

Contrast – Based Intelligent Image Dehazing Technique

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ABSTRACT: Images captured in weather conditions like haze, fog, mist etc are seriously distorted due to scattering of atmospheric particles. This degrades the image quality and directly influences the performance of outdoor computer vision systems. Image dehazing is a useful technique to eliminate the effect of such distortions due to haze on images. In this paper, an efficient contrast based method is proposed to improve the quality of hazy images. This method highlights the salient regions of the image prior to local contrast enhancement. The experimental results show that the method provides better results with clear details and low contrast loss.

KEYWORDS: Colour constancy, Saliency map, Morphological opening, Contrast Normalization, AHE.

I. INTRODUCTION

Outdoor images are prone to have poor image quality, particularly low contrast and lack of clarity. This is due to the scattering induced by particles in the transmission medium. The prominent sources of scattering are aerosols i.e. small particles suspended in air. These arise mainly from natural phenomena like fog, mist, volcanic eruptions and from man-made pollutions. The low quality images so generated affect the performance of various image processing algorithms. The main purpose of image dehazing is to satisfy the visual perception of the human eye and provide greater convenience for computer recognition systems.

The atmospheric scattering model proposed in [1] divides the scattering of atmospheric particles into two parts: one is the attenuation process of the reflected light and other is the scattering of airlight reaching the camera. The image captured in hazy conditions can be modelled as:

$$I(x) = J(x)t(x) + A(1 - t(x)) \quad (1)$$

where $I(x)$ and $J(x)$ denote the hazy image and haze-free image respectively, A is the atmospheric light and $t(x)$ is the reduction of radiance due to scattering. Dehazing algorithms are based on the determination of the unknowns $J(x)$ and $t(x)$. There are two types of image dehazing namely, multi-image dehazing and single image dehazing. Multi-image dehazing employs several input images taken in different atmospheric conditions in order to remove the haze. However this type of image dehazing needs more memory and processing time. Single image dehazing on the other hand uses only a single image to dehaze the image. This paper proposes an algorithm for single image dehazing.

Paper is organized as follows. Section II gives an account of the related works in literature. Section III discusses in detail the proposed image dehazing technique. Figure.1 gives the flow diagram of the proposed algorithm. Section IV evaluates the experimental results obtained with different hazy images. Finally, Section V concludes the work.

II. LITERATURE REVIEW

Image dehazing methods currently employed come under the category of either image enhancement-based methods or image restoration-based methods. Image enhancement-based methods enhance the contrast of the hazy image in order to remove haze. This includes homogenous filtering [2], histogram equalization [3,4], wavelet transformation [5], Tan's [6], Tarel and Hauteire [7] dehazing methods and others. Tan's [6] method is based on the idea that contrast on hazy image is less than haze-free image. This method dehazes image by maximization of local contrast while restricting image intensity within the atmospheric light value. However, in this approach, colour can become oversaturated in a heavily hazy image. Histogram equalization enhances the overall contrast of a hazy image by increasing the dynamic range of the gray values [3]. However the Global Histogram Equalization (GHE) may not provide optimal value for each local area. Wavelet Transform [5] employs method to enhance the high frequency regions and dehaze low frequency regions. However, this approach cannot handle over-brightness and uneven illumination issues. According to Tarel and Hauteire [7] atmospheric veil function changes gently in local region. Hence the transmission coefficient $t(x)$ of the medium can be determined by median filtering after pre-treatment of the image. Kim et al. [11] optimises contrast enhancement by maximizing the blockwise contrast, while minimizing information loss due to pixel truncation.

Image restoration-based methods are statistical approaches that use the depth information of the image for haze removal. Fattal [8], He et al. [9], Nishino [10] methods come under this category. Fattal's method [8] uses Independent Component Analysis (ICA) and the Markov Random Field (MRF) model to estimate the surface whiteness. This method is based on the assumption that object surface shading and scene transmission are regionally correlated. He et al. [9] presented a method on the statistical observation of the Dark Channel Prior (DCP), which gives a rough estimation of the transmission map. Krantz and Nishino [10] introduce a novel Bayesian probabilistic method for dehazing.

III. PROPOSED METHOD

The proposed method of dehazing is a contrast-based method which is designed to capture the image intelligence at two levels. The schematic representation of the proposed method is shown in Figure.1. The various steps in the method are colour constancy, saliency map, morphological opening, contrast equalization and adaptive histogram equalization.

A. COLOUR CONSTANCY

Colour Constancy is basically the stable representation of colour despite illumination changes. Colour Constancy algorithms do global adjustment of the intensities of the primary colours (R, G, and B). In the proposed method colour constancy is applied to remove the chromatic casts that are created by the atmospheric colours. Among various colour constancy algorithms we choose Shades - of - Gray algorithm proposed by Finlayson and Trezzi [13]. The method is based on Minkowski norm of the images. Given an image f , an illuminant (α, β, γ) is considered as the scene illuminant if it satisfies,

$$\left(\frac{\int f^n \partial x}{\int \partial x} \right)^{1/n} = k. (\alpha, \beta, \gamma) \quad (2)$$

where k is a constant. In shades of gray [13], n can take any value between 1 and ∞ . As the value of n increases, the influence of the components is directly proportional to their intensity. In our method we have chosen $n = 12$. The result had good visibility in non-hazy regions and discards colour shifting that is caused by the atmospheric colours.

B. SALIENCY MAP

Saliency map is estimated to distinguish important parts of the image. In the proposed method, morphological opening is an important step to capture the image intelligence. Saliency map of an image indicates visually important objects of the image. In this proposed method we adopt the saliency map algorithm of Achanta et al [14]. This perceptual quality measure assesses that a certain object/person stands out from the rest of the image, or from nearby regions [14]. The Saliency weight Map of an image I is defined as

$$S_w(x, y) = \|I_w - I_\mu\| \quad (3)$$

where I_w is the Gaussian blurred version of the image. It is obtained by convolving the image with 5 x 5 Gaussian filter. I_μ represents the arithmetic mean pixel value of I .

In the proposed method, saliency map is computed on the image obtained after colour constancy. Saliency is obtained per pixel by performing the Euclidean distance. The salient regions get emphasized and the high frequencies resulting from noise and other artefacts are degraded in the process.

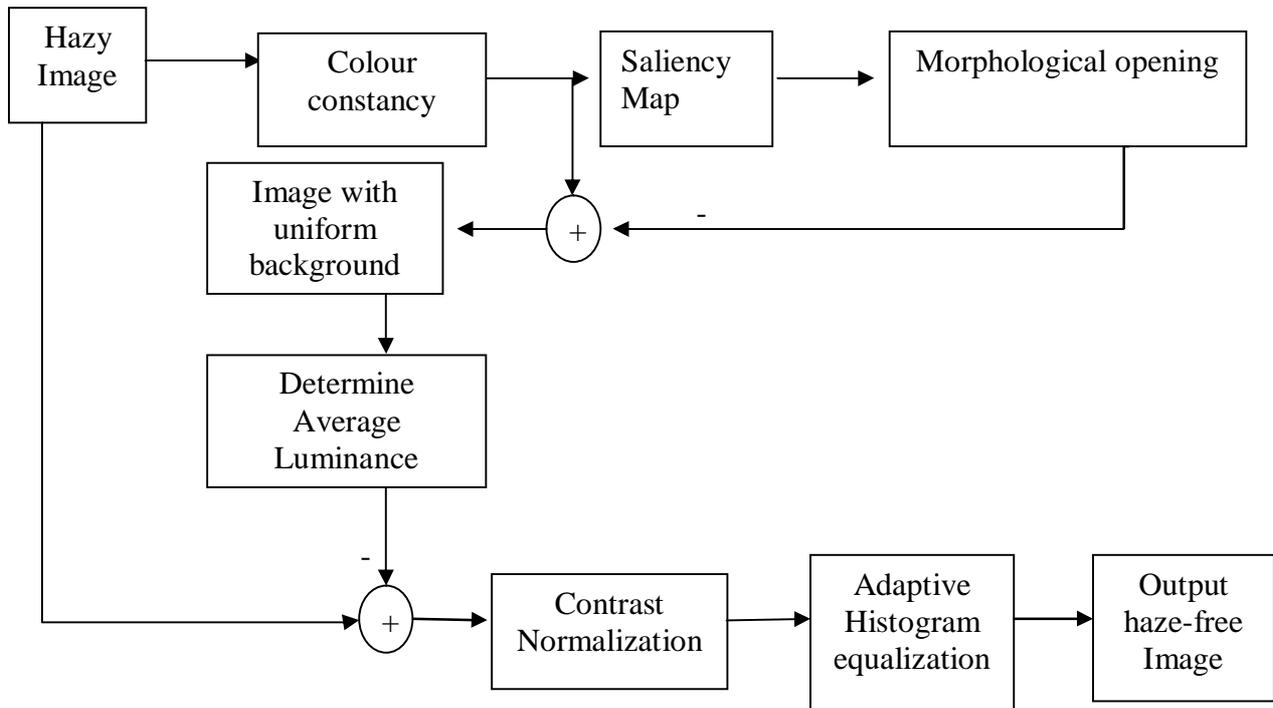


Fig. 1.Schematic representation of the proposed method

C. MORPHOLOGICAL OPENING

Morphological Opening is performed to effectively preserve the foreground images. Morphological opening is done by manipulating the image with small object called structuring element. Structuring element is equivalent to a window matrix that can have any arbitrary shape and size. Morphological opening is the process of arranging the structuring element inside the object and removes those regions that are too small for the structuring element to be located inside. In this algorithm morphological opening is performed on the saliency map $S_w(x, y)$. The resultant image is subtracted from the image obtained after colour constancy to create a more uniform background.

D. CONTRAST NORMALIZATION

In the proposed method, contrast normalization is performed to make sure that local contrast is neither exaggerated nor understated. This is the second stage of preserving the image intelligence. Contrast normalization maintains a constant local contrast throughout the image. This prevents the possibility of occurrence of artefacts in the adaptive histogram equalization process.

In this method, the image with uniform background is normalised according to the weight map. The weight map used here is Gaussian modelled distance to the average normalized range value.

$$W_c = \exp\left(-\frac{(L - I_{avg})^2}{2\sigma^2}\right) \tag{4}$$

where L is the luminance value of the uniform background image. I_{avg} is the average normalized range value of pixels and σ is the standard deviation.

E. ADAPTIVE HISTOGRAM EQUALIZATION

Histogram Equalization helps to increase the dynamic range of a given image, thereby improving clarity of the object of interest. Adaptive Histogram Equalization (AWE) is effective in enhancing the local details of an image. In AWE, the image is partitioned into blocks and then spreads out dynamic range of intensity values within the blocks individually [15]. Pizer et al [16] introduced Contrast Limited Adaptive Histogram Equalization (CLAHE) to overcome the blocking effect of AHE. In the proposed method, CLAHE is used for contrast enhancement.

As per the atmospheric scattering model proposed in [1], the light intensity of each pixel in a hazy image is due to two main factors: direct attenuation and airlight. Among them the airlight increases linearly with the distance and therefore, the luminance of these regions amplifies with the distance. In order to minimize this effect we subtract the average luminance I_{avg} from the image $I(x, y)$.

$$J'(x, y) = \gamma \left((I(x, y) - I_{avg}) \right) \tag{5}$$

γ is a factor that increases the luminance linearly. In this method, γ is chosen in correlation with the average luminance of the image. CLAHE is applied on $J'(x,y)$ to improve local contrast in the image. Similar to AWE, CLAHE also partitions the image into a number of blocks and spreads out dynamic range of intensity values within each block. The adjacent blocks are then joined by bilinear interpolation to minimise blocking effect on boundary pixels. CLAHE also minimizes probability of artefacts by restricting contrast amplification of the uniform areas.

IV. EXPERIMENTAL RESULTS

The proposed algorithm was tested on a large set of hazy images which were classics in the field and selected from well-known literature sources. The experiments were conducted with $\gamma = 2(0.5 + I_{avg})$, where I_{avg} is the average luminance of the image used for CLAHE. Figure.2 shows the result of the proposed method. The first column is the original hazy image, and the second is the haze-free image. The results show that the method can effectively remove haze and retain the fine details of the regions closer to the horizon.

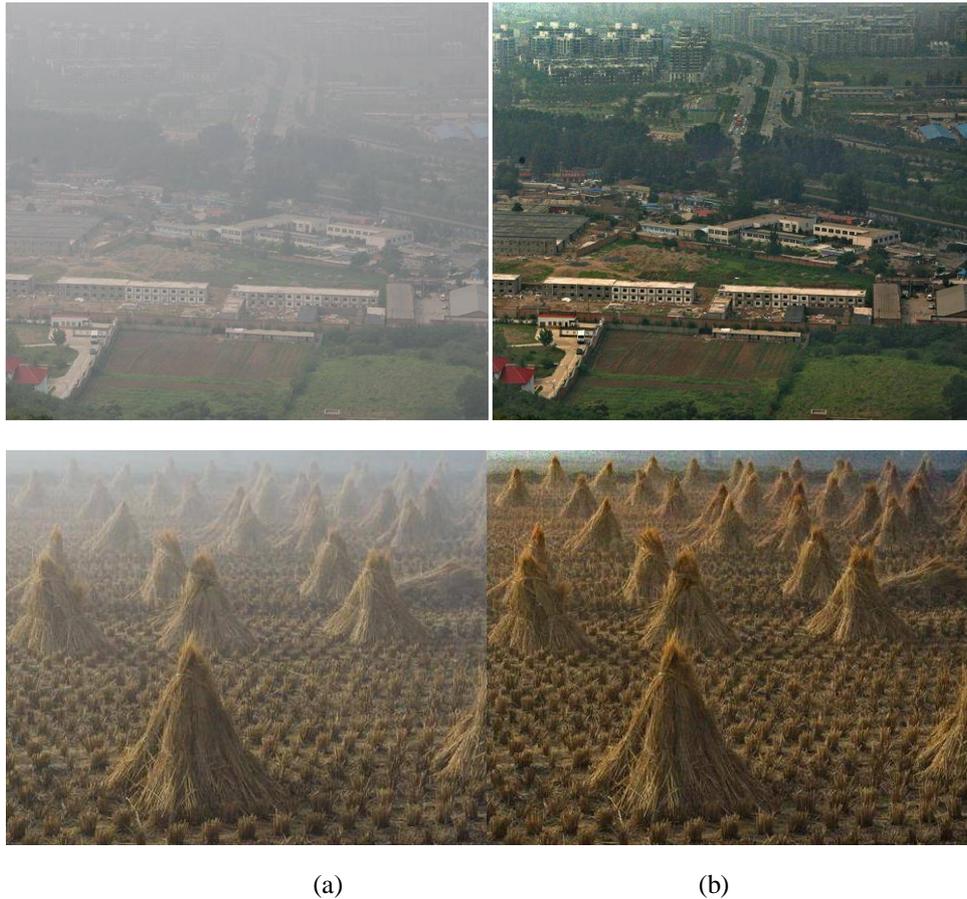


Fig. 2. Experimental results of the proposed dehazing method. (a) Hazy Image (b) Haze-free Image

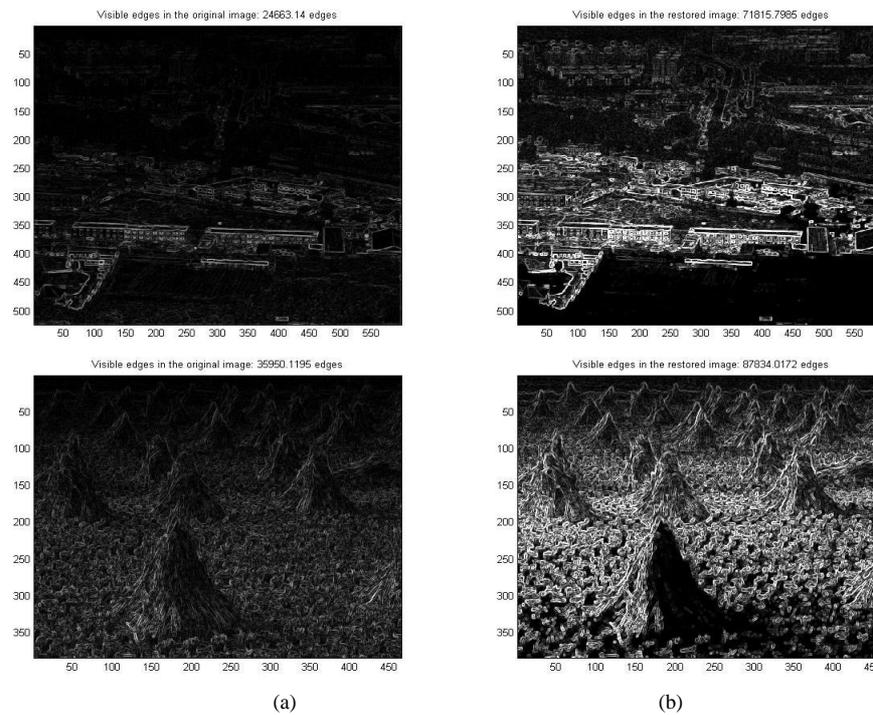


Fig. 3.Gradient Profile of. (a) Hazy Image (b) Haze-free Image

Fig.3 shows the gradient profile of the hazy image and the result after application of the proposed algorithm. In the top image in Fig. 3(a) the image has 24663 visible edges prior to processing. The resultant haze-free image has 71815 edges. In the case of bottom image in Fig. 3(a) the visible edges increases from 35950 to 87834 edges after the application of the proposed dehazing method. This proves the ability of the algorithm to capture the image intelligence features effectively.

The proposed method was also compared with the well-known dehazing methods in literature to show the advancement in results. Figure.4 shows the results of various dehazing methods such as Tan’s method [6], Fattals’s method [8] and Kim’s method [11]. Figure.4(e) shows the result of the proposed method.

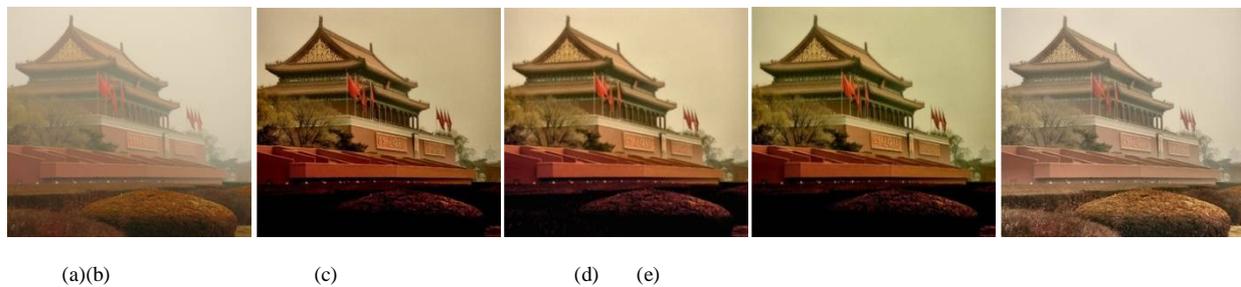


Fig. 4 The result of various dehazing methods. (a). Hazy Image (b). Tan [6] (c).Fattal [8] (d).Kim [11] (e). Proposed method

The results in Fig.4.(b) and 4.(d) have significant shift in colour tone. These methods fail to reproduce the true colour of the image. This is due to the oversaturation of colours leading to pseudo colour. The result in Fig.4(c) has loss of fine details in the dense haze regions. Our proposed method shows the best result (Fig.4 (e)) with minimal tonal shift and effective reproduction of fine details of the image.

The quantitative evaluation of the results is done using the methods specified in [17]. Three indicators e, σ, \bar{r} are used. e represents the measure of newly detectable edges, σ represents the percentage of pixels which become ultimately black or white after restoration and \bar{r} represents the mean ratio of gradients at visible edges. The best results will have high values for e and \bar{r} and low values for σ .

Table. 1. Quantitative evaluation of different dehazing methods using methods in [17].The hazy image in Fig.4 is used for evaluation

Dehazing Method	Tan[6]	Fattal[8]	Kim[11]	Proposed Method
e	0.076	0.042	0.07	0.71
\bar{r}	2.19	1.15	1.19	1.07
σ	0.01	0.023	0.01	0.003

The results in Table. 1 shows that the proposed method gives the best result for e . Thus the method preserves most of the edges. The value of σ is also small as all other methods. Also a value for \bar{r} closer to unity shows less chromatic casts in the haze-free image.

V. CONCLUSION

In this paper, we have proposed an efficient algorithm to improve the quality of hazy images. The method reproduces best the intelligence part of the image. The algorithm was tested on a considerable set of hazy images. The experimental results shows that the image retrieved have fine details enhanced with minimal tonal shift.

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