Enhancement of Ultrasound Images
(Removing of Speckle Noise Using Special An Isotropic Diffusion Filter)

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ABSTRACT

Medical imaging techniques are predominantly used in medical diagnosis and therapy. The success of this technique depends largely on the quality of images. Due to various factors images do not have appropriate contrast and are often overridden by noise, making the interpretation of the images too difficult leading to incorrect diagnosis. This will be a very important and significant contribution to the medical professional. Removing noise from the original image is still a challenging research in image processing. Generally there is no common enhancement approach for noise reduction. Several approaches have been introduced and each has its own assumption, advantages and disadvantages. The speckle noise is commonly found in the ultrasound medical images. This paper presents different filtering techniques based on Statistical methods for the removal of speckle noise in ultrasound images. The quality of the enhanced images is measured by the Statistical quantity measures: Peak Signal-to Noise Ratio (PSNR), Mean Square Error (MSE) and Correlation coefficient (COC).

Keywords : Ultrasound Images, Speckle Noise, Diffusion filter, speckle reduction anisotropic diffusion filter, PSNR, MSE, COC(β)

I. INTRODUCTION

Ultrasound imaging is a widely used and safe medical diagnostic technique, due to its noninvasive nature, low cost and capability of forming real time imaging. However the usefulness of ultrasound imaging is degraded by the presence of signal dependant noise known as speckle. The speckle pattern depends on the structure of the image tissue and various imaging parameters. There are two main purposes for speckle reduction in medical ultrasound imaging (1) to improve the human interpretation of ultrasound images (2) despeckling is the reprocessing step for many ultrasound image processing tasks such as segmentation and registration. A number of methods have been proposed for speckle reduction in ultrasound imaging. While incorporating speckle reduction techniques as an aid for visual diagnosis, it has to keep in mind that certain speckle contains diagnostic information and should be retained. The objective of this paper is to give an overview about types of speckle reduction techniques in ultrasound imaging.

ULTRASOUND imaging application in medicine and other fields is enormous. It has several advantages over other medical imaging modalities.
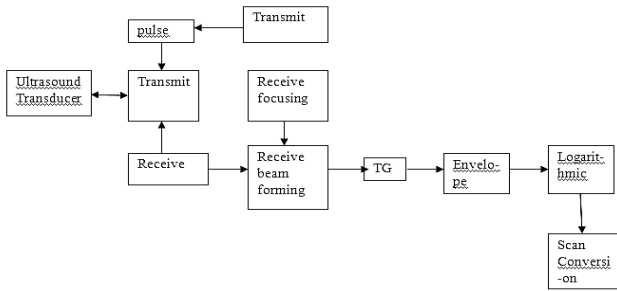
Figure 1. Block diagram of ultrasound imaging system

The use of ultrasound in diagnosis is well established because of its noninvasive nature, low cost, capability of forming real time imaging and continuing improvement in image quality. It is estimated that one out of every four medical diagnostic image studies in the world involves ultrasonic techniques. US waves are characterized by frequency above 20 KHz which is the upper limit of human hearing. In medical US applications, frequencies are used between 500 KHz and 30 MHz B-mode imaging is the most used modality in medical US. An US transducer which is placed onto the patient's skin over the imaged region sends an US pulse which travels along a beam into the tissue. Due to interfaces some of the US energy is reflected back to the transducer which converts it into echo signals. These signals are then sent into amplifiers and signal processing circuits in the imaging machine's hardware to form a 2-D image. This process of sending pulses launched in different directions is repeated in order to examine the whole region in the body. Thus, US imaging involves signals which are obtained by coherent summation of echo signals from scatterers in the tissue.

In many cases volume quantification is important in assessing the progression of diseases and tracking progression of response to treatment. Thus, 3D ultrasound imaging has drawn great attention in recent years.

II. SPECKLE NOISE

Speckle noise is the characteristic seen in ultrasound images that contribute to the visual noise. The image of a relatively uniform object with many scattering sources within a resolution cell will have pixel values that vary randomly with position due to constructive and destructive interference.

Speckle is not a noise in an image but noise-like variation in contrast. It arises from random variations in the strength of the backscattered waves from objects and is seen mostly in medical imaging.

NEED FOR SPECKLE REDUCTION

Thus, speckle is considered as the dominant source of noise in ultrasound imaging and should be processed without affecting important image features. The main purposes for speckle reduction in medical ultrasound imaging are:

To improve the human interpretation of ultrasound images – speckle reduction makes an ultrasound image cleaner with clearer boundaries.

Despeckling is a preprocess step for many ultrasound image processing tasks such as segmentation and registration – speckle reduction improves the speed and accuracy of automatic and semiautomatic segmentation & registration.
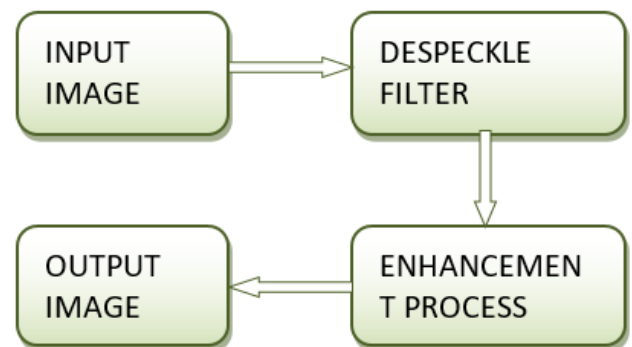

Figure 2. Block diagram of Enhancement of ultrasound imaging system

Diffusion Filtering

Diffusion filters remove the noise from an image by modifying the image via solving a partial differential equation (PDE). Smoothing is carried out depending on the image edges and their directions. Anisotropic diffusion is an efficient nonlinear technique for simultaneously performing contrast enhancement and noise reduction. It smoothes homogeneous image regions, but retains image edges without requiring any information from the image power spectrum. It may, thus, directly be applied to images. Consider applying the isotropic diffusion equation given by $\frac{dg_{i,j,t}}{dt} = div(d\nabla g)$ using the original noisy image $g_{i,j,t=0}$ as the initial condition, where $g_{i,j,t=0}$ is an image in the continuous domain, *i* and *j* specify the spatial position, *t* is an artificial time parameter, *d* is the diffusion constant, and ∇g is the image gradient. Modifying the image according to this linear isotropic diffusion equation is equivalent to filtering the image with a Gaussian filter. In this paper, we will present conventional anisotropic diffusion, speckle-reducing anisotropic diffusion.

Anisotropic Diffusion Filtering (DsFad)

Perona and Malik replaced the classical isotropic diffusion equation, as described above, by the introduction of a function $di,j,t = f(|\nabla g|)$ that smoothes the original image while trying to preserve brightness discontinuities with

$$\frac{dg_{i,j,t}}{dt} = div[d_{i,j,t}\nabla g_{i,j,t}] = \left[\frac{d}{d_i}d_{i,j,t}\frac{d}{d_i}g_{i,j,t}\right] + \left[\frac{d}{d_j}d_{i,j,t}\frac{d}{d_j}g_{i,j,t}\right]$$

….1.a

Where $|\nabla g|$ is the gradient magnitude, and $d(|\nabla g|)$ is an edge stopping function, which is chosen to satisfy $d \to 0$ when $|\nabla g| \to \infty$, so that the diffusion is stopped across edges. This function, called the diffusion coefficient $d(|\nabla g|)$, which is a monotonically decreasing function of the gradient magnitude $|\nabla g|$, yields intraregion smoothing and not inter region smoothing by impeding the diffusion at image edges. It increases smoothing

parallel to the edge and stops smoothing perpendicular to the edge, as the highest gradient values are perpendicular to the edge and dilated across edges. The choice of $d(|\nabla g|)$ can greatly affect the extent to which discontinuities are preserved. For example, if $d(|\nabla g|)$ is constant at all locations, then smoothing progresses in an isotropic manner. If $d(|\nabla g|)$ is allowed to vary according to the local image gradient, then we have anisotropic diffusion. A basic anisotropic PDE is given in Eq. (1.a).

$$d(|\nabla g|) = \frac{1}{1 + (|\nabla g_{ij}|/K)^2} \quad \text{and} \quad cd(|\nabla g|) = \frac{2(|\nabla g_{ij}|)}{2 + (|\nabla g_{ij}|/K_1)^2}$$

… 1.b

where *K* and *K*1 are positive gradient threshold parameters, known as diffusion or flow constants. In this book, the first diffusion coefficient in Eq. (1.b) was used as it was found to perform better in our images.

A discrete formulation of the anisotropic diffusion in Eq. (1.a) is

$$\frac{dg_{i,j}}{dt} = \frac{\lambda}{|\eta_s|}\left\{\begin{array}{l}d_{i+1,j,t}[g_{i+1,j} - g_{i,j}] + d_{i-1,j,t}[g_{i-1,j} - g_{i,j}] + \\ d_{i,j+1,t}[g_{i,j+1} - g_{i,j}] + d_{i,j-1,t}[g_{i,j-1} - g_{i,j}]\end{array}\right\}$$

…2.a

Where the new pixel gray value $f_{i,j}$ at location i, j is

$$f_{i,j} = g_{i,j} + \frac{1}{4}\frac{dg_{i,j}}{dt}$$

…2.b

where $d_{i+1,j,t}$, $d_{i-1,j,t}$, $d_{i,j+1,t}$, and $d_{i,j-1,t}$ are the diffusion coefficients for the west, east, north, and south pixel directions, respectively, in a four-pixel neighborhood around the pixel *i*, *j* where diffusion is computed. The diffusion coefficient leads to the largest diffusion where the nearest-neighbor difference is largest (the largest edge), whereas the smallest diffusion is calculated where the nearest neighbor difference is smallest (the weakest edge). The constant $\lambda \in R^+$ is a scalar that determines the rate of diffusion, η_s represents the spatial

neighborhood of pixel *i, j,* and $|\eta_s|$ is the number of neighbors (usually four except at the image boundaries). Perona and Malik linearly approximated the directional derivative in a particular direction as $\nabla g_{i,j} = g_{i+1,j} - g_{i,j}$ (for the east direction of the central pixel *i, j*). Modifying the image according to Eq. (2), which is a linear isotropic diffusion equation, is equivalent to filtering the image with a Gaussian filter. The parameters for the anisotropic diffusion filter used in this $\lambda = 0.25$, $\eta_s = 8$, and $K = 30$, which was used for the calculation of the edge stopping function $d(|\nabla g|)$, in Eq. (1.b).

Speckle-Reducing Anisotropic Diffusion Filtering

The essence of speckle-reducing anisotropic diffusion is the replacement of the gradient-based edge detector $cd(|\nabla g|)$ in an original anisotropic diffusion PDE with the instantaneous coefficient of variation that is suitable for speckle filtering $csrad(|\nabla g|)$. The speckle-reducing anisotropic diffusion filter uses two seemingly different methods, namely, the Lee and Frost diffusion filters. A more general updated function for the output image by extending the PDE versions of the despeckle filter is

$$f_{i,j} = g_{i,j} + \frac{1}{\eta_s} div\left(C_{srad}(|\nabla g|)\nabla g_{i,j}\right) \quad \dots 3$$

The diffusion coefficient for the speckle anisotropic diffusion $csrad(|\nabla g|)$ is derived [5] as

$$C_{srad}^2(|\nabla g|) = \frac{\frac{1}{2}|\nabla g_{i,j}|^2 \frac{1}{16}(\nabla^2 g_{i,j})^2}{(g_{i,j} + \frac{1}{4}\nabla^2 g_{i,j})^2} \quad \dots 4$$

It is required that $csrad(|\nabla g|) \geq 0$. The above instantaneous coefficient of variation combines a normalized gradient magnitude operator and a normalized Laplacian operator to act like an edge detector for speckle images. A high relative gradient magnitude and a low relative Laplacian indicate an edge. The *DsFsrad* filter utilizes speckle-reducing anisotropic diffusion after Eq. (2.b) with the diffusion coefficient $csrad(|\nabla g|)$ in Eq. (4).

PROPOSED ALGORITHM FOR DESPECKLE FILTER

STEP-1 Load the image for filtering.

STEP-2 Specify the original image to be filtered (*K*), the number of iterations (*n*), the time step (lambda), and the region of interest to be filtered (rect).

STEP-3 Transform the original image to double and normalize it to *fi, j* = (*fi, j* - min pixel value)/(max pixel value - min pixel value), where min pixel value and max pixel value represent the minimum and maximum pixel values in the image.

STEP-4 Starting from the left upper corner of the image, select a [3*3] pixel neighbourhood and compute a new grayscale value according to Eq.

$$f_{i,j} = g_{i,j} + \frac{1}{\eta_s} div\left(C_{srad}(|\nabla g|)\nabla g_{i,j}\right)$$

STEP-5 Assign the new grayscale value to the middle pixel in each window.

STEP-6 Repeat steps 4 and 5 for the whole image by sliding the moving window from left to right.

STEP-7 Repeat steps 4–6 for niter iterations.

STEP-8 Compute the image quality measurement parameter for the original and de-speckled images.

STEP-9 Display the original and despeckled images, the image quality measurement parameters.

EXPERIMENTAL ANALYSIS AND DISCUSSION

The proposed algorithms have been implemented using image processing tool box of MATLAB 7.0. The performance of various spatial enhancement approaches are analyzed and discussed. The measurement of image enhancement is difficult to measure. There is no common algorithm for the enhancement of the image. The statistical measurement could be used to measure enhancement of the image. The Mean Square Error (MSE), Peak Signal-to-Noise Ratio (PSNR) and correlation coefficient(β) are used to evaluate the enhancement performance . The noise level is measured by the standard deviation of the image:

$$\sigma = \sqrt{\frac{1}{N}\sum(bi - b)^2}$$

Where, i=1,2,3,…,N , b is the mean gray level value of the original image and bi is the gray level value of the surrounding region and N is the total number of pixel in the image.

TABLE I.   QUALITY MEASUREMENT PARAMETER

Statistical Measurement	Formula
MSE	$\dfrac{\sum f(i,j) - F(i,j))^2}{MN}$
PSNR	$20log_{10} \dfrac{255}{RMSE}$
CORRELATION COEFFICIANT (β)	$\dfrac{\sum (g-\bar{g})(\hat{g}-\bar{g})}{\sqrt{\sum(g-\bar{g})^2 \sum(\hat{g}-\bar{g})^2}}$

The parameters which are used in the filter performance appraisal are Mean Square Error (MSE), Peak Signal to Noise Ratio (PSNR). Where, f is the original image F is the filtered image and MN is the size of image. Where, g and Ùg are original and de-noised images respectively and g and Ùg are the mean's of the original image and de-noised image respectively.

MSE: is an estimator in many ways to quantify the amount by which an filtered/noisy image differs from noiseless image.

PSNR: is the ratio between possible power of a signal and the power of corrupting noise that affects the fidelity of its representation.

CORRELATION COEFFICIENT: Correlation indicates the strength and direction of linear relationship between two signals and its value lie between +1 to -1. The original ultrasound image and filtered images of the focal liver lesions obtained by various filtering techniques are shown in figure. If the value of MSE is low and the values of β is low and PSNR are larger than the enhancement approach is better.

The performance analysis of the proposed approaches and existing approaches with the regard to ultrasound medical images for focal liver lesions.

- After getting enhanced image, I have concerned Radiology doctor.
- As par doctor opinion this enhanced image is very Impressive and informative.

It should be more useful for radiologists to interpret images and arrive at a perfect diagnosis.

III. EXPERIMENTAL RESULTS

Result of De-speckle filter

Original   De-speckle
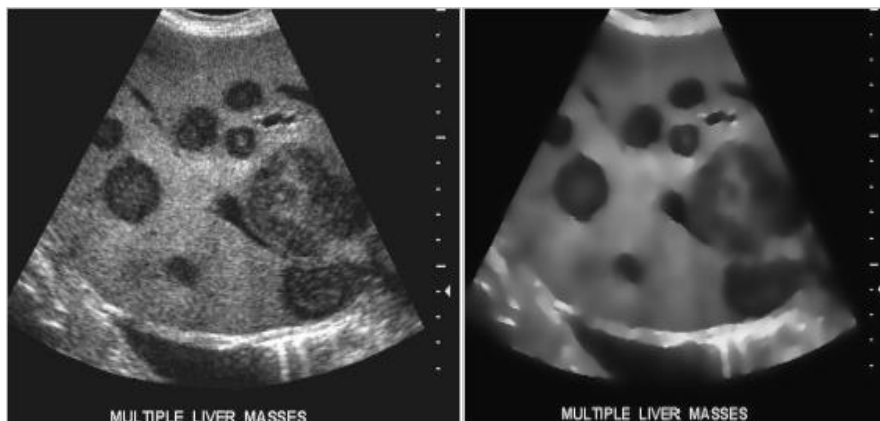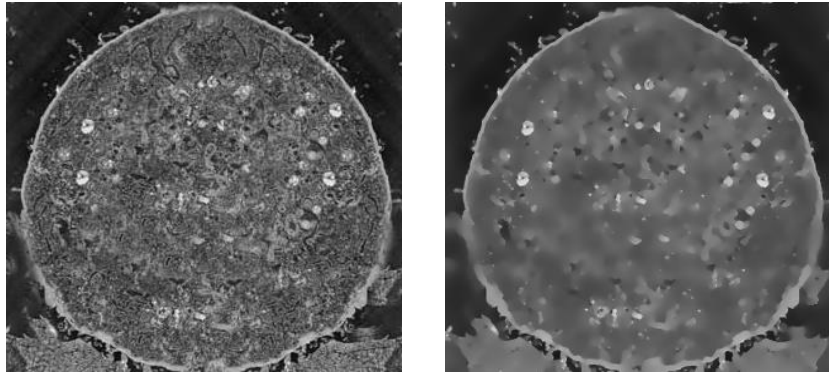Figure 3: Focal lever lesions

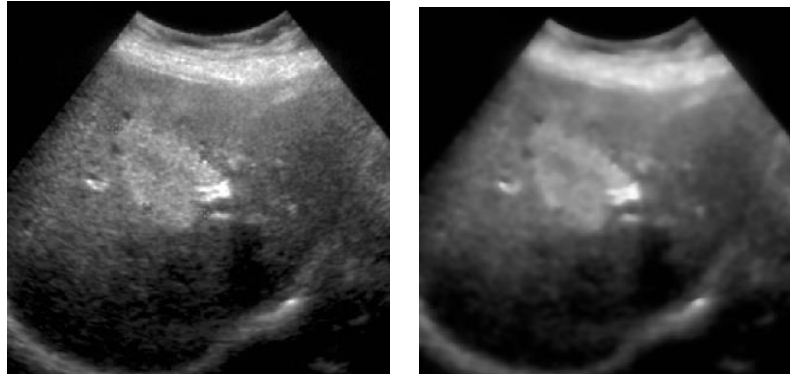Figure 4: Prostate cancer cell

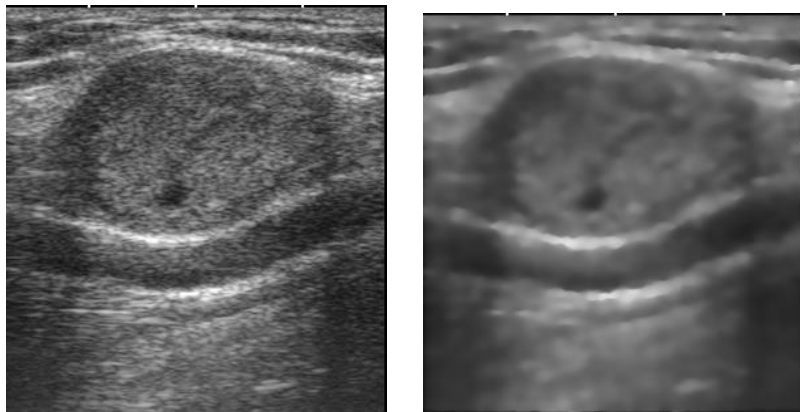Figure 5: Focal Hepatic Lesions
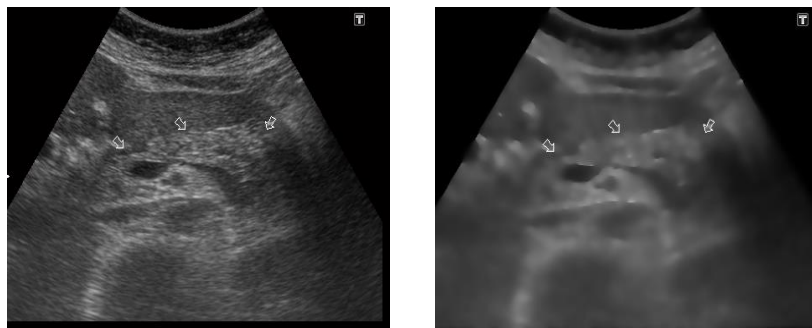

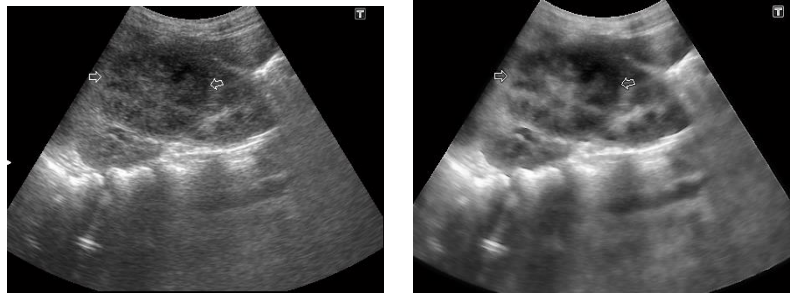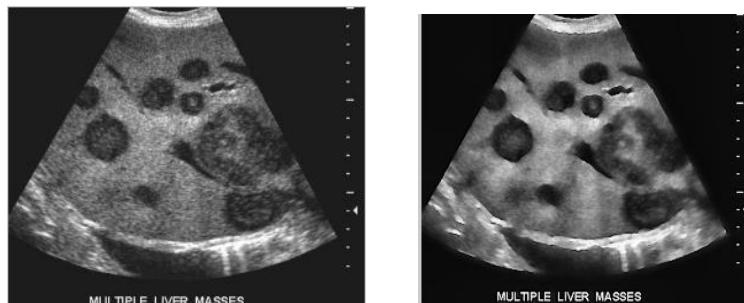Figure 6: Neurofibroma

Figure 7: Pancreas

Figure 8: Kidney

Figure 9: Abdomen

TABLE II.   QUALITY MEASUREMENT PARAMETER

Sr.no	Ultrasound Images	MSE	PSNR	COC
1	focal liver lesions	0.0024	74.27	0.96
2	Prostate cancer cell	0.0047	71.43	0.98
3	Focal Hepatic Lesions	6.41	80.05	0.99
4	Neurofibroma	0.0014	76.68	0.98
5	Pancreas	9.12	78.53	0.99
6	Kidney	9.66	78.28	0.99
7	Abdomen	0.0013	76.97	0.98

Result of Enhancement Process

Original   Enhanced

Figure 10: Focal lever lesions

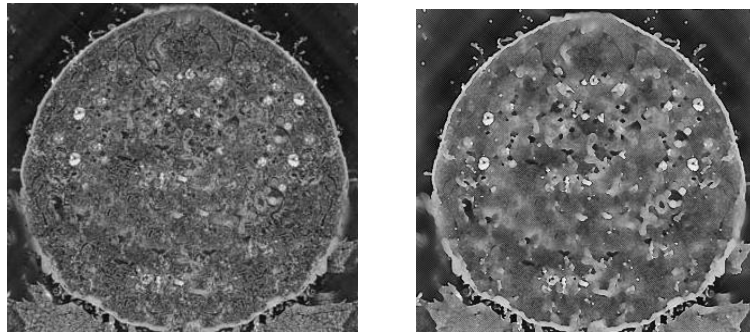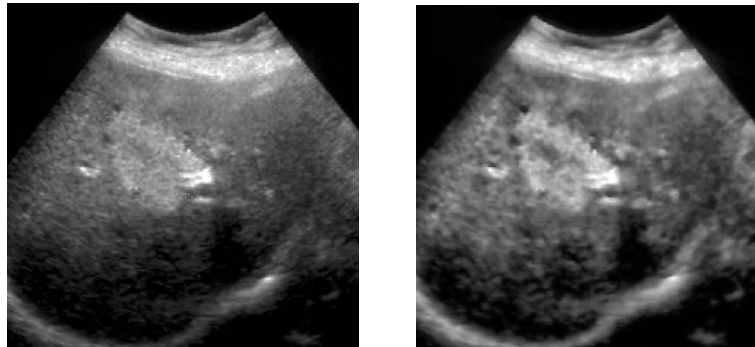Figure 11: Prostate cancer cell

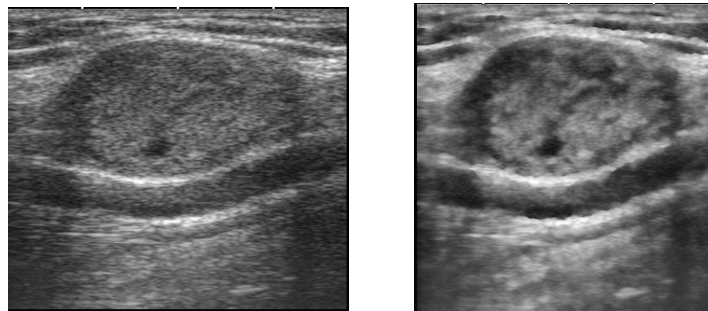Figure 12: Focal Hepatic Lesions
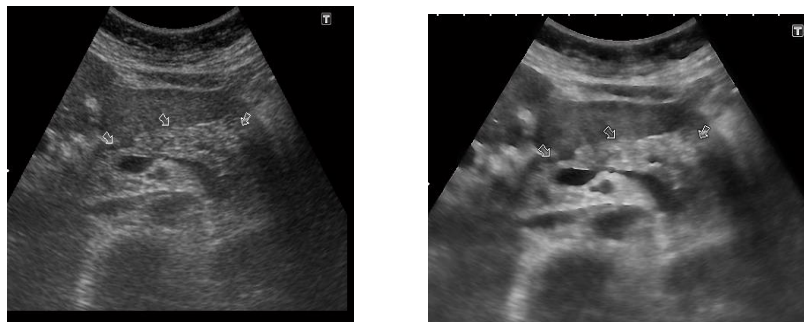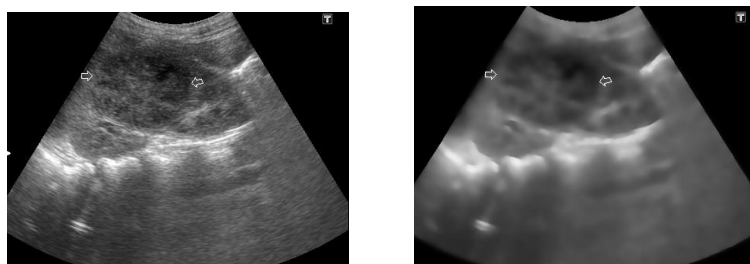

Figure 13: Neurofibroma
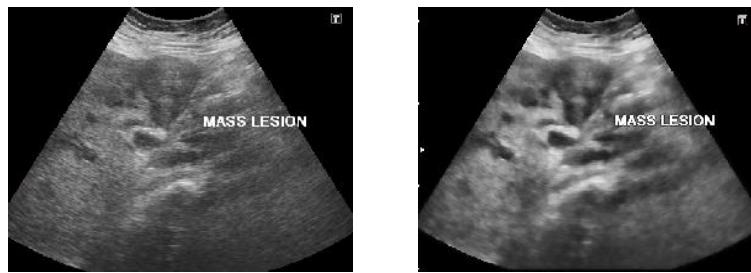

Figure 14: Pancreas

Figure 15: Kidney

Figure 16: Abdomen

TABLE III.   COMPUTATIONAL RESULTS OF ENHANCED IMAGES

Sr.no	Ultrasound Images	MSE	PSNR	COC
1	focal liver lesions	0.0043	71.79	0.99
2	Prostate cancer cell	0.0076	69.33	0.98
3	Focal Hepatic Lesions	0.0054	70.82	0.98
4	Neurofibroma	0.0022	74.75	0.99
5	Pancreas	0.0028	73.64	0.98
7	Kidney	0.0016	76.07	0.99
8	Abdomen	0.0019	75.45	0.99

The net result is an image in which small details were enhanced and the background tonality was perfectly preserved. Results like these have made Laplacian based enhancement a fundamental tool used frequently for sharpening Digital images.

IV. CONCLUSION

The performance of noise removing filtering techniques is measured using quantitative performance measures such as PSNR and MSE as well as in term of visual quality of the images. Many of the methods fail to remove speckle noise present in the ultrasound medical image, since the information about the variance of the noise may not be identified by the methods. The computational result showed one of the proposed filtering techniques.

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Cite this article as :