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Detection and Segmentation of Ischemic Stroke Using Textural Analysis on Brain CT Images

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Abstract— The detection of the brain strokes from Computed Tomography CT images needs convenient processing technique starting from image enhancement to qualify the brain image by isolation process, region growing and logical operators (OR and AND). Morphological techniques (opening and close) with the logical operator produce a good result. These results with the help of the simplest segmentation process, which is the thresholding process, are used to extract a stroke region from the CT image of the brain. The median filter is applied to remove the noise from the image. The statistical features calculated using first-order histogram were utilized in the detection of the stroke region.

Index Terms— Ischemic stroke; CT scan image; Brain segmentation; statistical features.

1 Introduction

Medical imaging refers to the techniques and processes which are used to produce images of various parts of the human body for clinical purposes. The quality of these images plays an important role in the medical field. The success in the diagnosis mainly depends on the accuracy of segmentation algorithm [1, 2]. There are two types of brain stroke; hemorrhage stroke and ischemic stroke [3, 4].

In this paper the stroke is discussed. Ischemic stroke happen when a blood clot blocks the artery supplying blood to the brain. This may occur in two reasons: first one Thrombotic stroke occurs when the artery becomes narrow and the clot is stick on the wall of the artery because of many reasons like fat and cholesterol [5]. The second one Embolic stroke occurs when the clot is stopped the blood vessel in the brain, or comes from other part of the body [3, 4]. Ischemic stroke is a very common disease that affects blood vessels in the brain causing cerebral tissue damage [6]. Computed Tomography (CT) images are widely used to diagnose brain stroke for many reasons, lower cost, sensitiveness to early stroke [1] and non-invasive technique [7].

Andrius U. et. al. describes a new method to segment ischemic stroke region on computed tomography (CT) images by utilizing joint features from mean, standard deviation, histogram, and gray-level co-occurrence matrix methods. Presented unsupervised segmentation technique shows ability to segment ischemic stroke region [8]. S. Fueanggan, et. al. resents a new designed program to initially analyze Ischemic Stroke area from Computed Tomography Perfusion (CTP) based on Digital Image Processing Techniques. The new designed software can specify Ischemic Stroke Area by assigning Threshold level of CTP from CBV (Cerebral Blood Volume), CBF (Cerebral Blood Flow) and MTT (Mean Transit Time) images [9]. Santichai Fueanggan, et. al. the objective of this research is to specify Ischemic Stroke Area by using Digital Image Processing principle to analyze Computed Tomography Perfusion (CTP) images from CBV (Cerebral Blood Volume) and CBF (Cerebral Blood Flow) images. By assigning Threshold level of CBV and Threshold level of CBF. results will be shown in N-Match (normal tissue areas), D-Match (dead tissue areas), Mismatch (blood clot tissue areas) and Undefined area. Then, separate the brain into left and right to compare distribution of Mismatch and D-Match information in order to specify Ischemic Stroke Area. As a result of experiment, it is possible to sort elementary information of left and right side of the brain to specify Ischemic Stroke Area to compare the results with brain specialists [10]. Ming Sian, Lee, et. al. in this study propose an Increasing visual perception brain stroke detection system. They used mathematic morphology to extract brain area. Then using median filter to remove noise, and using canny edge detection to find out the edge of the brain tissue, setting peak value in edge histogram as seed to perform region growing. Finally, they can clearly recognize the area of stroke [11].

This paper is concerned with brain strokes and investigates proposed image processing techniques to improve the detection of such strokes. The adopted procedure is illustrated in the flow chart shown in figure 1. The following sections explain the various parts of the proposed method of stroke detection.

2 Preprocessing

CT images need preprocessing operations because of unorganized nature of the brain tissue that is why we applying method for the diagnosis of the infraction.

2.1 Gray Image

The images received from CT scans are usually colored by RGB (red, green and blue) components. However, they are converted into gray-scale image by eliminating brightness information, thus converting the image format 512$\times$512$\times$3 color RGB to 512$\times$512 gray-image [12] as shown in figure (2-a). This image was obtained from CT scanning of the head of a patient suffering from brain stroke.

2.2 Skull Removal (Brain Insulation)

The removal of the bony skull surrounding the brain tissue is considered as a challenge to the brain isolation. This process will allow us to extend the segmentation of the stroke. The following methods and mathematical operation are used to perform the skull removal.

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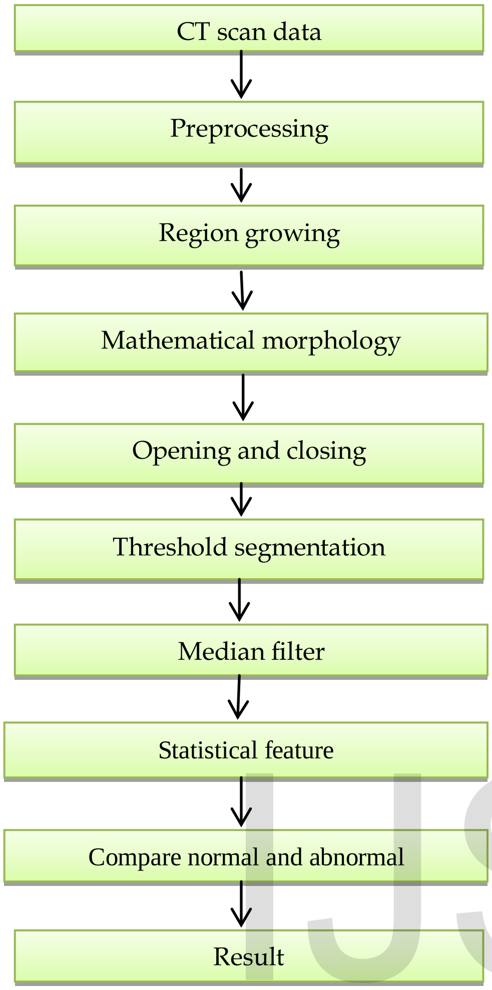

Fig. 1 the diagram for the assumed system for the detection of strokes from CT brain images.

2.2.1 Region Growing

The region growing is a step that groups the pixels or sub-regions into larger regions based on a predefined criteria for growth. A "Region" forms pixels growing with the same intensity level which is used to calculate the area of white mater for the skull [13].

2.2.2 Image Masking

To remove the cortex, the logical operator (OR) is applied. This makes the region of study black while the background is converted into white as shown in figure (2-c). We have also used the AND operator which transforms the regain of study into white and background into black as shown in figure (2-b). These two operators were used to extract the brain tissue as can be seen in figure (2-d).

2.2.3 Filtering

The resulting image need a filtering operation so a median filter of window [3 X 3] was applied on the image for three successive time to remove the noise in the CT image. Smother images were obtained as can be clearly seen in figure (2-e, f, g).

2.2.4 Opening and Closing

Using morphological techniques called "opening-by-reconstruction" and "closing-by-reconstruction" to "clean" up the image. These operations will create flat maxima inside each object that can be located. Opening is erosion followed by dilation, while opening-by-reconstruction is erosion followed by a morphological reconstruction. Following the opening with a closing can remove the dark spots and stem marks. Compare a regular morphological closing with a closing-by-reconstruction. Reconstruction-based opening and closing are more effective than standard opening and closing at removing small blemishes without affecting the overall shapes of the objects as shown in figure (2-h, i, j, k).

3 THRESHOLDING

The thresholding technique is the simplest method used in the segmentation process. The process collects all the pixels with a certain threshold and rejects other pixels which have values less than the threshold. After the thresholding procedure is applied the stroke region will be isolated from the brain tissue. The stroke regions will be more clearly visible in the output images.

3.1 Ischemic stroke

To obtain an image contain the ischemic stroke the threshold method was applied twice on the image. For each time the threshold value differ from the other. The median filter applied to the segmented image to smooth it and remove the noise, figure (1-l, m, n) shows these result.

4 METHODOLOGY

The brain image has been divided into two equal parts one of these parts includes abnormal area and the other one contains the normal area. The statistical features were then calculated from the first-order histogram. Comparisons were made between the histograms of the two parts to check which part carries the stroke.

4.1 First-Order Histogram features

The random variable i represents the gray levels of the image region. The first-order histogram p (i) is defined as: [13]

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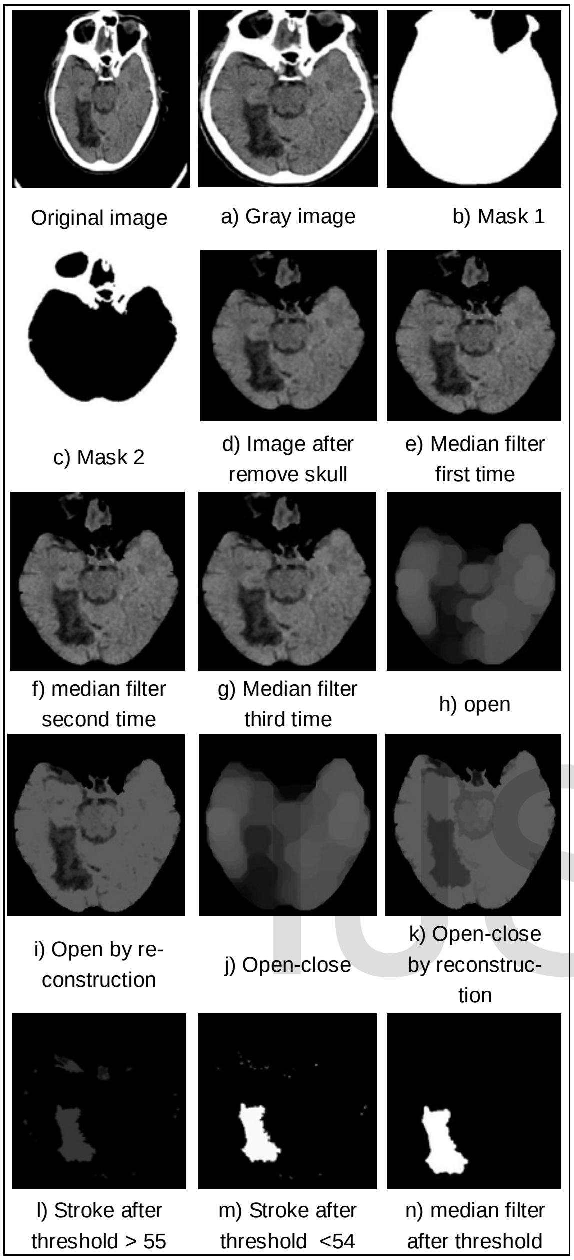


Fig. 2 images obtained from the Preprocessing and thresholding process

$$p(i) = \frac{\text{number of pixels with gray level } i}{\text{total number of pixel in the region}} \quad (1)$$

P (i) = H (i)/NM
P (i) = is the probability of occurrence of the i.
Where i=0, 1, 2………G-1
G= gray level tone of an image (255), N= number of cells in the horizontal domain.
M= number of cell vertical domain [15]

Mean: $$\mu = \sum_{i=1}^{G-1} ip(i) \quad (2)$$

Standard deviation: $$\sigma = \sqrt{\sum_{i=0}^{G-1} (i-\mu)^2 \, p(i)} \quad (3)$$

Energy: $$E = \sum_{i-1}^{G-1} (p(i))^2 \quad (4)$$

Entropy: $$\mathrm{H} = -\sum_{i=1}^{G-1} p(i) log2\, [p(i)] \quad (5)$$

Variance: $$\sigma^2 = \sum_{i=1}^{G-1} (i-\mu)^2 p(i) \quad (6)$$

Skewness: $$skew = \sigma^{-3} \sum_{i=1}^{G-1} (i-\mu)^3 p(i) \quad (7)$$

Kurtosis: $$kurt = \sigma^{-4} \sum_{i-1}^{G-1} (i-\mu)^4 \, p(i) \quad (8)$$

The first order histogram represents the estimation of the probability density function (PDF) for the selected neighborhood [14]. Useful features of the image can be obtained from the histogram; including mean value which represented the white color in the image so the normal part has the higher value of the mean. Variance tells about the intensity variation around the mean. Standard deviation gives the measure of the average contrast so the variance and standard deviation related to the mean so the normal part is higher. Energy gives indication about the number of gray level in the image the normal part is higher since it has a great number of gray level compare with the abnormal part in which there is a stroke which causes a defect in the brain tissue. Entropy represents the uniformity of the histogram and inversely proportional to the energy so the value for the abnormal part is greater than normal part. Skewness tells the symmetries of the histogram around the mean so for the normal part is higher and for the abnormal part is lower. Kurtosis is the fatness of the histogram, for normal part is higher as shown in table (1) and figure (3).

TABLE 1
texture features for the normal and abnormal part

Image	Normal	Abnormal
Mean	45.2236	40.9740
Energy	0.2439	0.1998
Entropy	0.4336	0.442
Variance	2.7122e+003	2.1887e+003
Standard Deviation	52.07878	46.78354
Skewness	1.0670e-005	1.4925e-005
Kurtosis	3.9340e-009	6.8194e-009

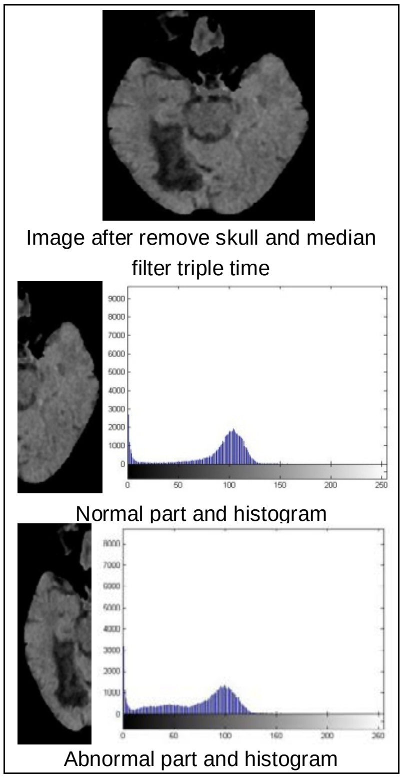
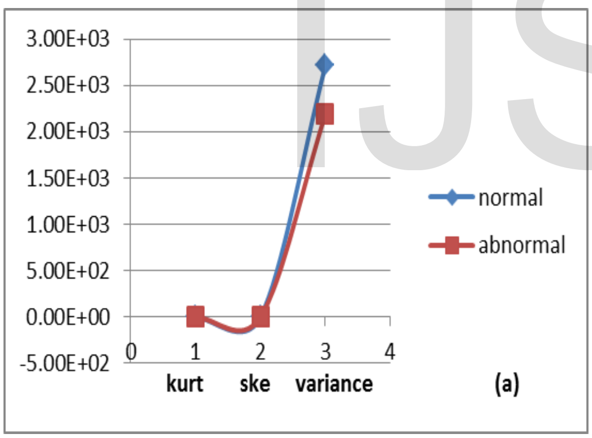
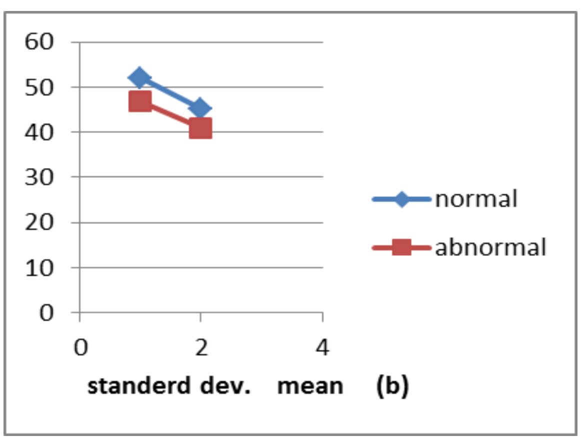


Fig. 3 The histogram for brain parts





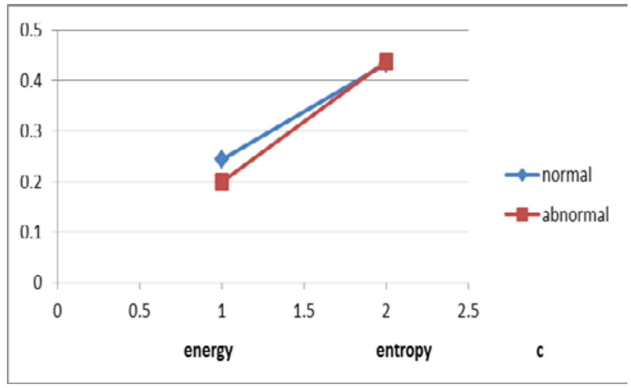


Figure (4) the graph of the statistical features (a, b, c)

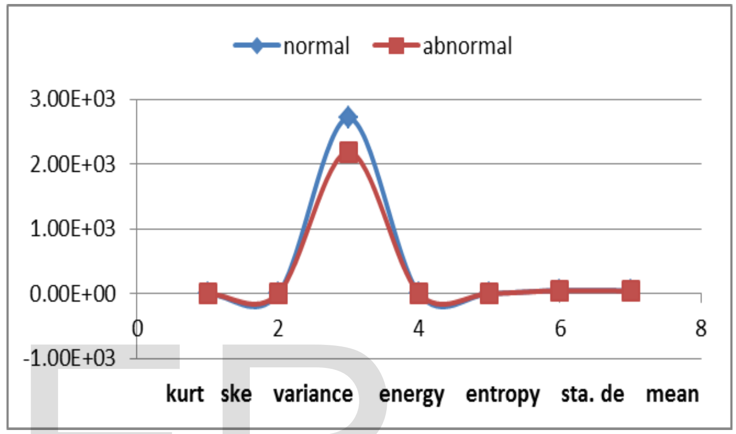


Fig. 5 the statistical features for normal and abnormal part

5 Conclusion

The pre-processing methods are important to make the segmentation easier and faster than the familiar process. Features are used to compare between the normal and abnormal parts of the brain. Different pre-processing methods have been used to improve the abnormal part in the statistical features which were obtained from the first-order histogram gives information about two half. From figure (4) and table (1) the statistical features shows higher value for the entropy. Since it represented the randomness in the image and its inversely proportional to the energy so the energy value for the abnormal part is lower than normal part this means that the number of gray-level value is higher than the normal part, because appearance of stroke in this part. Skewness and kurtosis shows a lower value for the normal part. The variance which depend on the mean value, and the mean value are lower for abnormal part since the stroke appear more dark than the normal brain tissue and the mean represented the brightness part in the image. This method gives good result about the detection and segmentation of brain stroke with the help of the statistical features.

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