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MEASURING CHOLESTEROL USING INTIMA MEDIA AND APPLYING FUZZY TECHNIQUES FOR QUALITY ENHANCEMENT

[1]ARUMUGAVELAN S, [2] PRAMOD K V, [3] BABU SUNDAR S

[1,2,3]Department Computer Applications, Cochin University of Science and Technology, Kerala.

Abstract

Major focus of this proposed research is to apply a fuzzy reasoning system to efficiently identify the intima media thickness of the carotid artery to measure cholesterol in any ultrasound machine. In my previous research fuzzy principles have been embedded to overcome uncertainty parameters such as pixel size variation, colour variation and orientation problems in the image processing at some level. In a more generalized way, in the current research, both heuristic patterns, the generated Intima media lines have been given importance and utilized the same as input to fuzzy reasoning modules to improve the quality of the generated intima media images in a ultrasound machine in addition to efficiently fix the uncertainty parameters such as pixel size variation, orientation, problems in the image processing. These give better results comparing to my previous research. By this research, more number of heuristic patterns have been generated and given as input to the required BPN based neural network to increase the performance of the neural network and the system picked up the correct image efficiently using the same, comparing to my previous research. Thus, using any ultrasound machine, this non-invasive sonographic examination of carotid artery with these fuzzy and neural network techniques has its potential to detect skin cholesterol and cardiovascular diseases early and efficiently. The quality enhancement here in ultrasound imaging has been taken care by fuzzy reasoning techniques.

Keywords— B-Mode Ultrasound Image, Common Carotid Artery, Intima-Media Thickness, Back Propagation Neural Network.

1.INTRODUCTION

Medical Image processing plays a vital role for the analysis and diagnosis of data obtained from various imaging modalities. This helps doctors for ease interpretation of the information in medical images and better diagnosis [1]. According to the recent statistics recorded in the Journal of Radiological Society of North America, Stroke is the third major cause of increasing global death rate. People of different age groups are prone to be affected by stroke which is mainly due to carotid artery occlusion. The deposition of fatty substances such as cholesterol in carotid artery wall leads to vascular plaque and the elastic nature of the arterial wall is reduced. This causes arrest of blood supply to brain resulting in problems related to cerebral dis functioning. The prime objective is to analyse this and therefore this has been carried out in the carotid artery as a step towards early diagnosis of high risk diseases like stroke and skin cholesterol [2], [5].

Ultrasound imaging is one of the clinical diagnosis procedures, a non-invasive technique and is of low cost that can be employed to detect carotid artery occlusion, blood flow through the artery which alters with age due to thickening of carotid artery [3]. It is also possible to early diagnose stroke, which is due to the interruption of blood flow to brain. Normally ultrasound images are poor quality and contain lot of noise. Hence it is possible for the efficient and experienced physicians to extract the diagnostic details from the image. Even though manual segmentation differs from one physical to other and it is impractical when large number of carotid artery images are to be analysed which is a time-consuming task [4]. Many researchers attempt to develop different methods for automatic delineation of carotid artery boundaries.

The automatic methods have the potential in reproducing results and eliminating the strong variations in the manual tracings of different observers. Moreover, the processing time can be considerably reduced. The motivation of this study is to develop a confidential system which can identify the intima and adventitia of CCA and ICA (Internal Carotid Artery) automatically even under strong speckle noises and under different sonographic instrumentation with few modifications.

To our knowledge, there is no method which can be applied on images made by different sonographic instrumentation directly. The authors have claimed that their system can be used on other sonographic instrumentation, however, it needs some manual tracing as training patterns to re-initialize the weighting factors in their dynamic programming method [6]. The main problem is that they detect intima and adventitia separately. Although both of them use the previously detected layer as a reference, it lacks a global consideration in detecting these two layers. In my previous paper, proposed a IMT evaluation method that can detect the intima and adventitia simultaneously [14].

After detecting these edges, allowing these images for classification that can be classified as normal or abnormal. In this work, the neural network is trained with the feature extracted from the normal and abnormal images for this neural network employing back propagation training algorithm [8]. For training the neural network, compared to my previous research, more number of generated heuristic patterns have been utilized to give an efficient and quality output.

2.METHODOLOGY

A. Acquisition of the image

Carotid artery image is acquired by using ultrasound imaging, a painless and harmless test that uses high-frequency sound waves to create pictures of the insides of the two carotid arteries in neck. The basic measurement sites are four images: the front and side surfaces of the left and right common carotid arteries. Adding the four images of the front and side surfaces of left and right internal carotid arteries brings the total to eight, which is the number of measurements that can be recorded for a single patient in one day. The physician put the transducer against different spots on the neck and moves it back and forth. The transducer gives off ultrasound waves and detects their echoes after they bounce off the artery walls. A computer uses the echoes to create and record pictures of the insides of the arteries usually in black and white. Figure 1 Echoes in an ultrasonic artery image can be mapped to anatomical artery structures.

With the labelling scheme as shown below, the goal of the automated procedure is to automatically detect the echo boundaries markedI3, I5, and I7, and measure the distance between the lines I3 and I5, which is the artery's lumen diameter (LD), and the distance between I5 and I7, which is the intima - media thickness (IMT).

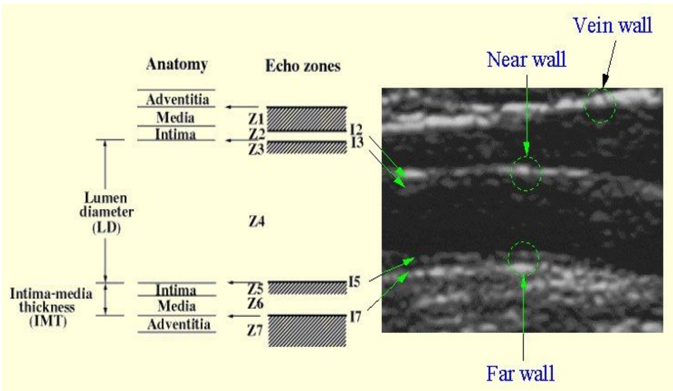

Figure 1 Mapping between ultrasonic image and anatomical structure

B. Image Pre-processing

The pre-processing module is performed for noise suppression, image smoothing and boundary enhancement. Ultrasound imaging is a widely used medical imaging procedure because it is economical and comparatively safe. But, one of its main shortcomings is the poor quality of images, which are affected by speckle noise and so filtering is used to enhance the image.

In order to extract diagnostic information from an ultrasound image, we need many kinds of image processing techniques. Among them, pre-processing is indispensable, and is particularly important to extract diagnostic information. Speckle noise in an ultrasound image, results in unclear contour of the region of interest, such as organ or a blood vessel. Speckle should be removed and the edge is preferable enhanced in the pre-processing stage. Various kinds of smoothing techniques may eliminate noise effectively.

1) Speckle Reducing Anisotropic Diffusion Filter

SRAD is an edge sensitive diffusion method for removing noise specially to speckled images. The advantage of anisotropic diffusion includes intra-region smoothing, contrast enhancement and edge preservation. Anisotropic diffusion performs well for images corrupted by additive noise. In this technique partial differential equation framed regulates the diffusion rate near the edges by calculating instantaneous coefficient of variation in the image which serves as an edge detector in speckled imagery. The function exhibits high values at edges or on high contrast features and produce low values on homogenous regions. In this proposed work speckle noise is modelled by the following (Eq.1).

$$f = u + \sqrt{un} \qquad (1)$$

where *f* is the observed image

u is the desired image to find

n is the Gaussian noise.

Due to its advantage compared to the conventional techniques, ultrasound images of carotid artery are pre-processed using SRAD method.

C. IMT Evaluation

1) Edge Detection:

Normally, the entire intima media image is a complex gray scale Patterns produced by any ultrasound machine. Hence, directly finding out the thickness of intima media image is rather a difficult one [12]. From the previous research these heuristic patterns have been generated by using the proper BPN based Neural Networks and the fuzzy concepts utilized for Noise Removals to address pixel size variation, color variation and orientation problems [14]. For training the neural network, compared to my previous research, more number of generated heuristic patterns have been prepared to give an efficient and quality output. In the current research, both heuristic patterns and the generated Intima media lines have been given importance including noise removals and utilized the same as input to fuzzy reasoning modules to improve the quality of ultrasound images in addition to efficiently fix the uncertainty parameters such as pixel size variation, orientation, problems in the image processing. These give better results comparing to my previous research This paper will discuss these fuzzy reasoning modules in the following sections, which have been utilized in this research.

2. Uncertainty Parameters addressed by Fuzzy Techniques

The above uncertainty parameters such as pixel size variation, orientation and all the related problems have been covered under grayness ambiguity, spatial ambiguity problems. These have to be addressed to different ultrasound machines (different hardware) produced by different manufacturers with different hardware specifications. To produce a generic solution, it has been decided to utilize the combination of modified fuzzy technique and suitable BPN based Neural Networks to generate suitable heuristic patterns of Intima Media line images based on any ultrasound machine. Image processing and analysis in fuzzy set theoretic framework has been addressed. Various uncertainties involved in these problems and the relevance of fuzzy set theory in handling them have been done. Different image ambiguity measures based on fuzzy entropy and fuzzy geometry of image subsets have been considered. Necessary steps have been taken to address grayness ambiguity or spatial (geometrical) ambiguity or both using fuzzy logic. Different analysis is made on the flexibility in choosing membership functions. Illustrations of commonly used fuzzy image processing operations such as enhancement, edge detection segmentation, skeleton extraction, feature extraction have been provided, along with their significance and characteristics.

3. The importance of recognition system in fuzzy tool

In ultrasound imaging, a gray tone image possesses some ambiguity within the pixels due to the possible multivalued levels of brightness. This pattern indeterminacy is due to inherent vagueness rather than randomness. The incertitude in an image pattern is because of grayness ambiguity or spatial (geometrical) ambiguity or both. Grayness ambiguity means "indefiniteness" in deciding a pixel as white or black. Spatial ambiguity refers to "indefiniteness" in shape and geometry (e.g., in defining centroid, sharp edge, perfect focusing, etc.) of a region. The conventional approach to image analysis and recognition consists of segmenting (hard partitioning) the image space into meaningful regions, extracting its different features (e.g., edges, skeletons, centroid of an object), computing the various properties and relationships among the regions, and interpreting and/or classifying the image [15], [16]. Since the regions in an image are not always crisply defined, uncertainty can arise at every phase of the aforesaid tasks. Any decision taken at a particular level will have an impact on all higher-level activities. Therefore, a recognition system (or vision system) has been added in the fuzzy tool to represent the uncertainties involved at every stage, i.e., in defining image regions, its features and relations among them, and in their matching, so that it will retain as much as possible information content of the original input image for making a decision at the highest level. Using this fuzzy representation, the ultimate output (result) of the system has been associated with least uncertainty (and unlike conventional systems, it will not be biased or affected very much by the lower level decisions).

4. Implementing fuzzy sets for image recognition system

When we consider the problem of object extraction from Intima Media scanning. Now, the question is "how can someone define exactly the target or object region in that when its boundary is ill-defined?" Any hard thresholding made for its extraction will propagate the associated uncertainty to the following stages, and this might affect its feature analysis and recognition. Similar is the case with the tasks of contour extraction and skeleton extraction of a region.

From the aforesaid discussion, it becomes therefore convenient, natural and appropriate to avoid committing ourselves to a specific (hard) decision (e.g. segmentation/thresholding, edge detection and skeletonizing) by allowing the segments or skeletons or contours to be fuzzy subsets of the image; the subsets being characterized by the possibility (degree) of a pixel belonging to them. Current research proposed that the results of image segmentation has been fuzzy subsets, rather than ordinary subsets. For describing and interpreting ill-defined structural information in a pattern, it is natural to define primitives (line, corner, curve, etc.) and relations among them using labels of dynamic fuzzy sets. These primitives which do not lend themselves to precise definition may be defined in terms of arcs with varying grades of membership from 0 to 1 representing its belonging to more than one class [17], [18]. The production rules of a grammar have been constructed to account for the fuzziness in physical relation among the primitives; thereby increasing the generative power of a grammar for suitably recognizing of any pattern.

By considering the problem of classification or clustering of Intima Media image points where the uncertainty may arise from the overlapping nature of the various classes or image properties. This overlapping may result from fuzziness or randomness. In the conventional classification technique, it is usually assumed that a pattern may belong to only one class, which is not necessarily true. A pattern may have degrees of membership in more than one class. It is therefore necessary to convey this information while classifying a pattern or clustering a data set [17], [18].

In this research, we have utilized various fuzzy set theoretic tools for image analysis, their effectiveness in representing/describing various uncertainties that might arise in an image recognition system, and the ways these can be managed in making a decision. These tools which were developed based on the realization of many of the necessary concepts in pattern analysis.

Therefore, here, the final heuristic patterns database has been got by this study using more number of ultrasound machines and the above fuzzy reasoning modules. Also, fuzzy applied edge detection module used for noise removal picks up the nearest (x, y) coordinates to form a required Intima Media pixel curved line Image which is thicker in shape. Till, we receive the correct Intima Media pixel curved line Image, ultrasound scanning needs to be continuously done. Once we receive the correct Intima Media pixel curved line Image, BPN Neural Networks module will signal the system based on the above fuzzy logic applied final heuristic patterns and further scanning will be stopped, since it has not been required.

This aforesaid IMT Algorithms draws the Best fit curve for every ‘n’ pixels using 3rd order Polynomial Equation with Least Square Methods. The 3rd order Polynomial Equation is selected for more accuracy and more efficiency instead of using the 2^{nd} order polynomial Equation and 4^{th} order Polynomial Equation. Here, the 2^{nd} order polynomial Equation, the 3rd order Polynomial Equation, the 4^{th} order Polynomial Equation were tested against accuracy and efficiency. Results showed that the 3rd order Polynomial Equation is the best suited one for accuracy and efficiency are concerned. For every ‘n’ pixels of these (x, y) coordinates, the constants ‘a’, ‘b’, ‘c’ and ‘d’ are calculated using the 3rd order Polynomial Equation y=a+bx+cx^2+dx^3. Using these constants, the estimated (x, y) coordinates are computed for these sixty pixels (Edges). Like this, for every ‘n’ pixel by ‘n’ pixels, the edges of the entire Intima Image and the entire Media Image are formed. Based on the nature of any intima media Image, it is identified by the iterative methods and the number of intima media image patterns selected, the Polynomial (Eq.2)

$$Y = a + bx + cx^2 + dx^3 \qquad (2)$$

is more suitably applied for every ‘n’ pixels in the Intima Media pixel line Image.

Detection of the intima and adventitia edge points along the carotid artery wall allows the detection of the IMT locus. However, ultrasound images do not have inherently clear image quality so it is normal for edge points to be difficult to extract. To deal with this, IMT distances are inferred from echo intensity variations by using methods such as statistical processing to minimize the error from dispersion. Intima and adventitia edge curves are inferred from the connection of third-order polynomials by least-squares method at every 30 points. After the successful edge detection of Intima Media Image, the required fuzzy filter has been applied for noise removal. Trying to distinguish between noise and edge detection in the image is an inherently ambiguous problem and naturally leads to the development of a required fuzzy filter. This required fuzzy filter has given superior results when compared to other conventional image processing filters. Once after applying this fuzzy filter, for finding out the Intima Media Thickness, the following 5 Methods of IMT evaluation (IMT – Intima Media Thickness) are used.

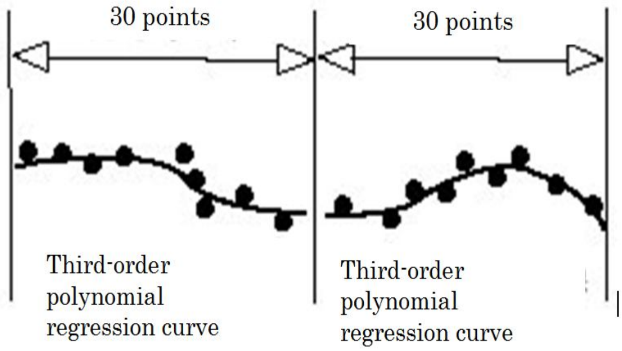

Figure 2 Third order polynomial regression curve

5. Evaluation Methods

Although these methods are based on conventional caliper methods, the computer processing allows computation of the IMT over a freely specified range. So appropriate evaluation methods have also been incorporated that can provide precision and reduced variability.

Y Method IMT Evaluation:

This method considers the conventional caliper method using the average of the max. IMT and points 1cm to the left and right. The Y method calculates the average using the max. IMT and averages obtained from the regions at the left and right, excluding the area within 0.5cm from the max. However, in computer processing, the maximum IMT value does not always matches the center.

If taking averages at the left and right regions separately, error may occur when the number of available points is not sufficient. To solve this problem, the average is calculated by combining the data at left and right regions, and the computation method is formally likened to the conventional caliper method. Therefore, the average is determined using three points.

Maximum IMT Evaluation Method:

This method only evaluates the maximum IMT value. In this case, the evaluation uses only one point and therefore tends to cause a large variation. However, this method is useful when measuring the size of protrusions such as plaques.

Three-point Average IMT Evaluation Method

This method resembles to the conventional caliper method in that it uses the average of three points; the center of the cut-out template and points 1cm to the left and right of the center. Therefore, the method requires the operator to manually move the center of the cut-out template to the position though to be the maximum IMT. Care must be taken because the computer does not automatically find the maximum IMT value.

Average IMT Evaluation Method

This method averages the detected IMT values. This is the most stable evaluation method because it does not process the maximum IMT as a special point. This method is especially useful when the IMT values are comparatively uniform.

Bifurcation IMT Evaluation Method:

This method evaluates a point that is closer to the heart by a specified distance from the point where the internal carotid artery branches from the common carotid artery. The distance can be selected from 5mm, 10mm, 15mm and 20mm.

Generally, 15mm is the most commonly used reference point. This method is especially effective when evaluating IMT around the common carotid artery although plaques are present near the branch. The edge detection algorithm, finally, uses the above 5 methods to calculate a single unique IMT value.

Classification

Recent study says that Neural Network techniques are employed for analyzing Intima Media Clinical data. In another recent study, an ANN neural networks which can accurately identify the patients' risk status by using low-cost routine data.

The purpose of this study is to determine Intima Media Thickness efficiently by improving the quality of these Intima Media images using Fuzzy techniques and it needs to address image uncertainty parameters to receive generic solutions using the own IMT algorithms and the combination of fuzzy recognition module and BPN based Neural Networks which are new innovative approaches.

The different patterns of intima media images are given as input to fuzzy reasoning modules and BPN. The typical neural network consists of a layer of input neuron, a layer of output neuron and one hidden layer which is determined by trial and error.

3.RESULTS AND DISCUSSIONS

This BPN training algorithm involves feed forward of the input vector, calculation of error and back propagate to reduce the error by adjusting the weights. Once the training of BPN is over, in the production mode BPN is able to identify the valid and invalid patterns of fuzzy applied intima media images which, in fact, avoid wasting of time for identifying the required patterns.

From any single valid pattern of intima media image, multiple valid patterns are generated using interpolation, pattern matching techniques and fuzzy reasoning module, this in turn, are stored in a Database which will be additional input to BPN Neural network. Therefore, BPN Neural Network gets enough input to train itself and is able to identify the valid and invalid patterns correctly. To address the aforesaid uncertainty parameters and to get the generic solutions independent of ultrasound scanners, the heuristic patterns received from database will be recreated or displayed on any particular ultrasound scanner and the same patterns have been given as input to fuzzy reasoning modules to get the modified heuristic patterns local to that ultrasound scanner. The present research has proved that identifying of valid and invalid patterns correctly and efficiently are true for different ultrasound scanners after applying these fuzzy modules.

The generated intima media images are pre-processed using fuzzy techniques to remove the noises. Speckle noise is overcome using image pre-processing method.

Enhancing the quality of the image is essential in diagnosis of illness and injury. Therefore, these fuzzy concepts have been utilized here to remove noise and protect the edges of the image. In this work, these proposed techniques are implemented using VC+ + program. These proposed methods are carried out for 303 Patients and 6 ultrasound scanners have been utilized for this study.

A. Capturing Screen

When the IMT software starts up, the screen switches to the IMT software Capturing Screen shown in Fig.3 The IMT software automatically evaluates the IMT from the captured image.

Figure 3 Capturing screen

B. Analysis Screen

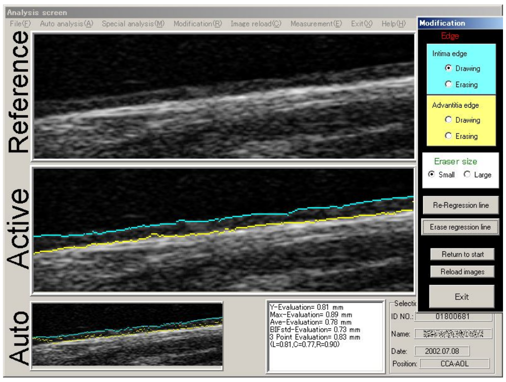

Figure 4 Analysis screen

This analysis screen is selected from the Capturing Screen when attribute data is saved on the Data Attribute Dialog as shown in Fig.4 on the Analysis Screen, the image selected by template in the Capturing Screen appears in enlarged form. This functions that can be performed from the Capturing Screen.

C. Output Analysis Screen

Fig.5 shows the output screen. The IMT algorithm, finally, uses the 5 evaluation methods to calculate a single unique IMT (Intima Media Thickness) value. Based on the Patient's Age and this IMT value, BPN classify whether the Patient has got the cholesterol level which is higher than the dangerous level or which is normal or which is below the dangerous level.

Fig.5 Output screen

4.Conclusion

In the proposed work the ultrasound of the carotid artery is acquired and analyzed to identify the intima media thickness of the carotid artery which could help in early diagnosis of cholesterol and stroke. This is the innovative approach where fuzzy reasoning modules and Neural Network are properly employed at the backend and so there is no change in the above user interface. With the combination of this fuzzy reasoning modules, Neural Network Method and the generalized IMT algorithm using Polynomial Equation gives desired results. The present research has proved that identifying of valid and invalid patterns correctly and efficiently which are true for the tested ultrasound scanners after applying these fuzzy modules. The fuzzy and BPN modules will be tested under optimum number of ultrasound scanners and the required modification needs to be done in these fuzzy and BPN modules to further improve efficiency and to further reduce the imaging problems.

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