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RESEARCH ARTICLE

A Framework to accelerate Visibility Restoration of Degraded Videos through Guided Interpolated Filter

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ABSTRACT

This paper intends to recover the quality of the image degraded through climatic conditions by the use of interpolated filter. Two types of modules viz. de-accelerated haze and colour analysis were used to enhance the image. An integrated approach of these two modules provided better restoration of haze free videos. The de-hazing accuracy of the damaged video was found to be 80% more than the existing methods, thus restoring its visibility to a greater extend.

Keywords: Interpolated filter, De-accelerated haze, Colour analysis, De-haze, Visibility restoration.

1. INTRODUCTION

Visibility restoration of poor quality video is a very challenging and difficult task in computer perception application. The quality of the video gets degraded because of the existence of atmospheric impurities that absorb and disperse light between digital cameras and objects thereby causing vision failure. Poor quality is a major threat to numerous applications such as outdoor observations, object detection, intelligent transportation, etc. Hence restoration of image quality is an extremely necessary one. In general, de-hazing technique is used to remove the haze effect in the seized videos and to recover the existing colour. Many de-hazing algorithms have been developed so far.

[1] elaborated models to restore the quality of outdoor images taken at worst weather conditions. The paper suggested three procedures to recover good images, still, more advance techniques have to be developed to withstand the weather conditions. [2] discussed the development of physics based approach to estimate the scene and then restoring the original contrast of the scene from images captured during poor weather conditions by depth segmentation or scene structure. However this technique could be utilized only for monochrome images. [3] resolved a technique to eliminate the impact of haze on image by highlighting the fact that scattered light is polarized to some extent. This method can be used for image synthesis and also it provides details about the surrounding particles.

[4] revealed new methods to identify depth terminations and to estimate a scene from images captured at different climatic conditions. The technique could be adapted only for multispectral, IR, broadband RGB and grey scale cameras which adds to the disadvantage. [5] presented an indicator to assess the contrast improvement through visible edges rationing. The major hindrance of this method is that it can be utilized only to improve the contrast of the image. [6, 7] elucidated a method to boost up the quality of colour pictures by the determination of specifications from the picture itself. Enhancement of image is observed in contrast, visible range and colour fidelity. [8] analysed three simple techniques to eliminate the impact of weather in images without accurate

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information. Even though the techniques that include weather effects are presented, it is useful for repeated scenes only.

[9] introduced an automatic method based on two considerations particularly the contrast of the images and distance between the object and observer. Only one input is enough without detailed information and can be applied for all the images. [10] suggested a method to evaluate the scattering of haze scenes by one image relying on the fact that transmission and surface shading has no effect on each other. [11] utilized dark channel prior to eliminate the haze effect on the image. A haze model and soft mating technique have been combined to provide the desired results. [12, 13] presented a brief discussion about the soft mating technique and highlighted certain disadvantages such as its inability to restore colour, eliminate haze effects etc.

[14] discussed the application of median filter and adapted gamma correction to improve the transmission map. Improved transmission map and information related to colour of the image were used to remove the weather effect. [15] elucidated the use of guided joint bilateral filter in which the range kernel filter was computed using an extra guidance image. [16] utilized each pixel to compute the minimum and maximum values of the filter to obtain the dark channel. [17] explained an automatic technique to enhance the brightness of the image through gamma correction and probability distribution functions. The entire work has been carried out in three steps namely computing histogram, applying distribution function and adopting gamma correction. [18, 19] elaborated a detail summary on the application of computer vision processing and available algorithms in computer vision. [20] illustrated a new method for video de-hazing through edge interpolated filter. It was suggested that the computational efficiency and de-hazing accuracy was increased due to this technique.

The limitations of the algorithms used in the referred articles are overcome by the proposed work. This article presents a rapid and productive framework for video de-hazing depending on two modules that accelerated de-haze and colour analysis.

2. METHODOLOGY

2.1. Haze prototype

Degradation of an image or video can be mentioned as in equation (2.1) as,

$$\mathrm{I(x)} = \mathrm{J(x)t(x)} + \mathrm{A}\big(1 - \mathrm{t(x)}\big) \qquad (2.1)$$

where I(x) denotes the haze image, J(x) denotes the radiance of the scene, t(x) denotes the transmission of haze and A denotes the atmospheric light. The transmission of the haze and the scenery depth (d) can be correlated as equation (2.2).

$$\mathrm{t(x)} = \exp\left(-\int_0^{\mathrm{d}} \beta \mathrm{zd(z)}\right) \qquad (2.2)$$

in which β describes the scattering coefficient. The damage of the image due to J(x)t(x) is referred as direct attenuation that minimizes the radiance of the scene and A(1-t(x)) is referred as atmospheric veil which results in fading of the colour. The main motive of haze elimination is to recover the original radiance of the captured image.

2.2. Overall system view

The entire sketch consists of two techniques namely Accelerated De-haze (AD) and Colour Analysis (CA). The overall procedure is given below as follows:

- Convert the input hazy video into 1...n number of hazy frames.
- Acquire a small size frame I_{small} by down sampling each hazy frame I.
- Apply DE process on each small size frame I_{small} to get the enhanced map et_{small}
- Filter to refine and up sample the small size transmission et_{small} with GIF, under the guidance of I_g to get refined transmission T with same size as I_g.
- Take enhance edge by adding gradients of the hazy frame $I_{gx}.I_{gy}$ to hazy frame I by multiplying with a factor α.
- Obtain the enhanced haze free frame ET by comparing edge map in the guidance frame I_g with refined T.
- Get colour correlated information by analyzing the colour of input frame I.
- Obtain the visibility restored frame J by combining haze free frame ET and CA.
- Get the recovered haze free video by combining all haze free frames.

2.3. Accelerated De-haze (AD)

AD technique is more important for de-hazing. It consists of three processes viz. down sampling, determination of depth and up sampling.

2.3.1. Down sampling

In down sampling process, the image will be resized with less resolution than the original images by eliminating pixels from the original image. By this technique, the faded areas can be made sharp. The resulting image is thus denoted as I_{small} and it has very high quality.

2.3.2. Determination of depth

The depth of the scene or image can be computed from the following steps.

Step 1: Compute dark channel $J^{dark}(x)$ from each small size frame I_{small}.
Step 2: Estimate the atmospheric light A
Step 3: Evaluate the transmission map t^p.
Step 4: Obtain the initial atmospheric veils V, using median filter.
Step 5: Filter t^p using bilateral filter to receive reference frame.
Step 6: Filter V and take R as reference, to get corrected atmospheric veil VR with detailed edge information through GJBF.
Step 7: Compute the refined transmission t_{vr}
Step 8: Find the enhanced transmission et_{small} using adaptive gamma correction.

The depth estimation process with all the necessary equipment is displayed in figure 1.

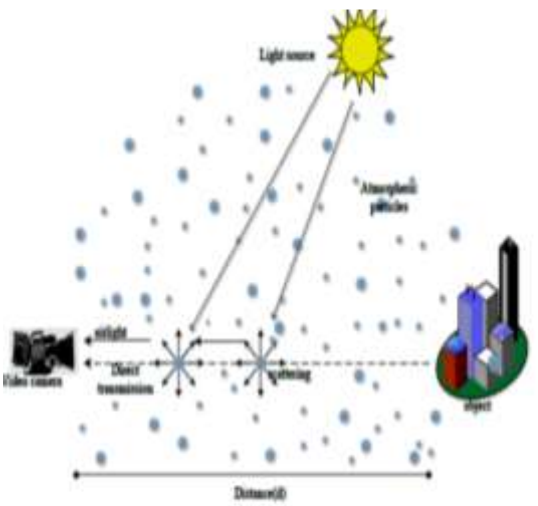

Figure 1.Estimation of depth

- **Dark Channel Prior (DCP)**

In non-sky regions, some pixels exhibit very low intensity almost to zero in one of the components of RGB. The low intensity pixels (granted by shadows and objects) are used to estimate the actual light owing to the clear visibility of air light on dark objects. The haze free frame J is denoted by the equation (2.3) as

$$J^{dark}(x) = \min_{y\in\Omega(x)}(\min_{col\in\{r,g,b\}} J^{col}(y)) \quad (2.3)$$

where $J^{(dark)}(x)$ express the dark channel of haze free frame, $\min\limits_{y\in\Omega(x)}$ express the minimum filter, $\min\limits_{col\in\{r,g,b\}}$ express the least possible value of the colour channel, $J^{(col)}(y)$ express the colour channel of image and Ω (x) express the patches centred at x. For outdoor, $\Omega(x)$ should satisfy the following criteria,

$$J^{dark}(x) \approx 0 \quad (2.4)$$

The overall process is termed as dark channel prior.

- **Atmospheric Light Estimation (ALE)**

Atmospheric light is the colour of atmosphere and the luminous value of the image is considered to be the ambient light. In haze free image, any one of the components in RGB has low intensity patches which will be useful to enhance the accuracy of the atmospheric light. The entire image is divided into small segments to estimate the atmospheric light of the image. From each segment, 0.1% brightest pixel will be chosen in the dark channel and then their average will be computed to determine the value of atmospheric light (A).

- **Transmission Map Assessment (TMA)**

The part of light that extent to the camera without losing its intensity is known as transmission. TMA can be done by DCP and Fast Fourier Transform (FFT). FFT is used to convert spatial domain of transmission map into frequency domain by adding frequencies to DCP.

- **Refined Transmission Assessment (RTA)**

Owing to DCP process, numerous block artifacts will be present through the depth discontinuities. Guided Joint Bilateral Filter (GJBF) is used to recreate the transmission map. GJBF follows both median and bilateral filter effects. Transmission map is filtered using median filter to discard the influence of contrasted texture. The mean and standard deviation can be found from the following equations.

$$B(x) = \text{median}\ \Omega(t^p) \quad (2.5)$$

$$C(x) = B(x) - \text{median}\ \Omega(|t^p - B|)(x) \quad (2.6)$$

$$V(x) = \max(\min(pC(x), t^p), 0) \quad (2.7)$$

where B(x) and V(x) denotes the mean and standard deviation of t^p. In order to control the transmission, restoration power is amplified by a scale factor, p∈[0,1]. To obtain the data about the edges in the image, bilateral filter is used, which filters the transmission map to obtain the reference image with edge information. The bilateral filter has two kernels viz. spatial filter kernel F(x, y) and range filter kernel $G(I_x, I_y)$. The former kernel indicated the spatial distance between the two pixel locations whereas the latter kernel denotes the intensity range between two pixels. The bilateral filtered image can be represented by equation (2.8) as shown below.

$$I^B(x) = \frac{1}{k}\sum_{y\in\Omega(x)} f(x-y)\,.\,g(C(x)-C(y)).\,C(y) \quad (2.8)$$

where k represents the colour difference of the image. In order to obtain the edge details, guided filter is used, in which range filter kernel is estimated using additional guidance image, containing the edge information. The resultant edge data will be identical to reference image due to the consideration of difference between two neighbouring pixels. The edge information is given by the equation (2.9) as

$$VR(x) = \frac{1}{k}\sum_{y\in\Omega(x)} f(||y||).\,g(||R(y)||).\,h(V(y)-R(y)).\,v(y) \quad (2.9)$$

where VR(x) denoted the edge information. Subsequently RTA can be obtained from equation (2.10)

$$t_{vr}(x) = t^p(x) - VR(x) \quad (2.10)$$

where t_{vr} indicates the intensity of the redefined transmission map.

- **Guided joint bilateral filter**

The bilateral filter calculates the filter response of a pixel as weighted mean of neighbouring pixel. By using guided joint bilateral filter, it is possible to maintain the border of the processed image.

$$I^B(x) = \frac{\sum_{y\in\Omega(x)} f(x-y).g(I(x)-I(y)).I(y)}{\sum_{y\in\Omega(x)} f(x-y).g(I(x)-I(y))} \quad (2.11)$$

where x and r denotes two pixels, $I^B(x)$ denotes the filtered intensity, Ω(x) denotes the patches centred at x, f and g are spatial and range filter kernels.

- **Enhanced Transmission Assessment (ETA)**

Enhancement of image is necessary due to the appearance of more haze in DCP method. Therefore gamma correction method has been used to improve the brightness as well as to preserve the brightness of the image. The enhanced transmission can be found from equations (2.12) and (2.13).

$$et_{small}(x) = (X_{max})(t_{vr}(x)/X_{max})^{\gamma} \quad (2.12)$$

$$\gamma = \begin{cases} 1 + (\frac{t}{X_{max}}) & if\, t \geq T \\ 1 & if\, t < T \end{cases} \quad (2.13)$$

where et_{small} highlights the enhanced image, X_{max} highlights the maximum intensity, t_{vr} highlights the intensity of RTA, γ highlights the changing adaptive parameter, t highlights the intensity value when cumulative density function equal to 1 and T highlights the adaptive threshold value (120).

- **Evaluation of scene radiance**

The radiance of the scene can be evaluated using equation (2.14).

$$J(x) = \frac{I(x) - A}{\max(t(x), t_0)} + A \quad (2.14)$$

where the direct attenuation reaches zero if the transmission map t(x) becomes zero. In order to minimize the noise and fog, t_0 is kept usually at 0.1.

2.3.3. Up sampling

In down sampling process, all the precise information such as edges may be lost. In the view of getting quality output, the guidance image is improved by adding gradients of the haze image by amplifying with a known factor which will be then converted into desired output as in equation (2.15).

$$I_e = I + \alpha\sqrt{I_{gx}^2 + I_{gy}^2} \quad (2.15)$$

where I_e represents the enhanced edge, I_g represents the guidance image. I_{gx} and I_{gy} represents the gradients, α represents the multiplying factor and I represents the haze image. The resultant filter used to obtain the above equation is known as edge guided interpolated filter. And also the final image from up sampling can be denoted by equation (2.16).

$$ET = I_e + T \tag{2.16}$$

where ET denotes the enhanced transmission, I_e denotes the enhanced edge and T denotes the image from up sampling.

2.4. Colour analysis

CA kit applies grey world hypothesis to evaluate the colour feature. From the resultant colour, RGB dispersion can be found out by estimating the average intensities of every colour channel. The average intensity is computed using the following formula (2.17)

$$\mathrm{Average}_{\mathrm{colour}} = \frac{\sum_{i=1}^{M} I^{\mathrm{Colour}}(i,j)}{MN} \tag{2.17}$$

where colour represents RGB, MN represents the size of the pixel, I represents the image. The colour difference of image can be estimated using the formula mentioned in equation (2.18)

$$d^{\mathrm{Colour}} = \mathrm{Average}_{\mathrm{red}} + \mathrm{Average}_{\mathrm{green}} + \mathrm{Average}_{\mathrm{blue}} - 3\mathrm{Average}_{\mathrm{Colour}} \tag{2.18}$$

in which d^{Colour} implies the colour difference and remaining terms implies the average of red, blue, green colours and the average image intensity.

The visibility restored frame after improvement is given in equation (2.19)

$$J^{\mathrm{Col}} = \frac{I^{\mathrm{Col}}(x) - \left(A^{\mathrm{Colour}} - d^{\mathrm{Colour}}\right)}{ET} + \left(A^{\mathrm{Colour}} - d^{\mathrm{Colour}}\right) \tag{2.19}$$

where ET represents the enhanced transmission. The J^{Col} denotes haze free frame and all the frames are joined together to obtain the desired haze free video.

3. RESULTS & DISCUSSIONS

The entire process takes place with the help of 3 GHz core processor PC in MATLAB environment. At first a video is captured in a haze condition. The captured video is converted into frames based on the size of the video as highlighted in figure 2. These frames are then subjected to prior processes. The process starts with the estimation of DCP via down sampling.

Figure 2.Input video frames

Almost all the regions are covered by sky regions and therefore low intensity pixel is chosen to determine the actual light by the haze frame. The input frames is segmented into numerous segments and the pixel which is highly luminous from each segment is selected to compute the atmospheric light from their average. Subsequently after this, transmission map has to be assessed. Once transmission map has been evaluated, it has to be redefined to recover the artifacts through three types of filter namely median filter, bilateral filter and guided joint bilateral filter. The filtered image is then subjected to enhancement to remove the haze effect due to dark prior method. After this the radiance of the scene has been estimated to effectively increase the quality of the image. To recover the precise details of the image up sampling is performed. Finally colour analysis has been done to further enhance the quality of the image. Subsequently all the haze free images are combined to obtain the desired video. The restored framework of the video is shown in figure 3.

Figure 3.Final quality restored images

Experiments have been conducted to estimate the effectives of median filter and the proposed filter. From figure 3, we can conclude that the proposed method is more effective than the existing filters and the obtained results are highlighted in figure 4.

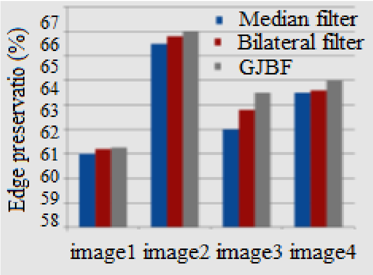

Figure 4.Comparison of existing and proposed method.

e and r metrics have also been utilized to determine the de-hazing efficiency of the captured videos. After de-hazing, the rate of newly visible edges evaluates the edge preserving capability in recovered images. The mean ratio r metric calculates the average gradient before and after visibility restoration to find the average visibility enhancement. The higher value of e and r shows superior restoration efficiency. The restoration efficiency attained through e and r metric for different environmental settings are depicted in figures 5 and 6 respectively where grey colour highlights the proposed method and other two colours represent the existing methods.

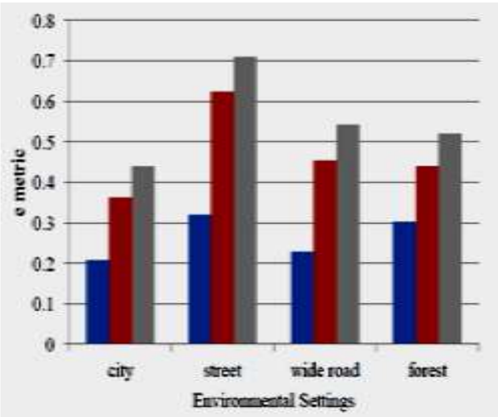

Figure 5.E-metric comparison

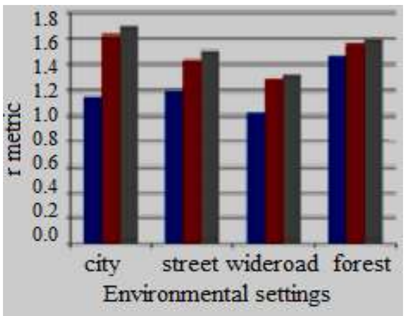

Figure 6.R-metric estimation

The measurement of the restoration efficiency produced through e and r metrics using the proposed method is higher than that of the existing methods. This is due to the fact that the proposed method can more effectively recover the degraded edge details than the other methods.

The computational time between existing methods and the proposed method is highlighted in figure 7. The proposed method is faster than the existing one as GIF improves the pace more than 20 times compared with median filter. So the processing time for images and videos for visibility restoration is far better than the existing approach. Experimental results show that, the proposed method can appreciably accelerate de-hazing speed without damaging the image and video quality.

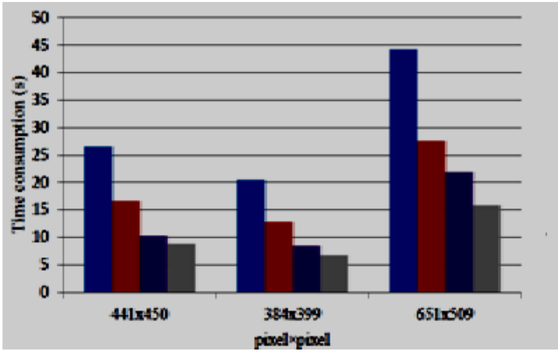

Figure 7.Comparison of computing speed

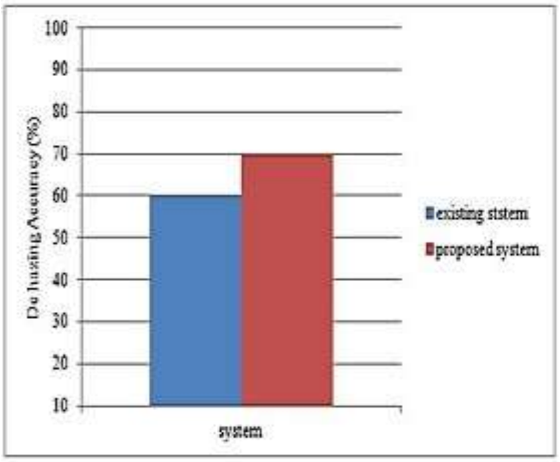

Figure 8.Comparios n of accuracy

The restoration quality of the proposed method is greatly improved by using GJBF and EGIF. GJBF enhances sharpness of the transmission map and improves computational efficiency. Subsequently, edge map in AD is utilized as guidance image in GIF to further enhance fine details in de-hazed video. The overall de-hazing accuracy is enhanced compared to existing system as shown in figure 8.

Thus an efficient algorithm has been proposed to recover the damaged video by two modules. The proposed method has better accuracy and efficiency than other existing methods.

4. CONCLUSION

An effective de-hazing technique has been used to restore the perception of video by two modules. The proposed algorithm processes faster than the existing algorithms. Yet, the time consumed for dark prior method is quite high. Future work can be focused to reduce the computation time of the dark prior process.

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