Image Enhancement Based on Selective - Retinex Fusion Algorithm

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Abstract—**The brightness adjustment method for the night-vision image enhancement is considered in this paper. The color RGB night-vision image is transformed into an uncorrelated color space--- the YUV space. According to the characteristics of the night-vision image, we develop the modified Retinex algorithm based on the S curve firstly, by which the luminance component is enhanced and the brightness of the night-vision image is effectively improved. Then the luminance component of source image is enhanced by the selective and nonlinear gray mapping to retain the essential sunlight and shade information. Based on the two enhancement images, the night-vision image with enough bright and necessary sunlight and shade information is combined by the weighted parameter. According to experimental results, the night-vision image obtained is very fit for the visual observation.**

Index Terms—**image enhancement, night-vision image, Retinex, the S curve, selective and nonlinear gray mapping**

I. INTRODUCTION

Statistics show that the traffic accidents have been increasing during the night over the past decade. In recent years, the night auxiliary driving systems, which are based on the image processing technology, have become the hot spot of the driving information technologies.

With the street lights, the night-vision images have the following characteristic. They are: (1) very lack of color information; (2) bright around the illumination sources, such as street lamps and car lights, but the whole illumination is inadequate; (3) very dark where without the light. So the night-vision image is needed to reduce light contrast between the lighting and shade part and increase the whole luminance to improve the visibility of night-vision images.

To get the colorful night-vision image, the source IR and visible images are fused by color transfer technology to obtain a colorful final image [1-3], which is the so-called pseudo-color technology. The IR image records thermal radiations emitted by objects in a scene which can capture the heat source material without the light, and the visible image has much more high-frequency information of the background which has rich colorful information. In this method, the appropriate reference visible images must be selected to get the suitable colorful image. The basic rules of those methods are mapping the IR image and visible image into the three components of the RGB image by a certain rules to obtain the false color image and transferring the mean and standard deviation of the selected natural day-time color image to the false color image for each channel in an appropriate color space. However, the obtained color can not be similar to the true scene. While for auxiliary driving systems, it is very important to get the true scene while driving. The more similar image to the true scene means the more reasonable information delivered to the drivers, and it can make the driver safer while driving.

Several techniques have been proposed to enhance the brightness night-vision image. One method is the histogram equalization(HE)[5-6]. The traditional HE strategy usually produces annoying artifacts and overstated contrast that makes the image unnatural. It will ignore a lot of detailed information and bring in the noise, so it does not fit for the image with the great contrast and visual observation.

Another bright adjustment method described is Retinex algorithm[7-9]. The idea of the Retinex is to decompose the source image into two different images, i.e., the luminance component image and the reflection component image. The reflection component image is the final enhanced image.

This paper proposes a brightness adjustment method for the night-vision image based on the modified Retinex algorithm. Firstly, the night-vision image is enhanced by the modified Retinex algorithm of the S curve, then the selective and nonlinear gray mapping is applied to improve the sunlight and shade information of the night-vision image.

II. THE S-RETINEX METHOD FOR NIGHT-VISION IMAGE

A. Retinex algorithm

The flow of the Retinex algorithm is shown as in Fig.1.The source image is decomposed into two different

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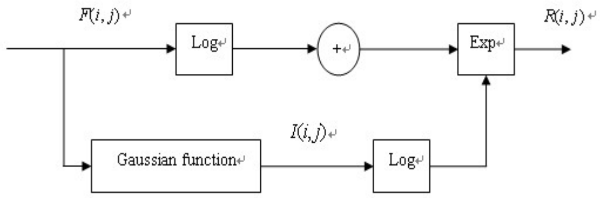
images, i.e., the luminance component image and the reflection component image. This method can eliminate the foreground and background luminance influence of the image, and can have a high dynamic range indoor/outdoor scene.



Figue 1. the flow of the Retinex algorithm

For an image $F(i, j)$, the formula is given by:

$$F(i, j) = R(i, j)I(i, j) \tag{2}$$

where $F(i, j)$ is obtained by observation or sensor reception, $R(i, j)$ denotes the reflection component image, and $I(i, j)$ stands for the luminance component image. In fact, the reflection component image $R(i, j)$ determines the essential property of the image, and the luminance component image $I(i, j)$ determines the maximum dynamic range of the image directly. So it is the essence of the Retinex theory to obtain the original property by removing the luminance component image $I(i, j)$ from the image $F(i, j)$.

Two-Dimensional Gaussian convolution function $G(i, j)$ could estimate the luminance component image $I(i, j)$ from the known image $F(i, j)$. It is given by:

$$G(i, j) = \frac{1}{2\pi\sigma^2} e^{-\frac{i^2+j^2}{2\sigma^2}} \tag{3}$$

where σ is the standard deviation in Gaussian function. The image enhancement effect is by the standard deviation directly, that controls how many fine details are left. Choosing σ should satisfy with below condition:

$$\iint G(i, j)\,didj = 1 \tag{4}$$

The Retinex output, the reflection component image $R(i, j)$, is given by:

$$\log R(i, j) = \log F(i, j) - \log\left[G(i, j) \otimes F(i, j)\right] \tag{5}$$

where $F(i, j)$ is the Retinex input image, $I(i, j)$ is the luminance component image, $G(i, j)$ is the Two-Dimensional Gaussian function, $\otimes$ stands for the convolution operation, (i, j) denotes the coordinates of the pixels.

To enhance the luminance is the key for night-vision image, so the YUV color space is chosen in this paper. There are some other color space, i.e., RGB, HSV, YCaCb and YUV, etc. In the RGB color space, three spatial components are correlative. Though in the HSV and YCaCb color spaces, the components are not correlative, but the transformation from the RGB color space to HSV and YCaCb are both nonlinear. While in the YUV color space, three spatial components are uncorrelated, and the transformation from YUV to the RGB color space is linear, moreover, it is the main acquisition color space of the color cameras.

Because the image get by camera is in the RGB color space. First, the RGB night-vision image is need to transform to the YUV response space. The transform RGB space to YUV space is written as:

$$\begin{bmatrix} Y(i, j) \\ U(i, j) \\ V(i, j) \end{bmatrix} = \begin{bmatrix} 0.299 & 0.587 & 0.114 \\ -0.1471 & -0.2888 & 0.4359 \\ 0.6148 & -0.5148 & -0.1000 \end{bmatrix} \begin{bmatrix} R(i, j) \\ G(i, j) \\ B(i, j) \end{bmatrix} \tag{1}$$

where R, G and B denote the spatial components of the color RGB image differently.

Now we use the Retinex algorithm to the image get by night driving systems shown as Fig.2 (a), whose luminance component is shown in Fig.2 (b). The Retriex algorithm in equation (5) is used to remove the luminance component of Fig.2 (b) and we obtain the result shown in Fig.2(c). According to the results in Fig.2(c), we can notice that the overall brightness component enhanced by the Retinex algorithm is dark and indistinct.

The histogram equalization method can be used to develop the brightness of image and improve the visual effect, and the result is shown in Fig.2 (d). We can see there is a very bright area in Fig.2 (d) which leads to a significant dividing line and there is some noise dot in the sky by incorrect processing. It is very dangerous for the driver who is driving at night because it is not conducive to observe the road information. Therefore, the histogram equalization is not suitable for improving the image of night driving systems.

In this paper, we propose a nonlinear transfer function of the S curve:

$$f = 0.5 + \frac{arc\tan(a * x - b)}{2t} \tag{6}$$

where a and b are used to control the curve shape, a stands for the growth speed, t determines the final value. As shown in Fig.3, it could be found that the S curve characteristic is very obvious. b determines the growth region position of the curve. a determines the growth region slope. The S curve has a relatively fast growth in the beginning and then will have a weak growth until reaching a certain constant. Its derivative is smooth, so it could fit reality better.

The modified Retinex algorithm by using of the S curve is given by:

$$P_R(i, j) = 0.5 + \frac{arc\tan(a * R(i, j) - b)}{2t} \tag{7}$$

where $R(i, j)$ is the reflection component image.

B. Experimental results

Then the modified Retinex algorithm with the S curve in equation (7) is carried out on the Y component. The image output is shown as Fig.4 with $b = 0,\ a = 0.7,\ t = 1.5$. Finally three components YUV are transformed to the RGB image as shown in Fig.5, the transformation formula is written as the following

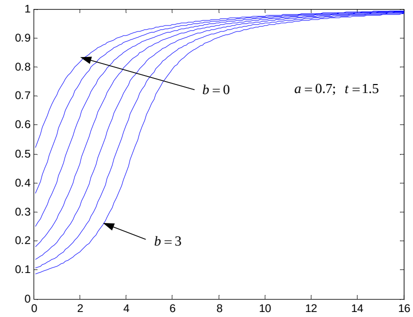
(a)

(b)

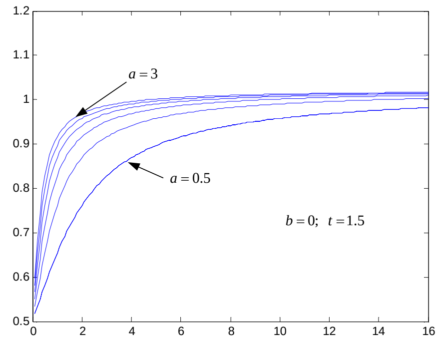
(c)

(d)

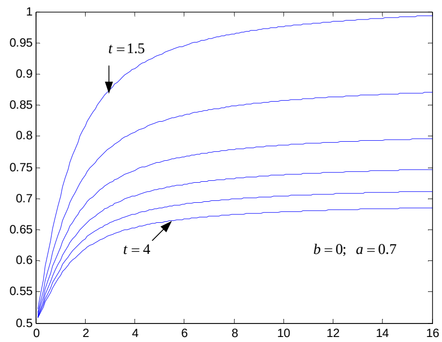
Figure 2. (a) the source image; (b) the brightness component of the source image; (c) the result by the Retinex algorithm; (d) the result by the histogram equalization method



(a)



(b)



(c)

Figure 3. S-curve in different conditions

(a) about b

where $a = 0.7; t = 1.5; b = 0, 0.5, 1, 1.5, 2, 2.5, 3$

(b) about a

where $b = 0;\ \ t = 1.5;\ \ \ \ a = 0.5,\ 1,\ 1.5,\ 2,\ 2.5,\ 3$

(c) about t

where $b = 0;\ \ a = 0.7;\ \ t = 1.5,\ 2,\ 2.5,\ 3,\ 3.5,\ 4$

Figure 4. the brightness component output by the S-Retinex method

(a)

(b)

Figure 5. (a) the source image; (b) the color image output by the S-Retinex method

$$\begin{bmatrix} R(i,j) \\ G(i,j) \\ B(i,j) \end{bmatrix} = \begin{bmatrix} 1 & 0 & 1.140 \\ 1 & -0.394 & -0.581 \\ 1 & 2.032 & 0 \end{bmatrix} \begin{bmatrix} Y(i,j) \\ U(i,j) \\ V(i,j) \end{bmatrix}$$

(8)

According to the result, the image contrast is enhanced, and the brightness of image is improved. The details of the scene are clear, so we can see the grass on the roadside, the building and the door. But we can also see the shade information is eliminated. Because the image is lack of the necessary three-dimensional information, the visual effect is not good. So it is necessary to keep the shade and color information on a basis of the bright enhancement to make the result image more suitable for observation.

In general, the image is get by camera with light, so with lots of three-dimensional and shade information. But here we deal with the night-vision image without enough light, so the source image looks very black. One method to enhancement the image is the histogram equalization (HE) shown in Fig.2 (d). The traditional HE strategy usually overstates contrast and ignores a lot of detailed information.

We know for the night-vision image with little light, the light and dark part of image need different processing: the light part need to reduce the brightness and its halo, while the dark part need to be enhanced according to the distance between the light source to keep distance information. The main reason that the traditional HE did not deal with the two parts differently.

III. THE SELECTIVE AND NONLINEAR GRAY MAPPING

Here we need the following four steps:

Firstly, find the light sources in the image. In the general, they are street and car lamp. Draw the component above the 80 percent of the maximum luminance, erode first to eliminate speckles, then dilate to recover the area, we can obtain the point light sources P_n, $n = 1 \ldots N$.

Secondly, reduce the halo. Get the center coordinates and the luminance of the point light sources, and compute the luminance-enhanced factor related to the distance from the center of the point light source $f_T(i,j)$:

$$f_T(i,j) = min\, exp\left(-\frac{c\sqrt{(i - i_{0n})^2 + (j - j_{0n})^2}}{M_n} \right), n = 1 \cdots N \tag{9}$$

where M_n is the area of each point light source. i_{0n} and j_{0n} stand for the X-coordinate and Y- coordinate of the center of each point light source. c is the undetermined coefficient.

Thirdly, deal with the two parts differently. Compute the luminance-enhanced factor related to the luminance $f_L(i,j)$:

$$f_L(i,j) = \begin{cases} 1 & \text{in the area of each point light source} \\ d \cdot (p(i,j) - Light)^2 + 1 & \text{other parts in the image} \end{cases} \tag{10}$$

where $p(i,j)$ is the gray value of (i,j), $Light$ is the 80 percent of the maximum luminance. d is 6 if the whole image is very dark (for example the luminance average is less than 0.15), otherwise is 3.

At last, the luminance component of the whole image is enhanced by

$$p_T(i,j) = p(i,j)\, f_L(i,j) \cdot f_T(i,j) \tag{11}$$

where $f_L(i,j)$ is the luminance-enhanced factor related to the luminance, and $f_T(i,j)$ is the luminance-enhanced factor related to the distance from the center of the point light source.

By the method proposed here the image shown in Fig.6 (b) can be obtained from the luminance image in Fig.6 (a) with light and three-dimensional information.

VI. SELECTIVE-RETINEX FUSION ALGORITHM

Compared Fig.6(b) with Fig.4, it could be found that the former has sunlight and shade information, but because of the limited lumination distance of the car lights, it is extremely dark in farther places; however the latter eliminates the sunlight and shade influence and is not fit for the visual observation, because lack of depth information.

We get the final luminance image $p_Y(i, j)$ by combine the two enhancement image get by (7) and (11) with the weight g

$$p_Y(i, j) = g \cdot p_R(i, j) + (1 - g) \cdot p_T(i, j) \qquad (12)$$

where g is the weight. The value of g will decide the fusion image performance greatly. With the different value of g, the different fusion images are shown in Fig.8. By large number of experiments, we know that if there are good light condition and visual observation distance, the best range for g is from 0.1 to 0.3; otherwise it is from 0.3 to 0.6. $p_R(i, j)$ is the gray value by the luminance adjustment method for the faint image based on the modified Retinex algorithm of the S curve and $p_T(i, j)$ is the gray value based on the selective and nonlinear gray mapping. Choosing the weighted parameter g properly could retain the essential sunlight and shade information and make the image fit for the visual observation, as shown in Fig.8.

We use the color transfer algorithm in refers [1,3] by the false color fusion method to the source image in Fig.9 (a). The principle of color transfer algorithm [1,3] needs a reference image and is implemented to make the final image and the reference image have the same mean and standard deviation for each channel in an appropriate color space. Here, the color space for the color transfer is also the YUV space. From the results compared with Fig8. (b), we can see that in Fig.9(c) the whole luminance is inadequate, and the target and background are not clear enough. In Fig.9(d), the reflection of the lights is so strong that it is hard to observe.

We apply the method developed here to several images get from the night-vision driving system. The results are shown in Fig. 10. We can see the bright of all the images are developed and the details can enhanced. The output results all show satisfactory effect by the selective-Retinex fusion method.

V. CONCLUSION

In this paper, we study the night-vision image in the YUV space and find the enhanced luminance component of the night-vision image is dark and indistinct. The Retinex brightness adjustment algorithm for night-vision image is proposed to obtain the image with enough bright by using S curve which has a relatively fast growth in the

(a)

(b)

Figure 6. (a) the luminance image of the source; (b) the luminance image by the method

(a)

(b)

(c)

(d)

(e)

(f)

(g)

(h)

(i)

Figure 7. the fusion image with different g
(a) $g = 0.1$ (b) $g = 0.2$ (c) $g = 0.3$
(d) $g = 0.4$ (e) $g = 0.5$ (f) $g = 0.6$
(g) $g = 0.7$ (h) $g = 0.8$ (i) $g = 0.9$

(a)

(b)

Figure 8. (a) the luminance component of the image $p_Y(i, j)$ (b) the final image with color

(a)

(b)

(c)

(d)

Figure 9. (a) the indistinct RGB night-vision image; (b) the reference image; (c) the final fused image[3]; (d) the final fused image[1].

beginning and then will have a weak growth until reaching a certain constant. In another way, the luminance component Y is enhanced by the two luminance-enhanced factors, to obtain the image necessary sunlight and shade information. Then with the weight, the former two images are fused to the final enhanced luminance image. By which, the color image is obtained with good visibility.

By the method developed here, the image brightness could be enhanced effectively, and the necessary sunlight and shade information could be reserved very well. It is suitable for the drivers to observe the road situation when traveling.

(a)

(b)

(c)

(d)

Figure 10. the results of this paper method;(a) (c): the color night-vision images in kinds of night road conditions; (b) (d): the results by the luminance adjustment method for the night-vision image based on the method developed here.

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