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Segmentation of Abnormality in Ultrasound Images using Active Contour Segmentation

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Abstract: Ultrasound imaging is a widely used imaging modality for diagnostic purposes, due to its many advantages. However, the usefulness of Ultrasound imaging is degraded by the presence of signal dependent noise known as speckle. This paper proposes a model to segment the abnormality present in the Ultrasound image such as tumor or the lesion or the calculi. First an SRAD (Speckle Reducing Anisotropic Diffusion) filter is applied to the Ultrasound image to reduce the Speckle noise. This is followed by segmenting the abnormality by using active contour approach. Three methods of active contour segmentation are used. First, an edge based active contour called Geodesic active contour is applied. Next, the region based methods which are Chan Vese active contour model and a modified version of Chan Vese method are applied. The algorithm is used to segment different types of abnormality in images of different parts of the body like liver, pancreas, kidneys, breast, prostate and uterus. Segmentation results are compared and visually it can be observed that modified Chan Vese active contour method works better than Geodesic and Chan Vese method in segmenting the abnormality.

Keywords: Ultrasound images, Speckle noise, active contour segmentation, abnormality.

I. INTRODUCTION

The use of Ultrasound imaging for diagnostic applications in the field of medicine has many advantages. It is completely safe, has lower cost for imaging, is non – invasive and the image can be viewed in real – time [1]. The Ultrasound machine is portable and hence it can be even taken to rural areas where the medical facilities might not be good. Since the Ultrasound imaging is cheaper it can be afforded by the poor people too. Due to these advantages disease diagnosis from Ultrasound images has lot of importance. Segmentation of the abnormality from Ultrasound images helps in diagnosis but these images have low level of contrast and the presence of Speckle noise in these images poses a unique challenge. To relieve humans from tedious handwork, computer-aided and reliable segmentation methods play an important role. Traditional image segmentation methods may not give good results due to the disadvantages of Ultrasound imaging mentioned above. Advanced segmentation methods are required for Ultrasound. One such segmentation technique is active contour method.

II. SPECKLE NOISE

Speckle noise is a form of multiplicative noise that is inherently present in Ultrasound images. Speckle is seen as a granular structure in these images. Speckle is formed by constructive and destructive coherent interferences of the Ultrasound waves that are scattered back from the tissue to be imaged. The nature of Speckle noise depends on the properties of the tissue to be imaged and also the various imaging parameters .It degrades the image quality to a great level and also reduces the contrast. Due to this noise, diagnosis using the Ultrasound image becomes tedious. The Speckle noise has to be reduced through processing without affecting important features of the image [2]. This will facilitate human interpretation of the image and is also a pre processing step for image processing operations like segmentation. There are certain guidelines while reducing noise through filtering in medical images, they are: important information like the object boundaries, details of structures should not be lost, noise has to be efficiently removed in homogeneous regions and finally the morphological definition has to be enhanced by sharpening discontinuities.

Fig 1 Lena image degraded by Speckle noise

III. THE SPECKLE REDUCING ANISOTROPIC DIFFUSION (SRAD) FILTER [3]

The Speckle Reducing Anisotropic Diffusion (SRAD) filter meets the requirements needed for noise filtering in medical images. It has a feature of improving the image quality significantly while it preserves the important boundary information and hence, in this study, SRAD filter is used.SRAD filter uses partial differential equation (PDE) approach for speckle removal. SRAD has the characteristic of not only preserving the edges but also enhancing them by inhibiting diffusion across edges and allowing diffusion on either side of the edge. SRAD is an adaptive filter and does not utilize hard thresholds to alter performance in homogeneous regions or in regions near

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edges and small features. The new diffusion technique works on the basis of minimum mean square error (MMSE) approach of filtering.

Given an intensity image $I_0(x,y)$ having finite power, the output image $I(x,y;t)$ is evolved according to the following PDE

$$\frac{\partial I(x,y;t)}{\partial t} = \mathrm{div}[c(q)\nabla I(x,y;t)]$$

Where, div is the divergence and r is gradient operator. The variables (x; y; t) indicate the pixel location at time t and I_0 are the initial image. Diffusion coefficient c (q) is defined as

$$c(q) = 1/[1 + (q^2(x,y;t) - q_0^2(t))/(q_0^2(t)(1+q_0^2(t)))]$$

In the above equation $q(x,y;t)$ is the instantaneous coefficient of variation determined by

$$q(x,y;t) = \sqrt{(\tfrac{1}{2})(|\nabla I|/I)^2 - (1/16)(\nabla^2 I/I)^2} \ / \ [1 + \left(\tfrac{1}{4}\right)(\nabla^2 I/I)]^2$$

In the above equation $q_0(t)$ is the speckle scale function. The instantaneous coefficient of variation $q(x,y;t)$ is the edge detector in the image with speckle noise. This function gives high values at edges or on high-contrast features and gives low value in homogeneous regions. The speckle scale function controls the amount of smoothing that is applied to the image by SRAD filter. It is estimated using

$$q_0(t) = \frac{\sqrt{\mathrm{var}(z(t))}}{\mathrm{mean}\,(z(t))}$$

Where $\mathrm{var}(z(t))$ and $\mathrm{mean}\,(z(t))$ are the intensity variance and mean over a homogeneous area at t respectively.

IV. ACTIVE CONTOUR SEGMENTATION

Active contours are used for image segmentation. This segmentation technique is able to segment objects from a noisy image. It was first introduced by Kass et al and was called Snakes [4]. In active contour segmentation technique we start with a closed curve or a contour and this contour is iteratively modified such that it shrinks to the shape of the object to be detected. The operations performed to modify the contour are called contour evolution. They are performed by minimization of an energy function .The energy functional is designed such that its minimum is obtained at the boundary of the object to be segmented.

A. Geodesic active contour segmentation [5]

The geodesic active contour model was introduced by Caselles et al .This approach of active contour implementation for object segmentation uses principles of energy minimization and theory of curve evolution. This is an edge based segmentation model. The edge detection model is derived from classical active contour model. The evolution equation for a curve 'C'is implemented using level set approach. In Level set approach the curve 'C' is implicitly represented via a function $'\varphi'$. The level set evolution equation for geodesic active contour model is given as

$$\frac{\partial\varphi}{\partial t} = K\, g(I)|\nabla\varphi| + \nabla\varphi\, \nabla g(I)$$

Where,

$$K = div(\frac{\nabla\varphi}{|\nabla\varphi|})$$

$g(I)$ is the edge detector function given by

$$g(I) = (\frac{1}{1+|\nabla I|^2})$$

div is the divergence operator and ∇ is the gradient operator

B. Chan Vese active contour segmentation [6]

An active contour model using the Mumford – Shah segmentation model was proposed by Chan and Vese and is named Chan – Vese active contour model. This method deforms the contours by using the energy minimization technique. It does not search for edges. This model can detect objects whose boundaries are not necessarily defined by gradients. Hence the Chan – Vese active contour model works well on noisy and blurred images.

The level set implementation of the model is given as follows

Assume that 'I' is a given image. The curve 'C' is represented implicitly via function φ, by

$$C = \{(x,y)|\varphi(x,y) = 0\}$$

Where φ is the level set function. Representing the curve in terms of level set function has many numerical advantages.

Chan and Vese deduced the associated Euler-Lagrange equation for φ given by

$$\frac{\partial\varphi}{\partial t} = \delta(\varphi)[\mu\, \mathrm{div}\frac{\nabla\varphi}{|\nabla\varphi|} - \vartheta - \lambda_1(I - c_1)^2 + \lambda_2(I - c_2)^2\ ]$$

The above is the evolution equation for Chan Vese model

Where $c_1 = \frac{\int I\, H(\varphi)dx}{\int H(\varphi)dx}$, $c_2 = \frac{\int I\,(1 - H(\varphi))dx}{\int (1-H(\varphi))dx}$

$\mu \geq 0,\ \vartheta \geq 0,\ \lambda_1,\ \lambda_2 > 0$ are fixed parameters

$\delta(.)$ is the diarc function

$H(.)$ is the Heaviside function

C. Modified chan vese method

The Chan - Vese model works well in the presence of noise and also for segmentation of objects with degraded edges. However it still has some disadvantages. Firstly, Chan - Vese model works well for images with homogeneous intensity and gives poor results of segmentation in the case of images with inhomogeneous intensity. Secondly, the segmentation of this model depends on placement of initial contour due to which different segmentation results are obtained in the same image when different initial contours are used. Thirdly, this model may require large number of iterations to obtain a steady state value of the level set function [7]. To overcome the disadvantages of Chan – Vese model and to get the full benefits of this model when applied to

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ultrasound image a modified Chan – Vese method is proposed. The evolution equation for the proposed modified Chan – Vese model is

$$\frac{\partial\varphi}{\partial t} = \mu\left(I - \frac{c1+c2}{2}\right) + \vartheta\left(\ddot{I} - S\right)^{-1}\delta(\varphi)\mathrm{div}(\nabla I) + \lambda\delta(\varphi)\mathrm{div}(D\,\nabla\, I)$$

Where $c_1 = \frac{\int I\,H(\varphi)dx}{\int H(\varphi)dx}$, $c_2 = \frac{\int I\,(1-H(\varphi))dx}{\int (1-H(\varphi))dx}$

$(\ddot{I} - S)^{-1}$ is the Sobolev gradient term where $\ddot{I}$ is identity matrix

μ , ϑ , λ are constant parameters

$\delta(.)$ is the diarc function

$H(.)$ is the Heaviside function

V. RESULTS AND DISCUSSION

The algorithm is implemented using MATLAB R2013b tool. The test Ultrasound images required to implement this algorithm is obtained from www.ultrasound-images.com and www.sonoworld.com . The images are of JPEG format .Types of images on which the algorithm is tested are images of different parts of the body like liver , kidney , pancreas , prostrate , breast ,uterus each having abnormality The algorithm was tested on Ultrasound images of specifications mentioned above. First an SRAD filter is applied on the images to remove Speckle noise. Partial differential equation approach is employed for SRAD filter implementation. For segmentation of abnormality active contour approach is used. The types of method used are Geodesic active contour method, Chan Vese active contour method and modified Chan Vese method. The Level set mathematical tool is used to implement the active contour method.

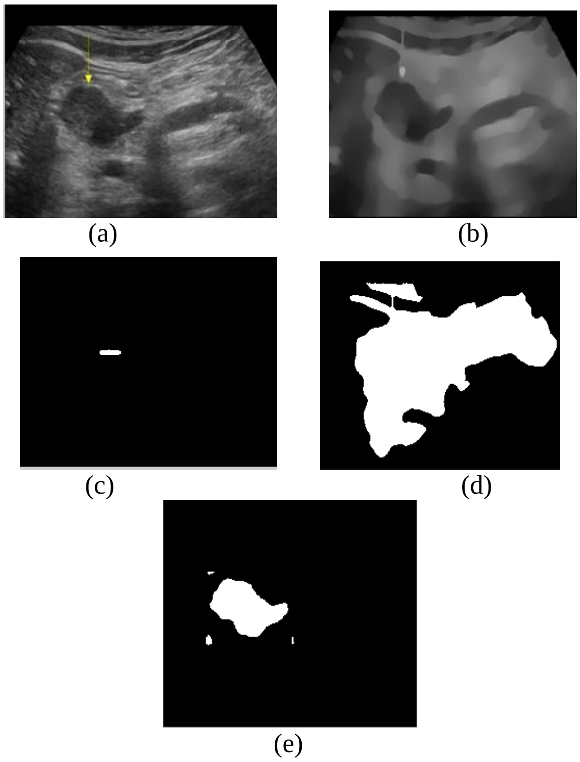

Fig 3: (a) Original image of pancreas showing tumour (b) Output of SRAD filter (c) Result of Geodesic active contour (d) Result of Chan Vese active contour (e) Result of modified Chan Vese active contour

Few of the results are shown below:

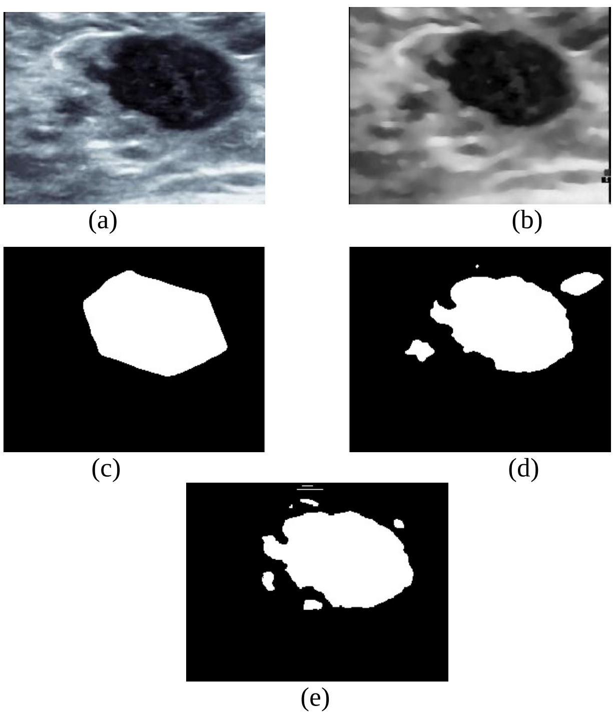

Fig 2: (a) Original image of breast showing malignant tumour (b) Output of SRAD filter (c) Result of Geodesic active contour (d) Result of Chan Vese active contour (e) Result of modified Chan Vese active contour

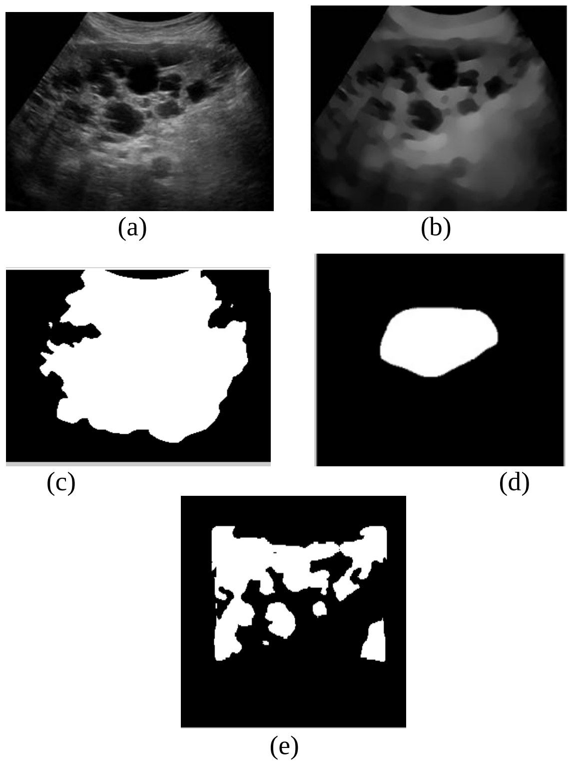

Fig 4: (a) Original image of liver showing multiple cysts (b) Output of SRAD filter (c) Result of Geodesic active contour (d) Result of Chan Vese active contour (e) Result of modified Chan Vese active contour

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VI. CONCLUSION

In this paper, a generalized algorithm to segment the abnormality present in Ultrasound images through active contour segmentation was presented. First the Speckle was removed by applying Speckle Reducing Anisotropic Diffusion Filter. This filter is specially designed for Speckle noise removal. The filter successfully removed the Speckle noise. The abnormality was segmented from the filtered image. Three methods were used for segmentation. The Geodesic active contour , the Chan-Vese active contour and the modified Chan Vese active contour segmentation. Visually it is found that modified Chan – Vese segmentation has superior performance in segmenting the abnormality. This method gives good results even in images where the edges are degraded and the abnormality is having low contrast compared to the background. The Geodesic active contour is not able to segment the abnormality since this active contour method is Edge based segmentation method and in Ultrasound images the edges of the abnormality may not be well defined. The Chan – Vese method is able to segment the abnormality since it can segment objects that are not necessarily defined by gradients. Modified Chan – Vese method is successful in overcoming the drawbacks of Chan -Vese method.

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BIOGRAPHY

Jean Magdalene Rodrigues has received B.E in Instrumentation Engineering from Visvevaraya Technological University in 2008 and is currently pursuing Masters degree in Electronics Engineering from Fr. Conceicao Rodrigues College of Engineering, Bandra, Mumbai. She has teaching experience of three years in Instrumentation department GSSSIETW, Mysore. Her areas of interests are digital image processing, medical imaging, biomedical instrumentation and Automation.

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