COMPUTED TOMOGRAPHY TO DETECT ABDOMINAL AORTIC ANEURYSM

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ABSTRACT

Abdominal aortic aneurysms (AAAs) can lead to a fatal hemorrhage when ruptured. Since it is asymptomatic, Computed Tomography (CT) is a commonly used imaging modality to determine the presence of AAA, and predict the risk of rupture. This project aims to automatically detect the presence of AAA by employing image processing techniques (morphological operations) combined with machine learning algorithms (k-means clustering) to segment and an abdominal CT scan and check for AAA.

Index Terms— Abdominal Aortic Aneurysm, Computed Tomography, K-Means Clustering, Morphological Operations

1. INTRODUCTION

1.1. Motivation

Approximately 15,000 deaths [1] occur each year in the United States due to Abdominal Aortic Aneurysm (AAA), usually because of rupture. The death rate is as high as 80% after a rupture of AAA [2]. Most patients die before reaching hospital. In developed countries, a ruptured abdominal aortic aneurysm is a catastrophic vascular disease that is responsible for 1-3% of the death of men between the age 65 and 85 [3]. Also, the outcome is poor in most patients and the surgical repair is successful in case of a ruptured aneurysm is only about 50% of cases [2]. Meanwhile, A statement from the Joint Council of the American Association for Vascular Surgery and Society for Vascular Surgery (20) indicated that annual rupture risk increases dramatically as AAA diameter increases. Thus, early detection is essential so that aortic aneurysm can be diagnosed in time, which will lead to a high probability of successful surgery before the aorta become way too enlarged or even ruptured.

The original goal was to analyze ultrasonic images. Comparing with CT images or MRI images, which are the other two common detection methods for aortic aneurysm diagnosis, ultrasound has its own advantages. First, ultrasound is effective in detecting aortic aneurysm. Normally medical images face a serious problem of low image quality; ultrasonic images, however, have image quality good enough for the physicians to determine whether the patient has AAA or not. Second, ultrasound is non-invasive and relatively simple to perform. As mentioned before, AAA has a higher occurrence in the senior, while frequent invasive medical examination will damage their health. Thus, a non-invasive examination method is preferred, especially for the early detection purpose on those people without symptoms. The third point would be the cost. Ultrasound is much cheaper than CT or MRI and more accessible to local hospitals. People don't have to drive a few hours to a major city, just for an examination on an unknown disease.

Our motivation is to create an autonomous algorithm to help segment the aorta on the ultrasonic image and provide our predicted diagnosis result. So far, the diagnosis is operator dependant, which is significantly based on the experience of the physicians. Inspired by ECG signal prediction algorithm, the authors wish to use the algorithm to alert the doctors and nurses about the examination result, especially when the cardiologists are not around, or to reduce the risk of misdiagnosis from a fatigue cardiologist.

Unfortunately, after two month's search, the authors couldn't find any useful ultrasonic image database online. We contacted the professors at Emory University and physicians from Emory Hospital, but none of them could help. One professor as well as physician said it would be too much work for us to collect those ultrasonic images one by one from the patient's' documentation at local hospital, even with permission. A few researchers at Emory University tried to provide us with certain images they have, but their IRB compliance office isn't engaged in our project so that they couldn't help.

In such a case, the authors decided to use CT images instead. Even though CT isn't as cheap as well as non-invasive as Ultrasound, CT has a better image quality. What's more, since CT images and ultrasonic images look so similar, an algorithm on CT images should be useful for the development of an algorithm on ultrasonic images in the future.

1.2. Organization of the Report

The rest of this paper consists of the following parts. The second part is Background Theory. Abdominal aortic aneurysm and K-means Clustering will be introduced briefly. The third part is Methodology. Unsupervised method (K-means clustering) and supervised method will be explained. The fourth part is Result and Analysis. Our result will be discussed here. The fifth, sixth and seventh parts are Conclusion, Acknowledgement and Reference correspondingly.

2. BACKGROUND THEORY

2.1. Abdominal Aortic Aneurysm

An abdominal aortic aneurysm is an enlarged area in the lower part of the aorta. The aorta runs from the heart through the center of the chest and abdomen.
Because the aorta is the body's main supplier of blood, a ruptured abdominal aortic aneurysm can be fatal. Once an abdominal aortic aneurysm is found, it is closely monitored so that surgery can be planned if necessary. [1]

In the past, aortography was commonly used for preoperative planning in the repair of AAAs. In recent times, computed tomography (CT) has replaced such invasive methods. Advantages of CT include minimal invasiveness, widespread availability, consistently reproducible results, and a relative cost savings compared with aortography and MRI. Advancements in CT technology, such as the advent of helical CT and CT angiography, are likely to increase the role of CT imaging in the evaluation of AAAs. It is used as a screening test when ultrasound images are suboptimal: as a diagnostic test when a hemodynamically stable, ruptured AAA is suspected; and in the preoperative work-up for the repair of AAAs. CT is a superior diagnostic modality compared with ultrasonography because it offers the clinician valuable information about not only the aneurysm but also the surrounding anatomy.

While CT has numerous advantages, there are limitations to traditional CT. CT images contain limited information on arterial anatomy. Complex cases involving AAAs may require additional imaging modalities to obtain the necessary road map of nearby vessels for planning surgical repair. [1]

2.2. K-means Clustering

K-means is one of the simplest unsupervised learning algorithms that addresses the clustering problem. The procedure follows a simple way to classify a given data set through a certain number of clusters (assume k clusters). The main idea is to define k centroids, one for each cluster. The next step is to take each point belonging to a given data set and associate it to the nearest centroid. When no point is pending, the first step is completed. At this point we need to re-calculate k new centroids of the clusters resulting from the previous step. After we have these k new centroids, the algorithm is run over the data again and associated with the new centroids. This goes on till the k centroids do not move any more. [4]

We use k-means in this project to segment the image into three clusters: aorta and walls of the abdomen (white), blood (gray), and background (black). Using this, we can isolate the aorta. By measuring the amount of blood (measuring ratio of gray pixels) based on a pre-determined threshold, we can determine whether or not a rupture has occurred. If there is no rupture, we check to see if the aorta is enlarged or not to determine whether there is an AAA that has not ruptured yet. [5]

It is important to note that we must check for rupture first before measuring the size of the aorta, because once the aneurysm has ruptured, the CT scan shows a much smaller aorta (owing to the rupture). At this point, it is very likely that the algorithm misclassifies this as non-AAA. Therefore, we must check for AAA/non-AAA only if the it has not already ruptured.

3. METHODOLOGY

The primary goal of this project is to be able to input and image and determine whether or not there is an Abdominal Aortic Aneurysm. To do this, we propose two approaches:

3.1. Unsupervised Learning: K-means Clustering

As discussed earlier, K-means clustering is an effective approach to image segmentation based on color. The application takes in an image, and on selection of ‘Unsupervised Method’, implements K-means Clustering. The CT image is grayscale, but in order for k-means to be effective, we convert it into and RGB image in the Parula colormap.[6] This is then converted to L*a*b space, which consists of a luminosity layer 'L*', chromaticity-layer 'a*' indicating where color falls along the red-green axis, and chromaticity-layer 'b*' indicating where the color falls along the blue-yellow axis. All of the color information is in the 'a*' and 'b*' layers. You can measure the difference between two colors using the Euclidean distance metric. We define three clusters in the CT image: aorta information, blood information, and background. On applying k-means, each of these clusters are segmented into separate images. An appropriate mask (using MATLAB command roipoly()) is created and applied to these images to isolate blood/aorta information. The resulting image is then binarized, and the ratio of white to black pixels in calculated. If this ratio is greater than a pre-determined threshold, we deduce that the scan shows an AAA.

3.1.1 Algorithm

1. Input the desired image.
2. Convert grayscale image to RGB.
3. Convert RGB image to L*a*b space.
4. Apply k-means using 3 clusters and the squared Euclidean as the distance metric. Repeat three times to avoid local minima.
5. Derive three separate images for three clusters.
6. Create a mask to isolate blood information.
7. Apply the mask to the images and binarize them: the one with the maximum pixel ratio is the one with the blood.
8. Calculate the ratio of white to black pixels and compare it with the threshold. If it is greater, the aneurysm has ruptured, therefore there is AAA.
9. If it is less than the threshold, check for AAA without rupture. To do this, create a new mask to isolate aorta.
10. Repeat steps 7-8. If the ratio is greater than the threshold, then there is an AAA.
11. Return the original image, segmented image, pseudo color image and a flag to indicate whether or not there is an AAA.

3.2. Supervised Learning

Supervised method requires a ground truth, so the students choose Image 24 as the reference image to determine to intensity range of blood, which is shown as gray color. After manually selecting a fixed starting pixel on the reference image, the authors calculate the average and standard deviation of the intensities in the block, based on the pre-determined block size.

Transform the original image into pseudo color image is the next step. Based on the average and standard deviation calculated from previous step, the authors determine the intensity range for blood pixels, with five sigma coverage. All pixels whose intensity value is larger than the upper limit will be set to 255, which is white color; all pixels whose intensity value is smaller than the lower limit will be set to 0, which is black; all the pixels within the range will be set to the average intensity.

After getting the pseudo color image from step two, the prediction of rupture or not can be approached, based the number of gray (blood) pixels on the image. Based on experience, Image 10 is a rupture while Image 9 is a non-rupture. Thus, all images with more gray pixels than Image 10 will be predicted as a rupture. In the codes, a ratio of gray pixels over all pixels is used.

The fourth step is to segment the aorta from the rest of the image. Besides a rupture, especially for early detection purpose, the size of the aorta is of top of our interest. First all non-white pixels will be set to black. Then an image erosion will be performed by using Matlab built-in function to get rid of the tiny white clusters that circle the human body. The author cannot use erosion too many times to remove the white spine due to the inaccuracy when dilating back. Thus, an elimination of white minor clusters from bottom to the top is implemented by using built-in function “imclearborder”. In order to preserve the aorta white cluster, a safety limit with 50% out of total white pixels is set when removing those minor white clusters. Whenever the last white cluster is found, or the safety is reached, the elimination search is over. The last process in this step would be the dilation of the aorta cluster.

The final step in supervised method is the prediction of abdominal aortic aneurysm. Due to the lack of image size (how many millimeter between two adjacent pixels), which is the normal way to diagnose AAA, the author decided to use the ratio of white pixels of the segmented aorta image over all the pixels in the image to make the prediction. This could be improved in future project, as long as more details about CT image from the database is provided.

4. RESULT AND ANALYSIS

The performance of the two methods are accessed by manually looking at them. The pseudo color images created by both methods look good to the authors, These pseudo color images increase the contrast between different clusters, which would help physicians to make the judgement.

On the other hand, the segmentation of aorta from both methods have some defects. The segmentation result from unsupervised method looks good for the first half of the images in the database while performs poorly for the second half. The point of interest method here wouldn't deal well with enlarged aorta cluster in the image. For supervised method, all the segmented images share the same characteristic, regardless of almost all size of aorta cluster. The erosion and dilation will surely lose some sharp angle and detailed information of the aorta cluster and make the result smoothen. Still, the supervised method cannot deal with the last four images, where aorta is too small to detect.

5. CONCLUSION

As discussed in the previous section, we can conclude that the two approaches at image segmentation and detection of AAA prove to be highly effective.

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7. REFERENCES

[1] "Abdominal Aortic Aneurysm Imaging: Overview, Radiography, Computed Tomography", *Emedicine.medscape.com*, 2016. [Online]. Available: http://emedicine.medscape.com/article/416266-overview. [Accessed: 02- Dec- 2016].

[2] A. Cashin-Garbutt, "Abdominal Aortic Aneurysm Prognosis", *News-Medical.net*, 2016. [Online]. Available: http://www.news-medical.net/health/Abdominal-Aortic-Aneurysm-Prognosis.aspx. [Accessed: 02- Dec- 2016].

[3] J. Dean, M.D. and Bon S. Ku, M.D, "Abdominal Aortic Aneurysm", Ultrasound Guide for Emergency Physicians, An Introduction.

[4] A. Rosebrock, "How-To: OpenCV and Python K-Means Color Clustering", *PyImageSearch*, 2016. [Online]. Available: http://www.pyimagesearch.com/2014/05/26/opencv-python-k-means-color-clustering/. [Accessed: 02- Dec-2016].

[5] "Segmentation Lectures", [Online]. Available: http://cs.gmu.edu/~kosecka/cs682/lect-segmentation-part1.pdf. [Accessed: 02- Dec- 2016].

[6] "A New Colormap for MATLAB – Part 2 – Troubles with Rainbows » Steve on Image Processing", *Blogs.mathworks.com*, 2016. [Online]. Available: http://blogs.mathworks.com/steve/2014/10/20/a-new-colormap-for-matlab-part-2-troubles-with-rainbows/. [Accessed: 02- Dec- 2016].