



Adaptive Contrast Image Enhancement Based on Fuzzy Set Theory

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Abstract— Image enhancement is one of the most key issues in high quality pictures such as digital cameras and image research area. Since image clarity is very easily affected due to lighting during image acquiring, weather, or other equipment that has been used to capture the image. These conditions lead to image may suffer from poor contrast and noise . so it is necessary to enhance the contrast and remove the noise to increase image quality. The main purpose of image enhancement is to bring out detail that is hidden in an image or to increase contrast in a low contrast image. In this paper, we propose a novel adaptive fuzzy contrast enhancement technique based on the fuzzy entropy principle and fuzzy set theory for low contrast grayscale imagees. We have conducted experiments on many gray scale images of poor quality. The performances of the proposed method are compared with the other methods .The experimental results show that the proposed algorithm is very effective in contrast enhancement as well as required minimum processing time than the other methods.

Keywords— Image Enhancement, Fuzzy domain, Grayscale, Membership Function, Spatial Domain.

I. INTRODUCTION

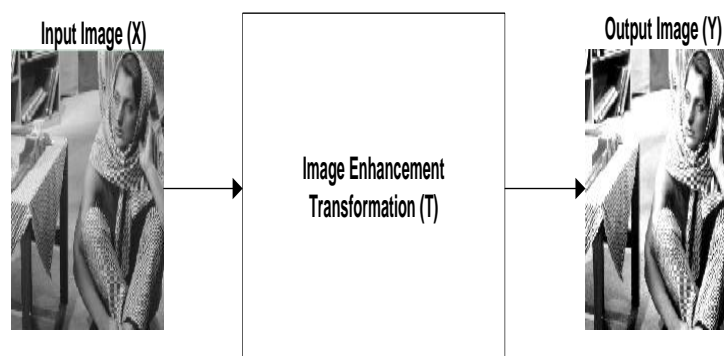
Good quality of contrast images with preserving details are required in many important areas such as machine vision, remote sensing, dynamic and traffic scene analysis, biomedical image analysis and autonomous navigation [1]. But most of the digital images suffer from poor contrast because of the inadequate lighting during image acquiring, weather, or other equipment problem such as wrong setting of aperture size and shutter speed as well as nonlinear image intensities mapping. Thus, image enhancement has been employed to increase the quality of the image. Image enhancement is a fundamental task applied in image processing to improve interpretability and appearance of the image. It provides better input image for further image processing task [2]. Image enhancement is a technique involving changes in the pixels intensity of the input image, so that the resulted image should subjectively looks better then original image [1]. The main aim of image enhancement is to improve the interpretability or visualization of information contained in the image for human observers, or to provide a “better” input for other automated image processing .

To understand to concept of image enhancement let we denote a two-dimensional digital image of gray-level intensities by I. The image I is ordinarily represented in software accessible form as an $M \times N$ matrix containing indexed elements $I(i, j)$, where $0 \leq i \leq M - 1$, $0 \leq j \leq N - 1$. The elements $I(i, j)$ represent samples of the image intensities, usually called pixels (picture elements). For simplicity, we assume that these come from a finite integer-valued range [3].

Image enhancement can be used in every field in which images are to be understood and analyzed such as machine vision, satellites images analysis , medical image analysis, etc. Image enhancement simply means that, process of transforming an image X into image Y With the help of Trasformation T so that it could be look better. The intensity of pixel (i,j) in images X and Y are denoted by $X(i,j)$ and $Y(i,j)$ respectively. As said, image enhancement process can be related by the expression,

$$Y(i, j) = T(X(i, j)) \quad \forall 1 \leq i \leq M \text{ and } 1 \leq j \leq N$$

Where T is a transformation algorithm that transform a pixel value $X(i,j)$ into a pixel value $Y(i,j)$.



Basic Image Enhancement process

In next section, we are presenting the research work of some prominent authors in the same field and explaining a short description of various techniques used for image enhancement.

II. LITERATURE REVIEW

Image enhancement can be classified into two groups namely spatial domain methods and frequency domain. Spatial domain techniques directly deal with the image pixels. The pixel values are manipulated to achieve desired enhancement. But In frequency domain methods, first of all, the image is transferred in to frequency domain. i.e., the Fourier Transform of the image is computed first. Next, all the enhancement operations are performed on the Fourier transform of the image and then finally the Inverse Fourier transform is performed to get the desired image. These operations are performed in order to modify the image contrast, brightness or the distribution of the grey levels. As a consequence the pixel value (intensities) of the output image will be modified according to the transformation function applied on the input values. However, computing the enhancement in frequency domain is time consuming process even with fast transformation technique thus made it unsuitable for real time application [4].

In last decade, there are many image enhancement methods have been proposed. A very popular technique for image enhancement is histogram equalization (HE). This technique is commonly used for image enhancement because of its simplicity and comparatively better performance on almost all types of images. The operation of HE is performed by remapping the gray levels of the image based on the probability distribution of the input gray levels. It stretches the dynamic range of the image's histogram and resulting in overall contrast enhancement [5]. Various researches have been performed on Histogram Equalization, and many methods have already been proposed. But Most of the HE techniques could cause a washed-out effect on the appearance of the enhanced image and/or amplify existing noises [2]. In addition, due to the poor and low contrast nature of the acquired image, vagueness and ambiguity are introduced and have led to the increment of uncertainty in the image information. This vagueness in the image appears in the form of imprecise boundaries and intensities during image digitization.

Therefore, fuzzy sets theory [6] has been proposed as a problem solving tool between the precision of classical mathematics and the inherent imprecision of the real world. The imprecision possessed by the acquired image can be perceived qualitatively by human reasoning. However, there is no specific quantification to describe the imprecision and thus machine may not understand them. Realizing this limitation to a great extent, fuzzy logic tools empower a machine to mimic human reasoning .

In the image enhancement field, the fuzzy set theory has been widely utilized by other researchers [1,4,7-14]. Pixel property such as gray tone intensity is modeled into a fuzzy set using a membership function. The image is considered as an array of fuzzy singletons having a membership value that denotes the degree of belonging to specific property.

In 2000 H.D. Cheng et.al [7], proposed a novel adaptive direct fuzzy contrast enhancement method, sigmoidal membership function is used to map an image from spatial to fuzzy domain. The resultant image obtained is properly enhanced. When transforming the image from one color space (RGB) to another color space (HSV, HIS, YIQ) hue is unaltered only the intensity and saturation components are changed, as a result gamut problem will occur. So in [8], S.K.Naik tried to keep the transformed values within the range of the RGB space so as to avoid the gamut problem. although the image is enhanced, the clarity of the enhanced image is not good.

In 2006 Madasu Hanmandlu, and Devendra Jha [4] proposed that Gaussian membership function to fuzzify the image information in spatial domain. They introduce a global contrast intensification operator (GINT), which contains three parameters, viz., intensification parameter , fuzzifier, and the crossover point , for enhancement of color images. They define fuzzy contrast-based quality factor and entropy-based quality factor and the corresponding visual factors for the desired appearance of images. By using the proposed technique, they observed a visible improvement in the image quality for under exposed images, and the entropy of the output image is decreased.

In 2009 Madasu Hanmandlu. et.al [9] presented a new approach for the enhancement of color images using the fuzzy logic technique. To provide an estimate of the underexposed and overexposed regions in the image , an objective measure called exposure has been defined. This measure serves as the dividing line between the underexposed and overexposed regions of the image. For the process of enhancement , The hue, saturation, and intensity (HSV) color space is employed. The hue component is preserved to keep the original color composition intact. For the enhancement of the luminance component of the underexposed image, a parametric sigmoid function is used. A power-law operator is used to improve the overexposed region of the image, and the saturation component of HSV is changed through another power-law operator to recover the lost information in the overexposed region. In 2011 Gang Li et.al [10] proposed image enhancement operation that used the value of grey entropy in the neighborhood window as parameters to measure the level of current pixel being edge point . This paper described a fuzzy mapping based on translation transformation, which can increase the stability of the algorithm; making use the grey entropy of pixels in neighborhood to judge the level of edge for pixels, the dynamic adaptive selection of central point of neighborhood in fuzzy contrast enhancement was achieved, and can increase the local gray contrast of the image, rich the texture layer of the image ,improve the quality of the image , make it more adaptive for further treatment and analysis. In 2012 Khairunnisa Hasikin and Nor Ashidi Mat Isa [11] presented a fuzzy grayscale enhancement technique for low contrast image. Most of the developed contrast enhancement techniques improved image quality without considering the nonuniform lighting in the image. Here, the fuzzy grayscale image enhancement technique is proposed by maximizing fuzzy measures contained in the image. Then, to enhance the image, membership function is modified by using power-law transformation and saturation operator..

Image enhancement algorithms offer a wide variety of approaches for modifying images to achieve visually acceptable images. The choice of such techniques is a function of the specific task, image content, observer

characteristics, and viewing conditions. In this section, a survey on various techniques for image enhancement. Our paper presents an enhancement technique for low contrast grayscale image. The paper first, transforms the gray scale image from spatial domain to fuzzy domain, then maximizes the fuzzy measures contained in the image by using the membership. And finally, defuzzification is applied that transforms the gray scale image from modified fuzzy domain back to spatial domain.

The paper is organized as follows: Section III-VI describes the proposed work implementation and algorithm which describes the method that we have defined for image enhancement. Section VII Shows experimental results of proposed method and comparison with other image enhancement Methods. Section VIII Describes the conclusion and future work of proposed method.

III. PROPOSED METHOD

The main purpose of this paper is to enhance the contrast of gray scale image in fuzzy domain effectively by minimizing fuzziness in the image without requiring complex procedure and long computational time. The first step is to map an image from spatial domain to fuzzy domain using the S-function as the membership function. Then we propose a more powerful and adaptive fuzzy contrast enhancement method that transforms image from fuzzy domain back to the spatial domain. The proposed approach employs fuzzy entropy principle and fuzzy set theory. It can automatically determine the related parameters according to the nature of the image.

Image in fuzzy set notation

The original image of size $M \times N$ has intensity levels $x_{i,j}$ in the range of $[0, L-1]$ can be considered as an array of fuzzy singletons in the fuzzy set notation. Each element in this array is the membership value representing the degree of brightness of the gray level. In the fuzzy set notation, we can write

$$X = \bigcup \{ \mu(x_{i,j}) \} = \{ \mu_{i,j} / x_{i,j} \quad i = 1, 2, \dots, M \text{ and } j = 1, 2, \dots, N \}$$

where $\mu(x_{i,j})$ denotes the degree of brightness possessed by the gray level intensity of the (i,j) th pixel.

Fuzzification

Membership function characterizes the fuzziness in a fuzzy set. The membership function of a fuzzy set maps all the elements of the set into real numbers in $[0, 1]$.

The most commonly used membership function for a gray level image is the S-function defined as

$$\mu(x_{ij}) = \begin{cases} 0 & \text{for } x_{ij} \leq a \\ \frac{x_{ij}-a}{(b-a)(c-a)} & \text{for } a < x_{ij} \leq b \\ 1 - \frac{(x_{ij}-c)^2}{(c-b)(c-a)} & \text{for } b < x_{ij} \leq c \\ 1 & \text{for } x_{ij} \geq c \end{cases}$$

Where $x_{i,j}$ is the intensity of the image and a, b and c are parameters that determined the shape of the S-function.

Calculation of parameters a, b and c are follows as:

Assume the image has gray levels from L_{min} to L_{max} .

- Calculate the histogram $Hist(x)$.
- Divide the Histogram into 16×16 matrix.
- Find the maxima of the histogram column wise, $Max(Hist(x_1)), Max(Hist(x_2)), \dots, Max(Hist(x_k))$.
- Calculate the average height of the local maxima.
- $\overline{Hist_{max}(X)} = \frac{1}{k} \sum_{i=1}^k Hist_{max}(X_i)$
- Select a local maximum as a peak if its height is greater than the average height $\overline{Hist_{max}(X)}$ otherwise, ignore it.
- To determine the value of parameter a and c , select the gray level of first peak $P(x_1)$ and the last peak $P(x_k)$ that is, $a = P(x_1)$ and $c = P(x_k)$;
- Determine parameters b the midpoint of the interval $[a, c]$.

The calculated membership function transformed the image intensity levels from the spatial domain to fuzzy domain.

Defuzzification

To make the contrast enhancement more adaptive and more effective and to avoid over-enhancement/under-enhancement, adaptive fuzzy contrast enhancement defuzzification is applied that transforms the membership value $\mu(x_{ij})$ to the gray level by using the following formula:

$$X_{ij} = \begin{cases} L_{\min} & \mu(X_{ij})=0 \\ L_{\min} + \frac{L_{\min} - L_{\max}}{c-a} \sqrt{\mu(X_{ij})(b-a)(c-a)} & 0 < \mu(X_{ij}) \leq \frac{(b-a)}{(c-a)} \\ L_{\min} + \frac{L_{\min} - L_{\max}}{c-a} (c-a - \sqrt{1 - \mu(X_{ij})(b-a)(c-a)}) & \frac{(b-a)}{(c-a)} < \mu(X_{ij}) < 1 \\ L_{\max} & \mu(X_{ij})=1 \end{cases}$$

It is known that the gray levels of the image are heap near the maximum gray level and minimum gray level for overexposed and underexposed regions respectively.

III. Proposed Algorithm

Input : An image X of size M*N having gray levels ranging from Lmin to Lmax
Output: An Enhanced image Y of size M*N having gray levels ranging from Lmin to Lmax

Procedure:

/*Obtain the histogram */

Z= hist(X);

/* Reshape the Histogram to 16*16 matrix*/

Zmf =reshape(Z,[16 16]);

/* Find the local maxima of the histogram */

For i=1 to 16

ZLM(i)=Max((Zmf(i));

End

/*Calculate the average height of the local maxima */.

$$Z_{\max} = \frac{1}{k} \sum_{i=1}^k Z_{LM}(i)$$

/*Select a local maximum as a peak if its height is greater than the average height Z_{\max} otherwise, ignore it */.

For i=1 to 256

If (Z(i) > Z_{\max})

P(i)=i ;

end

end

/* To determine the value of parameter a and c, select the gray level of first peak P(x1) and the last peak P(xk) that is,*/

a=P(x1) ;

c=P(xk);

/* Determine parameters b the midpoint of the interval [a, c]*/.

b=(a+c)/2;

/*Initialize μ (i, j), which stores the enhanced membership value */

for i=0 toM-1

for j=0 to N-1

μ [i][j]=0;

end

end

/* Mapping an image into fuzzy domain */

for i=0 toM-1

for j=0 to N-1

$\mu(x_{ij}) = s(x; a, b, c);$

end

end

/* Defuzzification */

for i=0 toM-1

```

for j=0 to N-1
     $X'_{ij} = T(\mu(x_{ij}) : a, b, c)$ 
/* where T is a defuzzification method defined in Eq. (3).*/
end
end

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IV. Proposed Block Diagram:

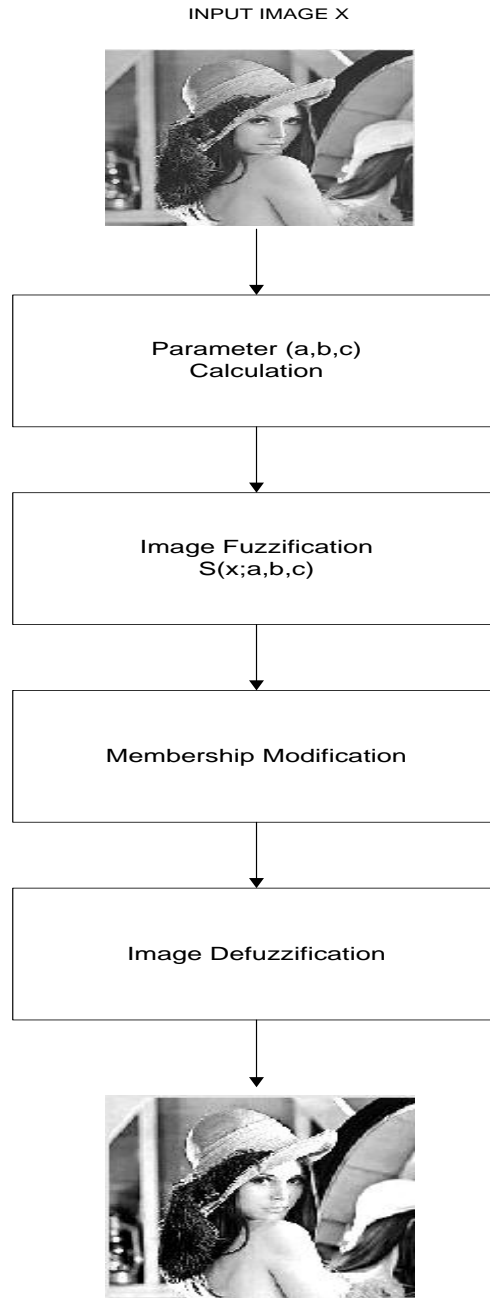


Fig. 1. Block diagram of the proposed image enhancement system working

V. Implementation

This chapter includes detail of the process to fuzzy image enhancement and their location. All the work has been implemented in MATLAB 7.8. MATLAB is a software package developed by Math Works. It integrates computation, visualization and programming in easy to use environment. MATLAB toolbox allows learning and applying specialized technology. Areas in which toolbox are available include signal processing, image processing, control system, neural networks, fuzzy logic, wavelets, simulation, and many others. Many research have done on fuzzy the fuzzy and image enhancement. General working of our system is explained below:

Step1: System starts by running the main program i.e. fuzzy_Enhancement.m, by typing the filename at command window of matlab or by simply click on run command in matlab shown in figure 3.

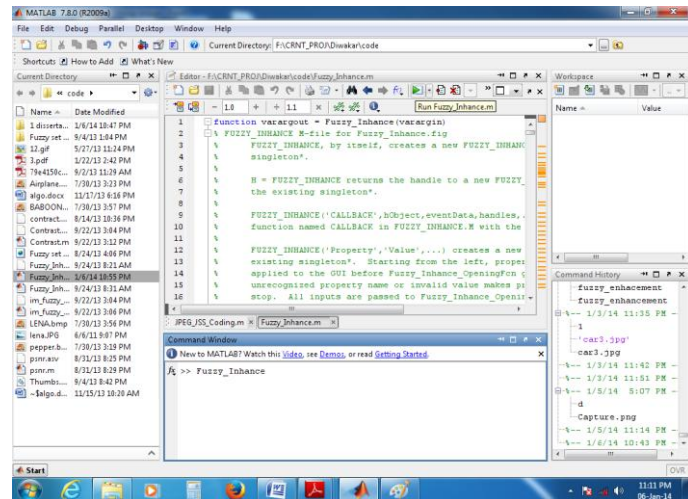


Fig. 2. Image depicts default position of our system using MatLab

Step2: After running the fuzzy_enhancement.m program, a GUI of our system will be appeared As shown in figure 4.

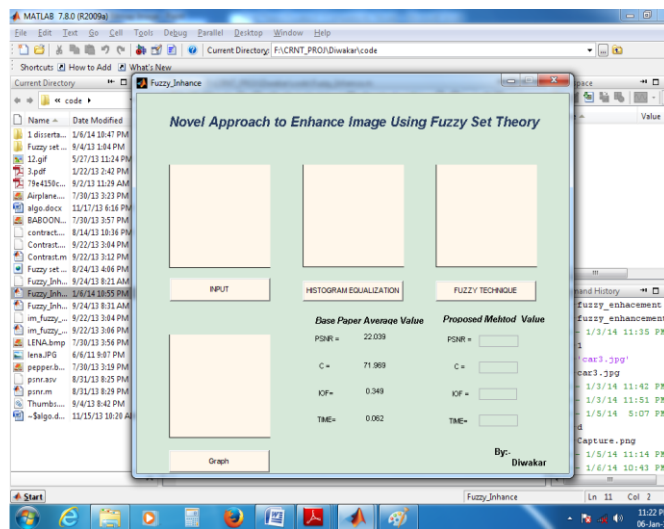


Fig. 3. Image depicts GUI interface of proposed system

Step3: As we click on the input button, a dialog box will appear where we select a gray image that is to be enhance from the image database. This process is illustrated in figure 5.

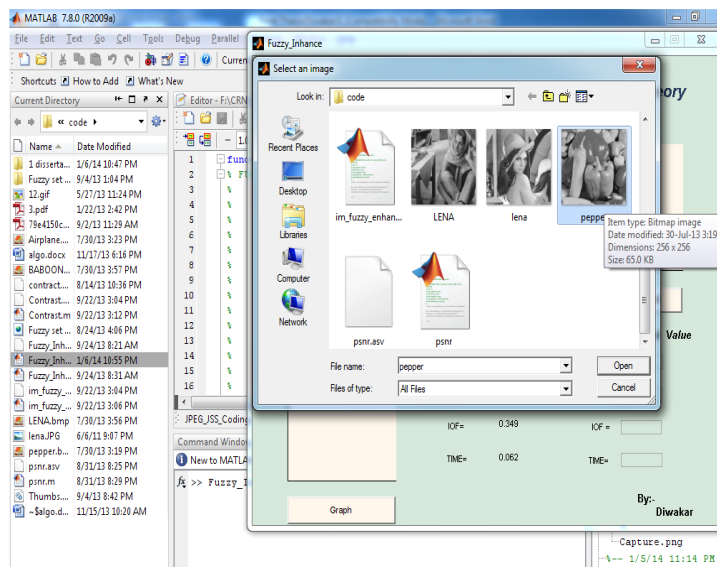


Fig. 4. Selection of individual image that is to be Enhanced by Proposed System.

Step4: As we select image X, then step by step the image Enhancement operations is performed. Finally we get the result as shown in figure 6.

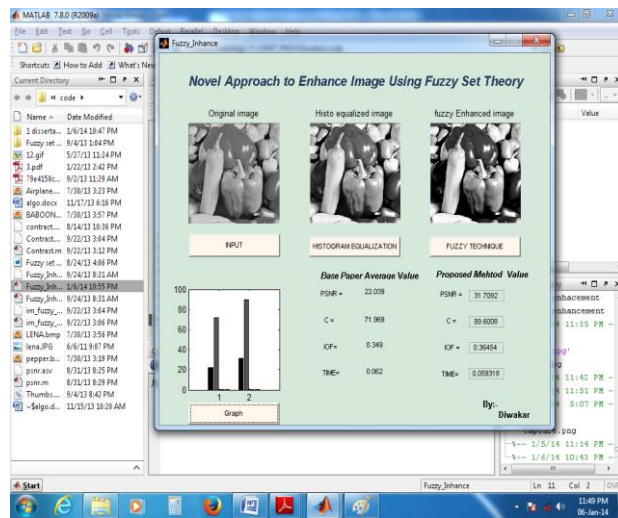


Fig. 5. Result after Enhancement End of our proposed System.

VI. Performance Analysis

The proposed method has been implemented on Intel Core 2 CPU 2GHz using Matlab R2009b. 100 standard images of various size obtained from California Institute of Technology database which consist of underexposed and overexposed regions are considered as test images. The enhanced image is tested in terms of its output quality and quantitative analysis such as index of fuzziness (IOF), peak signal to noise ratio (PSNR) and processing time. In order to demonstrate the performance of the proposed method, we compared qualitatively and quantitatively the experimental results of the proposed approach with other state of the art methods namely fuzzy set theory [1], conventional approach of NINT [6], application of fuzzy IF-THEN rules (fuzzy rule-based) [12], fuzzy quantitative measure [13] and fuzzy local enhancement [14], are widely used in image enhancement.

The enhanced images produced by the proposed methods are presented in Fig.7 to 11. For the subjective qualitative analysis of processed image appearance, the test images namely 'Lena', 'House', 'Man', 'Traffic' and 'Bycycle' are shown in these figures. The original images have poor brightness in the underexposed regions and brightness is higher in the overexposed regions.

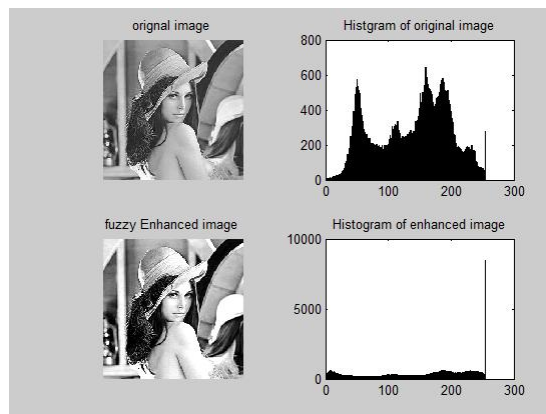


Fig. 6. (a) original image (Lena) and its Histogram, (b) enhanced image by proposed method with its Histogram

Fig. 7.

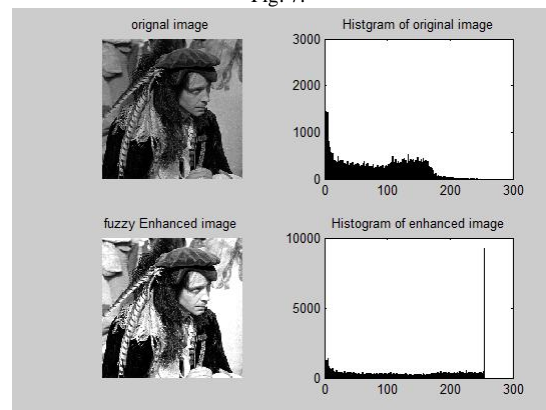


Fig. 8. (a) original image (Man) and its Histogram, (b) enhanced image by proposed method with its Histogram

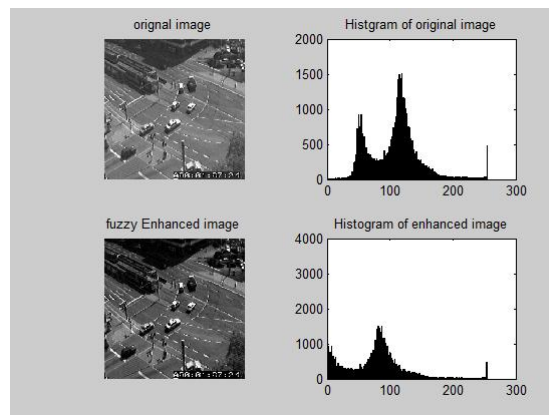


Fig. 9. (a) original image (traffic) and its Histogram, (b) enhanced image by proposed method with its Histogram

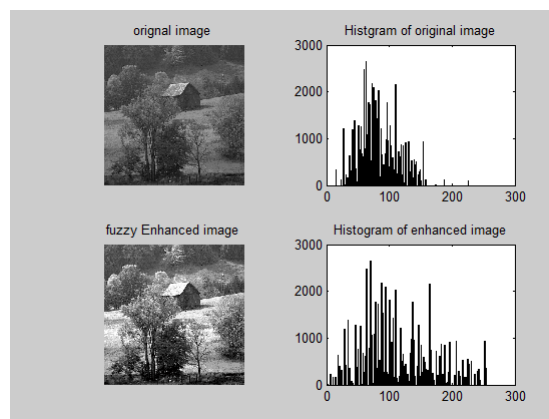


Fig. 10. (a) original image (House) and its Histogram, (b) enhanced image by proposed method with its Histogram

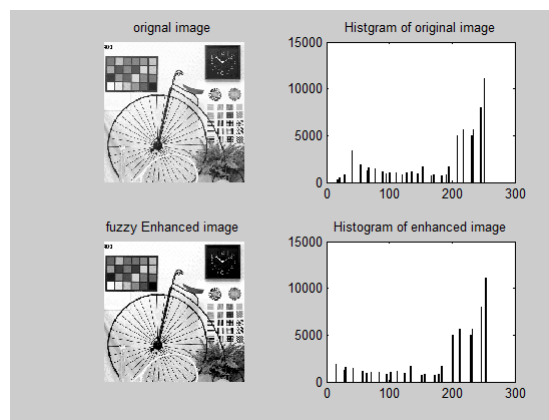


Fig. 11. (a) original image (Bicycle) and its Histogram, (b) enhanced image by proposed

The qualitative analysis presented in the Figures 1 to 4 can be supported by quantitative analysis presented in TABLE I. The average analysis for 20 standard images of proposed method, NINT, fuzzy rule-based, fuzzy quantitative analysis and fuzzy local enhancement presented in TABLE I are discussed. For each analysis, the best results obtained are made bold.

TABLE I indicates that the proposed method has the best performances in terms of smallest IOF, highest PSNR and obtained good contrast. However, in terms of the average execution time, NINT has the fastest processing time because NINT is less complex and treated the whole image as mixed region without considering overexposed and underexposed regions.

TABLE I. QUANTITATIVE ENHANCEMENT ANALYSES FOR 100 STANDARD IMAGES (AVERAGE VALUES)

Method\Analysis	Processing Time T(s)	C	IOF	PSNR (dB)
Proposed Method	0.031	93.25	0.334	31.63
Fuzzy Set Enhancement	0.062	71.969	0.349	22.039
NINT	0.050	88.391	0.443	13.947
Fuzzy rule-based	11.921	78.793	0.367	19.096
Fuzzy Quantitative	0.063	82.654	0.410	15.417

Measure				
Fuzzy Local	11.163	81.929	0.584	19.063

Fig.12 shows the computational time of the proposed method with other enhancement methods. Fig.13 to fig 15 shows comparison graph among proposed method and other enhancement methods with respect to the C, IOF, PSNR respectively.

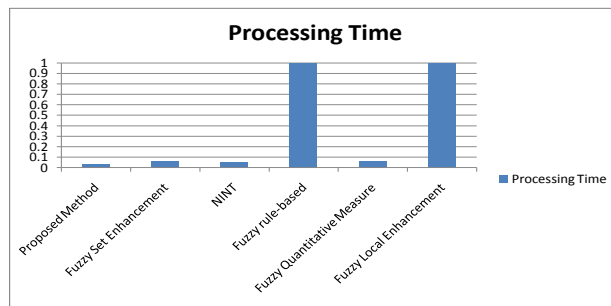


Fig. 12. The Execution Time(sec) comparison of Our proposed Method with other existing method

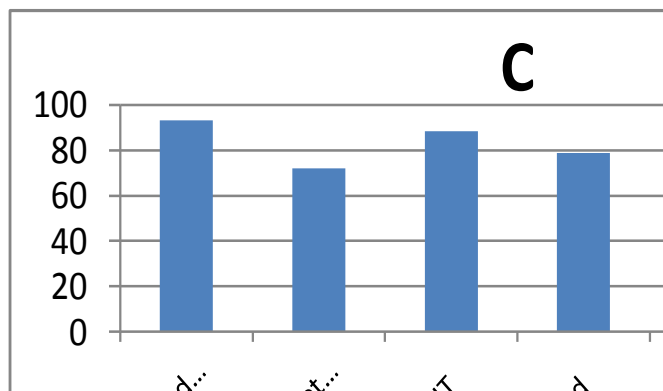


Fig. 13. The comparison graphs among Our proposed Method and other existing method against parameter C

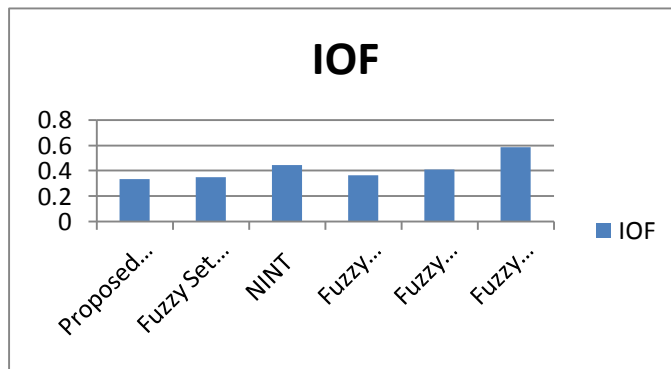


Fig. 14. The IOF comparison of Our proposed Method with other existing method

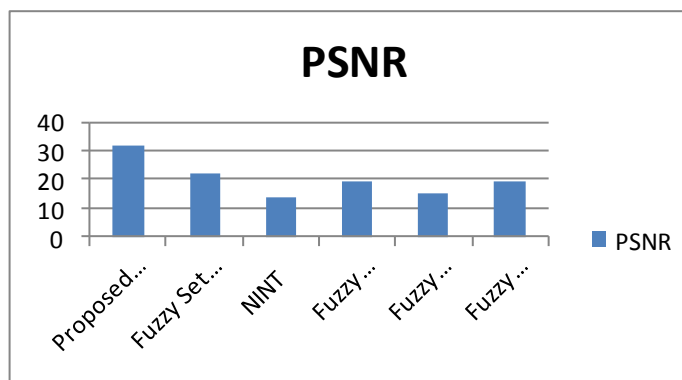


Fig. 15. The PSNR comparison of Our proposed Method with other existing method

VII. Conclusion

In this paper one membership function is defined to enhance the image and algorithm is proposed. The proposed algorithm is implemented in MATLAB 7.8. This proposed algorithm is able to overcome the drawbacks of spatial domain methods like thresholding, histogram equalization and frequency domain methods. This algorithm is able to get good contrasted image which increases the brightness of the low contrasted images. This algorithm is tested on different type of images. The experimental result shows that the brightness is increased as compared to previous one. Future work can be extended for other images then grayscale images to obtain better result with accuracy.

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