Modified Filter Equation with Improved Fuzzy Logic System Based Directional Median Filter for Mixed Noise

Bhageerath Singh Kaurav, Karuna Markam, Pooja Sahoo

Abstract: DWM (Directional weighted median) filter is very popular in filtering digital image and remove mixed noise. Fuzzy logic is implemented with median filters to improve its performance. In the previous work, fuzzy logic system is implemented with switching median filter and gives better performance than directional median filter as well as switching median filter. Experimenting directional median filter with same fuzzy logic system didn’t yield to better results therefore fuzzy logic parameters has been changed as per strong points of directional weighted median filter and a constant has been included in the filtering equation to improve the results. So in this proposed work, we have successfully implemented directional weighted median filter with fuzzy logic system which is proving better results than DWM and FSMF (Fuzzy Switching Median Filter). PSNR (Peak Signal to Noise Ratio) is used for qualitative analysis of results.

Keywords: DWM (Directional Median Filter), FSMF (Fuzzy Switching Median Filter), mixed noise, Gaussian noise, salt & pepper noise, fuzzy logic rules, membership functions, PSNR (Peak Signal to Noise Ratio), Fuzzification.

I. INTRODUCTION

Median filters are popularly used in removing noise from the digital images. DWM is the best out of all median filters due to its directional capabilities to look into the noise in between the pixels. Now a day, Fuzzy logic system is implemented in all the research fields to improve the results. Impulse noise and Gaussian noise are two most frequent noises which corrupts digital images [7]. Mixed noise is a combination of Gaussian noise and impulse noise. Pixels in Impulse noise have high intensity value. Impulse noise in the images appears in the form of black and white dots, these pixels has higher intensity value as compared to its surrounding [1]. Noise in the communication channels corrupts the digital images due to introduction of impulse noise. Due to this reason, there will be poor output of the image processing algorithms like detection of edge, segmentation of image, recognition of object and tracking of object.

Thus this noise has to be removed to perform computer vision algorithms [2]. Image pre-processing is the step which is used first to remove noises so that it will not come in the output; this pre-processing is used in all of the image processing applications [5]. In order remove these noises, median filters is used.

DWM filter is directional because difference in intensity of neighboring pixels in four different directions is used and center pixel, this helps in deciding whether center pixel is corrupted by impulse noise or it is still original. If the pixel is found corrupted, then standard deviation is calculated in the four directions and then in the direction of minimum standard deviation, median is calculated. The quality of output of DWM filter can be calculated by proper detection of the edge direction [4].

Usually images with Gaussian noise are recovered by using least-squares methods based algorithms [8]. Impulse noise fails these filters due to heavy load of noise on image. The filtering process will leads to change in intensity of all the pixels included uncropped pixels. In the proposed work, fuzzy logic system is implemented with DWM filter. Fuzzy logic system is created by considering the strong points of DWM filter to detect noise in the digital image. Some changes been done in the filtering equation by adding constant which results in improvement of the results in terms of PSNR value.

II. FUZZY LOGIC BASED SWITCHING MEDIAN FILTER

In FSMF, SMF is a combination of two process. In the first process, noise detection is performed, while in second process the corrupted pixels are filtered. In this work, detection of noise is performed by using fuzzy logic controller. Here, Fuzzy logic system with name fuzzysystem_f1 is formed. It has two inputs (input1 & input2) and one output (output1). Fuzzysystem_f1 represents the fuzzy logic system is shown in Fig.1[1].

Fig. 1: Fuzzy editor window for FSMF system
Modified Filter Equation with Improved Fuzzy Logic System Based Directional Median Filter for Mixed Noise

Membership function of inputs and outputs are defined in Fig. 2(a) & (b) & Fig. 3 respectively. As shown in Fig. 2(a) & (b), Input is taken as trapezoidal shape [10] membership function with two entries name “low” for small difference in pixel values and “high” for large difference in pixel values.

In above Fig. 3, the output is described as a triangle shape [11] membership function with two entries name noise which indicate noisy pixel and unchanged which indicates non-corrupted pixel.

Rule editor is the rule book in fuzzy logic system [9]. Rules have been decided by considering two decided inputs and according to that output are defined. Like if both the inputs are large (high) then output is noisy while if both the inputs are small (low) then output is unchanged or noiseless. If In(i,j) represents the center pixel, the difference represented by In(i,j)-In(i-1,j) & In(i,j)-In(i+1,j) will be sent as an input to fuzzy logic controller. The fuzzy logic output is represented by y1 which its range is set as [0 1] with triangular membership function. The output of the fuzzy logic controller is considered as a gain factor. The filtering equation is then represented by,

\[ f = (1 - y1) .* Z2 + (y1 .* m1) \]

Here, 
\( f \) = recovered image 
\( y1 \) = gain factor from fuzzy logic 
\( Z2 \) = noisy image 
\( m1 \) = output of median filter

Fig. 4: Fuzzy Rules for FSMF system
III. DIRECTIONAL WEIGHTED MEDIAN FILTER

As compared to other median filters, DWM has provided better results and also perform better even in the case when image is distorted by Salt & Pepper noise. It is assumed in DWM that digital images also includes edges with smoothly carrying area both side [3].

Let $S_k$ represent a set of pixels aligned with the k-the direction which is centered at $(0,0)$ is given

$$S_1 = \{(i-2,j), (i-1,j), (i+1,j), (i+2,j)\}$$

$$S_2 = \{(i,j-2), (i,j-1), (i,j+1), (i,j+2)\}$$

$$S_3 = \{(i,j-2), (i,j+1), (i,j+1), (i,j+2)\}$$

$$S_4 = \{(i-2,j), (i-1,j), (i+1,j), (i+2,j)\}$$

Four directions in the 5x5 sliding window is,

![Fig. 5: Four directions for impulse noise detection](image)

Now calculate the direction index $d_{i,j}^{(k)}$ using the following formula.

$$d_{i,j}^{(k)} = \sum_{(t,s) \in S_k} w_{s,t} |Y_{i+s,j+t} - Y_{i,j}|, \quad 1 \leq k \leq 4$$

$$w_{s,t} = \left\{ \begin{array}{ll}
2, & (s,t) \in \Omega^3, \\
1, & \text{otherwise}
\end{array} \right. \quad \Omega^3 = \{(s,t): -1 \leq (s,t) \leq 1\}$$

These direction index are sensitive with the edge in any of the four direction. Impulse can be detected by calculating the minimum value of directional index in all 4 directions and it is represented in the form of equation as,

$$r_{i,j} = \min \{d_{i,j}^{(k)}: 1 \leq k \leq 4\}$$

Conditions must be satisfied

1) Noise free flat-region current pixel, then $r_{i,j}$ is small, due to small direction indexes.
2) Current pixel is at edge then $r_{i,j}$ is also small, due to small directional index in at least one of the direction.
3) When the current pixel is an impulse then $r_{i,j}$ is large, because of the four large direction indexes.

Output of detection process is equated as:

$$x(i,j) = \begin{cases} 
\text{noisy pixel}, & \text{if } r_{i,j} > T \\
\text{noise - free pixel}, & \text{if } r_{i,j} \leq T 
\end{cases}$$

It can be seen that if the least value of direction index is more than the predefined threshold value $T$, it represents noisy center pixel else pixel is considered as noiseless. As the noise detection process is completed then the median filter is applied on noisy pixel in the window [6].

After it standard deviation $\sigma_{i,j}^{k}$ is calculated in all 4 directions and then the minimum values is calculated as represented by,

$$l_{i,j} = \arg \min_k \{\sigma_{i,j}^{k}: k = 1 \text{ to } 4\} \quad (8)$$

Here operator $\arg \min$ calculate the minimum value. Standard deviation provides information about similarity of all pixel value around the mean value in the neighboring pixels. Here $l_{i,j}$ represents the closeness of pixels in all 4 directions. So the center pixel will have similar intensity to protect edges. Median value can be calculated as.

$$m(i,j) = \text{median} \{(\tilde{w}_{s,t} \ast (i+s,j+t)): (s,t) \in \Omega^3\} \quad (9)$$

Where $\tilde{w}_{s,t} = \left\{ \begin{array}{ll}
\tilde{w}_m, & (s,t) \in S_{l_{i,j}}^{(0)}, \\
1, & \text{otherwise}
\end{array} \right.$

operator $\ast$ denotes repetition operation and normally $\tilde{w}_m = 2$.

The output of the DWM filter is given by following formula.

$$y(i,j) = \alpha(i,j)x(i,j) + (1 - \alpha(i,j))m(i,j) \quad (11)$$

Where

$$\alpha(i,j) = \left\{ \begin{array}{ll}
0, & r_{i,j} > T \\
1, & r_{i,j} \leq T
\end{array} \right.$$ 

IV. PROPOSED FUZZY LOGIC BASED DIRECTIONAL MEDIAN FILTER

In the proposed filter, detection of noise is performed by using improved fuzzy logic system. This system consists of 4 inputs which represents 4 different directions and one output as shown below:

![Fig. 6: Fuzzy editor window for proposed system](image)
Modified Filter Equation with Improved Fuzzy Logic System Based Directional Median Filter for Mixed Noise

There are 4 inputs with 2 entries named “low” and “high”. Trapezoidal membership function is used to represent these entries as shown in Fig. 7. “low” represents low difference in pixel values while “high” represents high difference in pixel values. Range of low and high is from 0 to 512 because if two pixels with maximum intensity (that is 255) are summed then value will be 512.

And there is 1 output with 2 entries named “noisy” and “noiseless”. Triangular membership function is used to represent these entries as shown in Fig. 8. “Noisy” represents noise in pixel while “noiseless” represents no noise in pixel. Range of low and high is from 0 to 1.

10 different rules have been defined in the fuzzy logic system which decides whether output is noisy or noiseless as shown in Fig. 9. These rules are creating by considering edges in the digital image as well so that edges won’t be detected as a noisy pixel.

To improve the results, the final filtering equation is modified to include a constant c in the equation because now fuzzy logic system will give output in the range of 0 to 1 unlike other cases where output is only 0 and 1.

\[ f = y_1 \cdot Z_2 + ((c - y_1) \cdot m_1) \quad (13) \]

Here,
\[ f \] = recovered image
\[ y_1 \] = gain factor from fuzzy logic
\[ Z_2 \] = noisy image
\[ m_1 \] = output of median filter
\[ c \] = constant = 2.5 (Experimentally find)

The results are shown in TABLE 1. PSNR values of DWM, FSMF and proposed DWM-FUZZY is shown this table for noise variation of 1 to 10%. Fig. 10 shows the plot of TABLE 1, which concludes that PSNR values of proposed DWM-FUZZY is much better than both DWM and FSMF filters.
TABLE 1: PSNR of Fuzzy-SWM, DWM filter and proposed Fuzzy-DWM filter for noise density from 1 to 10%

| S. No | Noise (in %) | PSNR (DWM) | PSNR (FUZZY-SWM) | PSNR (MODIFIED FUZZY-DWM) |
|-------|--------------|------------|------------------|---------------------------|
| 1     | 1            | 20.46      | 22.77            | 24.23                     |
| 2     | 2            | 20.41      | 22.58            | 24.03                     |
| 3     | 3            | 20.39      | 22.39            | 23.94                     |
| 4     | 4            | 20.32      | 22.05            | 23.80                     |
| 5     | 5            | 20.21      | 21.79            | 23.64                     |
| 6     | 6            | 20.09      | 21.58            | 23.41                     |
| 7     | 7            | 19.94      | 21.38            | 23.30                     |
| 8     | 8            | 19.88      | 21.01            | 23.10                     |
| 9     | 9            | 19.82      | 20.73            | 22.98                     |
| 10    | 10           | 19.67      | 20.58            | 22.80                     |

Fig. 10: PSNR Vs Noise Plot

TABLE 2: Images from Fuzzy-SWM, DWM filter and proposed Fuzzy-DWM filter for noise density from 1 to 10%

| Noise % | Noisy image | DWM | FUZZY-SWM | PROPOSED WORK (FUZZY-DWM) |
|---------|-------------|-----|-----------|----------------------------|
| 1       | ![Image](image1) | ![Image](image2) | ![Image](image3) | ![Image](image4) |
| 2 | ![Image](image1) | ![Image](image2) | ![Image](image3) | ![Image](image4) |
|---|----------------|----------------|----------------|----------------|
| 3 | ![Image](image5) | ![Image](image6) | ![Image](image7) | ![Image](image8) |
| 4 | ![Image](image9) | ![Image](image10) | ![Image](image11) | ![Image](image12) |
| 5 | ![Image](image13) | ![Image](image14) | ![Image](image15) | ![Image](image16) |
| 6 | ![Image](image17) | ![Image](image18) | ![Image](image19) | ![Image](image20) |
The noisy image with filtered images from DWM, FSMF and proposed DWM-FUZZY filter are shown in TABLE 2. It can be seen from these images that proposed filter is giving better quality filtering than others.

V. CONCLUSION

Non linearity in camera sensors, satellite communication and other type of data transfer leads to addition of mixed noise in the digital image. Mixed noise (salt & pepper noise with Gaussian noise) is used to corrupt the original image. In this experiment, salt & pepper noise is varied from 1 to 10% while Gaussian noise is taken with zero mean and 0.01 variance. Filtering equation has been modified and fuzzy logic is improved as per direction median filter to get good result. From the above tables and plots, it can be seen that the proposed fuzzy-DWM logic based algorithm provides better quality filtering than DWM & fuzzy-SWM. The PSNR of proposed algorithm is much better as compared to other filters.

REFERENCES

1. Jagrati Gupta, Sandeep Kumar Agrawal, “Fuzzy Logic Gain Factor Based Improved Switching Median Filter for Mixed Noise”, International Conference on Advance Computation and Telecommunication (ICACAT), sponsored by IEEE, 2018.
2. Rita Gupta, Akansha Yadav, “Fuzzy Logic based Switching Median Filter for Mixed Noise in Digital Image”, IJSRD - International Journal for Scientific Research & Development, Vol. 5, Issue 07, 2017.

3. Vahid Kiani, Iran Abbas Zahrevand, “A Fuzzy Directional Median Filter for Fixed-value Impulse Noise Removal”, Iranian Joint Congress on Fuzzy and Intelligent Systems (CFIS), Jan 2019.

4. Zong Chen and Li Zhang, “Multi-stage Directional Median Filter”, World Academy of Science, Engineering and Technology 59 2009.

5. Sweety Deswal, Surbhi Singhania, Shailender Gupta and Pranjal Garg, “An Optimised Fuzzy Approach to Remove Mixed Noise from Images”, International Journal of Signal Processing, Image Processing and Pattern Recognition Vol 9, No 4 (2016).

6. Chung-Chia Kang, Wen-June Wang, “Fuzzy reasoning-based directional median filter design”, Signal Processing, Volume 89, Issue 3, March 2009.

7. Bogdan Smolka, Damian Kusnik, “Robust local similarity filter for the reduction of mixed Gaussian and impulsive noise in color digital images”, SIViP, Springer, Oct 2015.

8. D. V. Murugan, R. Balasubramanian, “An Efficient Gaussian Noise Removal Image Enhancement Technique for Gray Scale Images”, International Journal of Computer, Electrical, Automation, Control and Information Engineering Vol 9, No 3, 2015.

9. Mahesh Prasanna K and Dr. Shantharama Rai C, “Applications of Fuzzy Logic in Image Processing – A Brief Study”, International Journal of Advanced Computer Technology, Volume 4, Issue 3, March 2015.

10. Kenny Kal Vin Tob, Haidi Ibrahim and Muhammad Nasiruddin Mahyuddin, “Salt-and-Pepper Noise Detection and Reduction Using Fuzzy Switching Median Filter”, IEEE Transactions on Consumer Electronics, Vol. 54, No. 4, NOVEMBER 2008.

11. Naga shettappa Biradar, M.L.Dewal, Manoj Kumar Rohit, “SPECKLE NOISE REDUCTION USING HYBRID TMAV BASED FUZZY FILTER”, International Journal of Research in Engineering and Technology, Volume 3, Special Issue 3, May 2014.

12. M. A. P. Chamikara, A. A. C. A Jayathilake, S. R. Kodituwakku, Fuzzy Based Statistical Method for Image Noise Filtering, International Journal of Advanced Research in Computer Science and Software Engineering, Volume 4, Issue 10, October 2014.

AUTHORS PROFILE

Bhageerath Singh kaurav, received Bachelor of Engineering in Electronics and Communication Engineering from Integral Institute of Information Technology & Management College, Sihoti, Gwalior, Madhya Pradesh in 2016. He is recently doing M.tech from Madhav Institute of Technology and Science, Gwalior, M.P, India.

Karuna Markam, graduated B. Engg. in Electronics and Communication from GEC Bhopal, M. Tech in Digital Communication from MANIT Bhopal and PhD from Barkatullah University Bhopal India. She has more than 18 years of teaching experience. She has guided 35 M. Tech dissertation. She published 40 papers in various national and international journals and conferences.

Pooja Sahoo, graduated B.Tech in Electronics and Communication Engineering from AEC Agra and received Master in Engineering in Microwave Engineering from MITS, Gwalior, India. She is pursuing PhD from RGPV, Bhopal. She has published 10 papers in various national and international journals and conferences till date.