IETE 46th Mid Term Symposium "Impact of Technology on Skill Development" MTS- 2015
Special Issue of International Journal of Electronics, Communication & Soft Computing Science and Engineering, ISSN: 2277-9477

Performance Comparison of Speckle Reducing Filters for Ultrasonography (USG) Images of Thyroid Glands

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***Abstract*—Ultrasonography(USG) images help physicians to examine and detect the abnormalities in the thyroid glands like tumor or cysts. These images are often affected by the occurrence of speckle noise which makes the fine details of the image unclear and degrades the quality of the image obtained. Hence filtering the speckle noise becomes important in ultrasonography images. It is an essential step in the preprocessing of medical ultrasonography image. There are various techniques used for the removal of speckle noise. In this paper, a comparison of three techniques namely Frost filter, spatiotemporal filter and SRAD filter is done based on their performance in reducing the speckle noise from the USG images.Among these, SRAD filter gives better performance over the other two methods in terms of mean preservation, variance reduction and edge localization.**

***Keywords*—Mean Square Error(MSE), Peak Signal to Noise Ratio (PSNR), SRAD filter, USG image.**

I. INTRODUCTION

Thyroid gland is very thin and soft organ located in the front part of the neck that enhances human body's metabolism by producing hormones. Any abnormalities in thyroid glands causing many disorders are diagnosed by Ultrasonography (USG) images.

Ultrasonography images provide good means of disease diagnosis in thyroid glands as it is cost efficient, non-invasive,gives real-time images safe to human body and. It is important to make appropriate interpretation of thyroid data. Among the common steps of image processing algorithm such as image preprocessing, image segmentation, feature extraction, feature selection and classification, image preprocessing is done to reduce the noise in the image [1].

The speckle noise arises from the ultrasound scatterers in the ultrasound beam range. Ultrasonography examinations are sensitive to motion. There are two types of noises that affect the quality of an image: Additive noise and Multiplicative noise. Modeling of multiplicative noise is more difficult than that of additive noise. Multiplicative noise can be described mathematically as

$$u_0(x, y) = h_d(x, y) * f(x, y) + n(x, y) \quad (1)$$

Where f is ideal image u_0 is noisy image and n is the additive noise with mean 0 and variance σ^2. h_d is the point spread function (PSF). This speckle noise degrades the image quality due to locally correlated multiplicative noises from scatterers having wavelength smaller than ultrasound beam wavelength. The image denoising techniques have been used to minimize the effect of speckle noise and to retain the details of the image as much as possible [2].

Speckle noise is also known as texture in medical imaging literature. The performance of the texture feature is characterized by its roughness, directive and contrast gradient [3]. Thus there is a necessity to provide the filtering techniques that will allow the features of texture remain as they are [4].

Filtering of speckle noise is done by moving a kernel over each pixel of the image one at a time. The pixel values are then mathematically treated and each central pixel value is replaced with the new calculated value. The entire image is processed in this way to reduce the speckle noise [4].

Earlier several techniques have been introduced to reduce the speckle noise and thereby increasing the texture of the ultrasonography images. But some of these methods require no change or motion of the object under observation.

In earlier times, grey-level histograms were used to analyze and reduce the speckle noise in the USG images of thyroid gland [5].In [3], co-occurrence matrix of greyscale images is calculated to minimize speckle noise and retain the details of the image. The mean filter and Adaptive Mean filter are the forms of linear filters used in spatial domain for the minimization of speckle noise in USG images. The mean filtering is done by averaging the speckles into the data with loss of detail and resolution as its drawback. The Adaptive Mean filter reduces the effect of blurring in the image [6]. The Adaptive Mean filter proves to be effective in terms of detecting and preserving edges and features.

Non-linear filters such as Median filter, Homomorphic filter [11] and Diffusion filter have been previously used to reduce the speckle noise in the USG images. The Median filter takes the median of the greyscale levels and replaces original grey level by the median value. Homomorphic filter allows the conversion of multiplicative noise to the additive noise and becomes useful for the purpose of image enhancement and image restoration. The Diffusion filter uses Partial Differential Equation (PDE) and reduces the speckle noise with the advantage of edge enhancement. Hence this filter controls the image features using an edge detection function [7].

For solving the problems occurring in Adaptive filtering method a Fuzzy Edge Detection method has been used on the grey-levels of an image. It provides the advantage of edge detection and enhancement [9]. This paper is organized into seven sections which involve the introduction of ultrasonography (USG) images and previously used speckle noise reducing techniques, sections for each of the three filters namely Frost filter, Spatiotemporal filter and SRAD filter, their experimental results and discussion and conclusion.

Journal Impact Factor-2.02
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II. Frost Filter

The Frost filter is a form of an adaptive and exponentially weighted averaging filter [8]. It subtracts the mean of an image from the original image so that the smoothening of the image will be performed to reduce the blurring in the ultrasonography (USG) image of thyroid gland. The filter proves itself to be useful by restoring the information content in the edges of an image. This filter forms an exponentially shaped filter kernel that achieves a balance between the averaging and the all-pass filter. It varies from an averaging filter to an identity filter on a pointwise and adaptive basis.

The response of the filter varies locally with the coefficient of variation. When the low coefficient of variation is discovered, filter behaves as averaging filter. When the high coefficients of variation are discovered, the filter no more behaves like an averaging filter and attempts to preserve the edges of an image. An exponentially damped convolution kernel is used by the Frost filter. This kernel exploits the local statistics of the USG image and adapts to the regions containing edges in the image. The output of the Frost filter isdetermined by

$$I_s = \sum (mp \cdot Ip) \qquad (2)$$

Where

$$mp = \exp[-k * C_s^{\,2} * ds, p] / \sum [\exp(-k * C_s^{\,2} * ds, p)]$$

$$ds, p = sqrt[(i - i_p)^2 + (j - j_p)^2]$$

Here, k is the damping factor

(i, j) are the grid co-ordinates of pixel s and

(i_p, j_p) are the grid co-ordinates of pixel p

The factor k required to calculate the kernel in"(1)" is chosen deliberately. So that in homogenous region when the value of $k * C_s^{\,2}$ approaches zero, it derives the output of the Mean filter. While at the edges of an image, the value of $k * C_s^{\,2}$ becomes so large that the filtering process slows down completely which allows the filter to preserve the edges of an USG image.

The algorithm for the Frost filter can be written as:

1. Read the Ultrasonography image of thyroid gland.
2. Store it in the form of an array so that the mean of thatimage can be computed.
3. Calculate mean of the specified array.
4. Subtract the computed mean from the original image.
5. The smoothed image will be the result of subtraction.
6. For smoothening of each pixel the above steps are performed in the loop, so the entire image is filtered.

The smoothening of the image is symmetric and balanced at the edges of an image. Also it becomes difficult to decide the smoothening parameter. Due these drawbacks the use of Frost filter in Ultrasonography(USG) images is limited.

III. Spatiotemporal Filter

The spatiotemporal image filtering is the combination of two steps: Temporal processing and spatial processing.The temporal processing of an image is based on the Wavelet transform which has the ability to enhance the image contrast. This step of filtering is linear filtering. The spatial signal processing is the form of non-linear filtering. The behavior of the same pixel is analyzed in space. There is a specific relation between the neighboring pixels using which the spatial signals are processed [2].

The Discrete Wavelet Transform is used for temporal filtering of USG image. The USG image is decomposed into different levels by using DWT which gives a unique and non-redundant representation of the image. The image is decomposed into approximation component and details. The second component contains the horizontal, vertical and diagonal details of an image. The Approximation and details components are obtained by applying a low-pass filter and a high-pass filter respectively. Spatial filtering is done using anisotropic diffusion on the pre-filtered image. It enhances the image by solving a Partial Differential Equation.

$$\frac{\partial I}{\partial t} = f(I, \nabla I, \nabla^2 I, D) \quad (3)$$

Where, I is the original USG image,

$f(.)$ is the scalar function of the data and

D is the diffusion coefficient[10].

The algorithm for spatiotemporal filtering consists of following steps:

1. Calculate the DWT of the original image.
2. Calculate the wavelet coefficients for thresholding.
3. Evaluate the inverse DWT to get the denoised image.

The noise level in the resultant image depends upon the threshold value. The threshold value should be moderate. If it is too small the image remains noisy. On the other hand if it is large then it may destroy the image details making the image blur.

IV. Speckle Reducing Anisotropic Diffusion (SRAD) Filter

The Speckle Reducing Anisotropic Diffusion(SRAD) filter provides the balance between speckle reduction and feature preservation. This method employs Partial Differential Equation(PDE) and allows the generation of image scale space. Image scale space is a set of filtered images varying from fine to coarse. SRAD filter slows down diffusion across edges and allows diffusion on the either side of the edge. In this way, it not only preserves edges but also enhances edges[7]. The non-linear Partial Differential Equation(PDE) for SRAD filter can be given as

$$\left.\begin{aligned} \frac{\partial I}{\partial t} &= \partial iv[c(|\nabla I|) \cdot \nabla I \\ I(t=0) &= I_0 \end{aligned}\right\} \quad (4)$$

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Where $c(|\nabla I|)$ is the diffusion coefficient and
I_0 is the original image[7].
There are two diffusion coefficients

$$C(x) = \frac{1}{1+(x/k)^2}$$

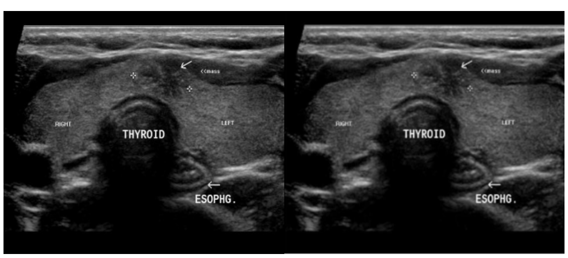
And $$C(x) = \exp[-(x/k)^2]$$

Where k is the edge magnitude parameter.

If $|\nabla I| >> k$ then $C(|\nabla I|) \rightarrow 0$ which gives all pass filter and if $\nabla I << k$ then $C(|\nabla I|) \rightarrow 1$ which gives Gaussian filtering that is anisotropic diffusion[13]. As the gradient strength increases, diffusion coefficient decreases. Speckle Reducing Anisotropic Diffusion (SRAD) filter shows better performance for additive kind of noise. At the region of edges or on high contrast fields in the image, this function gives high values while in other regions it produceslow values. The SRAD filter has the speckle scale function which helps in the smoothening of the image. It shows an adaptive behavior like mean preserving behavior in homogenous fields and edge preserving behavior in the region of edges. In order to modify the performance in homogenous regions and in the fields near the edges and detail features, this filter does not need to have a specific threshold value [13].

V. Experimental Results And Discussion

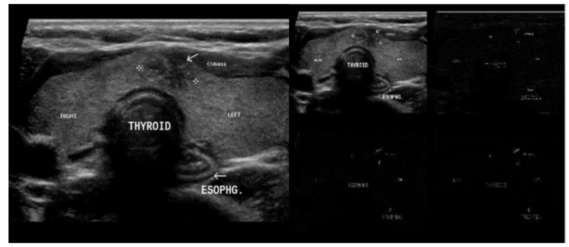
The Ultrasonography (USG) image of the thyroid gland is taken as a test image. The test image is contaminated with the speckle noise. The effectiveness of the three filters namely Frost filter, Spatiotemporal filter and the Speckle Reducing Anisotropic Diffusion (SRAD) filter is compared from their output. Simulation of each filter is carried out using MATLAB.



(a) (b)

Fig. 1 (a) Original Ultrasonography image of a thyroid gland with speckle noise and (b) Output of Frost filter

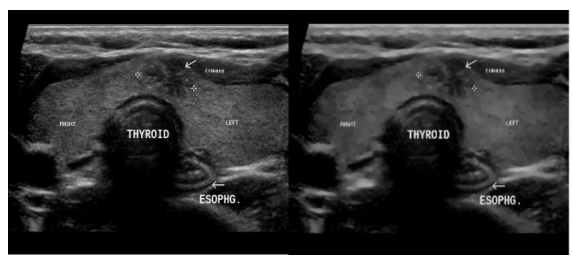
The Frost filter output of is shown in Fig. 1. It is a kind of median filter and gives output better than mean filter. Fig. 2 shows the results obtained from the spatiotemporal filtering. First, the speckle corrupted USG image is decomposed into four components as approximation, horizontal, vertical and diagonal components and then by applying Inverse Discrete Wavelet Transform (IDWT) and diffusion filtering the despeckled image is obtained at output. Fig. 3 shows the output image obtained from the SRAD filter.



(a) *(b)*

(c)

Fig. 2 (a)Original Ultrasonography(USG) image of a thyroid glandwith speckle noise (b) Discrete Wavelet Transformed image and (c) Image obtained after taking IDWT and diffusion in spatiotemporal filtering



(a) (b)

Fig. 3 (a)Original Ultrasonography(USG) image of a thyroid gland with speckle noise and (b) Output of Speckle Reducing Anisotropic Diffusion(SRAD) filter

VI. Performance Parameters

The performance of three filters can be effectively compared based on the performance parameters Mean Square Error(MSE) and Peak Signal to Noise Ratio (PSNR). MSE is calculated as the mean square error of the corresponding pixel in the input image and the image obtained after despeckling. PSNR value should be higher for the despeckled USG image.

$$MSE = \sum \frac{(F_i - D_i)^2}{MN} \quad (5)$$

$$PSNR = 20\log_{10}\left(\frac{255}{\sqrt{MSE}}\right) \quad (6)$$

Where, MN is the number of pixels in USG image
F_i is the threshold value of the original image
D_i is the threshold value of the image obtained after removing speckle [12].
The table below shows the comparison of the three techniques.

TABLE I
PERFORMANCE COMPARISON OF VARIOUS FILTERS

Filter	Mean Square Error (MSE)	Peak Signal to Noise Ratio (PSNR)
Frost	1.0992e-009	137.7542
Spatiotemporal filter	4.3967e-007	111.7336
Speckle Reducing Anisotropic Diffusion (SRAD) filter	2.7479e-010	143.7748

It can be seen that SRAD filter removes speckle from the USG image substantially. From the results it is observed that SRAD gives the best performance with minimum MSE and maximum PSNR values.

CONCLUSION

The Ultrasonography (USG) image of a thyroid gland frequently gets corrupted by the speckles which may arise due to motion. It is a multiplicative noise and has granular nature. Speckle in the original image should be suppresed while retaining the details of the image as much as possible. Speckle Reducing Anisotropic Diffusion (SRAD) filter gives better performance over the other two filtering techniques. The Mean Square Error of the SRAD filter is very less as compared to the other two filters. Hence it can be chosen as the preprocessing filter for the Ultrasonography(USG) images of thyroid glands. Smoothening of the mage is carried out by increasing the number of iterations.

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