Thrombus Localization in Middle Cerebral Artery of Patient with Acute Ischemic Stroke on ncCT Image

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***Abstract*—A common cause of an Acute Ischemic Stroke (AIS) is a thrombus in the middle cerebral artery (MCA). Localizing the thrombus on a set of non-contrast computerized tomography (ncCT) image for some composite type is not easy. This work presents an algorithm for localizing thrombus in MCA region on ncCT using an image processing method. Given an ncCT image *P*, brain region is extracted by considering a homogeneous intensity area using *k*-mean cluster. A set of candidate regions is obtained by considering size and average intensity of each connected region. Also, location of the MCA is located to filter the candidate regions that are in the interested region. Experiment is perform on a number of images of the different composite of thrombus. The result shows that the proposed image-processing-based thrombus localization algorithm is able to automatically locate the thrombus on ncCT of both red blood cell-rich and fibrin-rich composite.**

Keywords—acute ischemic stroke, image processing,

I. Introduction

The Acute Ischemic Stroke (AIS) is a neurovascular disease that is major cause of death in the world[3]. A common cause of AIS is a clot in a blood vessel, also called Thrombus. Treatment are varied from alteplase to help thrombolysis and an intervention for fibrin-rich composite. Since the time that the patient receive the treatment as early as possible increase the chance of recovery.

To locate thrombus, non-contrast CT (ncCT) and CTA images are currently used. The CTA images are better than ncCT in locating thrombus, but it requires a specialized doctor to prescribe an injection. For this reason, locating thrombus on ncCT would help shortening the time for deciding whether to perform an intervention to allow blood flow.

Machine-learning techniques was applied to classify the composite of thrombus for predicting the outcome of alteplase treatment [7]. Given a ncCT and a CTA images, a thrombus was segmented manually by an expert. The result shows that utilizing 12 features from both types of images can predict the outcome of the alteplase. One limitation of this method is manually localization of the clot by an expert. MCA dot sign are automatically detected in ncCT[6]. Using 3D Region growing to detect the lentiform nuclei region. Because the MCA dot sign are only occurred inside it. The support vector machine (SVM) was used to find the MCA dot sign region inside lentiform nuclei region.

In this work, we proposed an algorithm that localize thrombus in middle cerebral artery (MCA) from the ncCT image. A region-based image segmentation and interested region localization are applied. The detail of the proposed method can be found in Section 3. The experimental results are reported in Section 4.

II. Previous Work

A. Salient Regions Segmentation on CT Image

Takahashi N [7] proposed an automated detection method for the MCA dot sign of acute stroke in unenhanced CT. 3D region growing are used on the left and right lentiform nuclei with seeds given by Statistical Parametric Mapping 8 (SPM8) program. Because the MCA dot sign did not appear outside the lentiform nucleus. The candidate regions are selected if it was inside of lentiform nucleus region. Then, a support vector machine (SVM) is applied with four feature; maximum and an average pixel value within a region, the number of pixels within a region and the number of connections of the region. The localization results are compared with the manually located boundary by the neuroradiologists. This method gave 0.975 accuracy.

Jonas J. Schöttler [2] proposed an automatic thrombus segmentation on CT image using a cascaded convolutional neural network (CNN). Two CNN networks were applied for candidates segmentation and classifying thrombus region. The candidate regions also contain the information i.e., location, shape, density, and volume of each region. Then, the regions are classified whether or not it is a thrombus by using the second CNN network. This method gave 0.99 accuracy on prediction of the existence of the thrombus and its location. However, the authors mentioned that it could be worthwhile to evaluate simpler and more efficient approaches without using the CNN network for segmentation.

B. Intervention Outcome Prediction

W. Qiu.[7] proposed a method for predicting the recanalization with intravenous alteplase using radiomics-based features. A thrombus is manually segmented by neuroradiologists. The linear discriminative and receiver operating characteristic were used for feature selection. The multivariable SVM is used to predict the outcome of the recanalization with intravenous alteplase. The best accuracy is 0.85 ± 0.03 on selected 12 features from the combination group of NCCT, CTA, and radiomics.

C. Image Segmentation

The k-mean clustering method is a widely used for separating interested region from its background. J. Macqueen.[4] describe the k-mean method to be a process for partitioning an N-dimensional population into k sets. The method find the k amount of center in the data that represent each data group.

The Otsu's threshold method is a segmentation method that propose by N. Otsu [5]. The separate the front-ground from the back-ground using a threshold values that calculate from intensity of the image. This method can sperate really well when the front-ground and back-ground have a high different in intensity value.

Canny is an edge detection method proposed by Canny. J.[1]. Edges in an image are found using; Gaussian filter for noise reduction, find intensity gradients and Apply non-maximum suppression to select only the maximal intensity gradients value. Then double threshold weak edge to reduce false detection.

III. PROPOSE METHOD

We propose an automatic thrombus localization using the region growing method combine with MCA position filter.

First, we find the brain region using region growing method which have seeds provided from k-mean method. After we have the brain region, we use the region growing method to segment the candidate region. Different intensity from each candidate region is use as filter to select a high intensity region as candidate regions. MCA position were located to filter only candidate regions that are inside or near the MCA position as the candidate regions. An overview of the proposed is shown in Fig. 1.

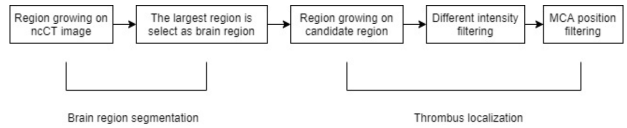


Fig. 1. Overview diagram of proposed method

A. Dataset Preparation

In this work, a set of ncCT images of Data set that use in this paper obtained from Siriraj Hospital. For each patient, a ncCT image that contain thrombus were provided with the boundary of the thrombus provided by a radiologist as a ground truth. See Fig. 2, for illustration.

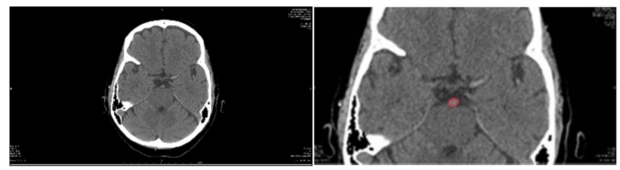


Fig. 2. Example of CT image and the boundary of the thrombus

B. Image Preprocessing

The CT images contains unnecessary data such as background, bone area, and unrelated organ. A pre-processing step is applied to retrieve only brain region for analysis. In this work, k-mean cluster and region growing method are applied. A set of initial seeds is found by using center of k cluster. For each seed, a monogenous region is found by a region growing.

To retrieve only brain region, $k = 4$ is used for k-mean clustering and the seeds, which are from the middle intensity levels, are applied for the region growing. Let $\{c_1, c_2, c_3, c_4\}$ be the k cluster center value which $c_1 < c_2 < c_3 < c_4$. Let I_{min}, I_{max} be intensity range from minimum and maximum respectively, where $i_{min} = c_1 + ((c_2 - c_1) \div 2)$ and $i_{max} = c_3 + ((c_4 - c_3) \div 2)$. The region growing can be described as follows.

Let $S = \{s_1, \ldots, s_k\}$ be a set of the initial seeds .For each seed $s_t \in S$. The pixels around 8 windows, P_s be a set of pixels that surround s_t, and (i, j) is the position of the seed as in Fig. 3.b .Surrounding pixels $p \in P_s$ are selected if their intensity are within the predefined range. The range is the intensity level from i_{min} to i_{max}. The selected pixel p will be added to the seed set S if $p \notin S$. The next seed that is not already inside the region is selected to expand the region. The process is stop when all of the seeds are inside the region and there is no new seed to be added.

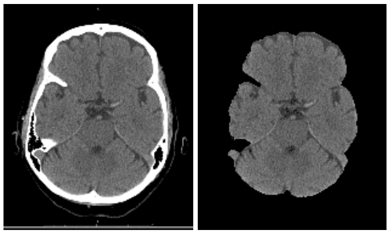
a.

4	5	1
4	5	4
3	3	4

b.

p_{s1}(i-1,j-1)	p_{s2}(i-1,j)	p_{s3}(i,j+1)
p_{s4}(i,j-1)	s_t(i,j)	p_{s5}(i,j+1)
p_{s6}(i+1,j-1)	p_{s7}(i+1,j)	p_{s8}(i+1,j+1)

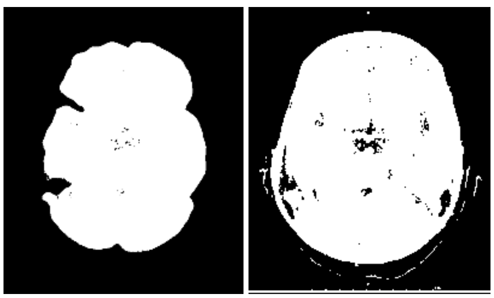
Fig. 3. a. The example of the region growing, when I_{min} is 4 and I_{max} is 5. b. The position matrix of the P_s and the s_t.



a. b.

Fig. 4. a. The original image. b. The segmented image of brain region.

An example of the connected region is shown in Fig. 4aThe output of the segmented brain tissue is shown in Fig. 4d. It can be seen that only the brain tissue is segmented. A comparison of the segmented region using the proposed method and the Otsu's threshold[5] are shown in Fig. 5. It can be seen that the mask region of Otsu's method includes the unnecessary parts which are bones and ears, while our proposed method focuses on the brain tissue.



a. b.

Fig. 5. The mask for k-mean (a) compare to the mask for otsu-threshole(b).

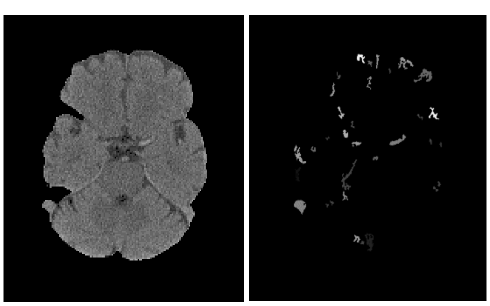
C. Thrombus Localization

Given a brain tissue as shown in Fig. 3d, the thrombus in an interest region is localized using k-mean and region growing method.

A set of candidate regions is found by using region growing and k-mean cluster. Let $C_L \in \{c_1, c_2, \dots, c_k\}$ be the centers value which $c_1 < c_2 < \cdots < c_k$ obtained from k-mean clustering.

The pixels, which are in c_k cluster, are used as a set of initial seeds. The range for including the surrounding pixels is the maximum intensity of the pixels in c_k to the minimum in c_{k-1}.

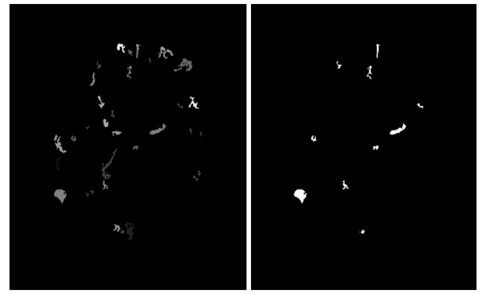
Some regions are too big or too small to be the thrombus. Therefore, the candidate regions are exclude if it is larger than 0.05 percent of the brain area or smaller than 0.5 percent of the brain area.



a. b.

Fig. 6. a. The brain region.b. The candidate region after region growing

The candidate regions are further filtered to remove the ones that are common. The differences of intensity distribution of each region to other regions is used. The candidate is selected when the differences to the other region is more than the average different among them.

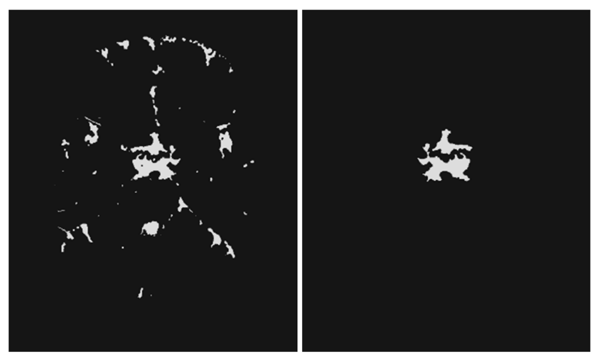


a. b.

Fig. 7. a. The cadidate regions.b. The cadidate regions after apiled the distance filter.

To ensure that the thrombus is in MCA, the interest position from MCA to sylvian fissure is automatically defined.

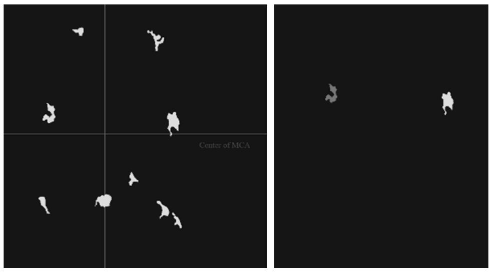
The dark area in the brain region is defined using the center value of k-mean with the least intensity value, and find each region that have connected region. Then the circle of willis is the region in the center of the brain region. We will call this the willis center point.



a. b.

Fig. 8. a. The dark region in brain image b. The dark region that are used to find center of willis

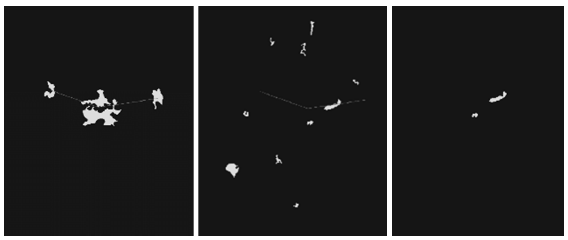
The two sylvian fissure positions are on the left the right. Using the position of willis center point, the left sylvian region is the largest region that have positioned above on the left of willis center point. The right sylvian region is the largest region that have positioned above on the right of willis center point. We called this as left and right sylvian center.



a. b.

Fig. 9. a. The dark region with cross line on willis center point b. The left and right sylvian region

After obtaining willis center point and both sylvian center, two lines are drawn from willis center point to both sylvian center. The candidate region is selected as thrombus if the distance to the closest line is less than 0.1 of the height of the brain region.



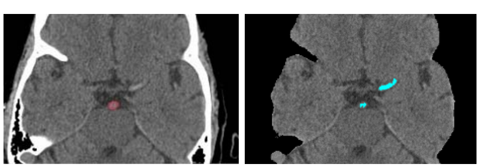
a. b. c.

Fig. 10. a. The line drawn from willis center point to both sylvian center b. The line drawn over the previous candidate region c. The candidate region after the MCA filter

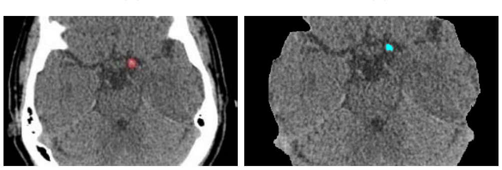
IV. RESULT

The segmentation is visually compared with the corresponding ground truth from the radiologist. The ground truth images are shown in Fig. 11a(1) and b(1). The segmentation result of our proposed method of the corresponding images are shown in Fig. 11a(2) and b(2), respectively. The result in Fig. 11a show an additional region is wrongly segmented. This ncCT was taken from red blood cell / fibrin composite. The result of Fig. 11b shows that the proposed method can correctly segmented the thrombus region of red blood cell / fibrin composite

More segmentation result can be found in Fig. 12.



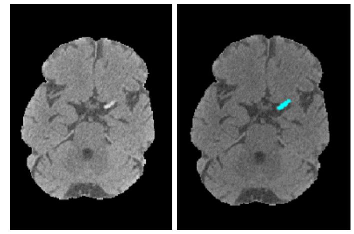
a(1) a(2)



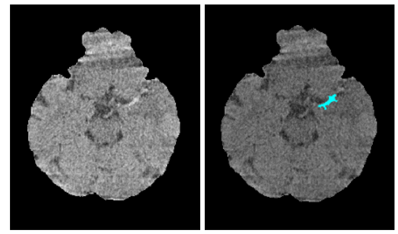
b(1) b(2)

Fig. 11. a(1).,b(1). The ground truth from radiologist Figure a(2).,b(2). Corresponding region from our method.

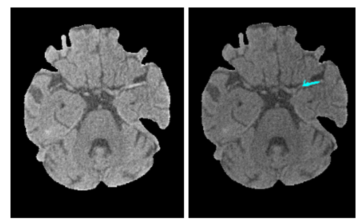
Image segmentation result of other ncCT of AIS patient.



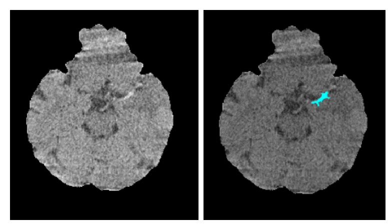
a.(1) b.(1)



a.(2) b.(2)



a.(3) b.(3)



a.(3) b.(4)

Fig. 12. a.(1)(2)(3)(4) The brain region b.(1)(2)(3)(4) the corresponding result image with thrombus region

V. CONCLUSION

The method can highlight the area of MCA that have thrombus inside according to the ground truth as show in Fig. 11. Our method might select some of the result region that are the MCA, so further work might try to eliminate that problem.

However, the thrombus localization method has some limitation. The first limitation is when the thrombus region does not have a highest k-mean center value inside. The second limitation is the resolution of the image affect time to compute for the method directly, because the region growing method need to calculate every pixel of the image.

In the future work, we can use this method to create an application to help radiologist detect the thrombus faster.

VI. ACKNOWLEDGEMENT

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REFERENCES

[1] Canny, J., A Computational Approach To Edge Detection, IEEE Transactions on Pattern Analysis and Machine Intelligence, 8(6):679–698, 1986.

[2] Jonas J. Sch¨ottler, Andr´e Kemmling and Linda F. Aulmann. Automatic Detection and Segmentation of the Acute Vessel Thrombus in Cerebral CT. 10.1007/978-3-658-25326-4_19.

[3] Mackay J and Mensah G. The Atlas of Heart Disease and Stroke. World Health Organization. 2004; p. 18–19.

[4] MacQueen, J. Some methods for classification and analysis of multivariate observations, Proceedings of the Fifth Berkeley Symposium on Mathematical Statistics and Probability, Volume 1: Statistics, 281--297, University of California Press, Berkeley, Calif., 1967.

[5] N. Otsu, "A Threshold Selection Method from Gray-Level Histograms," in IEEE Transactions on Systems, Man, and Cybernetics, vol. 9, no. 1, pp. 62-66, Jan. 1979.doi: 10.1109/TSMC.1979.4310076

[6] Takahashi N, Lee Y, Tsai DY, et al. An automated detection method for the MCA dot sign of acute stroke in unenhanced CT, Radiol Phys Technol. 2014;7(1):79-88.

[7] W. Qiu, H. Kuang, J. Nair, Z. Assis, M. Najm, C. McDougall, et al. Radiomics-Based Intracranial Thrombus Features on CT and CTA Predict Recanalization with Intravenous Alteplase in Patients with Acute Ischemic Stroke, American Journal of Neuroradiology January 2019, 40 (1) 39-44.