Fuzzy based Image Enhancement Method

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ABSTRACT
Though, there has been an enormous research contribution on image de-noising methods which are also called as image enhancement methods that actually enhance the desired information and suppress unwanted portion in a digital image. However, robustness is still a major challenge in this area of digital image processing. The performance has been improved by several research papers using fuzzy approaches. This work proposed a non-linear method for removing impulse noise, that is salt and pepper noise in digital grayscale images. The modified fuzzy based decision algorithm (MFBDA) is used. The noisy pixels are detected and then fuzzy based filtering works to correct the pixel. The proposed method performs better than conventional and other non-linear fuzzy based image enhancement methods. The values of statistical parameters such as PSNR (Peak signal-to-noise ratio), IEF (Image Enhancement factor), IQI (Image quality index) and SSIM (Structural similarity index) were obtained better as compared to conventional fuzzy filters.

Keywords:
Fuzzy logic, image de-noising, image enhancement, salt-and-pepper noise.

1. INTRODUCTION
Digital images are used as powerful means of communication in the era of information and communication technology. Images contain huge amount of information. However, the images are sometimes or in many cases corrupted with noise due to noisy conditions in the transmission or some difficulties in sensor or image acquisition systems [1-7]. Image de-noising or image enhancement is an appropriate technique that could help in removing or reducing the amount of noise mixed with the digital images [8-13]. An appropriate or suitable filter is used for de-noising blurred or noisy image to get the output as approximated original input image [1-3]. Sinha et al. in [14] presented concepts and applications of image processing and basics of noise reduction filters. If the image corrupted by salt-and-pepper noise, the noisy pixel can take only the maximum and minimum values in the dynamic range which degrades the image quality. Many linear and non-linear filters have been developed for removing the impulse noise or other noise signals. The filters produce better results than the linear filters in terms of image blurring. Fuzzy based filtering is implemented basically as non-linear filtering method [1, 6]. The fuzzy logic has advantage of reduction of uncertainty of noise detection and imprecision by forming fuzzy rules and membership functions applied over the images for noise removal. Stefan et al. [2] proposed fuzzy impulse noise detection and reduction method (FIDRM) for the detection and removal of all kinds of impulse noises. Sinha et al. [3] proposed de-noising filter algorithm for the removal of additive noise in an image and a bilateral filter (non-linear and local technique) for the medical images corrupted with additive white Gaussian noise [4]. The filter preserves the features while smoothing the image. Sanyam et al. [7] suggested a new technique based on fuzzy classical methods for the gray scale images which could remove two or more type of noises from different image or same image. The present work suggests an efficient and new decision based fuzzy algorithm, MFBDA for images corrupted with salt-and-pepper noise in the gray scale images.

2. FUZZY BASED METHODS
For removal of noise present in digital images, various linear and non-linear filtering algorithms have been extensively studied. Fuzzy based decision algorithms (FBDA) are available to remove the noise. Linear filtering methods do not work adaptively and produce image blurring at low noise densities and hence fuzzy based methods as non-linear filters provide improved filtering performance even at low noise densities. The most popular non-linear filter for removing impulse noise is median filter because it has good noise suppression capability and easier to implement. There are several variants of the median filtering such as switching median filters (SMF), wherein a noise detection mechanism is incorporated so that only those pixels identified as "corrupted" would undergo filtering process and "uncorrupted" pixels will remain unchanged. Nonlinear filters such as adaptive median filter (AMF) [8]; efficient decision-based algorithm (EBDA) and improved decision based algorithm (IDBA) demonstrate good results than median filter but did not produce good results for high density impulse noises.

Madhu et al. [9] proposed a fuzzy based decision algorithm (FBDA) for high density impulse noise removal to overcome the problems of conventional fuzzy based methods. FBDA is a novel fuzzy based switching median filter that selects only the uncorrupted pixels for the filtering process in the selected window based on the fuzzy distance membership value. The algorithm provides noise detection as well as the power of eliminating corrupted pixels during the filtering process [9-12]. However, the results are not convincing for low noise densities because the rule for deciding for the corrupted pixel will misclassify certain pixels as noisy pixels. For high noise densities the filtering results are good [13-15].

3. MODIFIED FBDA

A modified method of fuzzy based decision algorithm (MFBDA) provides better results at low noise densities.

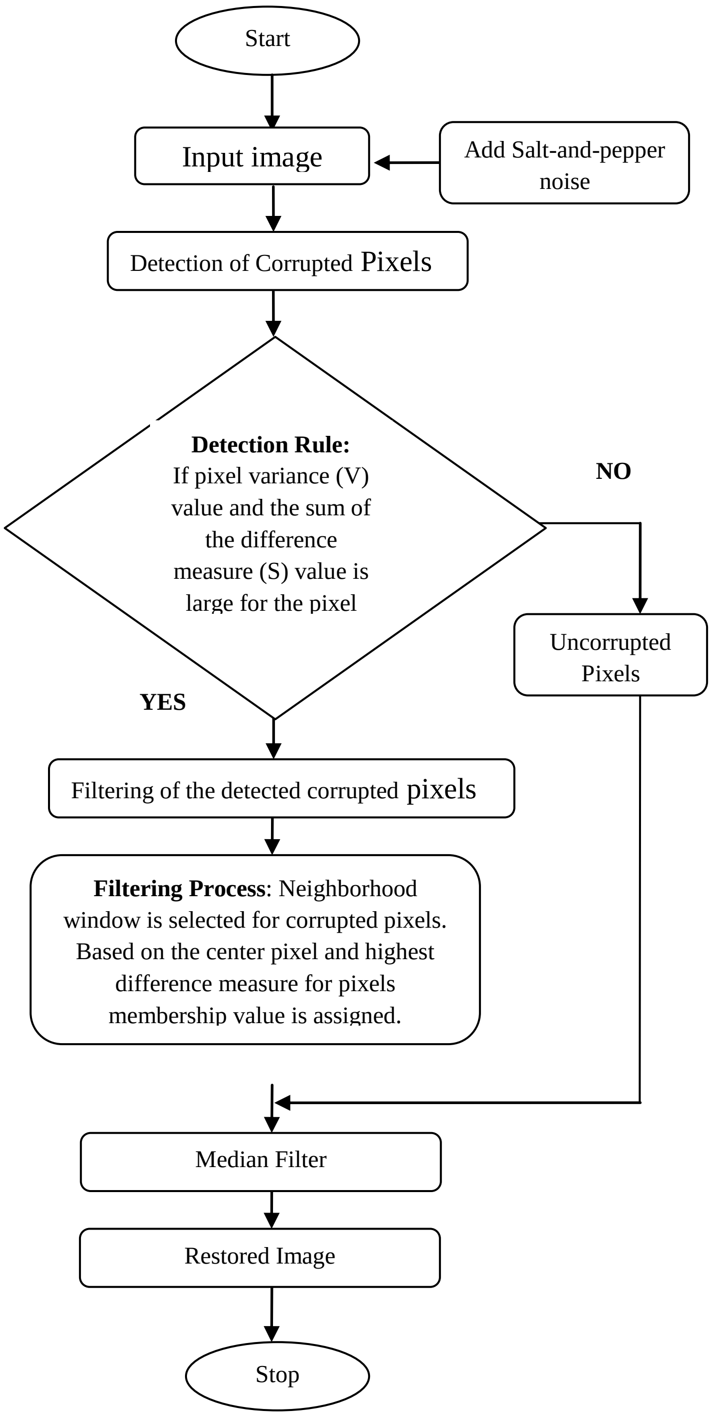


Fig 1: Flow Diagram of the MFBDA algorithm.

The algorithm is divided in two stages: Detection and filtering. In the detection stage, the variance value for each pixel is calculated based on the neighborhood values. Two important conditions are applied for detecting the noisy pixel in a 3×3 window: (i) Variance is high for the noisy pixel and therefore pixels are detected based on suitable threshold values, (ii) The difference value for each pixel in the neighborhood is computed and the values are summed up. The sum will be large for noisy pixels.

MFBDA is applied to all pixels which are uncorrupted during the time of filtering based on fuzzy distance membership value in the selected 3×3 window. For noisy pixels the algorithm selects a neighborhood window and based on the value of the central pixel, a difference measure value is evaluated. The membership value for the pixels is calculated based on the highest difference. The median filter is applied to all remaining pixels in the window to get the new pixel value for the current pixel position.

The performance of the modified method is compared with conventional method using statistical parameters such as MSE, PSNR, SSIM, IEF and IQI. These are interpreted here briefly. Mean square error (MSE) is the average squared difference between the original image (O (m,n)) and the restored image (R(m,n)).

$$\text{MSE} = \frac{1}{mn}\sum_{i=1}^{m}\sum_{j=1}^{n}(O_{i,j} - R_{i,j})^2 \quad (1)$$

Peak Signal to Noise Ratio(PSNR) is calculated as:

$$\text{PSNR} = 10\log_{10}\frac{255^2}{MSE} \quad (2)$$

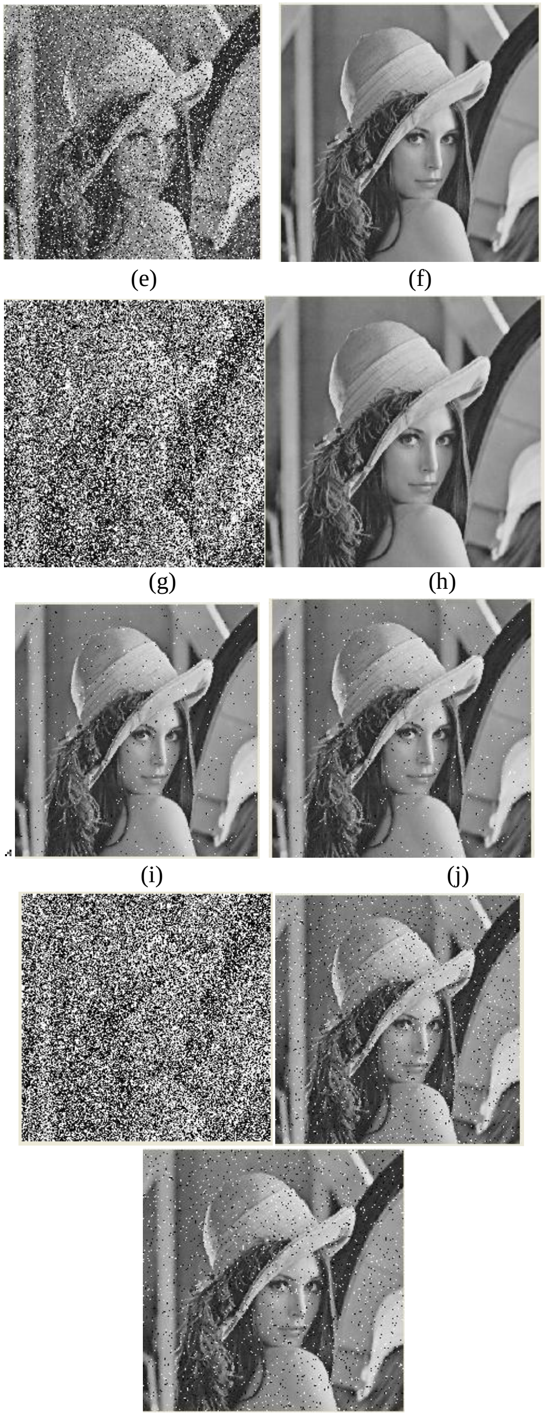
Structural similarity index measure (SSIM) is used to measure [12] the change in luminosity, contrast and structure of an image. Image enhancement factor (IEF) is estimated as:

$$\text{IEF} = \frac{\left(\Sigma_{m,n}\left[N(m,n) - O(m,n)\right]^2\right)}{\left(\Sigma_{m,n}\left[R(m,n) - O(m,n)\right]^2\right)} \quad (3)$$

Image quality factor (IQI) [11] is a combination of three measures: loss of correlation, luminance factor and contrast factor. The dynamic range of IQI is [-1,1].

4. EXPERIMENTAL RESULTS

The MFBDA is applied to images of size 256×256 at various noise densities. The cameraman and Lena images are corrupted with salt-and-pepper noise at low and high noise densities. TABLE 1 and TABLE 2 shows the comparative performance analysis of the FBDA and MFBDA for the Lena image at low noise densities. The modified method produces better results at low noise densities than fuzzy decision based algorithm (FBDA). However, at high noise densities the PSNR and IEF values get reduced as shown in TABLE 3 and TABLE 4. Fig. 1 shows the original Lena image corrupted at various noise levels (10%, 20%, 60%, and 70%) and results of MFBDA.



(e) (f) (g) (h) (i) (j) (m)

Fig 2: Results of MFBDA and FBDA (a) Original 'Lena' image (b) Noisy Lena image corrupted with 10% salt-and-pepper noise. (c) Result of FBDA (d) Result of MFBDA. (e) Lena image corrupted with 20% salt-and-pepper noise. (f) Result of FBDA. (g) Result of MFBDA. (h) Lena image corrupted with 60% salt-and-pepper noise (i) Result of FBDA (j) Result of MFBDA (k) Lena image corrupted with 70% salt-and-pepper noise (l) Result of FBDA (m) Result of MFBDA.

TABLE 1: Performance analysis of MFBDA for Lena image with low noise level.

Performance Evaluation Parameters	10% noise		20% noise	
	FBDA	MFBDA	FBDA	MFBDA
PSNR	38.38	38.64	36.9	37.1
IQI	0.997	0.998	0.997	0.998
SSIM	0.997	0.998	0.9972	0.998
IEF	194.2	206.3	285.3	289.5

TABLE 2: Performance analysis of MFBDA for Lena image with low noise level.

Performance Evaluation Parameters	30% noise		40% noise	
	FBDA	MFBDA	FBDA	MFBDA
PSNR	35.4	35.5	33.37	33.38
IQI	0.995	0.996	0.9934	0.9935
SSIM	0.995	0.996	0.993	0.993
IEF	296.1	297.1	248.94	249.05

TABLE 3: Performance analysis of MFBDA for Lena image with high noise level.

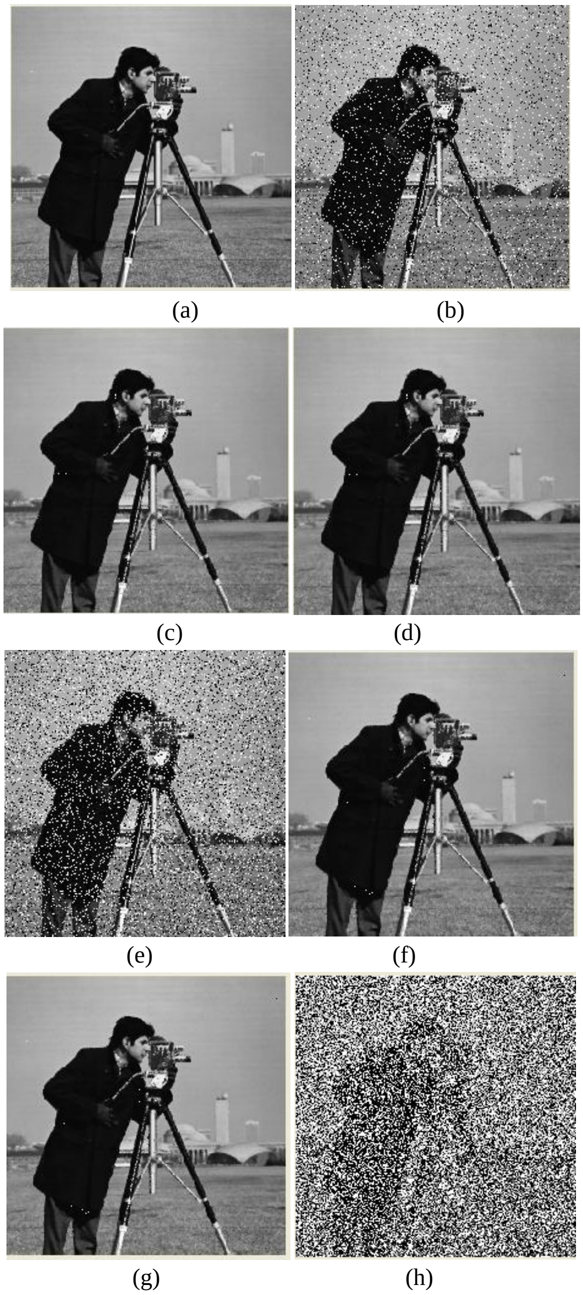
Performance Evaluation Parameters	60% noise		70% noise	
	FBDA	MFBDA	FBDA	MFBDA
PSNR	24.277	24.28	18.858	18.858
IQI	0.948	0.948	0.835	0.835
SSIM	0.949	0.949	0.837	0.837
IEF	45.790	45.791	15.367	15.367

TABLE 4: Performance analysis of MFBDA for Lena image with high noise level.

Performance Evaluation Parameters	80% noise		90% noise	
	FBDA	MFBDA	FBDA	MFBDA
PSNR	13.92	13.92	9.50	9.50

IQI	0.595	0.595	0.272	0.272
SSIM	0.599	0.599	0.276	0.276
IEF	5.640	5.640	2.287	2.287

Table 5, 6 and Table 7, 8 show performance analysis of FBDA and MFBDA for Cameraman image at low and high noise densities. At low noise densities the proposed algorithm, MFBDA gives better result than FBDA. If the noise density increases then PSNR and IEF are slightly reduced. Fig. 2 shows the original Cameraman image corrupted at various noise levels (10%, 20% and 70%) along with results for the algorithm.



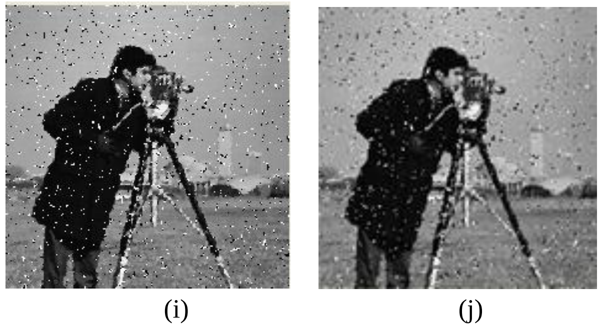


Fig. 2: Results for Cameraman image (a) Original image (b) The image with 10% salt-and-pepper noise (c) Result of FBDA (d) Result of MFBDA (e) The image with 20% noise (f) Result of FBDA (g) Result of MFBDA (h) Cameraman image with 70% noise (i) Result of FBDA (j) Result of MFBDA.

TABLE 5: Performance analysis of MFBDA for Cameraman image with low noise level.

Performance Evaluation Parameters	10% noise		20% noise	
	FBDA	MFBDA	FBDA	MFBDA
PSNR	30.24	30.3	29.12	29.13
IQI	0.9920	0.9921	0.989	0.99
SSIM	0.9921	0.9922	0.9897	0.9899
IEF	32.3	32.4	49.9	50.1

TABLE 6: Performance analysis of MFBDA for Cameraman image with low noise level.

Performance Evaluation Parameters	30% noise		40% noise	
	FBDA	MFBDA	FBDA	MFBDA
PSNR	27.77	27.78	26.77	26.78
IQI	0.986	0.987	0.9823	0.9823
SSIM	0.9867	0.987	0.9824	0.9824
IEF	58.58	58.62	58.28	58.29

TABLE 7: Performance analysis of MFBDA for Cameraman image with high noise level.

Performance Evaluation Parameters	60% noise		70% noise	
	FBDA	MFBDA	FBDA	MFBDA
PSNR	21.675	21.676	17.704	17.704
IQI	0.9436	0.9436	0.8659	0.8659

SSIM	0.9440	0.9440	0.8668	0.8668
IEF	27.560	27.560	12.785	12.785

TABLE 8: Performance analysis of MFBDA for Cameraman image with high noise level.

Performance Evaluation Parameters	80% noise		90% noise	
	FBDA	MFBDA	FBDA	MFBDA
PSNR	13.272	13.272	9.012	9.012
IQI	0.6745	0.6745	0.3570	0.3571
SSIM	0.6765	0.6765	0.3600	0.3601
IEF	5.271	5.271	2.2304	2.304

5. CONCLUSION

The proposed method of image enhancement is modified fuzzy based decision algorithm (MFBDA) which produced better results than various other noise algorithms produced. The performance has been improved and the analysis is made in terms of performance parameters such as PSNR, IQI, and SSIM etc. The algorithm is tested at low and high noise densities. Experimental results show that at low noise densities, MFBDA performs better than FBDA. The proposed work has been analysed for the gray scale images which can be further extended for color images. Further work can be done to develop and implement universal fuzzy filter to remove all types of noises from the images.

6. REFERENCES

[1] Geoffrine Judith. M.C, N. Kumarasabapathy,"Study and Analysis of impulse noise reduction filters," International Journal of Signal and Image Processing (SIPIJ), Vol. 2, No.1, pp.82-92, March 2011.

[2] Stefan Schulte, Mike Nachtegael, Valerie De Witte, Dietrich Vander Weken and Etinne EKerre, "A Fuzzy Impulse noise detection and Reduction Method", IEEE Transaction on Image Processing, Vol. 5, NO.5, pp.1153-1162, May 2006.

[3] G.R. Sinha, Ravindra Ramteke and Vikas Dilliwar, "Implementation of Image Denoising Algorithm for Additive Noise using MATLAB", International J. of Engg. Research & Indu. Appls. (IJERIA), Vol.2, No.1, pp.221-226(2009).

[4] Devanand Bhonsle, Vivek Chandra and G.R.Sinha, "Medical Image Denoising Using Bilateral Filter" ,International Journal of Image, Graphics and Signal Processing 6, pp.36-43, 2012.

[5] Zhang Hong-qiao, MA Xin-jun, WU-Ning, "A New Filter Algorithm of Image Based on Fuzzy Logical", International Symposium on Computer Science and Society, pp.315-318 (2011), DOI 10.1109/ISCCS.2011.91.

[6] Mike Nachtegael, Tom M' elange, "Advances made in Image and Video filtering using Fuzzy Logic", the 3rd International Conference on Machine Vision (ICMV 2010), pp.215-219, (2010).

[7] Sanyam Anand, Navjeet Kaur, "New Fuzzy Logic Based Filter for Reducing Noises from anImages", IJCST Vol.3 Issue 2, pp.322-326, April-June 2012.

[8] Hwang, H.,Haddad, R.A. ,"Adaptive median filters: new algorithms and results". IEEE Trans. Image Process **4**(4), pp.499–502 (1995).

[9] Madhu S. Nair, G. Raju, "A new fuzzy-based decision Algorithm for high-density impulse noise removal", Signal, Image and Video Processing, 6: pp.579-595 (2012), Springer-Verlag,(In press). DOI: 10.1007/s11760-010-0186-4.

[10] Madhu S.Nair, K.Revathy, Rao Tatavarti, "An Improved Decision-Based Algorithm for Impulse Noise Removal", cisp, vol. 1, pp.426-431, 2008 Congress on Image and Signal Processing, Vol.1, 2008.

[11] Zhou Wang, Alan C. Bovik "A Universal Image Quality Index", IEEE Signal Processing Letters, VOL.XX, NO.Y, Pp.1-4, March 2002.

[12] Zhou Wang, Alan C. Bovik, Hamid R. Sheikh, Eero P. Simoncelli, "Image Quality Assessment: From Error Visibility to Structural Similarity", IEEE Transactions on Image Processing, VOL.13, NO.4, pp.1-14, April 2004.

[13] Gonzalez, R.C. Woods, R.E: Digital Image Processing. 3rd edn. Prentice –Hall, Englewood Cliffs NJ (2008).

[14] G.R. Sinha, Bhagwati Charan Patel: Medical Image Processing: Concepts and Applications, ISBN: 978-81-203-4902-5, Prentice Hall of India.

[15] S.N Sivandanam, S.N Deepa: Principles of Soft computing 2nd edn, ISBN: 978-81-265- 2741-0, WileyIndia.

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Neha Agrawal has received the BE degree from Shri Shankaracharya College Of Engineering & Technology, Bhilai in Electronics and Telecommunication Engineering in 2009. She is working towards the M.E. degree in Communication from Shri Shankaracharya Technical Campus Bhilai. Her areas of interests include digital image processing and secure communication.

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