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Contrast Enhancement for Fog Degraded Video Sequences Using BPDFHE

C.Ramya, Dr.S.Subha Rani
ECE Department,PSG College of Technology,Coimbatore, India.

Abstract--- **Under heavy fog condition the contrast of the videos gets degraded and suffers from poor visibility. In this paper a novel method is proposed to enhance the degraded video sequences using Brightness Preserving Dynamic Fuzzy Histogram Equalization (BPDFHE).It enhances visibility of the frames and also maintains the color fidelity. Brightness Preserving Dynamic Fuzzy Histogram Equalization uses fuzzy statistics of video sequences for their representation and processing. Representation and processing of video frames in the fuzzy domain enables the technique to handle the inexactness of gray level values in a better way. Thus it results in improved performance than traditional methods. Experimental results show the effectiveness of the proposed method and its performance is also analyzed with contrast improvement index (CI) and Tenengrad criterion (TEN).**

Keywords--- **Fog, fuzzy sets, video processing, image enhancement, Histogram, color fidelity**

I. INTRODUCTION

Usually outdoor image acquisition depends on the weather conditions. As one of the most common weather conditions, is fog which has whitening effect on the scenery, drops the atmospheric visibility that leads to the decline of image contrast and produces fuzziness to the image. Optically, poor visibility in bad weather is due to the substantial presence of atmospheric particles that have significant size and distribution in the participating medium. Light from the atmosphere and light reflected from an object are absorbed and scattered by those particles, causes degradation in the visibility of the scene. All these problems may bring great difficulty to the image information extraction, outdoor image monitoring, target identification and tracking and so on. It can be seen that in the fog degraded images, the low gray value is strengthened while the high gray value is weaken, that leads to the over-concentrated distribution of pixel gray value, which is an obvious contrast degradation problem. Therefore, it is necessary to enhance foggy images.

Many techniques are available for image contrast enhancement. The techniques that use first order statistics of digital images (image histogram) are very popular. Global Histogram Equalization (GHE) [1] is one of the widely used technique. GHE is employed for its simplicity and good performance. while it introduce major changes in the image gray level its histogram spread is not significant and cannot preserve the mean image-brightness. To overcome this, several brightness preserving histogram modification approaches, such as bi-histogram equalization [2][3], multi-histogram equalization, Contrast limited adaptive histogram equalization(CLAHE) and histogram specification [4-6]have been proposed in literature. Dynamic Histogram Equalization method, proposed by Abdullah-Al-Wadud, et al., partitions the global image histogram into multiple segments based positions of local minima, and then independently equalizes them. This technique claims to preserve the mean image brightness. But this method has the limitation of remapping the peaks which leads to perceivable changes in mean image brightness. To avoid peak remapping, Ibrahim and Kong, in their Brightness Preserving Dynamic Histogram Equalization (BPDHE) technique, use the concept of smoothing a global image histogram using Gaussian kernel followed by its segmentation of valley regions for their dynamic equalization. These techniques process the crisp histograms of images to enhance contrast. The crisp statistics of digital images suffers from the inherent limitation that it does not take into account the inexactness of gray-values. Also, crisp histograms need smoothing to achieve useful partitioning for equalization.

Brightness Preserving Dynamic Fuzzy Histogram Equalization technique [7-12] uses fuzzy statistics of digital images. The imprecision in gray levels is handled well by fuzzy statistics. The fuzzy histogram computed with appropriate fuzzy membership function, does not have random fluctuations or missing intensity levels and is essentially smooth. This helps in obtaining its meaningful partitioning required for brightness preserving equalization. In this paper, Brightness Preserving Dynamic Fuzzy Histogram Equalization technique is used to enhance the contrast of the fog degraded videos.

The rest of the paper is organized as follows: section II discusses the Fuzzy based fog removal method using BPDFHE in detail. Experimental results are reported in section III and section IV concludes the paper.

II. PROPOSED FUZZY BASED FOG REMOVAL METHOD USING BPDFHE

In GHE the remapping of the histogram peaks takes place which leads to the introduction of undesirable artifacts and large change in mean image brightness. The Brightness Preserved Dynamic Fuzzy Histogram Equalization technique manipulates the image histogram in such a way that no remapping of the histogram peaks takes place, while only redistribution of the gray-level values in the valley portions between two consecutive peaks takes place. The BPDFHE technique [8] consists of following operational stages:

A) Fuzzy Histogram Computation.
B) Partitioning of the Histogram.
C) Dynamic Histogram Equalization of the Partitions.
D) Normalization of the image brightness.

The following sub-sections contain the details of the steps involved.

A. Fuzzy Histogram Computation

A *fuzzy histogram* is a sequence of real numbers $p(t), t \epsilon \{0,1,\dots,B-1\}$ where $p(t)$is the frequency of occurrence of gray levels that are "around t". By considering the gray value $T(a,b)$ as a fuzzy number$\check{T}(a,b)$, the fuzzy histogram is computed as:

$$p(t) \longleftarrow p(t) + \sum_a \sum_b \mu_{\check{T}(a,b)t}\, , s\epsilon\,[c,d] \;(1)$$

Where $\mu_{\check{T}(a,b)t}$ is the triangular fuzzy membership function defined as

$$\mu_{\check{T}(a,b)t} = \max\ (\ 0{,}1 - \frac{|T(a,b) - t|}{4})\quad (2)$$

and [c,d] is the support of the membership function. Fuzzy statistics is able to handle the inexactness of gray values in a much better way compared to classical crisp histograms thus producing a smooth histogram. Thus the use of fuzzy histogram is suitable for this particular application.

B. Partitioning of the Histogram

The local maxima based partitioning of the histogram, to obtain multiple sub-histograms, is performed in this step. This way every valley portion between two consecutive local maxima forms a partition. When the dynamic equalization of these partitions is performed the peaks of the histogram do not get remapped and this results in better preservation of the mean image-brightness while increasing the contrast.

1) Detection of Local Maxima: The local maxima in the Fuzzy Histogram are located using the first and second derivative of the Fuzzy histogram. Since the histogram is a discrete data sequence, we use the central difference operator for approximating a discrete derivative (3).

$$p^{'}(t) = \frac{dp(t)}{dt} \stackrel{\Delta}{=} \frac{p(t+1) - p(t-1)}{2} \quad (3)$$

Where $p^{'}(t)$ represents the first order derivative of the fuzzy histogram $p(t)$corresponding to the t^{th} intensity level.

The second order derivative is computed directly from the fuzzy histogram using the second order central difference operator (4). This is done in order to minimize approximation errors which propagate if computed from the first order derivative.

$$p^{''}(t) = \frac{d^2p(t)}{dt^2} \stackrel{\Delta}{=} p(t+1) - 2p(t) + p(t-1) \quad (4)$$

Where $p^{''}(t)$ represents the second order derivative of the Fuzzy Histogram $p(t)$ corresponding to the t^{th} intensity level.

The local maxima points are then indicated for those values of intensity levels where zero crossings of the first order derivative are detected along with a negative value of the second order derivative (5).

$$t_{max} = t \forall \{p^{'}(t+1) \times p^{'}(t-1) < 0. p^{''}(t) < 0\} (5)$$

However, points of ambiguity arise in most situations as perfect zero crossings do not occur at integral values of intensity levels. In such situations, generally two neighboring pairs are detected as points of maxima. The ambiguity can be resolved by preserving the point with the highest count among the neighboring pair of maxima.

2) Creating Partitions: The local maxima points in the fuzzy histogram can now be used to form the partitions. Let $(r+1)$ intensity levels corresponding to the local maxima, detected in the previous stage of operation, be denoted by $\{q_0, q_1, \dots, q_n\}$. Assuming the original fuzzy histogram to have a spread in the range of $[T_{min}, T_{max}]$, then the $(r+1)$ sub-histograms obtained after partitioning are $\{[T_{max}, q_0], [q_0+1, q_1], \dots [q_n+1, T_{max}]\}$.

C. Dynamic Histogram Equalization of the Sub histograms

The sub-histograms obtained are individually equalized by the DHE technique. The equalization method uses a spanning function based on total number of pixels in the partition to perform equalization. It involves two stages of operation, namely, mapping partitions to a dynamic range and histogram equalization.

1) Mapping Partitions to a Dynamic Range: The following set of equations give the parameters that are useful in dynamic equalization process.

$$spn_t = hi_t - lo_t \qquad (6)$$

$$fact_t = spn_t \times log_{10} M_t \qquad (7)$$

$$ran_t = \frac{(B-1) \times fact_t}{\sum_{s=1}^{r+1} fact_s} \qquad (8)$$

where hi_t and lo_t are the highest and lowest intensity values contained in the t^{th} input sub-histogram, M_t is the total number of pixels contained in that partition. The dynamic range of the input sub-histogram is specified by spn_t, while the dynamic range used in the output sub-histogram is ran_t.The dynamic range for the t^{th}output sub-histograms can be obtained from ran_t as

$$upper_t = \sum_{s=1}^{t-1} ran_s + 1 \qquad (9)$$

$$lower_t = \sum_{s=1}^{t} ran_s \qquad (10)$$

The exceptions are present at the two extremities, where

$$[upper_1, lower_1] = [0, ran_1] \text{ and}$$

$$[upper_{r+1}, lower_{r+1}] = \left[\sum_{s=1}^{r+1} ran_s, B-1\right]$$

2) Equalizing each Sub-histogram: The method for equalizing each partition of the histogram is similar to that used for global histogram equalization. For the t^{th} sub-histogram, the remapped values are obtained as in (11).

$$z(u) = upper_t + ran_t \sum_{s=srt_t}^{u} \frac{p(s)}{M_t} \qquad (11)$$

where $z(u)$ is the new intensity level corresponding to the u^{th} intensity level on the original image, $p(s)$ is the histogram value at the s^{th} intensity level on the fuzzy histogram, and $M_t = \sum_{s=upper_t}^{lower_t} p(s)$ is the total population count in the t^{th} partition of the fuzzy histogram.

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D. Normalization of Image Brightness

The image obtained after the dynamic histogram equalization of each sub histogram is has the mean brightness that is slightly different than the input image. To remove this difference the normalization process is applied on the output image.

Let q_t and q_0 be the mean brightness levels of the input image and the image v obtained after dynamic histogram equalization stage. If w *is* the output image of BPDFHE technique then the gray level value at the pixel location $(a, b)$for the image w *is* given as

$$w(a,b) = \frac{q_t}{q_0} v(a,b) \qquad (12)$$

This brightness preserving procedure ensures that the mean intensity of the image obtained after process is the same as that of the input.

III. EXPERIMENTAL RESULTS

In a fog degraded traffic video, frame 5, 35, 55 and 87 were selected to evaluate the performance of the proposed method. The original frame 5, 35, 55 and 87 are shown in fig. 1, fig.2, fig. 3 and fig. 4 respectively. The defogged output frame of 5, 35, 55 and 87 by the proposed method are shown in fig. 5, fig. 6, fig. 7 and fig. 8. To demonstrate the effectiveness of the proposed method which adapts Brightness preserving dynamic fuzzy histogram equalization for enhancing the fog degraded videos, frame number 55 in fig. 9 has been taken and compared with other histogram equalization techniques. The output image after applying Histogram equalization (HE) is shown in fig. 10. The output of Local Histogram equalization (LHE) is shown in Fig. 11. Fig. 12 is the output of Contrast limited adaptive histogram equalization (CLAHE) technique. The output of the proposed method is shown in fig. 13. The histogram of the frame 55 before applying any removal technique is shown in fig. 14. The histograms of the frame 55 after applying HE, LHE, CLAHE and the proposed method output are shown in fig. 15, fig. 16, fig. 17 and fig. 18 respectively. By comparing the output of the proposed method with other techniques, clearly shows that the proposed method is much more effective in fog removal. Also it preserves the color fidelity of the video sequence

Fig. 1

Fig. 2

Fig. 3

Fig. 4

Fig. 5

Fig. 6

Fig. 7

Fig. 8

Table I: Comparison of CI and Tenengrad Values of the proposed method with other traditional methods

Frame No. 55	**CI**	**TENENGRAD**
HE	1.0132	45060
LHE	1.2135	49425
CLAHE	1.7583	50359
PROPOSED METHOD	2.8375	53522

Fig. 9

Fig. 10

Fig. 11

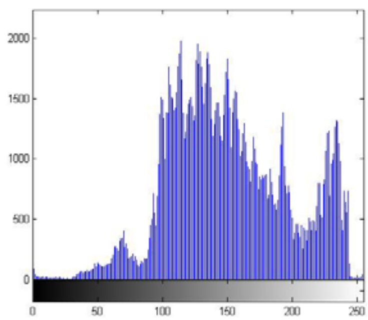

Fig. 14

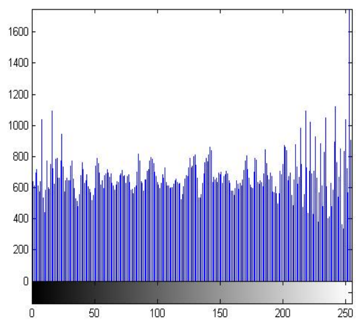

Fig. 15

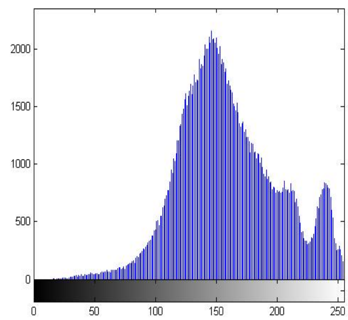

Fig.16

Fig. 12

Fig.13

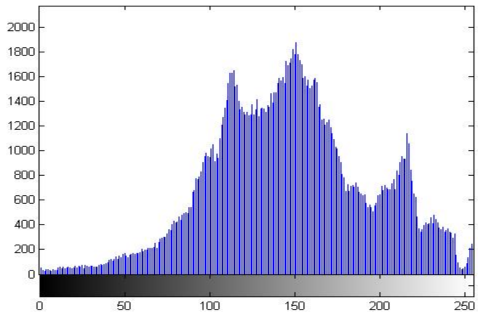

Fig. 17

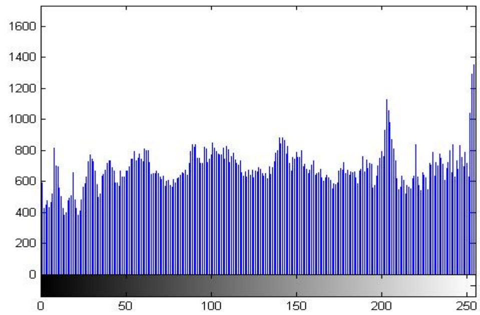

Fig. 18

Performance Analysis

Contrast Improvement Index (CI)

The performance of the proposed method is also evaluated by contrast improvement index and Tenengrad criterion. The contrast improvement index is calculated by

$$CI = \frac{C_{\Pr ocessed}}{C_{Original}} \qquad (13)$$

where C is the average value of the local contrast measured with a 3X 3 window as

$$C = \frac{\max - \min}{\max + \min} \qquad (14)$$

Tenengrad Criterion (TEN)

The Tenengrad criterion is based on gradient ∇ I (x, y) at each pixel (x, y), were the partial derivatives are obtained by a high-pass filter, eg., the sobel operator, with the convolution kernels i_x and i_y. The gradient magnitude is given by

$$S(x, y) = sqrt[(i_x X I(x, y)^\wedge 2 + (i_y X\, I(x, y))^\wedge 2] \, (15)$$

And the Tenengrad criteria is formulated as

$$TEN = \sum_x \sum_y S(x, y)^2, \quad for\, S(x, y > T) \qquad (16)$$

where T is the threshold. From the table I, it can be observed that the CI and Tenengrad values of the proposed method output are comparably higher than those of other techniques. The higher CI value signifies better contrast improvement in the output image. The higher value of Tenengrad signifies good visibility and sharpness.

IV. CONCLUSION

This paper proposes a defogging method for video sequences using BPDFHE. BPDFHE has an ability to enhance contrast and preserve brightness of an image. The novelty of the proposed method lies in the use of fuzzy statistics of video sequences for representation and processing of the foggy frames. This gives it the improved ability to preserve brightness and provide better contrast enhancement compared to other techniques. From the results it is clear that the proposed method can effectively remove the fog from fog degraded color videos also it efficiently preserves the mean image-brightness.

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