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A Review: Contrast Enhancement Methods

Namrata Khaparde[1], Dr. S.S. Agrawal[2]

ME Student, Signal Processing (E&TC), SKNCOE, Pune, India[1]

Assistant Professor, E&TC, SKNCOE, Pune, India[2]

Abstract: Information extracted from the images used in modern image processing application is crucial for processing and for post processing decisions. Hence it is important for the information to be true. Images captured under bad weather conditions tend to lose information regarding the color and contrast. A lot of work has been carried out for clearance of unwanted optical factors from images under adverse weather in terms of its color. This work is aimed at studying the effect of fog on the contrast of the images captured in fog conditions. The aim is to study different methods for the restoration of contrast in images. It gives a better understanding of these methods for appropriate use.

Keywords: Image Processing, Fog, Air light, Contrast Enhancement.

I. INTRODUCTION

As technology advances, image processing is extensively used in many applications in day to day life. It has importance in navigation, traffic surveillance, weather forecast, satellite image restoration, driving assistance systems and related fields. Thus, it is important for the acquired image to convey the correct information.

The outdoor images taken under adverse weather conditions tend to be degraded making them unsuitable for use in applications. Adverse weather conditions include fog, mist, heavy rain, snow, glare due to sun rays or reflection etc. Images captured under the bad environment have degraded quality and fail to convey true information of the scene. Fog is a phenomenon produced due to suspended water droplets in air. Fog degrades the images by producing the optical scattering. Optical scattering is referred to as “air light”.

It is produced due to the additional scattering of light at the places where light is not originally present. Air light within an image is approximately constant when the distance between the camera position and the points of image captured by the camera is constant. Air light reduces the visual quality of the outdoor images captured under fog conditions by affecting the contrast in the images and altering the colors of original scene. Contrast restoration is an important aspect for the restoration of original images for which the algorithms are developed in very recent past.

In the following section the basic methods for fog removal and correction is presented. The discussion for methods for contrast restoration is also presented. Two of the cases for modelling methods employing depth information and not employing depth information are discussed for better understanding. Finally, a conclusion is drawn.

II LITERATURE SURVEY

Many algorithms have been proposed for the classification of fog and correction of colors as well as removal of blur due to fog. In this section the related work based on the effect of fog, that is air light and degradation of contrast in images captured under fog conditions is presented.

A. Fog Removal

Present fog removal techniques broadly classified follows:

1. Fog Removal
2. Fog Correction

1. Fog Removal

Fog removal processes are based on the level of fog on the image. In the process the overall level of the fog in entire image is found out. Next, a procedure to remove the fog is decided and hence an improved image without fog is generated. Air light, transmission map, depth map or some time depth information estimated from scene properties are the aspects used to measure the depth information for the input image. A three dimensional scene is converted into two dimensional in the form of image in image acquisition using camera. Hence it is important to consider the depth of the scene in an image. Basic fog removal technique is shown in Figure 1.

2. Fog Correction

Fog Correction Techniques follow the principle of correction of contrast in the fog degraded images. First step is to acquire the input image and convert it into the HSV color space. Next, color correction is applied over the obtained HSV color space. The result of color correction is a transmission map. Estimation of the air light is done using the transmission map. The procedure is shown in Figure 2.

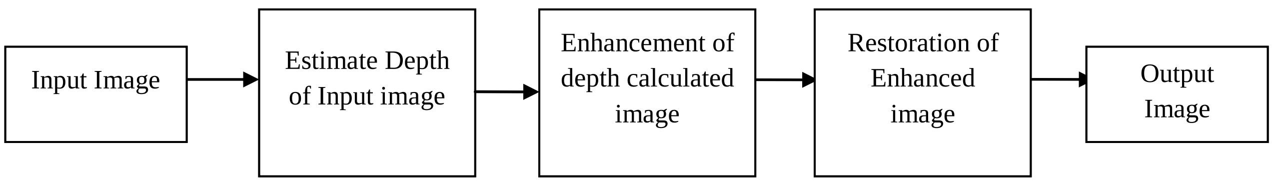

Figure 1: Fog Removal Technique

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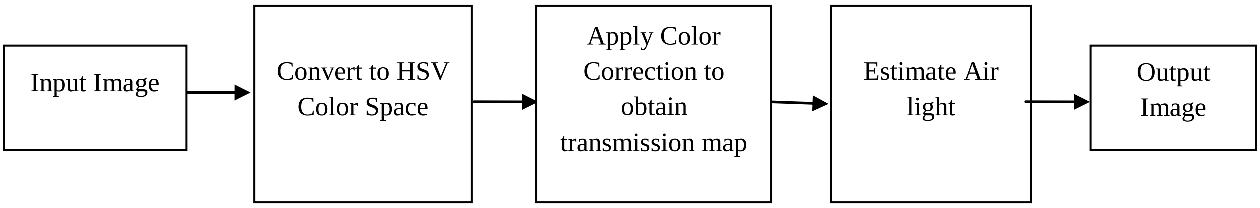

Figure 2: Fog Correction Technique

B. Contrast Enhancement

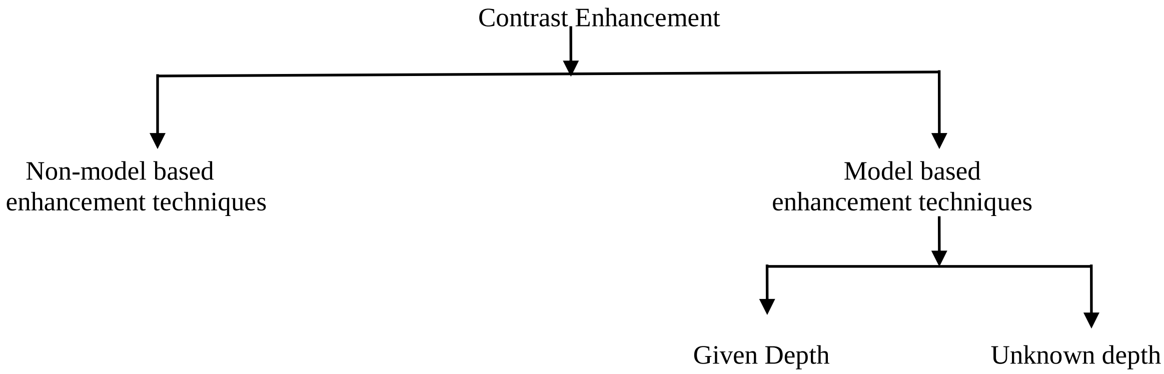

Figure 3: Classification of the contrast enhancement techniques

Contrast is an important part for portraying the visual quality and details in an image. The methods for contrast enhancement are broadly classified as shown in the figure 3. Two broad categories of the contrast enhancement technique are modeling methods and non modeling methods. The two methods chosen for discussion are the modeling methods. Modeling methods are further classified as methods with known depth and methods with unknown depth.

C. Non-model based Contrast Enhancement Method

Non-model based techniques for contrast enhancement do not use any specific model for solving the problem of contrast enhancement. In this method no extra information from the user is needed. In non-model based methods only information from inside the image is used.

Histogram equalization, unsharp masking and retinex theory are the most common methods under the non-model based methods. Histogram equalization method is the most used and accepted method. Variations have been done in this method to get better results. Some of the Histogram equalization methods are discussed below.

1. Histogram Equalization

Histogram equalization refers the distribution of intensity evenly across the image. It improves the contrast globally. Let the gray scale input image be x , with the number of occurrences of gray level I being n_i. A probability function of occurrence of a pixel of level I in the image x is defined as:

$$p_x(i) = p(x = i) = \frac{n_i}{n} \quad 0 \leq i \leq 1 \qquad (1)$$

Stark, J.A. in [1] separately adjusted intensity values for background and foreground objects using Histogram equalization method. The two images are then fused into one to make a better contrast image.

2. Adaptive Histogram Equalization

A modification of Histogram Equalization method is Adaptive Histogram Equalization method. Contrast of a specific region of the image is adjusted according to their neighbour pixels. Inhye Yoon [2] proposed method for homogeneous fog correction. Enhancement of HSV color space is done using Adaptive Histogram Equalization. Gyu-Hee Park, HwaHyun Cho [3] divided histogram into some predefined parts. Next, intensity of every part is adjusted to distribute it uniformly in the gray scale image. This method is called Dynamic range separation Histogram equalization (DRS HE) method for enhancement.

3. Contrast Limited Adaptive Histogram Equalization

A modification of Adaptive Histogram Equalization method is Contrast Limited Adaptive Histogram equalization method. This method is applied over all the pixels in the image. Zhiyuan Xu, Xiaoming Liu, Xiaonan Chen [4] used Contrast Limited Adaptive Histogram Equalization method on gray as well as color images. The method is separately applied on the background and the foreground objects. A maximum clip value is used and the intensity is redistributing in the gray scale image. The method enhances contrast and limits noise.

4. Brightness Preserving Bi Histogram Equalization

Some electronic products need to protect the brightness and colors in the image. After the Histogram Equalization process, brightness and natural colors of the restored image is affected. To overcome this issue Brightness Preserving Bi Histogram Equalization method is used. Yeong-Taeg

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Kim [5] divided input image in two parts. Each sub image was processed individually using Histogram Equalization method. The output image so obtained preserves the mean brightness of the image. Naturally improved enhancement image is then obtained by applying normal histogram. The resultant image can be used for electronic products.

5. Quantized Bi Histogram Equalization
For consumer electronics it is necessary to preserve mean brightness of original image. Whereas, Brightness Preserving Bi Histogram Equalization method alters the mean brightness of original image. Quantized Bi Histogram Equalization overcomes this drawback by calculating the cumulative density function of a quantized image. Yeong-Taeg Kim [6] applied Quantized Bi Histogram Equalization on an algorithm for simple hardware structure and the resultanat image is enhanced preserving the mean average of original image.

6. Recursive Mean Separate Histogram Equalization
In this method the input image is recursively separated based on its mean. Then histogram equalization is independently perforamed on each of them. It is an improved version of Brightness Preserving Bi Histogram Equalization method that preserves brightness better and achieves better scalable brightness as compared to the latter.

7. Weighting Mean Separated Sub Histogram Equalization
In the process of preserving contrast of the image, the Histogram Equalization method effects the visual property of the image. To overcome this issue Weighting Mean Separated Sub Histogram Equalization is used. Pei-Chen Wu; Fan-Chieh Cheng [7] produced enhanced output images preserving its visual quality. Piecewise transformed function is used along with precise histogram equalization.

8. Brightness Preserving Dynamic Histogram Equalization
Histogram Equalization poses the problem of maintaining the mean brightness of an image. Ibrahim, H.; Kong, N. S.P., [8] produced the output value with mean intensity which is equal to the input image mean intensity which thereby overcoming this issue. The input image histogram is smoothed. Smooth histogram is then partitioned based on its local maximums. A new dynamic range is found. Normalization process of output image to the input mean brightness is done. Output is the enhanced input image.

D. Model based Contrast Enhancement Method
Model based contrast enhancement techniques are based on a physical model. A real world problem is converted into a mathematical model. It is then analysed and solution to the problem is formed. These methods require extra information from the user. Physical world problem is formulated in the understandable form using languages. Next, a mathematical model is created which represents the real world problem. It makes the analysis and understanding of the problem easier because mathematical modelling converts the real world problem in a measurable form using parameters. It helps to understand the extent and characteristics of the problem at hand. Model based methods are classified as:

1. Given Depth
2. Unknown Depth

1. Given Depth
The systems incorporating this algorithm have the depth as input from the user. In the scenario where depth information is known, this information can be used to restore the original contrast of the image.
Different haze removal approaches were studied by authors in [9]–[10]. The study is based on given depth information. The altitude, tilt and position of the camera is considered for inferring depth [9]. Also the manual approximation of the sky area is done and vanishing point is calculated of the captured image [11]. Another method to infer depth is by approximating the geometrical model of the analyzed image scene [10].These methods of calculating depth can be erroneous because the methods have to rely on the user input for estimation. If the approximation is not correct then the depth estimation will fail. Hence these methods are unreliable and not feasible for use in the real time applications.

2. Unknown Depth
Systems using this algorithm form a mathematical model and calculate the depth information available in the captured image in real time.
The authors in [12], [13]–[15] present methods for restoring contrast without depth information. Image enhancement is performed on a single image captured in adverse weather condition via a mathematical model. Oakley and Bu [12] found the Air light by making assumption for approximately constant distance between the camera and the points in the scene. It makes the Air light to be uniform on the whole image. Estimation of Air light is done by minimization of a cost function found out for the whole image. This approach is only suitable for simple contrast loss correction of broadcast images. It fails in scenes where the distance from camera position to the scene points varies.
The method proposed by Tan in [13] estimated Air light by using a cost function in Markov Random Fields setting This method restores the contrast of the original image but produces halos where depth discontinuities are present in the image.

Contrast Restoration with Depth Information
Contrast restoration for In-vehicle Vision System proposed by Nicolas Hautière et.al [11] for contrast restoration in in-vehicle vision system which takes the user input in the form of sky intensity and approximate value of the vanishing point.

A depth heuristic for the points of road surface is found and a depth heuristic for the points above the road surface is found. The two depth heuristics are combined for finding a depth heuristic for the system.
It carries out the following steps:

1. The user selects a region of the sky to obtain the sky intensity A_∞ and inputs the approximate location of the

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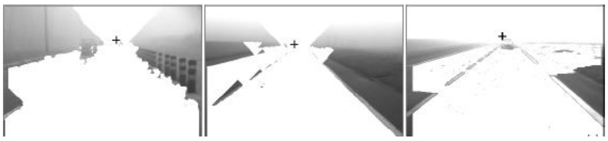
vanishing point of the image along the direction of increasing distances in the image.
2. The sky region is assumed to be the region of the image above the horizon line where intensity is higher than the intensity taken at the horizon line.
3. The coordinate system is given in Figure 4. The horizontal location of the vanishing point u_h is approximated by the centre of the area obtained by the region growing on the horizon line. The horizon line is depicted by v_h.

Figure 4: Coordinate system considered in the system

4. The black cross in indicates vanishing point in Figure 5. Partial segmentation is performed on the road and the sky. Resultant is painted white.



(a) (b) (c)

Figure 5: Estimation of vanishing point

5. First heuristic:
A depth heuristic is used in conjunction with the flat world assumption. This heuristic can be used to model vertical objects like building in urban streets.
Flat world assumption which associates a distance d with each line v of the image is used for points belonging to the road surface. Big distances are clipped using parameter c to reduce the modelling errors (in particular, flat world and non flat world are mixed near the horizon line:

$$d_1 = \begin{cases} \frac{\lambda}{v - v_h} & \text{if} v - v_h > c \\ \frac{\lambda}{c - v_h} & \text{if } 0 < v - v_h \leq c \end{cases} \quad (2)$$

6. Second heuristic:
Then, a depth heuristic is issued from to model the depth of points not belonging to the road surface. This is better to model cylindrical scenes like rural roads.

$$d_2 = \frac{k}{u - u_h} \quad \text{Or}$$

$$d_2 = \frac{k}{\sqrt{(u-u_h)^2 + (v-v_h)^2}} \quad (3)$$

7. The final depth d of a pixel (u,v) which does not belong to the sky region is finally:

$$d = \min(d_1, d_2) \quad (4)$$

8. Since for finding the depth heuristics flat world assumption is used, it is important to select a value of k. This value of k keeps balance between the flat worlds against the vertical surroundings. Figure 6 shows the depth modelling for the test images of Figure 5. In Figure 6(a) a cylindrical scene assumes a small value of k. In Figure 6(b) a cylindrical scene assumes a bigger value of k. Hence a larger surface of road and sky is visible. In Figure 6(c) the sky region has been added. The remaining problem is to determine the optimal values of k and c for correct restoration of contrast.

(a) (b) (c)

Figure 6: Construction of the depth modelling for the test image of Figure. 5.

Contrast Restoration without Depth Information
An automated method that only requires a single input image is proposed by Robby T. Tan [13]. The method is based on two basic observations:

1. Images captured on a clear day that have enhanced visibility have better balance of contrast than images plagued by bad weather.
2. Air light whose variation mainly depends on the distance of objects to the viewer, tends to be smooth.

Relying on these two observations, the authors developed a cost function in the framework of Markov random fields. Optimization of this cost function is done by various techniques.
The method does not require additional geometrical information about the input image. It can be used for colour and gray images. The main aim is to solely enhance the contrast of an input image to improve image visibility and contrast. The method is dependent on the object chromaticity to obtain output image and Air light. The contrast is maximized based on the principle that clear-day images have a larger number of edges than those affected by bad weather.

III. CONCLUSION

It is essential for images to convey true information in image processing applications. Hence, fog removal and correction methods are applied in this work. The importance of contrast for images captured under fog conditions is highlighted. The methods for enhancement of contrast are broadly categorized as modelling and non modelling methods. Some of the non modelling methods using Histogram Equalization are discussed here. Modelling methods are further divided into methods with given depth information and methods without depth information. Each case of every work has been discussed in this paper.

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