Multiplicative Noise Reduction using Fuzzy Logic and Feature Analysis of Ultrasound Images

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ABSTRACT
Ultrasound imaging is a vital tool for diagnosis in the field of biomedical imaging used to detect various types of abnormalities or diseases. Unfortunately, the multiplicative noise which coexists in these images makes it very challenging and difficult for doctors to provide accurate diagnosis. Multiplicative noise reduction is thus an important task for developing effective diagnosis system. In this paper, fuzzy logic is implemented to reduce multiplicative noise. Feature analysis like segmentation, determining region of interest and seed point selection is carried out and different existing de-noising algorithms are compared with the proposed method. The paper presents performance comparisons in terms of improvement in signal to noise ratio (SNR) of the proposed scheme with respect to MSE (Mean Square Error).

General Terms
Multiplicative Noise Reduction.

Keywords
Multiplicative noise, Speckle noise, Fuzzy Logic, Ultrasound, Denoising, Despeckle, Mean Square Error, Peak Signal to Noise Ratio.

1. INTRODUCTION
In the last few decades several new imaging systems have been developed. All these imaging systems acquire abundant images which are used by doctors for diagnostic purpose. The foremost problem faced by the doctors is the noise in the images produced by the imaging system which makes diagnosis difficult. Each of these imaging systems produces different types of noises namely poisson noise and multiplicative noise. X-ray images are often corrupted by poisson noise, while the ultrasound images are affected by multiplicative noise (or speckle noise).

Multiplicative noise degrades the image with the backscattered echoes which originates from microscopic diffused reflections that pass through internal organs and makes it more difficult for the doctor to distinguish finer details of the image. Thus reducing the multiplicative noise without affecting or altering the information of the image has become a challenging task [1].Multiplicative noise is considered as the dominant source of noise in ultrasound images and the reduction of this noise improves the clarity of ultrasound image with clearer boundaries. Despeckling or denoising is a pre-process step. It helps to improve the accuracy and speed of semi-automatic and automatic segmentation [2]. Many methods have been proposed in the literature to reduce the multiplicative noise in digital images. Some of these methods use known or local statistics, such as the Lee minimum mean square error filter (Lee MMSEF)[3], Frost filter (FROSTF), and Kuan filter . The concept of the local variance and mean proposed by Wallis was used in the Lee MMSEF for additive and multiplicative noise removal. The Kuan filter is a general form of the Lee MMSEF. The weighting function is the only difference between the Kuan filter and the Lee MMSEF. This is a scaling factor which is the difference between the mean and the center pixel of the filtering window. In this paper, fuzzy logic method is used for multiplicative noise removal. Texture or feature of images refers to the structure, arrangement and appearance of the parts of an object within the image. Images used for medical diagnostic purposes in clinical practice are digital. A two dimensional digital image is composed of little rectangular blocks or pixels (picture elements), and a three-dimensional digital image is composed of little volume blocks called voxels (volume elements) [4]. Segmentation is the most important part in image processing. Fencing off an entire image into several parts is more meaningful and easier for further process, Segmentation is carried out with thresholding method [5] [6]. Morphological operation like dilation operator is used for detecting the vicinity of the edges in the image [7]. Seed point selection, region of interest and automatic boundary detection is implemented.

2. RELATED WORK
Renuka Marutirao Pujari and Mr. Vikas D. Hajare [1] proposed different types of filters for denoising ultrasound image. The images with this type of noise display a granular pattern due to the dispersion of the ultrasound waves caused by the transducer. This noise is very harmful since it limits the detection of injuries especially in low contrast images. Various filtering techniques like median filtering, fourier filtering include ideal filtering and butterworth filtering.

Anita Garg, Jyoti Goal, Sandeep Malik, Kavita Choudhary and Deepika [2] used wiener filter and thresholding in discrete wavelet transform domain for despeckling of ultrasound image. For speckle noise the log of image is first obtained. This converts the multiplicative noise into additive noise. Wiener filter generates two images, the first image is the output of wiener filter and the second image is obtained by subtracting the first image from the log transformed observation. Both the images are denoised using an adaptive noise reduction method. In order to get the resultant image both the images are added together and the exponentional function is obtained. For gaussian and salt & pepper noise there is no need of log function because these are additive noise.

Mihir N.Dalwadi , Prof. D.N.Khandhar, Prof. Kinita H.Wandra,[3] used GVF method for boundary detection for FLL ultrasound images. The presence of speckle noise in ultrasound images, performing the segmentation methods for the FLL images were very challenging and therefore, deleting and removing the complicated background will speed up and increase the accuracy of the segmentation process.

Anushalin. P. S and Samson Isaac. J [4] used wavelet-based method for efficient speckle suppression and detection of calculi in sonographic images of the kidney. Wavelets were developed in applied mathematics for the analysis of multiscale image structures.

Siva Sankari.S, Sindhu.M , Sangeetha.R , ShenbagaRajan [5] used the concept for brain tumor segmentation and feature extraction . Normally the anatomy of the brain can be viewed by the MRI scan or CT scan.

3. PROPOSED METHODOLOGY

The proposed methodology has five blocks which are as shown in the Figure 1

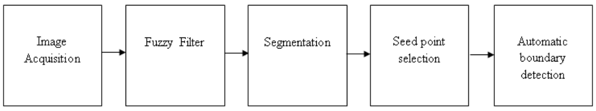

Figure 1: Block diagram of Proposed Methodology

3.1 Image Acquisition

Image acquisition is the first process and acquisition could be as simple as an image that is already in digital form. Generally, the image acquisition stage involves preprocessing, such as scaling.

3.2 Fuzzy Filter

The idea of Fuzzy logic is very much similar to the feelings of human beings and their inference process. Unlike classical control strategy, which is a point-to-point control, fuzzy logic control is a range-to-point or range-to-range control. The output of a fuzzy controller is derived from fuzzifications of both inputs and outputs using the associated membership functions. A classic data input will be converted to the different members of the associated membership functions based on its value. From this point of view, the output of a fuzzy logic controller is based on its memberships of the different membership functions, which can be considered as a range of inputs.

3.3 Segmentation

Threshold technique is one of the important techniques in image segmentation. This technique can be expressed as shown in the equation below

T=T[x, y, p(x, y), f(x, y]
Where: T is the threshold value.
x, y are the coordinates of the threshold value point.

p(x,y) ,f(x,y) are points the grey level image pixels.

3.4 Seed Point Selection

The left regions will undergo another selection step to determine which is the correct seed point. The algorithm for seed point detection, firstly, computes the number of connected components (region). Here "n" needs to be determined so that we can know how many regions are left in the image. If there is only one region left, it is automatically considered as the seed point if not, the region areas (pixel), A also needs to be determined and the threshold pixel area is set as 6k. If the area, A is less than 6k, that region is selected as the seed point otherwise the other region will be selected.

3.5 Automatic Boundary Detection

The boundaries of a lesion may be defined on an image or in a volume, for the purpose of measuring its size.

4. PROPOSED FUZZY FILTER

To implement fuzzy logic technique to a real application requires the following three steps:

1. Fuzzification – convert classical data or crisp data into fuzzy data or membership functions (MFs).
2. Fuzzy Inference Process – combine membership functions with the control rules to derive the fuzzy output.
3. Defuzzification – use different methods to calculate each associated output and put them into the lookup table based on the current input during an application.

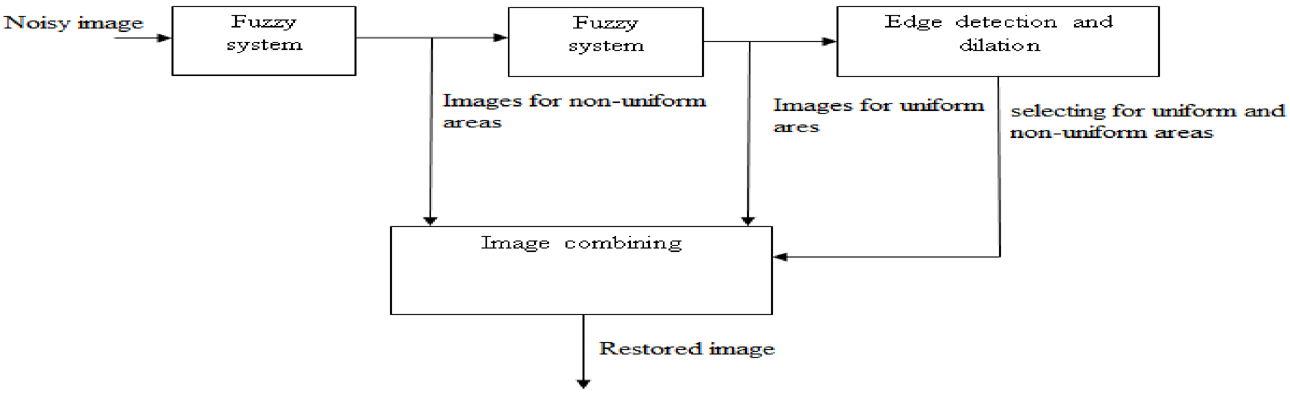

Figure 2: Proposed Fuzzy Filter

4.1 The Edge Detection and Dilation Unit

The edges in any digital image can be found easily using any differential mask kernel. However, finding edges in a noisy image is not easy, because the noise creates extra edges due to changing pixel values in the image. Since the fuzzy filter used in the proposed method already removes the speckle noise, any simple edge detection approach can be used for finding the edges. In the proposed method, the Sobel edge detector kernels, which are column and row kernels, are found to be sufficient for detecting vertical and horizontal edges respectively. The Sobel method, which is one of the most common edge detection approaches, is based on the central difference in the kernel. In the uniform areas, the differential kernels give a 0 luminance value for the center pixel.

However, the luminance value approaches 255 in the vicinity of the edges. After the corresponding edge magnitudes of all of the pixels in the input image are found, the edge image, where the pixel values can assume either 0 or 255, is obtained by applying a threshold to the edge image.

In the proposed method, the dilation operator is used for detecting the vicinity of the edges in the image. The dilation process is gradually applied to the edge image twice, using a 3 * 3 mask for finding regions close to edges, and the regions revealed after each dilation process are used to determine the transition area of the pixel values of the restored image by means of the two filtered noisy image outputs.

4.2 The Image Combiner

The edge image and its dilated forms are used to determine the filtered noisy image output (fuzzy system output) that will be used for the current pixel in the restored image. The edge regions in the restored image are obtained from the once-filtered noisy image output, while the areas remaining after edge dilation in the restored image are filled with the twice-filtered noisy image output. The pixel values of the dilated regions outside of these areas are computed by averaging of the once and twice filtered noisy image outputs. The contribution of the once filtered noisy image output is more in the first dilated region, whereas the contribution of the twice filtered noisy image output is more in the second dilated region. Experimental results indicate that the performance of the fuzzy filter is significantly increased with this approach.

4.3 Gaussian Bell Membership function

The generalized bell membership function is specified by three parameters as shown in Figure 3 and has the function name gbellmf. The bell membership function has one more parameter than the Gaussian membership function, so it can approach a non-fuzzy set if the free parameter is tuned. Because of their smoothness and concise notation,

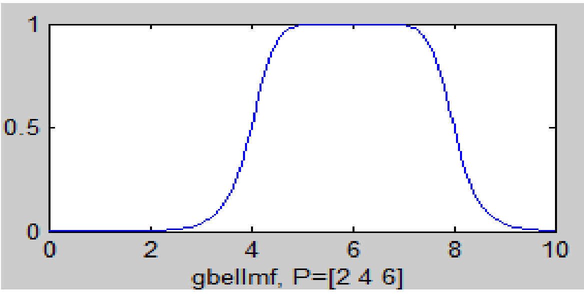

Figure 3: Gaussian Bell Membership function

Gaussian and bell membership functions are popular methods for specifying fuzzy sets. Both of these curves have the advantage of being smooth and nonzero at all points.

4.4 Trapezoidal membership function

The trapezoidal membership function, trapmf, has a flat top and is just a truncated triangle curve. These straight line membership functions have the advantage of simplicity as shown in Figure 4.

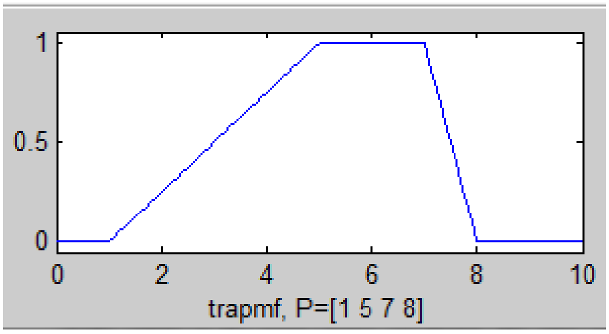

Figure 4: Trapezoidal membership function

4.5 Fuzzy Inference System

The fuzzy inference system used in the proposed method is a first-order Sugeno fuzzy model with five inputs and one output. The type of the antecedent membership functions of the fuzzy system are chosen as generalized bell, whereas the type of consequent membership functions are chosen as linear. The rule base of the fuzzy system contains 10 fuzzy rules, as listed here.

(1) If

$(X_1 \in M_{11}) \& (X_2 \in M_{12}) \& (X_3 \in M_{13}) \& (X_4 \in M_{14}) \& (X_5 \in M_{15})$

$Then Q_1 = d_{11}X_1 + d_{12}X_2 + d_{13}X_3 + d_{14}X_4 + d_{15}X_5 + d_{16}$

(2) If

$(X_1 \in M_{21}) \& (X_2 \in M_{22}) \& (X_3 \in M_{23}) \& (X_4 \in M_{24}) \& (X_5 \in M_{25})$

$\text{Then}Q_2 = d_{21}X_1 + d_{22}X_2 + d_{23}X_3 + d_{24}X_4 + d_{25}X_5 + d_{26}$

(3) *If*

$(X_1 \in M_{31}) \& (X_2 \in M_{32}) \& (X_3 \in M_{33}) \& (X_4 \in M_{34}) \& (X_5 \in M_{35})$

$\text{Then}Q_3 = d_{31}X_1 + d_{32}X_2 + d_{33}X_3 + d_{34}X_4 + d_{35}X_5 + d_{36}$

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(10) *If*

$(X_1 \in M_{101}) \& (X_2 \in M_{102}) \& (X_3 \in M_{103}) \& (X_4 \in M_{104}) \& (X_5 \in M_{105})$

$\text{Then}Q = d_{101}X_1 + d_{102}X_2 + d_{103}X_3 + d_{104}X_4 + d_{105}X_5 + d_{106}$

Here, X_J are inputs of the fuzzy system, Q_k denotes the consequent membership function of the *k* th rule, and *Mi;j* denotes the *i* th antecedent membership function of the *j* th input. The generalized bell-type membership function, which is used for input fuzzfication, is described as follows:

$$M_{ij}(x) = \frac{1}{1 + \left| \frac{x - a_{ij}}{b_{ij}} \right| 2c_{ij}} \rightarrow i = 1...10 and j = 1..5$$

Parameters *a*, *b*, *c*, and *d* determine the shape of the membership functions. The output of the fuzzy system is obtained by calculation of the weighted average of the individual rule outputs. The weighting factor of each rule ω_k is calculated by producing the memberships of the inputs. For this purpose, input values are first converted to fuzzy membership values by using antecedent membership functions. Next, the AND (&) operator, which corresponds to the multiplication, is applied to these membership values. Hence, the weighting factor of each rule is calculated by:

$$\omega_k = Mk_1(X_1)Mk_2(X_2)Mk_3(X_3)Mk_4(X_4)Mk_5(X_5) = \prod_{j=1}^{5} M_{kj}(X_j)$$

After obtaining the weighting factors, the output of the fuzzy system is calculated by the weighted average of the individual rule outputs as follows:

$$Y = \frac{\sum_{k=1}^{10} \omega_k Q_k}{\sum_{k=1}^{10} \omega_k}$$

5. SIMULATION RESULTS

The proposed algorithm is tested with different variety of grey scale images. The performance of the algorithm is evaluated quantitatively using the measures viz. Mean Square Error (MSE), Peak signal to noise ratio (PSNR in dB). MATLAB R2013a on a PC equipped with a 2.20 GHz and 4 GB of RAM memory has been employed for the evaluation of processing time of all filtering techniques.

$$MSE = \frac{1}{mn}\sum_{i=0}^{m-1}\sum_{j=0}^{n-1}[\mathrm{I(i, j)} - \mathrm{K(i, j)}]^2$$

$$PSNR = 10 \times Log(\frac{255^2}{MSE})$$

$$\text{Standard Deviation} \quad \sigma = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_i - \mu)^2}$$

$$\text{Variance} \quad \sigma^2 = \frac{\sum(x-\mu)^2}{N}$$

Table 1: MSE, PSNR, Standard Deviation and Variance

	MSE	PSNR	STD	VAR
Median	2.55	23.2012	34.1631	1.1671
Mean	2.5501	23.2011	31.0229	0.9624
GLP	2.55	23.2012	33.288	1.1081
Fuzzy	0.0393	59.4387	34.0541	1.1597

The obtained results are compared with outputs of all filtering techniques with a proper window size. The table displays that proposed approach gives high PSNR, low MSE, standard deviation and variance values. And the values in the table show that proposed algorithm gives better performance even for high density multiplicative noise.

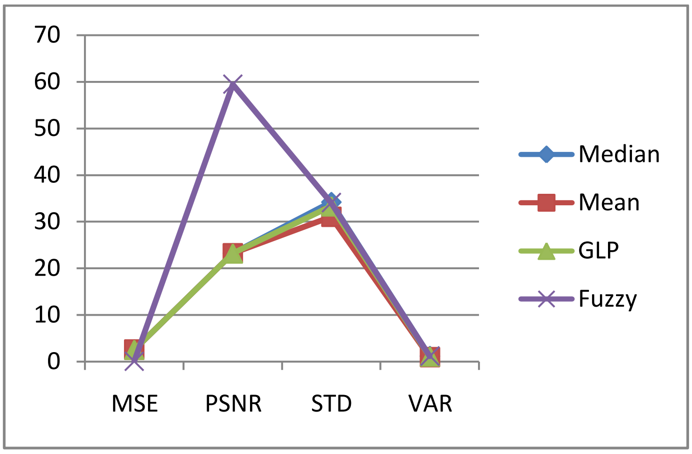
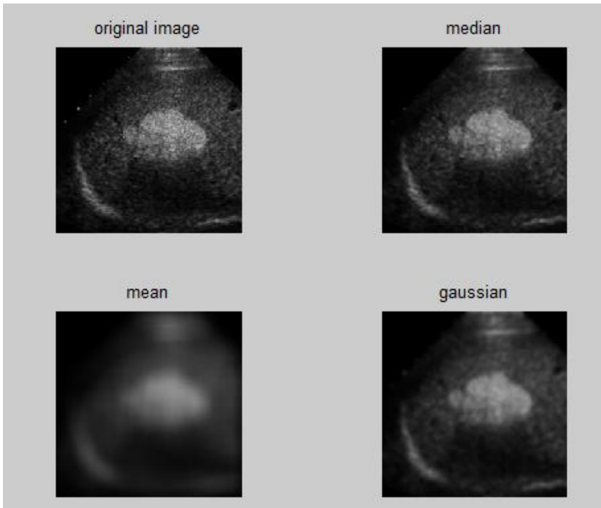
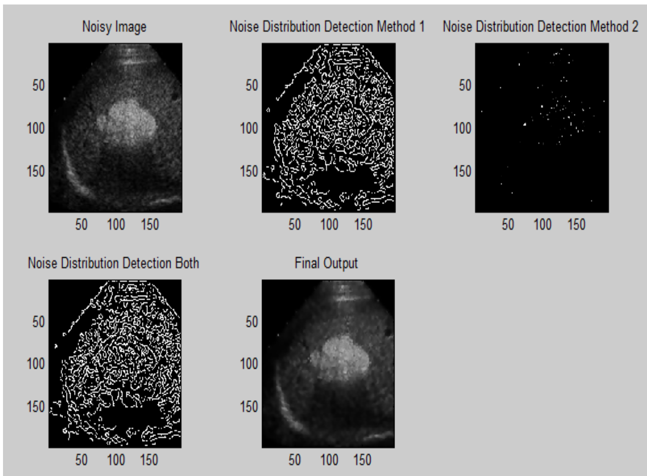


Figure 5: Comparison of the performance of the proposed Fuzzy filter with Mean, Median and Gaussian filter.

Results for Liver image





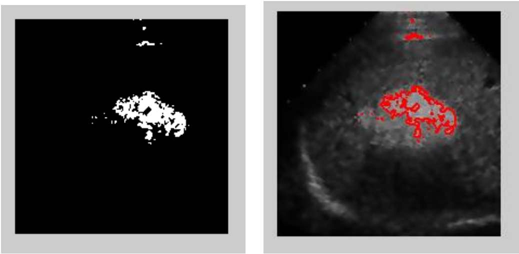


Figure 6: Experimental results for image

Figure 6 displays subjective visual perception. The proposed algorithm removes multiplicative noise simultaneously with edge preservation and reduced blurring. It has better subjective quality when compared with all filtering techniques.

6. CONCLUSION AND FUTURE WORK

Fuzzy image processing has widely been used in the context of image segmentation and noise reduction and for speckle suppression in ultrasound images. The proposed system is compared with some of the best state-of the- art techniques. The proposed method can be easily extended to multiple dimensions and used for multidimensional filtering, enhancement, preprocessing step for segmentation and feature extraction, and visualization applications.

The proposed methodology is only used to remove multiplicative clamor and extract the features of ultrasound images. Future work can be implemented using the proposed system on various medical images which include X-ray, MRI, SPECT to remove noise effectively without losing the information of the image.

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