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Automatic Detection of Carotid Artery in Ultrasound Image using Tresholding Method

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Abstract— Carotid artery is one of the parts that hard to identify by inexperience doctor or radiologist because the shape is almost same like the muscle layer. A common, non-invasive test used to check for carotid artery disease is a Doppler ultrasound. This variation of the conventional ultrasound assesses blood flow and pressure and possible narrowing of the blood vessel by bouncing high-frequency sound waves (ultrasound) off red blood cells. Ultrasound images of carotid artery are one of the parts that hard to identify by inexperience doctor or radiologist because the shape is almost same like the muscle layer. Hence, a carotid artery automatic detection method using threshold is proposed in this study. From 20 ultrasound images that have been tested in the proposed method, the percentage of accuracy of automatic detection is at least 90 percent. The results will help the doctors and radiologist for further diagnosis. Besides that, the patient can get the correct earlier treatment and the chance to recover is increased.

Index Terms— Ultrasound imaging, Tresholding, Carotid Artery, Doppler Ultrasound

1 Introduction

Ultrasound machine is a non-invasive diagnosis machine. It uses the high frequency sound wave to capture the human inner body image. Unlike other imaging modalities, the sound wave that transmits from the ultrasound machine probe is safe to human body. The sound wave create by ultrasound machine do not bring any side effects to human. Ultrasound machine will create high frequency sound wave and transmit the sound wave through the probe. The sound wave will go through human body and reflect back to the probe again. However, different types of tissue in human body will cause the wave to reflect in different ways. After the probe receive the reflect signals, it will send to post processing system to create an image of human inner body. The gray scale image created is based on the difference of the reflected sound wave.

A different frequency sound wave is created when the users use different types of probes. Higher frequency has higher resolution but has low penetration while lower frequency has lower resolution but higher penetration. As an example, when scan the abdomen of the patients, 3.5 MHz probe is suitable because the abdomen is big and deep. When scanning the carotid artery, 10 MHz probe is needed because the carotid artery is just under the muscle layer of human body.

However, for those who are not familiar with the ultrasound image will misdiagnosis the ultrasound image because many human parts look like alike in ultrasound images. Only the expert doctors or radiologists can differentiate the difference between the body parts

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Carotid artery is one of the hard parts to differentiate because carotid artery is almost looks alike like the muscle. Besides of that, the carotid artery is near the muscle layer. So, the inexperienced doctors and radiologist may confuse when want to differentiate the carotid artery and muscle.

In this study, a software system had been developed to detect carotid artery automatically on ultrasound image using thresholding method. With the software, carotid artery can easily be detected and the patients can get the correct treatment.

2 Literature Review

Common carotid arteries are two of the several arteries that supply blood to the head. The right common carotid artery branches from the artery and extends up the right side of the neck. The left common carotid arteries branches from the aorta and extends up the left side of the neck. Each carotid artery branches into internal and external vessels near to the top of thyroid. External carotid artery is the major artery of the head and neck. All the common carotid arteries differ in their length and the mode of origin. The right common arteries begin at the bifurcation of the innominate artery behind the sternoclavicular joint and are confined to the neck. On the other hand, the left common carotid arteries spring from the highest part of the arch of the aorta to the left of, and on a plane posterior to the innominate artery, and therefore consist of a thoracic and a cervical portion. The thoracic portion of the left common carotid artery ascends from the arch of the aorta through the superior mediastinum to the level of the left sternoclavicular joint, where it is continuous with the cervical portion.

Stroke is the third leading cause of death in the United States, accounting for 600 000 cases each year, of which about 500 000 are first attacks [1]. The causes of stroke are mainly due to the atherosclerosis of the aorta and its branches, especially the carotid artery. Atherosclerosis is a condition in which an artery wall thickens as the result of a

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build-up of fatty materials such as cholesterol [2].

A complete blockage leads to ischemia of the myocardial (heart) muscle and damage [3]. This process is the myocardial infarction or "heart attack". Hence, it is important to have early detection about the blockage of carotid artery and have some treatment before the blockage become serious and cause stroke or dead.

Figure 1 shows the cerebral infarction caused by an occlusive plaque. The image shows there are occlusive that happen in the carotid arteries. The extra thickness shows the occlusive plaque that might block the flow of the blood through the artery. The continuous the blockage of the arteries will cause stroke and heart attack. Thus early detection of blockage is important and can save lots of lives.

Carotid ultrasound may be difficult or impossible if a patient has a dressing covering a wound or surgical scar in the neck. An occasional patient is difficult to examine because of the size or contour of the neck. Calcium deposits in the wall of the carotid artery may make it difficult to evaluate the vessel. A small amount of soft plaque that produces low-level echoes may go undetected. Ultrasound cannot visualize the entire length of the vessel because the last portion of the carotid artery travels through the bone at the base of the skull [5].

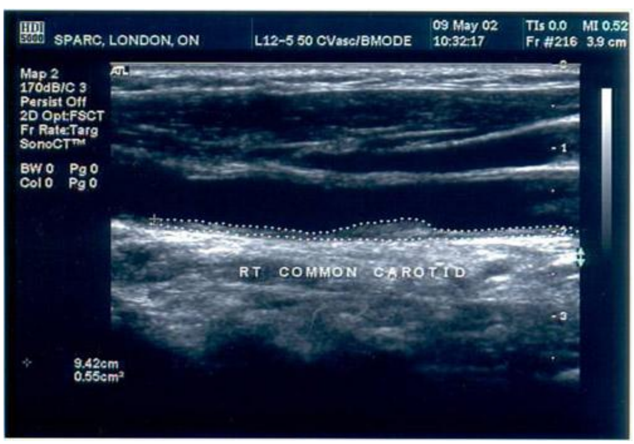

Fig.1: Figure of ultrasound image with cerebral infarction caused by an occlusive plaque.

Previous methods had been studied and the advantages and disadvantages are found out. In [2], a method for the measurement of the brachial artery diameter has been developed. They present a system for computing the brachial artery diameter in real-time by analysing B-mode ultrasound images. The method is based on a robust edge detection algorithm which is used to automatically locate the two walls of the vessel as shown in Figure 2. It is also based on a contour tracking technique applied to B-mode images of a longitudinal section of the vessel. The edge detector that they used is named “mass centre of the gray level variability.” On the other hand, the contour tracking algorithm is based on the assumption that the segment of the vessel under investigation can be correctly approximated with a cylinder [6].

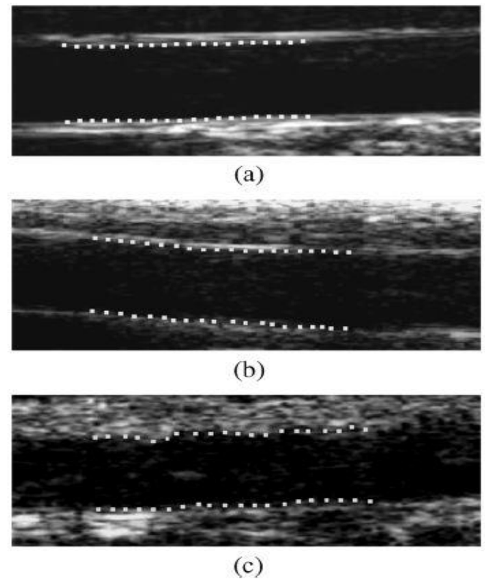

Fig. 2: Figure of the resulted images for three different qualities of images.

Another research proposed a new method to measure diameter of the wool fiber diameter [4]. The proposed method is used in carotid artery detection and measurement. In this research, the image of the wool fibers were first undergo the grayscale image transformation, image contrast enhancement and smoothing and noise degradation. The Watershed algorithm is used for edge detection as well as extracting the object. Robust method in edge detection is good. However, the robust method does not show high contrast image for the output image. Another method is Wiener filter and edge detection method. This method will blur the image when the mask using become bigger and bigger. This will cause the ultrasound image become blur and the edge detection is not accurate.

Besides that, active contours can use for edge detection also. With active contours, automatic detection can be done [8]. However, for the images which do not have a common point, it is hard to complete automatic detection. For carotid artery, different age of patients have different deep location of carotid artery. Hence, active contours cannot use for carotid artery automatic detection [9].

In this work, we choose the tresholding method because it can detect the carotid artery without blurring the image. This can remain the ultrasound image resolution. This is very important especially in medical image due to patient details will be lost if low ultrasound image quality occur. Moreover, in thresholding method, there is no need to set a common point to let the software system to automatic detect the carotid artery. This is suitable to use to automatic detect the parts that always changed.

Before thresholding, the ultrasound image had to be changed to grayscale and do some image processing. After that, the image needed to transform into binary image before threholding. After thresholding, the ultrasound image

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has to be remove some parts which is not carotid artery and fill up some parts in the middle of the carotid artery. After all these steps, the carotid artery can successfully be detected.

3 Material and Methods

3.1 Data Collections

In this study, 20 carotid artery ultrasound images are needed to check for the reliability of the software. 20 patients from different sex and age are invited to have a free scanning on the carotid artery and the images had saved as data. Figure 3 and 4 are the samples of 4 carotid artery images for male and female patients.

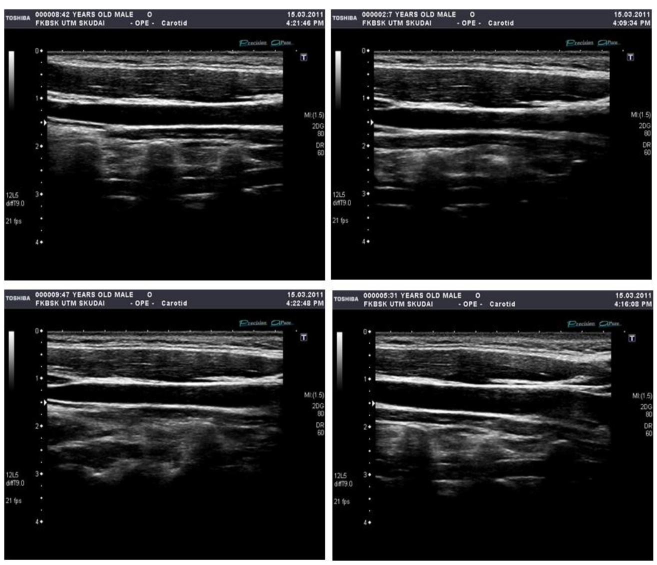

Fig. 3 : Carotid artery samples of 4 male patients.

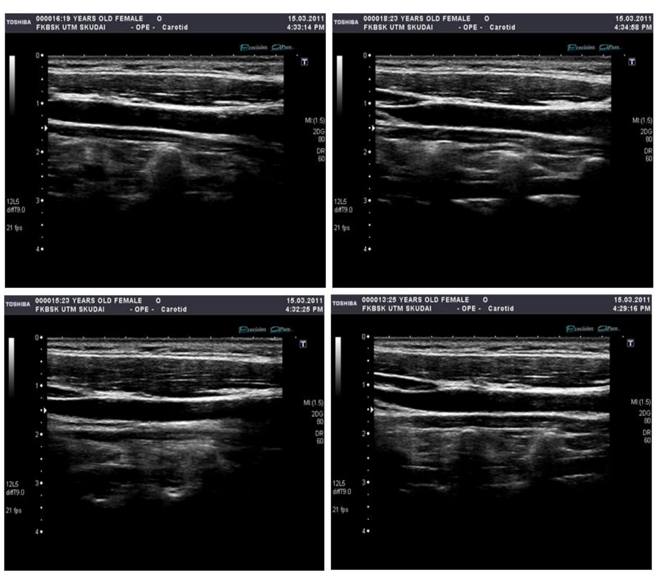

Fig. 4 : Carotid artery samples of 4 female patients.

Using the ultrasound images samples shown in Figure 3 and 4, carotid artery automatic detection is developed and the software is tested.

3.2 Methodology

For the algorithm of software, a few steps had to be taken in order to let the software system to automatic detect the carotid artery. Figure 5 shows the algorithm of the software that developed in this project.

In software part, Matlab is used to create a simple Graphical User Interface (GUI) so that is more users friendly to users. First of all, there is a button to press to insert the images that need carotid artery automatic detection.

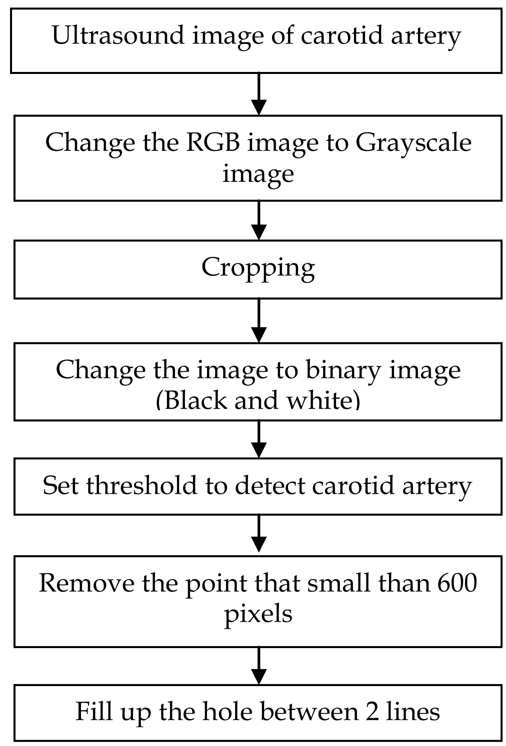

Fig.5: Flow chart of software algorithm.

Next, the RGB image is changed from RGB to grayscale image. After that, we need 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 in 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 detected and shown in the Graphical User Interface (GUI) format.

3.3 Image Before and After Processing

In this part, we use one sample of carotid artery ultrasound image that we take from the patient of carotid artery to be used for testing. Each steps and results will be display

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and explain accordingly. The final results will have an ultrasound image with only carotid artery.

Fig. 6: Original ultrasound image.

Figure 6 shows the original image that chosen to be processed. This image is used for testing automatic detect the carotid artery part. The image above is the carotid artery ultrasound image of a 31 years old male patient. After cropping, the image will become like Figure 7. The area that not in the area will automatic be erased and set to become black colour. The area remains in the image is the Region of Interest (ROI).

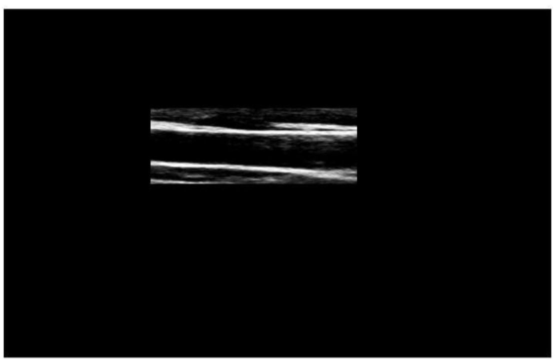

Fig. 7: Original ultrasound image.

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 is included in the image. These other parts are unwanted and have to be removed from the ultrasound image. To remove all these parts which are not related, any testing need to be done to check what is the biggest point of these parts and the biggest point is around how many pixels.

After that, the parts that not carotid artery is identified that all is below than 600 pixels. Hence, the parts which smaller than 600 pixels are set to be automatic removed. Figure 8 shown the image after filter the parts that smaller than 600 pixels.

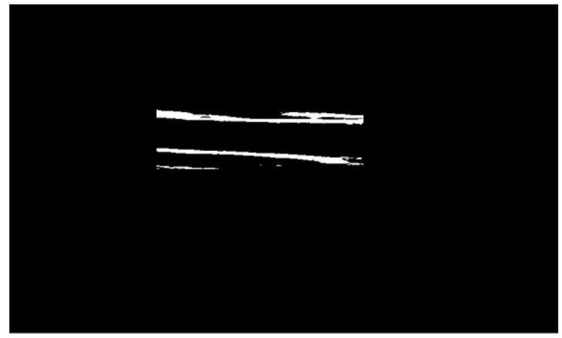

Fig.8: Ultrasound image after thresholding.

From the image, clearly we can dictate that the carotid artery almost been detected as shown in Figure 9. However, there are some holes in the middle of the line of carotid artery. We need to fill up all these holes so that a perfect carotid artery is shown out.

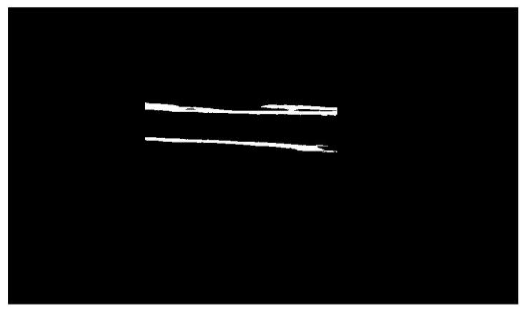

Fig. 9: Ultrasound image after removing the parts small than 600 pixels.

After set the software system to automatic fill up the hole in the middle of carotid artery lines, a perfect carotid artery is shown on Figure 10. A carotid artery automatic detection system is successfully developed.

Fig. 10: Ultrasound image that successfully detect the carotid artery.

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4 Result and Discussion

After the software development is completed, the software was tested on 20 carotid artery images to check the accuracy of automatic detection. The results are saved and use as references. Then the optimization step is taken to improve the software so that the accuracy increased. Figure 11 and 12 are the results from 20 carotid artery ultrasound images of male and female patients.

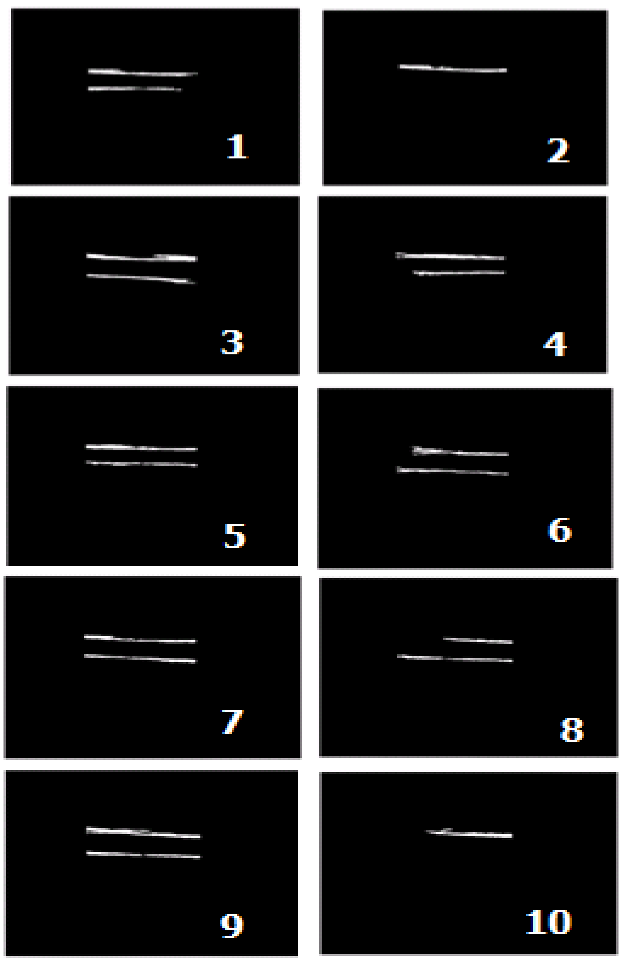

Fig. 1: Results of male patients of carotid artery ultrasound images.

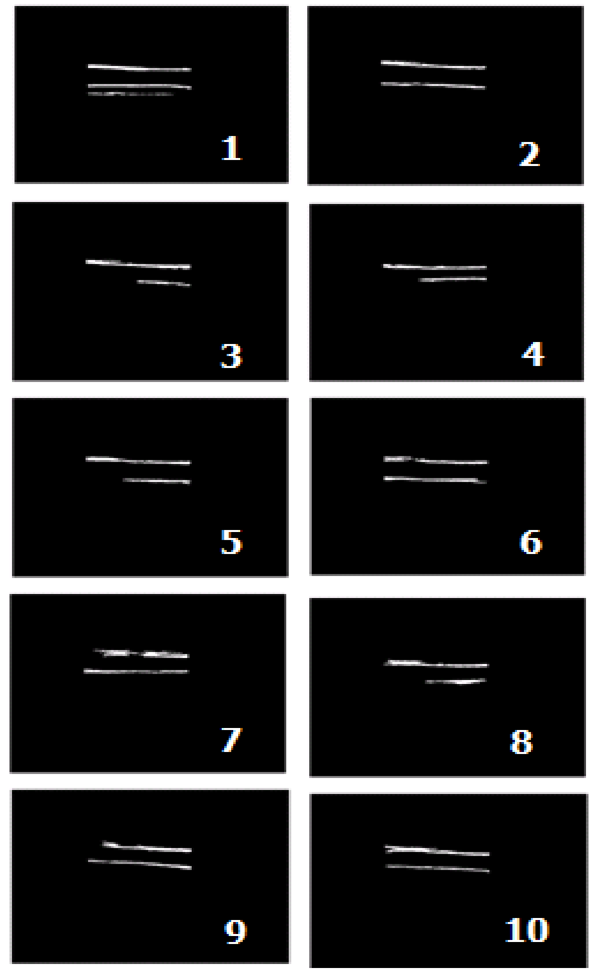

Fig. 12: Results of female patients of carotid artery ultrasound images.

To check the reliability of the software, some analysis had to be done. From the analysis, we can know how accurate the software can automatically detect the carotid artery.

Figure 13 shows the accuracy of carotid artery automatic detection using method thresholding. From the pie chart, eight out of ten male have the accurate carotid artery automatic detection. While only two of the images for male are not accurate. This bring up to 80 percent of the male's carotid artery can successfully automatic detect using tresholding method.

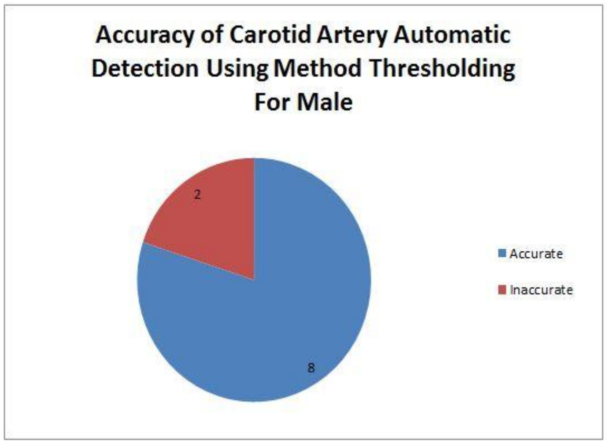

Fig. 13: Pie Chart of accuracy of carotid artery automatic detection using method thresholding for male.

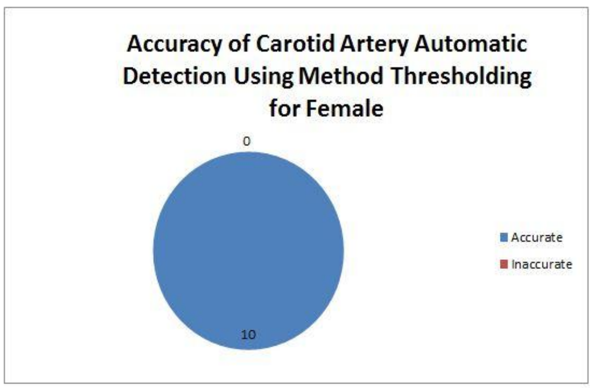

Fig. 14: Pie Chart of accuracy of carotid artery automatic detection using method thresholding for female.

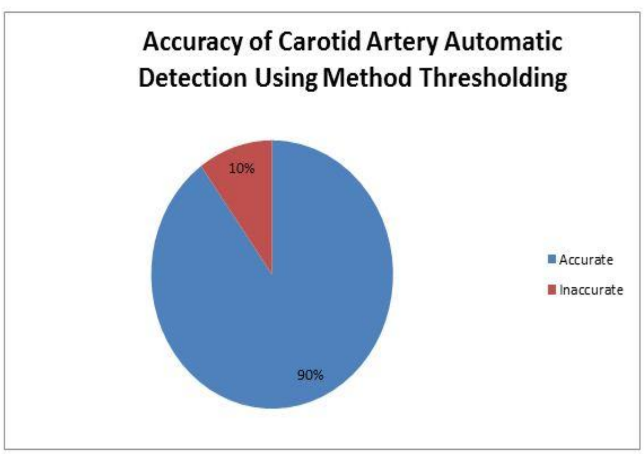

Fig.15: Pie Chart of accuracy of carotid artery automatic detection using method thresholding for male and female.

On the other hand, Figure 14 shows the Accuracy of carotid artery automatic detection using Method thresholding for female. From the pie chart, ten out of ten of the results are accurate whereby the carotid artery is detected. It means the software 100 percent successfully detects the carotid artery of female patients.

Figure 15 shows the total result of the automatic detection. There are 20 people who are involved in this experiment where 10 male and 10 female. From the pie chart, 90% of the result shows that the automatic detection is accurate whereas only 10% shows the automatic detection is not accurate.

This analysis shows that the automatic detection using thresholding is very accurate and is reliable. Compare to other methods like robust edge detection, wiener edge detection and also active contours, thresholding method is easier to detect the carotid artery. Besides that, the analysis also shows that the accuracy using thresholding is very high. This mean thresholding is one of the best methods to automatic detection carotid artery. The advantage of thresholding method is thresholding no need blurs the image to detect the edge. What makes the thresholding method differ from other method is that it does not need us to set common point like active contours. It is suitable to detect some objects that do not have same position in the ultrasound machine images. However, for different machine images, the thresholding value is different. The threshold value set for this work is suitable for machine of Toshiba Model Aplio MX. To minimize the weakness, before trying on patients, users can set their own threshold value to check whether is suitable for the ultrasound machine or not. After confirming the threshold value is suitable for the machine that going to be used, the software only applies to the ultrasound image that capture from the ultrasound images. The method thresholding not only can use to automatically detect cargnotid artery, but also can apply to other human parts. With find out the suitable threshold value, this software can be used to detect many parts of the human body.

5. CONCLUSION

Software had successful developed using MATLAB to automatically detect the carotid artery from ultrasound image. This software can help inexperience doctor to identify which is carotid artery. The method use in MATLAB is thresholding. Threshold value is set so that at final result only left carotid artery in the image. This proves that the carotid artery automatic detection software system is successfully developed and ready to use. The software able to create an output with only carotid artery left in the image. From the analysis of result, 90 percent of the carotid artery images are successfully being automatically detected. It means that the software is reliable. In future, software that can detect others part of human body can be done.

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