ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
Vol. 7, Issue 8 , August 2020

# A Review of Various Segmentation Methods for Ultrasound Thyroid Images

**Oluwadare Adepeju Adebisi , John Adedapo Ojo**

Lecturer, Department of Computer Engineering, The Polytechnic Ibadan, Nigeria
Professor of Communication & Signal Processing, Department of Electronic and Electrical Engineering, LadokeAkintola University of Technology Ogbomoso, Nigeria

**ABSTRACT*:*** A thyroid is an endocrine gland that produces hormones, which help the body to control metabolism. Segmentation of thyroid images plays important roles in delineation and assessment of thyroid nodules. Ultrasound imaging is commonly used for capturing thyroid because it is non-invasive, cheaper, non-radioactive, and widely available. However, segmentation of ultrasound thyroid images is challenging because they are easily affected by speckle noise and echo perturbations. In this work, various computer techniques for segmentation of ultrasound thyroid images are reviewed. The segmentation techniques are categorized into graph cut, active contour, neutrosophic, machine learning and deep learning. The computer based segmentation techniques could assist radiologist in the interpretation of the ultrasound thyroid images and thereby reduce false diagnosis of thyroid diseases.

**KEYWORDS*:*** Segmentation, Ultrasound, Thyroid, Machine Learning, Deep Learning, Neutrosophic.

## 1. INTRODUCTION

A thyroid is an endocrine gland that produces hormones, which help the body to control metabolism. It is a small butterfly shaped gland located in front of the neck below the thyroid cartilage (Adam's apple). The thyroid gland is made up of two lobes located along either side of the trachea and connected across the midline tissue. Thyroid disorders include hypethyroidism, hypothyroidism and thyroid nodules [1]. Hyperthyroidism is due to extra production of thyroid hormone by the thyroid gland. Hypothyroidism occurs when thyroid organ does not deliver enough measure of thyroid hormone while thyroid nodule refers to any abnormal growth that forms a lump in the thyroid gland.

Segmentation is used to separate a thyroid image into multiple parts for further analysis. Segmentation techniques convert complex image into simple image based on patterns, texture, shape, colour etc. [2]. Severalmetrics are used for evaluation of the segmentation algorithms such as True Positive, Accuracy, False Positive and Dice Coefficient. The segmentation metrics compare the segmented images with the ground truth. True positive (TP)is the number of true positive pixels which are marked as nodule in both automated and manual segmentation [3]. A high value of TP shows that the result of segmentation is closely matched to the value obtained by the expert approximation.

$$\text{True Positive} = \frac{|A_m \cap A_a|}{A_m} \times 100 \quad (1)$$

whereAa are the pixels automatically generated and $A_m$ are the pixels manually delineated by the expert.
Selvathi and Sharnitha [4] defined segmentation accuracy as

$$\text{Accuracy} = \frac{A_{TP}+A_{TN}}{A_P+A_N} \times 100 \ (2)$$

$A_P$= Total number of actual positive pixels.
$A_N$= Total number of actual negative pixels
$A_{TP}$=Number of pixels in the actual region segmented
$A_{FN}$ = false negative pixels

False Positive is defined as the number of false positive pixels, which are marked as nodule in automated but not in manual segmentation [5]. A low value of FP signifies that the segmentation result is closely matched to the value obtained by the expert approximation

$$FP = \frac{|A_m \cup A_a - A_m|}{|A_m|} \times 100 \ (3)$$

where $|A_a|$ and $|A_m|$ are the numbers of pixels within the regions Aa and Am.

ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
Vol. 7, Issue 8 , August 2020

The Dice similarity coefficient (DC) is a statistical validation metric that evaluates the performance of manual segmentations and the spatial overlap accuracy of automated segmentation of images.Zou [6] defined Dice coefficient (DC) as

$$DC(A_a, A_m) = \frac{2\times (A_a \cap A_m)}{|A_a|+|A_m|} \times 100 \quad (4)$$

where $|A_a|$ and $|A_m|$ are the numbers of pixels within the regions Aa and Am.

A DC of value 0% means, there is no overlap between the manual segmentation and the automated segmentation of the image while A DC of value 100% indicates complete overlap of manual segmentation region on the automated region.

The Hausdorff distance (HD) is the shortest distance between the segmented and the ground truth boundaries. Let Ag= $\{a_{g1}, a_{g2,} . . ., a_{gm}\}$ be the manually annotated ground truth of the nodule contour and $B_a= \{b_{a1}, b_{a2}, . . ., b_{an}\}$ be the resulting nodule contour from an automatic method. HD is computed as

$$HD(A_g, B_a) = \max(h(A_g, B_a), h(B_a, A_g)),$$

$$\text{where } \; h(A_g, B_a) = \max_{a_g \in A_g} \; \min_{b_a \in B_a} ||a_g - b_a|| \quad (5)$$

where $A_g$ and $B_a$ are the two curves being compared and $h(A_g,B_a)$ is called Hausdorff distance from $A_g$ to $B_a$.

There are several imaging modalities such as X-ray, CT scan Computed Tomography(CT scan), Ultrasonography, Magnetic Resonance imaging (MRI), Ultrasonography has become a commonly employed imaging method for capturing thyroid imagesbecause it is non-invasive, non-

## II. LITERATURE SURVEY

Segmentation techniques convert complex image into the simple image based on patterns, texture, shape,colouretc [2]. Table 1 shows the related works on segmentation of ultrasound thyroid images. Some of the segmentation methods include graph cut, active contour,neutrosophic, machine learning and deep learning.

### Graph Cut

A graph-cut is a grouping method in which the extent of variance between two classes is computed as the total weight of edges removed. The total variance between the different classes and the total similarity within the classes are determined bythe normalized cut criterion . This method make use of GrabCut algorithm developed by Rotheret al.[11]. It is a semi-automatic method of segmentation as the user mark the regions as thyroid and non-thyroid .Poudel et al.,[12] presented a graph cut method of segmentation and obtained a dice coefficient and hausdorff distanceof 0.7 and 8.3 respectively. Shi and Malik [13] proposed a normalized cut method of segmentation and obtained an accuracy of 92%. Since the method requires huge calculations, over segmentation or under segmentation can easily be generated.

## Active Contour

Active contour refers to a segmentation method that separates pixels of interest from the image based on constraints and energy. Chan and Vessse [14] presented an active contour model without a stopping edge-function for segmentation of thyroid images. This method is not established on the gradient of the image for the stopping process but on Mumford-shah Segmentation technique and level set. Mahmood and Rusli [15] applied active contour to segment thyroid nodule and lobe areas. The image was converted into gray scale and histogram equalization was used for contrast enhancement. The initialization mask which is the region of interest was determined manually. Poudel*et al.*,[16] proposed an active contour for segmentation of 2D ultrasound thyroid images. Histogram Equalization was applied to enhance the ultrasound thyroid image contrast while media filter was used to suppress speckle noise and preserver information. In order to achieve a 3D model, reconstruction algorithm was applied to the segmented thyroid image. The active contour segmentation technique used result in an average accuracy of 86.7%.

### Neutrosophic Methods

The neutrosophic set is a branch of neutrosophy that considers the nature and properties of neutrality (or indeterminacy). Haji and Yousif [17] developed an automatic neutrosophic technique for seed point selection based on higher order spectra (SSHOS) in thyroid nodules images. The segmentation technique was based on the principle that majority of its Higher Order Spectra Entropies (HOSE) from Radon Transform (RT) at various angles are within the

ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
Vol. 7, Issue 8 , August 2020

range between average and maximum entropies with application of the region growing image segmentation at constant threshold. The performance of the segmentation technique was evaluated and a True Positive (TP) value of 96.44 ± 3.01%, False Positive (FP) value of 3.55 ± 1.45% and Dice Coefficient (DC) value of 92.24 ± 6.47% were obtained. Table 1 shows the related works on segmentation of Ultrasound Thyroid Images.

Guo and Sengur [18] also applied Neutrosophic C-means to segment thyroid nodules and obtained True Positive (TP) of 88.5±62, False Positive (FP) of 10.93±10.9%. and Dice Coefficient (DC) of 78.50±18.40%. Koundal*et al.*,[19] proposed a Spatial Neutrosophic Distance Regularized Level Set (SNDRLS) which is based on Neutrosophic L-Means (NLM) clustering and spatial information for Level Set evolution. The SNDRLS estimates region of interest (ROI) as input provided by Spatial NLM (SNLM) clustering for segmentation of thyroid nodules and obtained a True Positive of 95.92 ± 3.7%, False Positive of 7.04 ± 4.21% and Dice Coefficient of 93.88 ± 2.59.

**Machine Learning**

Machine Learning is a process of training a machine to automatically learn from and make prediction on data without being explicitly programmed (Simon *et al.,* 2016)[20]. It is an application of an artificial intelligence that creates a model for the purpose of decision making. Machine Learning can be supervised, semi-supervised or unsupervised [21] [22]. Supervised learning is done under the supervision of a teacher. During the training of Artificial Neural network (ANN), the input vector presented to the network gives an output vector. This output vector is compared with the desired output vector and generates an error signal. If there is a variation between the desired output vector and the actual output, the weights are adjusted based on error signal until the actual output is matched with the desired output [23]. Supervised Learning are Regression, Decision Tree, Random Forest, K-Nearest Neighbors and Logistic Regression.

In unsupervised learning, the network recognizes the features and input data pattern without the assistant of a teacher [24]. The data given to unsupervised algorithm are not labeled. When training the ANN, the similar input vectors are combined to form clusters. In case of new input, the neural network produce an output response representing the input pattern class. The environment does not give any feedback or information about the expected desired output. Reinforcement Learning is a type of learning that is used to reinforce the network over some critic information [25]. This learning process is similar to supervised learning but with lesser information. The network receives some feedback from the environment which makes it similar to supervised learning. However, the feedback obtained is evaluative not instructive.

Chang *et.al* [26] also proposed an automatic method for thyroid nodule segmentation. Histogram equalization enhanced the thyroid image contrast and a 3 x 3 median filter were applied to suppress speckle noise. A decision tree algorithm segment the possible nodular area and refinement process obtain complete nodular contour. Chang *et al.[*27] determined the volume of ultrasound thyroid gland .The radial basis function neural network was used to classify blocks of thyroid gland. In order to acquire the integral region, a specific growing method was applied to potential points of interest. Selvathi and Sharnitha [28] developed an automatic system that segment ultrasound thyroid gland images usingsupport vector machine and wavelet transform. The Adaptive Weighted Median Filter (AWMF) was used for reducing speckle noise and a set of 3x3 closing operations were applied to remove the redundancy enhanced by AWMF. A Gray level compensation technique was used to adjust the intensity of the probable thyroid region and the method gives an accuracy of 86%. Only two statistical features (mean and variance) were extracted from the selected ROIs using Haar wavelet.

**Deep Learning**

Deep learning is a sub-field of machine learning in which a model learn features and tasks directly from data using neural network. Unlike other machine learning algorithms, it is capable of handling high dimensional data and efficient in focusing on the right features onits own [29]). A deep neural network consists of multiple layers between the input and output layers [30]. A **Convolutional Neural Network (CNN)** is a deep learning algorithm that is commonly applied to analyzing visual imagery. It consists of multiple layers with different functions.CNN is a class of deep *neural networks* that takes an input image, assign learnable weights and biases to various aspects in the image in order to segment the image.

ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
Vol. 7, Issue 8 , August 2020

Ma *et al.*,[31] segmented thyroid nodules using convolutional neural network. A thyroid nodules segmentation problem was formulated as a patch classification task. The CNN applied image patches from thyroid nodules as input and generated segmentation probability maps as output. Kumar et al., [32] developed an algorithm to segment thyroid anatomy into nodules, normal gland, and cystic components using multi-prong CNN (MPCNN) and achieved a mean Dice coefficient of 0.76, a mean true positive fraction of 0.90, and a mean false positive fraction of $1.61 \times 10^{-6}$ .

## III COMPARISON OF THE SEGMENTATION METHODS

Graph cut is an effective method because the user utilizes both the boundary and the regional information. However, it is a semi-automatic method as the user needs to mark the region as thyroid or non-thyroid. Active contour model developed by

Chan and Vessse [13] can work well on noisy images and can detect objects whose boundaries are not defined by gradient or with very smooth boundaries but assumes approximately piecewise constant intensities for object and background regions which is not true in thyroid US images. The neutrosophic method of segmentation proposed by Koundal et al [19] is proficient in revealing thyroid nodules regardless of intensities variation but require rough estimate of region of interest. Machine learning method of segmentation can easily identify the pattern in the thyroid images but require development of appropriate selection algorithm. Deep learning modellearns features directly from data using neural network and is efficient in focusing on the right features onits own but require large number of labelled training data.

Table1: Related Works on Segmentation of Ultrasound Thyroid Image

ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
Vol. 7, Issue 8 , August 2020

Table1: Related Works on Segmentation of Ultrasound Thyroid Image

| Author/Year | Segmentation Methods | Performance Metrics (%) |
|---|---|---|
| Shi and Malik [13] | Normalised Cut (N-cut Method) | Accuracy 92.00 |
| Chan and Vessse [14] | Active Contour Model Without Edge | Accuracy 80.00 |
| Selvathi and Sharnitha[28] | Support Vector Machine | Accuracy 86.00 |
| Guoand Sengur[18] | Neutrosophic C-Means (NCM) | True Positive: 88.5, False Positive:10.93 Dice Coefficient 78.50 |
| Koundal e*t al.* [19] | Spatial Neutrosophic Distance Regularizer Level Set (SNDRLS) | True Positive: 95.92, False Positive:7.04 Dice Coefficient 93.88 |
| Poudel*et al.*,[12] | Active Contour | Accuracy 86.70 |
| Ma et al., [31] | CNN | Accuracy 83.02 |
| Poudel*et al.*[16] | Graph Cut | Dice Coefficient 70.00 Hausdorff Distance 8.3 |
| Haji and Yousif[17] | Seed Point Selection based on Higher Order Spectra (SSHOS) | True Positive: 96.44, False Positive:3.55Dice Coefficient 92.24 |
| Kumar et al.,[32] | Multi-Prong CNN | Dice coefficient: 0.76, True positive: 0.90 False Positive: $1.61 \times 10^{6}$ . |

## IV. CONCLUSION AND FUTURE SCOPE

In this paper, various segmentation techniques have been reviewed which could assist the radiologists in the interpretation of ultrasound thyroid images and serve as second opinion tools for accurate segmentation of ultrasound thyroid nodules. Further research can also consider segmentation of thyroid images obtained from other imaging modalities such X-ray, CT scan Computed Tomography and Magnetic Resonance Imaging. Furthermore, more efficient computer techniques for determination of size of thyroid nodules can also be developed.

## REFERENCES


[1] Dhaygude P., .Maharashtra P., Handore S.M., "A Review of Thyroid Disorder Detection Using Medical Images "International Journal on Recent and Innovation Trends in Computing and Communication'', vol.7 issue12, : pp. 4194 – 4197, 2014

[2] Saini S., Arora K., "A Study Analysis on the Different Image Segmentation Techniques**,** International Journal of Information & Computation Technology.Vol. 4issue14: pp. 1445-1452, 2015

[3] Chalana V., Kim Y.,"A methodology for evaluation of boundary detection on medical images'',IEEE Transactions onMedical Imaging, vol. 16**:** pp. 642-652, 1997

[4] Selvathi D., Sharnitha D.,"Thyroid Segmentation in Ultrasound Images using Support Vector Machine, International Journal of Neural Networks and Applications,vol.4, issue1, pp. 7-12, 2011

[5] Ahirwar A.,"Study of Techniques used for Medical Image Segmentation and Computation of Statistical Test for Region Classification of Brain MRI', Information Technology andComputer Science, vol. 5:pp. 44-53, 2013

[6] Zou,K., Warfield,S.,Bharatha,A., Tempany, M., Kaus, S., HakerJ., KikinisR.,"Statistical validation of image segmentation quality based on a spatial overlap index''. Academic radiology, vol., 11,issue 2**,** pp.178–189, 2004

[7] . Keramidas, E., Iakovidis, D.,Maroulis, S.,Karkanis, S.,"Efficient and Effective Ultrasound Image Analysis Scheme forThyroid Nodule Detection''In the proceedings of 2007 International Conference on Image Analysis and Recognitionpp. 1052-1060, 2007

[8] Savelonas, M.A.,Iakovidis. D.K., Dimitropoulos, N.,Maroulis, D., "Computational Characterization of Thyroid Tissue in the Radon Domain'', IEEE International Symposium on Computer-Based Medical System,
[9] Savelonas, M.A.,Iakovidis, D.K., LegakisI., and Maroulis, D., "Active Contours Guided by Echogenicity and Texture for Delineation of Thyroid Nodules in Ultrasound Images'', IEEETransactions on Information Technology in Biomedicine, pp. 519-527, 2009
[10] Chang, V., Tsai, M., and Chen, S., "Classification of the Thyroid Nodules Using Support Vector Machines'', In the proceedings of 2008 International Joint Conference on Neural Networks,(IJCNN), pp.3093-3098, 2008
[11] Rother, C., Kolmogorov, V., Blake, A., "Grabcut: interactive foreground extraction using iterated graph cuts'',ACM,' vol.23, no. 3, pp. 309–314, 2004.
[12] Poudel, P.,. Hansen, C.,. Sprung, J.,Friebe, M.,"3D segmentation of thyroid ultrasound images using active contours'' Current Directions in Biomedical Engineering, vol.2, issue 1: pp. 467–470, 2015
[13] Shi, J., Malik., J., "Normalized Cuts and Image Segmentation'', IEEE Transactions on Pattern Analysis and Machine Intelligence ,vol. 22, issue 8, pp. 88-90., 2000
[14] Chan, T., Vessse, T.F., "Active Contours edges'', IEEE Transactions on. Image Processing'', pp 266-277., 2001
[15] Mahmood, N.H., "Segmentation and Area Measurement for Thyroid Ultrasound Image''. International Journal of Scientific and Engineering Research,vol.2 issue 12, pp 1-8,2011
[16] Poudel, P.,Illanes, A.,Sheet, D.,Friebe M.," Evaluation of Commonly Used Algorithms for Thyroid Ultrasound Images Segmentation and Improvement Using Machine Learning Approaches'' .Journal of Healthcare Engineering,. 2018; 2 018:8087624. DOI: 10.1155/2018/8087624.
[17] Haji, S.,Yousif, R.,"A Novel Neutrosophic Method for Automatic Seed Point Selection in Thyroid Nodule Images''. BioMed Research International, vol.1 pp.1-14, 2019
[18] Guo., Y.,Sengur, A., NCM: "Neutrosophic c-means clustering algorithm''. Pattern Recognition.vol.48,issue 8,pp. 2710-2724, 2015
[19] Koundal, D.,. Gupta, S.,Singh, S.,"Applications of Neutrosophic Sets in Medical Image Diagnosing and segmentation''. In F. Smarandache, (Ed.) New Trends in Neutrosophic Theory and Applications, Brussels, Belgium, pp. 257–275, 2016
[20] Simon, A., Singh, D,Selvam, V.,Ramesh, B.,"An Overview of Machine Learning and its Applications. International Journal of Electrical Sciences & Engineering. vol. 22-24.,2016
[21] .Bengio, Y.,Courville, A., Vincent, P., "Representation Learning: A Review and New Perspectives". IEEE Transactions on pattern Analysis and Machine Intelligence,vol.35,issue 8, pp. 1798 – 1828, 2013
[22] Schmidhuber, J.,"Deep Learning in Neural Networks: An Overview". Neural Networks. vol61, pp 85–117, 2015
[23] Kotsiantis S.B., Supervised Machine Learning: A Review of Classification Techniques, Classification Techniques Informatica vol.31,pp.249-268, 2007
[24] Brownlee, J. Supervised and Unsupervised Machine Learning Algorithms, https:// Machine learning mastery.com /supervised-and-unsupervised-machine-learning-algorithms/ 2016 Date accessed 6th August, 2018
[25] TechlabsM., Reinforcement Learning and Its Practical Applications,https:// chat botsmagazine.com/ reinforcement-learning and- its- practical-applications- 8499e6 0cf751, Date accessed: 3rd October, 2018
[26] Chang, C., Huang, H., Chen, S., Thyroid Nodule Segmentation and Component Analysis in Ultrasound Images, "In the Proceedings of 2009 Asia-Pacific Signal and Information Processing Association Annual Summit and Conference''Sapporo, Japan. pp 910-917, 2009
[27] Chang, C. Lei, Y. Tseng, C.,. Shih S.," Thyroid Segmentation and Volume Estimation in Ultrasound Images''. IEE Transactions on Biomedical Engineering'', vol. 57, issue 6, pp1348-1357, 2010
[28] Selvathi,, DSharnitha,V." Thyroid Segmentation in Ultrasound Images using Support Vector Machine'', "International Journal of Neural Networks and Applications'vol.4, issue 1, pp. 7-12, 2011
[29] Bengio,"Learning Deep Architectures for AI" "Foundations and Trends in Machine Learning'', vol. 2 issue pp 1–12, 2009
[30] Bengio, Y.,LeCun Y., Hinton , G., "Deep Learning". Nature. *vol 521 :* pp.436–444, 2015
[31] Ma, J.,Wu, F., Zhu, J.,Xu, D., Kong, D. "A Pre-trained Convolutional Neural Network Based Method for Thyroid Nodule Diagnosis. Ultrasonics',.Vol 73,2017
[32] V. Kumar V., J. Webb , A. Gregory, D. Meixner J.M Knudsen, M. Callstrom , "Automated Segmentation of Thyroid Nodule, Gland, and Cystic Components From Ultrasound Images Using Deep Learning, IEEE Access, vol. 8, pp. 6348-6349, 2020