

A Comparative Review of Various Techniques for Segmentation of Thyroid Nodule in Ultrasound Images

Gurinder Kaur¹ and Vikas Wasson²

¹Research Scholar, Dept. of Information Technology, Chandigarh University, Gharuan, Mohali, Punjab, India, gurinderk29@yahoo.in

²Assistant Professor, Dept. of Computer Science & Engineering, Chandigarh University, Gharuan, Mohali, Punjab, India vikaswasson.cse@gmail.com

*Correspondence: gurinderk29@yahoo.in

ABSTRACT- Thyroid is one of the endocrine gland which is located inside the neck in front of the larynx & just below the Adams apple. The unwanted growth of cells on thyroid gives rise to thyroid nodules or disorders. For detection of thyroid nodule various techniques are there like US, CT, OCT & MRI etc. But ultrasound (US) is one of the most promising techniques to detect different kinds of thyroid abnormalities because of its properties like non-invasiveness, inexpensive, flexibility and short acquisition times, capable to provide immediate information & free of ionizing radiations unlike CT. This paper involves the review of various algorithms for segmenting & classifying the thyroid nodules (benign/cancerous) from ultrasound (US) images. At the end, this paper contains comparison of various methods on the basis of their different characteristics.

Keywords: Image Processing, Thyroid, Thyroid nodule, US, Segmentation, Review.

ARTICLE INFORMATION

Author(s): Gurinder Kaur and Vikas Wasson;

Received: 14/01/2023; Accepted: 16/03/2023; Published: 30/03/2023;

e-ISSN: XXXX-XXXX;

Paper Id: IJCSR-020105;

Citation: 10.37391/IJCSR.020105



Publisher's Note: FOREX Publication stays neutral with regard to Jurisdictional claims in Published maps and institutional affiliations.

1. INTRODUCTION

Digital Image Processing is a wide area which includes large number of sub-areas further but fundamentally it is a single block in which image or a video acts an input and output is either an image or a video or set of parameters related with an image [1]. It is vastly applicable in medical image processing which helps radiologists for diagnosis of problem which manually consumes lot of time, so it saves time & comparatively less laborious [1].

Medical Imaging Analysis plays an important role to detect different kinds of human diseases [2]. With technology advancements, computerized diagnosis becomes an active research area and provides an accurate judgements.

Basic Principle of computerized diagnosis is an image processing which includes image acquisition, image pre-processing, image segmentation etc. by using different methods according to the requirements [1]. In case of medical image processing various techniques are there to diagnose the human body like CT Scans, MRI, X-rays, OCT, US etc. US (Ultrasound) is the most widely used tool [3] because it has number of advantages over other methods.

Thyroid Gland is a butterfly shaped organ & consists of two cone lobes. It comes under category of endocrine system & situated in the neck just front of the larynx [4]. It helps to control the thyroid hormone secretion which normalize the human body temperature and also deeply affects the childhood growth, intelligence as well as mature metabolism [4]. The undesired growth of cells over the thyroid gland give rise to mass of tissues also called as thyroid nodules [5]. Nodules are nothing but some kinds of disorders. Among these a large amount of the thyroid nodules are benign & some may cause cancer or malignant [5]

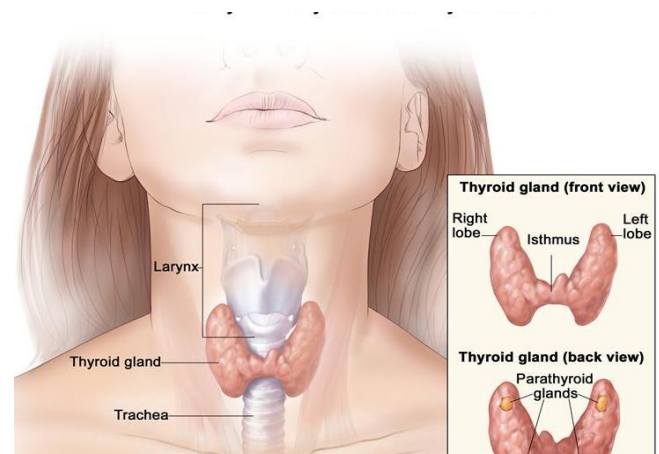


Figure 1: Thyroid Gland

Basically thyroid nodules except cancerous and benign involves two familiar categories i.e. hyperthyroidism (over active condition) & hypothyroidism (under active condition) [8]. Thyroid problems also may occur due to deficiency of iodine like goiter. Goiter may get arise in any case like hypothyroidism, hyperthyroidism, malignant or benign.

Table 1 shows the symptoms/signs of hypothyroidism & hyperthyroidism thyroid disorders [9].

Table 1: Symptoms of Thyroid Disorders

Hyperthyroidism symptoms	Hypothyroidism symptoms
Unexplained weight loss	Lack of energy/fatigue
Irritability & Nervousness	Dry coarse skin/hair
Muscle weakness	Depression
Irregular periods	Constipation
Difficulty in sleeping	Infertility
Goiter	Goiter
High heart rate	Slower heart beat than normal
High blood pressure	Puffy tissues
Excessive hair thinning	Decreased libido
Excessive sweating	Mental lethargy
Sensitivity to warm temperatures etc.	Sensitivity to cold temperatures etc.

In this paper, we present a review of different techniques used for thyroid gland with their advancements, advantages as well as drawbacks. We have also shown the comparison of different techniques in tabular form including their methods for feature extraction, searching of ROI's, classifiers & segmentation in order to detect the thyroid nodule accurately.

The remaining part of this paper is ordered as follows. Section II illustrates about the ultrasound imaging, its modes & its basic properties. Section III describes about segmentation, its areas as well as its methods. Section IV describes about the previous studies & their comparative analysis on the basis of their different features like accuracy, specificity & sensitivity etc. Section V contains conclusion of the paper

2. ULTRASOUND IMAGING

Ultrasound is also known as sonography [10] & is widely taken into consideration because of its benefits over MRI (Magnetic Resonance Imaging), CT (Computed Tomography) scans, X-ray etc. But also ultrasound images contain speckle noise in addition to grain noise [1]. Noise is the result of errors which can degrade the quality of an image. To enhance the quality of an image or to make image noise-free, image enhancement is necessary. Various filtering methods are there to enhance the image like AWM (Adaptive Weighted Median Filter) [1], anisotropic diffusion model [11], Gaussian filter, BPDHE (Brightness Preserving Dynamic Histogram Equalization) [12] & BPDFHE (Brightness Preserving Dynamic Fuzzy Histogram Equalization) [12] etc.

Various advancements of ultrasonography involves 2-D (Two dimensional), 3-D (Three dimensional) and 4-D (Four dimensional) ultrasound techniques, [10] out of which 2-D ultrasound is able to format the sound wave data into 2-D images, 3-D ultrasound can format sound wave data into 3-D images and 4-D ultrasound is about 3-D ultrasound but in motion [10].

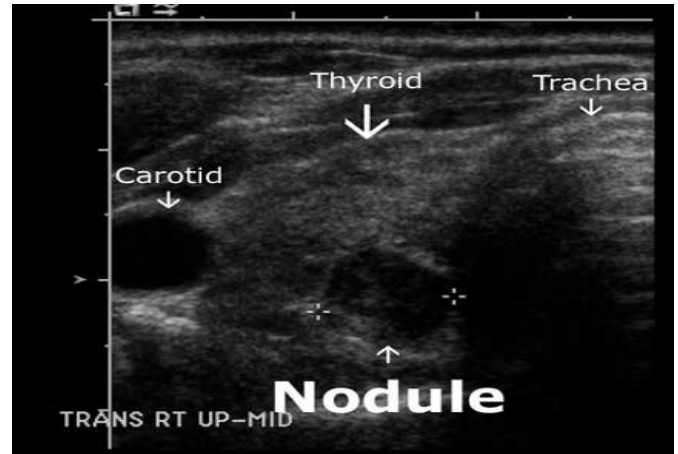


Figure 2: Thyroid Ultrasound Image [13]

Furthermore, this section involves modes of US imaging in addition to its important properties.

1. Modes of Ultrasound Imaging

Following are the methods that are widely used in sonography [14].

- Amplitude Mode (A-Mode):** In this a single transducer is there which scans a line throughout the body with that of echoes plotted on a screen as a function of depth.
- Brightness Mode (2-D or B-Mode):** In this a linear array transducers are there which simultaneously scans a plane throughout the body & can get viewed as 2-D image on the screen.
- C-Mode:** It gets formed in a plane normal to that of B-Mode.
- Motion Mode (M-Mode):** It is used to record a video in sonography & used to find out the velocity of an organ structures.
- Doppler-Mode:** It measures the blood flow by making use of Doppler Effect that involves continuous Doppler, color Doppler, pulsed wave (PW) Doppler & duplex.
- Pulse Inversion Mode:** It involves two successive pulses with opposite signs & their subtraction from each other.
- Harmonic mode:** In this mode, harmonic overtone gets detected by emitting the deep penetrating frequency into the body.

2. Properties of an ultrasound imaging

Fundamental properties of an ultrasound imaging are described further:

- Ultrasonography is a non-invasiveness technique.
- It is inexpensive & painless.
- It involves short acquisition times & able to provide an immediate information.
- They does not involve any harmful ionizing radiations.
- It is capable to provide clear picture of soft tissues.
- It does not involves any kind of side effects or discomfortless for the patients.

It is flexible comparative to other modalities.

Table 2 shows the advantages of an ultrasound over CT scans & MRI [15] [16] [17]

Table 2: Advantages of US over CT & MRI

Features	CT Scans	MRI	US
Acronym for	Computed Tomography	Magnetic Resonance Imaging	Ultrasound
Ionizing Radiations	Yes	No	No
Scan Time	10-45 mins	Longest	Shortest
Cost	Expensive	Most Expensive	Cheapest
Availability	Done by big hospitals	Specialized Units	Most widely Available
Contrast Agents	Adverse effect	Good safety profile	None used
Principle Used	Use of X-rays	Use of strong magnetic fields	High frequency sound waves
Application	Bone injuries, Lung & Chest imaging, cancer detection & emergency patient rooms.	For soft tissue evaluation, Spinal cord injury & Brain tumors.	Pregnancy, to detect abnormal masses, detection of changes in tissues, organs & vessels.

3. SEGMENTATION

Image segmentation is the process of partitioning a digital image into multiple segments or sets of pixels also known as super pixels [18]. It is used for locating the objects and boundaries in images like lines, curves, etc. Purpose of segmentation is to alter the image representation into the form which is more meaningful & easier to analyze.

Resultant segmentation image includes set of segments that can cover up the complete image collectively, or we can say that it is a set of contours (outlining) taken out from an image. When it is applied to a large number of images like in case of medical imaging, after segmentation of an image the resulting contours (outlines) can get used to generate 3D reconstructions by using required algorithms. Pixels are similar in context of some properties like intensity, color, texture etc. & adjacent regions are significantly different with respect to the same characteristics [18]. Further, this section contains an applicable areas & methods of image segmentation.

- 1) *Applicable areas of an image segmentation* [18]
 - i. Machine Vision

- ii. Medical Imaging for locating tumors and other Pathologies, Surgery planning, for diagnosis purpose, Measurement of tissue volumes, study of anatomical structure etc.
- iii. Object Detection such as face detection & locate objects in satellite images (roads, forests, crops) etc.
- iv. Recognition Tasks which involves iris recognition face recognition & fingerprint recognition etc.
- v. Traffic Control Systems.

2) *Image Segmentation Methods*

- i. Thresholding
- ii. Clustering methods
- iii. Compression based methods
- iv. Histogram based methods
- v. Edge Detection
- vi. Optimization Algorithms
- vii. Region growing methods & Graph partitioning methods.

4. RELATED WORK

Maroulis D.E. et al. [7] presented a paper on thyroid nodule detection in US images using computer-aided technique that takes into account the inhomogeneity of US images. They implemented VBAC (Variable Background Active Contour Model) involves variable subset of an image as its background which can change the shape in order to reduce the background inhomogeneity effects. Results get evaluated by using US images of 35 thyroid patients & shows that VBAC provides fast convergence as well as improved accuracy comparative to ACWE (Active Contour without Edges). As with VBAC they have reached the convergence in 10% less algorithm iterations than ACWE.

Tsantis S. et al. [19] presented a paper in which they described about speckle reduction in thyroid US images with the help of inter-scale wavelet analysis. The aim of this study was to check the regularity of the edges & their isolation across scales. This proposed study integrates back propagation maxima tracking and singularity detection modulus maxima derived from inter-scale analysis. Result shows that they have achieved high speckle reduction performance quantitatively including significant edge preservation accuracy comparative to other systems. In order to evaluate the efficiency of algorithm's speckle noise reduction, a questionnaire about qualitative image parameters had been done.

Maroulis D.E. et al. [20] presented a paper on VBAC (Variable Background Active Contour Model) for delineation of thyroid nodules in US images. They implemented VBAC & compared it with ACWE model in case of both synthetic as well as real ultrasound images. Experimental results show that VBAC outperforms ACWE when inhomogeneity was included. Also, its delineations in case of hypoechoic nodules are more accurate i.e. by 91% than that of ACWE in less iterations & it is comparable to expert radiologists according to which it is feasible in clinical practice. VBAC converged in 9.6% less iterations & execution time is also faster by 8.2% than that of ACWE.

Lakovidis D. K. et al. [21] presented a paper for segmentation of US images in order to delineate thyroid nodules accurately. They implemented an approach called GA-VBAC i.e. integration of GA (Genetic Algorithm) & VBAC (Variable Background Active Contour model). VBAC utilizes variable background regions in order to minimize the intensity inhomogeneity effects in thyroid US images. They employed GA to automatically & efficiently search the VBAC parameters without requiring any technical skills. Experimental results reveal that GA-VBAC is an effective, efficient and highly objective 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.

Kollorz Eva N.K. et al. [22] presented a paper on volumetric quantification of thyroid using 3-D US imaging. They proposed a semi-automatic segmentation approach for classification & analysis is done on the basis of 3-D US data. Images get scanned in 3-D then pre-processing, filtering & segmentation has been done. Extension of Geodesic active contour level is discussed in detail. They joined two anisotropic diffusion filters with level set based diffusion algorithm. Sensitivity & Specificity of segmentation was 75% & 97% respectively. Mean Hausdorff distance is required less than 3mm for clinical use.

Tsantis S. et al. [23] presented a paper which contains morphological & wavelet local maxima features to evaluate the malignancy risk of thyroid nodule by using ultrasonography. They implemented pattern recognition algorithms named SVM & PNN for classification of malignancy risk in thyroid nodule. In this study ROC (Receiver Operating Characteristics) analysis was done for classifiers features like sensitivity & specificity. They have used 85 US images after cytological confirmation & done two kinds of evaluations i.e. with or without presence of speckle for SVM & PNN. With presence of speckle, area under ROC curves is 0.88 for SVM & 0.86 for PNN whereas without presence of speckle it is 0.96 & 0.91 respectively. Results show that proposed method can increase the classification accuracy & decrease the chances of misdiagnosis in thyroid malignant or cancer.

Savelonas M.A. et al. [3] proposed a novel Active Contour Model for accurate delineation of thyroid nodules of diverse shapes on the basis of their texture & echogenicity in ultrasound images. Proposed model is named as JET (Joint Echogenicity Texture) which integrates regional image intensity & statistical texture feature distributions or LBP distributions by utilizing Mumford-Shah functional also known as minimal partition problem. Author implemented JET for segmenting the US images containing hypoechoic, hyperechoic and isoechoic nodules. Delineation Performance of JET is comparable to VBAC model (Variable Background Active Contour) and also extends its capability from delineation of hypoechoic to isoechoic nodules and also it copes with the limitations of hybrid multiscale model.

Chang C.-Y. et al. [24] presented a paper in which they described the diagnosis of thyroid grave's disease automatically by using US images. They have considered dataset of 28 US

images from 7 patients, out of which 3 were suffering from grave's disease. They have found total of 90 ROI'S in which 45 includes grave's disease & remaining 45 includes normal cases to train the classifier. They have measured 2 parameters i.e. sensitivity & specificity for selecting the suitable sizes of ROI. According to classification, value of accuracy obtained by different neural networks like MLP, RBF & SVM is 85%, 96% & 100% respectively. Result shows that proposed approach is able to provide immediate, effective & fast inspection for hyperthyroidism.

Lakovidis D.K. et al. [25] presented a paper in which they described about the classification of thyroid ultrasound patterns by using fuzzy statistical distributions. In order to classify the thyroid malignancy state, they provided non-resistant encoding of two features of sonography i.e. echogenicity & texture so that they can achieve uncertainty-aware representation. For classification purpose SVM classifier has been used because of its robust performance & experimental evaluation is done based on ROC (Receiver Operating Characteristics) which is capable of providing reliable performance. The representation of an ultrasound texture & ultrasound echogenicity is done with FLBP (Fuzzy distribution of Local Binary Patterns) & FGLH (Fuzzy Grey Level Histogram) respectively. They have used 250 US images from 75 patients & results show that proposed fuzzy fusion scheme outperforms previous approaches. They achieved best classification accuracy i.e. 97.5% by using polynomial kernel SVM classifier.

Chang CY. et al. [4] presented a paper in which thyroid gland segmentation & volume estimation of thyroid has been introduced. Radial Basis Function (RBF) Neural Network has been applied to classify the blocks. To recover the accurate shape of thyroid gland, region growing method has been applied & for volume estimation of thyroid gland, they applied PSO (Particle Swarm Optimization) algorithm & compared it with other methods like standard GA.

Molinari F. et al [26] presented a paper in which they introduced contrast enhanced 3-D ultrasound for characterization of intranodular vascularization of thyroid nodules. They have analyzed 20 nodules by using 3D contrast enhanced ultrasound imaging, out of which 10 were malignant. Then, they have performed preprocessing & skeletonization & 7 parameters were get computed on the skeletons involves number of branching nodes /points (NB), number of vascular trees (NT), vascular density (VD), mean vessel radius (MR), inflection count metric (ICM), 2-D (DM) and 3-D (SOAM) tortuosity etc. Results show that malignant contains higher values of NB (1453), NT (83.1), VD (00.4), ICM (19.9), DM (51) & SOAM (26) than that of benign. They concluded that proposed approach is effectively capable of skeletonization for differential diagnosis of thyroid lesions.

Lyra M.E. et al. [27] presented a paper in which they have discussed the quantitative texture characterization of the thyroid gland ultrasound images. The proposed method is concerned with echogenicity and homogeneity. First order & co-occurrence features were get quantified & to evaluate the optimal parameters set for the thyroid texture, multi-factor analysis is done. They have considered the ultra-sonogram

thyroid images of 40 patients, out of which 12 had normal echogenicity & remaining 28 contained hypo echogenic areas. Parameters were derived from GLCM (Grey Level Co-occurrence Matrix) & they applied Principal Component Analysis (PCA) for calculation of optimal components. Results show that proposed model is 100% successful after testing through binary logistic regression.

Luo S. et al. [28] presented a paper in which they described the classification of thyroid nodule by using ultrasound elastography features with the help of linear discriminant analysis (LDA). Linear discriminant classifier is beneficial for FNA (Fine Needle Aspiration) biopsy thyroid nodules & they observed two types of thyroid nodules i.e. FNA & no FNA. They proposed a classification algorithm to arrange the thyroid nodule by extracting power spectrum of strain rate waveform from image sequence of US elastography. In order to compress the thyroid nodule they have used pulsation from the carotid artery. They have acquired dataset from 98 thyroid nodules for the evaluation of classification algorithm. They achieved 100% sensitivity & 75.6% specificity for detection of malignant with 98 FNA thyroid nodules & reducing number of FNA's by 63.3%. Results show that proposed approach is more objective & less observer dependent.

Selvathi D. & Sharnitha V.S. [29] implemented a paper in which they have introduced machine learning algorithms for classification & segmentation of thyroid ultrasound images. They evaluated various features like variance, mean, Histogram Feature, Homogeneity, NMSID (Normalized Multi Scale Intensity Different) Feature & Coefficient of Local Variation Feature. They have used 2 classifiers i.e. SVM & ELM which get trained by considering these features as an input. In order to make ultrasound images noise free, image enhancement has been done. They evaluated accuracy after comparing their results with ground truth images which were obtained from radiologists. Result shows that segmentation by using ELM (Extreme learning machine) classifier provides better results comparative to SVM (Support vector machine) classifier.

Keramidas E.G. et al. [30] presented a paper in which they described TND (Thyroid Nodule Detector) which is a computer aided diagnosis prototype for ultrasound images & videos to detect the nodular tissue. 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 (Fuzzy Logic Binary Patterns) & FGLH (Fuzzy Grey Level Histogram). They investigated the feasibility of proposed method on real US images. Experimental results show that integration of FLBP & FGLH is more effective comparative to other methods. Accuracy in TND system has been estimated to exceed 95% & also proved that it can get used clinically.

Bibico D. et al [31] presented a paper in which they have introduced recognition of thyroid nodule automatically on the basis of feature selection & pixel classification. They implemented three steps which involves automatic extraction of the most discriminative first-order statistical texture features, construction of classifier to automatically pick the required

features & correlation of important texture parameters with four biological areas on the basis of location characteristics as well as pixel classification. They focused to develop a discriminant texture variation based analysis method which corresponds to 4 biological areas & they set different mean values of gray intensity intervals as classifier. They also developed a software application named CADi on the basis of these intervals in order to distinguish two pathologies. They acquired 40 ultrasound images & result shows that proposed approach is capable to identify thyroid nodules accurately with classification rate of 83% (whole image analysis) & 91% in case of ROI's analysis.

Huang J.-Y. et al. [32] presented a paper in which they introduced fully automated thyroid volume estimation system for planer scintigraphy (PS) image. This proposed method consists of four steps involves preprocessing, enhancement of an image contrast, image segmentation and to get automated ROI (Region of Interest). 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 have taken data of 40 grave's disease patients as a training set to calculate some parameters empirically. They adopted US as standard reference then co-related its results with proposed approach and performed statistical analysis with precision, bias & relative differences. Result shows not only good co-relation between US results & proposed method but also provides best precision, bias & relative differences.

Garg H. & Jindal A. [1] presented a paper in which Feed-Forward Neural Network for segmentation of thyroid gland US images has been discussed. First they have done image enhancement in order to remove the speckle noise. Then various required features were get extracted to estimate the texture & to train the neural network. Then author implemented Feed-Forward Neural Network for intensity based classification and their experimental results show that neural network provides better results.

Narayan N.S. et al. [33] presented a paper in which they proposed a technique that can automatically remove the artefacts so that image can get accurately stored. This technique was able to estimate number of segments as well as clusters automatically & was developed based on histogram properties of artefacts. Then algorithm was executed on dataset of US images of thyroid gland & found that proposed method is able to restore the image to high quality. For image restoration they have used POCS (Projection onto Convex Sets) algorithm.

Hwang Y.K. et al. [34] presented a paper in which they introduced MR-3D ultrasound system. They described that ultrasound devices are necessary for RFA (Radio Frequency Ablation) of cancer in case of prostate, liver & thyroid etc. Occasionally it becomes difficult to examine the tiny tumors so they considered the fusion of MR/CT & US imaging but it involves some manual inputs. They have performed IVC (Inferior Vena Cava) segmentation, liver surface segmentation, registration between 3-D US & MR volume over cancer images of liver. Then they concluded that this system is easy to use as well as increases the efficiency.

We had briefly explained the various techniques for extraction of disorders in thyroid gland along with their key features. Table 3 shows the comparative analysis of various segmentation &

classification techniques to detect thyroid nodule from an ultrasound imaging.

Table 3: Comparison of Various Techniques for Detection of Thyroid Nodule

Author Name & Year	Dataset	Key Features	Proposed Method	Results
Maroulis D.E. et al. (2005)	Ultrasound Images acquired from 35 patients	Considered inhomogeneity of US images & compared proposed method with ACWE.	VBAC Model	Execution time of VBAC model speeds up by 8.5% than ACWE model.
Tsantis S. et al. (2007)	Ultrasound Images acquired from 63 patients	Achieved high speckle reduction performance quantitatively & questionnaire about qualitative image parameters is done.	Inter-scale wavelet analysis.	Quality improvement value of proposed method is 4.3 or 23% which is more comparative to ASSF, soft as well as hard thresholding.
Maroulis D.E. et al. (2007)	Synthetic and real US images (including 45 hypoechoic nodule cases)	VBAC outperforms ACWE in case of inhomogeneity & delineations of hypoechoic nodules are more accurate.	VBAC & incorporation of benefits of ACWE with VBAC.	VBAC converged in 9.6% less iterations than ACWE & execution time is also faster by 8.2%.
Lakovidis D. K. et al. (2007)	45 Ultrasound Images of hypoechoic nodules	VBAC minimize the intensity inhomogeneity effects in US images as well as GA automatically & efficiently search the VBAC parameters without technical skills.	GA-VBAC (combination of Genetic Algorithm & Variable Background Active Contour model).	GA-VBAC obtained average overlap value 92.5% whereas experts obtained 91.8%.
Kollorz Eva N.K. et al. (2008)	3-D Ultrasound imaging.	Involves semi-automatic segmentation approach for classification, Extension of Geodesic active contour level & Mean Hausdorff distance.	Novel framework for volumetric quantification of thyroid gland & anisotropic diffusion filters with level set based diffusion algorithm.	Sensitivity and Specificity of segmentation was 75% & 97% respectively.
Tsantis S. et al. (2009)	Acquired 85 US images, out of which 54 contain low risk & 31 contain high risk.	ROC analysis for classifier features & LM based features has been used. Pros: It can increase the classification accuracy. -Decrease the chances of misdiagnosis in thyroid malignant or cancer. Cons: Speckle limited the performance of classifiers due to subtraction of features.	Pattern recognition algorithms named SVM & PNN.	Area under ROC curves is 0.88 for SVM & 0.86 for PNN With presence of speckle, whereas without presence of speckle it is 0.96 & 0.91 respectively.
Savelonas M.A. et al (2009)	Acquired 74 thyroid US images contain hypoechoic, hyperechoic and isoechoic nodules.	Regional image intensity & statistical texture feature distributions or LBP distributions & Chan-Vese Model for JET formulation. Pros: Capability to get precise delineation. -Performance is comparable to VBAC. -Extendable capability from hypoechoic to isoechoic nodules. -can cope with limitations of hybrid multiscale model. -Fast & feasible for clinical practice.	JET (Joint Echogenicity Texture) Model	Evaluated accuracy that involves parameters i.e. q, e, & dc. Maximum accuracy of q is 97.7%, e is 2.4 pixels & dc is 99% for hypoechoic nodule & it is 95.9%, 3.6 pixels & 98.6% respectively for isoechoic nodules.

		<p>Cons: Not always able to differentiate structures like bigger blood vessels from actual nodules.</p> <p>-Requires additional color Doppler US imaging.</p>		
Chang C.-Y. et al (2009)	Acquired 28 US images from 7 patients, out of which 3 were suffering from grave's disease.	Measured specificity & sensitivity for selecting the suitable sizes of ROI.	Automatic system to diagnose the grave's disease & used SVM, MLP, RBF neural networks, out of which SVM have highest accuracy.	Accuracy obtained by different neural networks like MLP, RBF & SVM is 85%, 96% & 100% respectively.
Lakovidis D.K. et al. (2010)	Acquired 250 US images from 75 patients.	Non-resistant encoding of two sonographic features i.e. echogenicity & texture, SVM for classification & ROC for experimental evaluation.	FLBP & FGLH fuzzy statistical distributions	Obtained accuracy is 97.5% by using polynomial kernel SVM classifier.
Chang CY. et al. (2010)	Acquired 20 Ultrasound images	Region growing method to recover the accurate shape of thyroid gland region. Pros: It can automatically segment the thyroid gland. -It can estimate the volume of thyroid gland accurately. Cons: Space is limited.	RBF Neural Network to classify the blocks & PSO for volume estimation.	-For segmentation all the average values are higher than 89% & MSE value is 0.582.
Molinari F. et al (2010)	3-D Ultrasound	Computed 7 parameters i.e. NB, NT, VD, MR, ICM, 2-D (DM) and 3-D (SOAM).	CEUS (contrast enhanced 3-D ultrasound for characterization of intra-nodular vascularization).	Malignant lesions obtained higher values than benign i.e. NB = 1453, NT= 83.1, VD= 00.4, ICM= 19.9, DM= 5 & SOAM =26.
Lyra M.E. et al. (2010)	Acquired US images of 40 patients (12 had normal echogenicity & 28 contained hypoechogenic areas).	First order & co-occurrence features as well as multi-factor analysis.	Quantitative Texture Characterization approach involves GLCM (to derive parameters) & PCA (to calculate optimal components).	Results show that proposed model is 100% successful for classifying the normal & hypoechogenic thyroid.
Luo S. et al. (2011)	Ultrasound elastography & acquired dataset from 98 FNA thyroid nodules.	Power spectrum of strain rate waveform (Ultrasound elastography features).	LDA (Linear discriminant analysis).	Value of sensitivity and specificity is 100% & 75.6% respectively for detection of malignant.
Selvathi D. & Sharnitha V.S. (2011)	Acquired 50 US Images (30 with thyroid nodule & 20 with normal thyroid)	Variance, Mean, Histogram, NMSID, Coefficient of Local Variation & Homogeneity features.	Machine learning algorithms (SVM & ELM Classifiers)	Accuracy obtained by SVM & ELM is 84.78 & 93.56 respectively.
Keramidas E.G. et al. (2012)	Ultrasound images & videos	FLBP (Fuzzy Logic Binary Patterns) & FGLH (Fuzzy Grey Level Histogram) based features.	TND (Thyroid Nodule Detector): A computer aided diagnosis prototype.	Accuracy in thyroid nodule detection has been estimated to exceed 95%.

Bibico D. et al. (2013)	Acquired 40 ultrasound images, out of which 20 contained thyroid nodule.	Automatic extraction of features, construction of classifiers which gets validated under ROC & co-relation of parameters with 4 biological areas. Pros: Capable to identify thyroid nodules accurately. -Provides better view of classification performance. - Diagnostic efficiency of the CADi system is good. Cons: Requirement of good contrast/good brightness US images. -Occurrence of diagnostic errors as a result of threshold & mask size.	First-order statistical texture features & pixel classification methods to recognize the thyroid nodule & CADi software to distinguish pathologies.	Classification rate is 83% & ROI's analysis is 91%.
Huang J.-Y. et al. (2013)	Dataset acquired from 40 grave's disease patients & adopted US as standard reference.	Performed statistical analysis & used Himanka- Larsson's formula or Allen-Goodwin's formula to calculate thyroid volume. Pros: -Provides good co-relation with US. -Provides best bias, best precision. -Provides best relative difference. Cons: Need for empirical parameters like standard deviation or mask size in Gaussian smoothing filter. -need of times of dilation & erosion in morphological operations. -need of percentage of CDF in adaptive thresholding.	Fully automated thyroid volume estimation system for planer scintigraphy (PS).	Co-relation with US is $R^2=0.99$ and bias, precision, & relative difference is 0.8, ± 2.32 ml & $2.2 \pm 6.1\%$ respectively.
Garg H. & Jindal A (2013)	Acquired 10 ultrasound images.	Intensity of pixels and texture is taken as criteria and it is a hybrid approach. Pros: Provides better results for segmentation. -Fast execution. Cons: Levenberg-Marquardt function has been used which takes more memory comparative to other algorithms.	Feed Forward Neural Network.	Average efficiency is higher than 89%.
Narayan N.S. et al. (2013)	Acquired 18 ultrasound images.	Can estimate number of segments & clusters automatically & based on histogram properties of artefacts.	Automatic removal of manually induced artefacts & used POCS for image restoration.	High restoration quality with average PSNR > 38 db.
Hwang Y.K. et al. (2014)	Fusion of MR/CT & US images.	Performed IVC (Inferior Vena Cava) segmentation, liver surface segmentation, registration between 3-D US & MR volume over liver cancer images.	MR-3D ultrasound system.	Average execution time & memory consumption is 31.52 seconds & 650 MB respectively.

5. CONCLUSION

Till now various algorithms have been implemented by different researchers for appropriate diagnosis, segmentation & classification of thyroid nodules on medical images such as MRI, CT & US etc. Ultrasound is most widely used technique because it is non-invasiveness, inexpensive, flexible & free of ionizing radiations unlike CT Scans. This review study involves

the brief understanding of medical analysis in image processing, ultrasound imaging, & segmentation. At the end, comparison of various techniques has been done that were used till 2014 by considering their key features including pros & cons, dataset information as well as with their results on the basis of accuracy, sensitivity, specificity etc. according their requirements

REFERENCES

- [1] Hitesh Garg and Alka Jindal, "Segmentation of thyroid gland in ultrasound image using neural network," in In 2013 Fourth International Conference on Computing, Communications and Networking Technologies (ICCCNT), IEEE, 2013, pp. 1-5.
- [2] Sheeja Agustin A and S. Suresh Babu, "Thyroid Classification as Normal and Abnormal using SCG based Feed Forward Back Propagation Neural Network Algorithm," *International Journal of Computer Science and Mobile Computing*, 2013.
- [3] Dimitrios K. Iakovidis, Ioannis Legakis, and Dimitris Maroulis Michalis A. Savelonas, "Active contours guided by echogenicity and texture for delineation of thyroid nodules in ultrasound images," *Information Technology in Biomedicine, IEEE Transactions on* 13, no. 4, pp. 519-527, 2009.
- [4] Yue-Fong Lei, Chin-Hsiao Tseng, and Shyang-Rong Shih Chuan-Yu Chang, "Thyroid segmentation and volume estimation in ultrasound images," *Biomedical Engineering, IEEE Transactions on* 57, no. 6, pp. 1348-1357, 2010.
- [5] B. Gopinath and B. R. Gupta, "Majority voting based classification of thyroid carcinoma," *Procedia Computer Science* 2, pp. 265-271, 2010.
- [6] "<http://www.cancer.gov/images/cdr/live/CDR719086-750.jpg>".
- [7] Michalis A. Savelonas, Stavros A. Karkanis, Dimitrios K. Iakovidis and Nikos Dimitropoulos Dimitrios E. Maroulis, "Computer-aided thyroid nodule detection in ultrasound images," in *In Computer-Based Medical Systems, 2005. Proceedings. 18th IEEE Symposium on*, 2005, pp. 271-276.
- [8] "<http://www.mdhll.com/thyroid-signs-symptoms/>".
- [9] "<http://www.sharecare.com/health/womens-health/article/symptoms-of-thyroid-problems>".
- [10] S. Sridevi and Dr. M. Sundaresan, "Survey of image segmentation algorithms on ultrasound medical images," in *In Pattern Recognition, Informatics and Mobile Engineering (PRIME), 2013 International Conference on*, 2013, pp. 215-220.
- [11] Wei Zheng, Li Zhang and Hua Tian Jie Zhao, "Segmentation of ultrasound images of thyroid nodule for assisting fine needle aspiration cytology," *Health Inf Sci Syst* 1, no. 5, 2013.
- [12] Hrushikesh Garud, Amit Suveer, Manjunatha Mahadevappa and Jyotirmoy Chatterjee Debdoot Sheet, "Brightness preserving dynamic fuzzy histogram equalization," *Consumer Electronics, IEEE Transactions on* 56, no. 4, pp. 2475-2480., 2010.
- [13] "<http://www.radiologyinfo.org/photocat/popup/thyroid.jpg>".
- [14] "http://en.wikipedia.org/wiki/Medical_ultrasonography".
- [15] "http://www.cyberphysics.co.uk/topics/medical/compareMRI_CT_US.htm".
- [16] "http://www.diffen.com/difference/CT_Scan_vs_MRI".
- [17] "<http://www.two-views.com/Ultrasound/Why.html>".
- [18] Nikos Dimitropoulos, M. Ioannidou, Dionisis Cavouras and George Nikiforidis Stavros Tsantis, "Inter-scale wavelet analysis for speckle reduction in thyroid ultrasound images," *Computerized Medical Imaging and Graphics* 31, no. 3, pp. 117-127, 2007.
- [19] Dimitrios K. Iakovidis, Stavros A. Karkanis and Nikos Dimitropoulos Dimitrios E. Maroulis Michalis A. Savelonas, "Variable background active contour model for computer-aided delineation of nodules in thyroid ultrasound images," *Information Technology in Biomedicine, IEEE Transactions on* 11, no. 5, pp. 537-543, 2007.
- [20] Michalis A. Savelonas, Stavros A. Karkanis and Dimitris E. Maroulis Dimitris K. Iakovidis, "A genetically optimized level set approach to segmentation of thyroid ultrasound images," *Applied Intelligence* 27, no. 3, pp. 193-203, 2007.
- [21] Dieter A. Hahn, Rainer Linke, Tamme W. Goecke, Joachim Hornegger and Torsten Kuwert Eva N.K. Kollorz, "Quantification of thyroid volume using 3-D ultrasound imaging," *Medical Imaging, IEEE Transactions on* 27, no. 4, pp. 457-466, 2008.
- [22] Nikos Dimitropoulos, Dionisis Cavouras and George Nikiforidis Stavros Tsantis, "Morphological and wavelet features towards sonographic thyroid nodules evaluation," *Computerized Medical Imaging and Graphics* 33, no. 2, pp. 91-99, 2009.
- [23] Hsiang-Yi Liu, Chin-Hsiao Tseng and Shyang-Rong Shih Chuan-Yu Chang, "Automatic Diagnosis of Thyroid Graves' Disease in Ultrasound Images," in *In Hybrid Intelligent Systems, 2009. HIS'09. Ninth International Conference on*, vol. 1, 2009, pp. 192-197.
- [24] Eystratios G. Keramidis and Dimitris Maroulis Dimitris K. Iakovidis, "Fusion of fuzzy statistical distributions for classification of thyroid ultrasound patterns," *Artificial Intelligence in Medicine* 50, no. 1, pp. 33-41, 2010.
- [25] Alice Mantovani, Maurilio Deandrea, Paolo Limone, Roberto Garberoglio and Jasjit S. Suri Filippo Molinari, "Characterization of single thyroid nodules by contrast-enhanced 3-D ultrasound," *Ultrasound in medicine & biology* 36, no. 10, pp. 1616-1625, 2010.
- [26] Nefeli Lagopati, Paraskevi Charalabistou, E. Vasoura, A. Antoniou, C. Georgosopoulos and K. Skouroliakou Maria E. Lyra, "Texture characterization in ultrasonograms of the thyroid gland," in *Information Technology and Applications in Biomedicine (ITAB)*, 2010.
- [27] Eung-Hun Kim, Manjiri Dighe and Yongmin Kim Si Luo, "Thyroid nodule classification using ultrasound elastography via linear discriminant analysis," *Ultrasonics* 51, no. 4 (2011): pp. 425-431.
- [28] D. Selvathi and V. S. Sharnitha, "Thyroid classification and segmentation in ultrasound images using machine learning algorithms," in *In Signal Processing, Communication, Computing and Networking Technologies (ICSCCN), 2011 International Conference on*, pp. 836-841.
- [29] Dimitris Maroulis and Dimitris K. Iakovidis Eystratios G. Keramidis, "TND: a thyroid nodule detection system for analysis of ultrasound images and videos," *Journal of medical systems* 36, no. 3, pp. 1271-1281., 2012.
- [30] Luminita Moraru and Anjan Biswas Dorin Bibicu, "Thyroid nodule recognition based on feature selection and pixel classification methods," *Journal of digital imaging* 26, no. 1, pp. 119-128., 2013.
- [31] Kun-Ju Lin and Yung-Sheng Chen Jia-Yann Huang, "Fully automated computer-aided volume estimation system for thyroid planar scintigraphy," *Computers in biology and medicine* 43, no. 10, pp. 1341-1352, 2013.
- [32] P. Marziliano and C. G. L. Hobbs N. S. Narayan, "Automatic removal of manually induced artefacts in ultrasound images of thyroid gland," in *In Engineering in Medicine and Biology Society (EMBC), 2013 35th Annual International Conference of the IEEE*, 2013, pp. 3399-3402.
- [33] Young-Taek Oh, Jung-Bae Kim, and Won-Chul Bang Young-Kyoo Hwang, "One click 3D ultrasound to MR registration," in *In Consumer Electronics (ICCE), 2014 IEEE International Conference on*, 2014, pp. 270-273.



© 2023 by the Gurinder Kaur and Vikas Wasson. Submitted for possible open access publication under the terms and conditions of the Creative Commons Attribution (CC BY) license (<http://creativecommons.org/licenses/by/4.0/>).