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*Research Article*

# A Proposed Approach to De-speckle an Ultrasound Image using Anisotropic Filter by Generating Diffusion Tensor

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**_Abstract_**

*Ultrasound imaging is a technique that is used to diagnose the diseases in medical field using radiology. US (ultrasound) imaging is a non -invasive technique and used for imaging of internal structure of the body without any kind of penetration which helps to identify the diseases that have probability and tissues. Many kinds of noises present in US images but the presence of speckle noise is a big challenge since last few years in biomedical field. Sometimes speckle noise becomes the part of information and vice-versa. So it becomes hard to find the disease for doctors. There are many de-speckled filters available for de-noising. This paper gives a proposed approach to de-speckled the US image using anisotropic diffusion filter by calculating the different numerical values like SSIM (structural similarity index), SNR (signal to noise ratio), MSE (mean square error), PSNR (peak signal to noise ratio), which results in coherence enhancement The proposed technique provides better and improved edge and coherence enhancement in ultrasound image data.*

**Keywords:** *Diffusion tensor, ultrasound images, an-isotropic filter, speckle noise, de-noising, structure tensor*

## 1. Introduction

Ultrasound imaging is more popular technique which is widely used in biomedical science for diagnosing various kinds of diseases. This is due to many advantages of such technique like high resolution, non-invasiveness, incontestable, less cost, real time operation and also portable [Amit Garg *et.al*, 2017]. When ultrasound waves are transmitted in human body then echo is received which is used to generate the projection. This projection is used as ultrasound image [Amit Garg *et.al*, 2017]. In ultrasound images, many kinds of noises are present like Gaussian noise and speckle noise etc. These noises sometime become clinical information and clinical information becomes noise so it's hard for doctors to diagnose the disease. So it is necessary to develop some techniques to remove such kind of noise from ultrasound image. These techniques have revolutionized diagnostic radiology, providing the clinical with new information about the interior of the human body that has never been available before [Fauzi Benzarti *et.al*, 2012].

In this paper the purpose is to remove speckle noise from ultrasound images by using an anisotropic filter by generating diffusion tensor. Many kinds of methods are used for removal of noise and image enhancement in 2D images. This paper purposed a method which subtracts the noise from ultrasound image and calculate various numerical results like SNR, PSNR, SSIM of 2d images, so that the comparison table is made up by using results of various methods in case Gaussian and speckle noise. This paper is organized in various sections such as: section 1 is introduction, section 2 is diffusion tensor, section 3 is description of 2d anisotropic filter, section 4 is about structure tensor, section 5 is purposed work, section 6 is evaluation of purposed work in terms of de-noising quality and section 7 is shows the conclusion of work.

## 2. Diffusion Tensor

A primary technique for imaging of diffusion tensor (Diffusion tensor imaging) has developed for non-invasive characterization in case of structure of an image and also in the local minima and maxima in the structure which are in the image and to develop more hard and fast anisotropic diffusion [Feriel Romdhane *et.al*,2012]. In case of the diffusion tensors such characterizations includes measurement of the parameters related to Eigen values. It also structure of organic cell and tissue [Zhaohua Ding *et.al*, 2005]. The diffusion tensor is used for the proper analysis deals with the evaluation of integrity of tissue structure by the differences in the calculated Eigen values and also the scrutiny of features of architecture in given Eigen vectors directions [Zhaohua Ding *et.al*, 2005]. The diffusion tensor can be constructed in two ways, such

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as edge-enhancing diffusion (EED) or coherence-enhancing diffusion (CED) [Fauzi Benzarti *et.al*, 2013]. But to form the hybrid diffusion filter with a continuous switch (HDCS), the CED and EED algorithms were linked and joined. The filtering equation in case of Diffusion tensor can be given as:

$$\frac{\delta u}{\delta t} = \nabla.(D\nabla u) \quad (1)$$

.

The actual procedure is to use the same inclination of Eigen vector for the D (diffusion tensor) is given below in the form of matrix which is called the structure tensor:

$$D = \begin{bmatrix} D11 & D12 & D13 \\ D12 & D22 & D23 \\ D13 & D23 & D33 \end{bmatrix} \quad (2)$$

$$D_{11} = \lambda_1 v_{11}^2 + \lambda_2 v_{21}^2 + \lambda_3 v_{31}^2 \quad (3)$$

$$D_{22} = \lambda_1 v_{12}^2 + \lambda_2 v_{22}^2 + \lambda_3 v_{32}^2 \quad (4)$$

$$D_{33} = \lambda_1 v_{13}^2 + \lambda_2 v_{23}^2 + \lambda_3 v_{33}^2 \quad (5)$$

$$D_{12} = \lambda_1 v_{11} v_{12} + \lambda_2 v_{21} v_{22} + \lambda_3 v_{31} v_{32} \quad (6)$$

$$D_{13} = \lambda_1 v_{11} v_{13} + \lambda_2 v_{21} v_{23} + \lambda_3 v_{31} v_{33} \quad (7)$$

$$D_{23} = \lambda_1 v_{12} v_{13} + \lambda_2 v_{22} v_{23} + \lambda_3 v_{32} v_{33} \quad (8)$$

The Eigen values are calculated with 2D extended equation given by Weickert. Other edge smoothing or enhancing Eigen value equations in literature, but most of the time they require edge threshold value [Wang Z.*et.al*, 2004]. The Eigen values are calculated from 2D to 3D extended equation given by Weickert.

$$\lambda_1 := c_1 \quad (9)$$

$$\lambda_2 := c_1 + (1-c_1)\exp\frac{-c_2}{(\mu_2-\mu_3)^2} \quad (10)$$

$$\lambda_3 := c_1 + (1-c_1)\exp\frac{-c_2}{(\mu_1-\mu_3)^2} \quad (11)$$

Where c1 (0; 1) is a global smoothing constant and c2 > 0, the edge smoothing or enhancing constant. The edge will be based on the number of iterations which is set by the user and can be determined after iterations.

## 3. Non Linear Anisotropic Filter

An anisotropic diffusion technique for image filtering is proposed by Weickert that smoothers images by using method of partial differential equation and to intensify the flow-like structures of scalar images [Weickert *et.al*, 1998]. The diffusion time controls the smoothing scale of image by using Gaussian filtering technique which is equal to linear diffusion technique. To save the regularization of edges non-linear diffusion (RPM) technique is introduced by Perona-Malik. Anisotropic diffusion filters has number of applications such as to improve coherence of flow like images by use of interrupted one-dimensional structures closing or de-noising of highly degraded edges [Weickert *et.al*, 1998, Weickert *et.al*, 2002] and can also better perform in case of isotropic ones with respect to certain given applications. The nonlinear anisotropic filter is superior to linear filter in terms of its advantages. Most of realizations in case of nonlinear diffusion filters are deployed on finite difference techniques, so it's easy to manipulate the structure in the form of pixels in case of digital images which gives a natural and fixed rectangular grid on the basis of already exists natural discretization.

## 4. Structure Tensor

Let a 2D image is denoted by I(x), where x = (x; y; z) shows the Coordinate of the given vector. A coordinate in the given image I, the structure tensor of image is a symmetric positive semi-definite 3×3 tensor which is given below:

$$J(\nabla I) = K_j * (\nabla I.\nabla I^T) \quad (12)$$

where $\nabla$ is gradient of an image and $K_J$ is a Gaussian weighting function with respect to sigma ρ. The Eigen vectors scrutiny of given structure tensor will also give the inclination about the features of local images:

$$J(\nabla I) = \left[V_1 V_2 V_3\right] \begin{pmatrix} \mu_1 & 0 & 0 \\ 0 & \mu_2 & 0 \\ 0 & 0 & \mu_3 \end{pmatrix} \begin{bmatrix} V_1^T \\ V_2^T \\ V_3^T \end{bmatrix} \quad (13)$$

The Eigen vectors v1; v2; v3 give the local image orientations, with $V_1 = \left[V_{11}; V_{12}; V_{13}\right]^T$ and Eigen values $\mu_1 \geq \mu_2 \geq \mu_3$ describing the average contrast in those directions.

## 5. Purposed Work

As speckle noise is the major problem in the field of medical science. Because due to the presence of such kind of noise it become hard to diagnose the diseases for the radiologist. For detection and removal of speckle and Gaussian noise no. of methods are used like Median, Perona, Catte, Alvarez, etc. and no. of linear isotropic filters are used for such purpose. But there is occurs a problem using such filters that it can't differentiate between noise and information by using linear isotropic filter. To escape from that problem we used nonlinear isotropic filter that is of high resolution and cost effective filter. Our proposed work is to enhance the image in terms of edge and coherence enhancement and numerically it provides improved values of SNR, PSNR, SSIM, MSE values of ultrasound images as compare to other methods as shown in comparison table.

## 6. **Evaluation**

The test performed on given ultrasound image data using 2d diffusion optimization scheme. By applying such method it will create diffusion tensor in terms of generate Eigen values, Eigenvector, gradient etc. This will enhance the image by edge and coherence. In the hybrid diffusion filter with a continuous switch (HDCS) using Eigen values, noise and image structure is separated by threshold value $\lambda_h$ .But in this, SNR is that much low that it hard to allow a better separation between noise and actual image structures and also the optimized scheme gives the highest pixel difference of edge. As such filter is preferred because the optimized filter despite the fact it sometimes enhances the noise image structure. The other method loses the small important detail also but the optimized filter enhances the some hardly visible structures. Finally the results of proposed filter in a scheme on ultrasound imaging are shown.

The optimized scheme shows the better enhancement and also the preservation. The diffusion and structure matrix is formed of size 257×257. The magnitude of Eigen values and Eigen vectors are calculated. The given image size is 794×559 pixel. The values of parameters are calculated shown in table form. By the comparison of this method with the others, the results in terms of figure shows a better picture quality after de-noising the ultrasound images by using the synthetic phantom shown in figure(1) and figure(2)

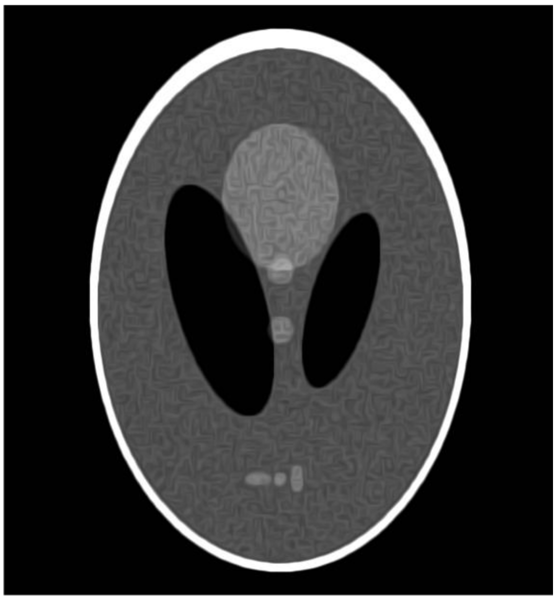


**Fig.1** Image for coherence enhancing diffusion at t= 35

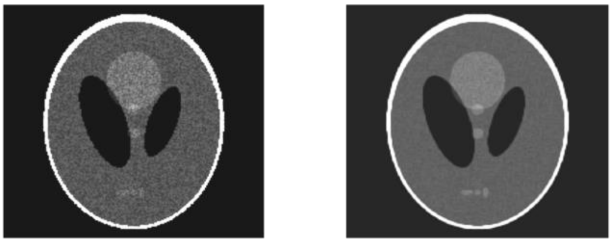

**Fig.2** (a) Noise image compared to original and (b) after coherence enhancement

This is to notify that CED method have also similar performance as the proposed approach. To evaluate the performance of the proposed method different quantitative measures is given, such as the signal to noise ratio (SNR), peak signal-to-noise-ratio (PSNR), and structural similarity (SSIM) index, mean square error (MSE).

The PSNR defined by:

$$PSNR = 10Log_{10}\left(\frac{N_{\max}}{MSE}\right) \tag{14}$$

Where $N_{max}$ shows the maximum fluctuation in case of the input image and MSE denoting the mean square error, which is calculated by formula given below in equation,

The MSE defined by:

$$MSE = \frac{1}{MN}\sum_{I=0}^{M-1}\sum_{J=1}^{N-1}\left\| f_o(i,j) - f_r(i,j)\right\| \tag{15}$$

in this $f_0(I=i,j)$ for the original image and $fr(I=i,j)$ for the restored image. SSIM notes the structures similarity index. Compare the structure of two images after subtracting luminance and normalized variance. Table 1 shows comparison between different methods for different parameters at variance value 0.05 and signal to noise ratio 50.43 and corresponding graph is shown in figure (3) and figure (4). Table 2 shows PSNR and SNR value for different levels of variance (noise) and also the corresponding graphs are shown in figure (5) and figure (6).

**Table 1:** Comparative table [3] at σ = 0.05, SNR=50.43

| Methods | PSNR | MSSIM | MSE |
|---|---|---|---|
| Kuan | 13.53 | 0.78 | 0.044 |
| Median | 13.62 | 0.71 | 0.043 |
| Frost | 13.83 | 0.74 | 0.041 |
| TV | 14.03 | 0.73 | 0.039 |
| Lee | 15.00 | 0.79 | 0.031 |
| Proposed | 27.86 | 0.89 | 0.021 |

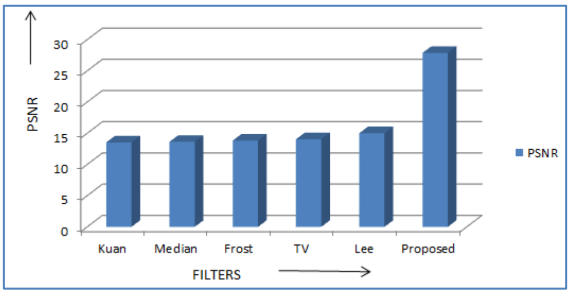


**Fig.3** PSNR values for different filters

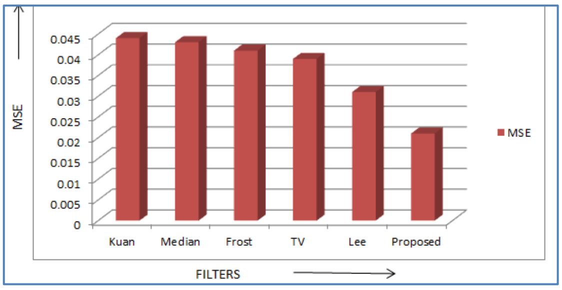


**Fig.4** MSE values for different filters

**Table 2:** PSNR, SNR values at different levels of variance (noise)

| Variance (σ) | PSNR | SNR |
|---|---|---|
| 0.01 | 26.83 | 34.34 |
| 0.02 | 27.07 | 36.57 |
| 0.03 | 27.31 | 39.51 |
| 0.04 | 27.58 | 43.60 |
| 0.05 | 27.86 | 50.43 |

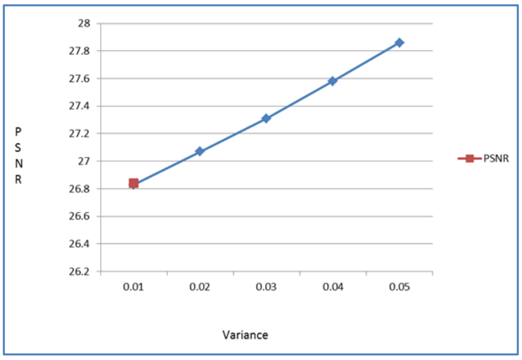


**Fig.5** PSNR for different values of variance

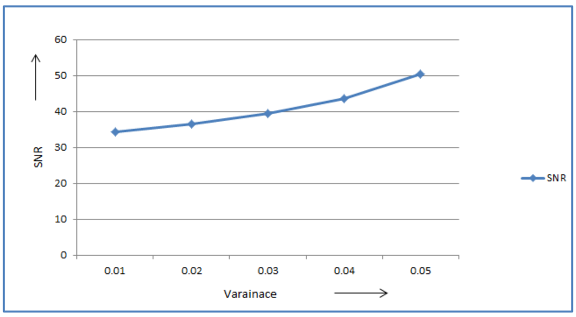


**Fig.6** SNR for different values of variance

As noted that the visual quality of SSIM is better as compare to PSNR value. The value of SSIM is given between 0 and 1 increasing with as the quality increasing. The edges are detected by applying the method of threshold on gradient magnitude. The filtration of image is with the optimized and standard scheme using Eigen values the given parameters σ= 0.05, ρ=5.5, τ=0.24, C=8. Number of iterations is 7. A real ultrasound (kidney) image is taken for de-noising shown in figure 4(a).

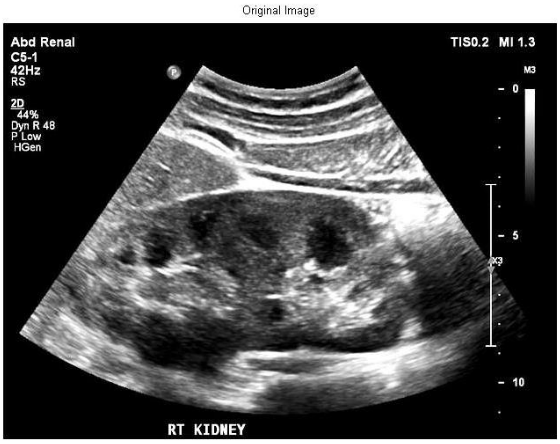


**Fig.7** Original ultrasound (kidney) image

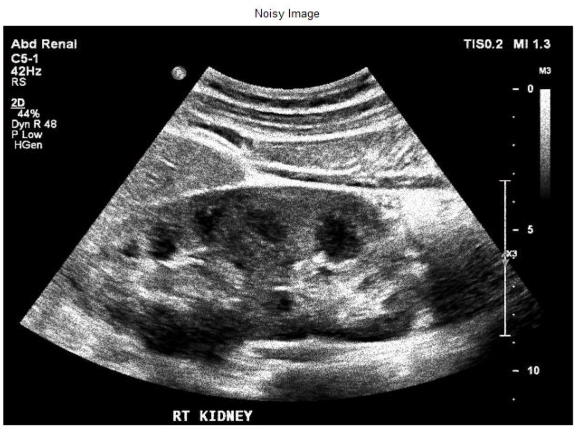


**Fig.8** Ultrasound image corrupted by speckle Noise

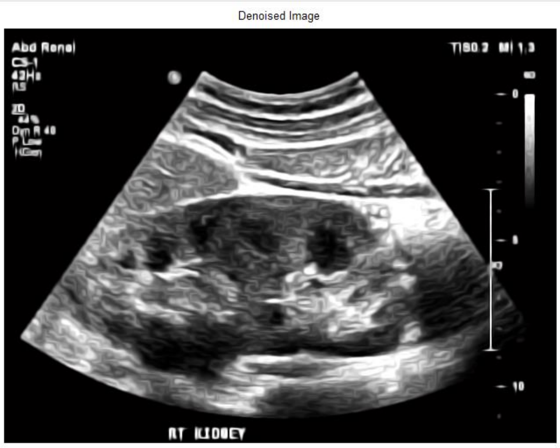


**Fig.9** Ultrasound (kidney) image after de-noising

## Conclusion

The presented 2D anisotropic diffusion scheme in this paper shows better and improved edge and coherence enhancement in ultrasound image data, compared to standard. This method preserves edge and coherence enhancement for high noise level also. This scheme is based on number of iterations performed by filter and diffusion time. It removes speckle noise from ultrasound (kidney) original image and provides quantity analysis of SNR, PSNR, SSIM, and MSE.

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