Automatic Ultrasound Kidney's Centroid Detection System

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Abstract: - Currently, kidney stone and tumor removal can be done without surgery. For this purpose, it is required imaging modalities that able to visualize kidney accurately. In order to improve the accuracy of kidney visualization in a short time, an automatic kidney centroid detection is required. This project developed a software to automatically detect the centroid of human kidney. The software was developed using MATLAB with smoothing filter, texture filter and morphological operators. They were used for image segmentation in order to extract important features. Test result shows the software achieve until 96.43% of accuracy in detecting the centroid. The detected centroid can be used as initial point to create ellipse model, which can be used to detect kidney's contour in further research. This software can be implemented in the most US machine that will be used as segmentation tool to reduce human errors and time.

Key-Words: - Kidney Ultrasound, Ultrasound Image Segmentation, Texture filter, Morphological Operators, Centroid.

1.0 Introduction

There are many modalities of medical imaging that can be used to evaluate the human kidneys parameters, for example magnetic resonance imaging (MRI), x-ray computed tomography (CT), ultrasound imaging (US), and many others. This is important for the clinician to determine the health of the kidneys and also to visualize any abnormalities present in the kidneys. The MRI gives accurate and clear images of the kidney but it is not affordable as US [2]. While CT scan can show the scanning image less than five minutes but it contributed high dose of radiation to the patient, and it also more costly than US. But the fuzzy noisy images of ultrasound make the data difficult to interpret [1] and make the procedure done in longer periods. So, segmentation tool was needed in the US machine so that we can get the result in shorter time [2].

US machines with automatic detection in the current market were increasing nowadays. But this increasing was majority in other field than kidney, such as to detect small tumor in breast and to detect chromosome abnormalities in fetus. Somo•v™ Automated Breast Ultrasound System (ABUS) was developed to take the breast's images automatically, not to detect the tumor or malignant. This system makes the images easier for interpretation by clinician [20].

The kidney scanning protocol is not much different than other abdominal organs, such as liver and stomach. The patient was advised to do the scanning in full bladder and drink lots of water. It is important to make the kidney's images clearer because the kidney was filled with urine. Then, the patient was asked to lie on supine position, which is lying on the right side or left side on the body, depends on which side of the kidneys needed to be scan. Conductive gel was applied on the 3.5 MHz transducer to eliminate air bubbles between the transducer and patient's skin. The bubbles can cause poor US image. Incorrect US transducer position for kidney scanning also resulting to an unpleasant US image, and cause difficulties for the sonographer to take the measurement.

Human errors always occurred while taking measurement during US scanning. This is usually caused by noisy US image and untrained sonographer. So, we were aspired to overcome the problem by filtering the noise using Gaussian filter. This project was developed to detect kidney's centroid from the US image. The detected centroid can be indicator for correct scanning protocol. Undetected centroid was the sign of incorrect procedure. So, this project also can help untrained sonographer to improve their skills in US scanning.

The main objective of this project is to develop a software that able to detect human kidney's centroid automatically. In order to achieve the main objective, we had designed a suitable algorithm for handling fuzzy and noisy US image and also to detect the kidney's centroid. And finally, I also had developed the software using MATLAB GUIDE.

The video of kidney US will be separated on single images using MATLAB function. The purpose of separating into single images is to apply image processing algorithm on each of the images. The completed processed images with detected centroid will be combined back into video format. To reduce noise in an image, we used Gaussian filter to eliminate small or unwanted objects. Next, we used texture filter and morphological operators for image segmentation. The kidney's centroid was selected based on properties of the objects in the image. After that, the software interface was built using MATLAB GUIDE. The image and video processing algorithm were implemented in the software.

2.0 Material and Methods

2.1 Specification and Description of the System.

The developed software can working in optimum condition using computer that equipped with 4 GB RAM, Intel Core Duo 2.40GHz CPU processor and installed with MATLAB versions 7.10. The software still can operate in good performance if the specification of the computer were lower than stated above, but it may take longer time to process the final result. The average time taken to process a one second video in optimum condition is one minute. The other equipments needed for the system to operate are ultrasound machine with 3.5MHz transducer.

This system is about a software that can do image processing automatically to find kidney's centroid from US video. The US scanning video was recorded and saved in .avi format before it will be uploaded into the software. Next, the video and image processing was done by the software for centroid detection.

The system's GUI was designed to be easy for user operation. The software contained 4 different areas, which are video display area, video's name area, instructions area and also control panel. There are six buttons in the control panel area and all of them were useful to upload, play, pause, stop, delete and process the video. The GUI of the system can be seen in Figure 2.1.

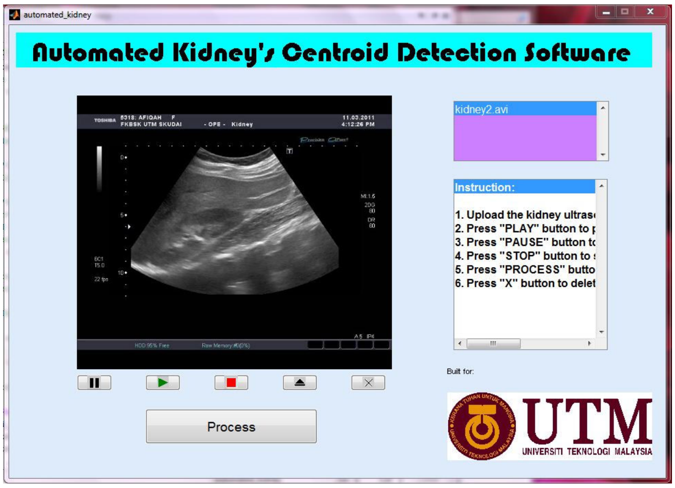

Figure 2.1: System's GUI.

Figure 2.2 shows the block diagram of the whole developed system. The sonographer would do kidney US scanning using ultrasound machine with 3.5MHz transducer. The scanning images will be captures and saved as video file or .avi format. Next, the video will be uploaded into a computer equipped with the developed software for video and image processing to detect the kidney's centroid. The result of kidney US video with detected centroid will be come out in popup window. The centroids were tagged with red mark.

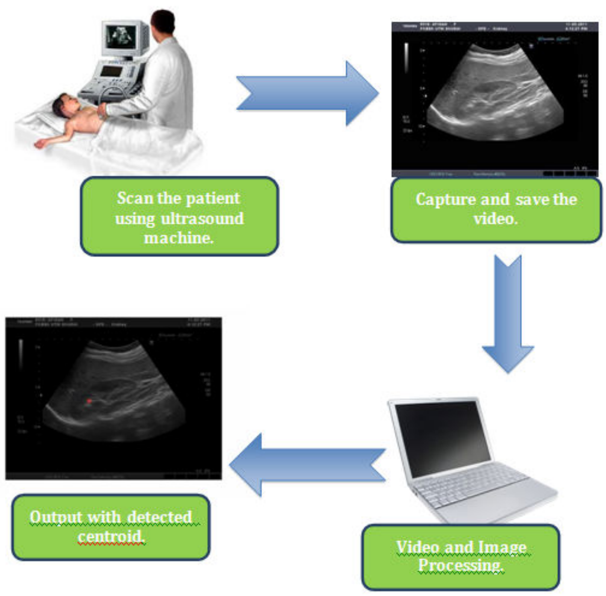

Figure 2.2: Block Diagram of the System.

2.2 Overview of the System.

The workflow of the system was shown in Figure 2.3. First, the user needs to upload the kidney US scanning video into the developed software. After process button was pressed (refer Figure 2.1), the video will be separated into each single frame and save as jpeg format picture. Next, image processing for centroid detection will be applied on every single frame image. The explanations on the image processing techniques will

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be discussed later under Algorithm Design. Lastly, the processed images will be combined and converted back into a video.

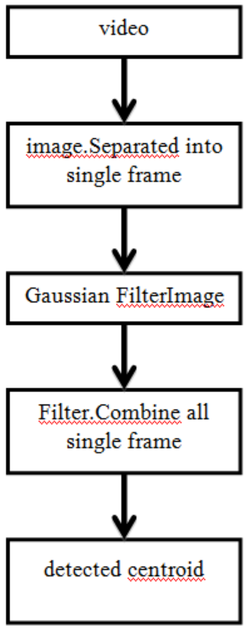


Figure 2.3: Workflow of the system.

2.3 Image Processing Algorithm.

Image processing is the main core of this project in order to reduce noise and to detect the kidney's centroid. The flowchart of image processing algorithm was shown in Figure 2.4.

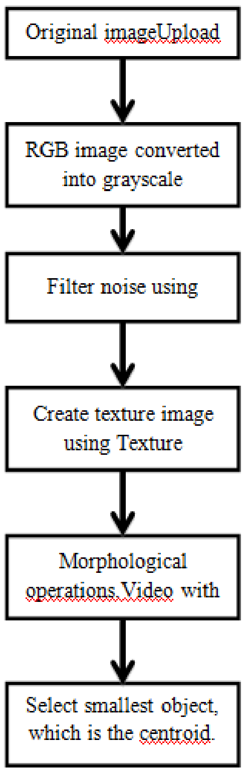


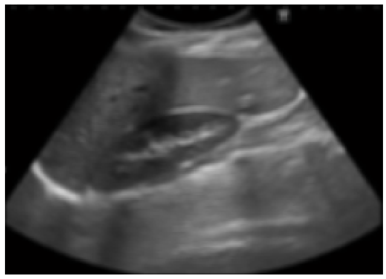
Figure 2.4: Flowchart of image processing algorithm.

Based on Figure 2.4, the original image was in format RGB must be converted into grayscale image using simple coding as follows:

```
I = rgb2gray(singleFrame);
```

Next, the noise in an image can be reduced using Gaussian Filter. Figure 2.5 shows the differences between original image and filtered image.

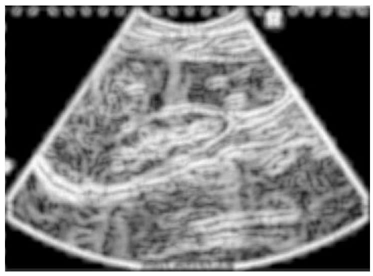
(a)



(b)

Figure 2.5: Original image (a) before and after (b) filtered by Gaussian filter.

Next, the filtered image will be filtered again using texture filter to create filter image. In this project, *entropyfilt* was chosen and after that, the filtered image was converted into binary image using *im2bw* function. The images can be seen in Figure 2.6.



(a)

(b)

Figure 2.6: Image after texture filter (a) binary image (b).

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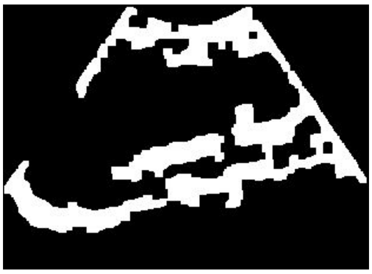
Then, morphological operations were done several times in order to segment the desired part, which is the centroid. *bwareaopen* with 3000 of filter kernel's size was used to extract the background with object while *imopen* and *imclosed* were used to eliminated the unwanted part in the image. *imfill* was used to fill in any holes in the object. Refer Figure 2.7 for the images.

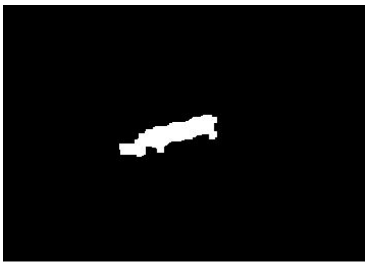
(a)



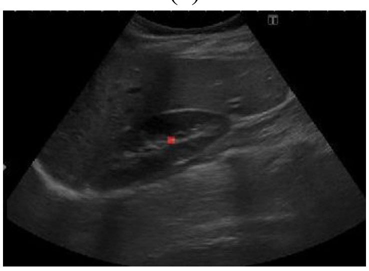
(b)

Figure 2.7: Image after *bwareaopen* (a) and after morphological operations (b).

After the morphological operations, the smallest object in the image, which is the kidney's sinus, was chosen. *regionprops* was used to measure the properties of objects in the image. The specific properties that important in this object were the area and also the centroid of the object. Next, the algorithm to select the smallest object and to tag it's centroid with red marks and the result images can be seen in Figure 2.8.



(a)



(b)

Figure 2.8: The smallest object was selected (a) and detected centroid (b).

3.0 Result and Analysis

The software was tested with three different videos and each video with different total images. Figure 3.1 shows the sample images with detected centroid and also images with undetected centroid. The results for all images from the three tested videos were summarized in Table 3.1. As explained before, the video uploaded into the software will be cut into single frames for image processing. Total images produced were depending on the length and frame rate of the video. For example, one second video with 26 fps (frame per second) will created 26 images.

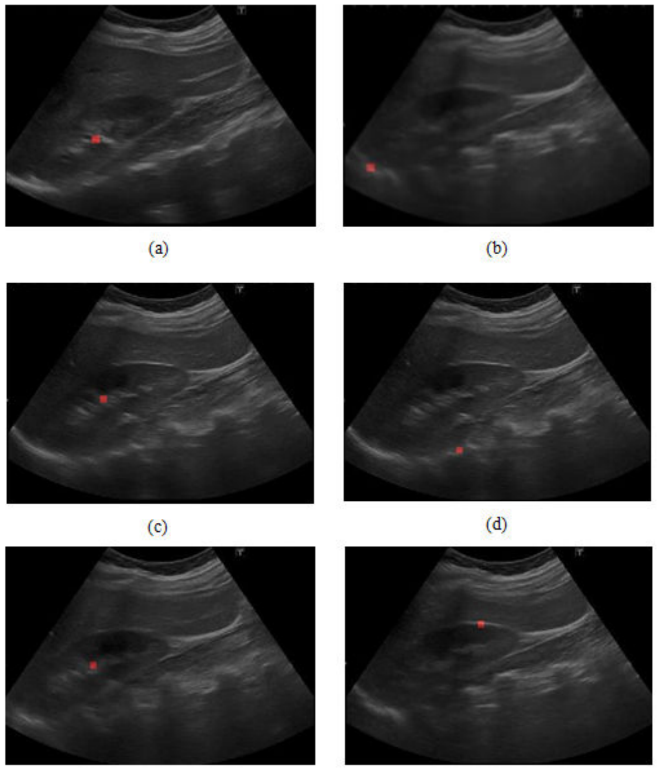


Figure 3.1: Sample images with detected centroid (a, c, e) and also images with undetected centroid (b, d, f).

Table 3.1: The results after software tested with three different videos.

Video	Total images	No. of Centroid Detected	No. of Centroid Not Detected	Percentage of Centroid Detection	Average Center Point
A	28	27	1	96.43%	[249, 280]
B	26	22	4	84.62%	[253, 240]
C	26	19	7	73.08%	[248, 259]

From the result, we can see that the first video gives higher percentage of centroid detection with 96.43%. That means only one of the 28 images was failed to detect the kidney's centroid. For video B, 84.62% of the total images were detected while other four images were failed to detect the kidney's centroid. And for video C, 73.08% which is represents 19 images of 26 images

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were successfully detected kidney's centroid. The average center point for each video was shown in the Table 3.1.

The undetected centroid in certain images was caused by noise in kidney US image, and it maybe caused by wrong probe position during scanning. Thus, the algorithm for image processing was failed to detect the centroid. The comparison between detected centroid and undetected centroid images can be seen in the previous Figure 3.1. We can clearly see that the image with detected centroid (a, c, e) was clearer and sharper compare to image with undetected centroid (b, d, f). That is why the algorithm failed to detect the centroid. It is also maybe due to the present of inefficient filters and some unnecessary image processing techniques in the algorithms.

4.0 Conclusion

Ultrasound image usually full with noise and sometimes caused difficulties to clinician to measure the kidney's parameters. Due to this problem, human errors and time taken for completing the scanning procedure will be increased. So, a segmentation tool with automatic detection system was needed to help the clinician or sonographer do their job in shorter time.

A new technique and software to detect human kidney's centroid automatically has been developed. Gaussian filter was used to reduce noise in US image and morphological operators were used for image segmentation. The centroid was selected based on object properties. All these image processing techniques were built using MATLAB image processing toolbox.

Test results show that the software could be used to detect the kidney's centroid automatically by giving great accuracy until 96.43%. Compared to other research, this software only produces one initial point, which is the kidney's centroid. The detected centroid can be used for further research to detect the kidney's contour automatically. The time taken to process the whole video was only one minute for each video. Thus, it had reduced the time for the detection of kidney. This is very important for the future automatic noninvasive kidney stone and tumor removal.

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