

PSO based Optimization of Tuning Parameter for Quadrilateral Maximum Likelihood Estimation Despeckling

Sridevi S¹, Nirmala S²

Assistant Professor, Department of ECE, Dhirajlal Gandhi College of Technology, Salem, Tamilnadu, India¹

Principal, Muthayammal Engineering College, Rasipuram, Namakkal, Tamilnadu, India²

ABSTRACT: Image denoising has become a very essential exercise all through the diagnosis especially in case of medical image processing involving ultrasound. Speckle pattern is one of the most complicated multiplicative noise which hardly degrades visual quality of clinical ultrasound images. Real time ultrasound images possess inherited speckle pattern which reduces its resolution and contrast there by degrading the diagnostic accuracy of the ultrasound image. The presence of speckle noise in fetal ultrasound images make the conditions worse to carry out prenatal diagnosis of congenital heart disease. This is due to the impact of edge and local fine details that are not very clear for diagnosis. There exists an ever growing research demand for contriving a robust speckle reduction filter to enhance the quality of the speckle affected image and to preserve the essential features. This paper describes about the proposed despeckling filter contrived with the concept of Particle Swarm Optimization of weight parameters to improve the algorithm of Quadrilateral Rayleigh Maximum Likelihood Estimator to suppress the speckle noise in clinical ultrasound images. The proposed filter establishes the Rayleigh Maximum Likelihood Estimator and particle swarm optimization technique hence called as PSO based QRML filter. The experimental result shown in this paper proves the efficacy of the proposed filter in comparison with several existing despeckling filters in terms several performance indices and image profile. Experimental results shows that the proposed filter removes the speckle noise effectively and thus outshine the conventional filters.

KEYWORDS: Quadrilateral Kernels, Rayleigh Maximum Likelihood Estimation, Particle Swarm Optimization, Speckle suppression, Tuning parameter

I. INTRODUCTION

Ultrasonography is a versatile and non-invasive imaging modality useful for performing prenatal diagnosis of congenital heart disease. It extracts unavoidable clinical diagnostic details and is routinely used in obstetric examinations. With respect to its diverse virtues such as economical, provides real time images and provides continuous improvement in image quality [1]. But still, the major weakness is its poor visual quality, only because of the speckle noise. Speckle noise is inherent in clinical ultrasound images which makes it very difficult to interpret fine diagnostic facets and prevents the identification of low contrast lesions approximately by a factor of eight [2]. The biological structures in ultrasound images are scanned with missing boundaries because of the presence of speckle pattern [3]. In fact performing thorough clinical diagnosis of prenatal congenital heart defects from ultrasound images is really a challenging task for physicians [4]. Typically prenatal diagnosis has to be performed as early as possible during the first trimester of pregnancy. Hence the suppression of speckle noise from Ultrasound images facilitates the untrained physicians to perform unambiguous disease diagnosis [5]. Hence it is obvious that this scenario provide a greater impact to provide an opportunity for appropriate design of robust despeckling filter.

Speckle noise interferes in ultrasonic images in the form of random, deterministic and interference pattern while scanning the coherent ultrasound echo beams [2]. Effective despeckling can be contrived by performing suitable assumption about the speckle statistics intruding in ultrasound images. Despite many statistical models have been proposed in order to model the speckle noise pattern in ultrasound image, Rayleigh distribution was largely used to

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Special Issue 6, May 2015

represent the fully developed speckle noise [6]. Speckle in B-scans is seen as a granular structure which is caused by the constructive and destructive coherent interferences of back scattered echoes from the scatterers that are typically much smaller than the spatial resolution of medical ultrasound system. This phenomenon is common to laser, sonar and synthetic aperture radar imagery (SAR). Speckle pattern is a form of multiplicative noise and it depends on the structure of imaged tissue and various imaging parameters [7]. The histogram of the amplitude of RF envelope ultrasound signal backscattered from a uniform area with a high scattered density follows a Rayleigh distribution with mean proportional to standard deviation [8].

Many generalizations have been made to improve the classical Rayleigh Maximum Likelihood Estimation based despeckling filter proposed by [9]. One of the modifications performed in Quadrilateral Maximum Likelihood Estimation Despeckling filter proposed in [10] solely depends on the use of three different statistical parameters instead of Coefficient of Variation parameter mentioned in classical RMLE method to differentiate the smooth and edge region. Second modification performed depends on the quadrilateral shape of kernel neighbourhood used for computing the noise estimation. The major modification performed in [11] is development of fuzzy rules in order to identify the type of image region as smooth or edge. The modification performed in case of [7] defines the use of morphological operations defining binary connectivity between pixel intensity within the kernel neighbourhood to identify whether the test pixel belongs to smooth or edge region. Other methods of speckle reduction methodology available in literature includes entropy based straight kernel and linear regression analysis for speckle suppression from ultrasound images proposed in [12, 13]. Various particle swarm optimization techniques were used to improve the performance of various speckle suppression filters [14-16].

The proposed filter computes the mean deviation and standard deviation statistical parameters across every kernel in order to identify the type of image region [10]. To surmount the tradeoff between speckle suppression and edge preservation, the proposed filter makes use of appropriate tuning parameter while estimating the noise free pixel intensity [11]. The tuning parameter is of two type's namely smooth parameter and edge parameter. These two tuning parameters need to be optimized in such a way that the variance of the uniform portion of the image region gets minimized when compared with the value of stopping criteria. In this proposed work, PSO technique is initialized with random values as edge and smooth tuning parameter and the fitness function of the optimization is chosen as the minimization of variance in uniform region. Rest of this paper is organized as follows, Section II describes the material and methods used to implement the proposed work. Section III discusses in detail about the quantitative and visual results of the proposed filter in comparison with the few existing filters. Section IV concludes the paper.

II. MATERIALS AND METHODS

The clinical ultrasound images used for this experimental study and evaluation of the proposed method were obtained from imaging modality with specifications of GE Logic 400 equipment with curvilinear transducer producing 2ultrasound beaming frequency of 3 to 5 MHz. The algorithmic steps involved in this proposed method are illustrated in figure.1. The methodology of the proposed filter involves the modification made to improve the Quadrilateral Rayleigh Maximum Likelihood Despeckling filter proposed in [10]. The fully developed multiplicatively speckle noise in the backscattered signal of ultrasound waves is modeled as

$$N(i, j) = O(i, j) * \eta(i, j) \quad (1)$$

for $i = 1, 2, \dots, A$ & $j = 1, 2, \dots, B$

Where $N(i, j)$ represents the observed noisy ultrasound image, $O(i, j)$ represents noise free original image and $\eta(i, j)$ represents multiplicatively corrupted speckle noise pattern in ultrasound image. The distribution of speckle noise pattern is approximated by independently and identically distributed Rayleigh probability density function specified in [9]. The noise free pixel intensity is estimated by establishing robust Rayleigh Maximum Likelihood Estimator and is given by

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Special Issue 6, May 2015

$$F(i, j) = \sqrt{\left(\frac{1}{\|\Omega\|2\sigma_\eta^2}\right) \sum_{a,b \in \Omega} N^2(i, j)} \quad (2)$$

In the above equation $2\sigma_\eta^2$ is used as filter tuning parameter. Now the proposed method computes the values of coefficient of mean deviation D shown in equation (3) and standard deviation S in every quadrilateral kernels to discriminate the type of image region.

$$D = \frac{\sum_{a,b \in n} [X - \bar{X}]}{n} \quad (3)$$

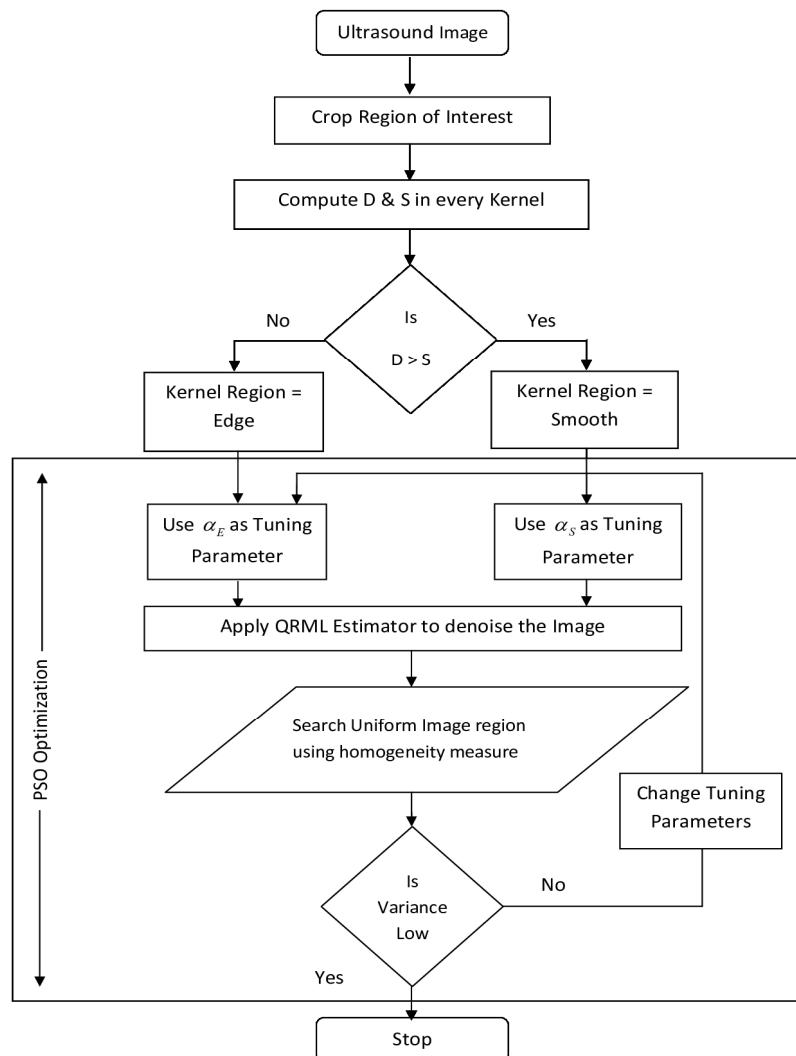


Fig. 1 Flow diagram of proposed filter

If $D >$ Standard deviation, then the filter identifies the region within the quadrilateral kernel as smooth and we use smooth tuning parameter $\alpha_s = 2\sigma_\eta^2$. If $D <$ Standard deviation, then the filter identifies the region within the kernel as edge and we use edge tuning parameter $\alpha_e = 2\sigma_\eta^2$. Standard deviation of the selected kernel is denoted by S.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Special Issue 6, May 2015

Particle Swarm Optimization is basically a social analogy inspired evolutionary computational intelligent technique developed by Kennedy and Eberhart in 1995 [17]. In PSO technique, the algorithm is initialized with random numbers of particles as population in the search space and search process is carried out to optimize the potential solutions. Every particle in the search space does the search operation by tracking the best solution in local neighbourhood and calls it as localBest value and best solution in the entire population area and calls it as globalBest value. This kind of tracking is accelerated toward best solutions in the search space by changing the velocity of particle movements. The optimization of the best solution is achieved by evaluating the fitness function and for this experimental study the fitness function is given by detecting the uniform area

$$\text{Fitness function } K = \frac{1}{AB} \sum_{i \in A} \sum_{j \in B} U_{i,j} - \mu \quad (4)$$

Where μ is the mean of uniform area and A, B represents the size of the uniform area U.

The initializing position and accelerating velocity of the PSO optimization technique is given the following equation

$$x_i = x_i + v_i \quad (5)$$

Where x_i and v_i are particle position and particle velocity. Particle velocity updating is validated by calculating the velocities of each particle in the search space and its corresponding equation is given by

$$v_i = w * v_i + c_1 * r_1 * (\text{localBest} - x_i) + c_2 * r_2 * (\text{globalBest} - x_i) \quad (6)$$

Where w represents the random weight factor and is expressed by the following equation

$$w = w_{\max} - \left[\frac{w_{\max} - w_{\min}}{\text{iter}_{\max}} \right] * \text{iter} \quad (7)$$

In this experimental study the concept of PSO based optimization is used for finding optimized tuning parameter values for finding the noise free pixel intensity using QRMLE despeckling filter. The pseudo code of the PSO optimization of tuning parameter is as follows

Step 1: Initialize population:

For each particle in each kernel

 Initialize particle as random tuning parameter α_S and α_E

END

Step2: Local Best particle selection using fitness function

Do

 For each particle

 Calculate fitness value according to equation (4)

If Current Variance measure < localBest

 set localBest = Current Variance measure

End

Step3: Global best particle selection using fitness function

If Current Variance measure < globalBest

 Then globalBest = localBest

For each particle

 Calculate particle velocity according to equation (5)

 Update particle position according to equation (6)

End

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Special Issue 6, May 2015

Step 4: Make decision to continue or stop iterations

Go to Step 1 if Variance is not equal to stopping criteria

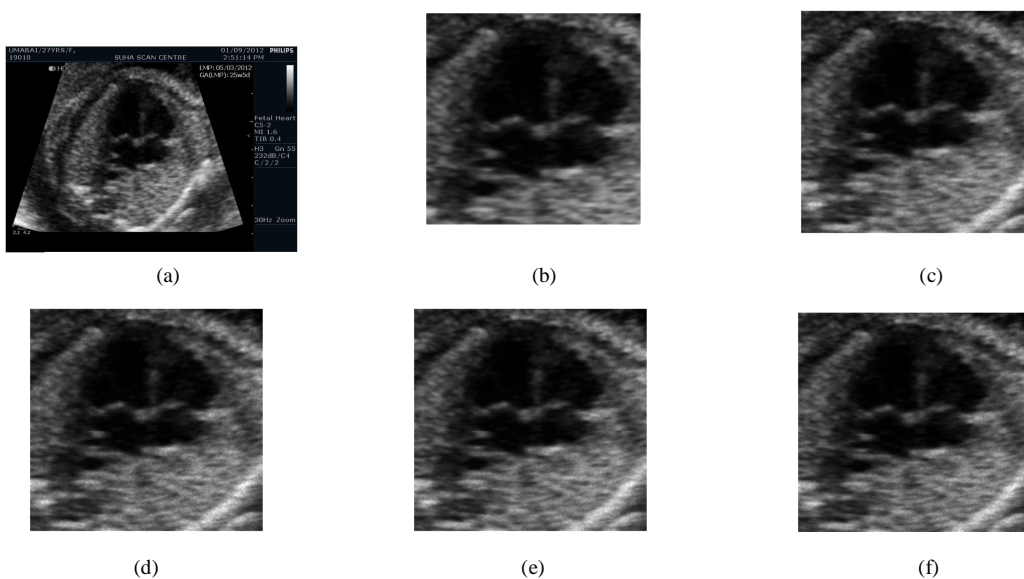
III. RESULTS AND DISCUSSION

Despeckling is carried out with the proposed method and few other existing methods using clinical ultrasound fetal heart images. Figure 2 shows the simulated results of processed images along with clinical original image. The ultrasound image is corrupted with various intensities of speckle noise density and the various performance metrics were measured for the conventional and proposed filters.

The proposed filter is compared in performance with respect to median filter, frost filter and classical Rayleigh Maximum Likelihood Estimation (RMLE) based despeckling filter. Table.1. Shows the various performance metrics measured for the proposed filter alone for different noise intensity levels. The performance metrics taken into account for proving the efficiency of the proposed despeckling process were Equivalent Number of Looks – ENL, Minimum Absolute Error – MAE, Peak Signal to Noise Ratio – PSNR and Feature Similarity Index Metric – FSIM. Table.2 shows the performance of the proposed filter compared with the above mentioned filters in terms of PSNR performance measure. Fig.3 and Fig.4 shows the graphical illustration of the performance metrics measured with Table.1 and Table.2 respectively.

Table 1: Various performance metrics computed for proposed filter

S.No	Noise Variance	ENL	MAE	PSNR	FSIM
1	0.02	13.70	1.60	33.49	0.97
2	0.04	12.63	2.12	32.88	0.95
3	0.06	12.31	2.84	32.40	0.93
4	0.08	11.53	4.1	31.12	0.91



International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Special Issue 6, May 2015

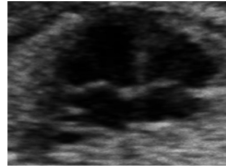


Fig. 2. Original and filtered ultrasound fetal heart images (a) Original image (b) Cropped image (c) Noisy image (d) Median filter (e) Frost filter (f) RML (g) filter

Table 2: PSNR measure for proposed filter and existing filters

S.No	Noise Variance	Median	Frost	RMLE	Proposed filter
1	0.01	24.06	28.64	32.61	34.30
2	0.02	23.94	27.45	32	32.94
3	0.03	23.15	25.92	31.80	32.6
4	0.04	22.48	23.54	30.07	31.32
5	0.05	21.34	22.42	29.32	30.43
6	0.06	19.31	20.71	29.01	30.21
7	0.07	18.02	19.15	28.45	29.85
8	0.08	16.91	18.18	27.21	29.06

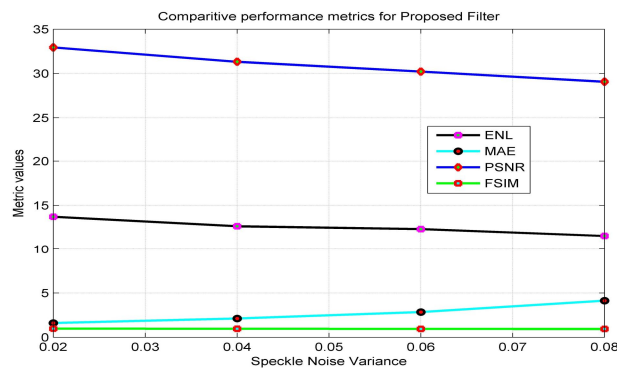


Fig. 3 Plot of various performance metrics for proposed filter

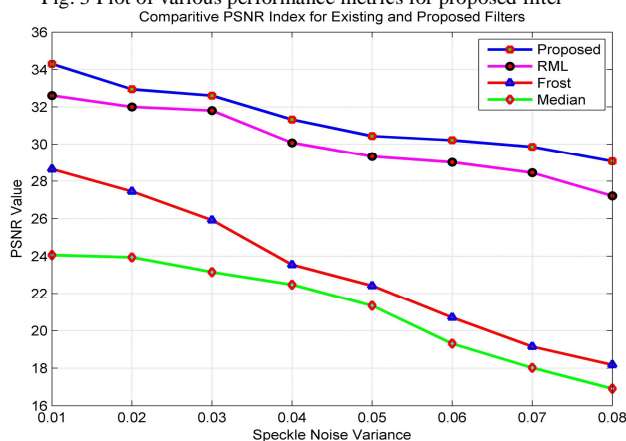


Fig. 4 Plot of comparative performance of various filters for PSNR metric

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Special Issue 6, May 2015

IV. CONCLUSION

We have modified the quadrilateral Rayleigh Maximum Likelihood Despeckling filter by synergizing the Particle Swarm Optimization technique. This process tends to reduce the variance in uniform image regions. Thus the image becomes more suitable without speckle noise to draw unambiguous diagnostic results. The proposed algorithm successfully optimizes the tuning parameter and thereby achieves the balance between speckle suppression and edge preservations. It is apparent that the proposed filter is capable of preserving the edges as well as suppressing the speckle noise. On comparing the quantitative performance metrics, it is found that the proposed filter outperforms the existing filters.

REFERENCES

- [1]. K. Kirk Shung, Diagnostic Ultrasound Past, Present and Future”, Journal of Medical and Biological Engineering, Vol 31, No:6, pp: 371 – 374, 2011.
- [2]. J.C.Bamber and C.Daft, “Adaptive filtering for reduction of speckle in ultrasonic pulse echo images”, Ultrasonics, pp: 41 – 44. 1986.
- [3] Sridevi. S and Nirmala. S, “Fuzzy Connectedness based segmentation of fetal heart from clinical Ultrasound Images”, Proceeding of Advanced computing, networking and Informatics, published in Springer Smart Innovation, Systems and Technologies, Vol: 27, pp: 329 – 337, 2014.
- [4] Jack Rychik et al, “American Society of Echocardiography Guidelines and Standards for Performance of the Fetal Echocardiogram”, Journal of the American Society of Echocardiography, July 2004.
- [5] R.W.Praeger, A.H.Gee, G.M.Treece, and L.Berman, “Speckle detection in ultrasound images using first order statistics”, GUED/F- I NFENG/TR 415, University of Cambridge, pp-1-17, July 2002.
- [6] In Jae Myng, “Tutorial on maximum likelihood estimation”, Journal of mathematical psychology -Elsevier, Vol. 47, pp. 90-100, 2003
- [7] P.John Vivek, C.Ganesh, S.Sridevi and S.Nirmala, “Binary connectedness based RML filter for speckle reduction in ultrasound images”, Proceeding of Innovations in Intelligent Instrumentation, Optimization and Signal Processing published in International Journal of Computer Applications, pp:6 – 12, 2013.
- [8] R.W. Praeger, A.H. Gee, G.M. Treece, and L. Berman, “Speckle detection in ultrasound images using first order statistics”, University of Cambridge, pp.1-17, 2002.
- [9] Tuncer C.Aysal and Kenneth E.Barner, “Rayleigh maximum likelihood filtering for speckle reduction of ultrasound images”, IEEE Trans. Medical Imaging, Vol. 26, page: 712 to 727, May 2007.
- [10] S.Sridevi and S.Nirmala, “Generalization of Rayleigh Maximum Likelihood Despeckling filter using quadrilateral kernels”, ICTACT Journal on Image and Video Processing, Vol: 3, No: 03, pp: 559-564, 2012.
- [11] S.Nirmala and S.Sridevi, “ Modified Rayleigh Maximum Likelihood Despeckling filter using Fuzzy Rules”, IEEE International conference proceedings on Information Communication and Embedded Systems, pp:755- 760, 2013.
- [12] S. Rajalaxmi, S. Nirmala, Entropy-Based Straight Kernel Filter for Echocardiography Image Denoising, Journal of Digital Imaging, Volume 27, Issue 5, pp 610-624, 2014.
- [13] Echocardiographic image denoising and objective fidelity criteria estimation using entropy paramounted linear regression filter, IEEE International conference proceedings of Emerging Trends in Science, Engineering and Technology, pp: 536 – 541, 2012.
- [14] S.Mohamed Mansoor Roomi and R.B.Jayanthi Rajee, “Speckle noise removal in ultrasound images using Particle Swarm Optimization technique”, IEEE International conference proceedings in Recent trends in Information Technology, pp: 926 – 931, 2011.
- [15] S.Mohamed Mansoor Roomi, P.L.Muthu Karuppi, P.Rajesh and B.GuruRevathi, “A Particle swarm optimization based edge preserving impulse noise filter”, Journal of Computer Science, Vol: 6, No:9, pp:1006 – 1012, 2010.
- [16] J.K.Mandal and Somnath Mukhopadhyay, “Image filtering using all neighbor directional weighted pixels: Optimization using Particle Swarm Optimization”, International Journal of Signal and Image Processing, Vol : 02, No: 4, pp:187 – 200.
- [17] Kennedy J and Eberhart R, “Particle Swarm Optimization”, IEEE International conference on Neural Networks, Vol:04, pp:1942 – 1948, 1995.
- [18] S. Nirmala and V.Palanisamy, “Clinical decision support system for early prediction of Down Syndrome fetus using sonogram images”, Signal, Image and Video Processing, Vol:5, No:2, pp: 245 – 255, 2011.