ISSN:0975-9646

A Novel Fuzzy Image Enhancement using S-Shaped Membership Function

Pushpa Devi Patel[#1] , Prof. Vijay Kumar Trivedi[#2], Dr. Sadhna Mishra[#3]

[1] *M. Tech (CSE Dept.) LNCT, Bhopal*
[2] *Asst. Prof. (CSE Dept.) LNCT, Bhopal*
[3] *Professor (CSE Dept.) LNCT Bhopal*

***Abstract*-Image enhancement is a process of improving the quality of image by improving its feature. Contrast enhancement is one of the challenging and interesting areas of image processing. Image enhancement plays a vital role in aerial image, medical images, even real life photographs, all these suffers from poor contrast. But the problem of existing contrast enhancement techniques are over-enhancement and under-enhancement and it can be rectified by using S-Shaped function of fuzzy set theory. So in this paper we proposed a new fuzzy image enhancement algorithm, which maps elements from image pixel plane to fuzzy plane using ramp function and to transformed plane by using fuzzy S-Shaped membership function. Performance metrics proves the improvement over other existing fuzzy technique of contrast enhancement.**

Keywords-Contrast enhancemen, Fuzzy sets, S-Shaped function, Fuzzy Image Enhancement, Over-enhancement.

I. INTRODUCTION

Image enhancement is a process of improving the quality of image by improving its feature. Image enhancement is a method of digital image processing which processes the digital image. Image enhancement includes contrast and edge enhancement, feature sharpening and noise filtering and so on. Among these technique contrast enhancement is important because human eyes are more sensitive to the luminance than to the chrominance/color component of an image. Principle of contrast enhancement is to improve the visual appearance of the image without introducing unwanted effects and artefacts. Various images like medical images, aerial images, satellite images, traffic scene analysis and even real life photographs may suffer from noise and poor contrast due to the inappropriate lighting during image acquisition and/or wrong setting of aperture size and shutter speed of a camera, so it is necessary to enhance the contrast and remove the noise to increase image quality. Application area of image enhancement ranges from medical images to real life photography. Contrast enhancement is one of the challenging and interesting areas of image processing.

Contrast enhancement techniques are categorized as spatial domain based enhancement and frequency domain based enhancement. Spatial domain image enhancement techniques directly work on the pixel elements of the image for enhancing purpose whereas frequency domain image enhancement works on the fourier transform of the image. Histogram equalization and histogram modification [1] are popular approach in spatial domain based image enhancement. As poor contrast image occupies only small range of the available grey levels so using histogram equalization technique grey level values are uniformly distributed.

Contrast can also be measured locally and globally. Local contrast measurements are more appropriate to define when image contains textural information. Dhnawal et al. [2] proposed local contrast enhancement function in terms of the relative difference between a larger surrounding area and central region of a given pixel element. And then contrast values are enhanced by using contrast enhancement functions such as square root function, exponential function and trigonometric function. However these methods are more efficient and powerful than that of indirect methods but may enhance noise and may lose the details for a large neighbourhood [3]. Laxmikant Dash and Chatterji [4] proposed an adaptive contrast enhancement technique in which contrast is enhanced with less noise amplification.

Because of the ability to handle and manage the imprecision encountered with images effectively, applying fuzzy set theory becomes a strong in road image processing areas like contrast enhancement. It is believed that fuzzy set theory is a universal tool for handling the uncertainty associated with imprecision, imperfectness, and/or vagueness. Fuzziness in the images comes due to the following reasons: ambiguity in defining the edges, boundaries, feature and regions, ambiguity in interpreting low-level image processing results. Moreover the contrast of the image is also on fuzzy nature. Hence, the fuzzy set theory can be applied to contrast enhancement. Many research works are still going on in this area to make improvements in the existing techniques [5, 6]. Use of intensification operator makes a boom in the field of enhancement of images [6]. Though, fuzzy set theory has been successfully employed to image processing and pattern recognition [7]. Approach in [8] uses modified algorithm of Ref. [6] to enhance image without using INT operator. They used to reduce the value of F_e for enhancing the image. Simple rule based approach to increase the contrast of the medical images [9]. An adaptive approach of contrast enhancement with S-membership function is used for fuzzification in [10]. Some contrast enhancement are developed using Gaussian membership function and for modification of property plane they used general intensification operator (GINT) [11]. They convert RGB color space to HSV color space to resolve gamut color problem. Other fuzzy based techniques that use partial histogram of the image [12]. Khairunnisa Hasikin [13] used S-function for fuzzification and power law transformation and saturation operator for modifying property plane of the input image. Reshmalkshmi C. [14] used logarithmic function for fuzzification and trigonometric function for property domain modification problem with this technique is over-enhancement of the images.

Rest of the paper is organized as follows. Section II describes briefly about Fuzzy set theory and fuzzy image processing. Proposed methodology is described in Section III. Description about experimental setup and evaluation metrics are presented in section IV. In section V result analysis of proposed approach is given and finally section VI concludes the proposed approach and gives its future scope.

II. FUZZY SET THEORY

Fuzzy set theory is a mathematical tool for handling imprecision or vagueness [15, 16]. A particular problem that is to be solved is represented in the form of human language can be solved easily with the help of fuzzy sets. So the extension of classical set theory-'Fuzzy set' becomes robust and flexible.

In a fuzzy set value are in the interval 0 to 1 rather than 0 or 1 as in the case of classical set. This varying degree of membership shows the degree of possessiveness of elements to its fuzzy set or simply it shows the fuzziness and is known as membership function. Depending on the values, these functions are classified as Gaussian, triangular, exponential, polynomial etc. Selection of particular function is user defined.

Let X= $\{x_1, x_2, ... x_n\}$be the universal set, a fuzzy set A defined as ordered pair:

$$A = \{\mu_A(x_i), x_i\} \quad (1)$$

where the membership function $\mu_A(x_i)$ having positive values in the interval (0, 1) denotes the degree of an element x_i may be a member of fuzzy set A.

A. Fuzzy Image Processing (FIP)

Ability to represent the concept of partial truthness, makes fuzzy suitable for image processing. Even if solution for solving a particular problem is not clear, fuzzy set can easily manage if that solution can be represented in the form of linguistic terms. Main steps in fuzzy image processing [15] are:

1. Fuzzification
2. Inference Engine
3. Defuzzification

Fuzzification is nothing but assigning required membership function to map images from pixel plane to fuzzy plane. For an 8x8 image of pixel value 0-255 becomes 0 to 1 to represents the fuzziness of pixels. In the fuzzy plane, with the help of enhancement / transform operator, images can be modified to get better ones. This plane is sometimes called inference plane. In the defuzzification plane, images from fuzzy plane are taken back to pixel plane with inverse transform. Fig. 1 shows the block diagram of FIP [15].

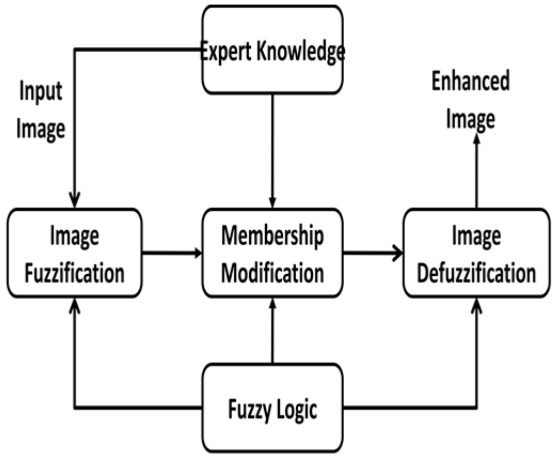

Figure 1: Fuzzy Image Processing

B. Fuzzy Image Plane

For any image processing application images from pixel domain are taken and converted into fuzzy domain. Let X be an image of size M×N, and X(i, j) represents the intensity element or simply pixels which has to be mapped to fuzzy characteristic plane. Image X can be expressed as follows:

$$X = \{\mu_{X(i,j)}, X(i,j)\} \ i = 1..M \text{ and } j = 1..N \quad (2)$$

Here $\mu_{X(i,j)}$ represents membership degree of each element between zero and one, and X(i, j) is $(i, j)^{th}$ pixel values, of the input image. So in the fuzzy image plane representation, pixel values between 0 to 255 are mapped between 0 to 1. Different transformation functions are applied in this plane to enhance the image.

III. PROPOSED METHODOLOGY

The main objective of this paper is to enhance the contrast of the image in fuzzy domain using S-Shaped function to avoid over-enhancement and under-enhancement problem of existing methods those used half-open or trigonometric function for enhancement.

We proposed a new approach to enhance the contrast of the image in such a way so that the image neither under-enhanced nor over-enhanced. Flowchart of proposed approach is given in Fig 2. Detailed procedure contains following steps.

A. Fuzzification of Spatial Domain

Fuzzification is the process of converting the grey scale values of spatial domain to the fuzzy or property domain i.e. crisp values between $L_{min}(0)$ to L_{max} (255) are converted into fuzzy values between 0 to 1. Here we used the ramp function given in eq. 3, for the conversion of spatial domain into the fuzzy domain.

$$\mu_{X(i,j)} = \frac{X(i,j)}{L_{max}} \qquad i = 1 \ldots M \quad j = 1 \ldots N \qquad (3)$$

Algorithm 1: Parameters calculation of S-Shaped function. Assume the input image X has grey level range between L_{min} to $L_{max.}$ Detailed procedure of calculation a, b, c parameters are as follows:

Step 1: Parameter a is calculated by entropy of the image.

a=entropy(X)

Step 2: Parameter b is calculated using median value of input image X:

b=median(X)

Step 3: Parameter c is calculated as:

i. Calculate max of the input image

C1=max(X)

ii. Calculate mean of the input image

C2=Mean(X)

iii. Find c as mid of the max and mean calculated in above step:

c= (C1+C2)/2

Since all the values are between 0 to 255, so we have to normalize calculated parameters values between 0 to 1.

B. Modification of Fuzzy Plane

For contrast enhancement, fuzzy modification is performed. Here we used S-Shaped membership function for the contrast enhancement. The S-Shaped function takes three parameters as input and produces the modified membership plane or property plane. The S-shaped membership function is given in eq. 4. By using S-Shaped membership function the shape of the input image is modified i.e. fuzzy domain values are modified.

$$\mu'_{X(i,j)} = S(\mu_{X(i,j)}; a, b, c) = \begin{cases} 0 & 0 \le \mu_{X(i,j)} \le a \\ \dfrac{(\mu_{X(i,j)} - a)^2}{(b-a)(c-a)} & a < \mu_{X(i,j)} \le b \\ 1 - \dfrac{(\mu_{X(i,j)} - a)^2}{(c-b)(c-a)} & b < \mu_{X(i,j)} \le c \\ 1 & \mu_{X(i,j)} \ge c \end{cases} \quad (4)$$

C. Defuzzification of Fuzzy Plane

To make contrast enhancement more adaptive and more effective, and to avoid the problem of over-enhancement or under-enhancement, adaptive fuzzy contrast defuzzification is applied. Defuzzification is a process of gaining back the grey level values from the fuzzy plane. Inverse S-function is given in eq. 5. By using inverse S function fuzzy values between 0 to 1 are converted into the spatial domain values i.e. between 0 to 255.

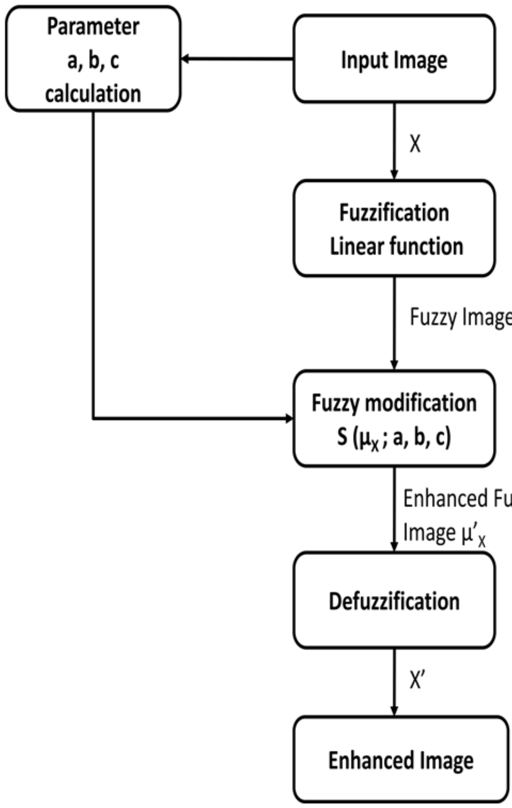

Figure 2: Flow Chart of the Proposed Algorithm

IV. EXPERIMENTAL SETUP

The proposed method has been implemented on Intel Core 2 CPU 1.47 GHz using MATLAB R2009a. Various low contrast images of 256×256 size are taken in our proposed approach as input image. Image that we have taken as input image are low contrast image and grey tone image shown in Fig 3.

$$X' = \begin{cases} L_{min} & \mu'_{X(i,j)} = 0 \\ \dfrac{L_{max}}{c-a}\sqrt{\mu'_{X(i,j)}(b-a)(c-a)} & 0 < \mu'_{X(i,j)} \le \dfrac{(b-a)}{(c-a)} \\ \dfrac{L_{max}}{c-a}\left(c - a - \sqrt{1 - \mu'_{X(i,j)}(c-b)(c-a)}\right) & \dfrac{(b-a)}{(c-a)} < \mu'_{X(i,j)} < 1 \\ L_{max} & \mu'_{X(i,j)} = 1 \end{cases} \quad (5)$$

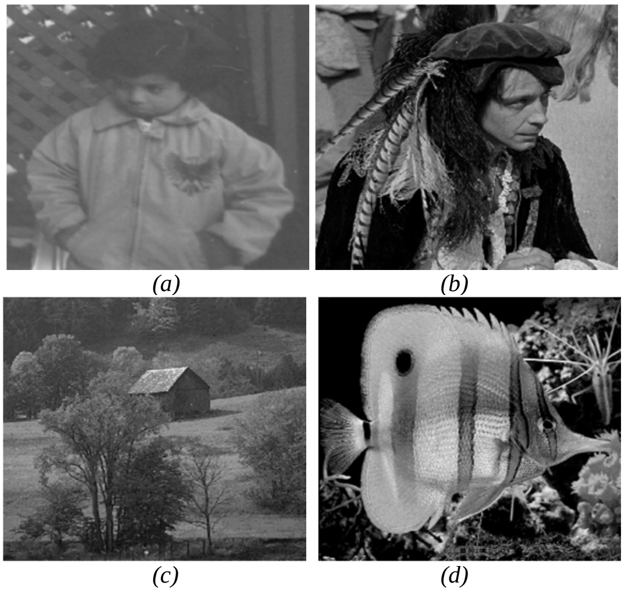

Figure 3: Input Images of 256×256 size namely (a) Image 1 (b) Image 2 (c) Image 3 (d)Image 4.

A. Evaluation Metrics

Several parameters are to be considered for the perceptive contrast enhancement evaluation. However some contrast enhancement methods were introduced earlier to model the human perceptive system, such as luminance changes, which includes Michelson law, Weber law and Power law [1]. Performance evaluation can be subjective and objective as well. Subjective parameters are discussed in the [17]. Subjective measures are based on the human perceptive system. These measures include amount of artefacts, edge enhanced and similarity etc. To evaluate the performance of proposed method following parameters are considered:

i) Measure of Entropy (ME)

This parameter is a statistical measure of randomness present in the image used to characterize the texture of the image. Entropy is calculated using the Shannon's entropy law. It is said that higher the entropy more information is present. So when entropy is high means that enhanced image is highly contrasted. Entropy can be defined as:

$$\mathrm{ME} = -\sum_{i=1}^{L_{max}} P_i \log_2 P_i \qquad (6)$$

where p is the histogram count of the enhanced image. Entropy of the original image and enhanced image should not differ too much.

ii) Peak Enhanced to Original Image Ratio (PEOIR)

Commonly used objective metric to check the quality of the image is a peak enhanced to signal noise ratio and Mean Squared Difference (MSD) [1]. Peak enhanced to signal noise ratio is often abbreviated as PSNR (Peak signal to noise ratio) or PEOIR. PEOIR is measured in dB and denoted as:

$$\mathrm{PEOIR} = 10\log_{10}\left(\frac{L_{max}^{\;2}}{\mathrm{MSD}}\right) \qquad (7)$$

$$\mathrm{MSD} = \frac{1}{mn}\sum_{i=1}^{m}\sum_{j=1}^{n}(X_e - X_o)^2 \qquad (8)$$

Where L_{max} is the maximum intensity of the enhanced image, X_e is the enhanced image and X_o is the original image. In order to achieve highly contrasted image, the intensity difference between both the enhanced and original image should be high. Hence the quality of the processed image will be high for high values of MSD, which means that large difference between the intensities of the enhanced and original image. Therefore PEOIR must be small for high values of the MSD. But PEOIR should not too low because it causes over-enhancement.

iii) Measure of Luminance Index(MLI)

Measure of Luminance index is used as a measure of intensity. This metric is a similarity based approach and it is defined as the ratio between the mean of enhanced image X_e and mean of original image X_o. For a high quality of enhanced image MLI must be high. It is calculated as:

$$\mathrm{MLI} = \frac{\mathrm{MI}(X_e)}{\mathrm{MI}(X_o)} \qquad (9)$$

$$\mathrm{MI} = \sum_{i=1}^{m}\sum_{j=1}^{n} X(i,j) \qquad (10)$$

iv) Measure of Contrast Index (MCI)

It is similar to luminance index, measure of contrast index is a ratio between contrast of the enhanced and original image. Here contrast is defined as the standard deviation of the image σ(X). Contrast index and standard deviation are calculated as:

$$\sigma(X) = \sqrt{\frac{1}{mn-1}\sum_{i=1}^{m}\sum_{j=1}^{n}(X(i,j) - \mathrm{MI})} \qquad (11)$$

$$\mathrm{MCI} = \frac{\sigma(X_e)}{\sigma(X_o)} \qquad (12)$$

Where X_e and X_o are enhanced and original images respectively. A good contrast image should have high value of the MCI but not too much high because it causes over-enhancement.

V. RESULT ANALYSIS

A new approach to contrast enhancement without over-enhancement, produces better results than other existing algorithms using fuzzy technique. Evaluated values obtained after applying proposed method for various images in Fig. 3 is given in Table 1.

In order to evaluate the performance of the proposed algorithm, we compared the experimental results of proposed method with Pal-King [5], Modified Pal-King [6], and R. Laxmi C [14].

TABLE 1

AVERAGE VALUES OBTAINED BY PROPOSED APPROACH

Images	Criterions				
	ME	*PEOIR*	*MI*	*MLI*	*MCI*
Fish	4.9599	13.6683	133.3156	1.4541	1.2143
Man	6.4695	13.7505	116.9103	1.5026	1.268
Home2	6.1210	13.5778	132.7202	1.5852	1.3038
Boy	5.7238	13.1402	164.9529	1.8132	1.2519
Average	**5.81855**	**13.5342**	**136.9748**	**1.5887**	**1.2595**

The improvement contributed by proposed method is measured by using various evaluation metrics which are defined in this paper. And its values are listed in the Table 2 for image1shown in Fig. 3(a) taken as input for comparison with other existing methods using fuzzy technique.

TABLE 2

COMPARISON OF VARIOUS METHODS FOR IMAGE

Criterions	Methods				
	Original Image	*Pal-King [5]*	*Modified Pal-King [6]*	*C. Laxmi R. [14]*	*Proposed Method*
ME	5.7599	4.02	4.37	5.4472	**5.7238**
PEOIR	Inf	18.92	20.4450	11.371	**13.1402**
MI	110.3037	69.27	82.59	121.9249	**164.9529**
MLI	1	.45	.74	1.1054	**1.8132**
MCI	1	.891	.8118	1.0896	**1.2519**

Enhanced images produced by Pal-king and Modified Pal-King have entropy (ME) less than that of original image. But entropy should not be less than that of original image as high entropy shows more information in the image. Our proposed method obtained entropy similar to that of original input image.

PEOIR achieved by our proposed is 13.1402 for image 1. R. Laxmi C.[14] produced higher MSD that cause over-enhanced image that is low PEOIR. Our proposed algorithm produced good contrast image when measure in term of PEOIR. We have also achieved high MLI and MI these are similarity based measure. For a good quality image MLI should be high and our technique achieved 1.8132. MCI should be high but not to be very high. We have also achieved good MCI similarity based measure. Enhanced images produced by other existing approaches and proposed approach are shown in Fig 4.

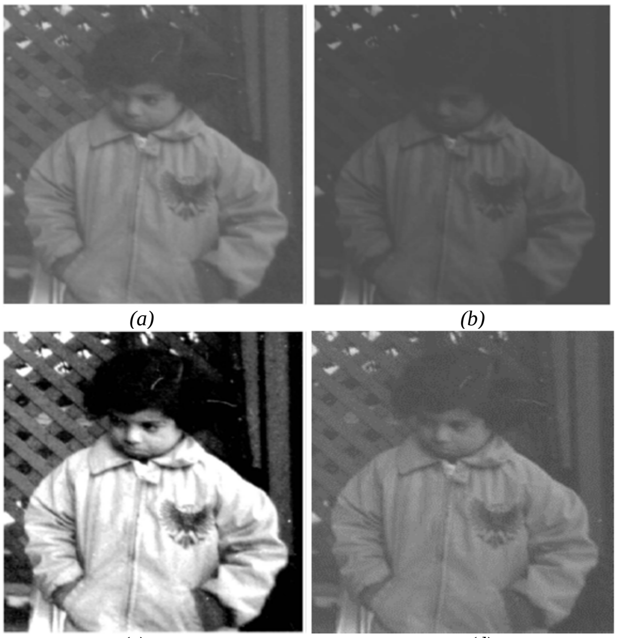

Figure 4: Enhanced images by: (a) Pal-King [5](b) Modified Pal-King[6] (c)R. laxmi C. [14] (d) Proposed approach

VI. CONCLUSION

Contrast enhancement plays vital role in image processing, computer vision and pattern recognition. In this paper we introduced new contrast enhancement method using fuzzy S-shaped membership function. Experimental results of our proposed method produces good results 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 color images.

REFERENCES

[1] Gonzalez R. C. and Woods R. E., *Digital Image Processing*, 3'd ed. Upper Saddle River, NJ Prentice- Hall, 2006.

[2] A.P. Dhnawan, G. Buelloni, R. Gordon, *"Enhancement of mammographic features by optimal adaptive neighbourhood image processing,"* IEEE Trans. Med. Imaging, vol. 5, pp. 8-15, 1986.

[3] A. Beghdad, A.L. Negrate, *"Contrast enhancement technique based on local detection of edges,"* Computer Vision Graphics Image Process, vol. no.46, pp.162-174 1989.

[4] Laxmikant Dash, B.N. Chatterji, *"Adaptive contrast enhancement and de-enhancement,"* Pattern Recognition vol. 24 pp. 289-302, 1991.

[5] Pal S K, King R A., *"Image enhancement using fuzzy sets,"* IEEE Electronics Letters, vol. 16 no. 10, pp. 376-378, 1980.

[6] S.K. Pal, R.A. King, "*Image enhancement using smoothing with fuzzy sets,*" IEEE Trans. System Man Cybernet, vol. SMC-1, no. 7, pp. 404-501, 1981.

[7] S.K. Pal, D. K. D. Majumder, *"Fuzzy Mathematical Approach to Pattern Recognition,"* Wiley, New York, 1986.

[8] Sankar K. Pal, *"Image enhancement and a quantitative index using fuzzy sets,"* Int. Systems, SCI, vol. 18, no. 9, pp. 1783-1797, 1987.

[9] Tizhoosh, H.R., Krell, G., Michaelis B., "*On Fuzzy Image Enhancement of Megavoltage Images in Radiation Therapy*," *FUZZ-IEEE* , pp. 1399–1404, Spain, 1997.

[10] H.D. Cheng, H Xu, *"A novel fuzzy logic approach to contrast enhancement,"* pattern recognition society Elsevier, pp. 809-819, 2000.

[11] Madasu Hanmandlu, Member of IEEE, and Devendra Jha, "*An Optimal Fuzzy System for Color Image Enhancement,*" IEEE Transactions on Image Processing, vol. 15, no. 10, October 2006.

[12] Balasubramaniam Jayaram, Kakarla V.V.D.L. Narayana,V. Vetrivel, *"Fuzzy Inference System Based Contrast Enhancement,"* Aix-les-Bains, France Published by Atlantis Press pp. 311-318, 2011

[13] Khairunnisa Hasikin and Nor Ashidi Mat Isa, *"Enhancement of the low contrast image using fuzzy set theory,"* 14th International Conference on Modelling and Simulation, IEEE, pp. 371-376, 2012.

[14] Reshmalakshmi C, Sasikumar M. *"Image Contrast Enhancement using Fuzzy Technique,"* IEEE International Conference on Circuits, Power and Computing Technologies [ICCPCT], ISSN 978-1-4673-4922, vol. 2, pp. 861-865, 2013.

[15] Klir. G. J and Yuan B. *Fuzzy sets and Fuzzy logic*. Upper Saddle River,NJ: Prentice - Hall, 1955.

[16] L. A. Zadeh, *"Fuzzy sets,"* Inform. Contr., vol. 8, pp. 338-353, 1965.

[17] Tizhoosh H.R. and Michaelis B. *"Subjective, and Fuzzy technique: A new approach to image enhancement",* IEEE, pp. 522-526, 1999.