Segmentation of Carotid Artery Wall towards Early Detection of Alzheimer Disease

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Abstract: - Alzheimer's disease (AD) is a progressive neurodegenerative disorder associated with disruption of neuronal function mostly in the elderly. Some methods have been explored to detect AD in the early stage. However, the developed methods have either high risk (using positron emission tomography (PET) and computed tomography (CT) scanning), high cost and long scanning duration (magnetic resonance imaging [MRI]) or not accurate enough (electroencephalography [EEG]). Fortunately, previous studies found that AD could be accurately detected by analyzing the carotid artery structure using ultrasound machine since this modality has been used safely, accurately, cost effectively and quickly in evaluating carotid artery. Ultrasound images, however have some limitations due to speckle noise and resolution causing difficulties in the characterization of carotid artery. Hence, the segmentation method of carotid artery wall has been implemented in this study in order to evaluate carotid artery structure. Image cropping has been done first before change it into grayscale image. Threshold was set to remove unwanted pixels smaller than 600 pixels. The filling up the holes between lines has been done before produce the output ultrasound image. Test result shows the developed method is able to segment the carotid artery wall with 90% accuracy. This enables the further and easier analysis of carotid artery.

Key-Words: - Alzheimer disease, image segmentation, ultrasound images, carotid artery (CA)

1 Introduction

Alzheimer's disease (AD) is a progressive neurodegenerative disorder associated with disruption of neuronal function which is the most common cause of dementia in the elderly [1]. AD has affected 24.3 million people worldwide in 2010 with increment around 4.6 million yearly [2]. Early detection among potential individuals to get AD is very essential in order to reduce the risk of AD. Treatment in the early stage is very efficient especially before any clinical symptoms shown [3]. In order to detect AD at early stage, structural and functional brain has to be accessed first. Basically, computed tomography (CT) and magnetic resonance imaging (MRI) are used for brain structural imaging while single photon emission tomography (SPECT) and positron emission tomography (PET) are used for brain functional imaging. CT and MRI will show tissue atrophy due to loss of synapses and neurons while SPECT and PET will show reduced neuronal function in human brain such as altered cerebral glucose and altered cerebral blood flow cause of AD disease process [4,8].

Previous studies found that AD could be accurately detected by analyzing of carotid artery structure. This is due to vascular dysfunction can stimulate synaptoxic B-amyloid (AB) accumulation in the brain which is considered as the central process for AD [5,7].

Due to this matter, variety of new techniques have been used to study vascular function in term of cerebral blood flow (CBF) such as diffusion weighted imaging (DWI), diffusion tensor imaging (DTI), arterial spin labeling (ASL) and blood oxygenated level dependent (BOLD) [6]. However, doppler imaging technique using ultrasound machine is preferred compared to other method since this modality has been used safely, accurately, cost effectively and quickly in evaluating carotid artery. Hence, it is very important to have good and clear ultrasound image of carotid artery to assess its structure and condition using ultrasound machine. This could be done through the segmentation method of ultrasound image carotid artery wall.

In this study, a software system has been developed for segmentation of carotid artery wall on ultrasound image using MATLAB. With that software, carotid artery wall structure can be easily segmented accurately. Currently, varieties of methods have been used for image processing including robust edge detection algorithm, contour tracking algorithm, watershed algorithm. However, all these methods have their own weaknesses such as low contrast image, blur image, less accurate and need common point to complete wall segmentation. Thus, segmentation method has been selected for image processing due to it does not blur the image, no need to set a common point and can be applied for other parts of human body [10-14].

2 Material and Methods

There are a few steps for carotid artery wall segmentation which consist of images or data collections, algorithm for image processing and segmentation method.

2.1 Images/Data Collections

In this study, 200 carotid artery ultrasound images have been collected.

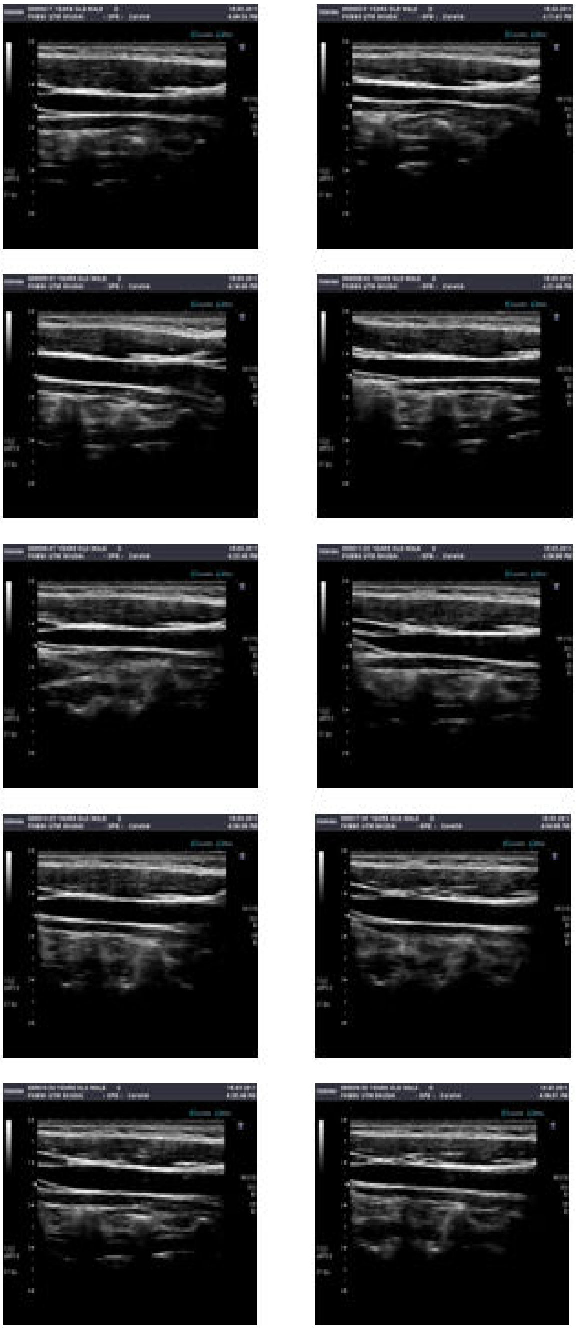

Fig. 1: Ten male carotid artery ultrasound images

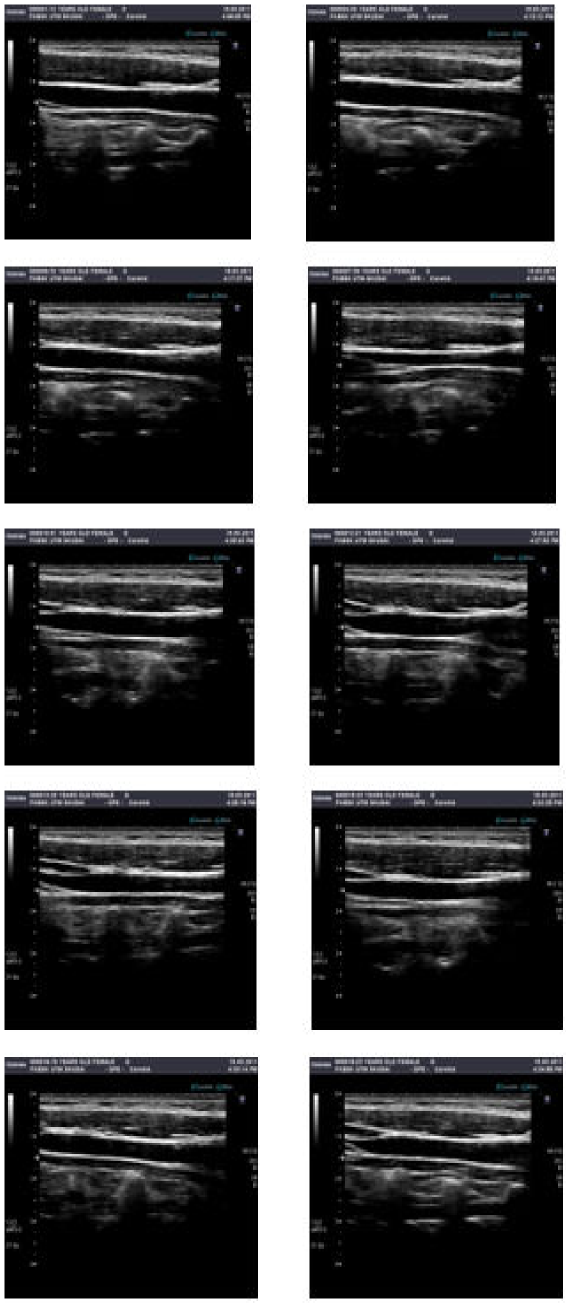

Fig. 2: Ten female carotid artery ultrasound images

2.2 Algorithm for Image Processing

There are some steps have to be done before the carotid artery wall could be segmented. Figure 3 shows the flow chart of software algorithm.

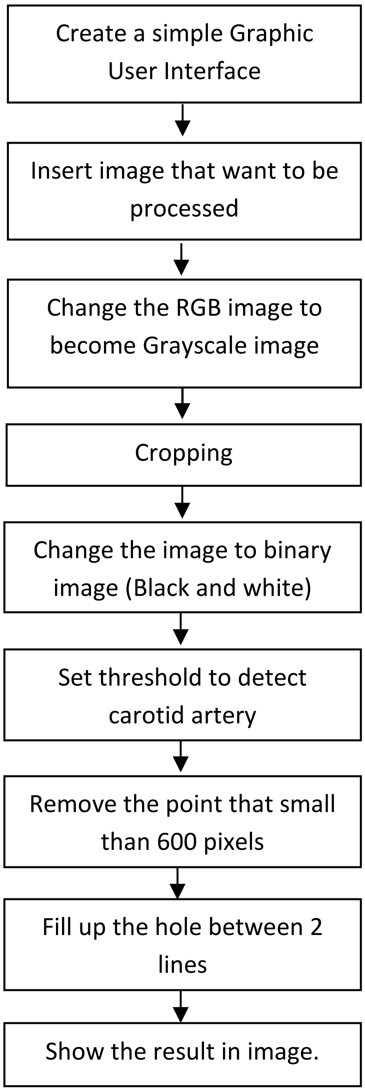

Fig. 3: Flow chart of software algorithm

In the project, MATLAB has been used to create a simple Graphical User Interface (GUI) so that it is friendlier towards the users. First of all, there is a button to press to insert the images that need carotid artery automatic detection. Next, the RGB image is changed from RGB to gray scale image. After that, it is needed to set a rectangular cropping area for the image so that the software system can detect the carotid artery more accurate. Furthermore, the image is changed to become binary image. The suitable threshold value is found and set to the software system. Then, points which smaller than 600 pixels are removed from the image. After that, the column (hole) between 2 lines is filled up. Lastly, the carotid artery is segmented and shown in the Graphical User Interface (GUI).

2.3 Segmentation

There are four significant steps in the segmentation. They are image cropping, image thresholding, image removing according to pixel size and image filling of the hole.

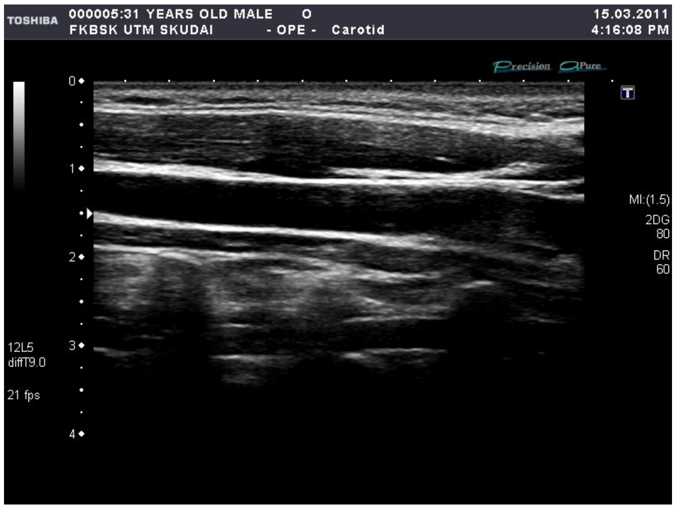

Fig. 4: Original ultrasound image

Figure 4 show the original image selected to be processed using segmentation technique. The image above is the ultrasound carotid artery image of 31 years old male subject.

After cropping, the image will become like figure 5. The area that not included in the crop area will be erased automatically and set to become black colour. The area remain in the image is the region of interest (ROI).

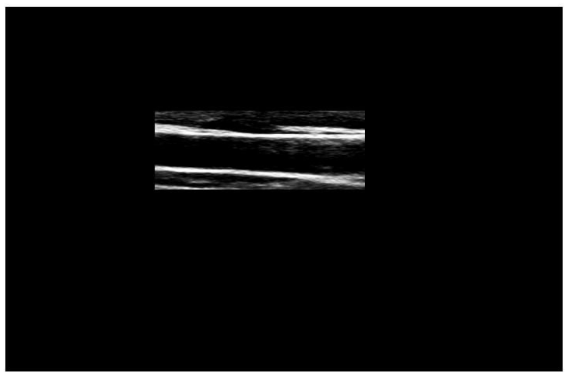

Fig. 5: Ultrasound image after cropping

Next, the ultrasound image is changed to binary image and the threshold set to be 0.6. The carotid artery is shown but still have a lot of other parts are included in the image. These other parts are unwanted parts and need to be removed from the ultrasound image. To remove all these parts which are not related, some testing need to be done to check what is the biggest point of these parts and the amount of its pixel number.

Fig. 6: Ultrasound image after thresholding

After that, the parts which are not the carotid artery have been identified consist of below than 600 pixels. Hence, the parts which are smaller than 600 pixels are set to be automatically removed. Figure 7 shown the image after filter the parts that smaller than 600 pixels. From the image, we can see the carotid artery wall is almost been segmented. However, there are some holes in the middle of the line of carotid artery. These holes need to be filled up so that a perfect carotid wall outline is shown out.

Fig. 7: Ultrasound image after removing parts smaller than 600 pixels

After set the software system to fill up the hole in the middle of carotid artery lines, a perfect carotid artery lines of wall is shown in figure 8. A carotid artery wall segmentation system is successfully developed.

Fig. 8: Ultrasound image of carotid artery wall after successfully being segmented

3 Result and Analysis

3.1 Test Result

After complete the software development, the software was tested on 200 carotid artery ultrasound images to check the accuracy of automatic detection. Results shown in figure 9 and 10. Then, the optimization step is taken to improve the software so that the accuracy level will be increased.

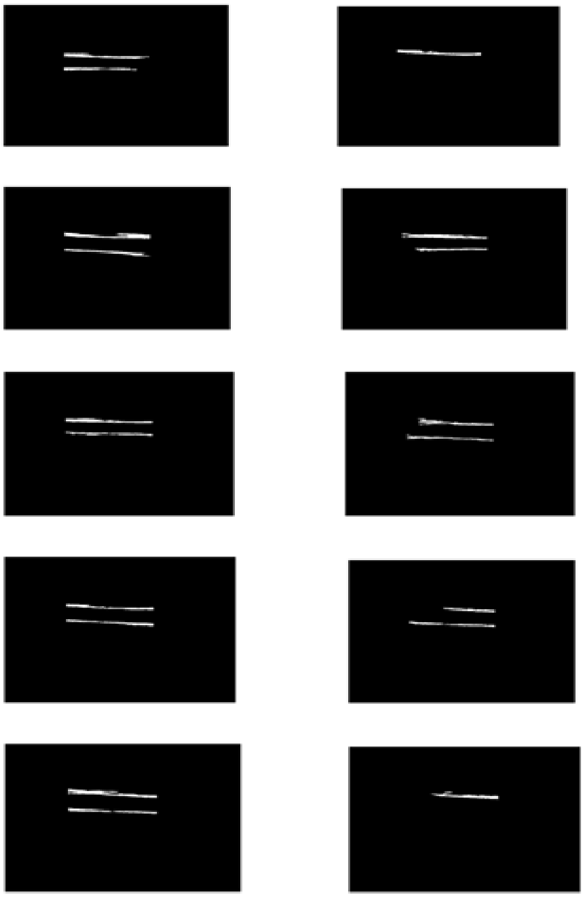

Fig. 9: Results of 10 males carotid artery ultrasound images

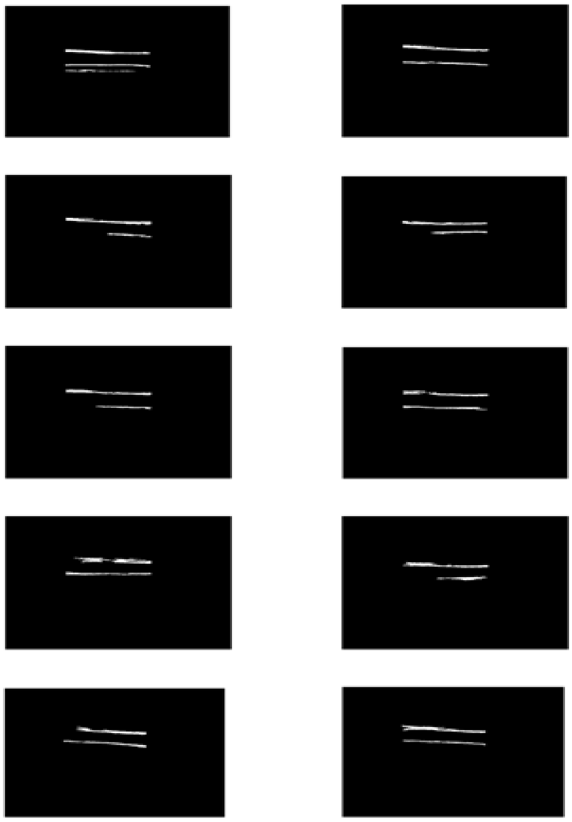

Fig. 10: Results of 10 females carotid artery ultrasound images

3.2 Analysis of accuracy and error

To check the reliability of the software, some analysis need to be done. From the analysis, we can know how accurate the software in segmenting the carotid artery wall.

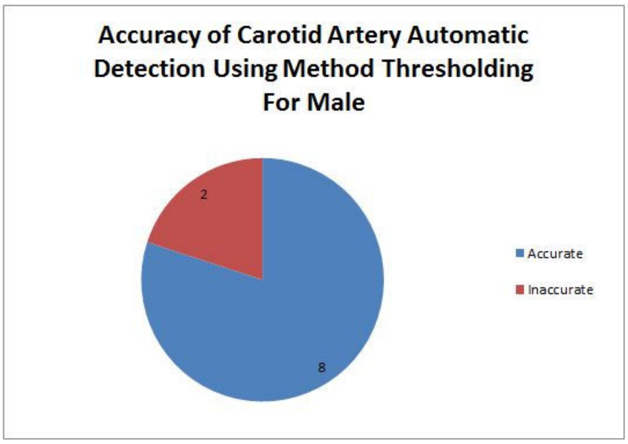

Fig. 11: Pie Chart of accuracy of carotid artery wall segmentation for male.

Fig. 11 shows the accuracy of carotid artery wall segmentation. From the pie chart, eight out of ten male carotid artery images show the accurate result in carotid artery wall segmentation. While only two of the images for male are not accurate. It means that 80 percent of the male's carotid artery walls can successfully being segmented.

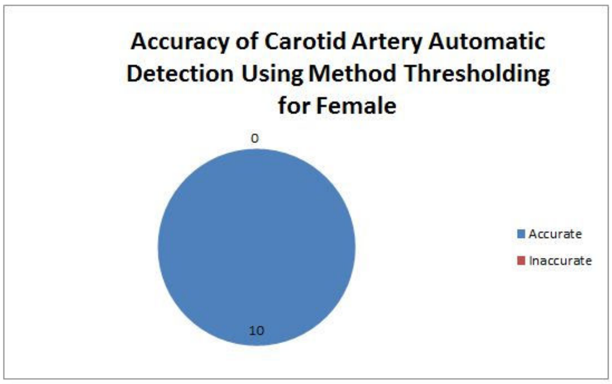

Fig. 12: Pie Chart of accuracy of carotid artery wall segmentation for female.

On the other hand, figure 12 shows the accuracy of carotid artery wall segmentation for female. From the pie chart, ten out of ten of the result are accurate whereby the carotid artery wall is successfully segmented. It means the software 100 percent effectively segment the carotid artery wall of female subjects.

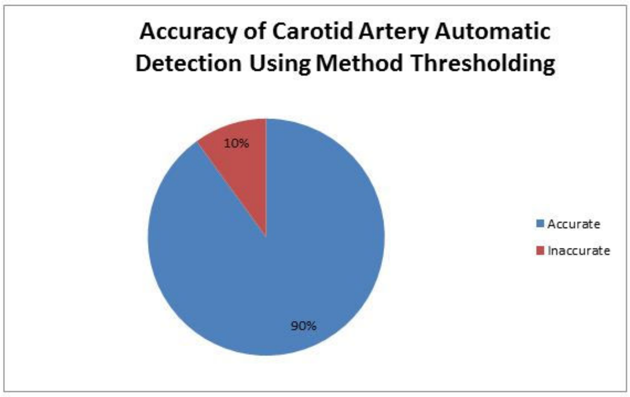

Fig. 13: Pie Chart of overall accuracy of carotid artery wall segmentation

Figure 13 shows the overall accuracy result of the carotid artery wall segmentation. From the pie chart, 90% of the result shows that the carotid artery wall segmentation is accurate whereas only 10% shows otherwise. This analysis shows that the developed software using segmentation method is very accurate and reliable for carotid artery wall segmentation.

4 Conclusion

A new technique for carotid artery wall segmentation has been successfully developed and implemented in MATLAB. The technique is able to create an output with only carotid artery wall left in the image. This could help in providing good and clear image of carotid artery wall for carotid artery structure evaluation. Test result shows 90 percent of the carotid artery walls are successfully segmented. Hence, this technique is very useful for radiologist in the early detection of Alzheimer disease.

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