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Unsupervised Segmentation Method for Thyroid Nodules in Ultrasound Images

Hajer Z. Refaat[1], Faleh H. Mahmood*[2]

[1]Department of Physics, College of Science, University of Baghdad, Baghdad, Iraq

[2] Remote Sensing Unit, College of Science, University of Baghdad, Baghdad, Iraq

Abstract

Thyroid is a small butterfly shaped gland located in the front of the neck just below the Adams apple. Thyroid is one of the endocrine gland, which produces hormones that help the body to control metabolism. A different thyroid disorder includes Hyperthyroidism, Hypothyroidism, and thyroid nodules (benign/malignant). Ultrasound imaging is most commonly used to detect and classify abnormalities of the thyroid gland. Segmentation method is a tool that used widely in many applications including medical image processing. One of the common applications of segmentation is in medical image analysis for clinical diagnosis that has an important role in terms of quality and quantity.

The main objective of this research is to use the Computer-Aided Diagnosis (CAD) algorithms to help the early detection of thyroid tumors. Thyroid ultrasound images may contain speckle noise which leads to obtain incorrect result. In order to obtain good accuracy; the noise must be removed from the input image. Those propose method is started with pre-processing of the thyroid ultrasound image to enhance its contrast and removing the undesired noise in order to make the image suitable for further processing. In our proposed work, we are using bilateral filter and unsharp filter to remove speckle noise to perform the pre-processing operations on the thyroid ultrasound images. The segmentation process is performed by using Fuzzy C-Means (FCM) algorithm to detect and segment thyroid ultrasound images for the thyroid region extracted image to 6 classes for two sample normal and abnormal images. The resulted segmented ultrasound images, and then used to extract the tumor region from thyroid's image.

Keywords: Medical imaging, Thyroid nodules, Ultrasound imaging, bilateral filtering, unsharp filtering, Segmentation, fuzzy c-mean

طريقة تقسيم غيرمرشدة لعقيدات الغدة الدرقية لصور الموجات فوق الصوتية

هاجر زهير رفعت[1]، فالح حسن محمود[2]

[1]قسم الفيزياء، كلية العلوم، جامعة بغداد، بغداد، العراق.

[*2]وحدة الاستشعارعن بعد، كلية العلوم، جامعة بغداد، بغداد، العراق

الخلاصة

الغدة الدرقية هي غدة على شكل فراشة صغيرة تقع في الجزء الأمامي من الرقبة أقل بقليل من تفاحة ادام. الغدة الدرقية هي واحدة من الغدد الصماء، التي تنتج الهرمونات التي تساعد الجسم على السيطرة على عملية التمثيل الغذائي. يتضمن اضطرابات الغدة الدرقية المختلفة ، نشاط الغدة الدرقية المفرطة، تضخم الغدة الدرقية، وعقيدات الغدة الدرقية (الحميدة / الخبيثة). يعتبر التصوير بالموجات فوق الصوتية (Ultrasound)

*Email: faleh_sine@yahoo.com

الأكثر شيوعا لكشف وتصنيف شذوذ الغدة الدرقية. ان طريقة تقسيم الصور هو الأداة التي تستخدم على نطاق واسع في العديد من تطبيقات المعالجة الصورية بما في ذلك معالجة الصور الطبية وهي واحدة من التطبيقات المهمة والشائعة للتجزئة لغرض تحليل الصور الطبية وكذلك لتشخيص المرض سريريا والتي لها دور مهم من حيث النوعية والكمية.

الهدف الرئيسي من هذا البحث هو استخدام خوارزميات التشخيص بواسطة الحاسوب (CAD) للمساعدة في الكشف المبكر عن أورام الغدة الدرقية. ان صور الغدة الدرقية الماخوذة بواسطة الموجات فوق الصوتية(US) تحتوي على ضوضاء بقعية تؤدي الى حصول نتائج غير مرغوب فيها .ولغرض الحصول على نتائج مرضية يجب ازالة الضوضاء من تلك الصور . الطريقة المقترحة تتمثل بالتهيئة الاولية ما قبل المعالجة لصورالموجات فوق الصوتية للغدة الدرقية لغرض زيادة الوضوحية وإزالة الضوضاء غير المرغوب فيها من أجل جعل الصورة مناسبة للمعالجة. وقد تم اعتماد المرشحات لهذا الغرض. ان عملية تجزئة الصورة تمت باستخدام خوارزمية معدل التضبيب المسماة بالـ ((Fuzzy C–Mean (FCM لتجزئة الصورة الى ستة اجزاء. حيث تم استخدام نتائجها بعد ذلك لعزل منطقة الورم من صورة الغدة الدرقية .

Introduction

Medical imaging has experienced tremendous progress during the past decade. Continuous innovations have been fueled by the need to improve diagnostic yield and achieve fast turnaround through robust information management, which should ultimately improve patient outcome. The rapid changes in digital technology have also created opportunities for the development of high-tech equipment employed in medical imaging practice. Incidentally, these changes tend to revolve around key modalities such as radiography, Computed Tomography (CT), Magnetic Resonance Imaging (MRI) and Ultrasound (US). In many instances, one modality tends to augment the limitations associated with others [1-2].

Thyroid is one of the endocrine Gland. Thyroid can be classified into normal, nodule and cancers thyroid. The characterization of the thyroid tissue in digital image processing techniques offer's the texture description and using the ultrasound images [3]. Thyroid ultrasound technology can ensure that you get a lot of information about thyroid nodule before the operation. Through the ultrasound images, we can locate the position of the thyroid nodule, measure the size, and decide whether an operation is needed or not. The properties of ultrasound, such as echo, shadow, and reflection, will degrade the image quality, which makes it difficult to recognize the edges for an experienced physician. This image quality degradation caused by the nature of ultrasonic image. Especially it is very difficult to complete the nodules and tracheal of nodules positioning area of the regional segmentation. In ultrasound images, there are some other ultrasound characteristics which can also be acted as a judgment indicator which shows possibility of nodular malignant, such as the shape and contour of nodules [4].

Epidemiological studies show that the infection rate of thyroid nodule is very high and increases with the age. Thyroid nodule may presage appearance of cancer. Thyroid carcinoma is different from other cancer. Most thyroid nodules are symptomatic which makes thyroid cancer different from other cancers. The thyroid nodule can be completely cured if detected early. Therefore, it is necessary to correctly classify the thyroid nodule to be benign or malignant. The accuracy of ultrasound diagnosis of thyroid nodule improves constantly, and it has become the first choice for auxiliary examination of thyroid nodular disease. If we could combine medical imaging technology and Physician experience, the diagnostic rate of thyroid nodule would be improved significantly [5].

Ultrasound imaging system is widely used diagnostic tool for modern medicine. It is used to do the visualization of muscles, internal organs of the human body, size and structure and injuries. Obstetric sonography is used during pregnancy. In an ultrasound imaging speckle noise shows its presence while doing the visualization process [6]. Reducing noise from the medical image is a challenge for the researchers in digital image processing. Medical images are usually degraded by noise during image acquisition and transmission process. Thyroid ultrasound images may contain speckle noise which leads to obtain incorrect result. The speckle noise produced in the formation process of ultrasound image of thyroid tumor makes the quality of the image deteriorate. In order to obtain good accuracy; the noise must be removed from the input image. Several approaches are there for noise reduction. The main purpose of the noise reduction technique or image enhancement is to remove speckle noise or to improve the interpretability or perception of information in images for human viewers, or to provide `better' input for other automated image processing techniques [7].

At present, one of the most important operations in computer vision is segmentation. The segmentation method which is widely used in the clinical application of ultrasound imaging systems is based on the threshold value method or the doctor manual segmentation method. Although the implement method of threshold segmentation is convenient and simple, inevitably, the speckle noise and texture in the ultrasound image make the method difficult to obtain satisfactory results [8].

Segmentation is the task of recognizing objects in an image. The rest of the image is background. The aim of image segmentation is the domain independent partition of the image into a set of regions which are visually distinct and uniform with respect to low level information, such as gray level, texture or color. The output of this is used as input in high level processing such as object recognition, scene analysis etc. Generally segmentation methods are based on two basic properties of the pixels in relation to their local neighborhood: discontinuity and similarity. Methods based on some discontinuity property of the pixels are called boundary based methods, whereas methods based on some similarity property are called region-based methods. Unfortunately, both techniques often fail to produce accurate segmentation results [9]. In our proposed work, we are using image segmentation technique based on the fuzzy C-Means algorithm (FCM).

The remainder of this paper is organized as follows. In section 2, analyze the characteristics of thyroid glands and nodule ultrasound image. The material and methods for segmentation of thyroid ultrasound image based on the fuzzy C-Means algorithm (FCM) is introduced in section 3. The thyroid region has been segmented using the algorithm of the proposed method and the implementation and results are given in section 4, this paper is concluded in section 5

Thyroid Glands and Nodules

The thyroid gland is a butterfly-shaped endocrine gland that is normally located in the lower front of the neck is composed of two cone-like lobes. It starts cranially at the oblique line on the thyroid cartilage (just below the laryngeal prominence or Adam's apple) and extends inferiorly to the fifth or sixth tracheal ring as shown in Figure-1. It is difficult to demarcate the gland's upper and lower border with vertebral levels because it moves position in relation to these during swallowing. The thyroid's job is to make thyroid hormones, which are secreted into the blood and then carried to every tissue in the body. Thyroid hormone helps the body use energy, stay warm and keep the brain, heart, muscles, and other organs working as they should [10].

The term thyroid nodule refers to an abnormal growth of thyroid cells that forms a lump within the thyroid gland. Although the vast majority of thyroid nodules are benign (noncancerous), a small proportion of thyroid nodules do contain thyroid cancer. In order to diagnose and treat thyroid cancer at the earliest stage, most thyroid nodules need some type of evaluation. Most thyroid nodules do not cause symptoms. Often, thyroid nodules are discovered incidentally during a routine physical examination or on imaging tests like CT scans or neck ultrasound done for completely unrelated reasons. Occasionally, patients themselves find thyroid nodules by noticing a lump in their neck while looking in a mirror, buttoning their collar, or fastening a necklace. Abnormal thyroid function tests may occasionally be the reason a thyroid nodule is found [11].

Thyroid nodules may produce excess amounts of thyroid hormone causing hyperthyroidism. However, most thyroid nodules, including those that cancerous, are actually non-functioning, meaning tests like Thyroid-Stimulating Hormone (TSH) are normal. Rarely, patients with thyroid nodules may complain of pain in the neck, jaw, or ear. If a nodule is large enough to compress the windpipe or esophagus, it may cause difficulty with breathing, swallowing, or cause a “tickle in the throat”. Even less commonly, hoarseness can be caused if the nodule invades the nerve that controls the vocal cords but this is usually related to thyroid cancer [12].

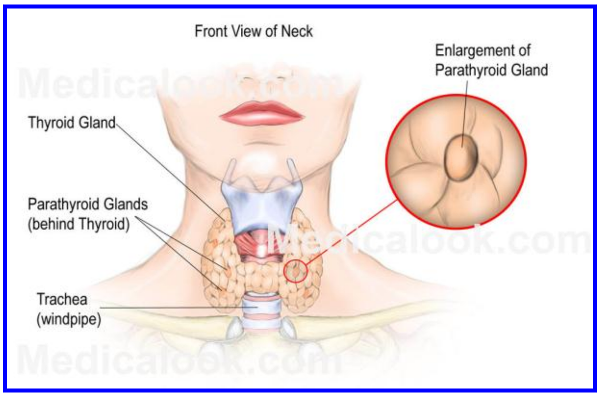


Figure 1- Structure of thyroid gland [12]

Material and Methods

In this research, the image analysis steps represents manipulation of the image data to determine the exact information required to develop the computer imaging system followed is shown in Figure-2 includes;

Image Acquisition Stage

Thyroid ultrasound images acquisition is the first step or process of the fundamental steps of digital image processing. Image acquisition could be as simple as being given an image that is already in digital form. Abnormal Ultrasound images are used in this research. A total of 10 thyroid US images were used in which 7 malignant and 3 benign images are present. In proposed method was implemented and performed only 3 cases (two malignant and one benign) that showed distinguishable tumors (i.e. preferable for our segmentation and isolated operations).Generally, the image acquisition stage involves preprocessing, to remove the noise from the input image in order to obtain a good accuracy. Here, it is worth mentioning that the samples of images used in this research are available in internet (Thyroid Images Wilmington Endocrinology PA, UBM Medical Network and AL-Kadhmiya teaching Hospital.

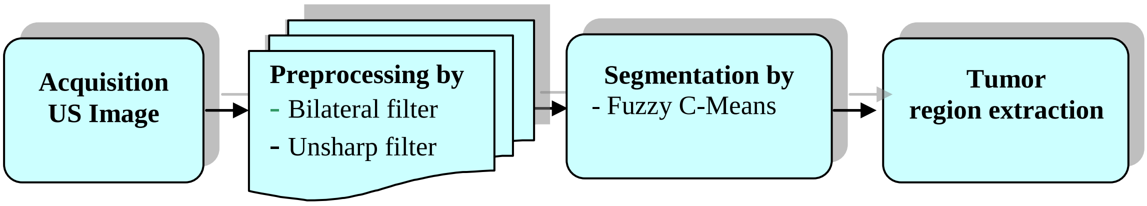


Figure 2- represents the block diagram of the processes followed in this research.

Pre-processing Stage

The first stage in any recognition system is preprocessing; in this stage, a set of image processing operations are performed in order to get the best results. preprocessing is the name for operations on images at the lowest level of abstraction whose aim is an improvement of the image data that suppress undesired distortions or enhances some image features important for further processing [13],[14] . In medical image processing and especially in tumor segmentation task it is very important to preprocess the image so that segmentation and feature extraction algorithms work correctly. Real world input data always contains some amount of noise and blur, so certain processing is needed to reduce their effects. Some desirable properties of data may also be enhanced with preprocessing stage before the image data is fed into the recognition system. Proper detection and segmentation of the tumor leads to exact extraction of features and classification of those tumors. The accurate tumor segmentation is possible if image is preprocessed as per image size and quality .The preprocessing is required for US images as [15]:

- Labels present (Film artifacts) can interfere in the post processing of these images.
- Images are to be made more suitable for further processing in CAD systems.

- The image quality needs to be enhanced
- Noise in the image needs to be removed

Preprocessing stage starts with image enhancements which tend to improve the interpretability, in this proposed work, the using of bilateral filter and unsharp filter to remove speckle noise.

The bilateral filter is technique to smooth images while preserving edges. The bilateral filter is a non-linear technique that can blur an image while respecting strong edges. Its ability to decompose an image into different scales without causing haloes after modification has made it ubiquitous in computational photography applications such as tone mapping, style transfer, relighting, and denoising . The use of bilateral filtering has grown rapidly and is now ubiquitous in image-processing applications. It has been used in various contexts such as denoising. The bilateral filter is a nonlinear technique that can blur an image while respecting strong edges. Its ability to decompose an image into different scales without causing haloes after modification has made it ubiquitous in computational photography applications such as tone mapping, style transfer, relighting, and denoising [16].

The unsharp filter technique is the most known method for contrast image enhancement. The edge extraction procedure in the unsharp masking process is usually implemented using Laplacian operator. Although this method is quite effective for enhancing a low contrast images, but it does not discriminate between the feature information and noise. This leads to poor visual perception. An Unsharp filter enhancement process has been developed for noise cancellation using the extended Teager algorithm [17]. An unsharp masking filter is also known as edge enhancement filter, which is a simple sharpening operator. The name was given because the fact that the unsharp masking filter improves details and other high frequency components in edge area via a process by subtracting an processed image from original image. Therefore, the unsharp masking filter is generally employed in the printing industries or photographic for enhancing details. An unsharp masking filter generates an detail image $d(x,y)$ from an input image $f(x,y)$ by following equation[18] .

$$d(x,y) = f(x,y) - f_s(x,y) \tag{1}$$

Where $f_s(x,y)$ is a smoothed image of $f(x,y)$ and obtained as

$$f_s(x,y) = f(x,y) - \{f(x,y) * HPF\} \tag{2}$$

Segmentation Stage using Fuzzy C-Means

Image segmentation is one of the most important tasks in computer vision and image processing. It can be performed either manually or using certain image processing and computer vision techniques. It is often an essential step in image analysis system as well as in high-level image interpretation and understanding such as robot vision, object recognition, and medical imaging. Generally, image segmentation techniques locate objects consisting pixels having something in common; e.g. having similar intensity values or same colors tone or texture, etc. [19]. It is one of the most widespread means to classify correctly the pixels of an image in a decision oriented applications. The goal of image segmentation is to partition an image into a set of disjoint regions with uniform and homogeneous attributes such as intensity, color and texture, etc. [20].

In our proposed work, we are using image segmentation technique based on the fuzzy C-Means algorithm (FCM). FCM algorithm generalizes the hard c-mans algorithm to allow a point to partially belong to multiple clusters. Therefore, it produces a soft partition for a given dataset. In fact, it produces a constrained soft partition.

FCM is a clustering algorithm introduced by Bezdek [21] based on minimizing an object function as follow:

$$J_p = \sum_{i=1}^{n} \sum_{j=1}^{m} u_{ij}^{q} d(x_i, \theta_j) \tag{3}$$

Where *u* is fuzzy membership of data x_i to cluster with center $\theta_{j,}$ and *d* is the distance between data x_i and center of the cluster (θ_j), *u* has the following conditions:

$$u_{ij} = [0,1], \sum_{j=1}^{n} u_{ij} = 1$$

Where

$$0 < \sum_{j=1}^{n} u_{ij} < n$$

The membership function and center of each cluster are obtained as follow

$$u_{ij} = 1 / \sum_{k=1}^{m} \left(d(x_i, \theta_j) / d(x_i, \theta_k) \right)^{(2/i-1)} \quad (4)$$

$$\theta_j = \sum_{k=1}^{n} u_{ij}^{q} x_i \Big/ \sum_{k=1}^{n} u_{ij}^{q} \; .$$

Where q specifies fuzziness degree of clustering. FCM optimize object function by continuously update the membership function and centers of clusters until optimization between two iteration is not more than a threshold [22].

Data is size m-by-n, where m is the number of data points and n is the number of coordinates for each data point. The coordinates for each cluster center is returned in the rows of the matrix center. The membership function matrix u contains the grade of membership of each data point in each cluster. The values 0 and 1 indicate no membership and full membership respectively. Grades between 0 and 1 indicate that the data point has partial membership in a cluster. At each iteration, an objective function is minimized to find the best location for the clusters and its values are returned [23] Implementation of the FCM segmentation can be done using the following algorithm:

Step 1: *Read the US image after thyroid region extracted.*
Step 2: *input number of clusters, fuzziness factor and number of iteration (default 100).*
Step 3: *Randomly select the initial centroid of clusters.*
Step 4: *Calculate the Euclidean distance between each pixel and centroid by:* $d = \|x_i - \theta_j\|$ *; then find the membership function using equation (4).*
Step 5: *Find an object function using equation (3).*
Step 6: *Compare between calculated object function according to above equation for two iterations. Stop if there is no change in membership function or cluster centers at two successive iterations. Otherwise go to Step 4 to update the membership values and cluster centroid.*
Step 7: *FCM method groups elements of the clusters to suitable cluster so that the distance between the element and its corresponding cluster center is minimum.*
Step 8: *Display the output image by find the index matrix for the maximum probability of each pixel have the same position in all clusters.*

Tumor Region Extraction Stage

Finally the thyroid and tumor regions are separately segmented from the US image. The operation of tumor extraction from the result classes of fuzzy c-means methods can be summarized by the following steps:

Step1*: apply* fuzzy c-means *clustering method on thyroid US image in which the tumor appears.*
Step2*: Binaries* fuzzy *C-Means class image that contain tumor with threshold 0.7 or 0.9 (depend on the image).*
Step3*: Morphologically open image to remove small objects that have fewer than P pixels (P depend on the tumor and object size), producing another binary image. The default connectivity is 8 for two dimensions.*
Step4*: Repeat steps 2-3 for all samples,*
Step5*: Extract only the object that has the area of tumor (depend on the sample) and eliminate other objects.*

The Results

In this paper overcomes the results of segmentation for thyroid nodules in ultrasound images. In the pre-processing stage, in order to obtain good accuracy, the noise must be removed from the input image we are using bilateral filter and unsharp filter to remove speckle noise as shown in (Figures - 3, 6 and 9). In the segmentation stage, FCM algorithm used to detect and segment thyroid ultrasound images for the thyroid region extracted image to 6 classes for one sample represent normal image and two sample abnormal images as shown in (Figures -4, 7 and 10). Finally the thyroid and tumor regions are separately segmented from the US image as shown in(Figures -5, 8 and 11).

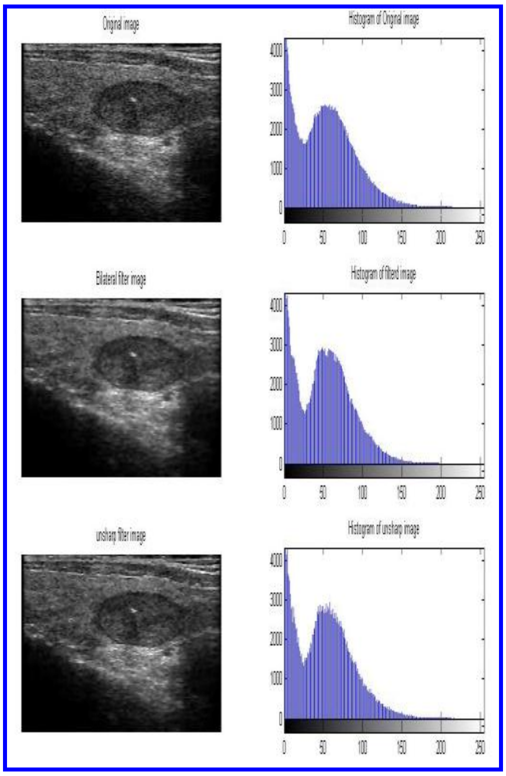


Figure 3 -(Case1) benign (noncancerous), enhancement which tend to improve image quality by remove speckle noise using;- Upper line original images, mid line bilateral filter and lower line unsharp filter

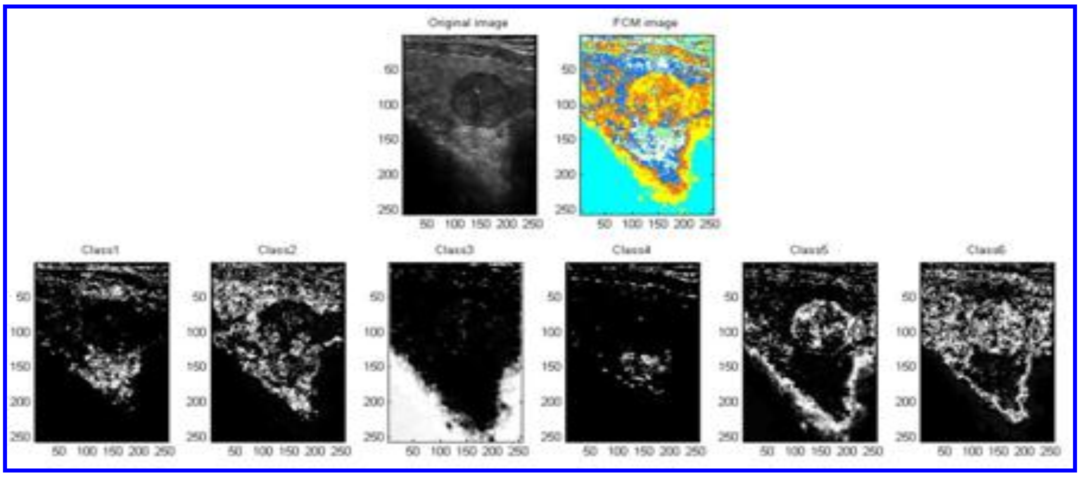
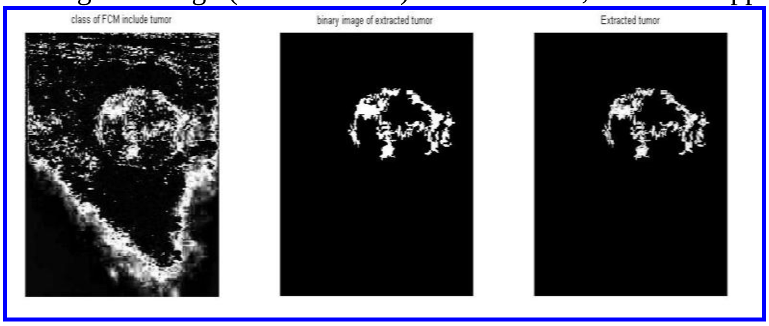


Figure 4- FCM clustering for benign (noncancerous) with 6 classes, the tumor appears in class5.



a **b** **c**

Figure 5- a) Class o FCM include tumor **b)** Binary image of extracted tumor **c)** extracted tumor

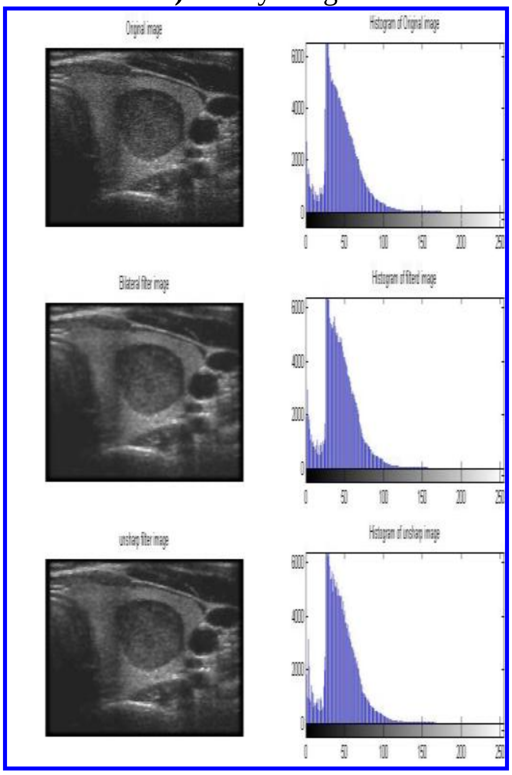


Figure 6- (Case2) malignant case (cancerous) enhancement which tend to improve image quality by remove speckle noise using;

- Upper line original images, mid line bilateral filter and lower line unsharp filter

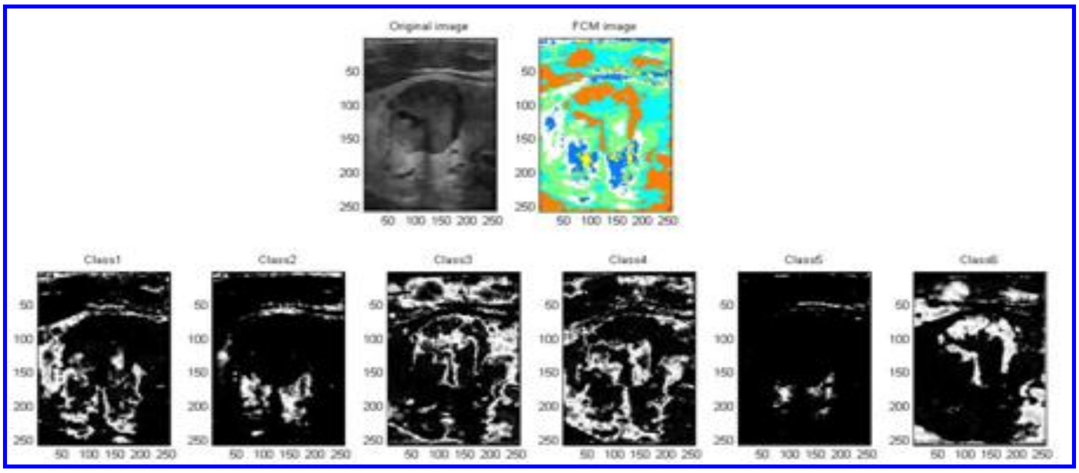
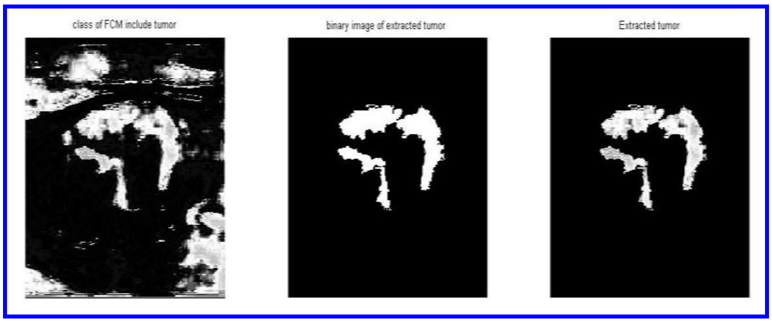


Figure 7- FCM clustering for malignant image (cancerous) with 6 classes, the tumor appears in class6.



a **b** **c**

Figure 8- a) Class o FCM include tumor **b)** Binary image of extracted tumor **c)** extracted tumor

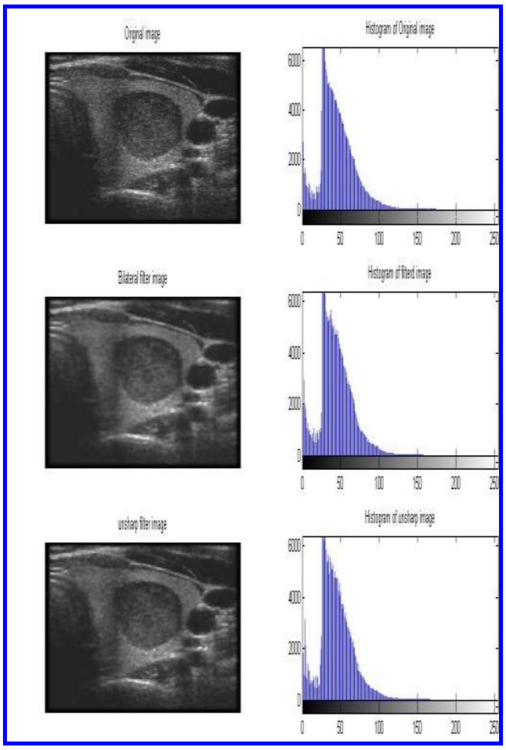


Figure 9- (Case3) malignant case (cancerous) enhancement which tend to improve image quality by remove speckle noise using;-Upper line original images, mid line bilateral filter and lower line unsharp filter

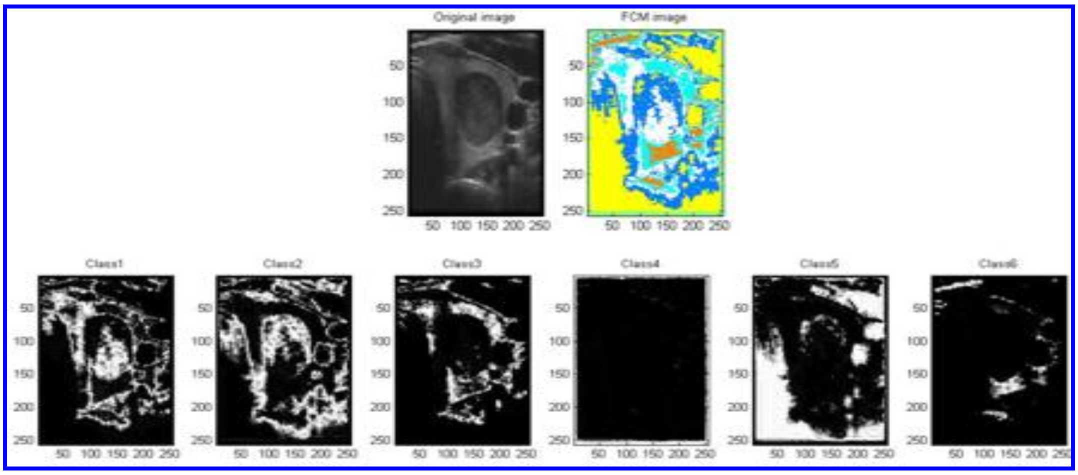
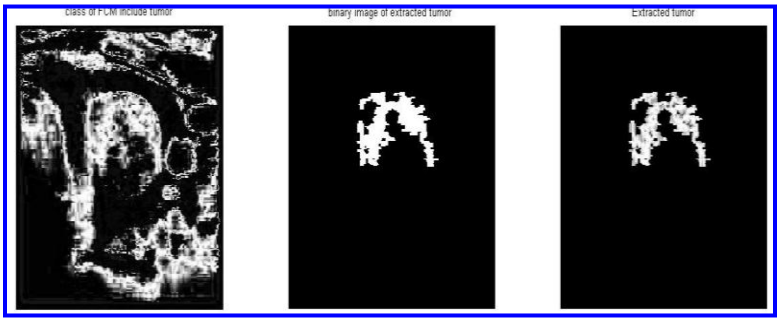


Figure 10- FCM clustering for malignant image (cancerous)) with 6 classes, the tumor appears in class2.



a **b** **c**

Figure 11- a) Class o FCM include tumor **b)** Binary image of extracted tumor **c)** extracted tumor.

Conclusion

Diagnostic imaging is an important tool in medical science due to the constrained observations of the expert and uncertainties in medical knowledge. A thyroid ultrasound is a non-invasive imaging study used to detect and classify abnormalities of the thyroid gland. Computerized system is a valuable and beneficial means for feature extraction and classification of thyroid nodule in order to eliminate operator dependency and to improve the diagnostic accuracy.

In this paper, a semi-automatic segmentation algorithm for thyroid's tumor detection and extraction is presented**.** This paper addresses the problem of segmenting a thyroid node region from US images. In the preprocessing stage, the US image process is carried over with bilateral filter and unsharp filter The algorithm is applied to image segmentation using fuzzy C-Means. Finally the Thyroid and tumor regions are separately segmented from the US image.

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