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Denoising Of Ultra Sound Images Using Fuzzy-Shrinkage Based Diffusion Filtering

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Abstract— An Ultrasound provides images and information for diagnosis, therapy and prevention. It is the ideal choice for the orthopedic medicine and pain management. Images obtained from the ultrasound suffer from a problem called speckle and this is called as 'Speckle Noise' in terms of noise. It is due to multiple coherent reflections from the ambience around the object under consideration. In this paper a fuzzy based diffusion filter is proposed for the reduction of the speckle noise. A fuzzy model is proposed that uses Gaussian function for the shrinkage of diffusion filter. Experimental results prove that the proposed method is efficient in reaching convergence quickly and gives better quantitative result.
Index Terms—Gaussian function, complex diffusion, speckle Noise, Ultrasound.

I. INTRODUCTION

Ultrasound wave is used in medical imaging as sonographical images [17]. The noninvasive nature, smaller cost, movability, and run-time image formation make ultrasound (US) image an essential tool for medical diagnosis. This imaging modality, when used noninvasive, allows high acquisition rates and provides images in real-time, but the images is corrupted by a high level of speckle noise [18]. The problem of isolating intensity changes in US imagery is exacerbated by the presence of speckle, which appears as a jumble of randomly placed bright and dark spots. This noise makes it difficult to accurately identify edges, since in some regions the noise produces artificial edges, while in other regions there are no echoes present and the edges seem ambiguous. In such low-quality images (which are very common in US imaging), generic algorithms do not identify the border accurately. Ultrasound is becoming a major tool in medical diagnostics due to its non-invasive and non-radiation properties. It is used for imaging soft tissues in organs like liver, kidney, spleen, uterus, heart, brain etc. The speed, low cost of imaging and the portability of scanning machine makes it very popular. Advantages of ultrasound as diagnostic tool are well known: it is a safe, low cost, real-time and portable medical imaging technique, but some drawbacks of ultrasound imaging limit its use. A major and well-known problem is the so called speckle and noise, which significantly affects human interpretation of the images. As a result, ultrasound diagnosis demands a high level of operator experience. Speckle in ultrasound imaging (and all coherent imaging systems) is caused by the interference of energy from randomly distributed scatters, too small to be resolved by the imaging system. Speckle degrades both the spatial and contrast resolution in ultrasound images and thereby reduces the diagnostic value of the images. The intent of speckle reduction is to remove the distracting speckle pattern without reducing the detail in the ultrasound image, in other words, to make ultrasound images less granular and easier to "read". Thus, it seems necessary to remove speckle noise from the images prior to further processes such as feature extraction, analysis, and recognition from medical imagery measurements. Multiple methods are used to remove speckle noise from ultrasound medical images. Linear filters such as mean filters are not suitable for the speckle noise of ultrasound images, because they eliminate the high frequencies and thereby tend to smooth out the image edges. Temporal averaging methods are effective for noise reduction, although tissue motion, caused by external force, and hard spatially object adjustment in multi images are drawbacks of such method [16, 19]. Median filters are among the best methods for accomplishing speckle reduction 9, 10, 11, 12, 13, 14, 15, 16. The adaptive weighed median filter can effectively suppress speckle, but it fails to preserve many useful details, being merely a low-pass filter. Chirungrueng and Suvichakorn2 suggested a new filter, referred to as the 2-D weighted Savitzky-Golay, filter, which could achieve at least the same level of speckle reduction as the median filter, but with far less computational time. This filter is suitable for filtering problems with large windows. Jain5 developed a homomorphic approach, in which he took the logarithm of the image, converted the multiplicative into additive noise, and then applied the Wiener filter. Husbeyet al.7 recommended a new filter, based on Markov random field and bayesian statistical methods. They described a model for the scattering distribution of homogeneous tissue. The model is used in algorithms to restore speckle ultrasound images and shows that this filter is better than the Wiener filter. Both filters have limitation on quasi-periodic components and specular structure.

In this paper, a new adaptive filter based on a fuzzy system for ultrasound image speckle reduction is proposed. This filter is

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constructed from a feed forward multilayer network that integrates the basic elements and functions of a traditional fuzzy system into a connectionist structure. In this filter linguistic information is about the input–output relationship and is usually expressed as fuzzy if-then rules. This filter uses a real-time genetic algorithm to adapt network parameters. The neuro-fuzzy filters are used as a nonlinear filtering for noise cancellation in removal of impulse, gaussian, and uniform noises, but still had not been used for speckle noise reduction.

II. RELATED WORKS

Previously some work has been done on speckle noise reduction in ultrasound image. K. Thangavel et al. [15, 16] discussed speckle reduction in ultrasound prostate cancer images. The speckle noise is commonly found in the ultrasound medical images. Gallagher, Wise and Nodes have analyzed the properties of median filters in detail [1]. G.R.K.S. Subrahmanyam et al. [14] proposed a recursive spatial-domain speckle reduction algorithm for synthetic aperture radar (SAR) imagery based on the Unscented Kalman Filter (UKF) with a discontinuity-adaptive Markov Random Field (DAMRF) prior. Speckle noise severely impedes automatic scene segmentation and interpretation, and limits the resolution of SAR images [9] as well as their utility. A speckly suppression filter is expected to filter effectively homogeneous areas, retaining image texture and edges, and preserve features (both linear and point – type). In the Lee filter [6], the multiplicative model is approximated by a linear combination of the local mean and the observed pixel, and a minimum mean square error estimator is applied to determine the weighting constant. The enhanced Lee and Frost filters proposed by Lopes et al. [7] divide an image into homogeneous, heterogeneous areas, and isolated point targets based on the coefficient of variation c (low, intermediate, and high, respectively). Argenti et al. [1] proposed despeckling in the undecimated wavelet domain using a space-varying generalized Gaussian distribution for the wavelet coefficients. Adaptive filters [5, 6] are simple but tend to over-smooth image texture and suffer from ineffective denoising around edges. The adaptive block-Kalman filter [2] requires the autoregressive (AR) coefficients of the noise-free image to be known accurately. Recently proposed wavelet domain [4] and MAP approaches [1] have superior performance but require explicit optimization and/or parameter estimation.

III. RESEARCH METHODOLOGY

A. Speckle Noise

Speckle noise affects all coherent imaging systems including laser, SAR (Synthetic Aperture Radar) imagery, and ultrasound. Speckle may appear distinct in different imaging systems, but it is always manifested in a granular pattern due to image formation under coherent waves. Goodman has described the basic properties of speckle[4]. A general model for speckle noise proposed by Jain[5] was also used by Zong.[17] In the following; we will formulate the ultrasound speckle model. Denote by N(x,y) a noisy recorded ultrasound image, M(x,y) the noise-free image that has to be recovered and by $S_m(x,y)$ and $S_a(x,y)$, the corrupting multiplicative and additive speckle noise components, respectively. One can write:

$$N(x,y) = M(x,y)S_m(x,y) + S_a(x,y)$$

B. Speckle Reducing Anisotropic Diffusion (SRAD)

Anisotropic Diffusion is a nonlinear smoothing filter which utilizes a variable conductance term, that controls the complexity of the edges that impact the dispersion[1]. This filter has the ability to preserve edges, while smoothing the rest of the image to reduce noise [2]. SRAD is an edge-sensitive Partial Differential Equation (PDE) anisotropic diffusion approach to reduce speckle noise in images. SRAD have anisotropic diffusion which smoothes the uniform area and also preserve edges. It reduces blocking artifacts by deleting small edges amplified by homomorphic filtering. SRAD equation for an image u is given

$$SRAD(u') = ut + 1 = ut + \frac{\Delta t}{4} div(g(ICOV(u'))X\nabla u')$$

where t is the diffusion time index, Δt is the time step responsible for the convergence rate of the diffusion process (normally in the range 0.05 to 0.25), g(.) is the diffusion function and is given by equations

$$g\big(ICOV(u')\big) = e^{-p}$$

where p is represented by

$$p = \frac{\left(\frac{ICOV(u')}{q^t}\right)^2 - 1}{1 + (q^t)^2}$$

where ICOV is instantaneous coefficient of variation and is represented by

$$q(x,y;t) = \sqrt{\frac{\left(\frac{1}{2}\right)\left(\frac{|\nabla I|}{I}\right)^2 - \left(\frac{1}{4^2}\right)\left(\frac{\nabla^2 I}{I}\right)^2}{\left[1+\left(\frac{1}{4}\right)\left(\frac{\nabla^2 I}{I}\right)\right]^2}}$$

The execution of SRAD is better than the conventional anisotropic diffusion filter. On the other hand, SRAD has the burden that the diffusion time increments with the input highlight and it is as of now realized that when diffusion time expands the denoised image quality decreases. A non-linear fourth order PDEs are acclimated finer in the acreage of babble abridgement because they are faster in denoising and actualize a larger set of anatomic behavior that can be exploited during edge enhancement. The L2-curvature gradient flow method of [3] is used and given in Equation below

$$\frac{\partial u}{\partial t} = -\nabla^2[c(|\nabla_u^2|)\nabla_u^2]$$

here $\nabla_u^2$is the Laplacian of the angel u. Hence, the Laplacian of an angel at a pixel is aught if the angel is planner in its neighborhood, the PDE attack to abolish babble and bottle edges by approximating an empiric angel with a piecewise collapsed image. The adorable circulation of efficient c(.) should be such that above Equation diffuses added in smooth areas and beneath about less intensity transitions, so that small variations in edge acuteness such as noise and exceptionable arrangement are smoothed and edges are preserved. Above differential equation is associated to a cost function which is convex, therefore, the evolution of equation is a process in which the image is smoothed more and more until it becomes a planar image. But in the case of second order anisotropic diffusion the image is evolved towards a step image and that is why it suffers from blocky effects.

C. Proposed Method

The current models experience the ill effects of blocky impacts, which in the present study are evacuated by utilizing fourth request PDE. This strategy preserve edges and limits which are more steady through the scale 't'. Another trouble confronted by the current models is that, if the picture is extremely loud, the angle □u will be extensive, and thus, the capacity c(.) will be near to zero at each point. At the point when the smoothing is presented the commotion will remain thusly. This trouble is settled by utilizing a suitable channel that can lessen commotion and in the meantime be consolidated with fourth request PDE based anisotropic dissemination. So the SRAD channel was viewed as and to accelerate the convergence, FuzzyShrink is utilized.

A block diagram for the proposed model is shown under

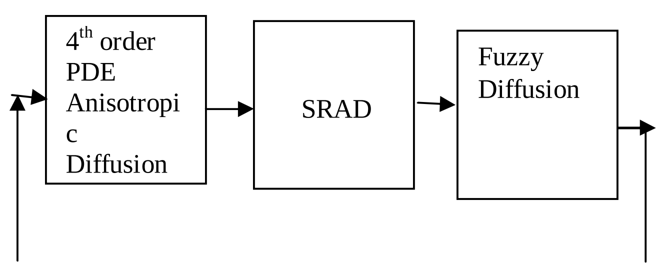

Fig. 1. Block diagram of proposed method.

This work give solution to the convergence problem of the diffusion filter with the advantage of fourth order PDE and SRAD. Study in the papers[20][1] found that the convergence of the diffusion largely depend up on the variance in the input image. Low variance input image converge quickly as compare to the large variance input image and the relation between the variance and the PSNR is gussian function. This study evolved the fuzzy shrinkage based on the input variance. The process of diffusion and cost function is then decided on the basis of the fuzzy rule. Convergence process increases the PSNR value and also the time consumption because this method also prevent unnecessary iterations.

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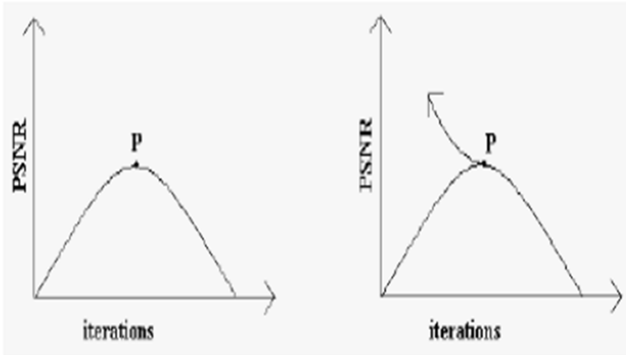
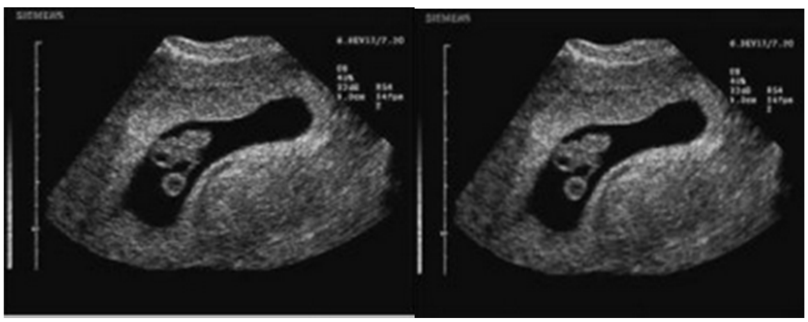


Fig. 2. Convergence Process

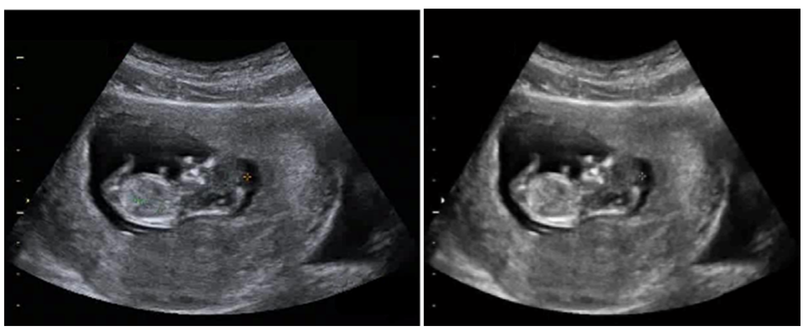
IV. RESULT AND DISCUSSION

We tested our proposed speckle noise reduction algorithm on ultrasound images. To validate our method we took various test images of different database. Database of images are taken from http://www.ob-ultrasound.net/ and http://www.ultrasound-images.com/. In our experiments, we considered three different variance levels speckle noise. Figure 3 and 4 show input images and denoised images; that shows optimal performance of our method.



(a) (b)

Fig. 4. (a) Speckle noisy image (b) Proposed fuzzy-diffusion filter output.



(a) (b)

Fig.4. Noisy and Output Image

For each filtering operation, we measure its ability to reduce speckle noise by PSNR. The proposed method is compared against state of art method for speckle denoising. Figure shows that our method performs better that both the method. Proposed method is also compared against time parameter because number of iteration is now more controlled and found that our method is superior then both LEE and KUAN filters.

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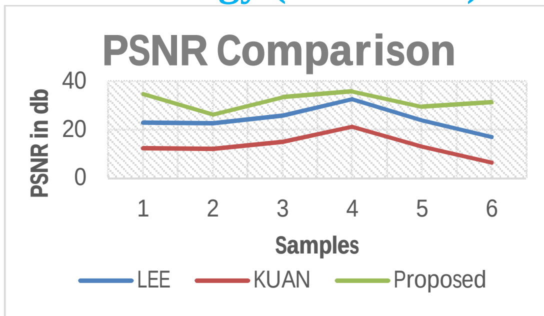

Fig. 5. PSNR values obtained for various samples.

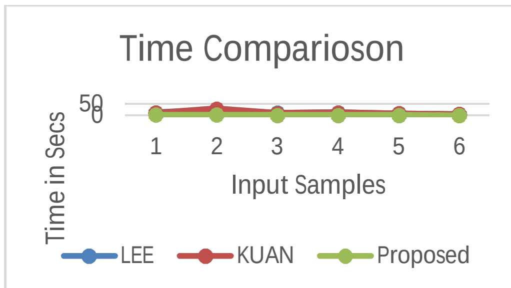

Fig. 6. Time taken during the testing process.

V. CONCLUSION

In this paper, we introduce a fuzzyShrinkage based diffusion filter for speckle noise reduction in ultrasound images. The combination fuzzy paradigms and diffusion permits us to exploit the effectiveness of fuzzy reasoning and the ability to converge quickly. Acceptance of the system has been done by considering gatherings of distinctive ultrasound pictures defiled by spot clamor. An inside and out examination of the separating conduct has been proposed by contemplating the MSE assessed on diverse classes of pixels and has demonstrated that this filter is compelling in commotion lessening and edge conservation. Exploratory results have demonstrated that the fuzzy filter has the capacity outflank various surely understood strategies in the literature. Our strategy can without much of a stretch be stretched out to different measurements and utilized for multidimensional sifting, improvement, division, and visualization applications. Research in this bearing is under way and will be introduced in a future report.

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