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 changes 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 uncorrupted 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 has 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].
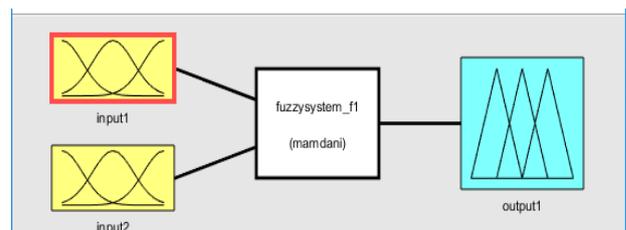

Fig. 1: Fuzzy editor window for FSMF system
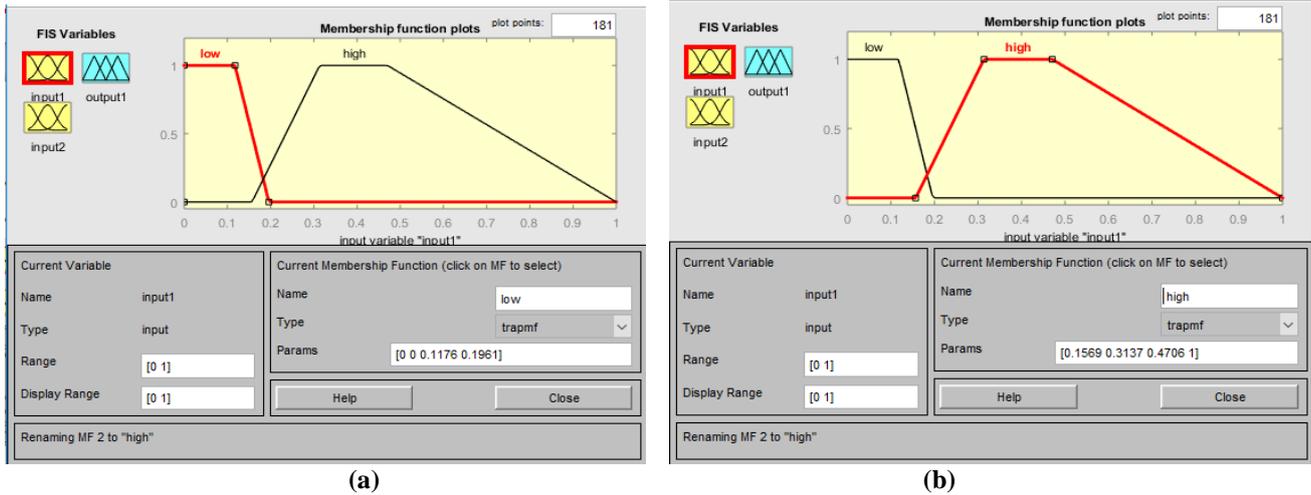
(a) **(b)**

Fig. 2: Membership function for inputs (a) showing limits of low (b) showing limits of high.
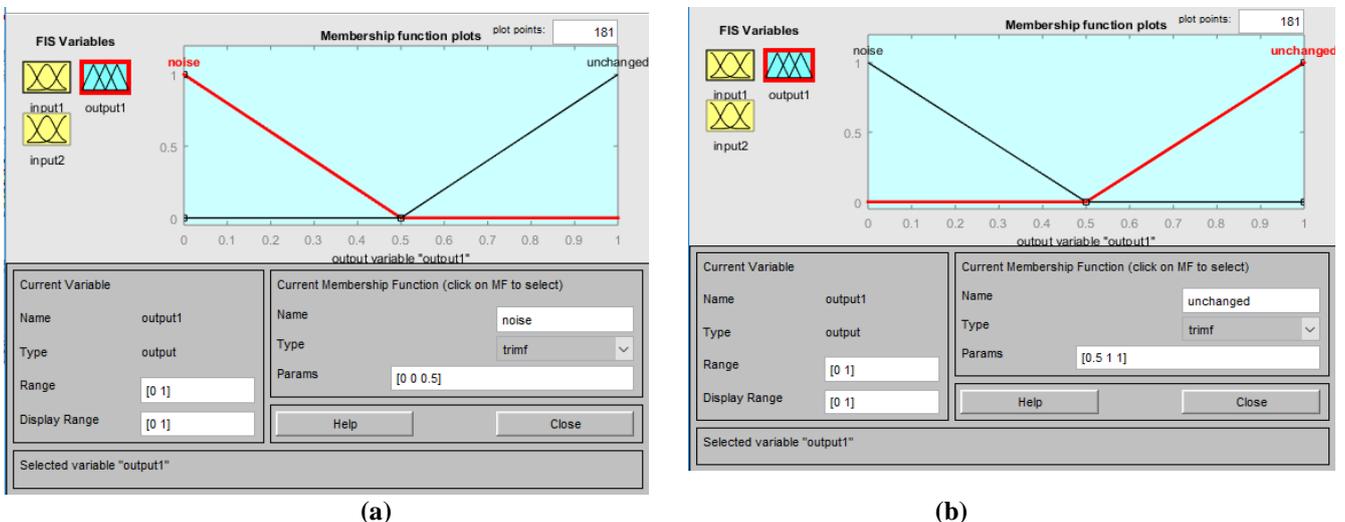

(a) **(b)**

Fig. 3: Membership function for output (a) showing limits of noise (b) showing limits of unchanged.

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 y1and 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)   ref(4) Here, f=recovered image

y1=gain factor from fuzzy logic
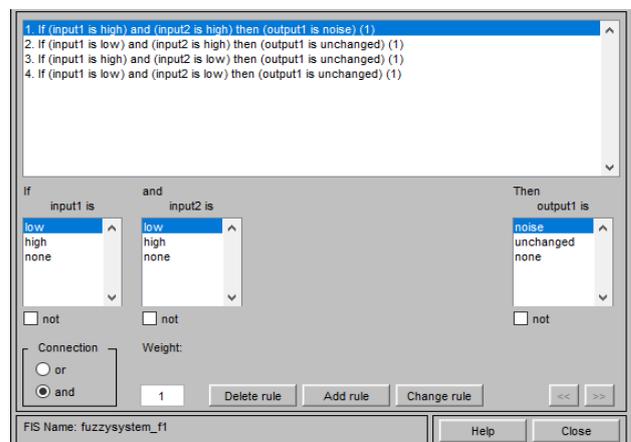Z2=noisy image
m1=output of median filter

Fig. 4: Fuzzy Rules for FSMF system

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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 incldes edges with smoothly carying 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

$S_1 = \{(-2,-2),(-1,-1),(0,0),(1,1),(2,2)\}$
$S_2 = \{(0,-2),(0,-1),(0,0),(0,1),(0,2)\}$
$S_3 = \{(2,-2),(1,-1),(0,0),(-1,1),(-2,2)\}$
$S_4 = \{(-2,0),(-1,0),(0,0),(1,0),(2,0)\}$
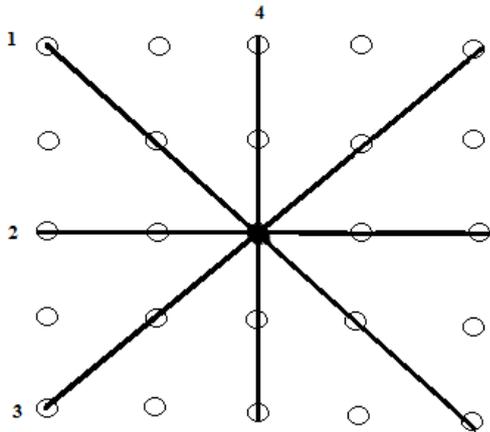
Four directions in the 5×5 sliding window is,

Fig. 5: Four directions for impulse noise detection

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

$$d_{i,j}^{(k)} = \sum_{(s,t) \in S_k^0} w_{s,t} |y_{i+s,j+t} - y_{i,j}|, \qquad 1 \le k \le 4 \quad (4)$$

$$w_{s,t} = \begin{cases} 2, & (s,t) \in \Omega^3 \\ 1, & otherwise \end{cases}, \quad \Omega^3 = \{(s,t): -1 \le (s,t) \le 1\} \quad (5)$$

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,

$$r_{i,j} = \min \{ d_{i,j}^{(k)} : 1 \le k \le 4 \} \quad (6)$$

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:

$$x(i,j) \text{ is } a \begin{cases} noisy\ pixel, & if\ r_{i,j} > T \\ noise-free\ pixel, & if\ r_{i,j} \le T \end{cases} \quad (7)$$

It can be seen that if the least value of direction index is more than than the pre defined threshold value T, it represents noisey center pixel else pixel is considered as noiselss. As the noise detection process is completed then the median filter is applied on noisy piexel 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,

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

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 closness of pixels in all 4 directions. So the center pixel will have similar intenstiy to protect edges. Median value can be calculated as.

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

Where $\widetilde{w}_{s,t} = \begin{cases} \widetilde{w}_m, & (s,t) \in s_{l_{i,j}}^{(0)}, \\ 1, & otherwise \end{cases} \quad (10)$

operator $\diamond$ denotes repetition operation and normally $\widetilde{w}_m = 2$.

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 $\alpha(i,j) = \begin{cases} 0, & r_{i,j} > T \\ 1, & r_{i,j} \le T \end{cases} \quad (12)$

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:
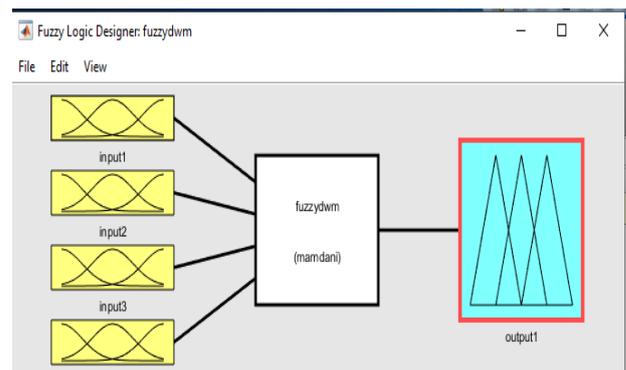

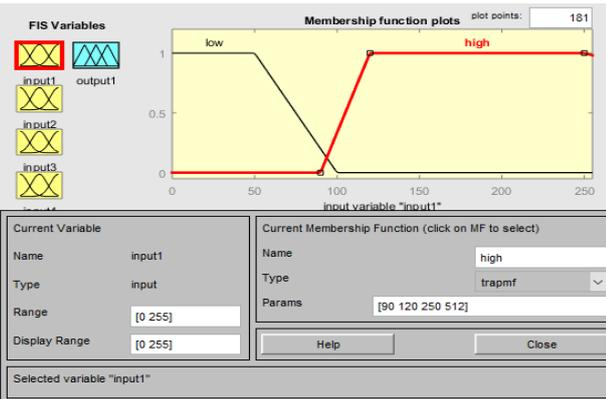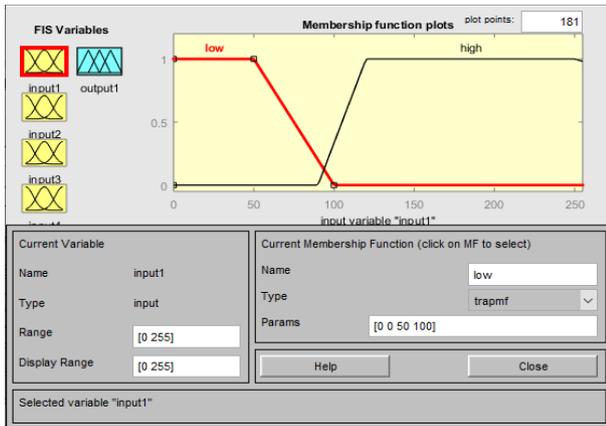**Fig. 6: Fuzzy editor window for proposed system**

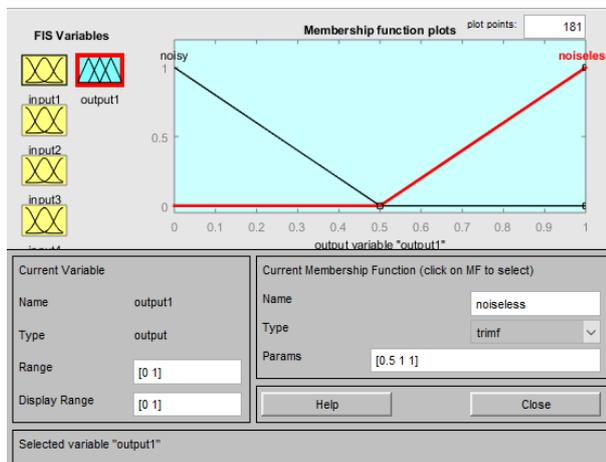**Fig. 7: Membership function for inputs (a) showing limits of small diff. (b) showing limits of big diff.**
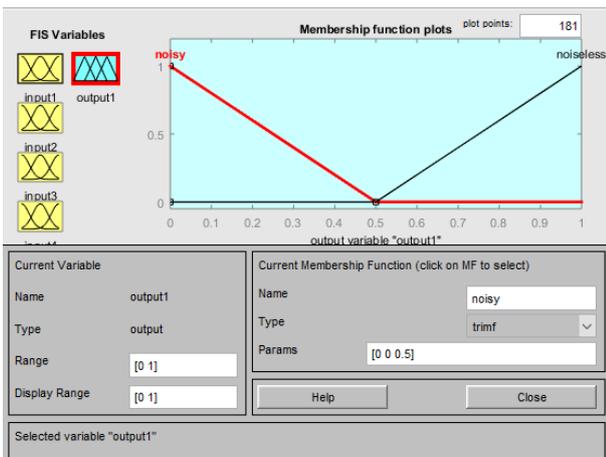

Fig. 8: Membership function for output (a) showing limits of noise (b) showing limits of unchanged.
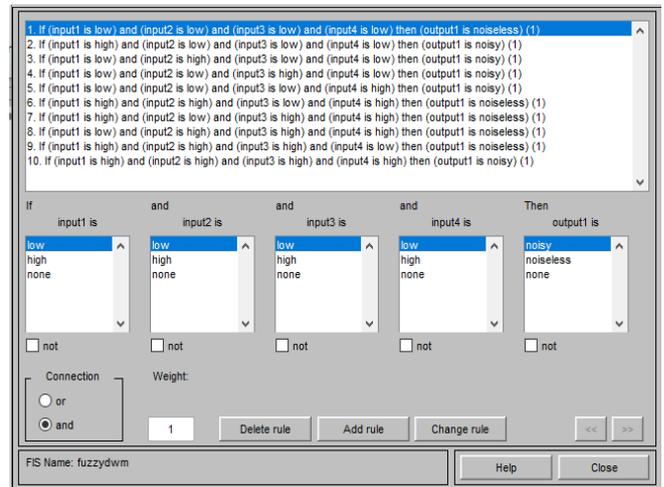

Fig. 9: Rules for proposed system

There are 4 inputs with 2 entries named "low" and "high". Trapezoidal membership function is used to represents 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 represents 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.

$$f = y1.*Z2+ ((c-y1) .*m1) \qquad (13)$$

Here,
f=recovered image
y1=gain factor from fuzzy logic
Z2=noisy image
m1=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.

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

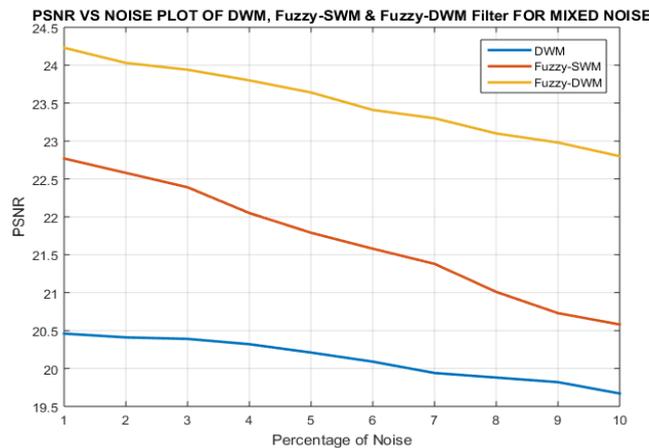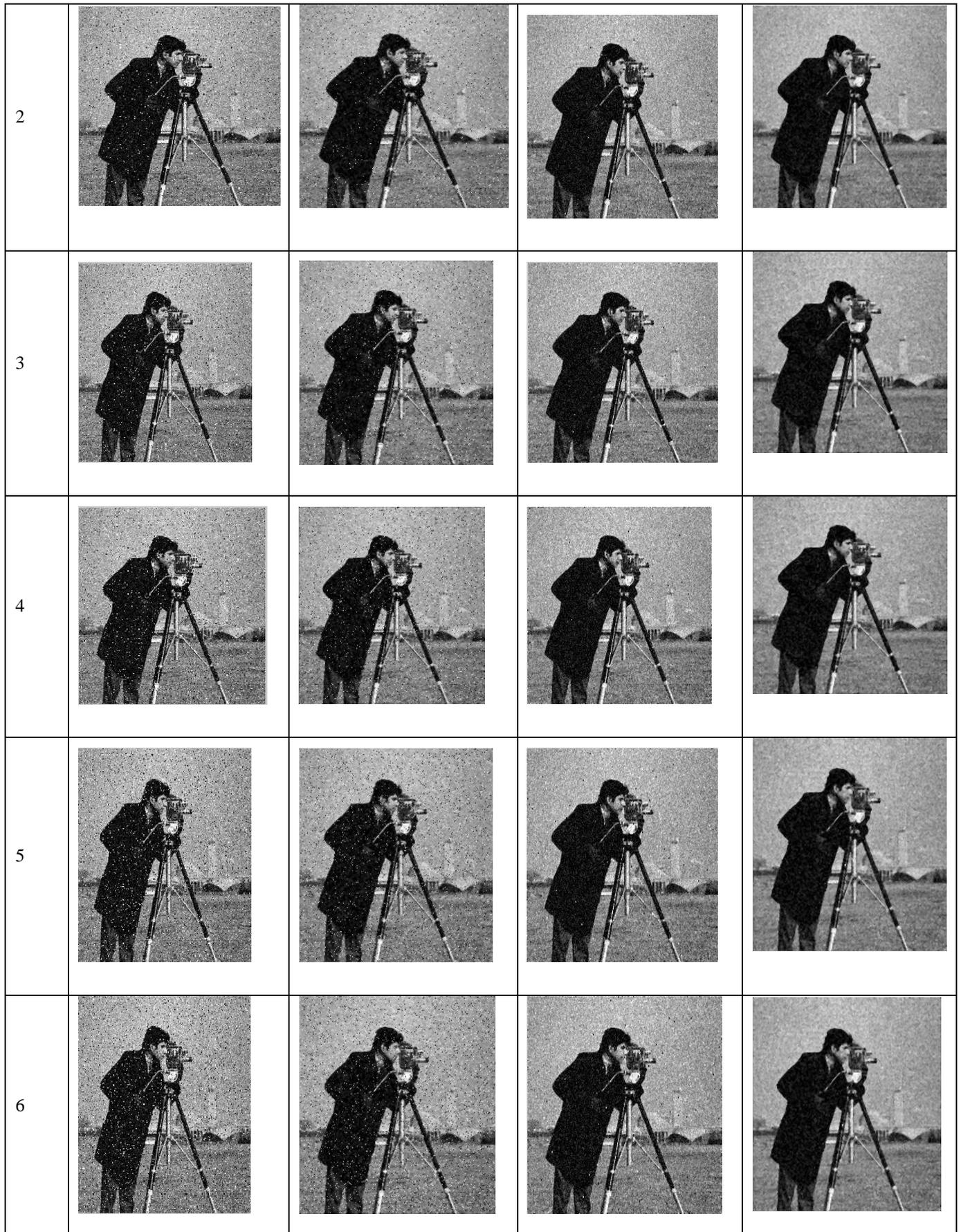| S. No	Noise (in %)	PSNR (DWM)	PSNR (FUZZY-SWM)	PSNR (MODIFIED FUZZY-DWM)
1	1	20.46	22.77	24.23
2	2	20.41	22.58	24.03
3	3	20.39	22.39	23.94
4	4	20.32	22.05	23.80
5	5	20.21	21.79	23.64
6	6	20.09	21.58	23.41
7	7	19.94	21.38	23.30
8	8	19.88	21.01	23.10
9	9	19.82	20.73	22.98
10	10	19.67	20.58	22.80

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				

2				
3				
4				
5				
6				

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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.

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.

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

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