Fuzzy Based Adaptive Anisotropic Diffusion Despeckling Filter

Prashant G. Bannulmath, Raviraj H. Havaldar

Abstract: ***Echocardiography is an ultrasound of the heart for the assessment of cardiac structure and function. Images obtained from the ultrasound suffer from a speckle Noise. Speckle is an inherent multiplicative noise which affects the visual perception by discriminating the fine details in the echocardiography. Speckle removal is important step to improve the visual quality of the echocardiography for better diagnosis. Anisotropic diffusion is one of the popular techniques to despeckle the ultrasound image in recent times. In this paper, we propose a fuzzy based adaptive anisotropic diffusion despeckling filter to despeckle echocardiography ultrasound image. The results show that fuzzy diffusion when combined with adaptive anisotropic diffusion filter gives better performance compared with existing despeckling filters.***

Keywords: Anisotropic diffusion, Despeckling Echocardiography.

I. INTRODUCTION

Echocardiography is a non invasive ultrasound of the heart for cardiac structure and function assessment [1].It provides real time images at high acquisition rates. The main problem of echocardiography ultrasound imaging is speckle noise which is inherent and highly multiplicative. The spatial and contrast resolution of an image may be degraded by granular pattern speckle noise thus resulting in improper diagnosis of a cardiac function. Hence despeckling is an essential step in echocardiography. Despeckling is necessary step before segmentation, feature extraction, region based detection, and analysis of echocardiography images. Many techniques are used to despeckle the echocardiography images. However, some regions of the echocardiography has a unique speckle pattern and can provide important features for clinical purpose, so despeckling should be done without over-filtering relevant details in the echocardiography.

Despeckling can be done either in frequency domain or spatial domain. Linear filter such as mean filter are not much suitable for despeckling because they eliminate the high frequencies edges in the echocardiography.

Median filters are the most popular non linear filters they are extensively used to despeckle the ultrasound images because of its computational efficiency. But they do not preserve edges by smoothing out the image. The Lee and kuan filter adapt local the properties of the image to despeckle the ultrasound images [2], [3]. Both the lee and kuan do not remove speckle in high variance area of ultrasound [4]. The median filter with adaptive weights can effectively despeckle the ultrasound image but it removes useful speckle pattern which gives diagnostic information about underlying tissue. Dutt [5] developed a new homomorphic approach which applies logarithm on speckle noise and then wiener filter was applied. In the past few decades wavelet based despeckling technique have gain much attention by researchers [6]. Performance analysis of all such techniques is also carried out [7]. Shrinivasan and Ebenezer [8] proposed modified median based filter in which the corrupted pixels are replaced by neighborhood pixel. More recently, modified version of the Frost filter and Lee filter [9] have been proposed to achieve less computational time to remove same level of speckle as the median filter. This filter is applicable for filtering problems with large windows.

Anisotropic diffusion is one of the popular techniques to despeckle the ultrasound image in recent times. It was initially introduced by Perona, P. and Malik [10] and has been improved in several manners. The drawback of anisotropic diffusion filter is blocking artifact resulting as appearance of high frequency components which destroy structural and spatial neighborhood information [11].Sometimes as diffusion process progresses these anisotropic diffusion filters also tend eliminate relevant information required for diagnostic [12].Various methods have been proposed to improve anisotropic diffusion. Well-posed inhomogeneous nonlinear diffusion schemes are used to reduce the diffusion rate near edges [13], but they will dislocate the small scale edges. Local variance based methods [14], [15] are useful to locate small scale edges, but can be obstructed by noise along edges. In this work we propose an adaptive anisotropic diffusion despeckling filter with fuzzy diffusion which reduces blocking artifacts and measures edginess in each neighborhood of pixels for selective smoothing**.**

The contents of this paper are organized as follows. Section II describes the proposed method. Performance evaluations are presented in section III. Conclusion is discussed in section IV

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Mr. Prashant G. Bannulmath *, Department of E&CE , Angadi Institute of Technology and Management, Belagavi ,India. Email: pgbmath@gmail.com

Dr. Raviraj H. Havaldar, Department of BME , KLE Dr MSSCET**,** Belagavi, India Email: raviraj61@gmail.com

II. PROPOSED METHOD

The main objective of the proposed method is to minimize the blocking artifact and edge preserved selective smoothing which enhances the structural and spatial information. The proposed method has two steps as shown in Figure 1.

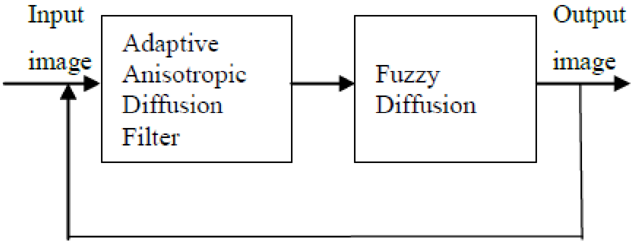

Figure 1: Proposed fuzzy based adaptive anisotropic diffusion filter.

A. Adaptive Anisotropic diffusion filter

Adaptive anisotropic diffusion filter is non-linear filter. Diffusion filters are used to soften images without affecting the sharpness and contrast of an image. The general anisotropic complex diffusion filter [16], [17] is represented by equation (1).

$$\frac{\partial I}{\partial t} = \nabla.(D\nabla I) \quad (1)$$

∇ is gradient and D is the diffusion coefficient approximated according to equation (2).

$$D = \frac{1}{1+\left(\frac{\Delta I}{k}\right)^2} \quad (2)$$

Where k is parameter which indicates the spread of the diffusion coefficient and it should be selected based on edges and speckle pattern. The calculated edges based on gradient do not reflect the edges in the original image because of multiplicative nature of speckle. This uncertainty can be overcome by fuzzy rule base diffusivity.

B. Fuzzy rule based diffusivity

Fuzzy logic is powerful tool because of its ability to deal with complex image processing problems [18]. Fuzzy rules describe quantitative relation between variables in linguistic terms. In the proposed method to control the diffusivity a rule based approach on a 3×3 neighborhood of a pixel is constructed. The fuzzy system maps each very low resolution quantization interval of input ultrasound image corrupted by speckle noise into very low resolution quantization interval of the output despeckled ultrasound image [19]. Mapping relations are defined using IF-THEN formalism as shown below.

Rule 1: IF P_{NE} is *Zero* AND P_E is *Zero* AND P_{SE} is *Zero* THEN is *Black* ELSE is *White (Shown in figure 2).*

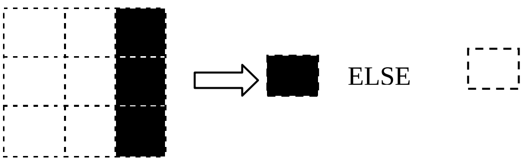

Figure 2: Rule 1.

Rule 2: IF P_{NW} is *Zero* AND P_N is *Zero* AND P_{NE} is *Zero* THEN is *Black* ELSE is *White (Shown in figure 3).*

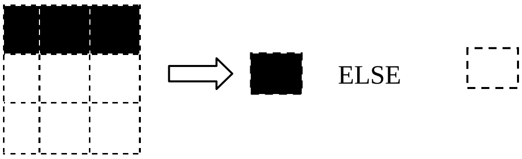

Figure 3: Rule 2.

Rule 3: IF P_{NW} is *Zero* AND P_W is *Zero* AND P_{SW} is *Zero* THEN is *Black* ELSE is *White (Shown in figure 4).*

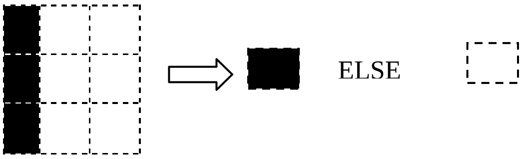

Figure 4: Rule 3.

Rule 4: IF P_{SW} is *Zero* AND P_S is *Zero* AND P_{SE} is *Zero* THEN is *Black* ELSE is *White (Shown in figure 5).*

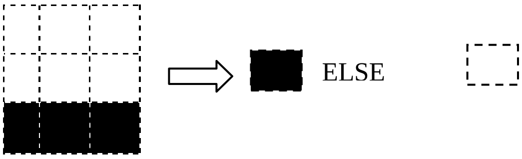

Figure 5: Rule 4.

Rule 5: IF P_E is *Zero* AND P_{SE} is *Zero* AND P_S is *Zero* THEN is *Black* ELSE is *White (Shown in figure 6).*

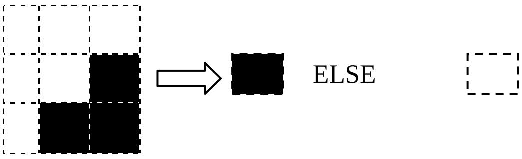

Figure 6: Rule 5.

Rule 6: IF P_N is *Zero* AND P_{NE} is *Zero* AND P_E is *Zero* THEN is *Black* ELSE is *White (Shown in figure 7).*

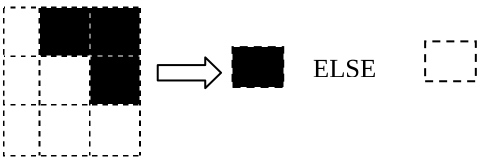

Figure 7: Rule 6.

Rule 7: IF P_N is *Zero* AND P_{NW} is *Zero* AND P_W is *Zero* THEN is *Black* ELSE is *White (Shown in figure 8).*

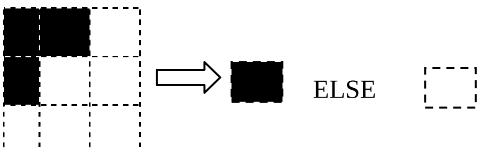

Figure 8: Rule 7.

Rule 8: IF P_W is *Zero* AND P_{SW} is *Zero* AND P_S is *Zero* THEN is *Black* ELSE is *White. (Shown in figure 9)*

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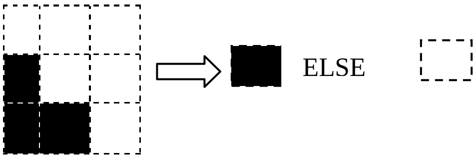


Figure 9: Rule 8.

Where P_N, P_S, P_E, P_W, P_{NE}, P_{NW}, P_{SE} and P_{SW} are the nearest neighborhood differences.

III. RESULTS

The proposed algorithm is applied on echocardiography images which are corrupted by speckle noise. Simulations are carried out on MATLAB (R2013a) in Intel Core i3 with processor speed of 1.8 GHz and 4 GB RAM to evaluate the proposed method with existing despeckling techniques. The evaluation parameters used are Peak Signal to noise ratio (PSNR) and Edge preservation factor (EPF) [20].

PSNR is used to measure the quality of despeckled image. PSNR is calculated by the following equation (3).

$$PSNR = 10\log_{10}\left(\frac{I^2}{MSE}\right) \tag{3}$$

Where I^2 is the maximum intensity present in the original image. MSE is the Mean square error calculated by the following equation (4).

$$MSE = \frac{\sum_{XY}[I(x,y) - I_f(x,y)]^2}{X \times Y} \tag{4}$$

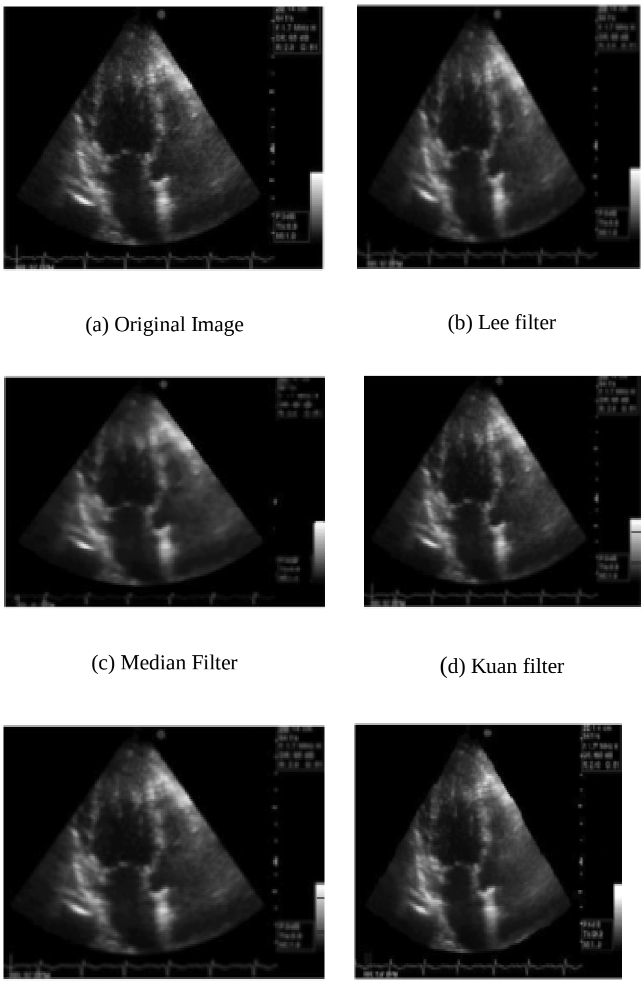
Where $X \times Y$ is the image size, m is number of rows, y is number of column, I is the original echocardiography image and I_f is the despeckled image.

EPF is the edge preservation capability of the filter. EPF is calculated by the following equation (5).

$$EPF = \frac{\sum(\Delta I - \overline{\Delta I})(\Delta I_d - \overline{\Delta I_d})}{\sqrt{\sum(\Delta I - \overline{\Delta I})^2 - \sum(\Delta I_d - \overline{\Delta I_d})^2}} \tag{5}$$

Where ΔI and ΔI_d are the sharpened version of the original image I and filtered image I_d. $\overline{\Delta I}$ and $\overline{\Delta I_d}$ are the mean values.

The values of PSNR and EPF are proportional to the quality of despeckled image. Figure 10(b-e) shows results of various existing despeckling filters when applied to echocardiography image of figure 10(a). Figure 10(f) shows the result of proposed method. Table I. shows the PSNR and EPF of various existing despeckling filters and proposed filter.



(a) Original Image (b) Lee filter

(c) Median Filter (d) Kuan filter

(e) Anisotropic Diffusion filter (f) Proposed Filter

Figure 10: Original image (a) and filtered images (b-f).

Table I: Performance Analysis

S. NO.	Filter	Evaluation Parameters	
		PSNR	***EPF***
1	Lee	34.918	0.2538
2	Median	34.628	0.3874
3	Kaun	34.712	0.2652
4	Anisotropic diffusion	35.837	0.6934
5	Proposed	36.568	0.7147

IV. CONCLUSION

In this paper a fuzzy based adaptive anisotropic diffusion despeckling filter is proposed to despeckle the echocardiography images. We compared the proposed method with existing despeckling filters. The performance of various despeckling filters is evaluated using PSNR and EPF. The combination of fuzzy diffusion with adaptive anisotropic diffusion filter exploits the effectiveness of fuzzy reasoning to minimize the blocking artifact and edge preserved selective smoothing. Results show that fuzzy based adaptive anisotropic diffusion despeckling filter gives better PSNR and EPF when compared with existing despeckling filters.

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AUTHORS PROFILE

Mr. Prashant G. Bannulmath is working as Assistant Professor in the department of E&CE, Angadi Institute of Technology and Management, Belagavi. He completed his M.Tech in Digital Communication and Networking at Gogte Institute of Technology, Belagavi and B.E. at Basaveshvara Engineering College, Bagalkot. His area of research includes Image processing and biomedical signal processing.

Dr. Raviraj H. Havaldar is a Professor & HOD in the Department of Biomedical Engineering, KLE Dr. M. S. Sheshgiri College of Engineering and Technology, Belagavi. He did his Ph.D at KLE University Belagavi, Karnataka, India. He completed his M.Tech in Biomedical Engineering at Manipal Institute of Technology, Manipal. His area of research includes Image processing, Biomedical signal processing and instrumentation.