An Adaptive Speckle Noise Filtering Technique for Medical Images

Nageswari P[1], Rajan S[2]

[1]Research Scholar, Department of Mathematics, Erode Arts and Science College, Erode, Tamilnadu, India
[2]Associate Professor (Rtd), Department of Mathematics, Erode Arts and Science College, Erode, Tamilnadu, India.

---***---

Abstract - *Speckle noise filtering has become a challenging role in medical ultrasound image processing. Based on the concepts of fuzzy logic and fractional integral operation, an adaptive speckle noise filtering technique for medical images is presented in this paper. This filtering technique has two steps. In the first step, using the coefficient of variation concept and Gaussian membership function, the image area is classified into three different regions such as homogeneous, edge and detail region. In second step, a simple average filter and fractional integral operation are employed for filtering the classified noisy pixels. The proposed filtering technique increases image quality by eliminating maximum unwanted noise whereas protecting the important image particulars.*

Key Words: Speckle noise, ultrasound image, fuzzy logic and fractional integral operation.

1. INTRODUCTION

Over last three decades, ultrasound imaging has become an important tool for medical diagnosis because of its low cost, portability, noninvasive nature and capacity of creating real time imaging. However, the effectiveness of ultrasound imaging is corrupted by the occurrence of noise known as speckle. The main issue of speckle noise presence is, initially, reduces the image contrast and consequently, creates a difficulty in differentiating image objects. Furthermore, its presence in ultrasound image not only affects the visual observation of the physicians but also creates a limitation for their diagnostic potential. Hence, Speckle noise filtering has turned into a challenging role in medical ultrasound imaging. Various despeckling methods have been proposed in the study.

2. RELATED WORK:

A number of local statistics based despeckling filters have been proposed including Kuan[1], Frost[2] and Lee[3]. These techniques perform well in smooth regions but fail to create a good performance in edge regions. An adaptive bilateral filtering method is proposed by farzana et al [4]. Diffusion algorithms utilize partial differential equation for noise removal. Perona and malik[5] proposed a despeckling algorithm to protect the edge region from diffusion. It gives good performance for additive noise but fail to perform well in multiplicative noise. Generally, various unique image pixels are scattered in an ultrasound image. Filter based on non-local mean technique spoils the similarities contain in an image. A weighted denoising technique for synthetic aperture radar image is proposed by cheng and Tian [6]. In this algorithm, each pixel is processed by using fuzzy technique. But this technique fails to protect the image which includes more texture and details. By using image gradient, Binaee et al [7] discussed a method which classifies the image areas into three different regions. Similarly, by using co-efficient of variation concept, J. Babu et al [8] proposed a methodology which divides an image into edge, homogeneous and detail regions. Then the filtering is carried out by utilizing appropriate filters.

Nowadays, fractional calculus concept has a remarkable effect in medical image processing. That is why it has become the center of attention for recent researchers. Generally, algorithms based on fractional differentiation are capable to protect the low frequency components such as homogeneous as well as preserving the high frequency components such as edge of image. G.Hung et al [9] and J.R.Hu et al [10] used a technique based on fractional order integration. But this technique fails due to the usage of same fractional order integration for the entire image. Saadia and Adnan[11] proposed a denoising approach for echocardiography image based on fuzzy logic and fractional order integration. This approach fails due to the usage of some filter throughout the image. R-L definition and G-L definition based approach are utilized by Y.F.pu et al [12] and Q-L.Chen et al [13]. These approaches fail to give an effective denoising, because the suitability of different fractional order curves in relation to image region. Fraction calculus based mask is proposed by N.He et al [14]. During convolution, this mask gives 45^0isotropic diffusion. This approach also considers a fixed fractional order integral for the whole image. A technique based on partial differential equation and fractional calculus theory has been proposed by D. Shao et al [15]. It creates blocky effect. H.A. Jalub et al [16] utilize fractional Alexander polynomials technique for denoising an image. If fails to protect texture regions.

Based on the concepts of fuzzy logic and Coefficient of variation, an adaptive speckle noise filtering technique for medical images is presented in this paper. This filtering technique has two steps. In the first step, using the coefficient of variation concept and Gaussian membership function, the image area is classified into three different regions such as homogeneous, edge and detail region. In second step, a simple average filter and fractional integral operation are employed for filtering the classified noisy pixels.

3. NOISE MODEL:

Let as consider the observed ultrasound image be $H(x,y)$ with size $X \times Y$. Since speckle noise is multiplicative in nature, it can be modeled as

$$H(x,y) = G(x,y).\beta(x,y) + \gamma(x,y) \quad (1)$$

Where $G(x,y)$, is noise free image, $\beta(x,y)$ and $\gamma(x,y)$ denote the multiplicative and additive noise respectively.

The additive noise effect is very low when compared with multiplicative, so the equation (1) can be remodeled as,

$$H(x,y) = G(x,y).\beta(x,y) \quad (2)$$

Co-efficient of variation is defined as the ratio between mean and standard deviation. A pixel which has maximum co-efficient of variation value corresponds to edge region. Similarly, a pixel with minimum and intermediate value represents the homogeneous and detail region. Based on this concept, the image noisy pixels have been partitioned into edge, homogenous and detail regions. During the process of image filtering, pixels cannot be removed as noise is spread over all the pixels in an image. Therefore, Gaussian membership function has been employed for describing the membership degree in a fuzzy system. There are two main advantages for employing Gaussian function in the proposed method (i) It moves toward zero only after few standard deviations (ii) It is non-zero and symmetric about into mean over the whole real axis. Hence the values of co-efficient of variation of noisy image are mapped to the fuzzy domain utilizing Gaussian function.

The Gaussian membership function is defined as:

$$\mu_g^k(u) = e^{\left[l-(u-m)^2/2\sigma_k^2\right]} \quad k = 1,2,3 \quad (3)$$

Where, μ_g^k is the fuzzy set for the sort of pixels N x N with mean m_i and variance σ_k^2 denotes the edge, homogeneous and detail regions in noisy images and N x N represents the square window. To classify the image pixels as edge, homogeneous and detail regions, threshold values *p, q, r* are described as:

$$H(x,y) \in \begin{cases} \mu_g^k(u) = edge & u > q \\ \mu_g^k(u) = \det ail & u \ge p \, and \, u \le r \\ \mu_g^k(u) = \hom ogenous & u < q \end{cases} \quad (4)$$

Where, p = maximum value of COV $[H(x, y)]_{N \times N}$

r = COV [gradient $H(x, y)]_{N \times N}$

Where COV [H(x, y)] represents the co-efficient of variation of H (x, y)

q = average [p, r]

We know that the pixels with minimum coefficient of variation value correspond to homogeneous region. Hence, the threshold point p which defines the detail region is calculated as the maximum value of co-efficient of variation [H (x, y)]. Similarly, pixels with maximum co-efficient of variation value belong to edges. So, the threshold point r which defines edge region is calculated as the co-efficient of variation [grad H(x, y)]. Note that the gradient operation is proficient in differentiating the edge pixels. Finally, the threshold point q is calculated as the average value of p and r. Furthermore, the variation in threshold value p, q, r and the classification of input noisy pixels are depends upon the quantity of noise added to the image.

After finishing the process of noisy pixel classification, an appropriate filter will be utilized on every pixel to obtain a de-noised image. Homogeneous region has no heavy affected part like edge and detail region. Hence, a simple average filter is enough for filtering the homogenous region. Fractional integral operation has the capability to protect edges and detail while eliminating noise. Therefore, fractional integral mask will be employed for filtering the edge and detail region pixels.

3.1 Homogeneous region:

Since Homogenous region has no high effected component like edge and detail region, we will reconstruct homogeneous region noisy pixels with the average value of 3 x 3 window pixels around it. Noisy pixels that are categorized as homogeneous region are processed utilizing the equation given below:

$$D(x,y) = \frac{1}{q} \sum_{j=-1}^{1} \sum_{k=-1}^{1} D(x+j, y+k) \quad (5)$$

Where, D is the noise free image.

3.2. Edge and detail region:

Average filter is not suitable for filtering detail and edge region noisy pixels. Because we have a chance to loss image structural details during filtering process. Hence, fractional order integration filter has selected for treating detail and edge region noisy pixels. It has the ability to eliminate noise while protecting edges and fine details.

Let f(s) $\in$ [a, b] be the period of a unitary signal. By considering the size of interval h = 1, split the signal f (z) into equivalent intervals. Then we have, n = $\left[{(b-a)}/{h} \right] = b - a$` and the difference of f(s) is given as:

$$\frac{d^v f(s)}{ds^v} \approx f(s) + (-v) f(s-1) + \frac{(-v)(v+1)}{2} f(s-2) + . \\ \ldots + \frac{\Gamma(-v+1)}{n!\Gamma(-v+n+1)} f(s-n)$$

$$\frac{d^v s(x,y)}{dx^v} \approx s(x,y) + (-v)s(x-1,y) + \frac{(-v)(v+1)}{2} s(x-2,y) \\ + \ldots + \frac{\Gamma(-v+1)}{n!\Gamma(-v+n+1)} s(x-m,y)$$

$$\frac{d^v s(x,y)}{dy^v} \approx s(x,y) + (-v)s(x,y-1) + \frac{(-v)(v+1)}{2} s(x,y-2) +$$

$$\ldots + \frac{\Gamma(-v+1)}{n!\Gamma(-v+n+1)} s(x, y-n) \quad (6)$$

Frequency reaction of fractional order integration illustrates that it has various reactions at various frequencies. Edge and detail region pixels are denoised utilizing (Equ. No.6), for detail region $\upsilon = -0.7$ and for edge pixels $\upsilon = -0.5$.

For detail region, order $\upsilon = -0.7$ is utilized because there are no heavy frequency components to be protected and hence greatest quantity of noise would be alleviated from detail region. Similarly, for edge region, order $\upsilon = -0.5$ is utilized because it less mitigates the heavy frequency components like edges and hence tiny texture of edge region will be preserved.

$$D(x, y) = H(x, y) * mask \quad (7)$$

Utilizing H, convolve masks for x and y direction one by one and then calculate mean to obtain the resulting image D.

Algorithm:

1. Let H (x, y) be the input image with size X x Y.
2. Calculate COV for every pixel of H (x, y).
3. Calculate thresholds for Gaussian functions employing
   $p \quad Max\ COV[H(x, y)]_{NxN}$
   $q \quad Avg\ [p, r]$
   $r \quad COV\ [grad\ H\ (x, y)]_{NxN}$
4. Separate every pixel of H into different region utilizing Gaussian function.

$$H(x, y) \in \begin{cases} \mu_g^k(u) = edge & u > q \\ \mu_g^k(u) = \det ail & u \geq p \, and \, u \leq r \\ \mu_g^k(u) = \hom ogenous & u < q \end{cases}$$

5. Employ suitable filter to denoise all pixels in each region.

$$D(x, y) = \begin{cases} 0 & H(x, y) \in edge \\ 0 & H(x, y) \in \det ail \\ 0 & H(x, y) \in \hom ogeneous \end{cases}$$

Where, $0 = \frac{1}{q} \sum_{j=-1}^{1} \sum_{k=-1}^{1} D(x + j, y + k)$

0 = H (x, y) *mask with $\upsilon = -0.7$

0 = H (x, y) *mask with $r = -0.5$

Simulation results:

The proposed method was implemented using MATLAB programming language on a computer. At first simple average filter for homogeneous and fractional integral operation for edge and detail region was implemented. The parameters such as peak signal to noise ratio and mean square error are calculated for proposed method. Table 1 and table 2 show the comparison of various denoising filters with proposed algorithm. It is seen that the filtering accuracy of the proposed technique is high.

Mean Square Error (MSE) is defined as:

$$MSE = \frac{\sum_{ij} (r_{ij} - X_{ij})^2}{MN} \quad (8)$$

Peak Signal to Noise Ratio (PSNR) is defined as:

$$PSNR = 10 \log_{10} \left[\frac{255^2}{MSE} \right] \quad (9)$$

Where, MSE is the mean square error between original image and filtered image.

The efficiency of the proposed methodology is tested by utilizing real human liver ultrasound image lung CT image. Figure 1 and figure 2 shows the original image, performance of existing fuzzy filter and proposed filter for human liver and lung CT images. From the results it is clear that the proposed filtering technique produces major act in terms of both edge protection and noise control.

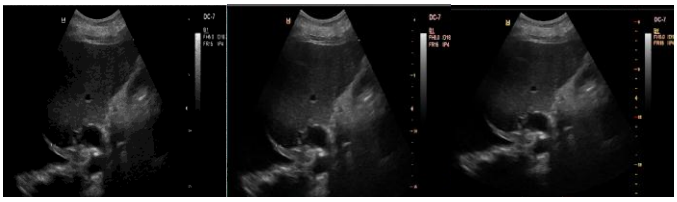

Figure.1 Performance of the Existing Fuzzy filter and proposed filter for human liver ultrasound image (a) Original Image (b) Existing Fuzzy Filter (c) Proposed Filter

Figure.2 Performance of the Existing Fuzzy filter and proposed filter for human lung CT image (a) Original Image (b) Existing Fuzzy Filter (c) Proposed Filter

Table (1) and (2) shows the quantitative results of ultrasound liver, and lung CT images between the existing filtering techniques and proposed method. Highest value of PSNR and lowest value of MSE indicates the noise reducing capability of the proposed method. Finally, the proposed algorithm eliminates maximum amount of noise as well as protect the image structural details in all situations when compared to other existing state-of-the art techniques.

Table: 1 Quantitative analysis of ultrasound liver image:

Noise Filters	MSE	PSNR
Average	128.563	21.574
Median	127.533	26.948
AMF	115.684	27.547
AWMF	112.805	28.365
Lee	110.164	29.814

ASSF	108.361	31.425
ANSF	102.482	33.432
ABF	98.564	34.896
Fuzzy filter	94.854	37.854
Fuzzy based two step filter	87.238	38.532
Proposed Filter	**86.326**	**41.520**

Table: 2 Quantitative analysis of Lung CT image:s

Noise Filters	MSE	PSNR
Average	118.552	24.362
Median	116.267	27.843
AMF	112.345	28.726
AWMF	110.788	29.366
Lee	108.522	30.142
ASSF	104.399	32.847
ANSF	102.464	34.926
ABF	96.433	36.724
Fuzzy filter	92.837	38.432
Fuzzy based two step filter	82.265	39.328
Proposed Filter	**81.042**	**42.586**

CONCLUSION

An efficient algorithm is proposed for filtering ultrasound and CT images. It is observed that the given method is able to filter both the images satisfactorily. On testing it with both types of images, the outcomes that were found were fairly better compared to other techniques. The proposed method for ultrasound and CT image filtering is useful for more analysis by the researchers and is appropriate to measure the noise level under any abnormality developed in both the ultrasound and CT mages.

REFERENCES

[1] D.T. Kuan, *et al,* "Adaptive restoration of images with speckle**"**, IEEE Trans. Acc. Speech Signal Proc., 35 (3) (March 1987), pp. 373-383
[2] V.S. Frost, *et al,* A model for radar images and its application to adaptive digital filtering of multiplicative noise", IEEE Trans. Pattern Anal. Machine Intel., PAMI-4 (1982), pp. 157-166
[3] J.S. Lee, "Digital image enhancement and noise filtering by use of local statistics**"**, IEEE Trans. Pattern Anal. Matching Intell., 2 (1980), pp. 165-168
[4] Farzana, E., et al. "Adaptive bilateral filtering for Despeckling of medical ultrasound images." TENCON 2010-2010 IEEE Region 10 Conference, IEEE, 2010.
[5] P. Perona and J. Malik, "Scale space and edge detection using anisotropic diffusion," IEEE Trans. Pattern Anal. Machine Intell., vol.12, pp. 629–639, 1990.
[6] Hua Cheng, Jinwen Tian, "Adaptive synthetic aperture radar image enhancement," Proc. SPIE 7494, MIPPR 2009: Multispectral Image Acquisition and Processing, 749426 (30 October 2009); https://doi.org/10.1117/12.830927
[7] Binaee et al, An ultrasound image enhancement method using local gradient based fuzzy similarity, Biomedical Signal Processing and Control, vol.13 pp- 89–101, 2014
[8] J. Babu et al, Adaptive speckle reduction in ultrasound images using fuzzy logic on coefficient of variation. Bio. Signal Process. Control 23, 93–103 (2016). Doi:10.1016/j.bspc.2015.08.001
[9] G.Hung et al. Research on image denoising based on fractional order integral. Syst. Eng. Electron. 33(4), 926–932 (2011)
[10] J.R. Hu, et.al, A novel image denoising algorithm based on Riemann–Liouville definition. J. Comput. 6(7), 35–39 (2011). doi:10.4304/jcp.6.7.1332-1338.
[11] A. Saadia, R. Adnan, Fractional order integration and fuzzy logic based filter for denoising of echocardiographic image. Comput. Methods Programs Biomed. 137, 65–75 (2016)
[12] Y.-F. Pu,et.al "Fractional differential mask: A fractional differential-based approach for multiscale texture enhancement", IEEE Trans. Image Process., vol. 19, no. 2, pp. 491-511, Feb. 2010.
[13] Q-L.Chen et al, Research on image denoising based on time space fractional partial differential equations, Systems Engineering and Electronics, 34(8), 1741-1752.
[14] N. He et al., "An improved fractional-order differentiation model for image denoising", *Signal Process.*, vol. 112, pp. 180-188, Sep. 2015.
[15] D. Shao et al, in 2015 8th International Conference on Biomedical Engineering and Informatics (BMEI). Ultrasound speckle reduction based on fractional order differentiation (IEEE, 2015), pp. 121–125. doi:10.1109/BMEI.2015.7401485
[16] H.A. Jalub et al, H.A. Jalab, R.W. Ibrahim, Fractional Alexander polynomials for image denoising. Signal Process. 107, 340–354 (2015). Doi:10.1016/j.si gpro.2014.06.004.