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A Novel Approach for Thyroid Segmentation of Ultrasound Images Based on Neural Networks

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Abstract: Ultrasound is most widely used modality among CT, MRI, OCT etc in medical field due to its various advantages like free of ionization radiations, non-invasiveness, immediate response, painless etc. Thyroid gland is made up of two cone lobes, located below the adam's apple & it is butterfly shaped organ which belongs to the endocrine system. Unusual variations in size of thyroid gland cause some nodules or disorders over thyroid. This paper contains the automatic as well as appropriate segmentation of thyroid gland from dataset of US images by using different techniques like BPDFHE for enhancement of images, DCT for extraction of relevant features and Feed Forward Neural Network to segment the thyroid region. Evaluation of results is done on the basis of certain parameters like Sensitivity, Accuracy, F-Measure & FN rate. Experimental results reveal that the proposed system is more efficient and provides better performance.

Keywords: Feature Extraction, Feed Forward Neural Network, Image Enhancement, Image processing, Segmentation, Thyroid Gland, Ultrasound Imaging.

I. INTRODUCTION

Image processing may be defined as a wide area in which there is an input and output which plays vital role for further processing. Input may be an image like photograph or a video frame and on the other side output may be an image or set of parameters or factors linked to that image. Image processing further involves medical image processing as its one of the associated area. In today's world, medical image processing vastly plays an important role in our daily life to diagnose the human diseases like in hospitals, clinics etc. because manual diagnosis becomes an issue which consumes lot of time as well as more laborious comparative to automatic diagnosis.

Ultrasound is one of the best diagnosis techniques among MRI, CT scans, X-rays, OCT etc. because of its properties like non-invasiveness, inexpensive, painless, immediate, short acquisition times, free of harmful ionizing radiations, able to recognize even soft tissues as well as more flexible comparative to other modalities [1]. Ultrasound imaging is used for automatic diagnose of various diseases like carotid artery , breast tumors, stones in kidney, broken bones, thyroid gland etc. Also various techniques have been developed for advancements in Ultrasound imaging. But there is an issue with ultrasound images that they contain speckle noise. Result of inherent nature of US images is speckle which causes adverse effect during diagnosis & image interpretation [2].

In order to remove speckle from US images researchers have implemented various algorithms. Han Y. et al. [3] proposed a variational model by using nonconvex sparse regularizer for removal of speckle noise. In order to resolve an issue related to nonconvexity they established augmented Lagrange multiplier method as well as the iteratively reweighted method. Results show that proposed method outer-performs than classical TV regularizer based methods. Zhan Y. et al. [4] proposed a nonlocal means method with weight refining. For weight refining they used PCA (Principal Component Analysis) to maximize accuracy and minimize complexity. Abrahim B.A. & Kadah Y. [5] proposed a method that combines total variation method & wavelet shrinkage .They divided an image into various bands, TV method works for bands which possess low frequency noise whereas which possess large frequency noise wavelet shrinkage method have been used. Results show that proposed method outer-performs than mean, median, variance local statistics, anisotropic diffusion filter & geometric. Rahman M.M. et al [6] proposed a speckle denoising method by using PCA with bit plane slicing & non-linear diffusion. They applied PCA for creating de-corelated dataset then bit plane slicing gets applied on that dataset, further non-linear diffusion is used for each bit plane level. Then they implemented inverse PCA for denoising images and result gets improved in terms of quality & visibility.

Thyroid gland is one of endocrine organs of human body and to be found in neck immediately under the adam's apple (thyroid cartilage) & cricoid cartilage. Its normal weight is 15-20 grams approximately but its size varies according to each individual's size and quantity of iodine intake .Basically it is composed of two cone lobes [2] called as right and left lobe & lies on either side of trachea or windpipe. These two lobes are connected to one another with the help of thin strip of thyroid tissue known as isthmus. Thyroid gland helps to control the secretion of thyroid hormone & influence the childhood growth and adult metabolism [1]. Thyroid nodules are abnormalities/disorders in thyroid gland due to unexpected variations in size of thyroid tissues. Thyroid nodules can be felt as lumps in throat or in front of the neck. Thyroid nodules can also be known as cystic or solid lumps in thyroid gland and it may be either benign or malignant (cancerous) [7]. But only small quantity of thyroid nodules can cause thyroid cancer.

Thyroid nodules can get detected automatically by using various segmenting methods which involves neural networks, Active contour models, Genetic algorithms and various other computer aided techniques. Garg H. & Jindal A. [2] proposed Feed-Forward Neural Network for segmenting the thyroid region in US images. For the purpose of segmentation of US images, intensity of pixels and texture is taken as criteria and it is a hybrid approach. First they have done image enhancement in order to remove the speckle noise. Afterwards various required features get extracted to estimate the texture & to train the neural network. Then authors implemented Feed-Forward Neural Network and results reveal that this method is efficient enough comparative to other methods. Keramidas E.G.et al. [8] proposed a computer aided method named TND (Thyroid Nodule Detector).This proposed method includes four components that consider novel contributions like TBD-2 algorithm includes thyroid parenchyma for automatic definition of ROI and integration of FLBP & FGLH. They investigated the feasibility of proposed method on real US images. Results reveal that combination of FLBP & FGLH is more effective & also TND system can get applied clinically. Accuracy in thyroid nodule detection has been estimated to exceed 95%. Maroulis D.E. et al. [9] proposed VBAC to delineate thyroid nodules. They incorporates the benefits of ACWE with VBAC & unlike classic active contour models which are sensitive in case of intensity inhomogeneities, this proposed model also involves the variable background regions. Then, they evaluated VBAC & compared with ACWE. Results reveal that VBAC has better performance than ACWE in case of inhomogeneity. VBAC converged in 9.6% less iterations than ACWE & execution time is also faster by 8.2%,as average segmentation time is 1min 33s for VBAC whereas for ACWE it is 1min 41 s. Lakovidis D. K. et al. [10] proposed a method to segment the US images for accurate delineations of thyroid nodules. They proposed a method named GA-VBAC i.e. a combination of GA (Genetic Algorithm) & VBAC (Variable Background Active Contour model). Experimental results show that GA-VBAC is an efficient & effective system for delineation of thyroid in US images. As GA-VBAC obtained average overlap value 92.5% whereas experts obtained 91.8%, so it is clear that GA-VBAC is capable to obtain high delineation accuracy comparatively. Huang J.-Y. et al. [11] proposed a method for planer scintigraphy (PS) image named fully automated thyroid volume estimation system. This consists of four steps involves preprocessing, enhancement of an image contrast, image segmentation and to get automated ROI. They set main focus to achieve maximum area or height of each thyroid lobe & then they have calculated thyroid volume by using Himanka– Larsson′s formula or Allen–Goodwin′s formula. They adopted US as standard reference then co-related its results with proposed approach and performed statistical analysis with precision, bias & relative differences. Results reveal good co-relation as well as best precision, bias & relative differences between US results & proposed method.

In this paper we apply Feed Forward Neural Network for segmentation of thyroid gland. Various steps are there for accurate and automatic segmentation of thyroid nodule which will get discussed further. The remaining paper is organized as follows. Section II involves thyroid nodule segmentation with its initialization steps. Section III provides the experimental results and comparative analysis. Section IV contains the conclusion & future scope of the paper.

II. THYROID SEGMENTATION

Segmentation of an image may be defined as interpretation of an image, if image has been enhanced properly after removing noise etc (Ultrasound images contain speckle noise) or it is the process of assembling the features /regions mutually that contributes identical characteristics. Various image segmentation methods are efficient graph based segmentation [12], hybrid segmentation [12], ACM's (Active Contour Models), Watershed, clustering methods & Neural Networks etc [2]. Among all these neural networks provide better results. Following figure shows the sequence of proposed method.

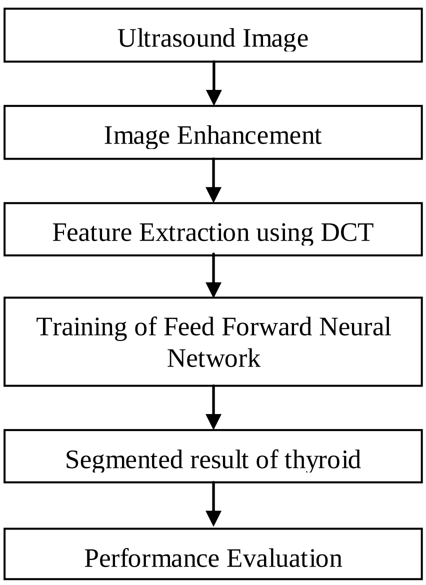


Figure 1. Steps for segmentation of thyroid

Following are the steps of proposed method for automatic segmentation of thyroid gland:

1. Data collection
2. Pre-processing

3. Feature Extraction
4. Training Phase
5. Segmentation of thyroid gland.

1) Data Collection: In thyroid US images, thyroid gland lies between dark & bright part of an image [2]. Dataset of US images get collected from hospital & Internet. Segmentation of both outlined as well as non-outlined US images has been performed. Sample of US images is given in table 1.

Table I Ultrasound Dataset

Ultrasound Dataset	
	

2) Pre-processing: Pre-processing involves following two steps:-

a) Image Enhancement
b) Morphological operations

a) Image Enhancement: As ultrasound images contain speckle noise in addition to grain noise [2]. Before proceeding further it is necessary to enhance an image or to make the image as noise free noise. Because noisy image can degrade the quality of a resultant image or it may also provide inaccurate results. So to get the accurate segmented results, image enhancement is very necessary. In order to enhance an image various filtering techniques are there like Gaussian filter, adaptive weighted median filter, anisotropic diffusion filter etc.

In this paper BPDFHE (Brightness Preserving Dynamic Fuzzy Histogram Equalization) [13] enhancement technique has been used. For processing & representation BPDFHE utilizes fuzzy statistics of digital images which facilitates it to hold the inexactness of grey level values in order to enhance the performance. It is best enhancement technique comparative to others. It works according to following four steps [13] :-

Fuzzy Histogram Computation
↓
Histogram partitioning
↓
Dynamic Histogram Equalization
↓
Normalization of Image Brightness

Figure2. Steps for BPDFHE Technique

b) Morphological operations: Morphological operators that are opening & closing operations get applied for the sake of enhancing the filtering results or to remove any kind of redundancy from an image [2] after its enhancement by BPDFHE enhancement technique. For e.g. Erosion and Dilation.

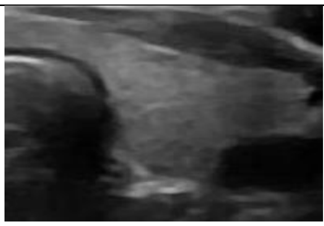
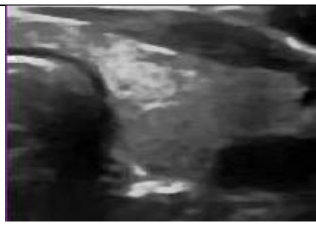
$$\textbf{Opening:}\ S \circ E = (S \ominus E) \oplus E$$

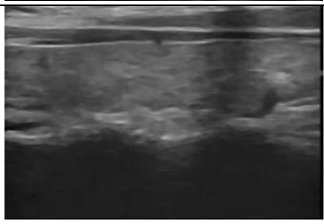
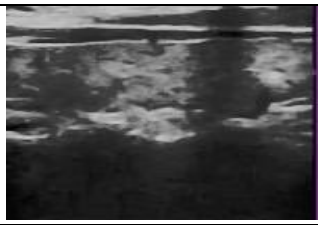
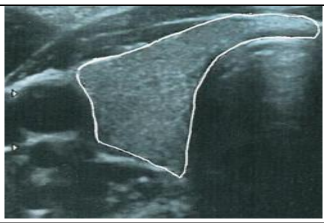
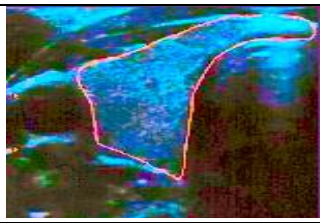
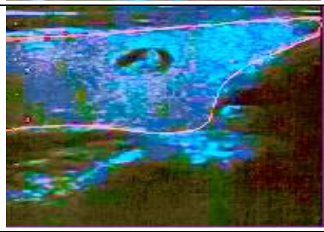
$$\textbf{Closing:}\ S \bullet E = (S \oplus E) \ominus E$$

Opening operation is the dilation of an erosion of set S by structured element E and closing is vice versa.

Following table shows figures with their pre-processing results.

Table II Us Images with Pre-Processing Results

S.no	**Input Images**	**Pre-processed Results**
Case1		

Case2		
Case3		
Case4		
Case5		

3) *Feature Extraction:* Feature extraction is the process of extracting some relevant features or desired values from large input data. These extracted features are treated as necessary information extracted from the data. It becomes easy to perform further processing tasks by considering some relevant information instead of whole initial data. Extracted features are not only informative but also non-redundant. Then these extracted features get used further in order to train the network. To get the desired and accurate outcome extracted features must be appropriate according to need. As various feature extraction techniques are there like first order histogram based features, multi-scale features [2], GLCM (Gray Level Co-occurrence Matrix) features [14], Haar wavelet features [2] , statistical features, DWT (Discrete Wavelet Transform) [14] etc. But in our proposed work we applied DCT (Discrete Cosine Transform) feature extraction technique.

a) *Discrete Cosine Transform (DCT) Feature Extraction:-* DCT [15] is the real version of DFT (Discrete Fourier Transform). DCT conveys finite series of data points in the form of summation of cosine functions oscillating at diverse frequencies. Previously, DCT had wide scope for lossy compression because of energy compaction property. But now a day, it can get applied in other fields also like in medical image processing for compression, segmentation and feature extraction etc. In this proposed work, DCT technique is used for feature extraction in order to train the network further. As DCT have four categories, DCT-II is widely used as DCT. But in this proposed work 1-D DCT gets applied.

***i)** 1-D DCT (One dimensional DCT): In* image processing, DCT technique is used for conversion of pixel values of an image into its elementary frequency components. DCT is widely applicable due to its benefits like it is able to provide better energy compaction, ability to pack up the larger amount of information in fewest coefficients, fast computation and able to minimize the block like appearance known as blocking artifacts etc [15]. In DCT all the calculations are real numbers. As we have applied DCT for extracting the features or coefficients of an image. Coefficients of DCT are cosine series expansion coefficients of band limited, symmetrically extended discrete signal. Also, it provides simple relationship.

1-D DCT:-

$$C(u) = \alpha(u) \sum_{x=0}^{N-1} f(x) \cos\left[\frac{\pi(2x+1)u}{2N}\right]$$

Where N is length & u=0, 1, 2, ……, N-1.

Inverse DCT:-

$$f(x) = \sum_{u=0}^{N-1} \alpha(u) C(u) \cos\left[\frac{\pi(2x+1)u}{2N}\right]$$

Where x=0, 1, 2,….., N-1 and in both equations.

$$\text{and } \alpha(u) = \begin{cases} \sqrt{\frac{1}{N}}, & for\ u = 0 \\ \sqrt{\frac{2}{N}}, & for\ u \neq 0 \end{cases}$$

4) *Training Phase:-* In this proposed work, we applied Feed Forward Neural Network trained with back propagation in order to extract the objects or patterns. In FFNN connections between different units provides no directed cycle [16]. Also, we can say that in artificial neural network information travels only in forward direction i.e. form the input nodes to output nodes through the hidden nodes. FFNN has better capability compared to other methods for providing us with meaningful information from an input data. It is incredibly able to extract precise patterns or objects from compound data whereas other techniques may undergo some difficulties [2].Basically neural network contains three layers i.e. input layer, hidden layer & output layer as shown in figure 3. Each circular node represents an artificial neuron and an arrow represents a connection from the output of one neuron to the input of another neuron.

Depending upon the number of extracted features or we can say that according to number of given inputs, hidden layer provides adequate number of neurons. Neural network takes the input in the vector form as mention below:-

$$Y_i = [x_{i,1}, x_{i,2}, x_{i,3}, \ldots, x_{i,m}]$$

Where $x_{i,m}$ is m^{th} feature of i^{th} pixel.

During training phase, weights of FFNN get modified by using back propagation algorithm. The main aim of the back propagation is to adjust the weights of the network in order to get the desired output with respect to every input pattern in pre-defined training set pattern.

Levenberg Marquardt (LM) [17], [18] back propagation is a training function used for network for updating the weights as well as bias values. In LM algorithm, weights during neural network training get adjusted by using following:

$$W_{n+1} = W(n) - (J(n)^T J(n) + \mu I)^{-1} J(n)^T e(n)$$

Where J is Jacobi matrix, μ guarantees that matrix inversion will get created as a result which depends upon the summation of squared errors, W denotes the weight vector and e denotes the error vector.

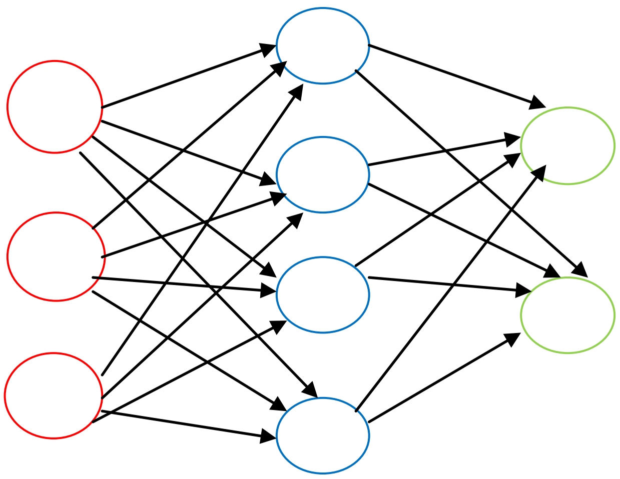


Figure 3. Architecture of Feed Forward Neural Network

5) *Segmentation of thyroid Gland:* Once training phase gets completed successfully, FFNN will provide the desired segmentation results of thyroid region from thyroid ultrasound images.

III. RESULTS AND COMPARISON

The proposed method is implemented on dataset of thyroid US images for extracting the exact position of thyroid. It also gets tested on different cases of dataset of thyroid gland US images. Then it has been compared with previous system i.e. Segmentation of thyroid gland in US image using neural network [2]. Proposed method gets applied on total of 9 US images. Total 9 inputs are there for image vector. So, network contains 9 input neurons, 10 hidden neurons and one output neuron. For evaluating the performance of the system, following parameters gets calculated:-

$$\mathbf{Accuracy} = \frac{\mathbf{TP + TN}}{\mathbf{AP + AN}}$$

$$\mathbf{Sensitivity} = \frac{\mathbf{TP}}{\mathbf{AP}}$$

$$\mathbf{FM} = \mathbf{2} * \left(\frac{\mathbf{RC * PR}}{\mathbf{RC + PR}}\right)$$

$$\mathbf{FN\ Rate} = \mathbf{FN/(TP + FN)}$$

Experiment gets performed on 9 US images and following

Table shows some figures with their segmented results.

Table III Us Images with Segmentation Results

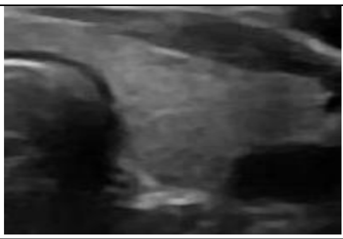
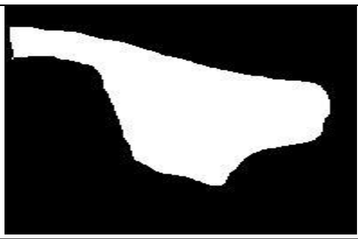
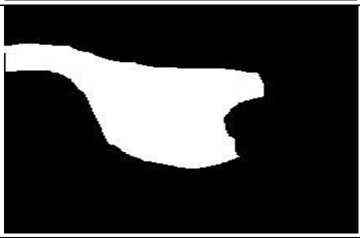
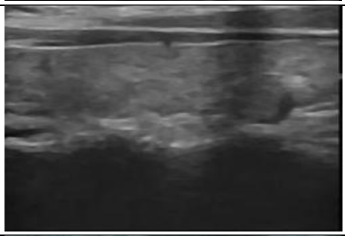
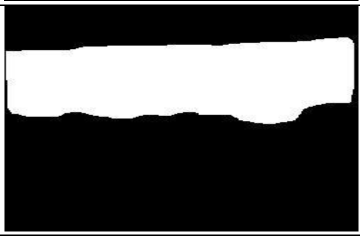
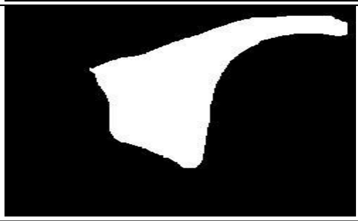
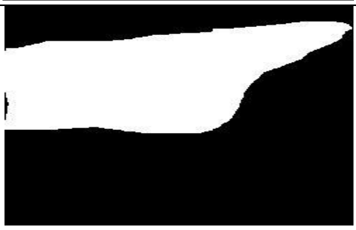
S.no	**Input Images**	**Segmented Results**
Case1		
Case2		
Case3		
Case4		
Case5		

Table IV shows the evaluated results of the proposed method by using above mentioned parameters.

Table IV Results of Proposed Method

US Image	**Accuracy**	**Sensitivity**	**F-Measure**	**FN rate**
Case 1	97.92	97.07	98.51	2.92
Case2	98.34	97.92	98.95	2.07
Case 3	97.90	96.98	98.47	3.01
Case4	98.22	97.77	98.87	2.22
Case 5	98.28	97.41	98.68	2.58

Table V shows the comparative analysis of proposed method with existing one. In proposed method, average values of all the parameters are greater than 97%. It becomes clear from following table that proposed method provides better performance.

Table V Comparison of Proposed Method and Existing Method

Case	**Accuracy**		**Sensitivity**		**FN rate**	
	Existing	Proposed	Existing	Proposed	Existing	Proposed
C1	97.44	97.92	93.11	97.07	6.89	2.92
C2	94.90	98.34	80.63	97.92	19.37	2.07
C3	96.94	97.90	95.84	96.98	4.16	3.01

C4	96.27	98.22	85.98	97.77	14.02	2.22
C5	96.51	98.28	89.75	97.41	10.25	2.58
Avg.	**96.51**	**98.13**	**89.06**	**97.43**	**10.93**	**2.56**

Following is the figure which shows comparison of existing and proposed method in graphical form.

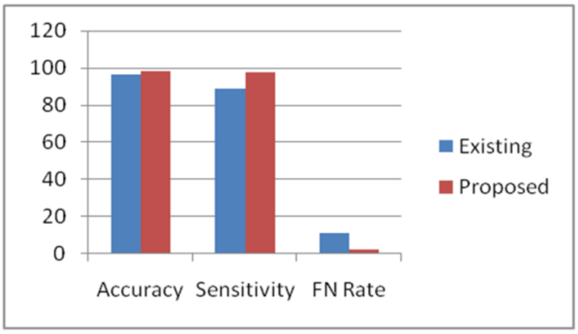


Figure 4: Comparison of proposed method with Existing method

So, it becomes clear that proposed method is more efficient comparatively.

IV. CONCLUSION & FUTURE SCOPE

Thyroid gland is one of part of human body that comes under the category of endocrine system. Variations in size of thyroid gland may give rise to various problems or thyroid nodules. Most of the nodules are benign and other may cause cancer. Ultrasound is one commonly used tool to test the thyroid nodules state because of its various benefits like non-invasiveness, less cost, no harmful radiations etc. Vast amount of work has been done on thyroid gland segmentation. In this paper, two methods such as BPDFHE for image de-speckling and 1-D DCT for feature extraction has been applied that have been never been used before. For segmenting the thyroid region Feed Forward Neural Networks with back propagation has been applied. In the end, by using different calculating parameters it has been shown that proposed system has better performance and efficiency.

Future scope is to enhance the system further by applying some other methods and volume estimation of appropriately segmented thyroid region.

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