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Thyroid Gland Segmentation of Ultrasound Images Based on Neural Networks: A Review

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Abstract: Thyroid gland is butterfly shaped organ which consists of two cone lobes and belongs to the endocrine system. It lies in front of the neck below the adams apple. Thyroid disorders are some kind of abnormalities in thyroid gland which can give rise to nodules like hypothyroidism, hyperthyroidism, goiter, benign and malignant etc. Ultrasound (US) is one among the hugely used modality to detect the thyroid disorders because it has some benefits over other techniques like non-invasiveness, low cost, free of ionizing radiations etc. This paper provides a concise overview about segmentation of thyroid nodules and importance of neural networks comparative to other techniques.

Keywords: Image Processing, US, Thyroid, Thyroid disorders, Neural Networks, FFNN, FBNN. Segmentation.

I. INTRODUCTION

Image processing is one of the kind of signal processing in which an image or video is an input and output may be an image, video or set of parameters interconnected with that image. Any Image can get taken according to our field or requirements. Image processing generally refers as digital image processing. Digital image processing involves computer algorithms to achieve processing over digital images [1].

Medical imaging is one of the important areas of image processing, as manual diagnosis is more laborious and time consuming comparative to computerized techniques. With technology advancements, lots of techniques had originated to detect the various diseases associated with human body. Various Imaging technologies are there like MRI (Magnetic Resonance Imaging), X-rays, CT (Computed Tomography), OCT (Optical Coherence Tomography) and US (Ultrasound).

Thyroid gland belongs to endocrine system & consists of two cone lobs. It is butterfly shaped organ and lies just below the thyroid cartilage within in neck. It is helpful in controlling the secretion of hormones, metabolism as well as childhood growth and intelligence [2]. Thyroid nodules are nothing but disorders in thyroid gland that may have adverse affect on human body. In addition to MRI and CT scans, US is one of the broadly used technique to detect the thyroid disorders because of its benefits like immediate response, short acquisition times, free of ionizing radiations, non-invasiveness and low cost comparative to other techniques [3].

Thyroid nodules contain two main types i.e. benign and cancerous or malignant [4], except these hypothyroidism and hyperthyroidism are also the categories of thyroid disorders [5]. Symptoms or signs of thyroid gland involve sudden increase in weight, unexplained weight loss, depression, constipation and infertility etc. [6].

As ultrasound images are best for clinical use in order to detect the thyroid nodule. But it has also a limitation that ultrasound images contain speckle noise in addition to grain noise [3]. Noise can corrupt the quality of an image as well as it may also leave adverse effect on results of segmentation. Various filtering techniques are there to remove the speckle noise from an ultrasound images like Gaussian filter, anisotropic filter, adaptive weighted median filter, median filter wavelet transform [7], BPDHE (Brightness Preserving Dynamic Histogram Equalization) and BPDFHE (Brightness Preserving Dynamic Fuzzy Histogram Equalization) [8]. Among these BPDFHE has been considered as best image enhancement technique after comparing its results with BPDHE and GHE (Global histogram Equalization).Following figure shows the ultrasound image of benign nodule.

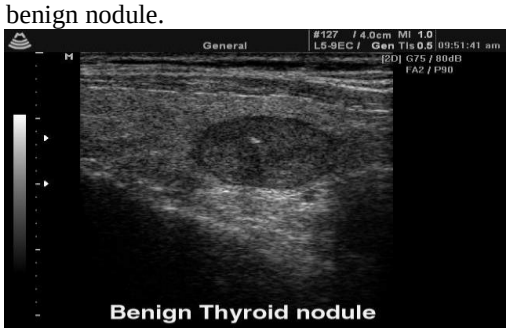

Figure 1. Ultrasound image of thyroid nodule [9]

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Segmentation is defined as process of partitioning an image into multiple set of pixels called super pixels. Basically segmentation is used to locate the objects like line, curves, boundaries etc. Pixels in particular region have same characteristics in some manner like color, texture and intensity etc [1]. Segmentation plays an important role in medical analysis or in clinical use like lung detection, cancer detection, iris recognition, locating tumors, surgery planning and intra surgery navigation etc [10].Segmentation of medical imaging becomes a challenge due to poor quality of images [1]. Except the medical field lots of other application of segmentation are machine vision, content based image retrieval, object detection, brake light detection and face detection etc [10]. .Segmentation of thyroid nodule involves different steps depending upon particular segmentation method. Various segmentation methods are there like neural networks, edge detection, histogram methods, compression methods, clustering methods, region growing methods etc [10].

An artificial neural network is a group of interconnected nodes similar to the huge network of neurons in a brain. 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 as shown below [11].Basically neural network has three layers i.e. input layer, hidden layer & output layer. These layers communicate with one another over a large number of weighted connections.

There is no single formal definition of artificial neural network. Though, a class of statistical models may commonly be called "Neural" if they consist of sets of adaptive weights & are capable of estimating non-linear functions. Adaptive weights are connection strengths between neurons, which get activated during prediction as well as training phase.

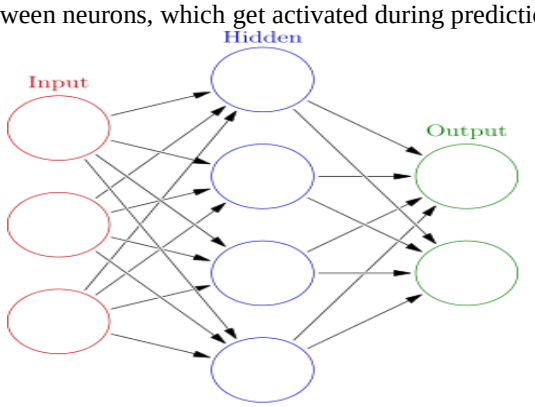

Figure 1. Neural Networks [11]

In machine learning, artificial neural networks (ANNs) are a family of statistical learning algorithms motivated by biological neural networks (Central nervous systems like brain) & used to estimate the functions that can depend on a large number of inputs and are generally unknown [11].Generally, they are presented as interconnected neurons to compute values from inputs & accomplished of machine learning as well as pattern recognition.

Typically neural network is defined by following three parameters:-

1. Interconnection pattern between the different neuron layers.
2. Learning process to update the weights of the interconnection.
3. Activation function to convert weighted input of neuron into an output.
   Various applications areas of neural networks are Function approximation or Regression analysis, Classification, Data processing, Robotics, control and decision making etc [11].

Two basic types of neural networks are [12] :-

1. *Feed Forward Neural Networks (FFNN)*: FFNN is an artificial neural network which do not involves any kind of directed cycle & it is totally different from recurrent neural networks.
2. *Feed Back Neural Networks (FBNN):* FBNN is an artificial neural network which forms a directed cycle & it is also called as recurrent neural network.

II. RELATED WORK

In Paper 2008 Helmy A**.** et al. [14] **"**Application of thermography for non-invasive diagnosis of thyroid gland disease**"** proposed an application called thermography which non-invasively diagnosis the thyroid gland disease. Based on non-invasive system, a computer based prototype device was designed which can detect & display the relative variations of skin temperature & can diagnose the hyperactivity within the thyroid gland. They also presented a FEA (Finite Element Analysis) of thyroid nodule to inspect the temperature distribution in combination with prototype and to determine the required sensor resolution. They have used Non-contact IR (infrared) thermocouple sensors & Data Acquisition (DAQ) system which is sensory 518 card having 16 bit resolution. Simulation results predicted that a thermocouple temperature resolution of 0.1 ^{o}C would be adequate for solving the problem. Drawbacks of the system are that it involves variability in sensor skin distance, limited resolution & optical overlapping in focus alignment.

In Paper 2008 Chen Y.T. et al. [15] "The image feature analysis for microscopic thyroid tissue classification" presented a paper in which they described the histological image feature analysis for classification of varying microscopic thyroid tissue. They characterized five kinds of typical thyroid tissues with seven features like hue, entropy, regularity, brightness, fractal analysis, energy & standard deviation of brightness. In order to classify the features, they have used

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statistical stepwise selection and multiple discriminant analysis to classify the pathological tissues successfully. They also proposed quad-tree based algorithm for segmentation of heterogeneous microscopic images. Results show that all features are significant & algorithm is capable to classify the pathological thyroid tissues.

In Paper 2010 Gopinath B. & Gupta B.R. [4] "Majority voting based classification of thyroid carcinoma" presented a paper which involves the segmentation and classification of Papillary carcinoma & Medullary carcinoma cells in FNAB (Fine Needle Aspiration Biopsy) microscopic cytological images of thyroid nodules. They have used mathematical morphology for image segmentation in order to remove the background staining information from microscopic images. Then, Feature Extraction is done by Discrete Wavelet Transform (DWT) and Gray Level Co-occurrence Matrix (GLCM).For classification they have used k-Nearest Neighbor (kNN) classifier. Diagnostic accuracy reported by the DWT & GLCM is 97.5% and 75.84% respectively. Authors implemented Majority voting rule to improve the diagnostic accuracy of GLCM by 90%.

In Paper 2010 Gabriel E. et al. [16] "Towards high performance cell segmentation in multispectral fine needle aspiration cytology of thyroid lesions" presented a paper in which they have discussed segmentation of thyroid lesions in multispectral FNAC (Fine Needle Aspiration Cytology). They introduced texture based two parallel versions of code for segmentation of FNAC images. Two versions are named as MPI and open MP; MPI version of the code exploits distributed memory of resources like PC clusters and open MP version provides parallel execution or multi-core CPU architectures. They have taken 21 spectral channel images with size from 1024×1024 pixels to 12288×12288 pixels. Then both versions undergoes through performance and scalability.

In Paper 2013 Azar A.T. et al. [17] "Fuzzy and hard clustering analysis for thyroid disease" presented a paper in which they introduced fuzzy & hard clustering methods for analysis of thyroid disease. They have compared performance of both hard and fuzzy clustering methods in order to find the optimal number of clusters by using various scalar validity measures. They have used features values as input and after carried out the several runs they recorded their number of clusters. In order to find the optimal number of clusters they applied elbow criterion and results show that elbow was located at c=3 for each algorithm. Then they used sammon mapping method to check the clustering results and to find the low dimensional representation in high dimensional pattern space. After visualization results they concluded that fuzzy c-means is better for thyroid disease and at the end they also gave some recommendations for improvement purpose.

In Paper 2014 Jin C. et al. [13] "MRI-based three-dimensional thermal physiological characterization of thyroid gland of human body" presented a paper in which they introduced 3D thermal physiological characterization of thyroid gland based on MRI. They reveal some facts such as thyroid gland shows non-uniform thermal distribution & localized hotter manifestation due to high metabolic & blood perfusion properties. Also intentional cooling modality increases the thermal manifestations of thyroid gland & helps us to identify the metabolic function. Results verified that temperature difference is 3.0–3.12◦C. between maximum of thyroid region & minimum of prominentia laryngea region. They suggested that airflow volume has largest effect whereas thermal effects caused by the blood-flow velocity as well as varying breathing frequency has minor or ignorable effect on total heat flux of thyroid surface. They also concluded that proposed method provides better understanding for thermal mechanism of thyroid diseases under different conditions and is more feasible to monitor the thyroid morphologic and functional alterations with the help of infrared thermography.

III. NEED AND SIGNIFICANCE

There are some of the drawbacks of previous techniques that are explained below:

- Existing techniques do not always able to distinguishing structures such as bigger blood vessels from actual nodules.
- Existing segmentation techniques generally results in broken edges and may suffers from problem of official overlap during focus alignment.
- Existing techniques are device dependent because they demand special set of parameters for the segmentation if they get taken from different US devices.
- In existing system there is lack of clarity in segmentation and also HAAR wavelet that they have used to extract features becomes obsolete in present scenario. Because it can increase the size of feature vector and can increase the complexity due to single decomposition waveform for input as well as output.

IV. PROPOSED METHODOLOGY

After studying lot of papers on different techniques, it becomes clear to choose the Neural networks which has incredible capability to provide the meaningful information comparative to other methods. It can provide precise information form imprecise as well as complex data in order to extract patterns and objects that may undergo difficulties with other techniques or in case of manual diagnosis.

V. CONCLUSION

Thyroid gland belongs to the endocrine system it is butterfly shaped organ consisting of two cone lobes. It is located in front of the neck below the adams apple. Thyroid nodules are some kind of disorders in thyroid gland which can give rise to various abnormalities or problems like hyperthyroidism, hypothyroidism, benign and malignant etc. To diagnose these problems at right time becomes very important task otherwise it may cause some more dangerous effects further. Ultrasound (US) is vastly used modality for clinical use for detecting the thyroid abnormalities because it has some benefits like non-invasiveness, low cost, free of ionizing radiations etc unlike MRI or CT scans. This paper presented a review on segmentation of thyroid nodules and capabilities of neural networks comparative to other techniques.

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