ISSN:0975-9646

Swati Tyagi et al, / (IJCSIT) International Journal of Computer Science and Information Technologies, Vol. 6 (3) , 2015, 2998-3001

Image Enhancement by Comparing Contrast value in Fuzzy Plane

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***Abstract*— In this paper, a novel approach is proposed for contrast enhancement of greyscale image using the fuzzy logic based techniques such as contrast intensification (INT) operator. In the proposed algorithm, a measure of contrast of an image is introduced which is maximized to obtain a suitable crossover point for an image. Using this crossover point, the enhanced image is obtained using the INT operator. The image enhancement results obtained are compared with conventional techniques, histogram equalization and adaptive histogram equalization. The index of fuzziness is demonstrated as the performance measure for the enhanced images.**

***Keywords*— Contrast enhancement, Fuzzy logic, Intensification operator, Measure of Contrast, Index of fuzziness.**

I. INTRODUCTION

Image enhancement is one of the important parts of digital image processing where images undergo for visual inspection or for machine analysis without knowledge of its source of degradation. The image is undergo the processes to bring out specific application of an image so that the result is more suitable that the original image. Image can be enhanced in various ways such as contrast enhancement, intensity, density slicing, edge enhancement, removal of noise, and saturation transformation. Contrast enhancement is a vital part of various fields, such as X-ray image analysis, biomedical image analysis, machine vision where pixel intensity of poor quality of input images is converted to high quality of output image by various image enhancement techniques to improve the contrast (the separation between the dark and bright areas) of an image for better visualisation or interpretability.

Image enhancement methods may be defined into two parts: frequency domain methods and spatial domain methods. The former method is based on Fourier transform of an image whereby transform is modified. Whereas latter method is spatial domain methods in which the direct manipulation of the pixel in an image is considered [1][8].
Also, several other image enhancement methods have been proposed. A very common technique for contrast image enhancement is histogram equalization (HE) [2][16]. The operation of histogram equaliser is performed by remapping the gray levels of the input image which is based on the probability distribution for adjusting image intensities to enhance contrast. The HE techniques could cause an over enhancement or under enhancement effect on the visualisation of the output image and also amplify existing noises. During image digitization this uncertainty present in an image appears in the form of unspecific boundaries and intensities.

Sathit Intajag, k. Paithoonwattanakij [3] proposed the method which introduced the INT operator where the various parameters are calculated on the basis of the standard deviation of the image. Pal, and King, [4] proposed a fuzzy intensifier operator for contrast enhancement in which the parameters are computed on the basis of the index of fuzziness and the entropy of the image. H.D. Cheng, Huijuan Xu [5] proposed a fuzzy logic approach for contrast enhancement in which maximum fuzzy entropy principle is used to map an image to fuzzy domain using the S-function as a membership function.

Sankar K. Pal and Azriel Rosenfeld [6] proposed algorithms based on better selection of threshold value by optimization of both compactness and fuzziness of a chromosome image in the spatial plane without considering to its histogram. And input image having a unimodal histogram and noisy image having a bimodal histogram in which membership function is modified for various bandwidths of blurred chromosome images.
S. K Pal, R.A. King and A.A. Hashim [7] proposed algorithms using concepts of fuzzy set where selecting optimum level of threshold on image segmentation without determining histogram. The crossover value of membership function (S-function) is calculated by minimizing index of fuzziness and entropy of unimodal and multimodal greyscale images among various regions in spatial plane.

In this paper, we have extended the approach in Pal and King [4] for the enhancement of greyscale images. A new measure of contrast, C, is introduced, which computes the approximate contrast vale of the image. The main motive of the algorithm is to maximize the measure of contrast, to obtain a good contrast enhanced image. The crossover point is computed for the maximum C. The 'index of fuzziness' [6][7][15] is used to represent the quantitative measure of image quality in the fuzzy domain, though the image quality remains subjective in nature.

II. CONTRAST ENHANCEMENT USING PROPOSED APPROACH

The fuzzy image enhancement is divided into three parts1: in figure 1, First is fuzzification block in which data (crisp value) of original image is converted into fuzzy value. Then this fuzzy set values is transformed to second block (modification of memebership) which is the main block of fuzzy image processing where membership values are modify by using appropriate fuzzy techniques (non linear or knowledge based such as fuzzy filtering, fuzzy rule based approach or integration approach) and last block is defuzzification block where modified fuzzy values is converted back into crisp values.[9][16][17]

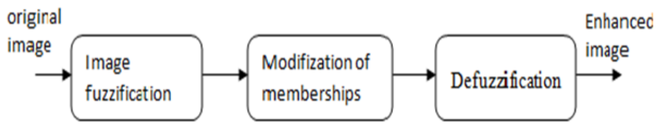

Fig. 1 Fuzzy Image Enhancement

A. *Enhancement using Contrast Intensification (INT) Operator*

The image enhancement approach using the intensification (INT) operator [10]-[13][16], proposed by Pal and King [4] in 1980, is a very effective a robust algorithm for image enhancement. For an image X, of dimensions MxN,[8] the fuzzy contrast enhancement algorithm, can be formulated as follows:

Step 1: Fuzzification, which involves the conversion of image X into the fuzzy plane:

$$p_{mn} = G(x_{mn}) = \left[1 + \frac{x_{max} - x_{mn}}{F_d}\right]^{-F_e} \qquad (1)$$

where x_{max} is the maximum grey level of X, x_{mn} is the (m,n) intensity pixel of image X, F_e and F_d are the exponential and the denominational fuzzifiers respectively, and m = 1, 2,....,M; n = 1, 2,....,N.

Step 2: Modification of memberships function ($\mu_{mn} \rightarrow \mu'_{mn}$) by following the transformation$T_r(p_{mn})$, or the intensification operator (INT),

$$\mu'_{mn} = T_r(p_{mn}) = \begin{cases} 2 * [\mu_{mn}]^2 & 0 \le \mu_{mn} \le 0.5 \\ 1 - 2 * [1 - \mu_{mn}]^2 & 0.5 \le \mu_{mn} \le 1 \end{cases} \qquad (2)$$

Step 3: Defuzzification for the generation of new gray levels p'_{mn} by the inverse transformation G^{-1}

$$p'_{mn} = G^{-1}(\mu'_{mn}) = x_{max} - F_d\left(\left(\mu'_{mn}\right)^{\frac{-1}{F_e}} - 1\right) \qquad (3)$$

For $\alpha \le \mu_X(X_{mn}) \le 1$

Thus, the final image obtained by the defuzzification process, is the required enhanced image for the input image, X.

B. *Calculation of F_e and F_d*

The exponential and the denominational fuzzifiers, F_e and F_d, from eq.1.are calculated on the basis of two conditions as follows-

- At $x_{mn} = 0$, p_{mn} has a finite value, α, so that p is restricted in the interval $[\alpha, 1]$, instead of [0,1].
- At $x_{mn} = x_c$ (crossover point), the value of fuzzy plane is 0.5, i.e., $p_{xc} = 0.5$.

Applying the above conditions in eq. 1 and solving for F_e and F_d, the equations are obtained as:

$$F_e = \frac{\log(\frac{1}{4\alpha})}{\log \frac{x_{max}}{x_c}} \qquad (4)$$

and

$$F_d = \frac{x_{max} - x_c}{2^{\frac{1}{F_e}} - 1} \qquad (5)$$

Thus, the values of the positive constants, F_e and F_d, are completely dependent on the crossover point of the image, since α is a fixed constant. Thus, the main objective of the approach is to compute a suitable crossover point, so as to obtain a satisfactory enhanced image.

C. *Measure of Contrast C(X)*

Contrast of an image is defined as the difference between its dark and bright regions. A measure of contrast, C, is introduced which provides an estimate of the contrast of the image. Hence, a measure of contrast, C(X), for an image X, is defined as:

$$C(X) = Dark(X) - Bright(X) \qquad (6)$$

Where Dark(X) and Bright(X) are the mean of the dark and the bright regions of X respectively.

Step 1: Compute the maximum ($x_{\max}$), the minimum(x_{min}), and the average value of the maximum and minimum grey level, termed as x_{mid}.

Step 2: Classify all the pixels of the image into dark and bright region as,

- If the pixel grey level is greater than average of $x_{\max}$and x_{mid},
  - Then it belongs to the dark region,
- Else if the pixel grey level is less than or equal to the average of $x_{\max}$and x_{min},
  - Then it belongs to the bright region.

Step 3: Compute the mean grey value for dark and bright regions, termed as Dark(X) and Bright(X) respectively.

Step 4: Compute C(X) as the difference between Dark(X) and Bright(X).

D. *Computation of Crossover Point (x_c)*

Since, our main objective is to improve the contrast of the image, a suitable crossover point can be obtained by maximizing the contrast of the image. This can be achieved by maximizing the measure of contrast, C(X), for a given image X.

Given an image X of dimensions, MxN, with maximum and minimum grey levels, $x_{\max}$, and x_{min} respectively, and the average value of the maximum and minimum grey level, termed as x_{mid}.

Step 1: Convert the image X into the fuzzy plane using eq. 1., considering the crossover point, $x_c = x_{mid}$.

Step 2: Compute the measure of contrast, C, using eq. 6., in μ_{mn}, taking $x_c = x_{mid}$.

Step 3: Vary x_c from $(x_{mid} - 20)$ to $(x_{mid} + 20)$, and select x_c, for which C(X) is maximum.
After heuristically analyzing a set of 50 images, the range for varying the crossover point, x_c, is set as $(x_{mid} - 20)$ to $(x_{mid} + 20)$, in which the contrast value obtained is optimum. This also avoids over and under-contrast enhancement of images.
x_c thus calculated is the suitable crossover point of μ_{mn}, having minimum fuzziness, and can be used for segmenting the image into corresponding regions, $0 \leq \mu_{mn} < 0.5$, and $0.5 \leq \mu_{mn} \leq 1$. Using this crossover point, the enhanced image can be obtained using eq. 1-3.

III. IMPLEMENTATION AND RESULTS

A new approach to contrast enhancement without over enhancement, produces better results than other existing algorithms using fuzzy technique. The proposed method was implemented in MATLAB 2013a. In order to evaluate the performance of the proposed algorithm, we compared the experimental results of proposed method with histogram equalizer [2] and adaptive histogram equalizer techniques.

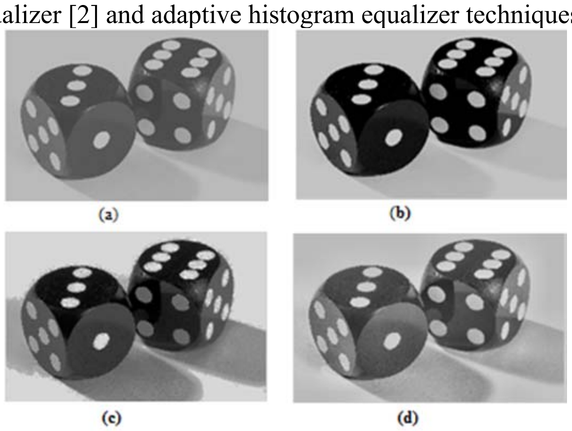

Fig. 2 (a) Original image (Dice .jpg), (b) Output of Proposed Method, (c) Output of Histogram Equalizer, (d) Output of Adaptive Histogram Equalizer

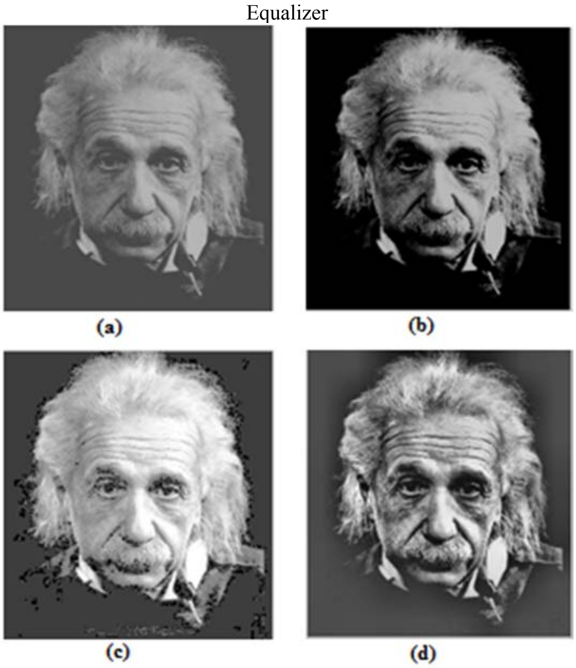

Fig. 3 (a) Original image (Einstein .jpg), (b) Output of Proposed Method, (c) Output of Histogram Equalizer, (d) Output of Adaptive Histogram Equalizer

Fig. 4 (a) Original image (Chaplin .jpg), (b) Output of Proposed Method, (c) Output of Histogram Equalizer, (d) Output of Adaptive Histogram Equalizer

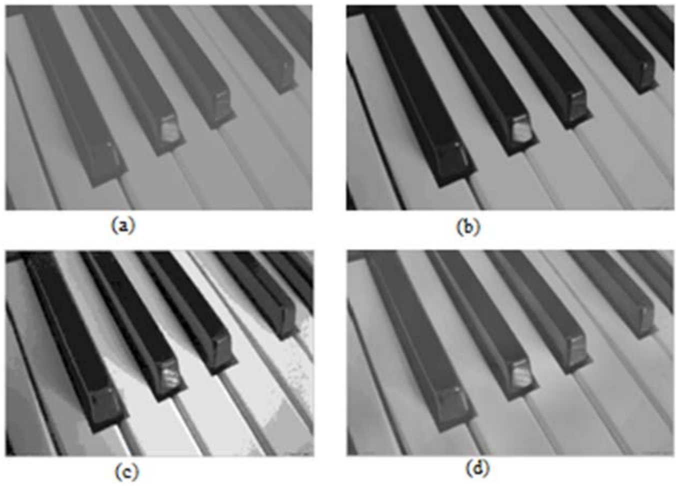

Fig. 5 (a) Original image (Piano .jpg), (b) Output of Proposed Method, (c) Output of Histogram Equalizer, (d) Output of Adaptive Histogram Equalizer

IV. DISCUSSION

The proposed method is applied on different gray-scale images to test its performance by visual inspection, at first. However, such a visual comparison is not sufficient to compare accurately all techniques.

A. *Measure of fuzziness in an image*

The linear index of fuzziness γ_1(X) define as the average amount of uncertainty or vagueness (fuzziness) present in an image X of fuzzy properties μ_X by intersection with its own complement fuzzy set properties$1 - \mu_X$ and the nearest two level property μ_x [6][7][14][15].

It can be express as follows:

$$\gamma_1(X) = \frac{2}{MN}\sum_{1}^{M}\sum_{1}^{N}\mu_{X\cap X}\,(X_{mn})$$

Or

$$= \frac{2}{MN}\sum_{1}^{M}\sum_{1}^{N}\min(\mu_X\,(X_{mn}), 1 - \mu_X\,(X_{mn})) \qquad (7)$$

Where, $\mu_x(X_{mn}) = 0$ if $\mu_x(X_{mn}) \leq 0.5$,
$= 1$ otherwise.

Above define as the amount of fuzziness is 0(zero) if all memberships are 0 or 1 and the fuzziness value is maximum when all membership values are equal to 0.5.

To quantitatively compare the enhancement techniques, the index of fuzziness to examine the percentage of fuzziness present in output enhanced image, is computed, as in Table I.

TABLE I
Comparison of Index of Fuzziness value on various images

	Original Image	Proposed Image	Histogram Equalizer Image	Adaptive Histogram Equalizer Image
Dice	0.5349	0.3091	0.6686	0.6751
Einstein	0.5082	0.3046	0.6631	0.7278
Chaplin	0.4719	0.2478	0.6654	0.6910
Piano	0.7195	0.5582	0.6649	0.6674

Thus, a reduction in the fuzziness, indicates an enhancement in an image, but at the cost of reduction in image information. Thus, an appropriate fuzziness measure indicates image enhancement, preserving the image information.

Another approach to examine the quality of enhanced image is by comparing the measure of contrast, C, computed in eq.6., on various images, as in Table II.

TABLE III
Comparison of Contrast value on various images

	Original Image	Proposed Image	Histogram Equalizer Image	Adaptive Histogram Equalizer Image
Dice	101.7517	198.0489	185.3236	129.0791
Einstein	94.3466	177.6560	168.8955	158.8142
Chaplin	62.0230	149.6619	176.4176	114.9271
Piano	68.9455	130.3761	198.3242	96.8140

An increment in the measure of contrast value clearly indicates the enhancement of the image, with respect to the contrast.

V. Conclusion

Contrast enhancement plays vital role in image processing, computer vision and pattern recognition. In this paper, we introduced new contrast enhancement method by measuring contrast of an image which is maximized to obtain a suitable crossover value. Experimental results of our proposed method produces good results by compared with other existing approaches using fuzz set theory. Moreover, proposed method rectified the problem of over-enhancement. A Straight forward future scope of this approach is to apply proposed algorithms to colour images.

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