Enhancement of Low Contrast Images using Fuzzy Inference System

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Abstract: ***Image enhancement is a technique to improve the quality of an image. The aim of image enhancement technique is to improve the interpretability or perception of information in images for human viewers, or to provide better input for other automated image processing techniques. This paper presents a fuzzy grayscale enhancement technique for low contrast image corrupted by Gaussian noise. The degradation of the low contrast image is mainly caused by the inadequate lighting during image capturing and thus eventually resulted in non uniform illumination in the image. The proposed method has better performance than available methods in the enhancement of noisy images and has been validated by the performance measures like PSNR, SNR, RMSE, and MSE.***

Keywords*:* Fuzzy Inference System, Image enhancement, Gaussian Noise, PSNR, MSE, Visual quality.

1. Introduction

Image enhancement is the improvement of image quality to a better and more understandable level for feature extraction or image interpretation. In many applications of image processing, the input image has noise and thus may not show the features clearly [4]. The goal of image enhancement is to improve the image quality so that the processed image is better than the original image for a specific application [8].

Image contrast enhancement techniques are of particular interest in photography, satellite imagery, medical applications and display devices [12]. Image enhancement can be clustered into two group's namely spatial domain and frequency domain methods [7]. In the spatial method, image pixels are directly modified to enhance the image. In the latter method, the enhancement is conducted by modifying the frequency transform of the image. However, computing the enhancement in frequency domain is time consuming process even with fast transformation technique thus made it unsuitable for real time application [17].

Numerous contrast enhancement techniques [3] normalized the image intensities and often fail to produce satisfactory results for a broad range of non-uniform illumination image. Low contrast image is the image whose intensity levels of the pixels resides densely in a narrow range in the histogram of the image. The objects in this type of image are not clear Or distinct. To improve the quality of the image and visual perception of human beings, different enhancement methods can be applied [2] [19]. Some methods work in frequency domain, some works in spatial domain and some works in fuzzy domain [11].

The enhancement of noisy data, however, is a very critical process because the sharpening operation can significantly increase the noise [8]. The noise as additional component to the image, is occurs in image for many reasons. There are many types of noisy images; probably the most frequently occurring noise is Gaussian noise of almost any signal. Gaussian noise is caused by random fluctuations in the signal [5].

The Gaussian noise is Gaussian white noise with constant mean and variance. Probably the most frequently occurring noise is additive Gaussian noise. The PDF of a Gaussian random variable, *z*, is given by

$$p(z) = \frac{1}{\sqrt{2\pi}\sigma} e^{-\frac{(z-\mu)^2}{2\sigma^2}} \quad (1)$$

Where z represents gray level, μ is the mean of average value of z, and σ is its standard deviation.

There are lots of classical filters in the literature to remove noise. The classical filters are the mean filter, the median filter, unsharps masking [9].The mean filter or the average filter helps in smoothing operations. It suppresses the noise that is smaller in size or any other small fluctuations in the image. It involves in calculating the average brightness values in some neighborhood m x n and replaces the gray level with an average value. Smoothing or averaging operation blurs the image and does not preserve the edges. These are not useful in removing noise spikes.

Fuzzy filters provide promising result in image processing tasks that cope with some drawbacks of classical filters. Fuzzy filter is capable of dealing with vague and uncertain information [10] [15]. Sometimes, it is required to recover a heavily noise corrupted image where a lot of uncertainties are present and in this case fuzzy set theory is very useful [20]. Each pixel in the image is represented by a membership function and different types of fuzzy rules that considers the neighborhood information or other information, classical filters removes the noise with blurry edges but fuzzy filters perform both the edge preservation and smoothing.

This paper presents an enhancement technique based on fuzzy logic to increase the contrast of structures of interest in image. Compared to other techniques, fuzzy method can manage the vagueness and ambiguity in many image processing applications efficiently. The method is able to represent and process human knowledge and applies fuzzy if-then rules. The basic principles of fuzzy enhancement scheme are illustrated in Figure 1.

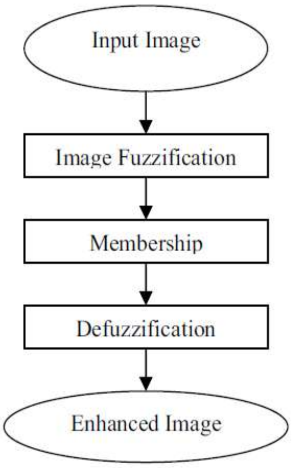


Figure1: The basic principles of fuzzy enhancement

2. Proposed Objective

Whenever an image is converted from one form to another, such as, digitizing, scanning, transmitting, storing, etc. some degradation occurs at the output. Hence, the output image has to undergo a process called image enhancement. The objective of the image enhancement is to process an image so that the result is more suitable than the original image for a specific application. Enhancement of noisy image data is a very challenging issue in many research and application areas. The proposed objectives are:

1. Image Preprocessing: It may be considered as the preprocessing step for pattern recognition, medical image analysis, satellite images etc.
2. To study the existing enhancement methods in spatial, frequency domain and fuzzy domain methods.
3. To propose an algorithm to enhance the poor quality images to good quality images by increasing the contrast.
4. To design the technique using FIS (Fuzzy Inference System) to improve the image contrast.
5. Test the designed technique using some degraded, low contrast images.
6. To compare the performance of proposed algorithm with existing methods.

3. Proposed Methodology

An algorithm is proposed and implemented to enhance images using fuzzy technique. The proposed algorithm is to avoid the problem that existing techniques of image enhancement are not effective in dealing with imprecise data, vague and uncertain information. It provides satisfactory results in low contrast and light variations areas. The proposed methodology has following steps:

- Input to the system an original image.
- Resize to 256X256.
- Convert it into Gray Scale image if it is RGB image.
- Add Gaussian noise to the image.
- Preprocess the noisy image.
- Apply different enhancement methods.
- Compare enhanced images of fuzzy inference mechanism with the other enhanced images.

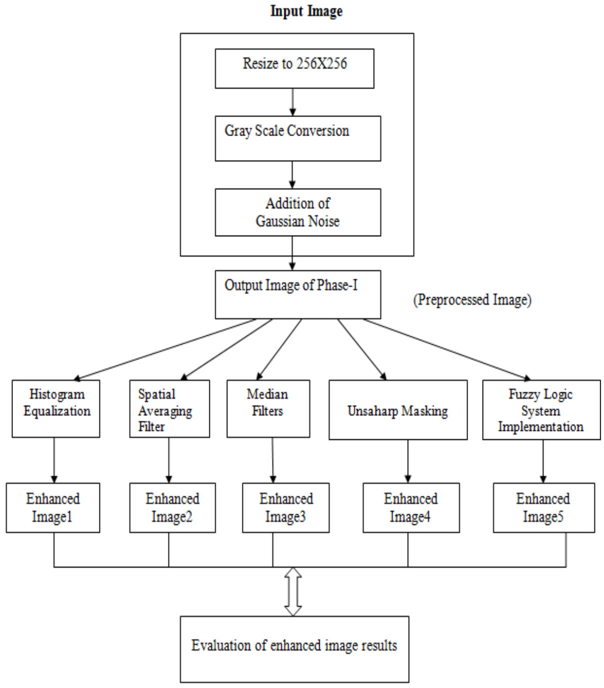


Figure 2: Proposed Methodology

Algorithm of the proposed method

Step-1: Take Noisy Image as Input image.
Step2: Apply Histogram Equalization, Spatial Averaging, Median filter, Un-sharp Masking filters to the Noisy Image
Step3. Apply Proposed Fuzzy Inference System based filter by follow the following steps:
Step4: Repeat the steps 5 to 11 for each pixel present in the input image.
Step5: Consider pixel under consideration as Current pixel.
Steps6: Clear the values of Linear arrays PFIS [] and Temp_PFIS [].
Step7: Apply 18 Fuzzy rules as filter masks on the Current_Pixel and initialize the linear array PFIS [] by Eighteen different responses Ri.
Step8. Update Linear array Temp_PFIS [] with the values of linear array PFIS [] according to the following rules:

a) Add The values of linear array PFIS [] to Temp_PFIS [] if the values lies between the range of Value (Left_pixel) and Value (Current_pixel). Do not repeat the contents if already exists in linear array Temp_PFIS [].
b) Add The values of linear array PFIS [] to Temp_PFIS [] if the values lies between the range of Value (Right_pixel) and Value (Current_pixel). Do not repeat the contents if already exists in linear array Temp_PFIS [].
c) Add The values of linear array PFIS [] to Temp_PFIS [] if the values lies between the range of Value (Up_pixel) and Value (Current_pixel). Do not repeat the contents if already exists in linear array Temp_PFIS [].
d) Add The values of linear array PFIS [] to Temp_PFIS [] if the values lies between the range of Value (Down_pixel) and Value (Current_pixel). Do not repeat the contents if already exists in linear array Temp_PFIS [].

Step9: Sort the contents of linear array Temp_PFIS [] in ascending order.

Step10: Find the median M from the contents of Linear array Temp_PFIS [].
Step 11: Set Value [Current_pixel]=M in output image.
Step 12: Compare the output images using parameters MSE, RMSE, SNR, and PSNR.

4. Results and Discussion

The proposed algorithm is tested for various images having the size of 256 x 256. Gray scale images are used for experimentation. The proposed method is compared with the various conventional methods like histogram equalization, Spatial Averaging, Median filters, Unsharp masking.

To confirm the improvement in contrast, hence, the visual quality of image, a well-known criteria like PSNR, SNR. MSE, RMSE are used to compare the results of the proposed method and the conventional methods. The proposed method achieved highest *PSNR* among other methods which concludes that the proposed method does not amplify existing noise in the original image.
Mean square error (MSE) is given by

$$\frac{\sum\left(f(i,j)-F(i,j)\right)^2}{MN} \quad (2)$$

Root Mean square error (MSE) is given by,

$$\sqrt{\frac{\sum\left(f(i,j)-F(i,j)\right)^2}{MN}} \quad (3)$$

$f(i,j)$ is the original image, $F(i,j)$is the enhanced image and MN is the size of image

SNR (Signal to Noise Ratio) in decibels is defined as

$$SNR=10\ \log_{10}(\sigma^2/\ \sigma_e^2)\ (4)$$

$\sigma^2$is the variance of the noise free image and $\sigma_e^2$is the variance of enhanced image.

PSNR (Peak Signal to Noise Ratio) is usually expressed in terms of the logarithmic decibel scale and is calculated as

$$PSNR = 20\ \log_{10}\left(\frac{255}{RMSE}\right)\ (5)$$

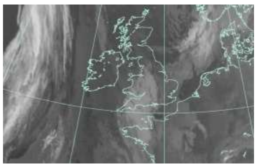
An identical image to the original will yields an undefined PSNR as the MSE will become equal to zero due to no error. This shows that a higher PSNR, SNR and low value of MSE & RMSE provides a higher image quality.

Table 1: Images extracted for experimentation


(a)Blue_Moon.jpg


(b) Rock.png


(c) Earth.gif


(d) Weather_forecast.bmp


(e) Moses_Lake.tif


(f) Aerial.jpg


(g) lena.bmp


(h) Moon.png

Table 2: Effect of SNR, PSNR, MSE, and RMSE on different images with the help of different methods and our proposed method

SNR	*Effect of SNR on Test Images*							
Enhancement Method	Blue_Moon.jpg	Rock.png	Earth.gif	Weather_forecast.bmp	Moses_Lake.tif	Aerial.jpg	lena.bmp	Moon.png
Histogram Equalization	3.7	3.22	2.17	0.68	1.15	0.82	1.44	-0.17
Spatial Averaging	6.56	10.73	8.59	7.77	3.85	8.82	6.69	6.97
Median Filter	5.99	9.25	8.57	8.72	4.67	5.92	6.92	4.9
Unsharp Masking	3.72	5.29	4.96	5.08	2.97	3.6	4.16	3.06
Fuzzy Inference System	8.29	15.32	14.19	13.43	6.53	9.22	10.57	7.21
PSNR	*Effect of PSNR on Test Images*							
Enhancement Method	*Blue_Moon.jpg*	*Rock.png*	*Earth.gif*	*Weather_forecast.bmp*	*Moses_Lake.tif*	*Aerial.jpg*	*lena.bmp*	*Moon.png*
Histogram Equalization	16.87	13.14	11.27	15.62	13.43	16.05	13.94	22.71
Spatial Averaging	14.86	11.21	9.53	12.27	11.06	14.44	11.64	20.73
Unsharp Masking	20.39	16.84	15.05	18.07	16.59	20.45	17.16	29.89
Fuzzy Inference System	24.71	21.06	19.38	22.13	20.92	24.29	21.49	30.57
MSE	*Effect of MSE on Test Images*							
Enhancement Method	Blue_Moon.jpg	Rock.png	Earth.gif	Weather_forecast.bmp	Moses_Lake.tif	Aerial.jpg	lena.bmp	Moon.png
Histogram Equalization	1337.63	3154.1	4857.8	1783.27	2952.53	1613.36	2622.84	348.74
Spatial Averaging	2122.48	4925.75	7251.66	3853.69	5089.29	2339.86	4457.45	549.41
Median Filter	603.15	1380.67	2232.52	1079.98	1580.67	656.05	1280.41	154.21
Unsharp Masking	595	1347.93	2032.52	1015.3	1426.63	586.01	1249.39	66.79
Fuzzy Inference System	219.61	509.2	749.43	398.36	525.99	242.02	460.84	57.01
RMSE	*Effect of RMSE on Test Images*							
Enhancement Method	*Blue_Moon.jpg*	*Rock.png*	*Earth.gif*	*Weather_forecast.bmp*	*Moses_Lake.tif*	*Aerial.jpg*	*lena.bmp*	*Moon.png*
Histogram Equalization	36.57	56.16	69.7	42.23	54.34	40.17	51.21	18.67
Spatial Averaging	46.07	70.18	85.16	62.08	71.34	48.37	66.76	23.44
Median Filter	24.56	37.16	47.25	32.86	39.76	25.61	35.78	12.42
Unsharp Masking	24.39	36.71	45.08	31.86	37.77	24.21	35.35	8.17
Fuzzy Inference System	14.82	22.57	27.38	19.96	22.93	15.56	21.47	7.55

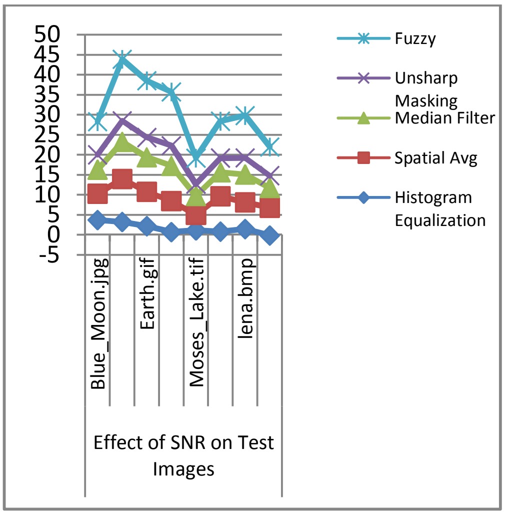


Figure 3: Effect of SNR

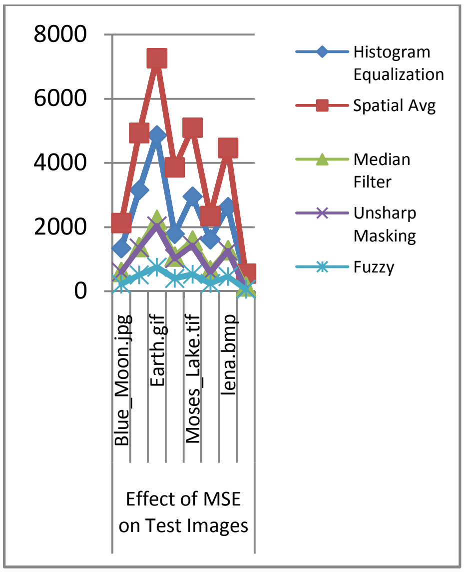


Figure 5: Effect of MSE

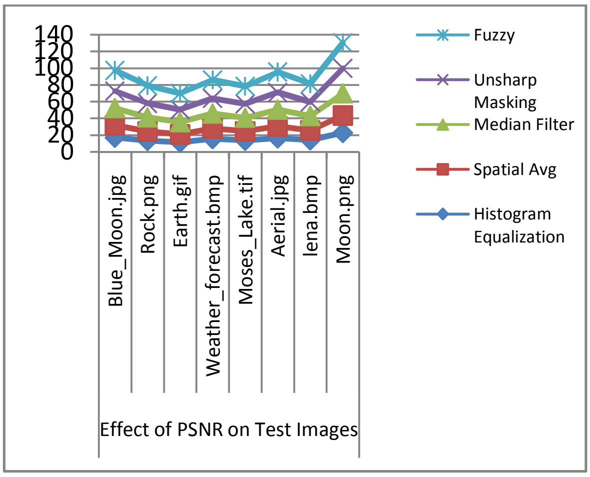


Figure 4: Effect Of PSNR

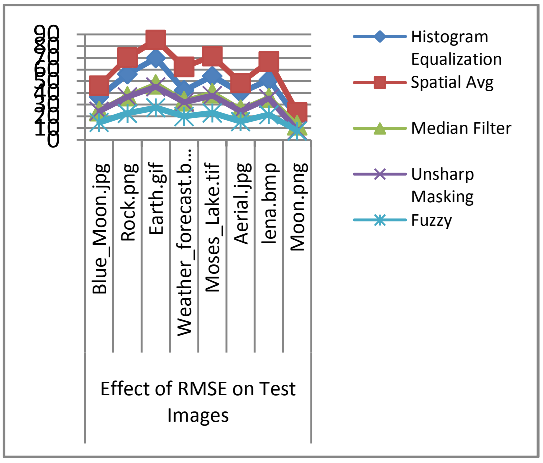


Figure 6: Effect of RMSE

5. Conclusion

Image enhancement algorithms offer a wide variety of approaches for modifying images to achieve visually acceptable images. Contrast enhancement techniques are widely used for improving visual quality of low contrast images. The Image enhancement method for noisy image is proposed and implemented in section 3. The image corrupted with Gaussian noise was enhanced using the histogram equalization, spatial averaging, median filter & unsharp masking filter and the results are shown in table2.Existing techniques of image enhancement are not effective in dealing with imprecise data, vague and uncertain information. These uncertainties include additive and non-additive noise in low level image processing, imprecision & ambiguities in interpretation during high level image processing.

Most of the existing techniques are either very sensitive to noise and do not give satisfactory results in low contrast and light variations areas. Noise smoothing and edge enhancement are inherently conflicting processes, since smoothing a region might destroy an edge, while sharpening edges might lead to unnecessary noise.

The experimental results show that proposed method enhances the images while edge preservation and smoothing compared with conventional methods. The proposed method outperforms for many test images & provides better image quality and defeated other methods in terms of image contrast without enhancing existing noise in the image.

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