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An Overview on Defogging a Fogged Image Using Histogram Equalization

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Abstract

In this paper, reported algorithms for the removal of fog are reviewed. Fog reduces the visibility of scene and thus performance of various computer vision algorithms which use feature information. Formation of fog is the function of the depth. Estimation of depth information is under constraint problem if single image is available. Hence, removal of fog requires assumptions or prior information. Fog removal algorithms estimate the depth information with various assumptions, which are discussed in detail here. Fog removal algorithm has a wide application in tracking and navigation, consumer electronics, and entertainment industries.

Keywords

Fog removal, Image contrast, Image enhancement, Histogram Equalization, Histogram Equalization Techniques.

INTRODUCTION

Bad weather reduces atmospheric visibility. Poor visibility degrades perceptual image quality and performance of the computer vision algorithms such as surveillance, tracking and navigation [1, 4]. Thus, it is necessary to make these vision algorithms robust to weather changes. Weather condition varies mainly in the types and sizes of the particles present in the space. Bad weather conditions are broadly classified into two categories: Steady and Dynamic. In Steady bad weather, constituent droplets are very small (1-10µm) and steadily float in the air. Example: Fog, mist and haze. In Dynamic bad weather, constituent are 1000 times larger than those of the steady weather. Rain and Snow represent dynamic weather condition. While capturing a scene in the camera in a bad weather condition, the irradiance received by the camera from the scene point is attenuated along the line of sight. The incoming light flux is blended with the light from all other directions called the airlight. The amount of scattering depends on the distance of the scene points from the camera; the degradation is variant in nature. Due to this, there is a resultant decay in the color and the contrast of the captured degraded image.

Fog is a collection of water droplets or ice crystals draped in the air at or near the earth surface. Fog can form in a number of ways, depending on how the cooling that caused the condensation occurred.

1. **Radiation Fog** is formed by the cooling of landafter sunset by thermal radiation in calm conditions with clear sky.
2. **Ground Fog** is fog that obscures less than 60% ofthe sky and does not extend to the base of any overhead cloud with the absence of wind.
3. **Advection Fog** occurs when moist air passes over a cool surface by advection (wind) and is cooled.
4. **Evaporation Fog** or **Steam Fog** forms overbodies of water overlain by much colder air; this situation can also lead to steam devils forming. Lake effect fog is of this type.
5. **Ice Fog** forming in very low temperatures can bethe result of other mechanisms such as the exhalation of moist warm air by herds of animals.
6. **Upslope Fog** forms when moist air is going up theslope of a mountain or hill which condenses into fog on account of adiabatic cooling, and to a lesser extent the drop in pressure with altitude.
7. **Precipitation Fog** or **Frontal Fog** formsas precipitation falls into drier air below the cloud.

TABLE 1: Properties of Particles

	Particle Type	Visibility	Weather Condition
Fog	Water droplet	Less than 1 km	Cloudy
Mist	Water droplet	Between 1 & 2 km	Moist
Haze	Aerosol	Between 2 & 5 km	Dry

The goal of fog removal algorithms is to recover color and details of scene. Hence, removal of fog requires information of scene depth.

quantitative evaluation

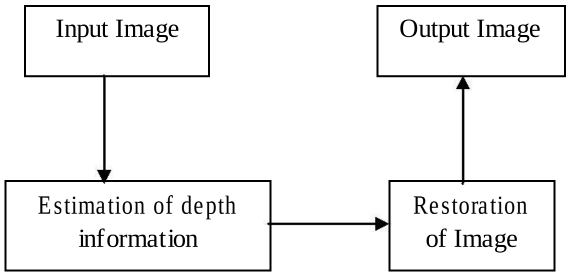

Figure 1: Framework for Fog Removal

LITERATURE REVIEW

This section covers the literature from the study of various research papers.

Y. Wang et al. [1] proposed techniques in which theimage is decomposed into two equal area sub-images based on its original probability density function. Then the two sub-images are equalized respectively. Finally, we obtain the results after the processed sub-images are composed into one image. The simulation results indicate that the algorithm can not only enhance the image information effectively but also preserve the original image luminance well enough to make it possible to be used in a video system directly.

S.D.Chen et al. [2] proposes a generalization ofBBHE which separates the input image's histogram into two based on its mean before equalizing them independently. In the proposed algorithm the separation is done recursively; separate each new histogram further based on their respective mean. It is analyzed mathematically that the output image's mean brightness will converge to the input image's mean brightness as the number of recursive mean separation increases.

I. Jafar, et al. [3] proposed a novel method for imagecontrast enhancement called Multilevel Component-Based Histogram Equalization. This method is simple and effective, and exploits the capabilities of the classical histogram equalization approach, multiple gray level thresholding, and connected component analysis to allow for both global and local contrast enhancements with minimum distortion in image appearance. Visual and revealed the capability of the new method to achieve this goal.

N.Sengee, et al. [5] proposed a new method named as"Brightness Preserving Weight Clustering Histogram Equalization" (BPWCHE) which can simultaneously preserve the brightness of the original image and enhance visualization of the original image. This method assigns each non-zero bin of the original image's histogram to a separate cluster, and computes each cluster's weight. Then, to reduce the number of clusters, they used three criteria i.e. cluster weight, weight ratio and widths of two neighboring clusters to merge pairs of neighboring clusters. The clusters acquire the same partitions as the result image histogram. Finally, transformation functions for each cluster's sub-histogram are calculated.

Robby T.Tan [6] has presented a mechanized strategythat just obliges a solitary data picture. Two perceptions are made in view of this system, first and foremost, crisp morning picture have more differentiation than pictures harassed by terrible climate; and second, airlight whose variation basically relies on upon the separation of articles to the spectator has a tendency to be smooth. This strategy builds up an expense work in the system of Markov arbitrary fields taking into account these two perceptions. The outcomes have bigger immersion qualities and may contain radiances at profundity discontinuities.

Mary Kim et al. [7] proposes a new histogramequalization method, called RSWHE (recursively separated and weighted histogram equalization), for brightness preservation and image contrast enhancement. The essential idea of RSWHE is to segment an input histogram into two or more sub-histograms recursively, to modify the sub-histograms by means of a weighting process based on a normalized power law function, and to perform histogram equalization on the weighted sub-histograms independently.

Tarel, et al. [8] has shown calculation forpreceivability reclamation from a solitary picture that is in view of a separating methodology. The calculation is in view of straight operations and needs different parameters for change. It is invaluable regarding its speed. This rate permits preceivability rebuilding to be sought constant utilizations of dehazing. They likewise proposed another channel which jelly edges and corner as a substitute to the middle channel. The restored picture may be saying great in light of the fact that there are discontinuities in the scene profundity.

Chen Hee Ooi et.al. [9]this paper proposed atechnique named as Bi-Histogram Equalization with a Plateau Level (BHEPL). In the proposed work, the input histogram is divided into two independent sub-histograms. This is done in order to maintain the mean brightness. Then, these sub-histograms are clipped based on the calculated plateau value. By doing this, excessive enhancement can be avoided.

Pei-Chen Wu et al. [10] proposes a novel histogramequalization method using the precise histogram separation along with the piecewise transformed function which is named as Weighting Mean Separated Sub-Histogram Equalization (WMSH).

Wang, et al. [11] has explored that haze removalfrom the image depend upon the unknown depth information. This algorithm is based on the atmospheric scattering physics-based model. In this model, on selected region a dark channel prior is applied to obtain a novel estimation of atmospheric light. This model is based upon some observation on haze free outdoor image. In non-sky patches, at least one color channel has very low intensity at some pixels. The low intensity in that region is due to shadows, colorful objects and dark objects etc.

Yu, et al. [12] Proposes a novel fast defoggingmethod from a single image based on the scattering model. A white balancing is used prior to the scattering model applied for visibility restoration. Then an edge-preserving smoothing approach based on weighted least squares (WLS) optimization framework to smooth the edges of image. At last inverse scene albedo is applied for recovery process. This method does not require prior information.

Fang, et al. [13] has examined another quick dimnessexpulsion calculation from different pictures in uniform awful climate conditions is proposed which based on the climate disseminating model. The essential thought is to set up an over decided framework by shaping the dim pictures and coordinating pictures taken in sunny mornings so that the transmission and worldwide airlight can be obtained. The transmission and worldwide airlight explained from mathematical statements are connected to the nearby cloudy zone. The examined calculation decreases darkness visibly and produce exact rebuilding.

Shuai, et al. [14] discussed problems regarding thedark channel prior of color distortion problem for some light white bright area in image. An algorithm to estimate the media function in the use of median filtering based on the dark channel was proposed. After making media function more accurate a wiener filtering is applied. By this fog restoration problem is converted into an optimization problem and by minimizing mean square error a clearer, finally fog free image is obtained. This algorithm can make hazed image more detailed, the contour smoother and clearer as compare to dark channel prior. This method is a recovery method, which is a combination of statistical characteristics of the function and noise. *Cheng, et al.* [15] has proposed a lowest channelprior for image fog removal. This algorithm is simplified from dark channel prior. It is based on a key fact that fog-free intensity in a color image is usually a least value of tri-chromatic channels. In dark channel prior to estimate the transmission model it performs as a minimum filter for lowest intensity. This filter leads to halo artifacts, especially in the neighborhood of edge pixels. In this algorithm instead of minimum filter they utilizes exact O(1) trilateral filter based on the raised cosines function to the weight value of neighbor to get fog-free image. The quality of the output image and the computation cost of the removal of fog procedure are improved by the trilateral filter used in this algorithm.

Xu, et al. [16] has recommended a model based onthe physical process of imaging in foggy weather. In this model a fast haze removal algorithm which is based on a fast trilateral filtering with dark colors prior is explained. Firstly, the atmospheric scattering model is used for to describe the formation of haze image. Then an estimated transmission map is formed using dark channel prior. Then it is combined with gray scale to extract the refined transmission map by using fast trilateral filter instead of soft matting. The reason why the image is dim after the use of dark channel prior is observed and a better transmission map formula is proposed to effectively restore the color and contrast of the image, leading to improvement in the visual effects of image.

Sahu, et al. [17] has proposed an algorithm of fogremoval from the color image and also useful in hue preserving contrast enhancement of color images. In this method firstly, the original image is converted from RGB to YCbCr (a way of encoding RGB information). Y′ is the luma component and CB and CR are the blue-difference and red-difference chroma components. Secondly, the intensity component of the converted image and the key observation of all the pixels of image are computed.

Matlin, et al. [18] has discussed in this paper amethod in which noise is included in the image model for haze formation. All images contain some amount of noise due to measurement error. A specific denoising algorithm known as Block matching and 3D filtering which has used a block matching and collaborative Wiener filtering scheme for removal of noise is used. After pre-processing step this algorithm is divided into two steps a haze estimation step and haze restoration step. Dark channel prior is used for haze estimation. At last image is restored in last step. In some cases when first step of denoising is not successful then a Simultaneous Denoising and Dehazing via Iterative Kernel Regression is used.

Kang, et al. [19] has proposed a single image basedrain removal frame work by properly formulating rain removal as an image decomposition problem based on MCA (Morphological Component Analysis). It is a new method which allows us to separate features contained in an image when these features present different morphological aspect. Before applying a proposed method the image is decomposed into the low and high-frequency parts using a trilateral filter. By using sparse coding and dictionary learning algorithms the high frequency part is decomposed into rain component and non-rain component. Sparse coding is a technique of finding a sparse representation for a signal with a small number of nonzero or significant coefficients corresponding to the atoms in a dictionary. The dictionary learning of the proposed method is fully automatic and self-contained where no extra training samples are required in the dictionary learning stage.

Yuk, et al. [20] has proposed a novel ForegroundDecrement Preconditioned Conjugate Gradient (FDPCG) for adaptive background defogging of surveillance videos. In this method first of all dark channels prior or soft matting is used for the estimation of map. Then, each background-defogged frame is then processed by background/foreground segmentation algorithm. The transmissions on foreground regions are recovered by the proposed fusion technique first. Then, transmission refinement by the proposed foreground incremental preconditioned conjugate gradient (FIPCG). The proposed method can effectively improve the visualization quality of videos under heavy fog and snowing weather.

Tarel, et al. [21] has recommended a model in thispaper for improving road images by introducing an extra constraint taking into account that a large part of the image can be assumed to be a planar road. Enhancement of image is based upon Koschmieder's law. This law is related to the apparent contrast of an object against a sky background, at a given distance of observation, to the inherent contrast and to the atmospheric transitivity which is assumed to be uniform.

Yeh, et al. [22] has proposed a pixel-baseddark/bright channel prior and fog density estimate method for dehazing process. Firstly estimation of atmospheric light is done to observe the effect of light. Then transmission map is used for estimation. Here two methods are used. A pixel-based dark/bright channel prior is used first. After that fog density estimation method is used to estimate fog for removal process. Then trilateral filter is used for refining the transmission map.

Tripathi, et al. [23] has studied that fog formation isdue to airlight and attenuation. Airlight increases the whiteness and attenuation increases the contrast in the scene. So a method is proposed which use trilateral filter to recover scene contrast and for the estimation of light. The proposed algorithm does not depend upon the density of fog and does not require user interference. It can handle both color and gray images. Histogram stretching is used as post processing for increasing the contrast of fog removed image. In this generated airlight map does not affect the edges and perform smoothing over the object region. As the algorithm is independent of density of fog present in image so it also performs better for image taken in heavy fog so, it can be widely used as a pre-processing step for various computer vision algorithms which use feature information such as object detection, recognition, tracking and segmentation.

Ullah et al. [24] has proposed a singular picturedehazing procedure utilizing enhanced dull channel. The dim channel former has been further cleaned. The chromatic colorless components of the picture are considered by the proposed model to depict the Dark Channel. Enhanced Dark Channel takes least of immersion and power segments rather than RGB parts. Refined Dark channel expands estimation of restored cloudiness free pictures. It keeps up shading dependability and enhances the difference.

Seiichi Serikawaand Lu [25] has discussed thatunderwater vision has become important issue in ocean engineering. Capturing images underwater has complicated, frequently due to attenuation that is caused by light that is reflected from a surface and is deflected and spreaded by particles, and as simulation significantly decreases the light energy. There have been many methods to renovate and improve the underwater images.

IMAGE ENHANCEMENT TECHNIQUE

Histogram Equalization

Histogram Equalization (HE) is one of the wellknown image enhancement technique. HE is contrast enhancement technique which adjusts pixels intensities in order to obtain new enhanced image with usually increased local contrast. The basic idea of HE is to re-map the gray levels of an image. Histograms can also be taken of color images either individual histogram of red, green and blue channel or a 3-D histogram can be produced with three axes representing red, blue and green.

$P_r(r_k) = n_k/N$; $0 \le r_k \le 1$; $k = 0,1,2\ldots L-1$

Where r_k represent normalized intensity value, L is number of gray levels in the image, n_k is number of pixels with gray level r_k, N is total number of pixels and r represent the gray level of image to be enhanced.

HE is divided into different types:

1. Adaptive Histogram Equalization
2. Contrast Limited Adaptive Histogram Equalization
3. Brightness Preserving Bi Histogram Equalization
4. Dynamic Histogram Equalization
5. Minimum Means Brightness Error Bi-Histogram Equalization
6. Dual Sub Image Histogram Equalization

Adaptive Histogram Equalization (AHE): AHE isa modified part of Histogram Equalization Method. In this method, enhancement processes are applied over a specific region of any image and adjust contrast according to their neighbor pixels. In this method, Pixels near the image boundary have to be treated especially because their neighborhood would not lie completely within the image. Hence, we extend the image by mirroring pixel lines and columns with respect to the image boundary. This method is used for images with non-uniform lighting.

Fig 2: a) Original Image b) Processed Image

Contrast Limited Adaptive Histogram Equalization (CLAHE):

CLAHE is a modified version of AHE. In this method, enhancement function is applied over all neighborhood pixels and transformation function is derived. This method does need any predicted weather information for the processing of foggy image. In this method, the captured image is converted from RGB color space to HSV color space because the human sense colors similarly as HSV represents colors. Steps of CLAHE method:

Step 1: The original image should be divided into sub-image which is continuous and non-overlapping. The size of each sub-image is M× N.

Step 2: The histogram of the sub- images are calculated.

Step 3: The histogram of the sub-images exceeds the value is clipped.

The number of remainder pixels in the sub-image is uniformly distributed to each gray level. Then the average number of pixels in each gray level is given as

$$N_{avg} = N_{SI-XP} * N_{SI-YP} / N_{graylevel}$$

Where N_{avg} represents the average number of pixels, $N_{graylevel}$ is the number of the gray levels in the sub-picture, N_{SI-XP} is the number of pixels in the X dimension of the sub-image and N_{SI-YP} is the number of pixels in the Y dimension of the sub-image.

$$N_{CL} = N_{clip} \times N_{avg}$$

Where N_{CL} is actual clip-limit and N_{clip} is the maximum multiple of average pixels in each gray level of contextual region. If the number of pixels is greater than N_{clip}, then the pixels will be clipped.

Brightness preserving Bi- Histogram equalization (BBHE):

BBHE is method which divides the image histogram into two sub images and histogram equalization is applied separately over two sub-images. In this method, the separation intensity is represented by the input mean brightness value, which is the average intensity of all pixels that construct the input image. After this separation process, these two histograms are independently equalized. So the mean brightness of the resultant image will lie between the input mean and the middle gray level. After this method is applied the output image which preserving mean brightness then normal histogram is used to get naturally improved enhancement image that can be utilized for electronic products.

Dualistic Sub-Image Histogram Equalization (DSIHE):

DSIHE follow the same basic ideas used by the BBHE method of decomposing the original image into sub-images and then equalizes the histograms of the sub-images separately. But the difference lie image decomposition criteria, In DSIHE image is decomposed aiming at the maximization of the

Shannon’s entropy of the output image. For doing this, the input image is decomposed into two sub-images, being one dark and one bright, respecting the equal area property (i.e., the sub-images has the same amount of pixels).The brightness of the output image O produced by DSIHE method is the average of the equal area level of the image I and the middle gray level of the image i.e., L/2.

Dynamic Histogram Equalization (DHE): TheDynamic Histogram Equalization (DHE) technique takes control over the effect of traditional Histogram Equalization so that it performs the enhancement of an image without making any loss of details in it. DHE divides the input histogram into number of sub-histograms until it ensures that no dominating portion is present in any of the newly created sub-histograms. Then a dynamic gray level (GL) range is allocated for each sub-histogram to

which its gray levels can be

mapped by Histogram Equalization. This is done by distributing total available dynamic range of gray levels among the sub-histograms based on their dynamic range in input image and cumulative distribution (CDF) of histogram values. This allotment of stretching range of contrast prevents small features of the input image from being dominated and washed out, and ensures a moderate contrast enhancement of each portion of the whole image. At last, for each sub-histogram a separate transformation function is calculated based on the traditional Histogram Equalization method and gray levels of input image are mapped to the output image accordingly. The whole technique can be divided in three parts partitioning the histogram, allocating GL ranges for each sub histogram and applying Histogram Equalization on each of them.

Minimum Mean Brightness Error Bi-Histogram Equalization (MMBEBHE):

MMBEBHE follow the same basic idea used by DSIHE and BBHE method of decomposing the original image into sub-images and then equalizes the histograms of the sub-images separately. The difference lies between image decomposition i.e., on the basis of threshold level. The Input Image I is decomposed into two sub-images $I[0,I_t]$ and $I[I_{t+1}, L-1]$ such that the minimum brightness difference between the input image and the output image is achieved.

PERFORMANCE METRICS

Removal of fog is analyzed qualitatively, but for research work, it is required to quantitatively measure the performance of the algorithm. A fog-removed image has more contrast in comparison with the foggy image. Hence, contrast gain can be a good metric for the quantitative analysis of fog removal algorithms. Contrast gain for all fog removal algorithms should be positive. High contrast gain indicates better performance of the algorithm. Contrast gain can be described as [26,27] mean contrast difference between de-foggy and foggy image. If C_{Idef} and C_{Ifog} are mean contrast of de-foggy and foggy image respectively, then contrast gain is defined as

$$C_{gain} = C_{Idef} - C_{Ifog}$$

Contrast gain should not be so high that the pixels of output image become saturated. Hence, along with the high contrast gain, it is also required to measure the number of saturated pixels. Percentage of the saturated pixels [28] σ is denoted as

$$\sigma = m/(M \times N) \times 100$$

Where *m* is the number of pixels which are saturated (either completely white or black) after the restoration but were not before. Low value of σ indicates better performance of the algorithm.

TABLE 2: Comparison of different Defogging Techniques

Technique	Advantage	Disadvantage	Application
Histogram Equalization	Straight forward technique. An invertible operator.	Indiscriminate. It may increase the contrast of background noise, while decreasing the usable signal.	This method usually increases the global contrast of many images, especially when the usable data of the image is represented by close contrast values
Adaptive Histogram Equalization	Equalization is computed piece-wise	Size of window affects the result. Over amplification of noise.	Used for images with non-uniform lighting
Contrast Limited Adaptive Histogram Equalization	Solve Over Amplification of noise problem. Increase contrast.	Computationally Expensive Complex and Time Consuming	Used to enhancement of low contrast image
Brightness Preserving Bi-Histogram Equalization	Preserve Mean Brightness of Image and thus provide natural enhancement	High Degree of Preservation is not handled.	Used to preserve the mean brightness of a given image while enhancing the contrast of a given images.
Dynamic Histogram Equalization	Image is enhanced without making any loss of details. It prevents over or under enhancements of any portion of the image. There will be no blocking effect in the image.	Require Complicated Hardware Implementation. Complex and Expensive	Used in real time systems.
Dualistic Sub Image Histogram Equalization	Preserve Brightness of using median	Time Consuming	Used for Video System
Minimum Means Brightness Error Bi Histogram Equalization	Brightness preservation, removed noise, better enhancement, better background color preservation	Low contrast edges are difficult to observe.	Used for Real-Time Application

CONCLUSION AND FUTURE SCOPE

In this paper, evolution of algorithms for removal of fog from images has been reviewed. Framework and challenges for the removal of fog have been presented. Merits and Demerits of existing algorithms are discussed, which motivate for the future research. Removal of fog from single image is always an under constraint problem due to the absence of depth information. Hence, single image fog removal requires an assumption and prior. It is necessary that during restoration of foggy image, both the luminance and chrominance should be recovered well to maintain the color fidelity and appearance. Hence, future research will focus on better estimation of depth information and restoration with better visual quality. A fast and accurate estimation of depth information increases the speed and perceptual image quality. A fog removal algorithm has wide application in tracking and navigation, entertainment industries and consumer electronics.

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