Fuzzy Logic based Image De-noising and Enhancement for Grayscale Images

Suraj Kamya
Department of Electronics & Communication
Lovely Professional University, Punjab

Madhuri Sachdeva
Department of Electronics & Communication
Lovely Professional University, Punjab

ABSTRACT
A picture is worth a thousand words. Trillions of digital images are used for different purposes in real life every day. Noise can corrupt the images in different ways which results in loss of information. Salt & Pepper is a form of noise which occurs randomly in an image as white and black pixels. Traditionally, median filter is used to remove this kind of noise but it introduces blurring in image which causes loss of small details. In this paper Fuzzy Logic based Adaptive Median Filter (FL-AMF) using MATLAB® is proposed which removes the noise effectively and also preserves small details. By introducing various densities of noise, performance of both filters are compared using PSNR & it is found that FL-AMF gives better results.

Keywords
FL-AMF, Fuzzy Inference System, PSNR, Membership set.

1. INTRODUCTION
An image contains a lot of information. Noise can degrade the image which causes loss of information. The main sources of noise in digital images arise during image acquisition and/or transmission. The performance of imaging sensor and transmission depends on various factors such as environmental conditions during acquisition and atmospheric condition during transmission [1].

Noise restoration is a vital part of digital image processing. To remove noise one must be wholly aware about the type of noise causing degradation in the image. In this paper, Salt and Pepper noise is used to degrade the image. For de-noising or restoration this kind of noise, conventionally median filter is used. Median filter changes value of every pixel in an image by median value of selected neighborhood of dimension (m, n). Salt and Pepper noise is also known as on-off noise, it is of two types Bi-polar and Uni-polar. It randomly introduces white and/or black pixels in an image. White pixel corresponds to maximum value and black pixel corresponds to minimum value of an image [1]. Instead of processing every pixel of an image, proposed FL-AMF first detects the noisy pixels and then produces a decision based on human reasoning about the actual value of that pixel. Simultaneously, median filter is also used for the same neighborhood and decision value is computed. By this method two values are obtained which can be used as replacement for noisy pixel. But for better results, again Fuzzy method is used to compute one value from these two calculated values. This final value is substituted for noisy pixel.

Following this introduction a brief background of the work based on the fuzzy logic and data used is presented in section 2. The proposed fuzzy based algorithm is described in section 3. Explanation of result is given in section 5. Section 6 concludes the work done and suggests future directions for further improvements.

2. BACKGROUND
In recent years, the number and variety of applications of fuzzy logic have increased significantly. The applications range from consumer products such as cameras, camcorders, washing machines, and microwave ovens to industrial process control, medical instrumentation, decision-support systems, and portfolio selection [1]. In 1965, Zadeh proposed a complete theory of fuzzy sets to represent and manipulate ill-defined concepts and according to Zadeh " in contrast to traditional hard computing, soft computing exploits the tolerance for imprecision, uncertainty, and partial truth to achieve tractability, robustness, low solution-cost, and better rapport with reality” [3].Fuzzy Inference Systems (FIS) are one of the better known applications of fuzzy set theory. They can be seen as a mapping between sets of fuzzy sets. Let X, Y be non-empty sets and f: $X \rightarrow Y$ be any continuous function. Let F(X), F(Y) denote the set of all fuzzy sets defined on X, Y, respectively, i.e. , $F(X) = \{A|A: X \rightarrow [0,1]\}$. Let an input $x \in X$ be given to the fuzzy inference system. With the help of a fuzzy if-then rule base and fuzzy logic operations on [0, 1], the inference module determines a corresponding output $y \in Y$. Thus, an FIS approximates f by a fuzzy function $\hat{f}: F(X) \rightarrow F(Y)$ [6]. The inference mechanism in an FIS itself can differ in their strategy of combining rules, choice of fuzzy logic operations, etc., and hence lead to various established types of FIS, viz., TS-fuzzy systems, Mamdani, Relational FIS, etc. A fuzzy inference system can be completely and uniquely characterized by the following 6-tuple [6]:

F= (X, Y, Ai, Bi, R, O), where

- X, Y are the input and output domains;
- Ai, Bi are the fuzzy sets partitioning X, Y;
- R is a set of n Single-Input Single-Output fuzzy rules of the form (i= 1…. n): Ri: If $\tilde{x}$ is Ai then $\tilde{y}$ is Bi;
- O is the set of fuzzy logic operations used in the inference.

The probability density function (PDF) Salt & Pepper (Impulse) noise can be defined as follows:

$$p(z) = \begin{cases} Pa & \text{for } z=a \\ Pb & \text{for } z=b \\ 0 & \text{otherwise} \end{cases}$$

If b>a, intensity b will appear as light dot and vice-versa. Pa and Pb define the probability of a and b respectively. If either Pa or Pb is zero then it is called as the uni-polar noise. For salt

& pepper noise, Pa must be equal to Pb and is also referred as Data-drop-out and spike noise [1].

PSNR (db) is peak signal to noise ratio and given as follows:

$$MSE = \frac{\sum_{M,N} [I_1(m,n) - I_2(m,n)]^2}{M * N} \qquad PSNR = 10\log_{10}\left(\frac{R^2}{MSE}\right)$$

MSE is the mean square error. *I* is the image matrix. *M* and *N* are the number of rows and columns in the input images, respectively. *R* is the maximum fluctuation in the input image data type. For example, if the input image has a double-precision floating-point data type, then *R* is 1. If it has an 8-bit unsigned integer data type, *R* is 255, etc [2].

3. PROPOSED SCHEME

Fuzzy inference system used in proposed method is 2-inputs and 1-output of Mamdani type.

$\mu_c(y) = \min_k [\ \min [\ \mu_A(\text{input(i)}), \mu_B(\text{input(j)}),\ ]]$

k = 1, 2… r.

For Fuzzification of input, Inference method is used in which membership function is defined by means of various shapes. Membership function defines the information contained in the fuzzy set. A fuzzy set Ã in the universe of discourse X can be defined as, Ã= {(x, $\mu_{\tilde{A}}$(x)) | x € X}, where $\mu_{\tilde{A}}$(.) is called membership function of Ã. The membership value ranges in the interval [0, 1]. Gaussian shaped membership functions are used as they provide smooth transition [2]. After Inference process, Defuzzification (linguistic variables to numbers) of values is required. For Defuzzification, Centroid method is used and defuzzified output x* is defined as:

$$x^* = (\int \mu\tilde{N}(x).\ x dx) / (\int \mu\tilde{N}(x)\ dx)$$

(∫ denotes algebraic integration).

In proposed scheme image restoration is performed in spatial domain. Because as already defined, Salt & Pepper noise can be easily identified by inspecting each pixel value as either 0 or 255.

Figure 1 represents Algorithm of Fuzzy Logic Based Adaptive Mean Filter (FL-AMF) and is explained in four stages. First Stage corresponds to detection of noisy pixel. Each pixel of image is inspected one by one. Whenever a noisy pixel [0 or 255] is detected, a desired neighborhood (3x3 in this paper) is selected and proper sets are formed from these 9 pixel elements to compute the result.

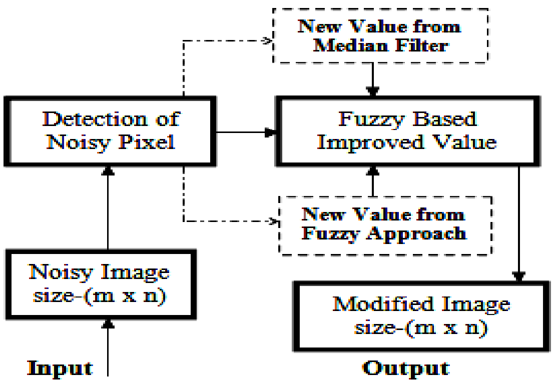
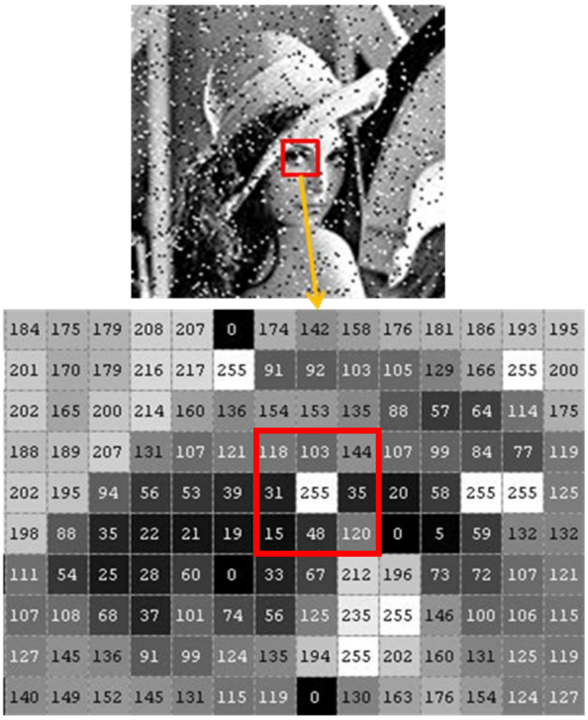


Fig 1: Block Diagram of FL-AMF process

In the selected neighborhood as shown below, four sets of two pixels each are formed. These four sets are; Set1 – [E2, E8], Set2 – [E4, E6], Set3 – [E1, E9] & Set4 – [E3, E7]. Each set has two pixels and labeled as P1, P2 in further explanations.

E1 N-W	E2 North	E3 N-E
E4 West	E5 Noisy Pixel	E6 East
E7 S-W	E8 South	E9 S-E

Fig 2: Selected 3x3 Neighborhood



184	175	179	208	207	0	174	142	158	176	181	186	193	195
201	170	179	216	217	255	91	92	103	105	129	166	255	200
202	165	200	214	160	136	154	153	135	88	57	64	114	175
188	189	207	131	107	121	118	103	144	107	99	84	77	119
202	195	94	56	53	39	31	255	35	20	58	255	255	125
198	88	35	22	21	19	15	48	120	0	5	59	132	132
111	54	25	28	60	0	33	67	212	196	73	72	107	121
107	108	68	37	101	74	56	125	235	255	146	100	106	115
127	145	136	91	99	124	135	194	255	202	160	131	125	119
140	149	152	145	131	115	119	0	130	163	176	154	124	127

Fig 3: Selected 3x3 Neighborhood from Lena Image

DP1= median [15 31 35 48 **103** 120 144 118 255]

DP1=103 and median filter replaces all the centre pixels with, DP1 value in same way, irrespective of pixel is noisy or not.

FL-AMF filter will process 3x3 neighborhood only if pixel is noisy (Noisy Pixel is [0 or 255]). Four sets will be formed & processed as follows:

s1 = [103, 48]; s2 = [31, 35]; s3 = [118, 120]; s4 = [144, 15];

NS1 = [fuzzy (s1), fuzzy (s2)] = fuzzy [76, 37.3] = 68.4

NS2 = [fuzzy (s3), fuzzy (s4)] = fuzzy [25, 75.5] = 40

DP2= fuzzy (NS1, NS2) = 45.3

In Third Stage the two final values obtained, are again processed by FL-AMF to deduce the final value. Fourth Stage replaces the value of noisy pixel by new pixel obtained in previous step. This process is repeated until all noisy pixels of image are modified.

f= fuzzy (DP1, DP2) = 30

Finally, the noisy pixel will be replaced by the value f = 30.

FIS used here has 3 sets in membership function (Figure-2) for each of the inputs and 5 sets in membership function for each (Figure-3) of output. Rule base contains total of nine rules as 2 inputs have 3 set each (3x3). Figure-4 represents the surface viewer for relationship between inputs and output according to rule base.

Fuzzy rule base for the system is deduced by mapping the input values to the output. For example:

1. If (P1 is Dark) and (P2 is Dark) then (Decision is Dark).

2. If (P1 is Light) and (P2 is Dark) then (Decision is Avg).

In the similar way all 9 rules are deduced. P1 and P2 define the pixel set from neighborhood and are considered as input to fuzzy system. To compute the complete neighborhood (3 x 3) except center pixel which is noisy (obtained in first stage of detection.), firstly four sets are formed from eight pixels. Clubbing of pixels is done with respect to centre pixel as: First set corresponds to N (North) and S (South) pixels,

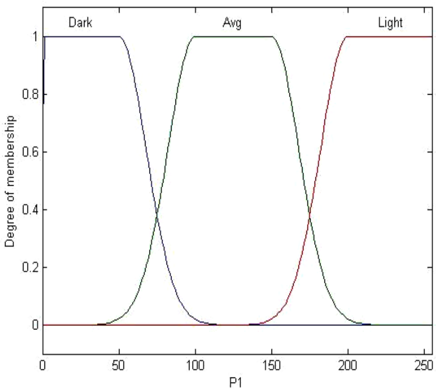


Fig 4: Membership Function for Input

Second set corresponds to W (west) and E (East) pixels Third set corresponds to NE (North-East) and SW (South-West) pixels and Fourth set corresponds to NW (North-West) and SE (South-East) pixels. These 4 sets are fed to FIS one by one and 4 pixels are obtained as the result.

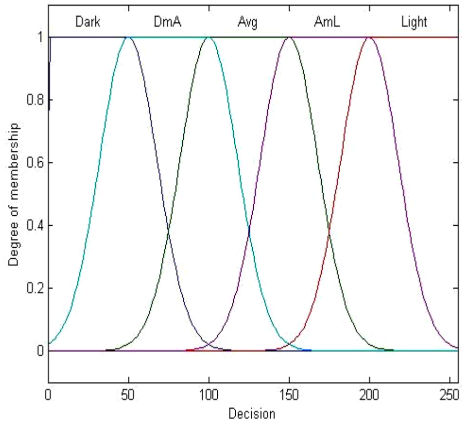


Fig 5: Membership Function for Output

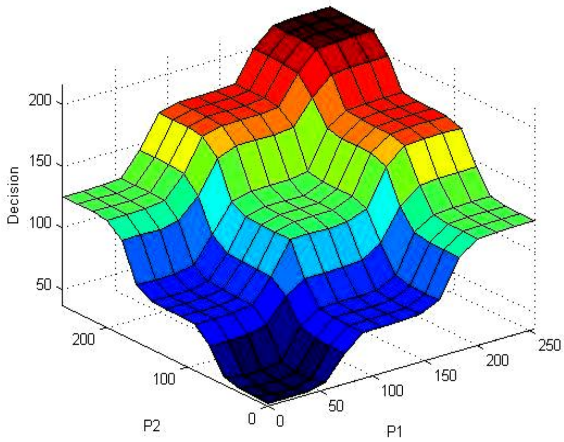


Fig 6: Surface Viewer

Again clubbing of 4 pixels in two sets is done according to weight and fed to FIS, which results in one set of 2 pixels and finally processed by FIS once again into one decision pixel (DP1). The same neighborhood is processed by median filter and resultant pixel is considered as DP2. By this process two values are obtained which can be replaced in central pixel.

(a)

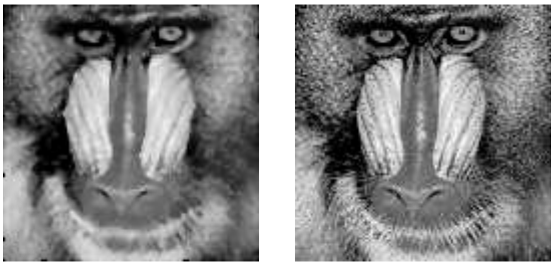
(b)

(c) **(d)**

Fig 7: Results for Lena Image

(a) Original Image, (b) Corrupted Image with 10% noise, (c) Median Filtered Image, (d) FZ-AMF Filtered Image

(a) **(b)**



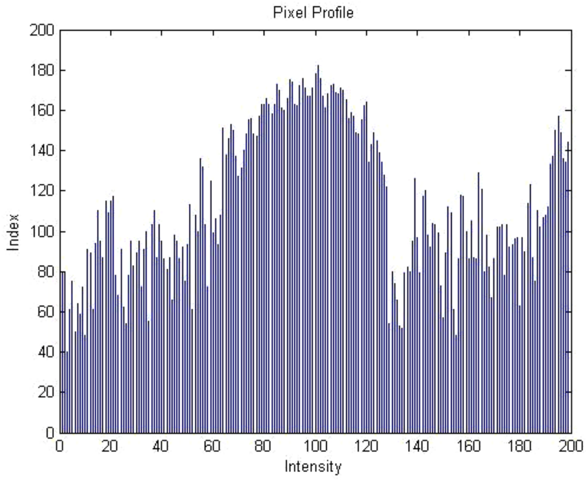
(c) **(d)**

Fig 8: Results for Mandril Image

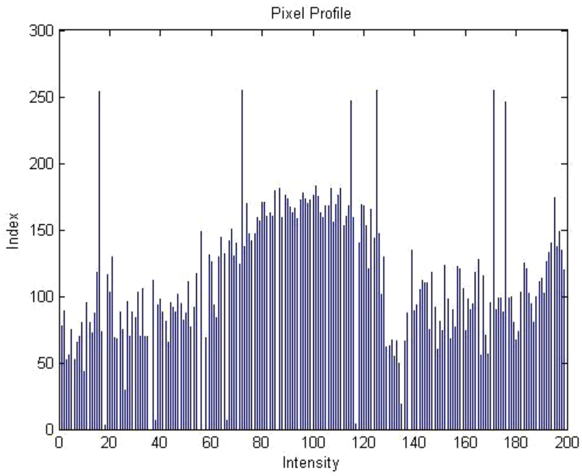
(a) Original Image, (b) Corrupted Image with 70% noise, (c) Median Filtered Image, (d) FZ-AMF Filtered Image

But again to deduce the better value by DP1 and DP2 both values are fed to FIS and final decision value is obtained and used as replacement for noisy or central pixel.

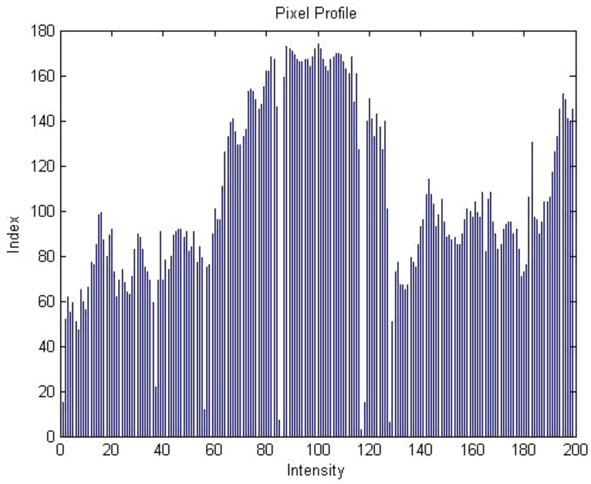
Figure-5 (Lena image) and Figure-6 (Mandril image) represents the final results of proposed approach and traditional median filter. Figure-7 represents pixel profile.



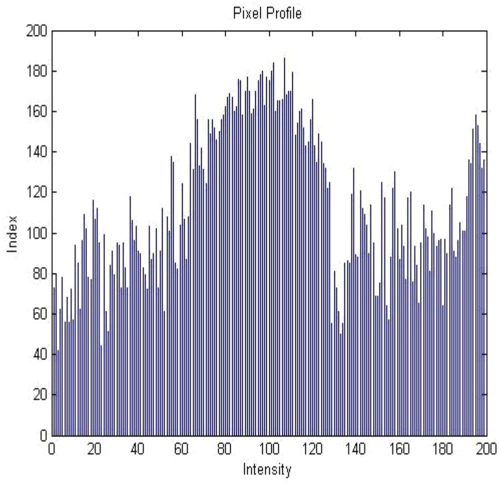
(a)



(b)



(c)



(d)

Fig 9: Pixel Profile for Mandril Image

(a) Original Image, (b) Corrupted Image with 70% noise, (c) Median Filtered Image, (d) FZ-AMF Filtered Image

4. RESULTS

Median Filter & FL-AMF are used and compared by PSNR value for a number of images and it is found that, FL-AMF performs well. Figure 8 represents PSNR values for Lena image (512x512) for a various range of salt and pepper noise densities. Noise pixels on boundary of image are left almost untreated by median filter.

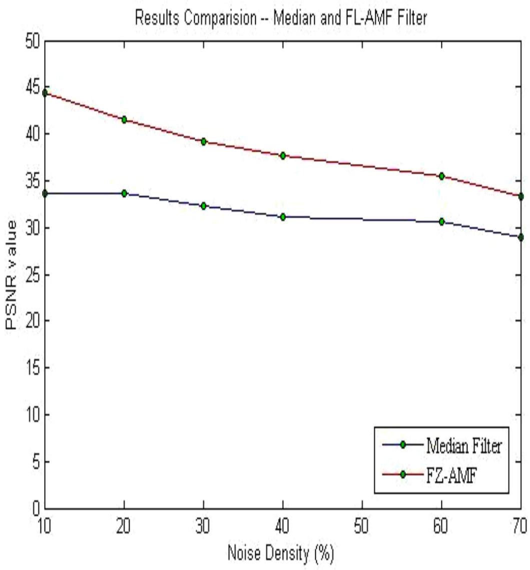


Fig 10: Comparison Results of PSNR – Median and FL-AMF Filters

Noise on boundary and preservation of Small details (edge details) are considered effectively by FL-AMF and can be visualized easily in Figure 7 which represents pixel profile for Mandril image.

5. CONCLUSION

In this paper proposed scheme performs very well in comparison to median filter for grayscale images. For further research, area of improvisation can be removal of Salt & Pepper noise in colored images and use of FL-AMF for de-noising of other noises. Iterative processing can also be considered for image enhancement purpose.

6. REFERENCES

[1] R. C. Gonzalez and R. E. Woods. Digital Image Processing. Pearson, 2011

[2] S.N. Sivanandam, S. N. Deepa Principles of soft computing. John Wiley & Sons, Inc, 2009.

[3] Fuzzy Logic Tool Box user guide Matlab(R2009b)

[4] A. B. Badiru, J. Y. Cheung, Fuzzy Engineering Expert Systems. John Wiley & Sons, Inc.

[5] T. J. Ross, Fuzzy Logic with engineering applications. Wiley

[6] B. Jayaram, "Fuzzy Inference System based Contrast Enhancement", EUSFLAT-LFA2011

[7] H. Xu, "An Adaptive Fuzzy Switching filter for images corrupted by impulsive noise" Sixth international conference on Fuzzy systems and Knowledge Discovery, 2009.

[8] Y. Zhou, "Adaptive Fuzzy Median Filter for images corrupted by impulsive noise", Congress on Image and Signal Processing, 2008.

[9] S. Zhang and M.A. Karim, ―A new impulse detector for switching median filters‖, IEEE Signal Processing Letters, vol 9, no 11, pp 360-363, Nov 2002.

[10] R. H. Chan, C. Ho, and M. Nikolova," Salt-and-Pepper Noise Removal by Median-type Noise Detectors and Detail- preserving Regularization," IEEE Transaction on Image Processing, Vol. 14, No. 10, Oct, 2005.

[11] K. M. Singh, "Fuzzy Rule based Median filter for Gray-Scale Images, ",Journal of information Hiding and Multimedia signal processing,vol.2,no.2, April 2011.

[12] H. Kundra," Filter for removal of impulse noise by using fuzzy logic", International Journal of image processing (IJIP), vol.3, issue 3, March 2011.

[13] J. Kaur, "SALT & PEPPER NOISE REMOVAL USING FUZZY BASED ADAPTIVE FILTER", International Journal of Science, Engineering and Technology Research (IJSETR) Volume 1, Issue 1, July 2012.

[14] Z. F. Deng, Z. P. Yin, and Y. L. Xiong, "High probability impulse noise-removing algorithm based on mathematical morphology," IEEE Signal Process. Lett., vol. 14, no. 1, pp. 31–34, Jan. 2007.

[15] Pei-Yin Chen, Chih-Yuan Lien, "An Efficient Edge-Preserving Algorithm for Removal of Salt-and-Pepper Noise", IEEE Signal Processing Letters, vol. 15, 2008.