Contrast Enhancement of Roads Images with Foggy Scenes Based on Histogram Equalization

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Abstract— **Bad weather, particularly fog, commonly obstruct drivers from observing road conditions. This could frequently lead to a considerable number of road accidents. To avoid the problem, automatic methods have been proposed to enhance visibility in bad weather. Methods that work on visible wavelengths, based on the type of their input, can be categorized into two approaches: those using polarizing filters, and those using images taken from different fog densities.**

Both of the approaches require that the images are multiple and taken from exactly the same point of view. While they can produce reasonably good results, their requirement makes them impractical, particularly in real time applications, such as vehicle systems. Considering their drawbacks, our goal is to develop a method that requires solely a single image taken from ordinary digital cameras, without any additional hardware.

For decades, several image enhancement techniques have been proposed. Although most techniques require profuse amount of advance and critical steps, the result for the perceive image are not as satisfied.

The method principally uses color and intensity information. It enhances the visibility after estimating the color of skylight and the values of air light. The experimental results on real images show the effectiveness of the approach.

***Index Terms*—Image enhancement, fog , Contrast enhancement AND poor visibility.**

I. Introduction

In the modern information system, digital images have been widely used in a growing number of applications. The enhancement techniques are employed in order to increase the contrast and brightness of an image using RGB color bands and the goal of the image enhancement is to improve the visual appearance of the image.

Noise removal and preservation of useful us information are important aspects of image enhancement. A wide variety of methods have been proposed to noise removal problem. Recently, researchers have focused their attention on nonlinear smoothing techniques in the spatial domain. Most of these techniques are local smoothing filters, which replace the center pixel of the neighborhood by an average of selected neighbor pixels.

A considerable number of vehicle accidents are caused by poor visibility in bad weather. This is mainly due to the presence of the considerable number of atmospheric particles with significant size and distributions in the participating media. Because of these particles, light from the environment and light reflected from an object are absorbed and scattered, making the visibility not as clear as if they are not present. Some techniques have been introduced to tackle the problem [1]. Briefly, based on their techniques, they can be categorized into several classes: physics-based, heuristics and no physics-based solutions. While based on the sensors they use, they are grouped into: visible spectrum sensors, infrared sensors, millimeter-wave (MMW) sensors, and laser radar (LADAR) sensors.

There are several approaches that have been developed: first, methods that use polarizing filters [2,3,4]; and second, methods that use multiple images taken from foggy scenes with different densities [5,6,7]. Both of the approaches require that the images are multiple and taken from exactly the same point of view. While those methods can produce reasonably good results, their requirement of the specific inputs makes them impractical, particularly in real time applications. Therefore, to develop a method that requires solely a single image taken from an ordinary digital camera. This goal is considerably challenging, since to our best knowledge, no current method published in the literature has been proposed.

Another method is based on contrast enhancement techniques which do not require any prior knowledge of atmospheric scattering conditions [11,12]. Histogram equalization and linear stretching are one of the most popular global enhancement algorithms. Because of using global information of the image, such techniques do not give satisfactory results when there are depth changes in the scene. In [12] authors find histogram of the degraded image and identify sky regions. Thereafter, they propose to move a mask and change the intensity value of the sky pixels to 255. Other pixels of the mask are subjected to contrast enhancement. This process improves the contrast level of degraded image. However, the major drawback of the method is that objects in the sky region loose their identity as their intensity value is also made 255. Moreover, the algorithm does worst in case of the degraded images which do not have any sky region. In this case the algorithm falsely identifies some region as sky region and moves all the pixel values to 255, leaving no way to identify the object in that region.

For color image enhancement algorithms [13,14] usually apply gray level enhancement algorithm to color images brightness factor, which amplify the image details, thus enhance the input image at certain extent. These methods ignore color information of the image resulting into output image looks blackish. Therefore, we need a color image enhancement algorithm to make the output image livelier.

Contrast of an image is determined by its dynamic range, which is defined as a ratio between the brightest and the darkest pixel intensities. Contrast enhancement techniques had various application areas for enhancing visual quality of low contrast images [15,16]. The HE was being very popular technique for enhancing the contrast of an image. Theoretically, it can be shown that the mean brightness of the histogram equalization image is always the middle gray level regardless of the input mean [17].

This paper presents new quantitative measures of image enhancement and novel image enhancement methods for object detection and visualization. A number of experimental results are described to illustrate the performance of these algorithms. Comparative analyses of transforms based image enhancement algorithms are given.

The structure of the paper is arranged as follows: section 1 included the introduction and section 2 included the methodology of the proposed scheme. The proposed method is explained with many details in Section 3. Section 4 included the results. Conclusions are shown in Section 5

II. Literature Review

A. Image enhancement

Image enhancement is a process principally focuses on processing an image in such a way that the processed image is more suitable than the original one for the specific application. The word "specific" has significance. It gives a clue that the results of such an operation are highly application dependent. In other words, an image enhancement technique that works well for fog images may not work well for satellite images and medical images [3].

The technique falls in two categories on the basis of the domain they are applied on. These are the *frequency* and *spatial* domains. The frequency domain methods works with the Fourier Transforms of the image. The term spatial domain refers to the whole of pixels of which an image is composed of. Spatial domain methods are procedures that operate directly on the pixels. The process can be expressed as:

$$g(x, y) = T[f(x, y)]$$

Where $f(x, y)$ is the input image, $g(x, y)$ is the processed image, and T is an operator on f defined over some neighborhood of (x, y) [1]. A number of enhancement techniques exist in the spatial domain. Among these are histogram processing, enhancement using arithmetic, and logical operations and filters.

B. Histogram Equalization

Histogram equalization is a general process used to enhance the contrast of images by transforming its intensity values [18]. As a secondary result, it can amplify the noise producing worse results than the original image for certain foggys. Therefore, instead of using the histogram equalization which affects the whole image, CLAHE is applied to enhance the contrast of small tiles and to combine the neighboring tiles in an image by using bilinear interpolation, which eliminates the artificially induced boundaries. In addition, the 'Clip Limit' factor is applied to avoid over-saturation of the image specifically in homogeneous areas that present high peaks in the histogram of certain image tiles due to many pixels falling inside the same gray level range[18]. Additionally, a combination of filters in both domains, spatial and Fourier are used to obtain a proper enhanced image.

C. Foggy Image Model

Fog is a physical phenomenon caused by tiny dusts or droplets of water in the air. Such environment causes poorer performance on vision based surveillance system than normal condition. Recently, the difference of RGB color space used for single input image [20]. Also, a dark channel prior is used for single image [21]. This particular work has shown a good performance for "de-haze" effect. However, the details by using multiple images can provide more information than using single. Multiple images of same scene in different weather conditions are used. In this paper, we obtain more detailed information by using two-images of same scene with different weather (or time) and propose a simple relative depth estimation model, without the use of exact parameters [22].

The most conventional fog image model is that model modified this model by adding the variable of sky intensity and pixel value[19,22].

$$E = I_{\infty} p e^{-\beta d} + I_{\infty}(1 - e^{-\beta d})$$

where E is a pixel value, I_{∞} is sky intensity, P is normalized radiance of a scene point, β is scattering coefficient of the atmosphere, and d is an optical depth between camera and object. If depth is zero (d = 0), then $E = I_{\infty} P$. If depth is very far (e.g. $d = \infty$), the pixel value E is equal to the sky intensity I_{∞}. This paper adopts the Narasimhan model for foggy image and assumes three properties concerning sky intensity I_{∞}, scattering coefficient β and P.

D. Wiener filtering noise reduction

We proposed to use a pixel-wise adaptive Wiener method for noise reduction. The filter is based on local statistics estimated from a local neighborhood η of size 3x3 of each pixel, which is given by[4][17]:

$$w(n_1,n_2)=\mu+\frac{\sigma^2-v^2}{\sigma^2}\left(I(n_1,n_2)-\mu\right)$$

where v^2 is noise variance, μ and σ^2 are local mean and variance, where we represented the gray level intensity in $(n_1, n_2) \in \eta$.

E. Binarization

The operation that converts a grayscale image into a binary image is known as binarization by computing the mean value of each 32-by-32 input block matrix and transferring the pixel value to 1 if larger than the mean or to 0 if smaller. We carried out the binarization process using the following an adaptive threshold [23].

$$I_{new}(n_1,n_2)=\begin{cases}1 \text{ if } I_{old}(n_1,n_2)\geq Local\ Mean\\ 0\ otherwise\end{cases}$$

F. Thinning

During this stage, the characterization of each feature is carried out by determining the value of each pixel. Some techniques exist based on thinning the pixel neighborhood having a maximum value initially (16) and filtered in the final step in order to eliminate the false lonely points and breaks; an algorithm is presented which eliminates the false information by slide neighborhood processing in a first step followed by thinning without any additional filtering. Then, the foggy image is separated from the background and local minutiae is located on the binary thinned image [23].

G. Measure of image enhancement

In this subsection, we present a short survey of existing quantitative measure of the image enhancement and presented a new one. When analyzing the signals and systems, it is useful to map data from the time domain into another domain (in our case, the frequency domain). The basic characteristics of a complex wave are the amplitude and phase spectra. Specifying amplitude and phase spectra is an important concept for complex waves. For example, an amplitude spectrum contains information about the energy content of a signal and the distribution of the energy among the different frequencies, which is often used in many applications. To solve the corresponding problem, the real variable, t, is generalized to the complex variable, (u + jv), which then is mapped back via the inverse mapping. For example, the Fourier transform maps the real line (time domain) into the complex plane, or real wave into the complex one. But, it has a high complexity of implementation which involves complex multiplications and additions.

The improvement in images after enhancement is often very difficult to measure. A processed image can be said to get an enhancement over the original image if it allows the observer to better perceive the desirable information in the imaging. In images, the improved perception is difficult to qualify. There is no universal measure which can specify the both objective and subjective validity of the enhancement method [16]. In practice, many definitions of the contract measure are used [9,11,10]. For example, the local contrast proposed by Gordon and Rangayyan [13] was defined by the mean gray values in two rectangular windows centered on a current pixel.

Another proposed definition of the local contrast based on the local edge information of the image, in order to improve the first mentioned definition. The local contrast proposed have been adopted, in order to define a performance measure of enhancement [10].

Use of statistical measures of gray level distribution measures of local contrast enhancement (for example, mean, variance or entropy) has not been particularly meaningful for mammogram images [13]. A number of images, which clearly illustrated an improved contrast, showed no consistency, as a class, when using these statistical measurements.

A measure proposed in [9], which has greater consistency than the statistical measures, is based on the contrast histogram. Intuitively, it seems reasonable to expert that a image enhancement measure values at given pixels should depend strongly on the values at pixels that are close by weekly on those that are further away and also this measure has to related with human visual system. in our definition we will use a some modification of the Webers and Fishers Lows. In the second image enhancement measure definition we will use the well known entropy concept: In Weber established its visual low, argued that the human visual detection depends on the ratio, rather than difference.

The Weber definition of contrast is used to measure the local contrast of a single object (One usually assumes a large background with a small test object, in which case the average luminance will be close to the background luminance. If there are many objects these assumptions do not hold). The Fisher Low, proposed the following relationship between the light intensity i(x, y) and brightness:

$$B=kLn\left(\frac{f}{f_{\max}}\right)+kLn\left(\frac{f_{\max}}{f_{\min}}\right)$$

Where f_{max} and f_{min} are the maximum and minimum luminance values (within a small window), respectively.

We now introduce two new quantitative measures of image enhancement. Let an image x(n,m) be split into k_1k_2 blocks $w_{k,l}(i, j)$ of sizes $l_1 \times l_2$, and let and $\{\phi\}$ be a given class of orthogonal transforms used for image enhancement with enhancement parameters (or, vector parameter) α, β *and* λ to be found, then we define

$$EME=\max_{\phi\in\{\phi\}} x(EME(\phi))$$
$$=\max_{\phi\in\{\phi\}} x\left(\frac{1}{k_1k_2}\sum_{t=1}^{k_2}\sum_{k=1}^{k_1}20\log\frac{I^w_{\max;k,t}}{I^w_{\min;k,t}}\right)$$

Where $I^w_{\min:k,1}$ *and* $I^w_{\max:k,1}$ are respectively minimum and maximum of the image X(n,m) inside the block wk,l. The function χ is the sign function, χ (x) = x, or χ (x) = −x, depending on the method of enhancement under the consideration. The decision of adding this function have been done after the study various examples of enhancement by transform methods using the different coefficients Ci(p, s), i = 1, 2, 3, which are described in the next section.

Definition 1: EME is called a measure of enhancement, or measure of improvement. In the second image enhancement measure definition, we use the well known entropy concept [17].

Definition 2: Let an image x(n,m) be split into k_1k_2 blocks $w_{k,l}(i, j)$ of sizes $l_1 \times l_2$. Then, the quantity is called a measure of enhancement by entropy.

$$EMEE = \max_{\phi \in \{\phi\}} x(EME(\phi))$$

$$x(EME(\phi)) = \left(\frac{1}{k_1 k_2} \sum_{t=1}^{k_2} \sum_{k=1}^{k_1} \log \frac{I^w_{\max;k,t}}{I^w_{\min;k,t}}\right) \quad (3)$$

Definition 3: The best (optimal) image improvement transform-based enhancement algorithm is called a transform ϕ_0 such as EME(ϕ_0) = EME, or EMEE(ϕ_0) = EMEE.

Definition 4: The best (optimal) image improvement transform-based enhancement algorithm is called a transform ϕ0 such as EME(ϕ_0) = EME, or EMEE(ϕ_0) = EMEE.

H. Weber's law

The ability to detect a spot of light does not depend so much on the luminance of the spot itself as on the *difference* in luminance of spot and background, *i.e.,* the *contrast*. Of course, the luminance must be above some minimal value, but it is the contrast of spot and background that must be above a certain threshold before we can detect the spot. We call this threshold the *just noticeable difference*. *Weber's law* states that the just noticeable difference ΔL is proportional to the background luminance *L*. In other words, the higher the background luminance, the higher the contrast needs to be before we detect a difference.

I. PROPOSED ALGORITHM OF ENHANCEMENT

Using the proposed scheme we can summarize the foggy road image enhancement and its results as shown in the following Figure 1:

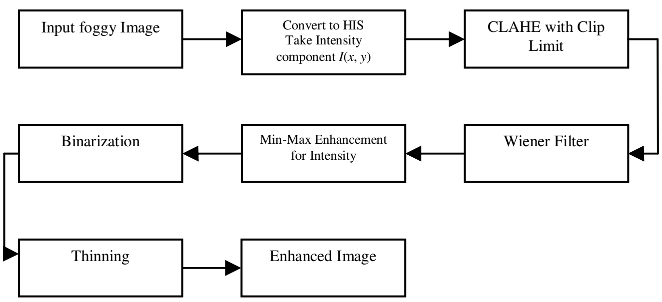


Figure 1: Shows the proposed algorithm

Step 1: At this step of the foggy image enhancement process, Convert this input image to HIS space. Take Intensity component as $I1(x, y)$.

Suppose R, G, and B are the red, green, and blue values of a color. The HSI intensity is given by the equation

I=(R+G+B)/3.

Now let m be the minimum value among R, G, and B. The HSI saturation value of a color is given by the equation

S=1-m/I if I > 0, or
S = 0 if I = 0.

To convert a color's overall hue, H, to an angle measure, use the following equations:

H = $\cos^{-1}$[(R - ½G - ½B)/√R² + G² + B² - RG - RB - GB] if G ≥ B, or
H = 360 - $\cos^{-1}$[(R - ½G - ½B)/√R² + G² + B² - RG - RB - GB] if B > G,

where the inverse cosine output is in degrees.

Step 2: At this step of the image foggy enhancement process, histogram equalization is applied to enhance the image's contrast by transforming the intensity values of the image (the values in the color map of an indexed image), which are given by the following equation: [23]

$$s_k = T(r_k) = \sum_{j=1}^{k} p_r(r_j) = \sum_{j=1}^{k} \frac{n_j}{n}$$

where s_k is the intensity value in the processed image corresponding to r_k in the input image, $p_r(r_j)$=1, 2, 3... L is the input feggy image intensity level , n is the total number of pixels in the image, n_j is the number of pixels that have gray level r_k and L is the total number of possible gray levels in the image. In other words, the values in a normalized histogram approximate the probability of occurrence of each intensity level in the image.

The differences between the histogram of the normal foggy before and after histogram equalization (implemented in the MATLAB Image processing toolbox by function "histeq") are depicted.

However, by enhancing the contrast of an image through a transformation of its intensity values, the histogram equalization can amplify the noise and produce worse results than the original image for some foggy, due to many pixels falling inside the same gray level range. Therefore, instead of applying the histogram equalization, which works on the whole image, CLAHE is used to enhance the contrast of the small tiles of an image and to combine the neighboring tiles using a bilinear interpolation which will eliminate the artificially induced boundaries.

In addition, 'Clip Limit' factor (implemented in the MATLAB Image Processing Toolbox by the function **adapthisteq (f,"clipLimit")** is applied to avoid the over-saturation of the image, specifically in homogeneous areas which display a high peak in the histogram of the particular image tile. In addition, the spread of the histogram over the entire intensity is increasing the contrast and the average intensity level in the histogram of the equalized image is higher (lighter) than the original.

Step 3: Apply the Min-Max Enhancement. The enhancement is done based on the minimum and maximum values of the pixels. Where the zero value of the pixels is replaced by the minimum value and the highest value becomes the maximum value there by increasing the intensity ranges making the image clearer.

Step4: The wiener filtering then is applying
Step5: Then Binarization the wiener filters result.
Step6: Then Thinning The result of the step5

Foggy Image

Step2

Step3

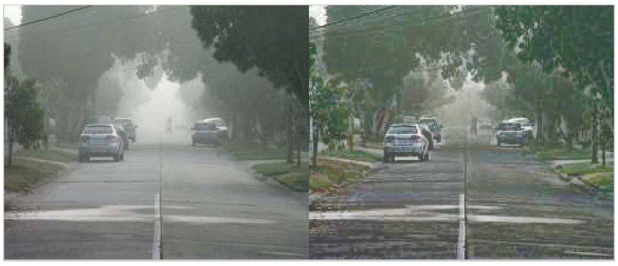
Step4

Step5

Step6

Enhanced Image

Figure2:



Input Foggy Image   Enhanced Image

Figure3:

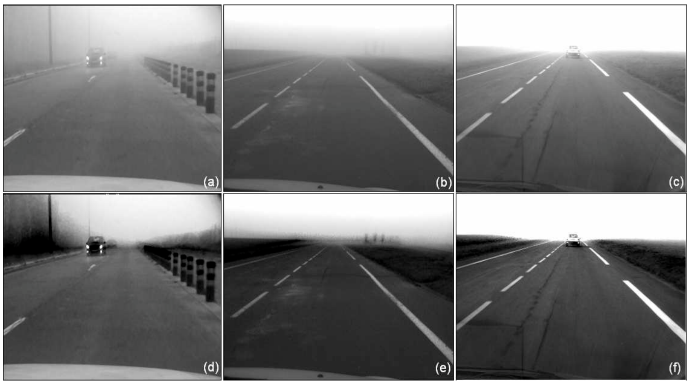


Figure4:

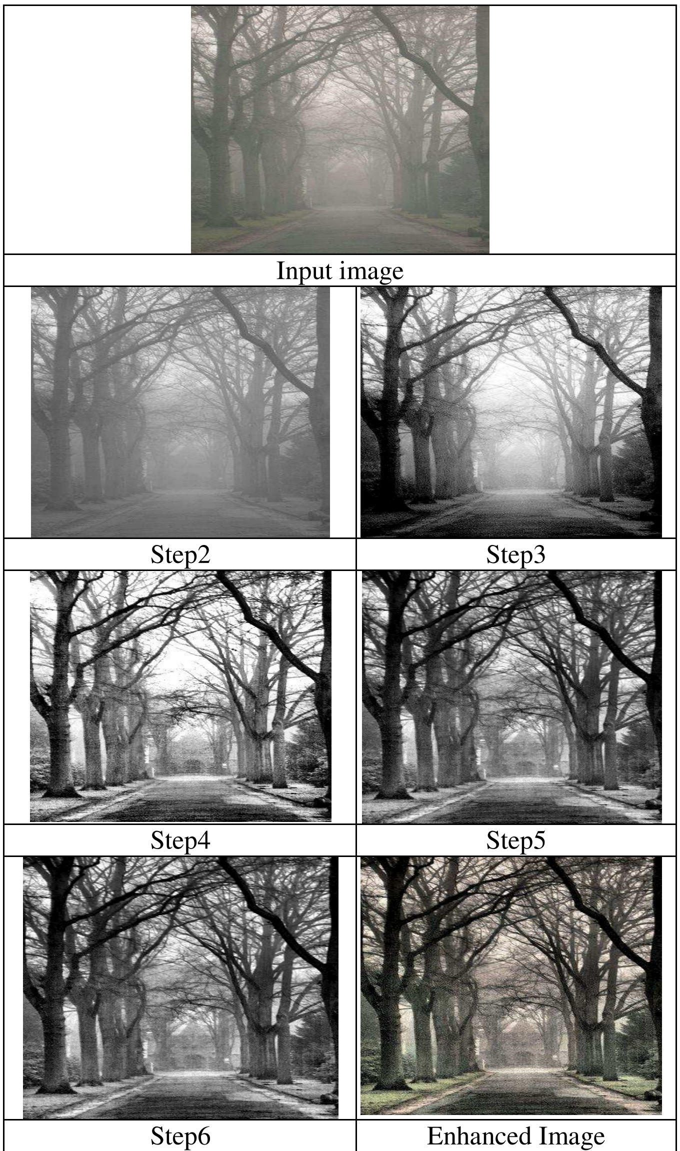


Figure5:

J. Result and Conclusion

We have introduced a new foggy image enhancement algorithm. This algorithm, unlike other algorithms, concentrates a large amount of effort to allowing superior performances.

To demonstrate the effectiveness of our method, we used real images of outdoor scenes in our experiments. Most of these images shown in this section were taken from the internet, and the quality is considerably low.

Figure2 shows a typical road scene partially covered with fog and then shows the enhancement result. As can be observed, the visibility in last steps is more significant than original image. Figure3,4,5 show examples of image with very dense fog.

The procedure follows first we enhanced version of I component with their enhanced images. we have set following parameters:

a). Block size as 128 X128.

b). Stepsize using in moving blocks is to set to 12.

c). Gamma correction factor, λ is found to be 0.6

These parameters are found with extensive experiments with large number of fog degraded images. The application of CLAHE with Clip Limit in order to enhance the contrast of small tiles, to eliminate the artificially induced boundaries and to avoid oversaturation of the image specifically in homogeneous areas.

In addition, the wiener filtering is used to obtain a proper enhanced image.

The another phase of this new enhancement methodology is the application of the slide neighborhood processing to obtain a thinned foggy image The analysis of its possible advantages is carried out through a simulated investigation.

This module checks the quality of the input foggy image objectively. The enhancement module is applied to the input foggy image if and only if the quality of the input foggy image is poor and the true ridge/valley structures are recoverable.

J. References

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