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The Defogging Algorithm for the Vehicle Video Image Based on Extinction Coefficient

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Abstract: For the serious visual obstacle problem to be caused by rain-haze disasters, the method is proposed that a fog-haze medium transfer rate valuation model is established using the extinction coefficient characteristics. In this way, the tunnel monitoring video image will be restored by fog-haze image degradation model. Due to the atmospheric visibility from the scattering type visibility meter, the estimates to fog-haze medium bit rate is more close to reality. The algorithm of process to be built by the method is very clear, and overcome the drawbacks of affect video fluency that needs a large number of time-consuming calculation through traditional methods. *Copyright © 2014 IFSA Publishing, S. L.*

Keywords: Vehicle video image, Defogging algorithm, Extinction coefficient, Fog-haze medium transmission rate.

1. Introduction

The visual obstacle problem caused by rain-haze disasters, as the main factor of causing major malignant traffic accidents, is getting more and more attention. In the field of tunnel visual perception, academics focused on video image dehazing processing based on two technology paths of the fog-haze image degradation model and the estimates to image pixel fog-haze concentration, in order to solve this problem. However, these methods can not meet the real-time requirement due to the complex and time-consuming processing caused by the fast moving vehicles in the freeway. The frame loss produced by time-lag also seriously affects the video image quality. Therefore, we proposed a removing fog-haze algorithm about the vehicle video image based on extinction characteristics. The algorithm can transform the fog-haze medium transmission rate into the contrast metric characterizing factor about the dark channel of degraded image based on measured values of atmospheric extinction coefficient, and get a clear image after dehazing by fog-haze degradation model.

2. Simplify of Fog Image Degradation Model

Fog-haze video image restoration technique is to study how to isolate atmospheric scattering light from the degraded image, then obtain the clear image. Its essence is the repairment of single frame image. The idea for this study dates to the 1950s [1]. In 1952, Middleton summarized a series of theories about atmospheric physics, then McCartney presented a physical model of the atmospheric scattering based on his theories in 1975 [2]. This model laid a theoretical foundation for later research on atmospheric scattering method.

According to the atmospheric scattering theory, due to combination of aerosols and water vapor in the atmosphere, the light intensity of video image system would decrease and the image would be degrade for the scattering, thus forming fog barrier. Nayar and others summed up the sky illumination model and direct attenuation model [3], as shown in Fig. 1.

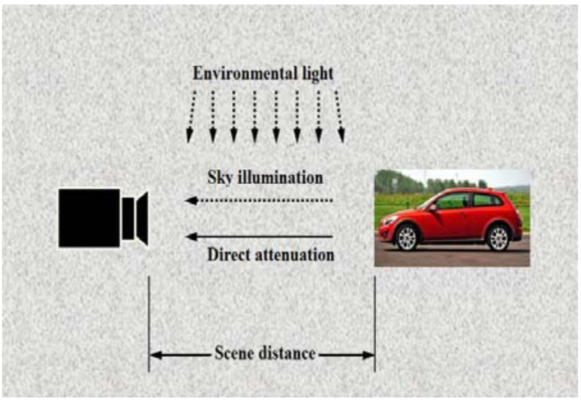

Fig. 1. Atmospheric attenuation model.

We can know from the law of light attenuation exponential in the atmosphere [4]:

$$\varphi(\mathrm{d}) = \varphi(0)\,\mathrm{e}^{-kd}, \tag{1}$$

where d is the scene distance shown in Fig. 1, $\varphi(0)$ is the acquired light energy in zero distance, $\varphi(\mathrm{d})$ is the received light energy after the transmission of d distance from $\varphi(0)$, k is the attenuation coefficient of atmosphere medium. According to this law, Nayar and others presented the light radiation intensity model at each point of the image in the scene [5]:

$$E(\mathrm{d},\lambda) = \frac{E_\infty(\lambda)\gamma(\lambda)\,\mathrm{e}^{-\beta(\lambda)\mathrm{d}}}{d^2} + E_\infty(\lambda)(1-\mathrm{e}^{-\beta(\lambda)\mathrm{d}}), \tag{2}$$

where E_∞ is the horizontal sky light intensity, $\gamma(\lambda)$ is the reflectance attribute of every point in the scene, $\beta(\lambda)$ is an atmospheric scattering coefficient based on the wavelength of light function, which is related to the fog-haze concentration. $E(\mathrm{d},\lambda)$ is the actual received image under the influence of the fog-haze. Through mathematical transformation of formula (2), we can obtain the brightness of each point, which is the received image:

$$E = I_\infty \rho e^{-\beta d} + I_\infty(1-\mathrm{e}^{-\beta d}), \tag{3}$$

where I_∞ represents the atmospheric light, ρ which has nothing to do with atmospheric conditions represents the radiation intensity of standard light. $I_\infty\rho$ is the image brightness without scattering, or the image without fog-haze. It is attenuated by the haze medium, and the degree is decided by the scene depth d. So $I_\infty \rho e^{-\beta d}$ is called direct attenuation [6], and $\mathrm{e}^{-\beta d}$ is called fog-haze medium transmission rate. $I_\infty(1-\mathrm{e}^{-\beta d})$ is called atmospheric scattering light which makes the light blur and distorts the color. Therefore, the purpose of image dehazing is to restore $I_\infty\rho$ from E.

Assume that $I_\infty\rho$ is R, $\mathrm{e}^{-\beta d}$ is t(x), formula (3) can be expressed as:

$$R = t(\mathrm{x})\bullet(\mathrm{E}-\mathrm{I}_\infty) + \mathrm{I}_\infty, \tag{4}$$

Formula (4) is so-called fog-haze image degradation model. As mentioned before, $t(\mathrm{x}) = \mathrm{e}^{-\beta d}$ is regarded as the fog-haze medium transmission rate reflected in the x region of the image because of the connection of β and fog-haze concentration. The model shows that we can know the fog concentration and restore the image R by the fog-haze medium transmission rate.

3. Relationship between the Transmission Rate and Extinction Coefficient

The fog-haze concentration associates with atmospheric extinction coefficient in the atmospheric visual optical theory. The coefficient reflects the optical absorption of aerosol in the air. Aerosol in gas is fine colloidal. It has variety of forms which is called smoke when dispersing as solid and called fog as liquid. Usually, the higher smog concentration in the air, the deeper the color of fine grain becomes, the greater light absorption will be, and the lower light transmittance, It shows the coefficient will be bigger, otherwise small. So the extinction coefficient determines the atmospheric visibility. In meteorology, the relationship between the extinction coefficient σ_{wu} of unit volume fog-haze and the horizontal atmospheric visibility [7] is shown:

$$N = \frac{3.912}{\sigma_{wu}}(km), \tag{5}$$

usually, to detect the vehicle visibility in the freeway, scattering visibility instruments with the optimal range in 2 km are always chosen. We can obtain the diagram between visual range N in the 2 km and the extinction coefficient from formula (5), as shown in Fig. 2.

Fig. 2 shows that the characteristics of the coefficient are consistent with the medium transmission rate reflected in formula (4). When the fog-haze becomes very high, the extinction coefficient tends to be 100 %, so the optical transmission is completely blocked. Then the atmospheric transmission medium and the visibility both approach 0.

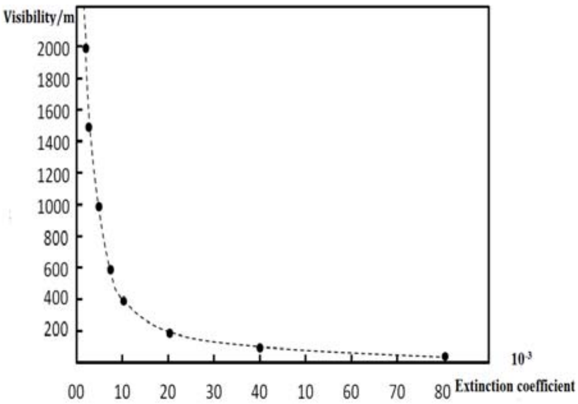

Fig. 2. Relationship between N and σ_{wu}.

When the fog-haze concentration is 0, the extinction coefficient is theoretically 0, the transmission rate is theoretically 100 %. So we can conclude R=E, the image observed should be clear with no haze. However, the transmission can never achieve complete. We can only assume that the rate is 100 % when the visibility N achieves a multiple of the optimal detection accuracy. The valuation model of the medium transmission rate can be constructed:

$$t(\mathrm{x}) = 1 - \frac{K_N - N}{K_N}, \tag{6}$$

where $t(\mathrm{x})$ is the atmospheric medium transmission rate $e^{-\beta d}$, K_N is n times the optical range of visibility meter, n is usually 2-8. For the visual range of vehicles on the highway, n can generally be 1.5-3. We can learn from formula (6): when $N \to K_N$, $\lim t(\mathrm{x}) \to 1$. Otherwise, $\lim t(\mathrm{x}) \to 0$. Take formula (5) into formula (6), then we can get:

$$t(\mathrm{x}) = \frac{3.912}{K_N \sigma_{wu}}, \tag{7}$$

where K_N is 2000 m, the relationship between $t(\mathrm{x})$ and σ_{wu} is just as Fig. 3.

It totally coincides with the curve in Fig. 2 because that formula (6) defined the range of valuation model $t(\mathrm{x})$ in mathematics while formula (5) defined the relation between $t(\mathrm{x})$ and atmospheric extinction coefficient in physics.

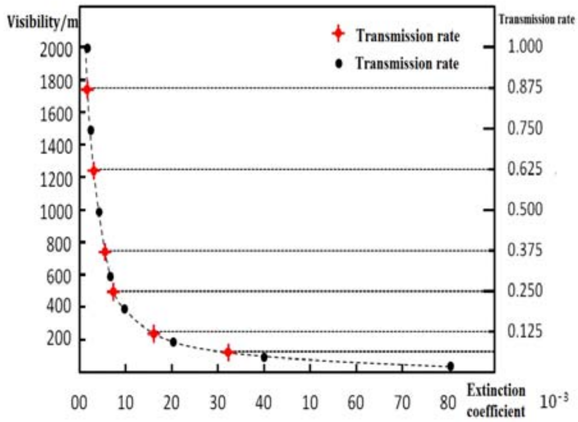

Fig. 3. Curve relationship with Atmospheric medium transmission rate and the extinction coefficient.

Because the extinction coefficient reflects the fog-haze concentration, the relationships in Fig. 2 and Fig. 3 are not only reflected in the fog-haze weather, but also in rain and snow, just as the statistical curve [7] in Fig. 4.

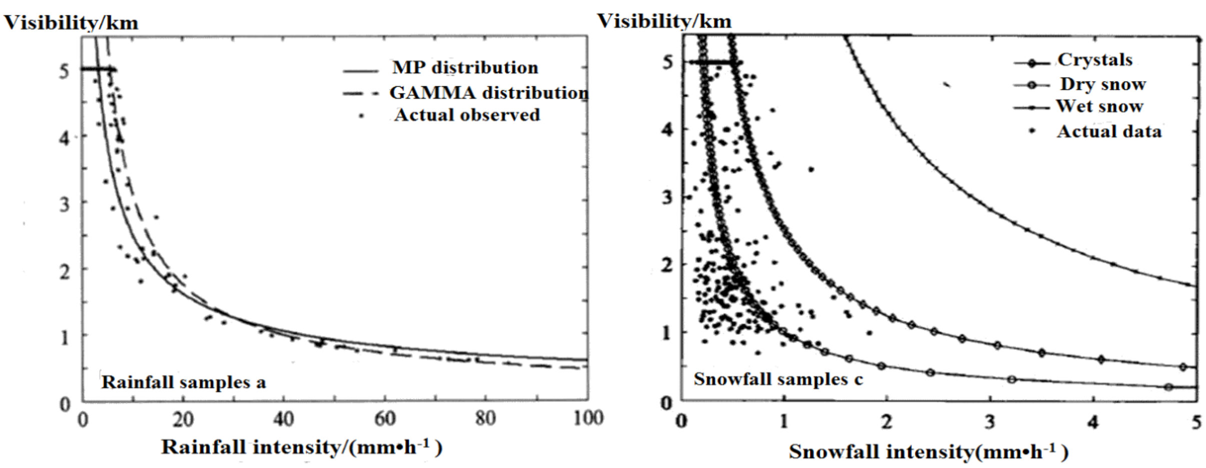

Fig. 4. Curve relationship with intensity (rainfall and snowfall) and visibility.

However, $t(\mathrm{x})$ can't be directly applied to formula (4) because it is a calculated value, instead of a contrast metric value. Therefore, we propose based on the atmospheric transmission medium valuation formula of the dark channel.

4. Calculate the Medium Transmission Rate Based on Dark Primary Color Theory

He Kiming and others put forward the Dark Channel Prior Theory [8]. They tried to get the fog-haze concentration by the dark channel. According to their theory, a picture can be defined as follows:

$$J_{dark} = \min(\min \mathrm{J}^C(\mathrm{x})), \quad (8)$$

where $C \in \{\mathrm{R,G,B}\}$, J^C is one of the three image channels RGB, $x \in \Omega(\mathrm{x})$, $\Omega(\mathrm{x})$ is the local image centered around x, so formula (8) is the darkest image channel and J_{dark} is the channel image with the lowest brightness in the area. From large analysis of the three color channels, it shows that the brightness of at least one channel is very low, sometimes, even tends to zero. It's the visual shadow or shading in physics. So J_{dark} is called dark channel of scene image J, also known as dark primary color image.

Due to the atmospheric light, fog-haze image is more bright than that without fog-haze when $\mathrm{e}^{-\beta d}$ is low. The dark primary image is brighter in thick fog. And statistics show that the luminance difference is close to the thickness of the fog-haze in the image. So we can estimate transmission rate and the entire atmospheric light.

Assuming that one of the three colors light I_∞ is A^C, the valuation model of atmospheric transmission rate $t(\mathrm{x})$ can be [5]:

$$\Delta t(\mathrm{x}) = 1 - \min(\min(\frac{E^C(\mathrm{y})}{A^C})), \quad (9)$$

where $y \in \Omega(\mathrm{x})$. In the formula (9), the second on the right side is black channel of the image, it provide a direct transmission rate valuation so that we can calculate $\Delta t(\mathrm{x})_0$ which is the initial value of $\Delta t(\mathrm{x})$ in the initial frame of video image. Assuming that the initial measured value of transmission rate is $t(\mathrm{x})_0$, the image contrast metric value is $\Delta t(\mathrm{x})\mathrm{B}$, we can conclude:

$$t(\mathrm{x})_B = \frac{\Delta t(\mathrm{x})_0}{t(\mathrm{x})_0} \bullet t(\mathrm{x}), \quad (10)$$

Thus, by formula (5), (7), (9) and (10), the image pixel contrast measured factor can be obtained according to real-time visibility, instead of the time-consuming calculations in each video image processing cycle.

5. The Dehazing Algorithm Design about Video Image

Described in the previous section, the luminance difference of the black channel is close to the thickness of the fog-haze in the image, we can estimate the entire atmospheric light by the black channel. Usually, select a small part (such as 0.1 %) of the brightest areas in the black channel, and put these pixels into the corresponding location, then choose the highest brightness as the estimating atmospheric overall light [5].

After getting the valuation we can remove the fog-haze in the image by formula (4), (6), (9) and (10). Its process is shown as Fig. 5.

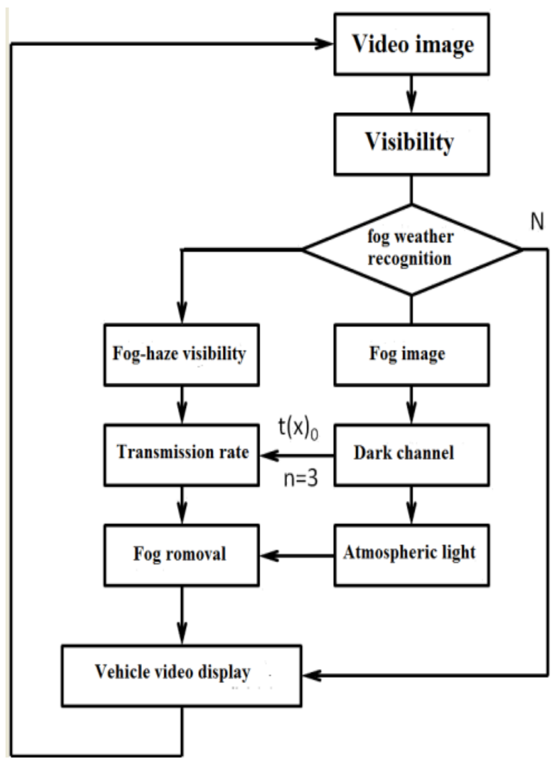

Fig. 5. Algorithm process about the video image method to reduce fog.

This algorithm reduces the time greatly. In addition, the dehazing effect and video image fluency are both improved obviously.

5. Simulation and Conclusion

The method proposed in the paper has been verified with simulation to different images by MATLAB. And SWS-200 scattering detector of Biral company is chosen. Relationship between its optical visual range and extinction coefficient can be taken as: $MOR = 2.996 / EXCO$. The result is shown as Fig. 6, and the processing speed is up to 30 frames per second. In Fig. 6, the fog-haze is divided into three kinds: mist, moderate and dense. The first line is the original fog-haze image, the second is the image after dark channel processing, and the third is the image after defogging restoration.

So we can conclude that the dehazing effect is obvious after fog removal, and the best ranging at the visibility is from 150 m to 300 m. At the same time, we can know from Fig. 4 that the method can also be applied to the rapid restoration of degraded image in the rainy and snowy weather.

Fig. 6. Simulation results about reduce fog program.

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