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Foggy Video Restoration Using Guided Filter

Mounika Kanala[1*], Shaik Taj Mahaboob[2],

[1,2]Department of Electronics and Communication Engineering, JNTUA College of Engineering, Pulivendula, Andhra Pradesh, India

**Corresponding Author: kanalamounika0435@gmail.com, Mob: +91-9492084074*

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Abstract- When videos are captured under the influence of atmospheric or climatic conditions, the overall quality of the image gets effected with fog and haze. This work focuses on haze removal which is also called as the visibility restoration which can infer to the various procedures employed for removing or reducing degradation from the image. Degradation in image can be due to various reasons such as miss-focus, relative atmospheric conditions and object-camera motion. This paper presents a method in which the fog in video can be removed by using dark channel method followed by Guided filtering. Guided filter has better filtering capability, fast running time and gives a clear haze free video. So, we can say that this method can be employed in real-life settings or video applications. Restoration of hazy videos is important in computer graphics, remote sensing and outdoor surveillance.

Keywords — Guided filter, dark channel method, Transmission map, Video Restoration.

I. INTRODUCTION

The images or videos that are captured in bad climatic conditions can be degraded because of having a turbid medium (for instance water particles or droplets) in the atmosphere. Haze, fog and smoke are such phenomena due to atmospheric absorption and scattering [1].Reducing fog and haze from the image improvises the image visibility and decreases the reliability upon surveillance system that are employed in outdoor conditions. So in bad weather the effect of such phenomenon needs to be removed, to recover clear haze free images or videos. Poor visibility of foggy images or videos is because of the articles that are present in the air. The light within the image or the setting is scattered in the air because of the suspended particles. When light distributes in the air it leads to airlight and attenuation, due to the incoming light in the camera, the person within the setting gets attenuated and hence the overall quality of the image or the outdoor scenery gets effected [2]. The contrast of the image decreases due to the light that scatters which is also known as attenuation and the whiteness effect within the image is referred as airlight.

Airlight increases when the distance between the camera and the object intensifies. Hence we can say that the effect of the fog exists due to the distance between object and camera and fog removal needs airlight estimation. Dehazing and fog removal is required in both computation and consumer photography and as applications related to computer vision. Firstly, dehazing can help in increasing the visibility of the image and help in correcting the colour variation which is directed from the airlight. In general, the images that are free from the interference of haze are visually impactful. Secondly, a majority of the computer vision applications whether low-level or high-level object recognition mostly assume that the image (after radiometric calibration) consists of scene radiance. The performance of the vision algorithms (for instance filtering, feature or object detection, and photometric analysis) will have a certain level of biasness and leads to low contrast levels of scene radiance. Lastly, the removal of the haze can provide information that is in-depth and can have an advantage to vision algorithms as well as in advanced editing methods. Hence we can say that in order to decrease the impact of fog and haze from the image, a much more reliable vision system is needed.

This paper proposes a technique or method that removes fog and haze in videos. Input video is divided into number of frames. Each frame is considered as a single image. Upon each frame dark channel prior and airlight are calculated. Then transmission map is estimated followed by guided filtering for better noise removal and FFT technique is used for enhancement of the image. Finally all haze free frames are combined to obtain haze free output video.

In this paper, Section I contains the introduction of related work system , Section II contain the related work of previous papers, Section III contain the methodology, Section IV contain the results and discussion, section V contains the conclusion and future scope.

II. RELATED WORK

Numerous methods have been subjected to decrease the effect of fog within a particular image [1-4], but only a few researchers focused on video. With the target of haze removal, multiple image haze removal methods are also proposed. These methods are based on multiple images captured during different weather conditions or numerous images that have different degrees of polarization. In the multiple images at different weather conditions [5],[6] haze removal methods used multiple images at different weather conditions to get a fog free image. The major limitation of these methods is availability of same scene at different weather.

In multiple images with different degree of polarization methods [7],[8] take just two images that are taken through a polarizer at different placements. Its main problem is their setting i.e, capturing two strictly aligned polarized images is trouble. To overcome the limitation of numerous images that require haze removal another approach is used which is known as single image haze removal. It is based on some assumption or knowledge. This strategy become more popular since, it requires only one image. Srinivasa G. Narasimhan and Shree K. Nayar[2] suggested a robust algorithm that can be used to restore the contrast within for. Experimentation with the images or video recordings that take place in conditions that are foggy will be discussed in this research paper. The results of the experiments are satisfactory. However the video used for this purpose is not continuous and it does not intact the foggy conditions in the video which means that the overall efficacy of the suggested method is not suitable for the video.

In [9] fog and haze in an image can be reduced by an enhanced image refinement technique. It is based on dark channel prior and airlight calculation. It gives the intensity values of pixels. Next transmission map is estimated and then cross bilateral filter is used to remove noise in image. Further contrast enhancement is performed to restore the contrast of captured image. Finally fog and haze are eliminated from the image and the image gets restored. It works better in terms of both processing time and quality. But the cross bilateral filter has some defects like noise and JPEG artifacts. There are a number of extensions for the filters that are used with these items or artefacts. Some substitute filters can include guided filter, as an effective alternative which does not have any limitations.

III. METHODOLOGY

In this section our proposed method is explained. It is know that video can divided into frames and each frame is equivalent to a single image. The number of frames depends on the size of the video .So in this proposed method input hazy video is first divided into number of frames and upon each such frame our method for haze removal is applied to obtain haze free frames. Finally by combining all these frames a haze free video is obtained. In this proposed haze removal method each frame undergoes two phases; transmission estimation and guided filtering. It is depicted as shown in fig 1:

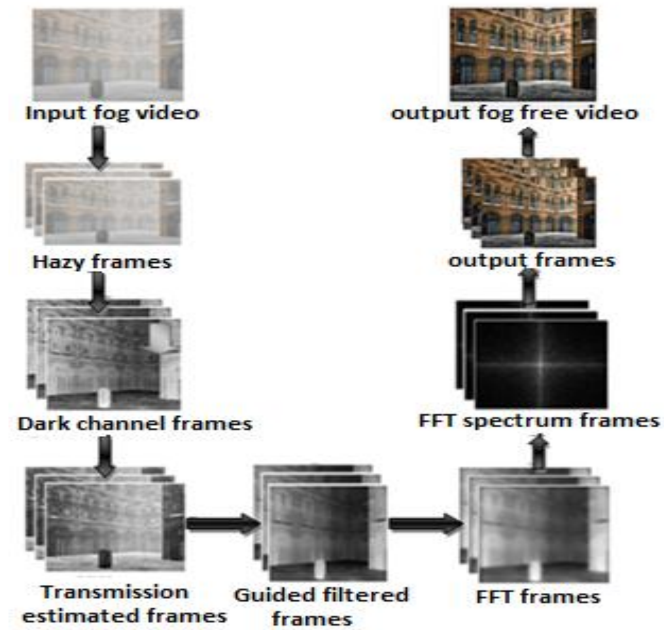


Fig 1: Framework of the proposed method

Haze image formation

A hazy image formation is shown in fig:2 . This model is utilized for the creation of the image within bad weather conditions. The quality of the image is degraded due to the presence of particles in the weather that have varying sizes that fall under 1-10 μm. The light that is coming in the camera is scattered and absorbed by these particles due to which a hazy image is created.

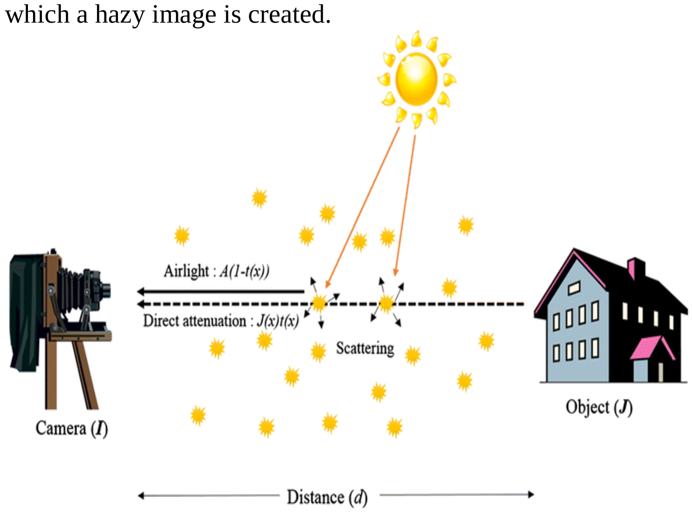


Fig2: Formation of hazy image

It can be mathematically modeled as follows [10].

$$I(x) = J(x)e^{-\beta d(x)} + A(1-e^{-\beta d(x)}) \quad (1)$$

where x denote the image coordinates, I(x) is an observed intensity, J(x) is the actual intensity that is reflected from the scene point , A denotes global atmospheric light, β is the coefficient of the scattering light in the atmosphere, and d is the scene path. Here, $e^{-\beta d(x)}$ is often characterized as the transmission map and is given by

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

In case of haze free images, we have $\beta \approx 0$ and thus $I \approx J$. But in case of hazy images β becomes non-negligible.

Dark Channel prior

In haze free image, a number of the local areas which does not cover the sky has a very low level intensity value within anyone color channel including green, blue and red. The low level intensities in the channels that are dark in nature are due to the following features or characteristics: (i) shadows, for instance. Shadows of buildings in an urban setting or shadow of leaves and rocks in landscape setting (ii) colorful items or surfaces, for instance, yellow or red leaves and flowers and (iii) dark articles or surfaces, For instance, dark stones or tree trunks. Depending upon the above observation, the pixel value at the dark channel can be approximately zero. But due to the fog factor within these dark channels have intensity values other than the zero. The dark channel of a hazy image can be calculated as follows:

$$Darkchannel(x) = \min_{c \in \{r,g,b\}}(\min_{y \in \Omega(x)} I^c(y)) \quad (3)$$

Where, I^c color hazy input image, Ω(x) is local patch centered at x.

The pixels which are having highest intensity values are considered as atmospheric light. Atmospheric light is considered as the color of the atmosphere, horizon or sky. Since the most opaque region gives the estimation of atmospheric light, region that has the high value in the dark channel is taken as the constant atmospheric light. while taking the concept of dark channel it is clear that in almost all local region which do not include sky has very low intensity value and its tends zero. Therefore dark channel of image J(x) is almost zero.

Transmission Estimation

Transmission is the part of light reaches camera without attenuation from the part of light reflected from the scene point. Since it is a fraction its value ranges between 0 and 1. The value of 0 means it's completely haze and nontransparent, 1 means no haze and completely clear, value in between 0 and 1 means semitransparent. Using the above described equations 1 and 3 and by above calculated we can easily estimate the transmission value as follows; normalize haze image equation 1 by A^c:

$$\frac{I^c(x)}{A^c} = t(x)\frac{J^c(x)}{A^c} + (1 - t(x)) \quad (4)$$

Applying dark channel method on the above equation 4, then it becomes:

$$Darkchannel(\frac{I^c(x)}{A^c}) = Darkchannel(t(x)\frac{J^c(x)}{A^c} + (1-t(x))) \quad (5)$$

By equating equation 4, on equation 5 it will give final transmission estimation as follows:

$$t(x) = 1 - \omega * Darkchannel(\frac{I^c(x)}{A^c}) \quad (6)$$

We can also introduce a constant parameter as an option w($0 < w \leq 1$) , its value depends on the application to keep a very small amount of haze because removing haze completely can make the image look unnatural.

Guided Filtering

Guided filter can be defined as form of edge preserving smoothing operator, which filters the image with the help of some other image [11]. On the above obtained haze free image J, we apply guided filter here. We are using guided filter here to get a better restored image. Let q be the output of guided filtering that is our required restored image, and I and J be the two images used for filtering. Guided filtering works on input image I under the guidance of another reference image J. Here we are taking initial hazy image I as input image that is filtered under the guidance of image J that is obtained as the haze free image in above section.

The output image can be represented as a linear transform of guidance image J as:

$$q_i = a_k J_i + b_k \quad , \forall\, i \in \omega_k \quad (7)$$

Here (a_k ,b_k) are linear coefficients presumed to be constant in window ω_k considering square window of radius r. We model the q by subtracting noise components n from I by:

$$q_i = I_i - n_i \quad (8)$$

We aim for a resolution that reduces the varaition between q and I and at the same time helps in maintaining linear model. So our need is to lessen the following cost function:

$$E(a_k,b_k)=\sum_{i\in\omega_k}(a_k J_k+b_k-I_i)^2+\in a_k^2 \qquad (9)$$

Here, ∈ is a regularization parameter avoiding large a_k .
Its solution is given by the appropriate calculation of a_k and b_k as follows:

$$a_k=\frac{\frac{1}{|\omega|}\sum_{i\in\omega_k} I_i J_i-\mu_k \overline{I}_k}{\sigma_k^2+\in} \qquad (10)$$

$$b_k=\overline{I}_k+a_k\mu_k \qquad (11)$$

Finally the filtered output is

$$q_i=\overline{a}_i J_i+\overline{b}_i \qquad (12)$$

where $\overline{a}_i$ and $\overline{b}_i$ are obtained with average filter:
$\overline{a}_i=\frac{1}{|\omega|}\sum_{k\epsilon\omega_i} a_k$,$\overline{b}_i=\frac{1}{|\omega|}\sum_{k\epsilon\omega_i} b_k$.

Fast Fourier Transform

The output image obtained after filtering is further enhanced using FFT technique. FFT is a very effectual execution of DPT and is utilized in the processing of digital images [12]. Here FFT is employed to modify an image to the frequency domain from the spatial domain. Fast Fourier Transform helps to modify the image into either its real form or even the imaginary form which is represented through the frequency domain. If the incoming signal is in the form of as image than the amount frequencies in the domain are equal in proportion to the amount of pixels within the image. The inverse transform re-transforms these frequencies in the spatial domain. The FFT and its inverse of a 2D image are given by the following equations:

$$F(x,y)=\sum_{m=0}^{M-1}\sum_{n=0}^{N-1} f(m,n)\, e^{-j2\Pi(x\frac{m}{M}+y\frac{n}{N})} \qquad (13)$$

$$f(m,n)=\frac{1}{MN}\sum_{m=0}^{M-1}\sum_{n=0}^{N-1} F(x,y)\, e^{j2\Pi(x\frac{m}{M}+y\frac{n}{N})} \qquad (14)$$

Where f(m,n) is the pixel value of the image in their spatial domain matching to the coordinates (m, n), F(x,y) is the value of the image in the frequency domain corresponding to the coordinates x and y, M and N are the dimensions of the image. Images are converted from time domain to frequency domain because employing filters to image in its frequency domain is computed inexpensively in comparison to the spatial domain. After apply the required operations in frequency domain the image is again converted to time domain. Filtering operation is performed on all the video frames and enhanced frames are obtained.
Finally, all the enhanced frames are combined and output haze free video is obtained.

IV. RESULTS AND DISCUSSION

The performance of the method that is used for enhancing the video recording has been accessed by using MATLAB software tool. The proposed method is tested on foggy videos with different environment. The performance of each frame is analysed by using the performance metrics Peak Signal to Noise Ratio, Mean Square Error, Normalized Cross Correlation and Signal to Noise Ratio.

Fig 3(a):Input and output defogged frame from fog video 1

Fig 3(b): Input and Output defogged frame from fog video 2

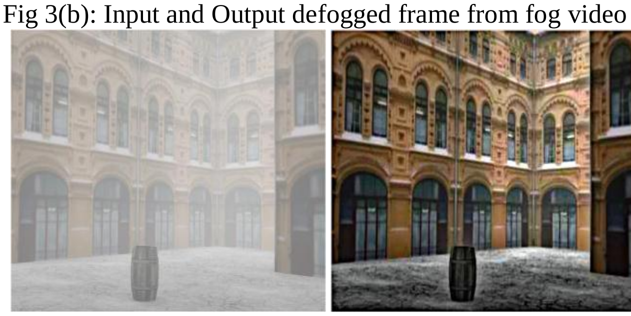


Fig 3(c): Input and Output defogged frame from fog video 3

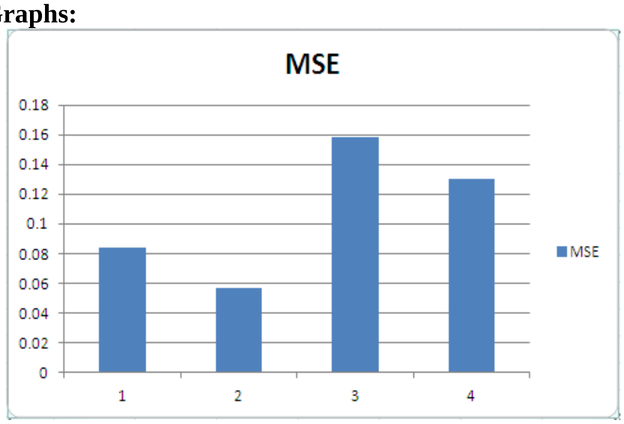
Fig 3(d): Input and Output defogged frame from fog video 4

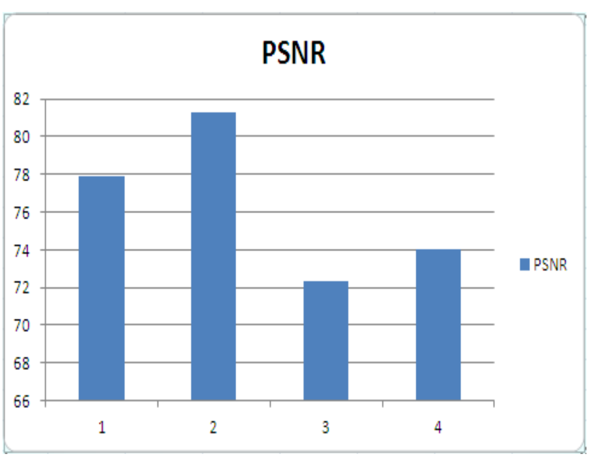
In the above fig 3(a),3(b), 3(c) and 3(d)shows the input fog frame and corresponding defogged frame from the input videos.

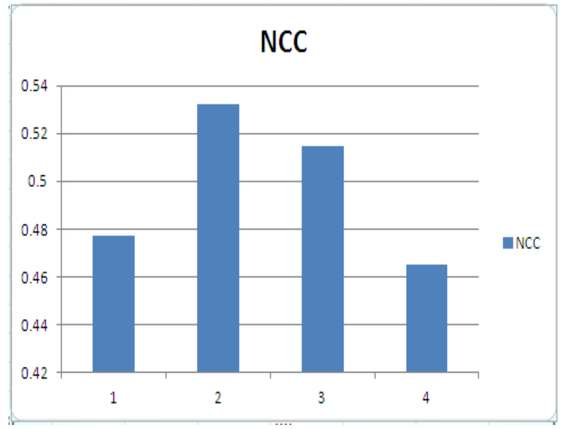
Table 1:The performance evaluation values of output videos

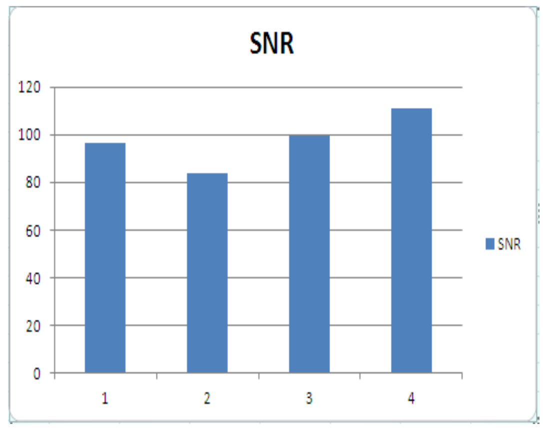
Parameters	Video 1	Video 2	Video 3	Video 4
MSE	0.0836	0.0566	0.1579	0.1298
PSNR	77.8816	81.2776	72.3618	74.0610
NCC	0.4772	0.5321	0.5144	0.4651
SNR	96.576	83.9051	99.5148	111.1526

Graphs:









V. CONCLUSION AND FUTURE SCOPE

This paper suggested a method for dehazing video. A new combination of guided filter with dark channel method is used in this work for dehazing videos from different scenes. The algorithm removes spatially varying haze based on the haze thickness estimation. As experiment is done on videos of different environment and it is obtained that proposed work is better on all the evaluation parameters of de-hazing images. The computational cost also decreased very much due to its low complexity. In Future improvements of the method will deal with possible corner, and histogram effects caused by the image processing.

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AUTHOR'S PROFILE

Kanala Mounika studied B.TECH from Narayana Engineering College, Nellore, Andhra Pradesh. And now pursuing Master of Technology in Digital Electronics and Communication Systems from JNTUA College of Engineering, Pulivendula, Andhra Pradesh.

Smt Shaik Taj Mahaboob is currently working as Assistant Professor of ECE, JNTUA College of Engineering Pulivendula, Andhra Pradesh. Her main research work focuses on Image Processing and Embedded system. She has 14 years of teaching experience and 8 years of research experience.

