

Image Defogging Based on Contrast Enhancement and Turbulence Mitigation

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Abstract— The general problem for imaging in the atmosphere is the appearance of fog and also the appearance of atmospheric turbulence in the images. Till now, they are many researchers are available to provide a recovery for either the fog or turbulence in the image. Additionally, many methods have been proposed by other researchers that address the atmospheric turbulence problem. But they did not recover both the problem at the same time. But in my project I provided an analysis that incorporates both models such as Fog removal and Turbulence mitigation. At last this contrast enhancement and turbulence mitigation algorithm is more efficient so that it can operate in fractions of second for the real-time applications while imaging.

Keywords— Single Image Defogging; Image alignment; Dehazing; Deblurring; Turbulence Mitigation; Contrast Enhancement.

I. INTRODUCTION

We begin with certain basic definitions. An image defined in the “real world” is considered to be a function of two real variables such as $a(x,y)$ with a as the amplitude (e.g. brightness) of the image at the *real* coordinate position (x,y) . In a highly developed image processing system it should be possible to apply specific image processing operations to selected regions. Thus one part of an image (region) might be processed to suppress motion blur while another part might be processed to improve color rendition.

Imaging system is often suffer in perceptuality, performance and objectively, because of atmospheric turbulence, atmospheric fog, sun-glare, camera motion from wind buffeting and many other adverse weather conditions. In case of long distance imaging systems, the most prominent are camera motion, fog, atmospheric turbulence and blur (from optics and atmosphere). The specific imaging environment we address in this article is an optical system that is observing targets of interest with the optical axis being parallel with the horizon (over-the-horizon viewing). The environment itself will have fog or haze, wind and heat that causes eddy currents which is observed as turbulence in an imaging system. Today, the medical industry, astronomy, physics, chemistry, forensics, remote sensing, manufacturing, and defense are just some of the many fields that rely upon images to store, display, and provide information about the world around us. The challenge to scientists, engineers and business people is to quickly extract valuable information from raw image data. This is the primary purpose of image

processing - converting images to information. Our main goal in this article is to develop a joint turbulence mitigation and fog removal method that can recover the object image $o(\mathbf{x})$ fast enough for near real-time performance. To accomplish this goal, we propose a method based on our analysis in turbulence mitigation that includes the fog model.

II. EXISTING APPROACH

Already in existing methods there are several approaches are available to remove fog substance and some more methods are available to remove turbulence from the image. So we can remove either turbulence or fog, but we cannot get both the result at the same time.

Atmospheric turbulence caused by variation of refractive index along the optical transmission path can strongly affect the performance of long-distance imaging systems. It produces geometric distortion, motion blur (if the exposure time is not sufficiently short), and sometimes out-of-focus blur when the turbulence is violent.

III. OBJECTIVE

A. Contrast enhancement and turbulence mitigation:

CETM is nothing but contrast enhancement and turbulence mitigation. Contrast enhancement can be done by improving the colour, brightness and enhancing the pixel size of an image. A simple method to enhance the contrast of a gray scale

images is the histogram equalization. The histogram of an digital image represents its tonal distribution. Histogram equalization effectively spreads out the most frequent intensity values, which results in a better distribution on the histogram equalization.

This allows areas of lower contrast to gain a higher contrast without affecting the global contrast. Local contrast enhancement is also useful for minimizing the effect of haze, lens flare, or the dull look created by taking a photograph through a dirty window.

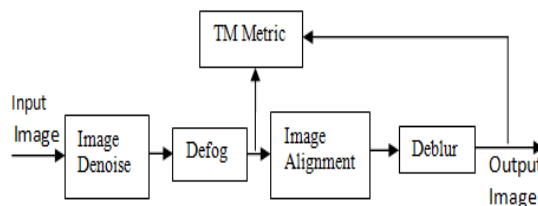


Fig.1. Proposed Block Diagram

IV. PROPOSED APPROACH

A. Proposed block diagram with description:

In the proposed method both the foggy particle and turbulence has been mitigated unlike existing system.

The block description of figure 1 is given below. The function of the image denoise is the process of removing noise from the image. Median filtering method is used here to remove the unwanted noise from the input image.

The Defogging block is used to remove fog effectively and efficiently for each frame. Adaptive wiener defogging method is used here for the defogging process.

Turbulence in the given image has been mitigated using the turbulence mitigation metric block. This turbulence problem can be caused due to bad weather or unbalanced atmospheric conditions. In this process, different Figure is matched with one another using Image Alignment block. Image alignment is the process of matching one image called template with another image. There are many applications for image alignment, such as tracking objects on video, motion analysis, and many other tasks of computer vision.

Image blurring is the old problem in image processing. To remove the blur caused by the atmosphere and image alignment errors, Image Deblur block is used. Weiner deconvolution method is used here.

V. PROJECT DESCRIPTION

A. Removal of noise from the turbulent image

Image noise is random (not present in the object imaged) variation of brightness or color information in Figure, and is usually an aspect of electronic noise. It can be produced by the sensor and circuitry of a scanner or digital camera. Image noise can also originate in film grain and in the unavoidable shot noise of an ideal photon detector. Image noise is an undesirable by-product of image capture that adds spurious and extraneous information.

It is shown that contrast enhancement does not improve the image alignment performance when image noise is present. The result in terms of error is the same if enhancement is before or after global tracking.. We therefore propose to remove noise, enhance the contrast and then estimate the global motion. In order to reduce the complexity of our algorithm such that the processing speed is near real-time, we use a two dimensional median filter for each color channel for fast single image denoising.

a. Median filter

A median filter belongs to the class of nonlinear filters unlike the mean filter. The median filter also follows the moving window principle similar to the mean filter. A 3×3 , 5×5 , or 7×7 kernel of pixels is scanned over pixel matrix of the entire image. Median filtering is done by, first sorting all the pixel values from the surrounding neighbourhood into numerical order and then replacing the pixel being considered with the middle pixel value. Note that the median value must be written to a separate array or buffer so that the results are not corrupted as the process is performed.

The median is more robust compared to the mean. Thus, a single very unrepresentative pixel in a neighbourhood will not affect the median value significantly. Since the median value must actually be the value of one of the pixels in the neighbourhood, the median filter does not create new unrealistic pixel values when the filter straddles an edge. For this reason the median filter is much better at preserving sharp edges than the mean filter.

These advantages aid median filters in denoising uniform noise as well from an image. The image processing toolbox in Matlab provides the `medfilt2()` function to do median filtering on an image. The input image and the size of the window are the parameters the function takes.



Fig.2. Input and Output of Median Filter

As mentioned earlier, the image "cameraman.tif" is corrupted with salt and pepper noise with the `imnoise()` function after loading the image using `imread()`. Figure 2 is the image corrupted with salt and pepper noise and is given to the function `medfilt2()` for median filtering. The window specified is of size 3×3 . Figure 2 is the output after median filtering. It can be observed that the edges are preserved and the quality of denoising is much better compared to the Figure 2.

B. Image Defogging

A defogger, demister, or defroster is a system to clear condensation and thaw frost from the windshield, back glass, and/or side windows of a motor vehicle. *Lets see the benefits and applications of image defogging.* To remove fog effectively and efficiently for each frame and have an estimate of transmission, we use the Locally Adaptive Wiener Defogging method. The Wiener Defogging method is 50 to 100 times faster than existing methods and can operate at real-time speeds for frames of sizes 720×480 and larger. We propose a modification to the Wiener Defog method in order to automate the defogging process. The window size must be sufficiently large to estimate a smooth transmission map that best reflects the scene depth. We present a method for automatically selecting $|\Omega|$ based on the statistics of the frames. Given a foggy color image $i \in \mathbb{R}^{\psi}$, We denote the number of color channels with ψ .

$$I(x) = t(x) \circ (x) + (1 - t(x)) a + w(x).$$

The main idea in estimating the transmission with an adaptive local Wiener filter in is that the observation model is composed of the veiling $v = (1 - t)$ and texture n_{tm} . The observation is the dark pixel measurement for each pixel is given by,

$$D(X) = \min_{c \in \mathbb{R}} i_c(X)$$

Where $I_c(x)$ is the th color channel of the image $i(x)$. (For grey Figure, $d(x) = i(x) \in \mathbb{R}$). The dark pixel measure takes advantage of the atmospheric dichromatic model by assuming at least one color component is possibly dark therefore exposing the atmospheric veiling. Thus the model at each pixel is

$$d(x) = v(x) + n_{txt}$$

Where v is $\min_{c \in R} i_c(X)$ the true veiling and n_{txt} is the textured noise. The goal in the Wiener Defog method is to filter out the texture from the observation d by treating the texture n_{txt} as noise but preserve edges from depth discontinuities. For Figure with a large amount of texture (forest floor with leaves), the size

of window must be sufficiently large to filter out the texture variations. The choice of Ω arises from the local moment estimators,

$$\hat{\mu}_v(x) = \frac{1}{|\Omega(x)|} \sum_{j \in \Omega(x)} d(x),$$

Where $|\Omega(x)|$ is the number of pixels within the local sample window positioned at pixel location x .

C. Image Alignment

We employ the adaptive correlation filter, Minimum Output Sum of Squared Error (MOSSE), to estimate the global motion parameter g . This filter is fast and efficient and works well with turbulent video because the phase correlation update averages out the zero mean phase perturbations induced by turbulence.

The local motion induced by turbulence must also be compensated in order to have a sharper image after frame averaging. We choose to enhance before optical flow in order to improve the motion estimation. Enhancing before motion compensation reduces the number of possible motion vectors for each pixel. For video coding, intra-frame coding is used more when enhancing first therefore details are preserved whereas inter-frame coding is used more when there is low contrast which results in loss of details.

D. Image Deblurring

Where deblurring is used to remove the blurriness from the image. Image deblurring can be formulated as the process of inverting image blurring. This section first introduces a model of image degradation, and then presents problem definitions of image deblurring with their basic solution strategies and associated difficulties.

E. Turbulence Mitigation Metric

A long-distance imaging system can be strongly affected by atmospheric turbulence, which randomly changes the refractive index along the optical transmission path, generating geometric distortion (motion), space and time-varying blur, and sometimes even motion blur if the exposure time is not sufficiently short. Aside from hardware-based adaptive optics approaches, several signal processing approaches have been proposed to solve this problem. These approaches attempt to restore a single high-quality image from an observed frame

sequence distorted by air turbulence. In order to illustrate that the turbulence has been mitigated in time with our proposed method, we present in this article a metric denoted as Turbulence Mitigation Metric (TMM). The goal in turbulence mitigation is to not only recover the true structure (phase) of the scene but also to enforce temporal consistency in each color channel. Instead of using a subjective measure by displaying multiple frames of a video sequence, we develop an objective measure.

Our goal in designing the TMM is to make it an objective measure of turbulence mitigation, simple to construct, and easily accessible such that it can be used in any other turbulence mitigation method. One approach to developing a TMM is to utilize the motion estimated from optical flow and global estimations. So the main goal of this approach is to recover the scene and also to get high contrast image then the original image.



Figure 4: Example for Wiener deconvolution method
 (a) Blurred image
 (b) Deblurred image

VI. PROJECT DESCRIPTION

A. Implementation

Our experiments were executed in a 64-bit machine with Intel(R) Core(TM) i5-2520M CPU @ 2.7GHz (4 processors) with 8GB of RAM (critical for large values). This software was written in Python v2.7 using OpenCV, SciPy and Numpy libraries similar to the tools used in existing methods.

B. Experiments With Simulated Data

To demonstrate the proposed method along with the TMM, Contrast Enhancement Turbulence Mitigation (CETM) algorithm method is applied to a simulated foggy and turbulent image sequence. We measured

the PSNR and TMM values with different K values and plot the results in the following figure. The minimum frames to average $K_{min} = 44$ was estimated. The TMM measure starts low and on average increases after each new image. The TMM is 0 at frame $K = 10$ because the sample size in time was set to 10. The highest TMM is with $K = 90$ and lowest with $K = 10$. What is interesting is that there is a significant improvement from 10 to 44 frames but not much improvement when the number of frames to average is almost doubled from 44 to 90. An identical survey can be made with the PSNR values in the figure. The PSNR is increased dramatically at the beginning and the performance reaches a limit at each K value. The performance of the method at each stage of the algorithm is

illustrated in Figure. The same simulated sequence is used and each measurement is with $K = 44$. The PSNR value of the contrast enhanced sequence is very low because noise is introduced after enhancement. The optical flow slightly improves the result and a dramatic improvement occurs with frame averaging. Without optical flow the frame averaging performs about 1 dB lower than with optical flow.

C. Simulation Output

The following figure is the output of fog removal for RGB colour image and also for gray scale image. This has been simulated using weiner defogging algorithm.

a. Simulation Result For Image Defogging



(a)



(b)

Fig.6. Example of Wiener Defogging method for colour image

- (a)Foggy image
- (b)Defogged image

b. Simulation result for turbulence mitigation

The below figure denotes the input and output for turbulence mitigation. Which is more effective approach for Turbulence removal by using CETM method. It can be possible for both colour image as well as gray scale images.



(a)



(b)

Figure 7: Distorted Chimney by real atmospheric turbulence

- (a) observed turbulent image
- (b) Image deblurred from (a).

c. Simulation Result Of Both Fog And Turbulence Removal



(a)



(b)

Fig.8.fog and turbulence removal from gray scale image

- (a) Input image with fog and turbulence
- (b) Defogged and turbulent mitigated image

VII. CONCLUSION

The progressed new CETM method is designed according to our analysis on image alignment in low contrast and defogging with frame averaging. We developed a contrast dependent frame averaging technique that measures the minimum possible number of frames needed to achieve a desired temporal variation. Then new turbulence mitigation metric (TMM) method has been developed that provides an objective measure for temporal consistency which is desired in turbulence mitigation. In our analysis, we have found that increasing contrast before tracking does not improve the performance when spatial noise is present. For removing turbulence it is common to average motion compensated Figure together in order remove the turbulent artifacts. And also I had discovered that removing fog before frame averaging is a better approach than removing fog after frame averaging because of the depth discontinuities in scenes. If

there are no depth discontinuities than both approaches are the same.

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