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An Algorithm of Single Image Fast Recovering for the Intelligent Transportation Monitoring

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Abstract

To solve the problem of image definition reduction caused by haze in intelligent transportation monitoring, an algorithm of fast recovering for image degraded by haze based on dark primary colors prior. Firstly, we estimate atmospheric light and transmission rate using global dark colors prior based on the shortage of existing dark colors prior. Secondly, according to the atmospheric physics model, image degraded by haze is recovered. Finally, brightness of image is compensated by using Retinex theory. Experimental results show that the proposed algorithm can increase image definition better and the calculation time is 30 frames per second.

Key words: *intelligent transportation; faze; definition; image recovery; dark colors prior*

1. Introduction

In recent years, the frequent haze weather has a serious impact on traffic. In low visibility, image sharpness of intelligent traffic monitoring drops greatly and loses some information which reduces the monitoring function. So it is necessary to recover the intelligent traffic monitoring image. Image recovering can be divided into two methods. One is using histogram equalization or Retinex algorithm to enhance image contrast. This method is simple and rapid, but also ease to loss some information. Another method is researching image degradation reasons (atmospheric scattering) and realizing image restoration according to the atmospheric physics model. Early studies are based on multiple images. Recently owing to a series of powerful prior and assumption appearing, single image recovering is developed greatly. For example, Tan, Fattal and He have studied on the single image recovering and got some new research results. But those methods have great calculation and are difficult to application. So we proposed an algorithm of fast recovering for image degraded by haze based on dark primary colors prior. Firstly, we estimate atmospheric light and transmission rate using global dark colors prior based on the shortage of existing dark colors prior. Secondly, according to the atmospheric physics model, image degraded by haze is recovered. Finally, brightness of image is compensated by using Retinex theory.

2. Atmospheric Physics Model

The method of image restoration is considering degradation reasons and establishing some physical model. McCarney put forward an atmospheric scattering model in 1975 which contained attenuation model and atmospheric optical model. Model is shown as follows:

$$I(x) = t(x)J(x) + (1 - t(x))A \tag{1}$$

$$t(x) = \mathrm{e}^{-\beta d} \tag{2}$$

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Where, $I(x)$ is the original haze image; x is pixel coordinate; $t(x)$ is transmission attenuation function (transmissivity); β is air scattering coefficient; d is scene depth; $J(x)$ is recovering image; $t(x)J(x)$ is attenuation model; A is global atmospheric light; $(1-t(x))A$ is atmospheric optical model which is caused by scattering.

According to the atmospheric scattering model we can conclude that the method of image restoration is mainly estimating $t(x)$ and A. The recovering image can be described as:

$$J(x) = \frac{I(x)}{t(x)} - \frac{(1-t(x))}{t(x)} A \tag{3}$$

Estimating $t(x)$ and A rely on single image need some prior knowledge or assumptions. Tan and Fattal have adopt their own prior or assumptions to achieve image recovering. In 2009, He has put forward a method of image restoration based on the prior dark grey which effect is better.

3. Image Restoration based on Prior Dark Grey Knowledge

3.1 Image Restoration Process based on Prior Dark Grey

Prior dark grey knowledge is an objective existence regularity which can be concluded by outdoor image with no fog. It can be described as in the vast majority of local non-sky area there are always some pixels which have very low strength values at least in one color channel. The formula is:

$$J_{\text{dark}}(x) = \min_{c \in [r,g,b]} \left(\min_{y \in \Omega(x)} (J_c(y)) \right) \tag{4}$$

Where J_c is one color channel of image J; $\Omega(x)$ is a square area with the center x. In addition to the sky area, J_{dark} is too low and tending to zero.

In a haze image, due to fog blanch action, the dark gray value becomes higher and the change is related to the atmospheric transmittance of light. Thus $t(x)$ can be estimated according to the dark grey value. The method is firstly He contains the local dark image based on haze image block; secondly He uses the prior dark grey to estimate transmittance function and improve it with soft cutout algorithm; thirdly in order to prevent $t(x)$ close to zero, He sets a limit t_0; finally the transmittance function is $\max(t(x), t_0)$.

In order to estimate atmospheric light, the method is choosing the maximum intensity value as atmospheric light. In fact, the maximum intensity value can also be the white object. Based on the prior dark grey can improve atmospheric light estimation. We choose the 0.1% of the maximum intensity value as atmospheric light.

Finally we can recover haze image based on physical model, $t(x)$ and A.

3.2 Disadvantage of Image Restoration Process based on Prior Dark Grey

Experiments show that image restoration based on prior dark grey can significantly improve image visual effect, but also has some deficiencies.

(1) The process of obtaining the local dark image based on haze image block can generate some block effect. He uses the prior dark grey to estimate transmittance function and improve it with soft cutout algorithm. But the method has great calculation. Such as an image, 350*500, the operation time is 23s.

(2) Due to the unknown image size, 0.1% of the maximum pixels are possible an object which can cause error optical estimation. In addition, image block is too small which also has an impact on optical estimation.

(3) Recovering image has low brightness and resolution and lose some details.

4. Improved Image Restoration based on Prior Dark Grey Knowledge

In a haze image the fog is well-distributed and local area changes slowly, so estimated transmission rate is alike. To reduce the calculation, we will consider the haze image as a block and use global prior dark grey to recover image.

4.1 Estimation of Atmospheric Optical Component

To reduce algorithm time, we only process the haze image brightness component. Firstly the haze image is changed from RGB space into HSV space. The sky area generally locates in the top of the image, so we choose the 15% of top pixels in H component and set the 1% of maximum pixels as estimation of atmospheric optical component. This method can effectively eliminate white vehicles or other objects.

4.2 Estimation of Transmission Rate

Based on the atmospheric scattering physical model and prior dark grey, dark colors of three channels (R, G, and B) are:

$$\min(\min(\frac{I_c(y)}{A_c})) = t(x)\min_c(\min_{y\in I(x)}(\frac{J_c(y)}{A_c})) + (1 - t(x)) \tag{5}$$

Where, c is one of three channels (R, G and B).

To transform formula (5), the global transmission rate is:

$$t(x) = 1 - \varpi \min_c(\min_{y\in I(x)}(\frac{I_c(y)}{A_c})) \tag{6}$$

Where, ϖ is adjustment factor which is used to balance the mist and fog.

Using atmospheric optical component and transmission rate, we can recover image according to atmospheric optical model. But we have found that recovering image has low brightness and resolution and lose some details.

4.3 Image Enhancement

The common algorithms of image enhancement are: histogram equalization [1-4], direct gray transformation [5-8] and light compensation based on the theory of Retinex [9-14]. We use the theory of Retinex to enhance image brightness. According to Retinex theory, image can be divided into two parts. One is illumination image L decided by incident light corresponding to the low-frequency part; another is reflection image R decided by object surface reflection properties corresponding to the high-frequency part. Illumination image directly determines the dynamic range of pixels; reflection image determines the internal properties. The purpose of Retinex theory is not to consider illumination image, but directly to get reflection image reflecting the original visage of objects.

Assume that mathematics model of single channel image is:

$$I(x,y) = L(x,y) \times R(x,y) \tag{6}$$

In the formula, $I(x,y)$ represents pixels; $L(x,y)$ represents illumination image; $R(x,y)$ represents reflection image.

Considering two functions' product of Fourier transform is inseparable, formula (6) is taken log conversion, as follows:

$$\log I(x,y) = \log L(x,y) + \log R(x,y) \tag{7}$$

According to the center/around Retinex algorithm, Jobson has deduced single scaling Retinex algorithm (Single Scale Retinex, SSR):

$$R(x,y) = \log[I(x,y)+\delta] - \log[F(x,y) * I(x,y)+\delta] \tag{8}$$

$R(x,y)$ represents output of Rentiex. $F(x,y)$ represents the center/around function and generally is defined as:

$$F(x,y) = K\exp(-(x^2+y^2)/\sigma^2) \tag{9}$$

Among them, σ represents the standard deviation of Gaussian function; K is determined by normalization conditions.

Multi-scale Retinex algorithm (Multi-Scale Retinex, MSR) not only can realize dynamic range of image compression, but also can ensure the details of image information. The function MSR is defined as:

$$R(x,y) = \sum_{i=1}^{n} \varpi_i [\log[I(x,y)+\delta] - \log[F_i(x,y) * I(x,y)+\delta]] \tag{10}$$

ϖ_i represents coefficient of corresponding scale which is chosen according to the dynamic range or the consistency of color; n represents scale number which contains large, medium and small dimensions.

In this algorithm, MSR light compensation method is used for low-frequency part of H component.

5. Algorithm Chart

The algorithm flow chart is shown in Figure 1.

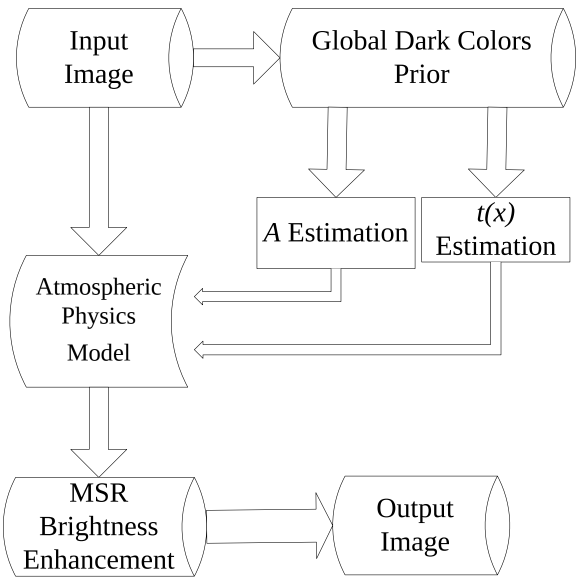

Figure 1. Diagram of Algorithm

6. Experiment Results and Analysis

6.1 Compared Experimental Results

In order to verify the validity of the algorithm in the paper, a series of intelligent traffic monitoring images are recovered. The results also are compared with histogram equalization and Retinex algorithm, as shown in Figure 2. Experimental results show that the proposed algorithm can increase image definition better.


(a) Original image (b) Histogram equalization


(c) Retinex method (d) Proposed method


(a) Original image (b) Histogram equalization


(c) Retinex method (d) Proposed method


(a) Original image (b) Histogram equalization

(c) Retinex method (d) Proposed method

Figure 2. Results of Algorithm

6.2 Compared Algorithm Time

The different algorithm time is shown in Table 1. We can conclude that although histogram equalization and Retinex algorithm have less time, the results are not ideal. Our algorithm time is 35ms which can be used in practical application.

Table 1. Comparison of Processing Time

Image	Size	Histogram equalization /ms	Retinex method/ms	Proposed method /ms
(1)	260*200	15.69	21.25	35.63
(2)	260*170	14.53	20.64	34.99
(3)	260*250	16.87	22.31	36.73

7. Conclusions

An algorithm of fast recovering for image degraded by haze based on dark primary colors prior. Firstly, we estimate atmospheric light and transmission rate using global dark colors prior based on the shortage of existing dark colors prior. Secondly, according to the atmospheric physics model, image degraded by haze is recovered. Finally, brightness of image is compensated by using Retinex theory. Experimental results show that the proposed algorithm can increase image definition better and the calculation time is 30 frames per second.

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