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Multiple Thresholding Methods for Extracting & Measuring Human Brain and 3D Reconstruction

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Multiple Thresholding Methods for Extracting & Measuring Human Brain and 3D Reconstruction

Sumijan*, Pradani Ayu Widya Purnama, and Syafri Arlis

Faculty of Computer Science, University of Putra Indonesia YPTK Padang, Jl. Raya Lubuk Begalung, Padang, West Sumatera

*sumijan@UPIYPTK.AC.ID

Abstract. Thresholding changes the gray image to binary imagery and improves image quality. This study applies the multiple thresholding method to extract and calculate the area of bleeding in the human brain. 10 samples of human brain image using multiple threshold method (Otsu and hybrid thresholding). The results of the Otsu method that still have noise can be overcome by the hybrid thresholding method. The results of the original image research with images that have been processed using the multiple thresholding method yield the optimum threshold value, the method applied produces excellent image quality. Results of calculation of MSE, RMSE and PSNR. the average PSNR Otsu thresholding: an average of 60.93 dB, the average PSNR Hybrid thresholding: 59.06 dB, and the average PSNR Multiple thresholding: 56.96 dB, the average MSE Otsu thresholding: 38.27, the average MSE Hybrid thresholding 36.15, mean MSE multiple thresholding: 34.30, mean RMSE Otsu: 9.49, mean RMSE Hybrid thresholding: 8.88, average RMSE Multiple thresholding: 7.58. The results of the calculation of the area of cerebral haemorrhage and the level of accuracy indicate a better multiple thresholding method. The results of the calculation of the bleeding area were carried out by 3D reconstruction using linear interpolation method.

1. Introduction

Image segmentation is the process of getting objects in the image area or dividing images into several areas with each object or area having similar attributes. In an image that has only one object, the object is distinguished from the background and object [1]. Thresholding is the process of converting images from gray intensity to binary imagery, it is expected that it can be known between areas including objects and the image background clearly that can be used in the next process. The image resulting from thresholding will be used for the process of identifying or detecting objects and feature extraction. In the thresholding method, it is divided into two. First, global thresholding by using a histogram partition, a global threshold is called T, all image areas are used by this global thresholding. Both adaptive thresholding by dividing images are grouped into sub-images. Then in each sub-image segmentation is done using a different threshold, according to the characteristics of noise [2]. The method of image segmentation can be based on two properties, namely the value of gray intensity: discontinuity and similarity between pixels. The first method of image separation is based on automatic changes to the intensity of grayscale. For example by using the line detector and edge detector approaches to the image. The second method is based on the level of similarity between pixels in a different area according to the characteristics of noise [3]. The two methods described are: thresholding based on histograms; number of object areas; separation and merging of object areas;



grouping or classification; graph theory approach; knowledge-based or rule-based approaches. Based on the techniques used, segmentation can be divided into the following four categories [4]: thresholding techniques; threshold based method; method based on object area; hybrid method that combines threshold criteria and object area.

Image acquisition of brain CT is generally carried out in 2-dimensional (2D) form recorded in the form of slices with a certain distance between one slice and another. At each slice the image represents the state of the brain in the position of the slice. The representation of visual information is in the form of variations in the intensity of color or gray level of the brain slices and other objects (if any), as shown in Figure 1. Figure 1 (a) shows one slice of normal brain image and image 1. (b) is a slice abnormal brain image and white area in the brain is the bleeding area [5].

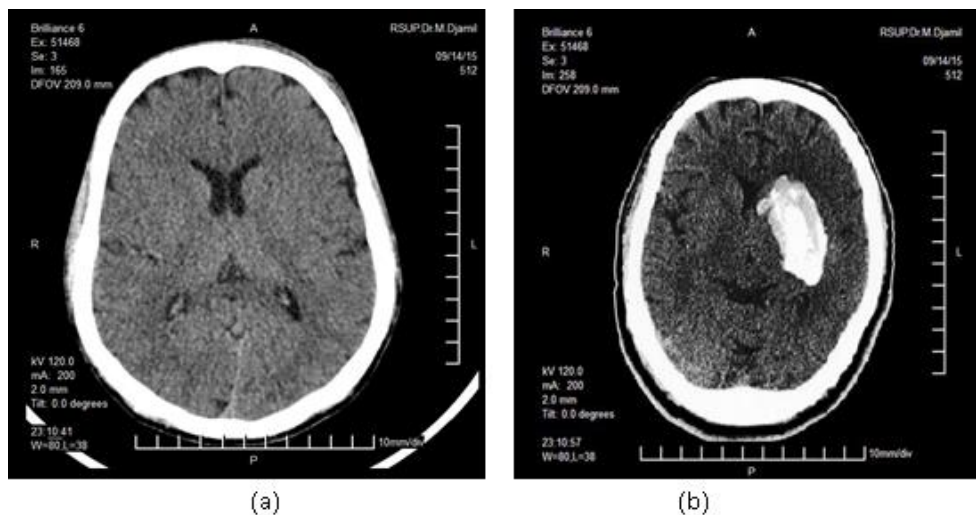


Figure 1. (a). Normal Brain Image, (b). Brain Image Bleeding
Source: RSUP M. Djamil Padang West Sumatra, 2015

A system of brain hemorrhage detection using image processing was used to classify cerebral hemorrhage in CT scan. Implement with MATLAB by making a procedure. In image processing procedures, such as the process of pre-processing, segmentation and feature extraction are carried out in detail. Produce more accurate processed images using various segmentation and refinement techniques [6]. The cancer detection scheme consists of four stages. Starting from Preprocessing, segmentation, classification and feature extraction. These four levels are used in image processing to improve precision tumor identification. The end result of this work is to find cancerous tumors as benign (or) malignant [7].

The function of restoration on CT scans in detecting both intracranial cranial cavity and additional skull lesions in patients with head injury is the most common cause, while the most frequent lesions are cerebral contusion [8]. Improving the quality of brain CT images with the aim of clarifying the contrast between parts of the brain through coloring with the help of the histogram algorithm. This research has not been oriented to the detection of brain injury. Karuna and Joshi [9] research has been conducted on the segmentation of the brain tumor area using texture analysis: Angular Second Moment (ASM), contrast, inverse difference moment (Homogeneity), dissimilarity and entropy [9]. Gillebert et al. In their study proposed an automated delineation algorithm that can automatically describe infarction and cerebral hemorrhage in CT (Scan Brain Stroke) images [10].

Subsequent research identified and extracted brain images from CT-Scan images to classify the brain that occurs bleeding and did not occur brain hemorrhage using the k-means algorithm classification method examined by Sharma [11]. The next study of Wenan et al. [12] in this study proposed the ICM (Iterated Conditional Mode) algorithm and Maximum A Posteriori Spatial Probability (MASP) to compare the two algorithms to analyze traumatic brain hemorrhage. The results focus on automatic processing of CT-scan brain images for segmentation and identifying brain ventricular bleeding [12]. Improving the quality of brain CT images with the aim of clarifying the

contrast between parts of the brain through coloring with the help of the histogram algorithm. This study has not been oriented to the detection of brain injury [13].

This study applies a multiple thresholding method, namely the otsu method and hybrid method (P-File and canny), the results of the Otsu method segmentation that still have noise, so there needs to be a hybrid thresholding method to overcome the noise on the Otsu. The hybrid thresholding method combines the P-File edge detection method with Robert, Canny, Sobel, LoG, and Prewitt. The results of the original image research with images that have been processed using the multiple thresholding method to obtain the optimum threshold value, so that this method is expected to produce better image quality. By combining the otsu and hybrid thresholding method (combining the P-File and Canny method) to extract the cerebral hemorrhage area in each slice of the CT scan image and calculate the area of bleeding. With the multiple thresholding method, the Otsu method segmentation that still contains noise can be overcome by the hybrid thresholding method.

2. Research Methods

The method or sequence of research conducted in this study is illustrated in Figure 2. This study consisted of 7 stages, namely:

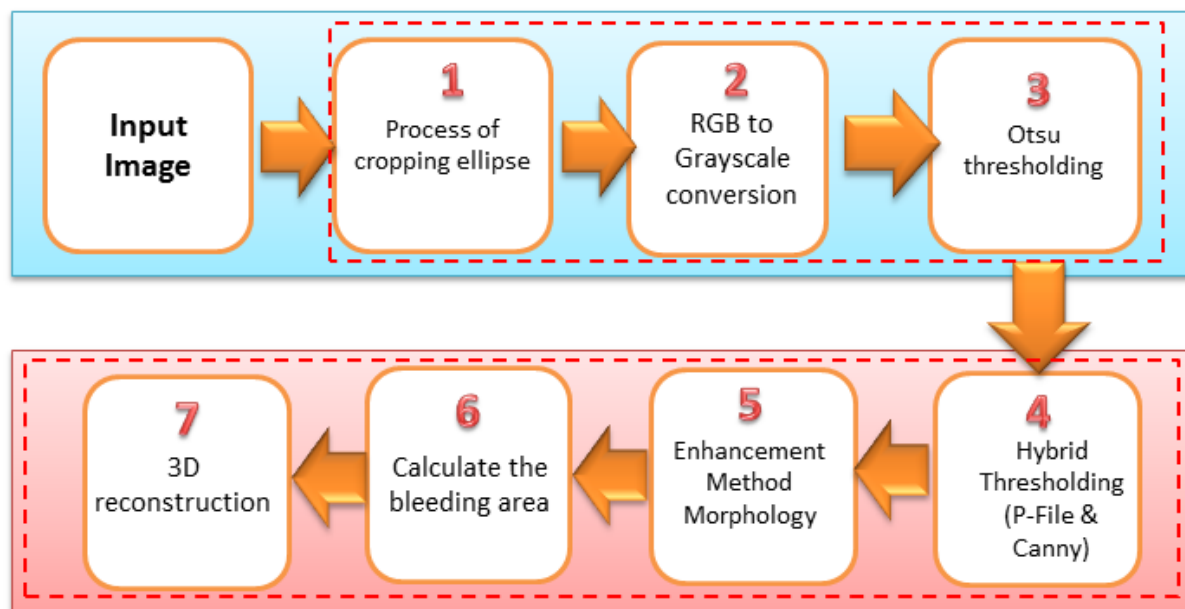


Figure 2. Research Framework

The main contribution proposed in this study is the merging of the Otsu method, the hybrid method, where the hybrid is a combination of the P-File method and the canny method (can be seen in Figure 2. which is marked by a dashed line box).

1. Input Image

The data used in this study were CT scan brain data from 10 patients with 8 images of brain hemorrhage (abnormal brain) and 2 images without bleeding (normal brain). The image used consists of 9 abnormal brain image images (image 1 s.d image 9), 1 image of a normal brain image (image 10). Brain image image data in file format in the form of "bitmap image (.bmp)", can be seen in Figure 3.

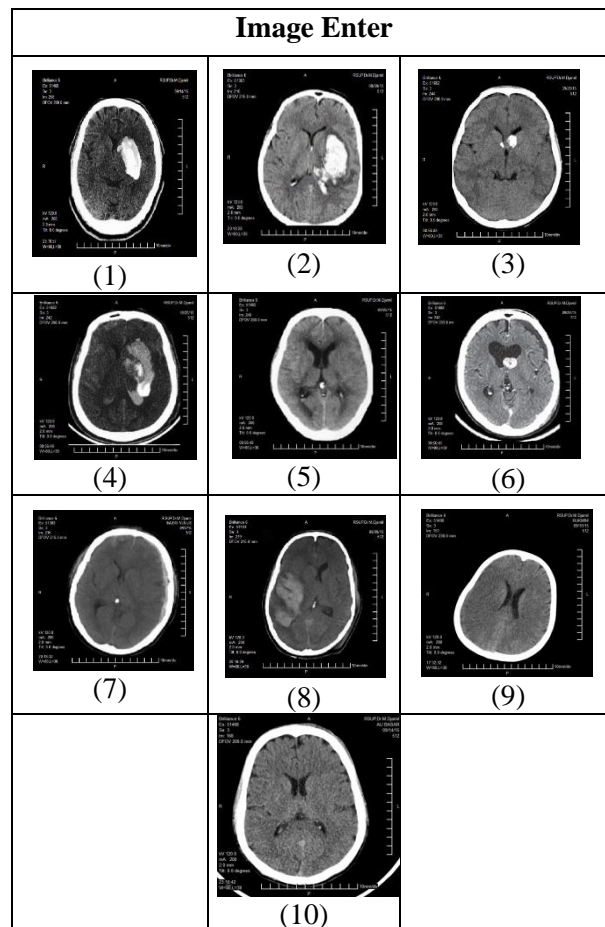


Figure 3.

CT-Scan Brain Imagery; Input Image (1), Input Image (2), Input Image (3), Image (4), Input Image (5), Input Image (6), Input Image (7), Input Image (8), Input Image (9) Image of brain input is not normal; and Input Image (10) Normal brain input image

2. *The first stage of cropping the input area:*

The cropping process aims to eliminate unnecessary noise outside the object of research, the cropping process is done automatically by using ellipse logic to determine the image of the research object to be analyzed and processed, and to reduce the size of the original brain image easily processed and analyzed.

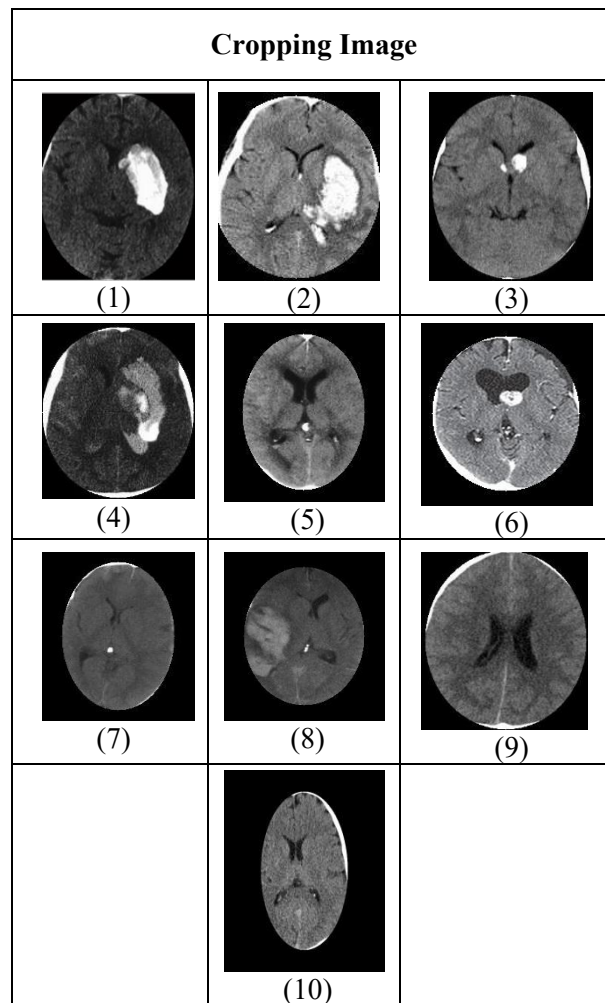
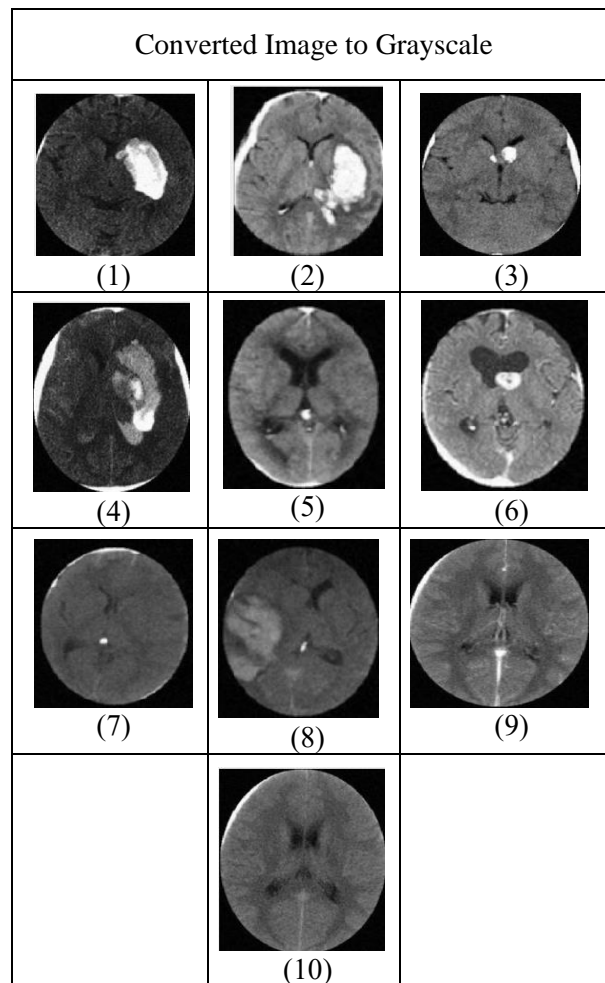


Figure 4.

Brain Image CT scan results from cropping; Image (1), Image (2), Image (3), Image (4), Image (5), Image (6), Image (7), Image (8), Image (9) Brain image is not normal; and Image (10) Normal brain image

3. *The process of converting images to grayscale aims to convert color images into gray-scale imagery considering that many image processing works on a gray scale.* However, sometimes gray scale imagery also needs to be converted to binary imagery, considering that some operations in image processing run on binary imagery. How do you change the color image into a gray scale image? In general, color images can be converted to gray scale images through formulas:

$$I = 0,2989 \times R + 0,5870 \times G + 0,1141 \times B \quad (1)$$

**Figure 5.**

Brain Image Scan results from conversion to grayscale images; Image (1), Image (2), Image (3), Image (4), Image (5), Image (6), Image (7), Image (8), Image (9) Brain image is not normal; and Image (10) Normal brain image

4. Multiple Thresholding Method

The multiple thresholding method is a method for digital image segmentation by combining the Otsu method and hybrid thresholding where this method combines the P-file and Canny methods.

- a. The otsu method for digital image segmentation by using a threshold value automatically, the image used in the otsu method is a binary image (black and white cira), the process carried out is to compare the threshold value with the pixel color value of a digital image. The Otsu thresholding method was first introduced by Nobuyuki Otsu, in his scientific journal entitled "A Threshold Selection Method from Grayscale Histogram" in 1979 [14]. The threshold value is obtained from the calculation as follows: The first step that must be done is to make a histogram. The next step results from the histogram will be known the number of pixels for each gray level. Then the gray level of the image is expressed with i to L . The otsu method can be expressed by equation (2):

$$\sigma_B^2(k) = \frac{[m_G P_1(k) - m(k)]^2}{P_1(k)[1 - P_1(k)]} \quad (2)$$

Keep in mind that the value of k is at the time $\sigma_B^2(k)$ Maximum

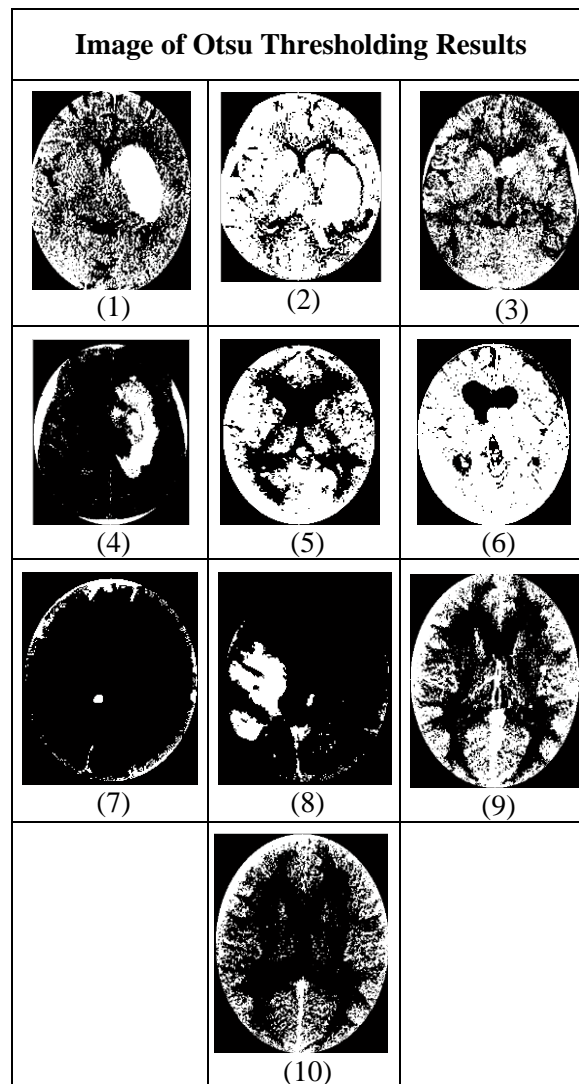


Figure 6.

CT-Scan Brain Image results from the Otsu thresholding method; Image (1), (2), (3), Image (4), Image (5), Image (6), Image (7), Image (8), Image (9) Brain image is not normal; and Image (10) Normal brain image

b. Hybrid Thresholding (P-file and Canny)

The purpose of the hybrid image thresholding method is to utilize image characteristics to help the process of calculating the threshold value. This method was developed by Samopa [15] with the aim of carrying out a thresholding process based on a combination of the P-tile method and the edge detection method. As in his paper entitled "Hybrid Image Thresholding Method Using Edge Detection", Samopa stated that the results of segmentation of objects obtained were more accurate than the usual method and also the Otsu method. Figure 3. shows an example of some edge detection methods used to calculate object area ratios by comparing the differences between the edges of the map and the original image with the threshold image. Try all possible object area threshold ratio values for an image and compare the edges of each edge of the original map image, the best estimate of the area of the ratio value object is determined as the value where the resulting edge has the smallest difference map with the original image. Application of MSE (Mean Squared Error) to calculate the difference between the edge of the threshold Map of the edge Map image and the original image. Giving the image I value to its original image and G to the threshold value threshold that is looking for [15], the Hybrid algorithm Thresholding Image method is as follows:

1. $O \leftarrow \text{EdgeMap}(I)$ # EdgeMap count from image I #
2. $v \leftarrow \text{initial_Value}$
3. $e \leftarrow \text{RealMax}$ # Set e as the maximum image value #
4. Loop until $v = \text{max_Value}$ in Step increment.
5. $T \leftarrow P\text{-tile}(I, v)$ # threshold I uses the method tile and v as the threshold value #
6. $C \leftarrow \text{EdgeMap}(T)$ # Calculate Edge Map from image T #
7. $r \leftarrow \text{MSE}(O, C)$ # Calculate the value of MSE in O and C #
8. If $r < e$ # if the MSE value is smaller than e #
9. $e \leftarrow r$ # exchange e value with MSE #
10. $G \leftarrow v$ # set v as search value #

This method is simple and is suitable for all types of edge detection, because it only iterates continuously (determining value step by step). This method does not add to the T-tile complexity method and edge detection makes this hybrid approach. In the Hybrid Image Thresholding method, it is necessary to find the best edge to be combined with the edge detection of the P-tile method. This method tries to combine the P-tile method with five types of edge detection, canny, Prewitt, Roberts, Sobel and Laplacian from Gaussian (LOG) [15].

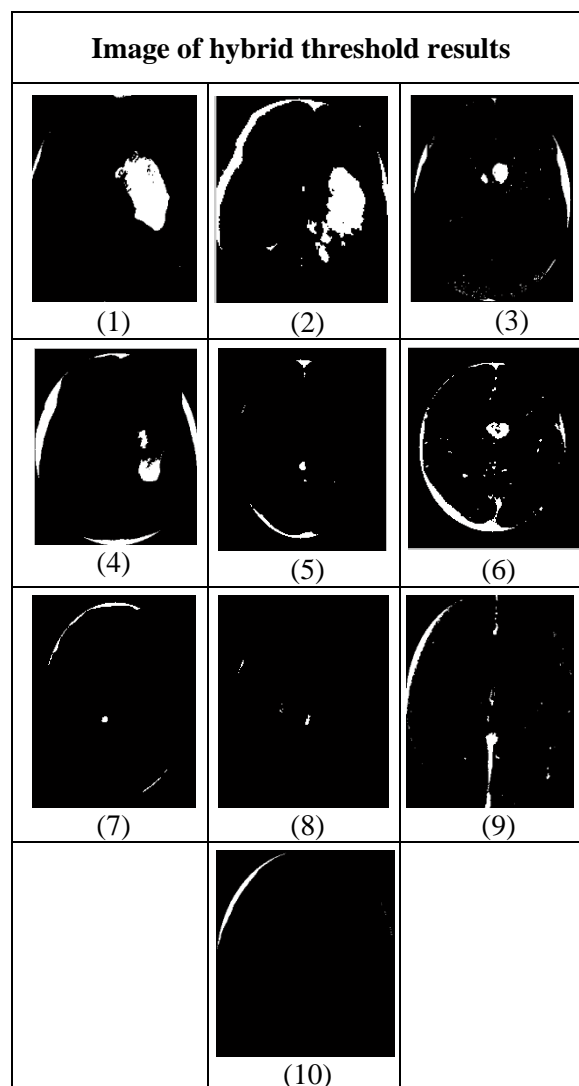


Figure 7.

Brain Image CT Scan results of Hybrid thresholding method; Image (1), Image (2), Image (3), Image (4), Image (5), Image (6), Image (7), Image (8), (9) Brain image is not normal; and Image (10) normal brain

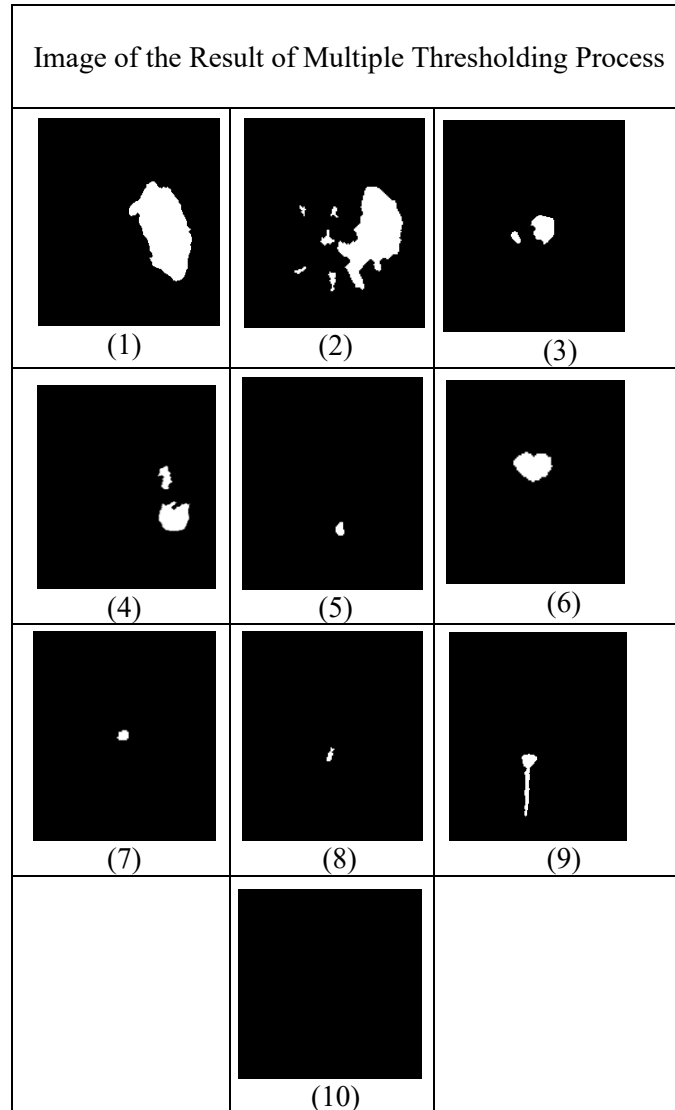


Figure 8.

Brain Image CT Scan results of the Multiple thresholding method; Image (1), Image / 92), Image (3), Image (4), Image (5), Image (6), Image (7), Image (8), Image (9) brain is not normal; and Image (10) normal brain

Figure 6. Shows the results of the merging segmentation of the Otsu method with the hybrid thresholding method which is a combination of P-File edge detection methods with Robert, Canny, Sobel, LoG, and Prewitt. In Figure 6, the original image with an image that has been processed using the multiple thresholding method gets the optimum threshold value, this indicates that this method produces good image quality.

4. The enhancement phase of the morphology method aims to remove the black spot on the bleeding of the brain image from the detection of the bleeding area based on the Morphology method (dilation process).

The mathematical morphology method is a branch of image processing that is very useful for analyzing shapes in images. Mat lab has many tools for binary morphology in the box of image processing equipment; most of which can be used for greyscale morphology as well [17]. The morphological theory of mathematics can be developed in many different problems. We will adopt one of the standard methods that use operations on set points [17]. 2 Basic concepts of operating morphological methods are dilation and erosion. Two other operations that are very important in image processing are opening and closing formed through these two basic operations. (a) Opening: to smooth out the lines of the object area, eliminate narrow parts, and eliminate, (b) Closing: Tends to smooth out lines of shape but is opposite of opening, rejecting narrow fragments and long, thin bays , removing small holes and filling gaps in contour lines.

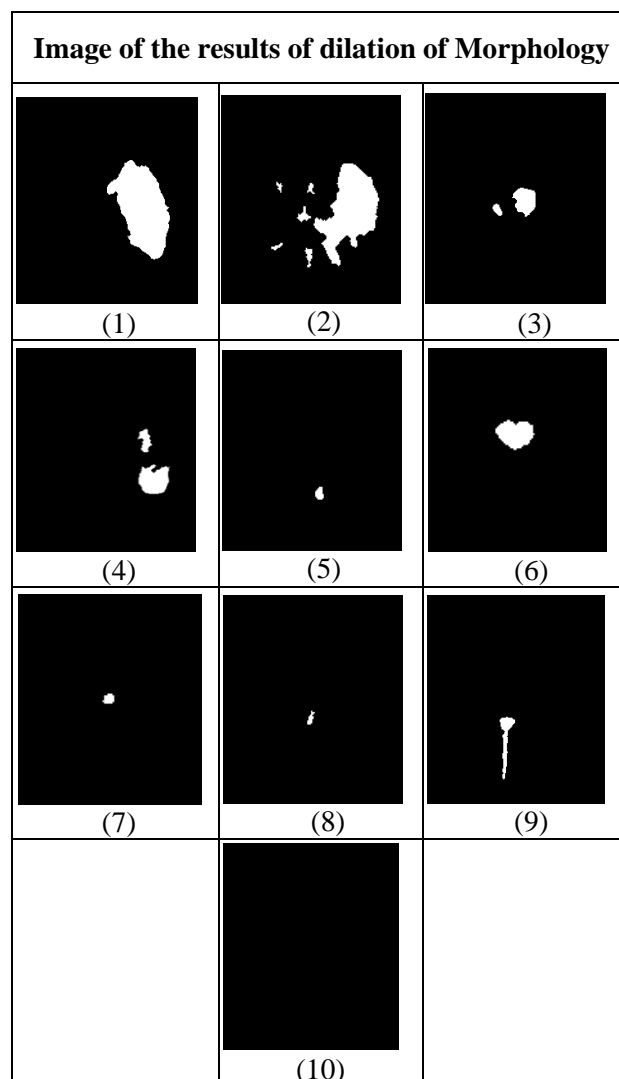
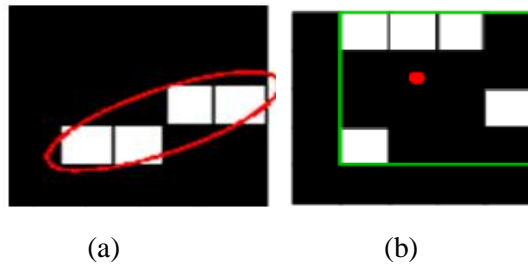


Figure 9.

Brain Image CT Scan results from the mathematical morphology method; Image (1), Dilated Result Image (2), Image (3), Image (4), Image (5), Image (6), Image (7), Image (8), Image (9) brain is not normal; and Image (10) normal brain

5. *The measurement area of the lighting area (Region Properties) to calculate the bleeding area of the brain per slice that has been extracted to calculate the bleeding area of the brain used the Region Feature method.*

The feature region method of an object is represented as a region with an elliptical approach. Figure 8. shows a region of a collection of white pixels that is represented by an elliptical shape approach. In Figure 5. there is a blue line that shows the major axis and the minor axis and the white point as the foci of the ellipse [16].



Source: Duin, et al. [16]

Figure 10. (a). Region representation with elliptical form approach and (b). Region representation with a rectangular shape approach

6. *The stage of calculating the bleeding area to calculate the area of the object in pixels into square centimeters using the morphological method.*

Calculation of objects (objects count) by displaying the values of images that have been labeled, more than one object that is in the image and in the form of numbers can be done by making the script or from the command prompt. Labeling is done simultaneously with the object calculation process, the results of labeling and calculation of objects will produce the number of objects from the region properties process. Objects count functions to determine the level of accuracy in calculating objects that are in the processed image [17]. Calculate the accuracy level to calculate the accuracy of MSE, RMSE and PSNR Mean Square Error (MSE), Root Mean Squared Error (RMSE), and Peak Signal-to-Noise Ratio (PSNR) are parameters used to measure the similarity of two images . Parameters needed to compare the results of image processing with the original image. To calculate the three parameters, use the following equation:

$$MSE = \frac{1}{m \times n} \sum_{i=0}^{n-1} \sum_{j=0}^{m-1} [f(i, j) - g(i, j)]^2 \quad (3)$$

$$RMSE = \frac{1}{m \times n} \sum_{i=0}^{n-1} \sum_{j=0}^{m-1} [f(i, j) - g(i, j)]^2 \quad (4)$$

$$PSNR = 10 \log_{10} \frac{255^2}{MSE} \quad (5)$$

MSE and RMSE do not have units while units from PSNR are decibels. The more similar the two images, the MSE and RMSE values are getting closer to zero. Whereas in PSNR, two images are said to have a low level of similarity if the PSNR value is below 30 dB

7. *Phase 3D reconstruction of linear interpolation methods*

Reconstructing a 3-dimensional image formed from a 2-dimensional image of brain hemorrhage that has been completely detected resulting from the extraction process using morphological methods.

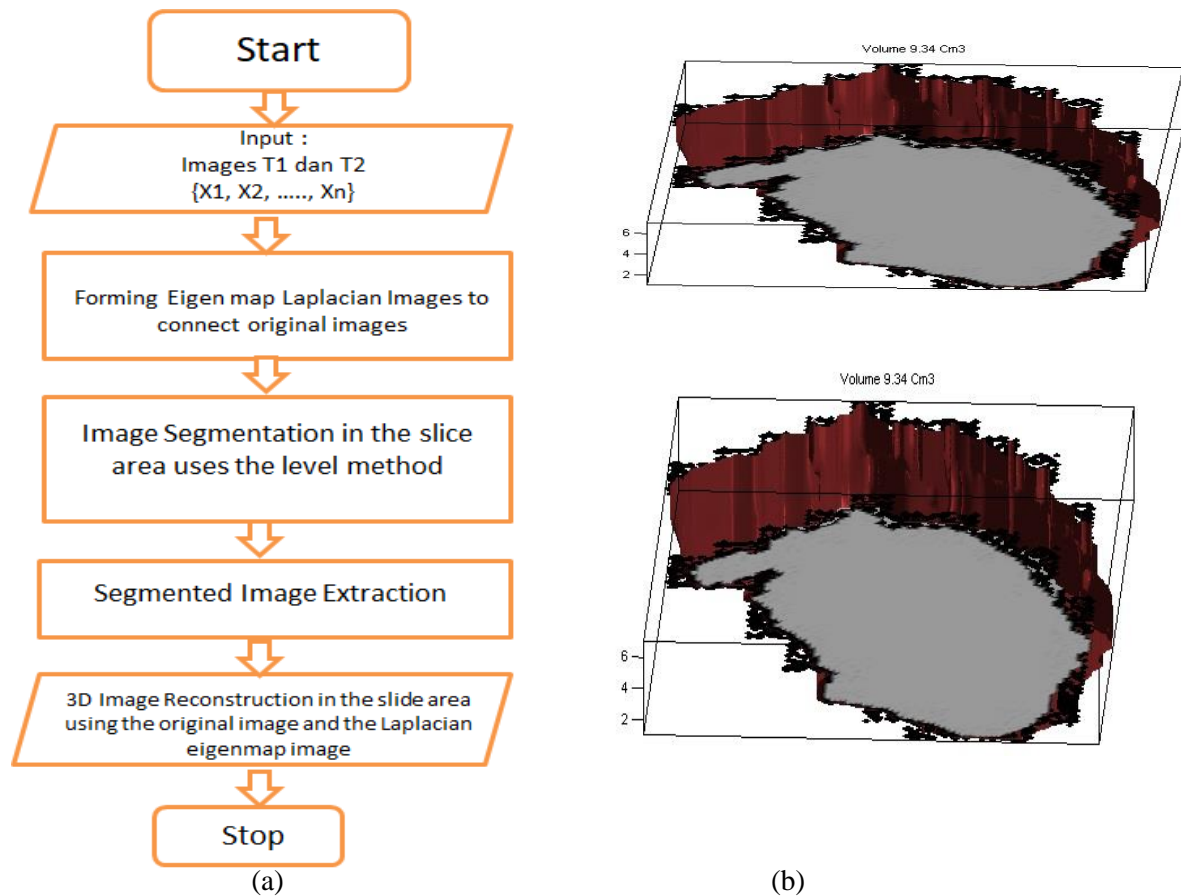


Figure 11. (a). 3D Reconstruction Flowchart and (b). Results of the 3D Reconstruction Process

Figure 11. is a step in the 3D reconstruction process using the results of the otsu method and morphological images consisting of 6-10 slices. Previously, image segmentation and extraction had been carried out to obtain information on the area of cerebral haemorrhage in each slice. Next, 3D reconstruction is carried out using 6-10 slices of brain haemorrhage images per patient previously obtained. The 3D reconstruction process is carried out using interpolation. In this study, the Slice method is used to connect these images. 3D reconstruction is used to obtain the volume of brain haemorrhage area.

3. Results and Discussion

3.1 Calculation of Bleeding Area

Previous discussions and trials such as cropping with the elliptical cropping process, image segmentation using the multiple thresholding method by combining the Otsu method and hybrid thresholding, image extraction with mathematical morphology methods, calculation of bleeding area with region properties feature. Then calculate the level of accuracy of a series of processes that have an influence on the accuracy of the determination of the threshold (threshold). By analysing the data the accuracy of the image in the form of PSNR, MSE, and RMSE values extracted from the characteristics of objects in the image of cerebral haemorrhage, abnormalities in the brain can be detected. The calculation process for the level of accuracy can be seen in table 1 as follows:

Table 1.

Brain Image CT scan results from the calculation of the bleeding area; Image (1), Image (2), Image (3), Image (4), Image (5), Image (6), Image (7), Image (8), Image (9) brain is not normal; and Image (10) normal brain





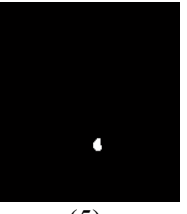

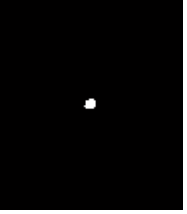
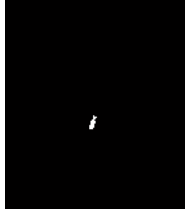

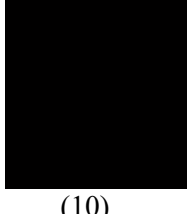
Image extraction results and calculation of the area of bleeding		
 <p>(1) Luas area : 3.314 pixel, PSNR : 31.18, MSE: 19.15, RMSE : 5.21</p>	 <p>(2) Luas area : 2.485 pixel, PSNR : 31.21, MSE: 19.16, RMSE : 5.09</p>	 <p>(3) Luas area : 1.071 pixel, PSNR : 31.22, MSE: 19.16, RMSE : 4.97</p>
 <p>(4) Luas area : 1.974 pixel, PSNR : 31.23, MSE: 19.17, RMSE : 4.85</p>	 <p>(5) Luas area : 458 pixel, PSNR : 31.22, MSE: 19.19, RMSE : 4.73</p>	 <p>(6) Luas area : 985 pixel, PSNR : 31.23, MSE: 19.23, RMSE : 4.25</p>
 <p>(7) Luas area : 101 pixel, PSNR : 31.27, MSE : 19.24, RMSE : 4.13</p>	 <p>(8) Luas area : 58 pixel, PSNR : 31.23, MSE : 19.20, RMSE : 5.61</p>	 <p>(9) Luas area : 993 pixel, PSNR : 31.22, MSE : 19.17, RMSE : 4.49</p>
	 <p>(10) Luas area : 0.0, PSNR : 0.0, MSE : 0.0, RMSE : 0.0</p>	

Table 1. shows the results of extraction and calculation of the bleeding area consisting of: Area of bleeding, PSNR value, MSE value and RMSE value, from the calculation results obtained: patient 1 Area: 3.314 pixels, PSNR: 31.18, MSE: 19.15, and RMSE: 5.21, Patient 2 Area: 2,485 pixels, PSNR: 31.21, MSE: 19.16, and RMSE: 5.09, patient 3 Area: 1,071 pixels, PSNR: 31.22, MSE: 19.16, RMSE: 4.97, patient 4: Area : 1,974 pixels, PSNR: 31.23, MSE: 19.17, and RMSE: 4.85, patient 5: Area: 458 pixels, PSNR: 31.22, MSE: 19.19, and RMSE: 4.73, patient 6: Area: 985 pixels, PSNR: 31.23, MSE: 19.23, RMSE: 4.25, patient 7: Area: 101 pixels, PSNR: 31.27, MSE: 19.24, and RMSE: 4.13, patient 8: Area: 58 pixels, PSNR: 31.23, MSE: 19.20, and RMSE: 5.61, patient 9: Area: 993 pixels, PSNR: 31.22, MSE: 19.17, RMSE: 4.49, patient 10: Area: 0.0, PSNR: 0.0, MSE: 0.0, RMSE: 0.0.

Table 2.

The calculation results for the accuracy of MSE, RMSE and PSNR for the Otsu, Hybrid and Multiple Thresholding methods

#	PSNR			MSE			RMSE		
	Otsu	Hybrid	Multiple	Otsu	Hybrid	Multiple	Otsu	Hybrid	Multiple
1	32,21	31,22	30,11	20,22	19,10	18,12	6.385	5.234	4.011
2	32.24	31.25	30.14	20.23	19.11	18.13	6.125	5.132	4.012
3	32.25	31.26	30.15	20.23	19.11	18.13	5.865	5.030	4.017
4	32.26	31.27	30.16	20.24	19.12	18.14	5.605	4.928	4.017
5	32.25	31.26	30.15	20.26	19.14	18.16	5.345	4.826	4.017
6	32.26	31.27	30.16	20.27	19.15	18.17	5.085	4.724	4.013
7	32.24	31.25	30.14	20.23	19.11	18.13	4.825	4.622	4.017
8	32.25	31.26	30.15	20.24	19.12	18.14	4.565	4.520	4.017
9	32.26	31.27	30.16	20.30	19.18	18.20	4.305	4.418	4.043
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	290.31	281.40	271.41	182.31	172.23	163.41	45.77	42.52	36.12
Average	60.93	59.06	56.96	38.27	36.15	34.30	9.49	8.88	7.58

Table 2. shows the results of the calculation of the accuracy of the Otsu thresholding method, Hybrid thresholding, and multiple thresholding. These results indicate that the multiple thresholding method is better both from the calculation level of PSNR, MSE and RMSE, the average PSNR Otsu thresholding: an average of 60.93 db, the average PSNR Hybrid thresholding: 59.06 db, and the mean PSNR Multiple thresholding: 56.96 db, the mean MSE Otsu thresholding: 38.27, the average MSE Hybrid thresholding 36.15, the average MSE multiple thresholding: 34.30, average RMSE Otsu: 9.49, RMSE Hybrid mean thresholding: 8.88, RMSE multiple thresholding average: 7.58.

The results of the calculation of the area of cerebral hemorrhage and the level of accuracy show the level of accuracy of the Otsu thresholding method, Hybrid thresholding, and multiple thresholding. These results indicate that the multiple thresholding method is better, the PSNR results of the three methods show good results, but multiple thresholding methods well.

3.2 3D reconstruction of the Linear Interpolarization method

The stage of 3D image reconstruction for patient 3 is done by arranging pieces (slices) of available images. The results of the preparation of 10 slices of the image of patient 3 as in figure 9.(a) 90° and 9.(b) 180°.

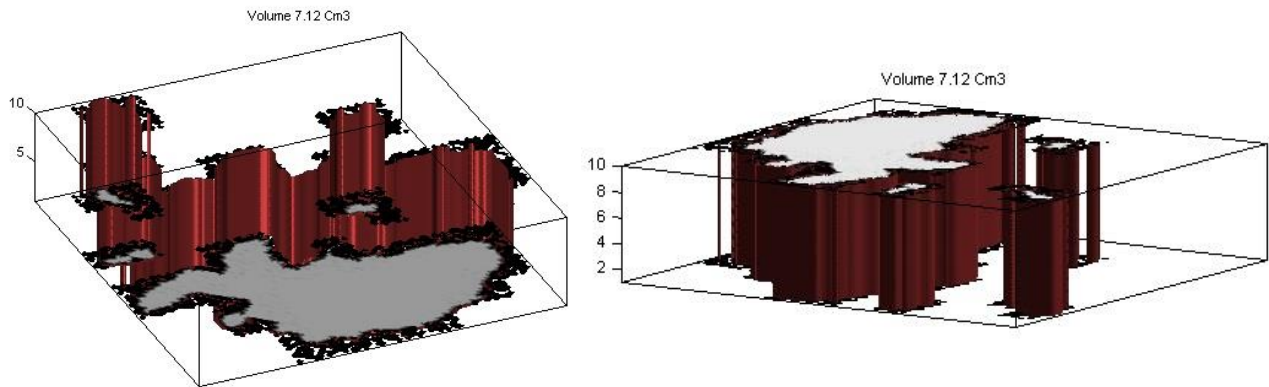


Figure 12. Reconstruction of 3D Imagery Brain Bleeding Area Volume using 10 slices

Table 3. Shows Calculation Results of Area and Volume of Brain Bleeding Area in mm^3 and cm^3

No	No. Slice	Luas Area ²	Volume	
			Area mm^3	Area Cm^3
.				
1.	Slice 1	2.849	712,2500	0,7123
2.	Slice 2	2.840	710,0000	0,7100
3.	Slice 3	2.831	707,7500	0,7078
4.	Slice 4	2.831	707,7500	0,7078
5.	Slice 5	2.840	710,0000	0,7100
6.	Slice 6	2.849	712,2500	0,7123
7.	Slice 7	2.840	710,0000	0,7100
8.	Slice 8	2.831	707,7500	0,7078
9.	Slice 9	2.840	710,0000	0,7100
10.	Slice 10	2.831	707,7500	0,7078
	<i>Total</i>	28,382	7.095,5000	7,0955

Figures 9. (a) and 9. (b) show the results of 3D image reconstruction volume of cerebral haemorrhage area using 10 slices with the Slice technique in the Matlab program produced from algorithm 9 in chapters 3, 3 can be visualized in the bleeding area and volume of bleeding areas such as seen in Figure 4.16. Furthermore, in the same way interpolation between slices is made, the number of slices from the reconstruction results is 10 slices, as shown in figure 9. (a) and 9. (b) and calculation of the area and volume of the bleeding area in table 1.

4. Conclusion

In this research, image segmentation process has been done using threshold, calculation of cerebral hemorrhage area, and Multiple Thresholding method, which is a combination of the Otsu thresholding and hybrid thresholding method, where the hybrid thresholding method combines the P-File edge detection method with Canny to improve quality CT-scan images in cases of brain hemorrhage.

1. The brain image used is 10 brain images, consisting of 9 abnormal brain images and 1 normal brain image. By choosing the right k value, the Multiple Thresholding segmentation method is able to provide output images with better quality compared to the other two methods.
2. The results of the analysis of the level of accuracy and visualization of the texture features found that the images of cerebral hemorrhage indicated by bleeding had the greatest PSNR, MSE, and RMSE values compared to other brain images. The smallest average PSNR, MSE, and RMSE values are found in brain images with small area values.

3. The results of the original image research with images that have been processed by the multiple thresholding method get a minimum threshold value, this indicates that this method produces good image quality.
4. The area and volume calculation algorithm can calculate the area of cerebral bleeding per slice and volume of all slices through the 3D reconstruction of the bleeding area. The 3D reconstruction algorithm of the cerebral hemorrhage area used is referring to a linear interpolation algorithm between two adjacent slices. For example, in the case of test images shown in chapter 4, the bleeding area is between 2,831 - 2,849 square pixels with a total area = 28,382 pixels² of the total slice. The volume of the cerebral bleeding area is obtained after converting from square pixel to cubic centimeter, so the volume of bleeding area = 7.0955 cm³.
5. The resulting 3D reconstruction results can help the medical authorities in deciding which patients have abnormalities in bleeding in the brain.

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