darkest doing the adjustment to the human eye optimal comfort acceptable, to a brighter image also having selective regulation, all of this will improve the overall tone appropriate to achieve better visual effect. Its formula is as follows:

$$R_{MSRCR}(x,y)''=\left\{R_{MSRCR}(x,y)'\right\}^{\gamma} \tag{11}$$

where $R_{MSRCR}(x,y)''$ is the image after Gamma correction, γ is global correction parameter, According to a large number of experiments, when the value of γ is 0.95, it has a better processing effect; $R_{MSRCR}(x,y)'$ is the image after local weights correction.

4. 4 EXPERIMENTAL RESULTS AND ANALYSIS

This experimental platform hardware is a dual-core 3.2GHz CPU, 1024MB, and the software is Matlab R2010a. The selected image to be processed is the different size of fog image, the processing results shows in Figure 2, 3, 4. In the experiment, the size of experimental image pixel are different, namely 800 × 600, 400 × 600, 900 × 600, in which mainly make contrast with the MSRCR algorithm.

(a) An original image; (b) an image after the MSRCR processing; (c) an image after the new algorithm processing
Figure 2: comparison of light fog image after processing

(a) An original image; (b) an image after the MSRCR processing; (c) an image after the new algorithm processing
Figure 3: comparison of moderate fog image after processing

(a)An original image; (b) an image after the MSRCR processing; (c) an image after the new algorithm processing
Figure 4: comparison of dense fog image after processing

From the results of three image processing in the Figure 2, Figure 3, Figure 4， it can be seen, for different sizes of images, the algorithm can adaptively adjust, and has a better effect in all aspects of image details, brightness, and contrast. But the MSRCR algorithm only chooses a fixed scale and cannot meet with the change in the size of image pixel. In the aspect of brightness and halo, the processing effect is not very ideal, due to the brightness not timely recovery, the overall tone of the image has a little dark, and cannot effectively to show details of the observation. In addition, for the tail phenomenon, the traditional MSRCR algorithm cannot be better solution, such as the above writing, after processing, there are still trailing phenomena at the edge. In the hue and saturation of the image, the traditional algorithm has reached a certain degree of recovery through the color recovery coefficient, but from the subjective observations in the absence of local scenery, such as the sky, it is still a small amount of distortion, so the traditional MSRCR algorithm is not better in the image defogging. Through the subjective observation after this algorithm processing, the brightness, hue and saturation has been improved to some extent, the detail of the image is enhanced. For the tailing phenomenon, although it is better than the traditional algorithm, but it still cannot be complete eliminated.

As for the image processing effects, the paper will do comparison and evaluation from the contrasts (energy gradient method), average gradient values and information entropy.

Table 1 the contrast of an image

The contrast of an image evaluation	The result of an original image	The result of the MSRCR processing	The result of the new algorithm processing
Figure 2	4.0117	9.9441	14.1347
Figure 3	3.4820	16.8527	22.2288
Figure 4	1.8377	7.6208	10.6930

The contrast of an image reflects the clarity. The greater the contrast is, the higher the sharpness of the image is, conversely, the lower is [12]. This paper chooses the unit energy gradient function, its formula is:

$$f(I) = sqrt\left\{\sum_x \sum_y \left\{[I(x+1,y)-I(x,y)]^2 + [I(x,y+1)-I(x,y)]^2\right\}\right\} / [(x-1)\times(y-1)]$$

where I is the pixel values, $f(I)$ is the unit energy gradient values[13]. It can be seen from the data in Table 1, compared with the original image, the contrast enhancing range is 2.4787 to 4.8399 times; compared with the MSRCR algorithm, it is improved by 31.9% -42.14%. The definition has been a greater degree.

Table 2 the average gradient of an image

The average gradient of an image evaluation	The result of an original image	The result of the MSRCR processing	The result of the new algorithm processing
Figure 2	0.7735	1.6914	2.3905
Figure 3	0.5481	2.6298	3.4248
Figure 4	0.9699	1.5500	1.8076

An important indicator is the average gradient in evaluation of image details. The average gradient is a measure of the ability to express the contrast of image details, reflects the character of small details in the image contrast and texture transforming features. In one image, when a gray level of an image has a large change rate, the average gradient is large [14]. From Table 2, compared with the original image, after the MSRCR algorithm processing, the minimum increases 1.5981 times and the maximum increases the 4.7980 times; compared with MSRCR algorithms, details of the image by the proposed algorithm has been effectively enhanced and improves the range of 16.62% -41.33%.

Table 3 the information entropy of an image

The information entropy of an image evaluation	The result of an original image	The result of the MSRCR processing	The result of the new algorithm processing
Figure 2	6.6930	7.3335	7.6531
Figure 3	6.6246	7.2747	7.4662
Figure 4	6.1200	5.9609	6.3326

For an image, the most important evaluation criterion is the information entropy of an image, which reflects the average amount of information from the gray level of each pixel conveyed in the image, and can measure the importance of the target in the image [15]. The higher the entropy is, the greater the amount of information containing in an image is. From Table 3,it can be seen that the information entropy of the MSRCR algorithm can improve -2.60%—9.81% basically, which is mainly due to contain the color recovery coefficient, and keeps the color of fog while retaining the color of the scene, also reduces the information entropy of an original image. But after the new algorithm processing, the information entropy of an image increases in the proportion of 2.63%—6.24% basically，information entropy has been improved to some extent, the effect of processing is better than MSRCR algorithm.

5. RESULTS

In this paper, it proposes enhancement MSRCR algorithm of color fog image based on the adaptive scale, and combines with the characteristics of fog image, also simultaneously processes in three channels, avoids some extent hue, brightness and saturation distortion in the single channel processing. Due to traditional Retinex algorithm in image processing, there will be a halo trailing phenomenon. In view of this, the paper introduces two-parameter correction and adaptive scales, to a certain extent, to avoid the MSRCR algorithm after processing problem, but there is still a degree of flare from the above image, this is the problem to be solved in the next step. In terms of processing time, due to the Retinex processing for each channel, it wastes much time rather than just dealing with a multi-channel, but the paper uses the fast convolution method, and greatly improves the efficiency ,also speeds of the algorithm. Through the subjective evaluation and objective evaluation, it is proved that the new algorithm has a better effect on detail enhancement, color fidelity and clarity results comparing with the MSRCR algorithm processing.

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