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# An Improved Fuzzy-based Image Filtering for High Density Salt and Pepper Noise

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**Abstract**

The proposed system presents a fuzzy switching filter to remove high density salt and pepper noise in an image. This system combined the ability of modified median filter, the proposed fuzzy median filter and the proposed fuzzy mean filter. At first, target pixel in a (3x3) kernel is checked whether it is noise pixel (0 or 255) or not. If there isn't noise, the noise checking process shifts to the next kernel. If there is noise pixel (0 or 255), the number of noise within a kernel is counted. If the noise count is less than or equal to four which is less noise density, the modified median filter is used to remove noise. If the noise count is greater than four and less than or equal to six, the proposed fuzzy median filter is applied. If the noise count is larger than six which is high noise density, the proposed fuzzy mean filter is used to remove noise. By switching these three filters depending on the noise count within a kernel, the propose system can remove high density salt and pepper noise without distorting the edge and fine details in an image. At the experimental results, the proposed system can give better performance in removing high noise density. Furthermore, the denoising performance of the proposed filters will also be presented by calculating the Peak Signal to Noise Ratio (PSNR) values.

***Keywords:*** salt and pepper; fuzzy based switching filter; heavy noise density; fuzzy membership function and fuzzy rules

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## 1. Introduction

Digital images are often distorted by impulse noise during image acquisition, transmission and storage. Noise can enter through image acquisition by a camera, scanner, and recording and/or when the image is transmitted over a noisy channel. Salt-and-pepper noise is a special case of impulse noise, where a certain percentage of individual pixels are randomly digitized into two extreme intensity values, maximum and minimum [1].

The contamination of image by salt-and-pepper noise is caused in great amount and the occurrence of noise can severely damage the information or data contained in the original image. So, the need to remove salt-and-pepper noise is very important before subsequent image processing tasks are carried out.

The simplest and the traditional way to remove salt-and-pepper noise is by windowing the noisy image with a conventional median filter [2]. The linear filter like mean filter and related filters are not effective in removing impulse noise. Non-linear filtering techniques like Standard Median Filter (SMF), Adaptive Median Filter (AMF) are widely used to remove salt and pepper noise due to its good denoising power and computational efficiency. SMF is effective only at low noise densities (less than 30% noise density). Adaptive median filter is better than SMF but it cannot handle in over 60% noise density. The result of denoised image is blurring. Hence, for the robustness of image detail in higher noise density, many fuzzy based filtering techniques have been researched since at the start of $20^{th}$ century.

The proposed system is a technique to remove high density salt and pepper noise. For removing the high density salt and pepper noise, there are many problems in the other techniques. In fuzzy weighted mean filtering, it can give noise free image but it is blur. In other fuzzy filters, image detail and edge preservation are very problems in removing entire noise. By considering the above problems, the proposed filtering technique is designed. In this technique, there are three filters (modified median filter, fuzzy based median filter and fuzzy based weighted mean filter) which are applied by switching according to the amount of noise level within a kernel. According to the amount of noise occurrences, the proposed filtering system can remove the high density salt and pepper noise by switching these three filters, with faster processing speed.

## 2. Related Works

Many researches have been conducted numerous methods to remove salt and pepper noise. Among them, some interesting related techniques are presented as the following:In 2007, R. Bansal and his colleagues proposed "Noise Adaptive Fuzzy Switching Median Filter for Salt-and-Pepper Noise Reduction" [3]. The work presented the combined ability of the RCM filter and fuzzy thresholding technique to preserve edges and fine details. The pixels lying outside the trimming range after ranking in the RCM filter are further tested for being noisy by the process of fuzzy thresholding. The work used range of threshold values rather than a crisp threshold value as the level of contamination varies from pixel to pixel. The modified value for the noisy pixel was calculated depending on the impulse noise present in it. It achieved good denoised result and fine details.

Next, M. I. Jubair and his colleagues [4] proposed "An Improved Adaptive Filtering Technique to Remove High Density Salt-and-Pepper Noise Using Multiple Last Processed Pixels", in 2012. This method calculated median only among the noise-free neighborhoods in the processing window and replaces the center corrupted pixel with that median value. The work achieved faster processing speed.

Then, “Modified Decision Based Unsymmetric Trimmed Median Filter (MDBUTMF)” was published by S. Esakkiraja and his colleagues [5]. This work tried to overcome the streaking effect at higher noise densities. In this work, at high noise density, the processing pixel is replaced by the mean value of elements within the window. This leads the blurring of fine details in the image. After that another salt and pepper denoising method was published by T. Veerakumar and his colleagues [6]. The work proposed a combination of decision based unsymmetrical trimmed median filter and fuzzy thresholding technique to preserve edges and fine details in an image. After that, B. Deshpande and his colleagues proposed “Fuzzy Based Median Filtering Method” [7]. By incorporating fuzzy logic after detecting and correcting the noisy pixel, the proposed filter is able to suppress noise and preserve details across a wide range of salt and pepper noise corruption, ranging from 1% to 60%.

Another method to remove the salt and pepper noise is “the recursive fuzzy filter” [8]. The detection and filtering stage includes 3x3 scanning and merge scanning process and applying the histogram approach. The scanning and merging was used to detect noise and histogram approach was used to tune fine details. Another interesting method was the use of super mean filtering [9]. The proposed filter works in two stages, in the first stage the noisy pixels are detected and in the second stage each noisy pixel is replaced by the mean value of noise free pixel of 2×2 matrix. Next, S. Mehta and his colleagues implemented, “Fuzzy Based Median Filter for Gray Scale Image” [10]. The method worked in two steps, the first detect noisy pixels using fuzzy reasoning with lowest uncertainty, and noisy pixels were replaced with an adaptive noise filter in the second. The filter was combined with human knowledge for select best replacement.

In 2013, M. González-Hidalgo proposed a method of fuzzy morphological approach [11]. The method was a two phased method. In the first phase, an impulse noise detector based on the fuzzy top-hat transforms is used to identify pixels which were likely to be contaminated by noise. In the second phase, the image was restored using a specialized regularization method using fuzzy open-close or fuzzy close-open sequences applied only to those selected contaminated pixels. Another fuzzy filter was the work of G.Sudhavani and his colleagues [12]. The filter consists of two parts. The first part computes the distances among the color components of the center pixel and its neighboring pixels. The distance was estimated by Minkowski’s distance. The second part of the filter calculates the color components differences and filtering result was decided by fuzzy rules to retain the fine details of the image.

Next faster denoising method was “modified adaptive median filter” [13]. The method introduced a ROAD (Rank Order Absolute Difference) statistics in this filter to identify the noisy pixels. After identify the presence of impulse noise, adaptive window filtering concept is used to filter the salt and pepper noise. Next, Zayed M. Ramadan designed “Salt-and-Pepper Noise Removal and Detail Preservation Using Convolution Kernels and Pixel Neighborhood” [14] .It consisted of two stages: detection and filtering. In the detection stage, convolution kernel estimation and the size of sliding window were considered. In the filtering stage, the conventional median filtering is used and replaces the corrupted pixel value. As a final related work, our previous fuzzy mean filter [15] is also wanted to discuss. In this work, gray level of a pixel corrupted by salt and pepper noise is either minimum gray level (zero) or maximum (255). According to the characteristics of the noise, triangular shape fuzzy membership functions and sets are constructed by the maximum, minimum and mean values of pixel in a kernel. Using the fuzzy sets, fuzzy decisions are done to entirely remove noises. We received more than PSNR 30 in higher density of noise (above 70% noise density).

Many technologies have been presented for the removal of high density salt and pepper noises. The proposed system also presents an improved fuzzy filtering technique to remove the higher noise density. The paper is composed of six sections. The first is introduction. The second is about of related work. In the third, theory background will be discussed. The fourth section is the detail discussion of our proposed method. In the fifth section, experimental results and performance comparisons will be presented. Conclusion of the proposed method will be discussed in final section.

## 3. Background Theory

Filter plays an important role in image denoising process. It is a technique for modifying and enhancing an image. The basic concepts behind reducing noise in noisy image using spatial domain based filters are linear filters and nonlinear filters. Among the various types of spatial domain based filters, median filter, mean or average filter are discussed as background theory because the basic concept of the proposed filters are based on median filter and mean filter.

### *3.1. Median filter*

The median filter is the best known order statistic filter which replaces the value of the pixel by the median of the gray levels in the neighbourhood of that pixel as shown in equation (1) and then the process of median filter is as shown in figure (1).

$$Z(x,y) = median_{(s,t)\in s_{x,y}} \{g(x,y)\} \tag{1}$$

Where, Z(x,y)= output image

g(x,y)=input image

The value of the pixel at *(x,y)* is included in the computation of the median. Since the median value must actually be the value of one of the pixels in the neighborhood, the median filter does not create new unrealistic pixel values when the filter straddles an edge. For this reason, the median filter is much better in preserving sharp edges than the mean filter. These advantages aid median filters in suppressing the uniform noise as well as other noises.

There are many drawbacks in the classical median filtering .In every filtering process, center pixel of a kernel is replaced with median value. There is no check that the center pixel is weather noise or not. Hence, the median filtering is still degraded in visual quality. Furthermore, the median filtering also need larger kernel size as the more noise density. The larger kernel can distort the edges of an image. Hence, the median filter can entirely remove the salt and pepper noise when its density is less than 30%.

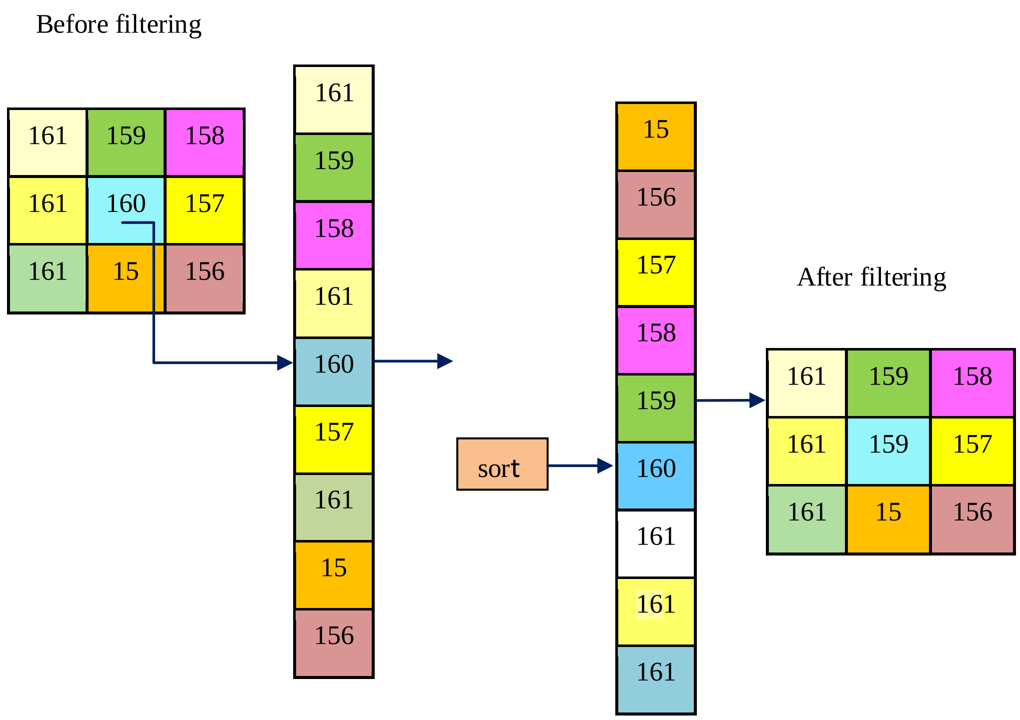



**Figure1:** the operation of median filtering

### *3.2. Mean filter*

Average or mean filter is the most simple and the easiest method to implement the smoothing of images (i.e. minimizing the extent of intensity variation among neighboring pixels). It is also used to minimize noise in images frequently. In this method the filtering concept is to replace the processing pixel element value in an image matrix with the average value of its neighbors including the centre pixel itself as shown in equation (2). Repeatedly, it removes these pixel values which are not representing their surroundings. The process of mean filter is as shown in figure (2).

$$Z(x,y) = \frac{1}{MN}\sum_{i=1}^{M}\sum_{j=1}^{N} I(x-i, y-j) \qquad (2)$$

Where, Z(x,y) = output filtering pixel

I(x-i, y-j) = neighbor pixel of the coordinate (i,j)

M and N = the number of rows and columns of filtering kernel

Before Filtering

| | | | |
|---|---|---|---|
| 161 | 159 | 158 | 161 |
| 161 | 160 | 158 | 220 |
| 161 | 15 | 158 | 159 |
| 158 | 157 | 158 | 157 |

After Filtering

| | | | |
|---|---|---|---|
| 161 | 159 | 158 | 161 |
| 161 | 143 | 158 | 220 |
| 161 | 15 | 158 | 159 |
| 158 | 157 | 158 | 157 |

**Figure 2:** the operation of mean filter

## 4. Proposed Methodology

The proposed technique is at first checked whether the pixel to be filtered is salt and pepper noise or not (0 or 255). If it is not noise, the following denoising processes are skipped. If it is a noise, the noise pixel within a 3*3 kernel is selected and the number of noise is counted within the kernel. If the number of noise is less than or equal to four, modified median filter is used to remove the noise. When the number of noise is greater than four and less than or equal to six in the processing window, the proposed fuzzy based median filter is switched to remove the noise. For the higher noise density, the noise count is larger than or equal to six, the proposed fuzzy mean filter is used. The detail proposed system flowchart can be shown in the following figure (3).

### *4.1. Proposed fuzzy median filter*

The fuzzy median filter can remove noise more robust in image details. In this proposed fuzzy filter, at first the number of $F_0$ and $F_{255}$ are separately counted in a kernel. The fuzzy membership function is defined based on the number of $F_0$ noise count and $F_{255}$ noise count in the processing window. $F_0$ is the total number of zeros in acurrent window. $F_{255}$ is the total number of 255s in a current window. The fuzzy rules are enacted for the proposed algorithm is summarized as follow:

**Rule 1:** If $F_0$ is very large and $F_{255}$ is very small, the $\psi_F(x)$ is very small.

**Rule 2:** If $F_0$ is large and $F_{255}$ is rather small, the $\psi_F(x)$ is median.

**Rule 3:** If $F_{255}$ is very large and $F_0$ is very small, the $\psi_F(x)$ is very large.

**Rule 4:** If $F_{255}$ is large and $F_0$ is rather small, the $\psi_F(x)$ is median.

**Rule 5:** If $F_0$ and $F_{255}$ are the same, $\psi_F(x)$ is median.

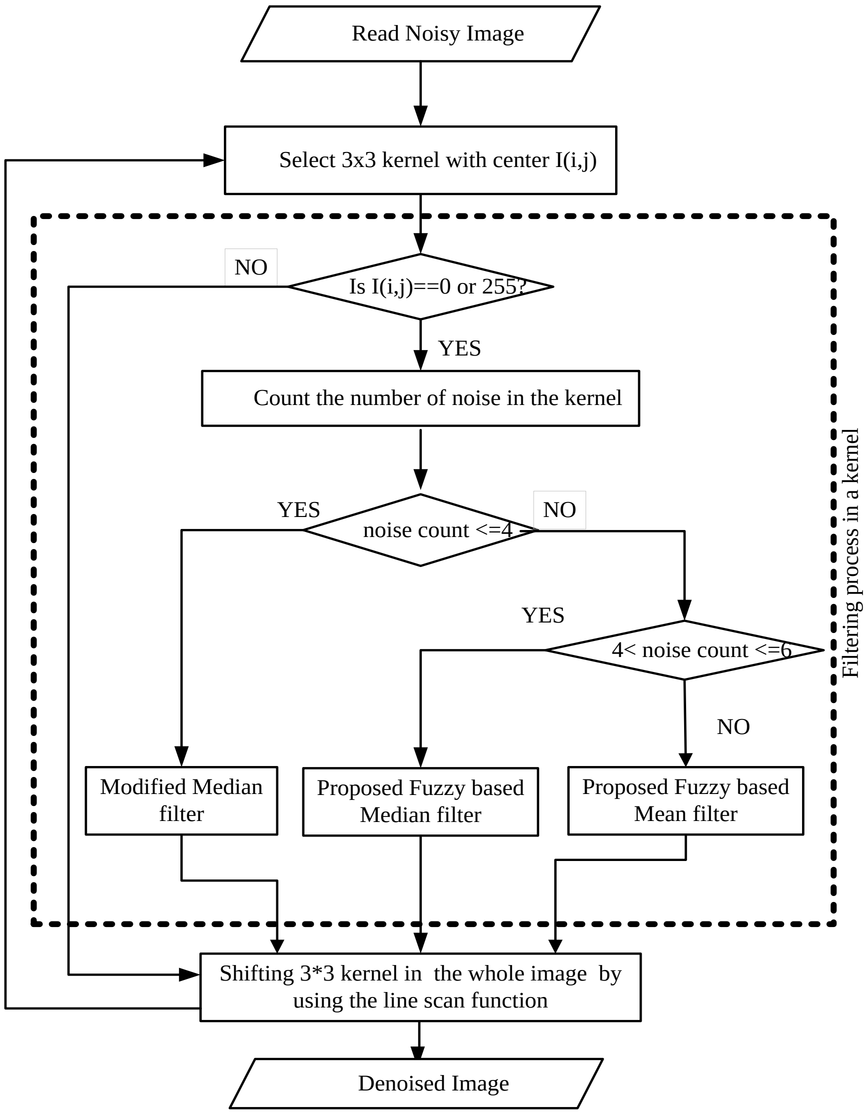



**Figure 3:** system flowchart of the proposed fussy based switching filter

According to the fuzzy rules, the membership function of the proposed system is defined as the following equation (3).

$$\psi(x) = \begin{cases} med - \left(\left(\frac{F_0}{F_{255}} * Std\right)\right) & if \quad \left(F_0 > T_2\right) and \left(F_0 <= T_1\right) \\ med & if \quad F_0 <= T_2 \\ med + \left(\left(\frac{F_{255}}{F0} * Std\right)\right) & if \left(F_{255} > T_2\right) and \left(F_{255} <= T_1\right) \\ med & if \quad F_{255} <= T_2 \\ med & if \ F_0 = F_{255} \end{cases} \qquad (3)$$

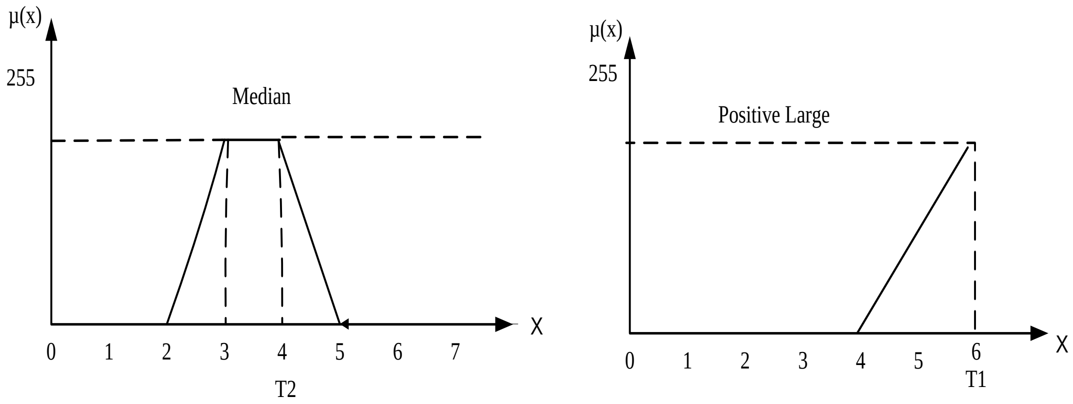
Where, $\psi_F(x)$ = filtering result of a selected kernel which contain x neighbors

med = the median value of the healthy pixels of the kernel

std = the standard deviation value of the healthy pixels of the kernel

T1 and T2 = predefined threshold values

For ($F_{255}$ >=$F_0$)




For ($F_0$>=$F_{255}$)

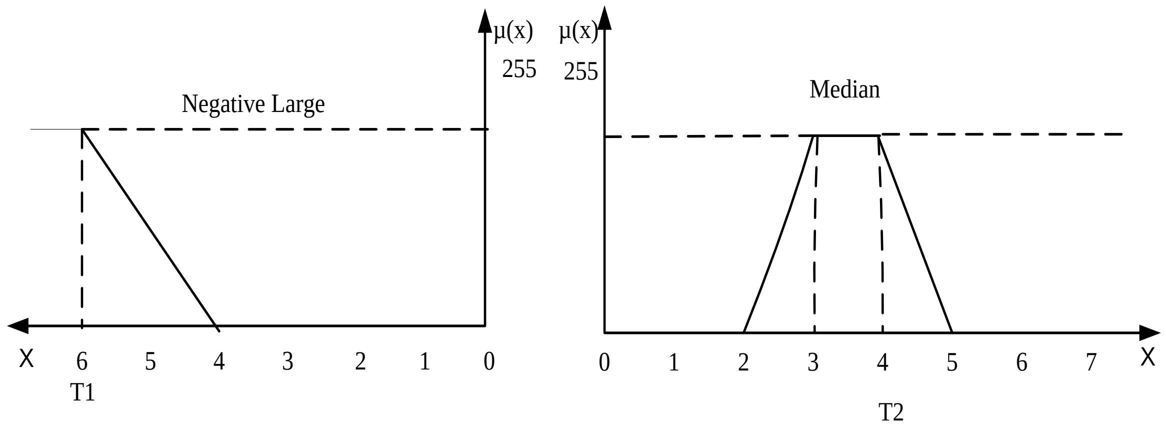



**Figure 4:** fuzzy membership function for the proposed fuzzy median filter

Where, μ(x)= the denoised output pixel intensity values

X= the number of noise counts within a kernel

According to the membership function and the total number of noises to the filter, the threshold *T1* is assumed as six because the maximum allowable noise count to this filter is also six. Similarly, *T2* is defined as four which is the lower bound of noises count. Hence, the two possible the total numbers of noises count are five and six which are input to this proposed filter. If input noises are six, there may be the same noise number case ($F_0$=3 and $F_{255}$=3). Hence, the median result is used as output for the case. Beside it, there are also so many of $F_0$ occurrence which is ($F_0$=5 and $F_{255}$=1) within a kernel. As the larger $F_0$ occurrence, the filtering result for this case is estimated as very small. Similarly, for the larger number of $F_{255}$ occurrences, the filtering result is defined as very large. Otherwise, the filtering result is assumed as median. The fuzzy membership function for the proposed fuzzy median filter is implemented by the following figure (4). By obeying the fuzzy rules and membership functions, the proposed fuzzy based median filter removes the salt and pepper noises.

### *4.2. Modified median filter*

The modified median filtering is very simple and fast. All pixels within a kernel except noisy pixel are sorted. After that, median pixel is selected and replaced the center pixel. By this way, the modified median filter can remove the noise in efficiently. The operation of modified median filter is as shown in figure (5)**.**

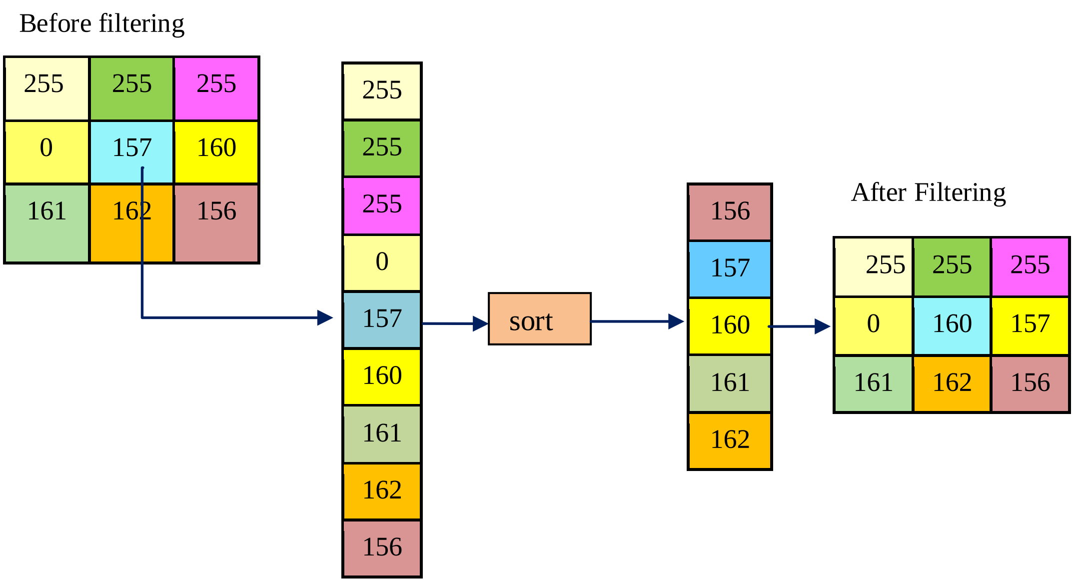



**Figure 5:** the operation of modified median filter

### *4.3. Proposed fuzzy mean filter*

The fuzzy weighted mean filter is designed for the high density noises. When the noise density is increase, almost of pixels within a kernel are noises. In this situation, median value of the kernel is also a noise so it cannot be used as filtering result. Hence, mean value is estimated and used as filtering result for this situation. Classical mean filters usually produce blurring results in denoising. Hence, for the higher noise density, the proposed fuzzy based weighted mean filter is implemented to remove higher density noises. For the proposed filter, the numbers of input noises are greater than six. Hence, the minimum number of input noises is seven and maximum is nine. As the intensities of noisy pixels are 0's (minimum) or 255's (maximum), mean value of the kernel must be the highest possibility of healthy pixels. Hence, the possibility of the healthy pixel for mean value is assumed as 1 and the other possibilities are slope down to minimum and maximum. At the minimum (0) and maximum (255), the possibilities of the noisy pixels are 0's. By using the concept, the proposed triangular fuzzy memberships and rules are implemented as shown in figure (6).

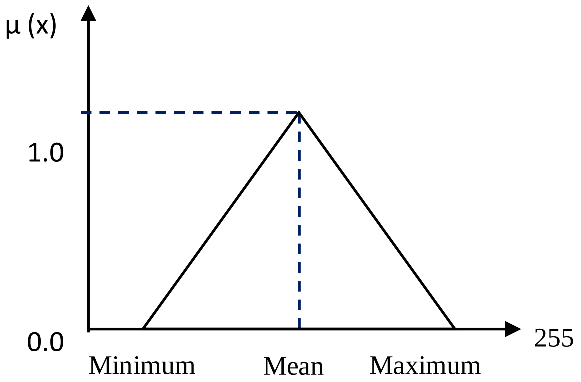



**Figure 6:** triangular fuzzy membership function for the proposed fuzzy mean filler

The gray levels of pixels within a kernel are divided into three ranks, minimum, mean and maximum. As the intensity values of noisy pixels is 0's (minimum) or 255's (maximum), the fuzzy fraction value is set 1 for mean. Other values within a kernel are estimated by the following fuzzy sets equation (4). Then, filtering result of the proposed filter is estimated by the following defuzzification equation (5).

$$\mu(x) = \begin{cases} 1 & \text{if } x = mean \\ 1 - \left( \dfrac{mean - x}{mean - x_{min}} \right) & \text{if } x_{min} \le x < mean \\ 1 - \left( \dfrac{x - mean}{x_{max} - mean} \right) & \text{if } mean < x \le x_{max} \end{cases} \quad (4)$$

Where, mean = average value of pixels within a kernel

$x_{min}$ = minimum value of pixels within a kernel

$x_{max}$ = maximum value of pixels within a kernel

x = gray value of current pixel within a kernel μ (x) = fuzzy fraction value of current pixel, x.

$$Z_{xy} = \frac{\sum_{i=1}^{m} \sum_{j=1}^{n} (\mu_{ij} * x_{ij})}{\sum_{i=1}^{m} \sum_{j=1}^{n} (\mu_{ij})} \quad (5)$$

Where, $Z_{xy}$= Center pixel of a kernel at the location of (x,y)

$x_{ij}$= gray value of pixel at the location of (i,j) within a kernel

$\mu_{ij}$= fuzzy fraction value of $x_{ij}$

According to the fuzzy sets and membership functions, the proposed fuzzy based weighted mean filter is used to remove high density salt and pepper noises (over 65% noise density).In the proposed system, modified median filter, fuzzy based median filter and fuzzy based weighted mean filter are switched according to the noise density of a processing kernel. Hence, the proposed filtering technique can remove the noise until 90% noise density with faster processing speed efficiently. The performance of the proposed filtering technique can be seen in next section in comparing with the other three fuzzy filters.

## 5. Experimental results and discussion

The performance of the proposed system is measured with various color images. The performances measurements are quantitatively measured by the Peak Signal to Noise Ratio (PSNR). The PSNR is the measure of how much the recovered image is similar with original. The equation for PSNR is described as shown in equation (6):

$$PSNR\,(dB) = 20\log_{10} \frac{255\sqrt{3MN}}{\sqrt{\sum_{i=1}^{M} \sum_{j=1}^{N} (B'(i,j) - B(i,j))^2}} \quad (6)$$

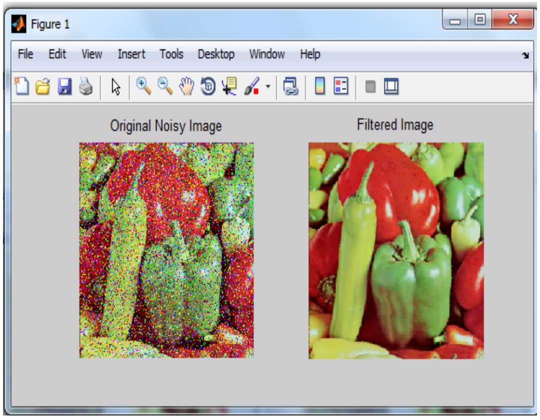
Where, *M* and *N* =the numbers of row and column of the images

B(i,j) = the original image pixel

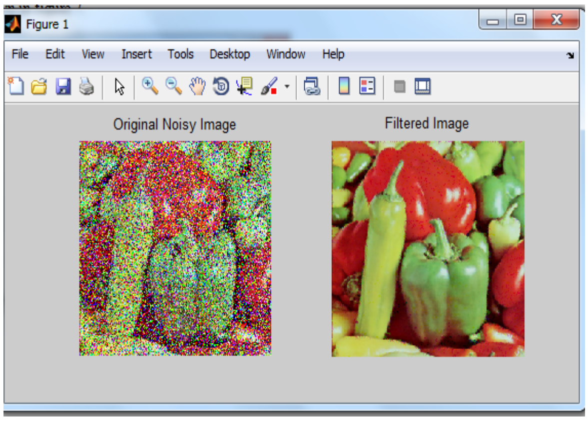
B'(i,j) =the denoised pixel at coordinate (i,j)

In this performance measuring, the proposed technique is tested with noise density from 20%, 40%, 50%, 60%, 80% and 90% on the various gray scale and color images. As the above expression in previous section, the proposed denoising technique is composed of three switching filters. As these filters can switch and denoised according to the number of noise count in a kernel the proposed technique also achieves faster processing speed. The Denoised image of the proposed system is tested with "pepper.bmp" color image as shown in figure (7).

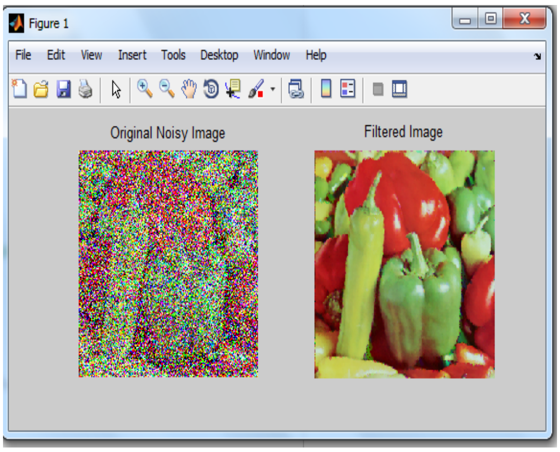
According to the performance results from figures (7), the proposed method can reduce noise until 90% noise density without damage of image detail preservation. By the result image of noise density 70%, the proposed technique can give clear and high detail denoised image result. In the lower noise density, the technique also gives quite noise free results. In the processing speed, this system takes processing time varying with the amount of noise density. As the noise density is increase, the proposed technique has to take more processing time. However, even in the highest noise density, the proposed technique takes only round about 30 seconds. Hence, the proposed technique achieves outperformance in processing speed and image denoising.In the performance comparison, modified median filter, the proposed fuzzy median filter and the proposed fuzzy mean filter are individually compared with median filter, and mean filter. The performance comparison is measured based on the PSNR of each technique at various noise densities as shown in table 1.



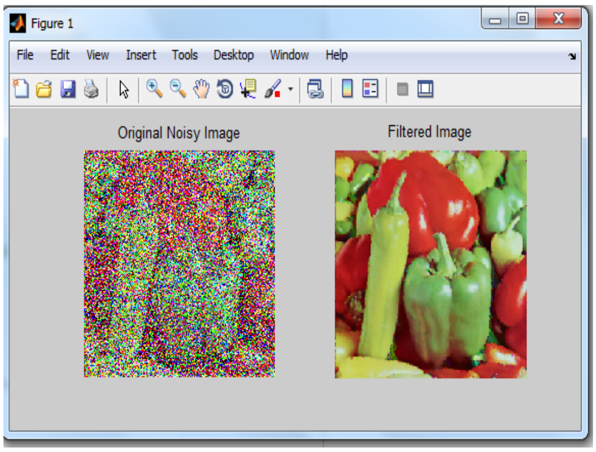

(a) Original noisy image , its filtered image and its processing speed is 6.163824 seconds at 20% noise density



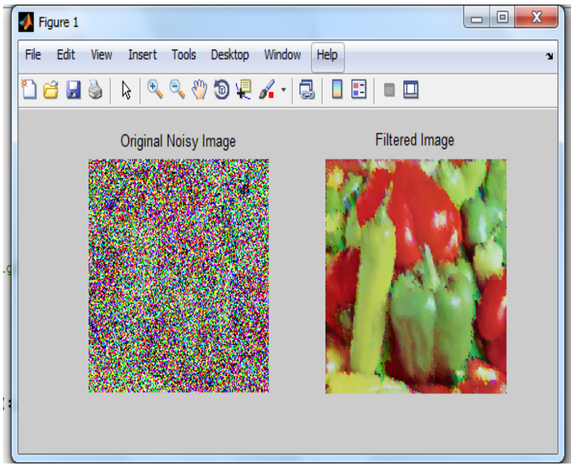

(b) Original noisy image , its filtered image and its processing speed is 9.892111 second at 40% noise density



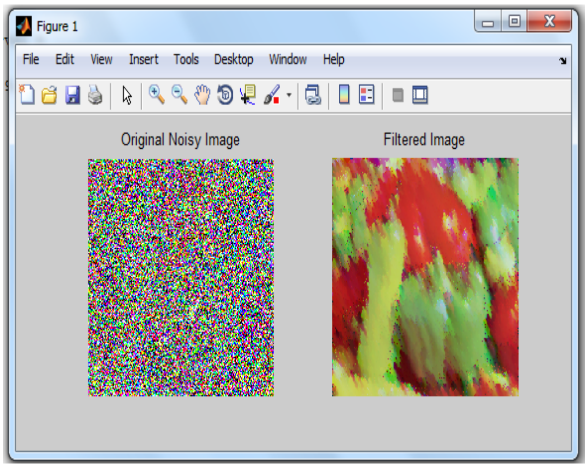

(c)Original noisy image, its filtered image and its processing speed is 13.024984 seconds at 50% noise density




(d) Original noisy image, its filtered image and its processing speed is18.41449 second at 60% noise density




(e) Original noisy image, its filtered image and its its processing speed is 20.317606 seconds at 80% noise density




(f) Original noisy image and its filtered image and processing speed is 31.483677 seconds at 90% noise density

**Figure 7:** denoised images and processing speed of the proposed system at various noise densities

**Table 1:** Performance comparison of Median Filter, Modified Median Filter, Proposed Fuzzy Median Filter, Mean Filter and Proposed Fuzzy Mean Filter

| Noise densities (%) | PSNR(dB) | | | | |
|---|---|---|---|---|---|
| | Median Filter | Modified Median Filter | Proposed Fuzzy Median Filter | Mean Filter | Proposed Fuzzy Mean Filter |
| 20 | 33.4671 | 42.5512 | 40.4241 | 28.5434 | 42.6705 |
| 40 | 31.9489 | 38.6553 | 37.2534 | 27.5846 | 38.7079 |
| 50 | 33.3802 | 37.0839 | 36.1796 | 27.3203 | 37.2957 |
| 60 | 31.8668 | 35.4523 | 35.0323 | 27.1668 | 36.0076 |
| 80 | 29.1673 | 32.3850 | 31.8902 | 26.9911 | 33.3055 |
| 90 | 28.1000 | 30.3879 | 29.4514 | 26.8924 | 31.7558 |

According to the table result, the modified median filter, the proposed fuzzy median filter and the proposed fuzzy mean filter give better denoising performance than the other previous filters in every noise densities. Note that the PSNR of the proposed filters are not lower than PSNR 30 dB in the heaviest noise density. It can be conclude that the proposed technique can preserve its image detail until the highest noise density.

## 6. Conclusions

An improved version of fuzzy based switching filter to remove high density salt and pepper noises is implemented. The filtering technique is designed by focusing on denoising performance. In this technique, modified median filter is designed to remove 40% noise density. The proposed fuzzy median filter can remove over 50% noise density. Then, the proposed fuzzy mean filter can remove over 70% noise density. Therefore, the proposed filter can remove all noise and maintain image detail at high noise density. So, the proposed filter has been achieved the highest noise removal performance. The fuzzy denoising techniques are very interesting and useful. Therefore, our future works play on the fuzzy platform of image processing.

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**References**

[1] Kenny Kal Vin Toh, Nor Ashidi Mat Isa, "Noise Adaptive Fuzzy Switching Median Filter for Salt- and-Pepper Noise Reduction‖, IEEE SIGNAL PROCESSING LETTERS, VOL. 17, NO. 3, MARCH 2010.

[2] Kh. Manglem Singh, ―Fuzzy Rule based Median Filter for Gray-scale Images‖, Journal of Information Hiding and Multimedia Signal Processing, Volume 2, Number 2, April 2011.

[3] Roli Bansal, Priti Sehgal, and Punam Bedi,"A Simple Fuzzy Filter for Impulse Noise Removal using Thresholding", Proceedings of the World Congress on Engineering and Computer Science (WCECS), Vol 2, pp 24-26, October, 2007.

[4] Mohammad Imrul Jubair, Imtiaz Masud Ziko and Syed Ashfaqueuddin, "An Improved Adaptive Filtering Technique to Remove High Density Salt-and-Pepper Noise Using Multiple Last Processed Pixels", Global Journal of Computer Science and Technology Graphics and Vision, Vol. 12, Issue 14, pp 104-111, 2012.

[5] S. Esakkirajan, T. Veerakumar, A. N.Subramanyam and C. H. PremChand, Removal of High Density Salt and Pepper Noise Through Modified Decision Based UnsymmetricTrimmed Median Filter, IEEE SignalProcessing Letters, Vol.18, No.5, pp.287-290, 2011.

[6] T. Veerakumar, S. Esakkirajan and I. Vennila,"Combined Fuzzy Logic and Unsymmetric Trimmed Median FilterApproach for the Removal of High Density Impulse Noise", WSEAS TRANSACTIONS on SIGNAL PROCESSING, Issue 1, Vol. 8, pp 32-42, January 2012.

[7] Bhavana Deshpande and H.K. Verma, Prachi Deshpande, "Fuzzy Based Median Filtering for Removal ofSalt-and-Pepper Noise", International Journal of Soft Computing and Engineering (IJSCE), Vol. 2, Issue 3, pp 76-81, July 2012.

[8] K. S. Srinivasan and D. Ebenezer, A new fastand efficient recursive fuzzy filter forremoval of high

density impulse noises, IEEESignal Processing Letters, Vol.14, No.3, 2007,pp.189–192.

[9] Shyam Lal, Sanjeev Kumar and Mahesh Chandra,"Removal of High Density Salt & Pepper Noise Through Super Mean Filter for Natural Images", International Journal of Computer Science Issues (IJCSI), Vol. 9, Issue 3, No 3, pp 303-309, May 2012.

[10] Sukomal Mehta1 and Sanjeev Dhull,"Fuzzy Based Median Filter for Gray Scale Image", International Journal ofEngineering Science&Advanced Technology (IJESAT), Vol. 2, Issue 4, pp 975 – 980, August 2012.

[11] M. González-Hidalgo, S. Massanet and D. Ruiz-Aguilera1,"High density impulse noise removal using fuzzymathematical morphology", 8th Conference of the European Society for Fuzzy Logic and Technology (EUSFLAT), Vol. 2, pp 728-735, July 2013.

[12] G.Sudhavani, G.Madhuri and P.Venkateswara Rao,"Additive Noise Removal for Color Image using Fuzzy Filter", International Journal of Computer Science, Engineering and Applications (IJCSEA) Vol.3, No.3, pp 45-51, June 2013.

[13] Sukhwinder Singh and Dr. Neelam Rup Prakash,"Modified Adaptive Median Filter forSalt & Pepper Noise", International Journal of Advanced Research in Computer and Communication EngineeringVol. 3, Issue 1, pp 5067-5072, January 2014.

[14] Zayed M. Ramadan, "Salt-and-Pepper Noise Removal and Detail PreservationUsing Convolution Kernels and Pixel Neighborhood", American Journal of Signal Processing, Vol. 4, Issue 1, pp-16-23, 2014.

[15] Yin Mon Swe and Nang Aye Aye Htwe, "A New Fuzzy Based Filter for High Density Salt and Pepper Noises",International Conference on Science and Engineering, 2014.