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# Automated Feature Description of Renal Size Using Image Processing

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**Abstract:** Ultrasonography (US) is one of the procedures to monitor the growth of renal size in diagnose kidney disease. However considering the complexity of renal size, this procedure leads to inter-observer variability and poor repeatability. Given images from Abdominal CT scan, a level set thresholding and combination of logical and arithmetic operation based method was developed to calculate the automated feature description of renal size. This is achieved by applying 2D CT scan image into image segmentation and feature extraction where thresholding and morphological segmentation method are conducted. Then, parameters of the kidney such as perimeter, area, major axis and minor axis were measured and analyzed in classification step. As a result, analysis on the kidney size between subjects who are normal and the results from the studies has shown capability to classify correctly the size of kidneys about accuracy of 80% to 81% in terms of the kidney's relative axis which is the ratio of right kidney and left kidneys. In addition, the method in measurement kidney size is compared between manual method and automated method and results shows that the accuracy of the automated method in terms of compactness is about 91% to 95.

**Keywords:** Renal Size, Automated Feature Description, Image Processing.

## 1. Introduction

In recent years, the statistics on kidney disease in Malaysia has been increased. According to 22nd Report of Malaysian Dialysis and Transplant Register, there has been an over 100% increase in the number of new dialysis patients in Malaysia over the past 10 years. Typically, Ultrasound is used to monitor the growth of renal size in diagnose renal disease. However, this method leads to inter-observer variability and poor repeatability. Diagnosis shows that renal size has correlation between kidney diseases. The average size of an adult human kidney is about 10 to 13 cm long, 5 to 7.5 cm wide and 2 to 2.5 cm thick [1]. However, the size of renal may change according to kidney problem.

For instance, polycystic disease or hydronephrosis is a condition where fluids accumulate inside the kidney can cause enlargement of the kidneys and atrophy where this problem lead to decrease size of kidney. Kidney is important in human body since it keeps the composition of the nutrients stable to let the body function and produces hormones that help regulate body pressure and make red blood cells [1]. Hence, it can be concluded that the assessment of renal size is important to determine the presence of kidney diseases.

This paper is conducted to develop an automated feature description of renal size for the purpose of accessing renal size from 2D CT scan image by using image processing software which is MATLAB Software. Other than that is to improve the accuracy of the kidney measurement of feature description. Along in this study, the suitable technique for pre – processing stage, post-processing stage and classification stage are identified and categorized as research question. The first research objective is to identify the suitable technique for pre-processing stage either is there a need for image enhancement and presence of filter in pre – processing stage. The second research objective is to determine the suitable method for post-processing stage which is involve in segmentation step. For example, what is the suitable technique for image segmentation technique based on the image 2D CT scan? Next, the third research objective is to determine and provide analysis of kidney parameters from 2D CT scan such as renal area, renal perimeter and renal compactness.

Different methods of kidneys segmentation have been developed over the recent years including Fuzzy C-Means Clustering [3, 5], Graph Cut [5], Edge Based [2] and Region Growing Method [2]. Moe Moe and Theingi proposed an Edge Based method is more suitable compared to Region Growing Method in kidney segmentation [2]. Edge based method is based on contour detection and this method is suitable to apply on the image which has clearly different intensity between object and background. However, Edge based method

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cannot be applied on the blurry image where the edge cannot be seen clearly.
Region growing approach based on the pixels that have similar grey values intensity. However, Region Growing based method is not suitable for image that has large variation of intensity in the kidney region. When process the image, the kidney exhibits almost similar intensity to other organs therefore kidney cannot be identified because it may be in physical touch with nearest morphological structures. In other way, Edge Based working on discontinuity contours in approach on detecting meaningful discontinuities in intensity value.

Other studies proposed a graph-cut method is suitable for kidney segmentation and cyst regions are suitable for Fuzzy C-Means Clustering method [3]. Clustering Method is conducted by grouping the pixels as the clusters of data. Rodney et.al determines the renal volume using an ellipsoid method by applying manual adjustment of ellipse formula and assumes the external boundary of kidney. The parameters in ellipsoid formula were taken using 2D kidney measurements. The parameters includes of length, lateral diameter, anterior-posterior diameter [4]. There is also a study that proposed an improved method of Fuzzy C Means and Graph Cut method in kidney segmentation [5]. A semi-automated method for kidney segmentation has been proposed by Jun Xie et.al which is by using both texture and shape segmentation method [6]. Andrzej et.al segments the kidney using level set method with the combination method of ellipsoidal shape constraints to determine the segmentation method [9]. Set level is a thresholding method where it converts the grayscale image to a binary image by replacing all pixels in the input image with luminance greater than level we set with value 1 (white) and replaces all other pixels with value 0 (black) [8]. Section 3 explains on the result obtained from the methods used and Section 4 explains on the conclusion and further work of this paper.

## 2. Methodology

The methodology consists of four main steps. The first step is use 2D CT scan as input image, then pre-processing, post-processing and classification as shown in Figure 2.1.

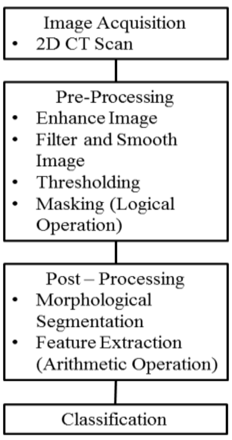



Figure 2.1: Block Diagram of Methodology.

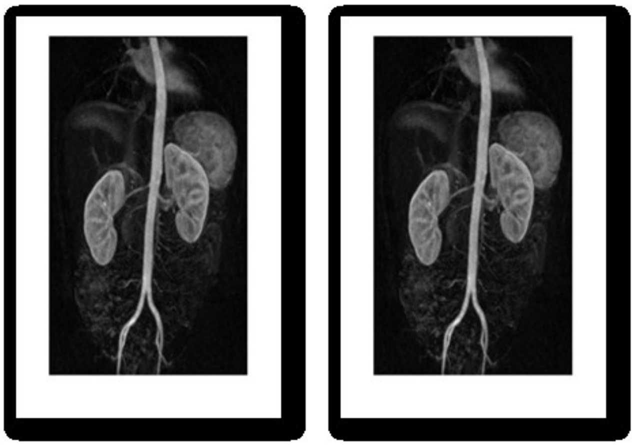
## 2.1 Image Acquisition

The input image of the proposed method is 2D CT scan as shown in Figure 2.The image is applied into MATLAB software to undergo pre-processing step. Based on Figure 2.2, the kidney and the middle one (Ureter) has the brightest object. In image processing, the scale of the brightest object is approach to 1 while the scale of the darkest object is 0[8]. At the end of the experiment, the output image has a pure black and white which is black color is background and the kidney is in white color.

Figure 2.2: Input Image

## 2.2 Pre-Processing

The step is continuing with pre – processing stage where the image is being enhanced and resized. The image is enhanced by adding a certain value into the original image where it leads to increasing number of pixel image. Then, the image is being filtered using Gaussian and Frequency Filter as shown in Figure 2.3 before thresholding step.



(a) Enhance Image (b) Gaussian Filter to smoothen

Figure 2.3: Pre Processing Stage I

Figure 2.4 shows the block diagram of thresholding. Based on the Figure 2.4, it shows that there is 2 images that need to be threshold before performs logical AND operation. Each image is being threshold under Set Level Method at different specified level which is 0.4 and 0.6.

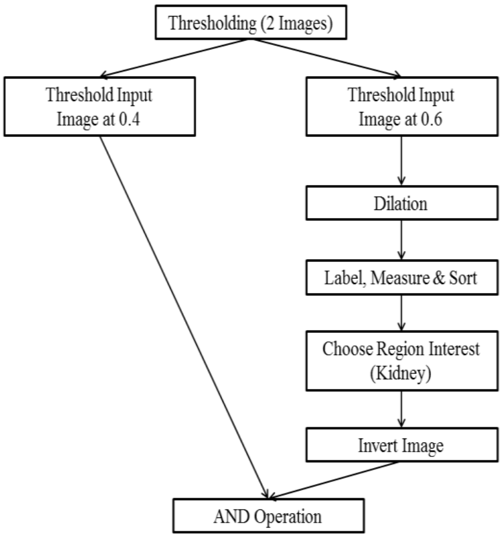



Figure 2.4: Block Diagram of Thresholding

Set level is a thresholding method where it converts the gray scale image to a binary image by replacing all pixels in the input image with luminance greater than level we set with value 1 (white) and replaces all other pixels with value 0 (black). The specified level in the function is relative to the signal levels possible for the image's class. The value above than 0.5 will result to white while the value lesser than 0.5 will result to black.

The image that has been threshold at 0.4 values is where the kidney and ureter is being threshold as shown in Figure 2.5(a) and at 0.6 values where only the ureter is being threshold as shown in Figure 2.5(b). The purpose of thresholding at two levels is to eliminate the ureter from the kidney where some of ureter pixel has same pixel intensity of the kidney.

(a) Threholding at Set Level 0.4 (b) Threholding at Set Level 0.6

Figure 2.5: Pre Processing Stage II

After that, dilation process is conducted on the ureter image to enlarge the object by thickening the trunk at ureter and select the object interest from the dilation image as shown in Figure 2.6.

Dilation is applied to threshold images where it replaces the pixel maximum value in the 3×3 neighborhood by adding the pixels to the edges of black objects. Meanwhile the object interest is selected by labeling and measures the objects in the image. The highest area of the labeled image is selected which trunk or ureter.

(a) Dilation at Threshold 0.6 (b) Select Region Interest

Figure 2.6: Pre Processing Stage III

Then, masking is conducted by applying Logical AND Operation between Figure 2.5 (a) and Figure 2.7 (a) which is then will be resulted as Figure 2.7 (b). Before masking process, invert the image that shows the interest object by converting the black object into white object and white object into black object as shown in Figure 2.7(a).

(a) Invert Image (b) AND Operation

Figure 2.7: Pre Processing Stage IV

## 2.3 Post Processing

This stage undergoes 2 processes which is morphological segmentation and feature extraction as shown in Figure 2.8 below. Based on Figure 2.8, it shows that the extraction of kidney is applied by choosing the two highest area of the object in Figure 2.7(b) as shown in Figure 2.9. Then using the add operation, add between the two object with highest area which give the result as depicted in Figure 2.10(a). After that dilation method is applied to repair breaks and intrusions of the kidney.

Using the result of that, fill the hole in the kidney where it has the dark pixel or holes in it. Figure 2.9 to Figure 2.11 below shows on the steps taken in post-processing stage.

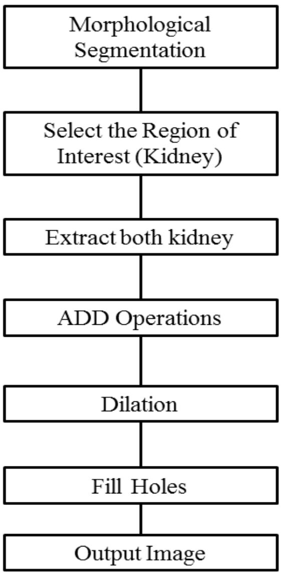


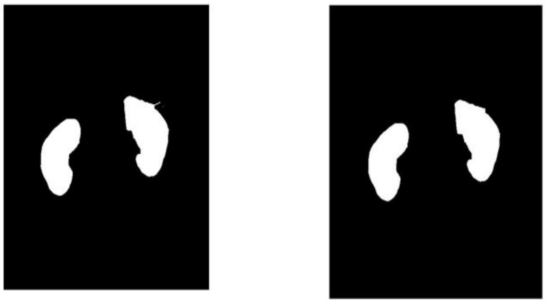

Figure 2.8: Block Diagram of Post Processing Stage

(a) Left Kidney ROI (b) Right Kidney ROI

Figure 2.9: Post Processing Stage I

(a) Add Operation (b) Dilation

Figure 2.10: Post Processing Stage II



(a) Fill Hole (b) Output Image

Figure 2.11: Post Processing Stage III

## 3. Results and Discussion

This section describes classification step where the step involves conducting measurements on the kidney that has been segmented on previous step in terms of geometric measurements. Then, the data from the measurement is used to compare with data taken from manual method in segmentation of kidney and average normal renal size. In other way, this section consists two parts where the first part is comparing the renal size in terms of segmentation method which is manual method (hand-illustration) and automated method (proposed method in this paper) through compactness measurement. The second part is comparing the average renal size in terms of ratio of length and width of kidney between proposed method in this paper and normal renal size.

**Manual Method of Kidney Segmentation**

Manual method is conducted by illustrating the edge of kidney using hand selection menu from Fiji software. The user needs to draw the edge of kidney before able to measure the area, perimeter and centroids of the kidney. The process can be summarized from the block diagram in Figure 3.1. The result from manual method is illustrated in Table 1 below.

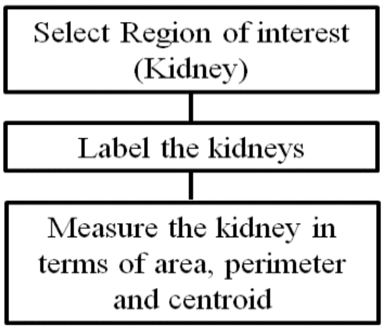
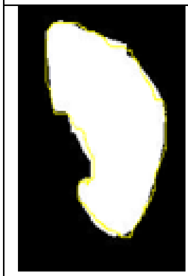
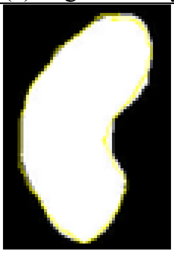



Figure 3.1: Block Diagram of Manual Method in Measurement Renal Size

Table 1: Geometric measurement of Renal Size (Manual Method)

| Diagram | Area | Perimeter |
|---|---|---|
|  (a) Right Kidney | 9605 | 451.77 |
|  (a) Left Kidney | 8288 | 402.26 |

**Automated Method of Kidney Segmentation**

MATLAB is used in conducting automated measurements for renal size based on Figure 2.11 (b) above. The properties that involved in measurements are area, perimeter, major axis and minor axis. These measurements are calculated by using function ‘regionprops’ from MATLAB Image Processing Toolbox Software. Parameters area and perimeter is used for the first part to calculate compactness while major axis and minor axis are used for the second part to calculate the ratio of length and width of kidney. The Equation 3.1 and 3.2 below is for the Compactness [10] and Relative axis equations. The result from automated method is illustrated in Table 2 below.

$$C = \frac{4\pi A}{P^2} \qquad \text{(Eq. 3.1)}$$

(where C is classical components, A is area and P is perimeter)

$$Relative\ axis = \frac{Length\ of\ Kidney}{Width\ of\ Kidney}$$

$$= \frac{Major\ Axis}{Minor\ Axis} \qquad \text{(Eq.3.2)}$$

Table 2: Geometric measurement of Renal Size (Automated Method)

| Parameter | Left Kidney | Right Kidney |
|---|---|---|
| Area | 8599 | 9890 |
| Perimeter | 376.76 | 418.21 |
| Major Axis | 145.26 | 152.42 |
| Minor Axis | 82.71 | 89.48 |

**Normal Measurements of Renal Size**

The average normal size of kidney is about 10 to 13 cm long and 5 to 7.5 cm wide [1]. The length of the kidney in this study is to be compared with the length of major axis of an ellipse and the width of the kidney is compared with the minor axis of an ellipse. In this paper, the comparison of the length of kidney is assumed to be in terms of major axis and the width of the kidney is assumed in terms of minor axis as shown in Figure 3.2.

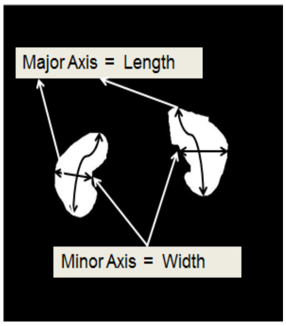



Figure 3.2: Definition of Major Axis and Minor Axis in Kidney

**Accuracy and Error Measurements of Renal Size**

At the end of result, the difference between values of manual method and automated method is calculated to measure the error between both methods. Since the method that wants to compare is manual method and normal renal size, the formula can be derived as shown in Equation 3.3 below [11]. The accuracy of automated method can be calculated from the error measurement that has been calculated. The formula of the accuracy can be seen in Equation 3.4 below [11].

$$\text{Error Measurement} = \frac{Automated - Manual}{Manual} \qquad \text{(Eq. 3.3)}$$

$$\text{Accuracy of Automated Method} = 1 - Error\ Measurement \times 100\% \qquad \text{(Eq. 3.4)}$$

## 3.1 Comparison of Renal Size between Manual and Automated Method in terms of Compactness

Table 3 below shows the compactness of the manual and automated method of left kidney and right kidney. The compactness can be calculated using Equation 3.1. The result can be illustrated using graph as depicted in Figure 3.3.

Table 3: Compactness of Kidney

| Method | Kidney | Area | Perimeter | Classical Compactness |
|---|---|---|---|---|
| Manual | Left | 8288 | 402.26 | 0.64 |
| | Right | 9605 | 451.77 | 0.59 |
| Automated | Left | 8599 | 376.76 | 0.76 |
| | Right | 9890 | 418.21 | 0.71 |

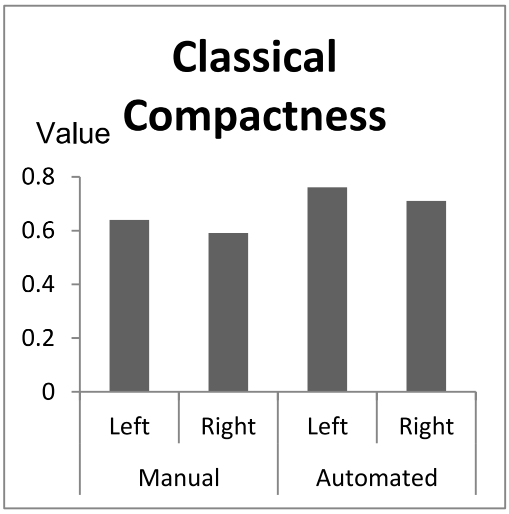



Figure 3.3: Graph on Classical Compactness

Based on Table 3, it shows that the perimeter of manual method is slightly larger compared to automated method. This happens due to error during drawing the edges of the kidney using hand selection. By having automated method in measurement of renal size, the error or difference in measurement can be improved and the data from the measurement of renal size can be more precise and accurate. In addition, it shows that the compactness of automated is higher compared to manual method. The compactness of manual method is lower compared to automated method due to the error during drawing the edges of the kidney will result difference value of area and perimeter of manual method.

Since the compactness equation is based on area and perimeter, it will affect the value of compactness of manual method. Hence, it leads to difference value of compactness between both methods. It also shows that left kidney is more compact that right kidney. This is due to the perimeter and area of the left kidney is bigger than right kidney. Since there is a different value of compactness between methods, error measurement and accuracy can be calculated using equation 3.3 and 3.4 as mention previously. The error measurement and the accuracy of the automated method can be summarized in Table 4 below.

Table 4: Error and Accuracy of both kidneys

| Parameter | Error Measurement (%) | Accuracy (%) |
|---|---|---|
| Left Kidney | 19 | 81 |
| Right Kidney | 20 | 80 |

.

## 3.2 Comparison of Relative Axis between Normal Renal Size and Proposed Method Renal Size

The parameters that are going to be compared consist of Major axis which is the length of the kidney and Minor axis of the kidney which is the width of the kidney. The ratio of width and length will composed of relative axis which has been mentioned at Equation 3.2 above. Table 5 shows the parameters of length and width of normal size kidney and automated method while Table 6 shows the relative axis of kidneys. Figure 3.4 shows on the graph of relative axis of renal.

Table 5: Length and Width of Renal size

| Parameter | Average Normal Size Kidney | Automated Method (in pixels) | |
|---|---|---|---|
| | | Right Kidney | Left Kidney |
| Major Axis = Length | 11.60 cm | 152.42 | 145.27 |
| Minor Axis = Width | 6.25 cm | 89.48 | 82.71 |

Table 6: Relative Axis of Kidneys

| Parameter | Relative Axis |
|---|---|
| Left Kidney | 1.76 |
| Right Kidney | 1.70 |
| Normal Kidney | 1.86 |

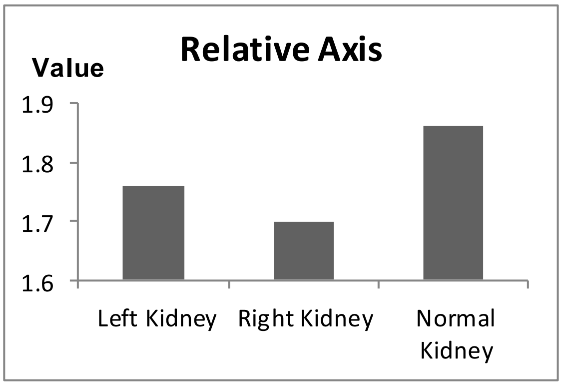



Figure 3.4: Graph on Relative Axis of the kidneys

Based on Figure 3.4, it shows that the relative axis of the normal size is 1.86, while for the right kidney is 1.70 and 1.76 for left kidney. The results of the relative axis left kidney and right kidney based on normal kidney shows that there is no large distinct value between them. The relative difference and accuracy between the relative axes can be calculated as defined on Equation 3.3.and Equation 3.4. Table 7 shows on the relative difference and accuracy of right kidney and left kidney based on normal kidney.

Table 7: Relative Difference and Accuracy of Right Kidney and Left Kidney based on Normal Kidney

| Parameter | Relative Difference | Accuracy |
|---|---|---|
| Right Kidney | 9% | 91% |
| Left Kidney | 5% | 95% |

Based on Table 7, it shows that the accuracy of the kidneys is above 90% from the normal size kidney. Hence, it can be concluded that the measurement of renal size is valid for the segmentation and classification step.

As a conclusion, the segmentation and classification stage is in range of valid measurement where the analysis in comparison of automated method and manual method based on compactness gives accuracy more than 80%. In addition, the analysis of the relative axis and accuracy on renal size give 90% value from the normal size. The accuracy of the compactness on right kidney is 80% and 81 % for the left kidney while the accuracy of the ratio of length and width of renal size for left kidney is 95% and 91% for right kidney as shows in Figure 3.5 below.

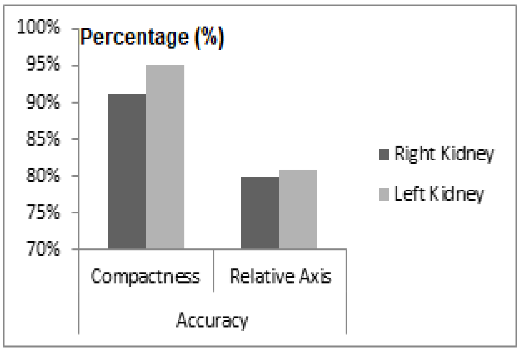



Figure 3.5: Graph of Accuracy on Compactness and Relative Axis of both kidneys

## 4. Conclusion

Based on this study, it shows that the image segmentation can be achieved by performing logical and arithmetic operation between two images that has same dimension. In addition, the analysis of the result and discussion section shows that the segmentation of the kidney and classification of the images in terms of compactness and relative axis has produce more than 80% in accuracy. The analysis is conducted by comparing the data taken from manual method and automated method in terms of area and perimeter to compute compactness. Results from the data produce error about 0.19 at left kidney and 0.20 at right kidney. The accuracy of the compactness for right kidney is 80% and 81% for left kidney.

Another analysis has been conducted by comparing the renal size in terms of major axis and minor axis and original renal size by using relative measurement. Results from the data produce error about 0.09 for right kidney and 0.01 for left kidney.

The accuracy of the renal size in terms of the size for right kidney is 91% and 95% for left kidney. Since the analysis shows about 80% accuracy, the measurement can be used for aiding diagnose purpose.

This study can be improved further by implement Fast Fourier Transform (FFT) method in preprocessing stage and develop automated volumetric measurement of renal size based on the study that had been conducted in 2D. FFT can be applied in this study at pre-processing stage in this study where the proposed method can eliminate noise much better compared to Gaussian filter. The second thing that may be improved in this study computing 3D Kidney Segmentation based on this study by using 15 slices of DICOM. The difference between this study and the proposed improvement study is this study only conducted using 1 image of 2D D while the proposed study is in 3D.

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