Luminance enhancement in single image dehazing

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Abstract

Haze is an extreme reason of the reduction of contrast when capturing image in the outdoor. Recently, there are several single image dehazing techniques, but they are not robust in dynamic variations of natural environment caused by the thickness, coverage of haze and appearance of sunlight. In this paper, we propose an effective and robust method to enhance luminance for image dehazing depending on histogram analysis. Compare with conventional methods, our proposal have better performance in term of contrast, and computation time.

1. Introduction

Digital image is hazed when capturing in the scattering-existed scene (e.g. near ocean, aerial image). Hazy natural form dues to atmosphere absorption such as haze, fog, and smoke. The received image at the camera is the result of blending the incoming light and airlight [1]. Properties of hazed image are low contrast and lost color fidelity. Then, haze is not only an extremely reason of degradation of visibility, but also reason of performance degradation of computer vision system. For example, in pedestrian detection system, the false positives per frame are significant increased when implementing in the scattering-exist environment. To enhance the quality of hazed image, there are two ways: (i) image enhancement based on visibility enhancement processing without knowledge of hazy image criteria, (ii) image restoration based on dichromatic model of hazy image. In the first category, there are varieties of classical methods such as histogram equalization, holomorphic filter, wavelet transform, Retinex algorithm. The advantage of these methods is globally able to apply in the wide scene without any assumption, but these methods just can enhance visibility lightly. With the second approach, the physics-based formation of hazy image must be described efficiently. The degradation model widely used is derived in [1-4]. The challenger of this model is to provide the estimation of unknown atmospheric airlight and unknown depth map of image effectively. Recently, airlight is maintained the same value in the all pixels of image constantly by indicating the highest intensity of pixels which are the top 0.1 percent values of dark channel prior [1]. Recently, dark channel prior (DCP) [1] and median dark channel prior (MDCP) [2] are the most attracting methods for transmission estimating, but still there are some constrains.

In our experiment, hazy image has no change in color component but has low contrast in luminance component. Then this paper tends to enhance luminance for image dehazing. Following sections describe details of method.

(a) (b) (c)

Fig 1. Intensity component of (a) hazy image, (b) dehazing with MDCP, (c) luminance enhancement with our propose.

2. Histogram-based luminance enhancement

2.1 Chromatic degradation model

In the almost of the physics-based image haze removal technique, the widely used model is given as follow [1-4]

$$J(u,v) = I(u,v)t(m,n) + A(1-t(u,v)) \quad (1)$$

Where $J(u,v) = (R(u,v)+G(u,v)+B(u,v))/3$ is the image luminance received at camera, $I(u,v)$ is the haze-free luminance which is expected to retrieve after dehazing process. A is the atmospheric airlight describing the illumination source of outdoor environment. $t(u,v)$ is the transmission describing the portion of radiance reached to the receiver and the portion of light is not captured. The first term $I(u,v)t(u,v)$ is called the direct attenuation and the second term $At(u,v)$ is called airlight. To recover the haze-free image, airlight and transmission must be estimated completely. In this paper, we use MDCP model to estimate airlight and transmission. We use this model because it maintain detail of image without halo effect, then soft matting step is not needed. Another hand, result of MDCP is too dark and low contrast (figure 1b), then in the next step we perform luminance enhancement step by using histogram analysis.

2.2 Histogram-based luminance enhancement

There are some several literatures about luminance enhancement that contains linear [5] and non-linear [6,7] methods. Each of method has advantage and drawback, but linear method maintains depth of image better than non-liear one. Therefore, we use piece-wise linear luminance enhancement in this paper.

In the first step, histogram of luminance in figure 1b is compute (figure 2a). This histogram refers to probability density function of random variable luminance $x(x=\overline{0,255}$ for 8-bit image), called $f_X(x)$. In our experiment, $f_X(x)$ obtains multi bunches of Gaussian and each of Gaussian represent one object in image. Cause of noise existence, these Gaussians are not clear, then $f_X(x)$ should be smoothed to retrieve distribution closer to noise-free distribution of luminance (figure 2b). $f_X(x)$ is smoothed by Gaussian function $G(x)=N(0,\sigma)$ derived as follow

$$g_X(x)=\int_{-\infty}^{\infty} f_X(u)\,G(x-u)\,du \qquad (2)$$

To distinguish every bunches of $g_X(x)$, the valleys (marked by red solid line in figure 2b) should be discovered by following equation

$$h(x)=\frac{d(g_X(x))}{dx} \qquad (3)$$

$$valley(x)=\{x|h(x-dx)<0\wedge h(x+dx)>0\} \qquad (4)$$

The discovered valleys divides histogram to bunches of Gaussian, with each of bunch should be stretched with different prior. In our method, we stretch luminance level by using piece-wise linear transform derived below

$$x'=f(x)=\begin{cases}\frac{y_1-a}{x_1}+a & 0\leqq x<x_1\\ \frac{y_{i+1}-y_i}{x_{i+1}-x_i}(x-x_i)+y_i & x_i\leqq x<x_{i+1},\ i=1,2,..,n-1\\ x+b-I_{\max} & x_n\leqq x\leqq I_{\max}\end{cases} \qquad (5)$$

where $x=\{x_i\}_{i=\overline{1,n}}$ is value of valleys discovered in previous step. $y=\{y_i\}_{i=\overline{1,n}}$ is transferred value depended on value of cumulative distribution function at $x=x_i$

$$G_X(x)=\int_{-\infty}^{x} g_X(x)dx \qquad (6)$$

$$y_i=\frac{x_n+b-a-I_{\max}}{G_X(x=x_n)}G_X(x=x_i)+a \qquad (7)$$

$G_X(x)$ is cumulative distribution function (c.d.f) of $g_X(x)$. (a,b) is the stretched range. For our experiment, in 8-bit RGB color we use (10,245) giving good result with eliminating too dark and too bright region of image. $I_{\max}$ is maximum value of noise-free luminance. Figure 1c and 2c are output luminance and enhanced histogram.

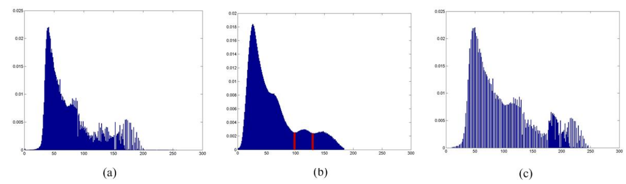

Fig 2. Histogram process: (a) histogram of 1b, (b) smoothed histogram, (c) enhanced histogram with our propose

Fig 3. Compare our propose and MDCP (a) first row: dense-haze image, (b) second row: MDCP, (c) third row: our propose

For checking the robust criteria of method, we process in set of more than hundred of dense-haze image and propose works well in all of data set. More examples are showed in figure 3 to compare MDCP and our propose.

3. Conclusion

In this paper, we propose new method to enhance luminance after dehazing by MDCP mehthod. Compare with conventional method, our propose has better performance in image contrast, computation time. Therefore, our propose is helpful for many real-time application.

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