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Image Enhancement Using Fuzzy Logic

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Abstract: *In this paper, develop and compare two types of image enhancement method using fuzzy logic. Fuzzy logic and histogram based algorithm for enhancing low contrast color images and another contrast enhancement technique using the concept of homomorphic filtering with fuzzy logic. These two methods have been compared with conventional contrast enhancement techniques. These methods are computationally fast compared to conventional and other advanced enhancement techniques. The performance of these contrast enhancement algorithms are evaluated based on the visual quality, CII and the computational time. The inter comparison of different techniques was carried out on different low contrast color images. Based on the performance analysis, advocate that the proposed fuzzy logic and histogram based method is well suited for contrast enhancement of low contrast color images and fuzzy logic based homomorphic filtering is well suited for contrast enhancement of low contrast gray images.*
Keywords: *Fuzzy Logic, Image Enhancement, Homomorphic Filtering.*

I. Introduction

The aim of image enhancement is to improve the visual appearance of an image, or to provide a better transform representation for future automated image processing. Many images like medical images, satellite images, aerial images and even real life photographs suffer from poor contrast and noise. It is necessary to enhance the contrast and remove the noise to increase image quality. One of the most important stages in medical images detection and analysis is the image enhancement techniques which improves the quality (clarity) of images for human viewing. Removing blurring and noise, increasing contrast, and revealing details are examples of enhancement operations.

A fast and efficient fuzzy and histogram based automatic contrast enhancement of low contrast color images and gray image contrast enhancement technique using the concept of homomorphic filtering with fuzzy logic has been proposed here, and compare these methods with the existing methods. The fuzzy and histogram based method is mainly based on two important parameters, one the average intensity value of the image M and the other a contrast intensification parameter K. The proposed method is applied to the HSV color space so that only the V component is stretched by preserving the chromatic information (H and S).

The homomorphic filtering with fuzzy logic technique combines the logarithmic transform with fuzzy membership functions to deliver an intuitive method of image enhancement. This algorithm reduces the computational complexity by eliminating the need for image dependent filter kernels and the forward and inverse Fourier Transforms. The log transform used here to separate illumination and reflectance components and thereby increasing the reflectance component that is, increases the contrast of the image. The fuzzy logic is applied to the log transformed image and then exponential operation is applied to get the enhanced image.

In order to study the statistical characteristics of the proposed system contrast improvement index (CII), peak signal to noise ratio and entropy calculation were calculated. The computational time taken for the execution of these two methods are also very less compared to the existing model.

1.1 Fuzzy Image Processing

Fuzzy image processing is a form of information processing for which input and output both are images. It is a collection of different fuzzy approaches which understand, represent and process the images, their segments and features as fuzzy sets. Fuzzy image processing is divided into three main stages: image fuzzification, modification of membership values, and image defuzzification. Power of fuzzy image processing lies in the intermediate step (modification of membership values) after first phase (image fuzzification), appropriate fuzzy techniques (such as fuzzy clustering, fuzzy rule-based approach, fuzzy integration approach and so on) modify the membership values. Fig-1 shows the block diagram of fuzzy image processing.

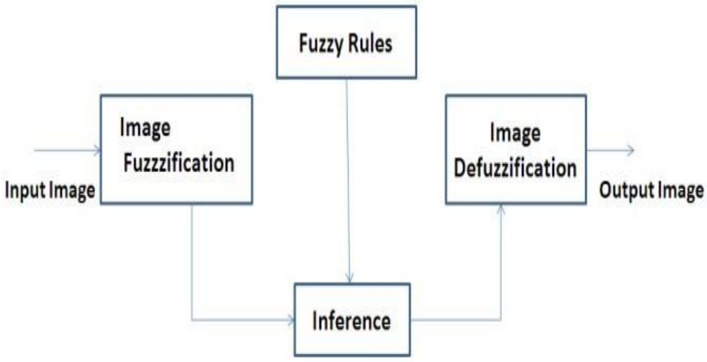


Fig -1: Fuzzy Image Processing

PROPOSED SYSTEM

Two type of image enhancement technique using fuzzy logic is proposed and compared here.

1. Fuzzy logic and histogram based algorithm for enhancing low contrast color images.

2. Homomorphic filtering with fuzzy logic for low contrast enhancement of gray images.

Fuzzy Logic and Histogram Based Method

The proposed system for low contrast color image enhancement can be partitioned into 3 stages: Fuzzification, Modification of membership function and De-fuzzification. The proposed method is meant exclusively for enhancing low contrast and low bright color images. Fig -2 shows the block diagram of the proposed system.

Stages of Image Enhancement Using Fuzzy Logic Fuzzification

In fuzzification process, the real scalar value is changed into a fuzzy value that is, the input pixel values are converted into gray level values. This is done by first converting the

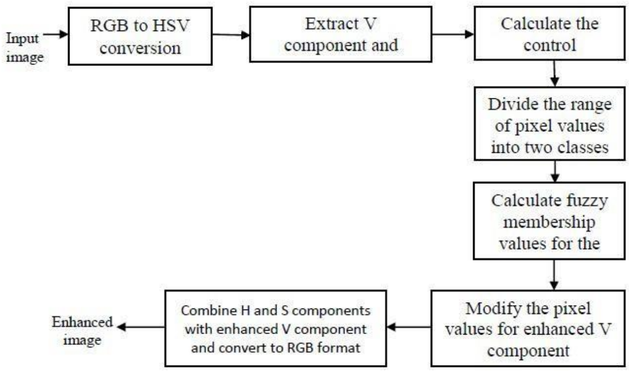


Fig -2: Block Diagram of Fuzzy Logic and Histogram Based Method

input color image into HSV (Hue Saturation Value) to preserve the chromatic information contained in the image. In HSV color model, the intensity components are decoupled from the color carrying information in a color image. As a result HSV model is an ideal tool for developing image processing algorithms based on color descriptions that are natural and intuitive to humans. In HSV, Hue is the dominant color perceived by the observer, Saturation is the relative purity of a color and Value or Intensity is the relative degree of black or white mixed with a given hue.

Once the HSV image model is obtained, the hue saturation and value components can be extracted. For this fuzzy based technique, Value (*V*) component is extracted and all the fuzzy operations are performed on this *V* component alone.

Modification of Membership Function

The membership function defines to which group the particular event should belong. After dividing the range of pixels into two classes (*C1* and *C2*) the membership functions for each class is calculated based on the fuzzy if-then rules. The membership values obtained are replaced with the original values.

Defuzzification
In this step the replaced membership values are converted into the original form with which the alteration is done.

2.2 Proposed Algorithm
Different steps to execute image enhancement using fuzzy logic.
Step 1: Initially, the input RGB image is converted into HSV format to preserve the chromatic information.
Step 2: *V* component is extracted and the corresponding histogram is calculated.
Step 3: The pixel range is divided into two classes based on the average intensity value calculated using equation (1). The stretching parameter K will be determined based on the fuzzy rules for each class as given in step 4.
Step 4: Membership function modification is performed based on the fuzzy rules which are defined as:

- Fuzzy rule for class *C1*:

If the difference between the average intensity value (*M*) and the intensity value of the pixel (*x*) is LARGE then the intensity of stretching should be SMALL. The above rule indicates that the pixels values closer to M will be extended more whereas values farther from M will be extended lesser. Pixel values in between will be extended proportionately. To implement the above fuzzy rule the following mathematical representation is given as:

Where $x \in C1$. Once the membership value for x is obtained, the contrast enhanced or intensified value x_{e1} for class C1 can be computed as follows:

- Fuzzy rule for class *C2*:

The fuzzy membership value m2 for class *C2* is based on the concept of how far the intensity value *x* is from the extreme intensity value *E* (for 8-bit image *E* =255). The fuzzy rule for class *C2* can be represented as follows: If the difference between x and *E* is LARGE then the intensity of stretching should be LARGE. The above rule indicates that the pixels values closer to E will be extended lesser whereas values farther from E will be extended higher. Pixel values in between will be extended proportionately. To implement the above fuzzy rule the following mathematical representation can be used:

Where $x \in C2$. Once the membership value for x is
obtained, the contrast enhanced or intensified value x_{e2} for class *C2* can be computed as follows:

Once the *V* component is extracted, the histogram of this component is calculated which defines the number of pixels

Where $x \in C1$. Once the membership value for x is obtained, the contrast enhanced or intensified value x_{e1} for class C1 can be computed as follows:

$$x_{e1} = x + \mu_1 K \quad (3)$$

- Fuzzy rule for class *C2*:

The fuzzy membership value m2 for class *C2* is based on the concept of how far the intensity value *x* is from the extreme intensity value *E* (for 8-bit image *E* =255). The fuzzy rule for class *C2* can be represented as follows: If the difference between x and *E* is LARGE then the intensity of stretching should be LARGE. The above rule indicates that the pixels values closer to E will be extended lesser whereas values farther from E will be extended higher. Pixel values in between will be extended proportionately. To implement the above fuzzy rule the following mathematical representation can be used:
Once the *V* component is extracted, the histogram of this component is calculated which defines the number of pixels

$$\mu_2 = \frac{E-x}{E-M} \quad .(4)$$

in the image with the intensity value *x*.
The enhancement of image is mainly based on stretching the dynamic range of pixel intensity values. To perform this, the average intensity value, *M* is calculated based on the histogram which is mathematically represented as:

Where $x \in C2$. Once the membership value for x is obtained, the contrast enhanced or intensified value x_{e2} for class *C2* can be computed as follows:

$$x_{e2} = x\mu_2 + (E - \mu_2 K) \quad (5)$$

Step 5: The replacement of the old x values of the V component with the enhanced x_e values will cause the V component to be stretched resulting in contrast and The average intensity value, M is used to divide the total range of pixels in the image in to two sets *[0, M-1]* and *[M, 255]* where 0 and 255 are the minimum and maximum intensity gray level respectively.

brightness enhanced component (V_e). The enhanced V component and its histogram is shown in fig 5.

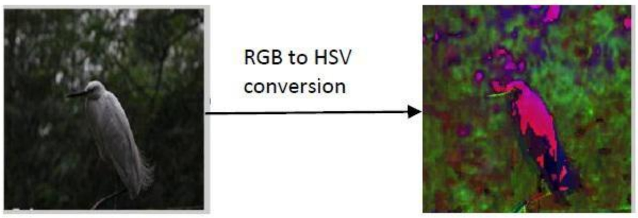


Fig -3: RGB to HSV Conversion

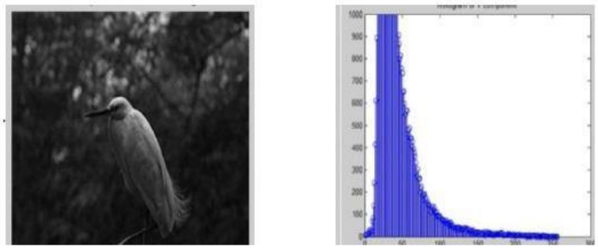


Fig -4: V Component Extraction and Corresponding Histogram

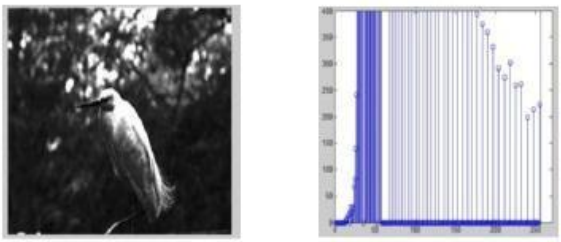


Fig -5: Enhanced V Component and its Corresponding Histogram

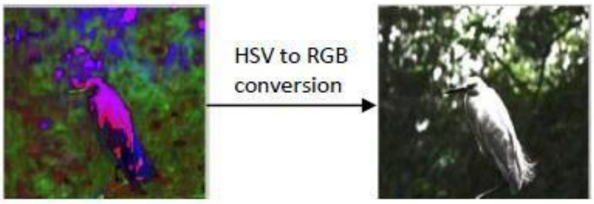


Fig -6: Enhanced HSV Component and the Final Enhanced Image

Step 6: The enhanced achromatic information V can be logarithm operator to an image can be useful in applications where the dynamic range may too large to be displayed on a screen.

Fuzzification

In fuzzification process, the real scalar value is changed into a fuzzy value. After the logarithmic conversion of image to a linear additive form, it is easy to transform the log image into the fuzzy domain using a suitable membership function. The fuzzification of the log image transforms the low frequency values into values with zero or near zero membership in the fuzzy domain of the attribute brightness while the high frequency values are then defined as values with full or near full membership of the brightness attribute.

Modification of Membership Function

The membership function defines to which group the particular event should belong. The crucial task is to select an appropriate membership function to be employed in the modification of membership. For membership modification, the function must be able to moderately modify that is, to increase or decrease the mid-range

membership while combined with the pre-served chromatic inform
en (Hue
drastically modifying the lowest membership values and

atio
and Saturation components) to obtain enhanced image HSV_e
component.
Step 7: Finally the HSV_e image is converted to RGB image
leaving the highest membership values unchanged. A custom membership function used at the modification stage is defined as:

$$\mu' = 1 - \frac{N-1}{} \, 1 - \mu \quad \beta \quad , N \geq 2 \qquad (7)$$

to get enhanced image.
mn
N mn

2.2 Homomorphic Filtering with Fuzzy Logic

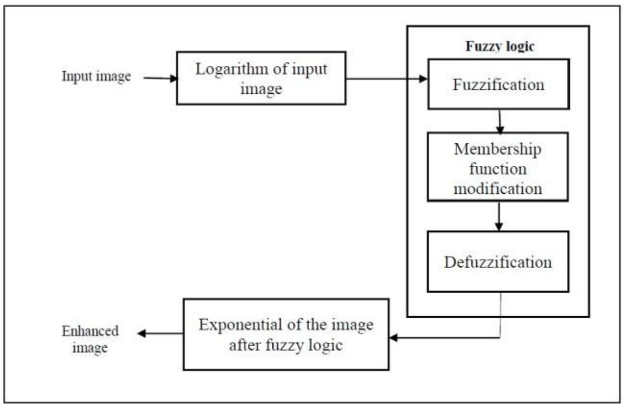


Fig -7: Block Diagram of Homomorphic Filtering Using Fuzzy Logic

The proposed system for image enhancement can be partitioned into 3 stages: Logarithm of image, Fuzzy logic and Exponential of image. The proposed method is meant exclusively for enhancing low contrast and low bright images. Fig 7 shows the block diagram of the proposed system.

Where β is a linguistic hedge that signifies the degree of brightness and N is the modifier of membership.

Defuzzification

In this step the replaced membership values are converted into the original form with which the alteration is done.

Exponential of Image

After the fuzzy logic operation on the log transformed image, exponential operation is performed on the resultant image to covert the image back into original format.

2.2.2 Proposed Algorithm

Different steps to execute image enhancement using homomorphic filtering and fuzzy logic.
Step 1: Apply log transformation to the input image using the following equation.
$log\ I = c.\ log(I + 1)$ (8) Where I is the input image and c is the constant value that is used to scale the range of the log function to match the input domain. Higher the c value, brighter the image will appear. Step 2: Apply fuzzy logic to the log transformed image.
Step 3: The function used for fuzzification is given as:

$$\mu_{mn} = \frac{g_{mn} - g_{min}}{g_{max} - g_{min}} \qquad (9)$$

2.2.1 Stages of Homomorphic Filtering Using Fuzzy Logic

2.2.1.1 Logarithm of an Image

The log transformation is used to expand the values of dark pixels in an image while compressing the higher level values. The basic image model is given as:

$I \; x, y \; = i \; x, y \; . r \, x, y$ (6)

Where *I(x, y)* is the input image, *i(x, y)* is the illumination component of the image and *r(x, y)* is the reflectance component of the image. The image in the frequency domain is non-separable due to the multiplicative nature of the illumination and reflectance components. The logarithm transform converts the multiplicative components of illumination and reflectance to an additive solution. Thus the dynamic range of an image can be compressed by replacing each pixel value with its logarithm. This has the effect that low intensity pixel values are enhanced. Applying a pixel

Where, g_{mn} is the current pixel value of the image at

coordinates *(m, n)*, g_{max} is the maximum intensity value and g_{min} is the minimum intensity values of the input image.

Step 4: Membership function modification is performed to enhance the intensity values according to the equation (9).

Where β is a linguistic hedge that signifies the degree of brightness and *N* is the modifier of membership.

Step 5: Exponential operation for the enhanced values of the image after the modification of membership function is done to get the enhanced output image.

A combined algorithm that uses the concept of homomorphic filtering method and fuzzy logic is explained in detail. The proposed technique combines the logarithmic transform with fuzzy membership functions to deliver an intuitive method of image enhancement. This algorithm reduces the computational complexity by eliminating the need for image dependent filter kernels and the forward and inverse Fourier Transforms. The log transform used helps to separate illumination and reflectance components and thereby increasing the reflectance component that is, increases the contrast of the image. The fuzzy logic is applied to the log transformed image and then exponential operation is applied to get the enhanced image.

II. Results And Discussion

The proposed system for digital image enhancement is simulated using MATLAB R2012b on a PC with a Windows 7 professional operating system.

i. Results of Image Enhancement Using Fuzzy and Histogram Based Logic Simulation Results

A number of standard images and some medical images are used as the test images for simulating the algorithm. We are taking different types of low contrast color and gray scale images (satellite and medical images) as test images. Then we test our algorithm. we get enhanced image using fuzzy logic and histogram based algorithm. Fig 8 and 9 shows the result of our algorithm for different types of images. Fig 10 compare our algorithm with existing method histogram equalization using different images.

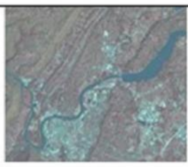
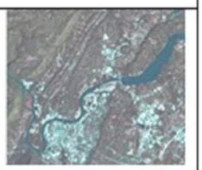
Name of the image	a) Test image	b) Enhanced image
Medical image		
Satellite image		
Building		
Tree		

Fig -8: Enhanced Image Using Histogram Based Fuzzy Logic.

ii. Performance Analysis

Quantitative performance measures are very important in comparing different image enhancement algorithms. Besides the visual results and computational time, Contrast Improvement Index (CII) and histogram analysis are the two important quantitative measures used here for the performance analysis. In this section, the proposed algorithm is analyzed for its performance.

The statistical measures used are the standard deviation, histogram, entropy, absolute mean brightness error and peak signal to noise ratio.

Name of the image	a) Test image	b) Enhanced image
Couple		
Man		

Fig -9: Enhanced Image Using Histogram Based Fuzzy Logic.

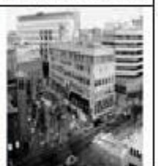
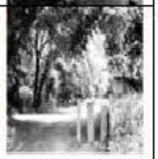
Name of the image	Enhanced image using our method	Using histogram equalization	Using image sharpening
Medical image			
Satellite			
Building			
Tree			
Couple			
Man			

Fig -10: Comparison of Enhancement Method.

1. Histogram

Histogram is one of the most important statistical characteristics of an image, and it plots the number of pixels against different gray level values. Here histogram of the test images „satellite.jpg"and „medical.jpg"before and after enhancement are compared to analyze the statistical performance of the system and it can be seen that the pixel

$$MSE = \frac{1}{MN}\sum_{x=1}^{M}\sum_{y=1}^{N}\left[I(x,y) - I'(x,y)\right]^2 \quad (16)$$

grey values of plain image are concentrated on some points, but the pixel grey values after the enhancement are uniformly distributed in the entire pixel value space. Hence the washed out effect is reduced and the contrast is spread throughout the image giving a better view of the image. Fig- 11 (a) and (b) depicts the histogram characteristic of proposed model for the test images satellite and medical.

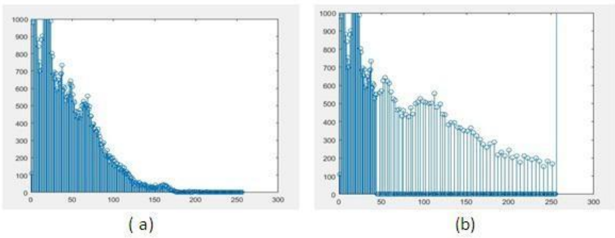


Fig -11: (a)Histogram of Input Image (b)Histogram of Enhanced Image.

Contrast Improvement Index (CII)

In order to evaluate the competitiveness of the proposed fuzzy method against existing contrast enhancement techniques, the most well-known benchmark image enhancement measure, the Contrast Improvement Index (CII) is used to compare the results of contrast enhancement methods. Contrast improvement can be measured using CII as a ratio. Contrast Improvement Index is defined as:

Where I and I' are original and enhanced images respectively.

Table 1 shows the performance analysis of histogram based fuzzy logic. Table 2 compare parameters between existing and proposed method. Here proposed method has better entropy, AMBE, CII values and time required is less compared to existing method.

Image	Entropy	AMBE	CII	Time(sec)
Satellite	3.527	9.386	1.154	1.53
Medical	6.755	18.080	1.184	1.63
Couple	4.029	19.84	0.97	1.55
Building	6.090	21.93	1.0110	1.35
Man	7.304	17.56	1.029	1.23
Tree	6.023	18.12	1.022	1.56

Table -1 : Performance Analysis of Histogram Based Fuzzy Logic

Image	Existing Method	Proposed Method
Entropy	3.56	4.02
CII	0.95	0.97
AMBE	21.76	19.84
Time(sec)	4.66	1.55

Table -2 : Comparison Parameters Between Existing and Proposed System for the Test Image „medical"

3.2 Results of Homomorphic Filtering With Fuzzy Logic

$\underline{C_{proposed}}$

$CII =$

$C_{original}$

(10)

3.2.1 Simulation Results

A number of standard images and some medical images are where C is the average value of the local contrast measured with 3X3 window as: used as the test images for simulating the algorithm. We are taking different types of low contrast gray scale images (tree

$C = \frac{max - min}{max + min}$

Cproposed and Corigin

(11)

erage values of the local and medical images) as test images. Then we test our algorithm. We get enhanced image using homomorphical are the av contrast in the output and original images, respectively.

3.1.2.3 Entropy

Introduced by Shannon, entropy is often applied to evaluate the amount of details in the image. A higher entropy value is desired because the higher the entropy value, the greater the amount of information contained in the image. The entropy of an image is independent of the other image since comparison on the information contained is done based on the same image before and after the processing. The entropy of the gray level grayscale image is calculated using. Thus, the entropy of the entire image is defined by equation (12) and (13) as the summation of all the individual entropies at every gray level.

$e\ k\ = p\ k\ \log p(k)$ (12)

filtering with fuzzy logic algorithm. Fig -12 shows the result of our algorithm for different types of images.

$Entropy = \sum_{k=0}^{L-1} e(k)$

(13)

3.1.2.4 Absolute Mean Brightness error (AMBE)

A good image enhancement technique should yield an image that retains its natural look. Specifically, the technique should not heavily magnify the noise level of the input image. PSNR is commonly used for evaluating image quality. It measures how much the enhanced image has degraded when referred to the input image, as expressed in equation (14).

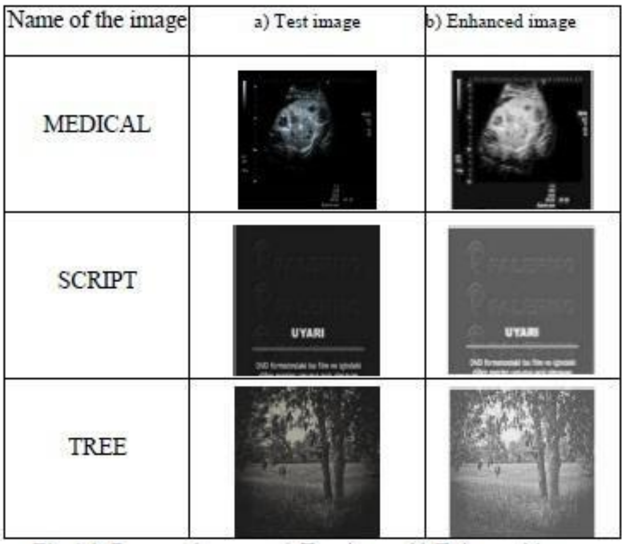


Fig-12. Enhanced Image with Homomorphic Filtering Based Fuzzy Logic

3.2.2 Performance Analysis

The performance analysis that is, statistical analysis (CII, entropy) of homomorphic filtering with fuzzy logic

using
$PSNR = 10log_{10}$
$size\ \ of\ \ image$

MSE
(14)
different types of images are is given in shows comparison of the existing method with proposed method. Table-3

where size of image=row *column where MSE is Mean Square Error denoted as :
$e\ \ k\ \ = -p\ \ k\ \ logp(k)$ (15)
shows the performance analysis of homomorphic filtering with fuzzy logic.

Image	Entropy	CII	Time(sec)
Medical	3.13	1.15	1.99
Script	4.81	0.11	2.01
Tree	4.99	1.30	1.76

Table -3: Performance Analysis of the Homomorphic Filtering with Fuzzy Logic Method

4.3 Comparison of Fuzzy and Histogram Based Method and Homomorphic Filtering with Fuzzy Logic Method

In this section we compare these two methods fuzzy and histogram based method and homomorphic filtering with fuzzy logic method. Table-4 shows the comparison of these two method by statistical analysis. Thus experimental results were discussed and the parameters were calculated. Initially, in order to study the statistical characteristics of the proposed system histogram analysis, contrast improvement index, absolute mean brightness error, and peak signal to noise ratio and entropy calculation were carried out. Histogram of the image after enhancement was distributed resulting in improved contrast of the image. The obtained PSNR values also indicate the better appearance of the image. The computational time taken for the execution is also very less compared to the existing model. Then we compare these two methods and result analyzed.

Image	Fuzzy and Histogram Based Method	Homomorphic Filtering with Fuzzy Logic Method
Entropy	4.02	4.99
CII	0.97	1.30
Time(sec)	2.04	1.76

Table-4 Comparison Parameters Between Histogram Based Fuzzy Logic and homomorphic Filtering with Fuzzy Logic

III. Conclusions

A fast and efficient fuzzy based color image enhancement method has been proposed. From comparative analysis it can be concluded that the proposed Fuzzy Logic method has improved the visual quality as well as yielded a higher PSNR and CII values. The method is computationally faster compared to existing advanced enhancement techniques. Hence it is concluded that the proposed method has given more advantageous results for the optimal visual perception of images with the help of a simple and understandable terminology.

A new method has been developed for the purpose of enhancing images based on fuzzy logic with homomorphic filtering technique. The low contrast input image is subjected to logarithmic transformations followed by fuzzy operations resulting in enhanced high contrast image. Parameter analysis such as entropy, CII are performed on the enhanced output image. The parameter analysis suggests that the proposed system performs better when compared with the available literature. Then compare the two method proposed in this thesis for gray scale images. Fuzzy logic with homomorphic filtering shows better performance value (CII, entropy, time).

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