

Medical Image Processing Using MATLAB in Detecting Kidney Stones

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Abstract: In this research project, the primary aim is to propose a technique in image processing that will assist individuals, particularly doctors and radiologists in detecting kidney stones and resulting in excellent quality. Several ultrasound images were acquired and then simulated in MATLAB software. Pre-processing of the image was performed to produce better image quality before it is processed further. Then, the image was segmented and it was used to identify the region of interest in the image. During processing, it removes the unwanted information known as pixels from outside the region and the region of interest (ROI) model was used to discover an abnormal region. Elimination of 'unwanted pixel' was done if the intensity value is 250 and below. Based on the results, the proposed techniques have successfully detected the presence of kidney stones in the region of interest after the image is applied in the simulation.

Keywords: Kidneys Stones, Image Processing, MATLAB

1. Introduction

Urolithiasis or commonly known as kidney stones are found in the upper urinary tract. A kidney stone can be a high-risk disease and the majority of people with stone formation in the kidney initially did not notice it. The prevalence of the disease in Asia is about 10% to 20% as compared to 15% to 18% in Western countries. Based on a study by Nouri and Hassali [1], a prevalence of 1.8% was found among the patients admitted to Hospital Universiti Sains Malaysia (HUSM) for the duration of January 2012 to December 2016. Obstruction by a kidney stone in the kidney or ureter can lead to infection. Apart from that, the patient may also experience urinary retention. The pressure from a blockage can damage the ureters and kidneys in the long run, resulting in renal failure. Hence, early diagnosis using medical imaging is vital to prevent severe damage [2].

The medical images of kidney stones taken from the ultrasound scan are sometimes difficult to see with the naked eye. It is because the ultrasonic beam might be blocked by the beam-attenuating tissue such as renal sinus fat and bowel. It could also be attributed to the weak posterior which causes shadowing to take place. Research shows that by utilizing the digital image processing techniques and the toolkit available in MATLAB, the existence of kidney stones can be highlighted from their surroundings [3]-[5]. In this context, the use of a suitable filter coupled with the appropriate threshold values plays the main role in removing the speckle noise [3]-[8]. In this paper, the image processing methods use a median filter as means to reduce the noise from the image before highlighting the region of interest in which the kidney stone is present.

2. Methods

This section describes the methods for detecting the presence of kidney stones through ultrasound images. The steps include image acquisition, image pre-processing, image segmentation and finally morphological analysis as shown in Figure 1. The whole process is done using MATLAB (R2021a) software.

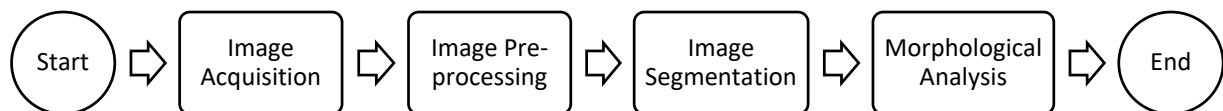


Figure 1: Image Processing Process Flow

2.1 Image Acquisition

In image processing, image acquisition is always the first step in the workflow sequence since it is impossible to simulate the program without data or in this study use images as the input data. Several kidney ultrasound images of different characteristics were acquired from Kaggle and Github. Variations in characteristics of the kidney images including contrast level and pixel values are important to test the reliability of the program.

2.2 Image Pre-processing

Image pre-processing is applied in the simulation to improve the quality of the image so that it can be analyzed better. During the pre-processing, the ultrasonic image of the kidney was converted from RGB to grayscale images. Then, the output of the grayscale image was converted to binary images. Pixel information tools are also created in the current figure. During binarization, the input binary image was filled with holes. After that, all connected components that have fewer pixels from the binary image were removed thus producing another binary image which is also commonly known as area opening. Next, the pre-processed image is adjusted in terms of intensity values to increase the contrast of the image. It was followed by filtering the image using a median filter. It improves the quality of the image by suppressing unwanted speckle noise or enhancing some image features for further processing.

2.3 Image Segmentation

Image Segmentation is the technique of dividing a digital image into sets of pixels, often known as super pixels. Normally, the region of interest (ROI) model is used to discover abnormal regions based on clusters and centroids. The current stage is using a clustering algorithm to sort the input data points into separate groups based on their actual distance from one another. It is used to locate the area of interest. Commonly, image segmentation is used to identify the region of interest. It is a process of dividing a digital image into sets of pixels also known as super pixels. During processing, it removes the unwanted information known as pixels from the outside region which include dilation and erosion.

2.4 Image Morphology

Objects are transformed from one shape to another through morphing. A morphological operation is applied to smoothen the region of interest. Structure elements morphologically based on shapes are processed when structuring elements. During processing, morphing removes the unwanted information commonly known as pixels from the outside region of interest. The process includes erosion and dilation. Eq. 1 and Eq. 2 show the equations for both dilation and erosion in image processing. The dilation procedure is applied to fix holes in a continuous object known as missing pixels [9]. Because the dilation procedure adds pixels to the object's border, it changes the intensity in that area resulting in a blurring effect. The erosion procedure eliminates any structures that are smaller than the structuring element. As a result, it may be used to eliminate the distracting 'connection' between two things. The net result is the sharpening of the object in an image since the undesired pixels are 'erased'

$$A \oplus B = \{z | (\hat{B})_z \cap A \neq \emptyset\} \quad Eq. 1$$

$$A \ominus B = \{z | (B)_z \subseteq A\} \quad Eq. 2$$

3. Results and Discussion

This section presents and discusses the result obtained from the image processing techniques. MATLAB is used to simulate the source code which includes image acquisition (stage 1), image pre-processing (stage 2), image segmentation (stage 3) and finally morphing process (stage 4).

3.1 Results of processed kidney images

Figure 2 and Figure 3 show the ultrasound images used in the simulation and its processed images after stage 1 until stage 4. One of the two kidneys has a stone presence in the ultrasound image (Image A) while the other image has no kidney stone detected (Image B). The properties of the images also differ in terms of pixel size and resolution as listed in Figures 2(b) and 3(b).

During pre-processing (stage 2), the ultrasonic image of the kidney is converted from RGB to a grayscale image before it is undergone binarization. At this stage, all connected components that have fewer pixels from the binary image were removed thus producing another binary image which is also commonly known as area opening. As depicted in Figures 2(c) and 3(c), the images lose some details. The images also darkened compared to their original images.

During segmentation (stage 3), it divides the digital image into sets of pixels. The region of interest (ROI) model was used to determine an abnormal region. During the process, it also removes unwanted information known as pixels from outside the region. The ROI is where the stone present is detected. Figures 2(d) and 3(d) show the segmented images of pathological image and normal image, respectively: The intensity level of each processed image is attuned to increase the contrast of the image.

Morphing in image processing is to eliminate defects in the image structure. In this project, an image that has an intensity value lower than 250 will be eliminated. The process during morphing is combined between two processes which are dilation and erosion. Morphing also helps in differentiating the region of interest (ROI) from the rest of the image using various pixel values. Figures 2(e) and 3(e) show the images after morphing (stage 4):

3.2 Discussion

From the results, there were some variations according to the exact position of the stone due to the nature of the disease itself. Adjusting the intensity to its optimum value is crucial in pointing out the location of kidney stones in each ultrasound image. This could assist in the removal of the stones from the kidneys appropriately. As indicated in Figure 2(e), the location of the stones in the ultrasound image

is shown after the final stage. The indicator of kidney stones is very similar to the study done Vineela et al. [4]. Meanwhile, a black screen is shown after the final stage when there are no stones detected in the ultrasound image as illustrated in Figure 3(e). It shows that no foreign object is detected in the region of interest.

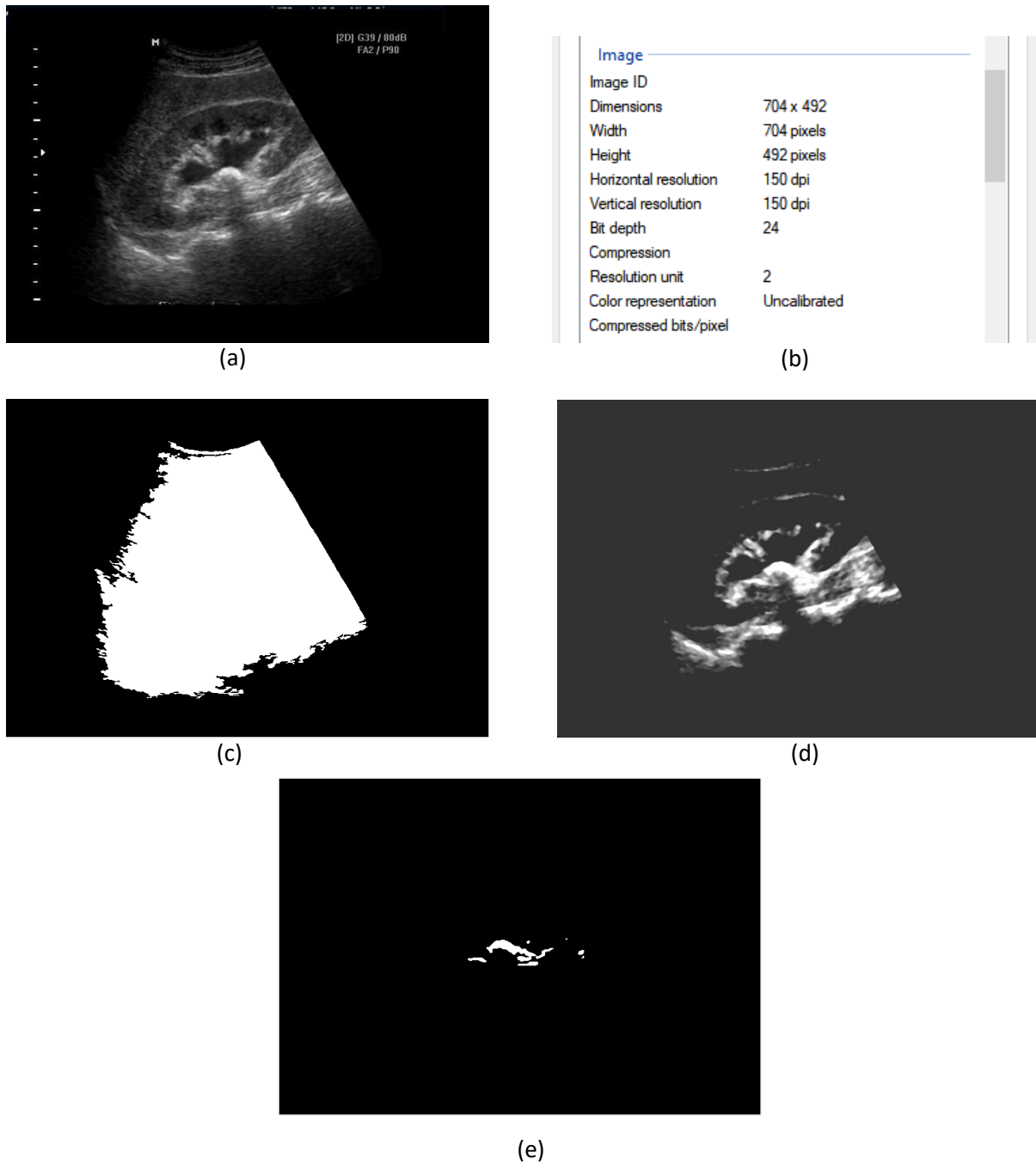


Figure 2: The Ultrasound Image A (a) the original image, (b) the properties of original image, (c) the processed image after stage 2, (d) the processed image after stage 3, and (e) the processed image after stage 4.

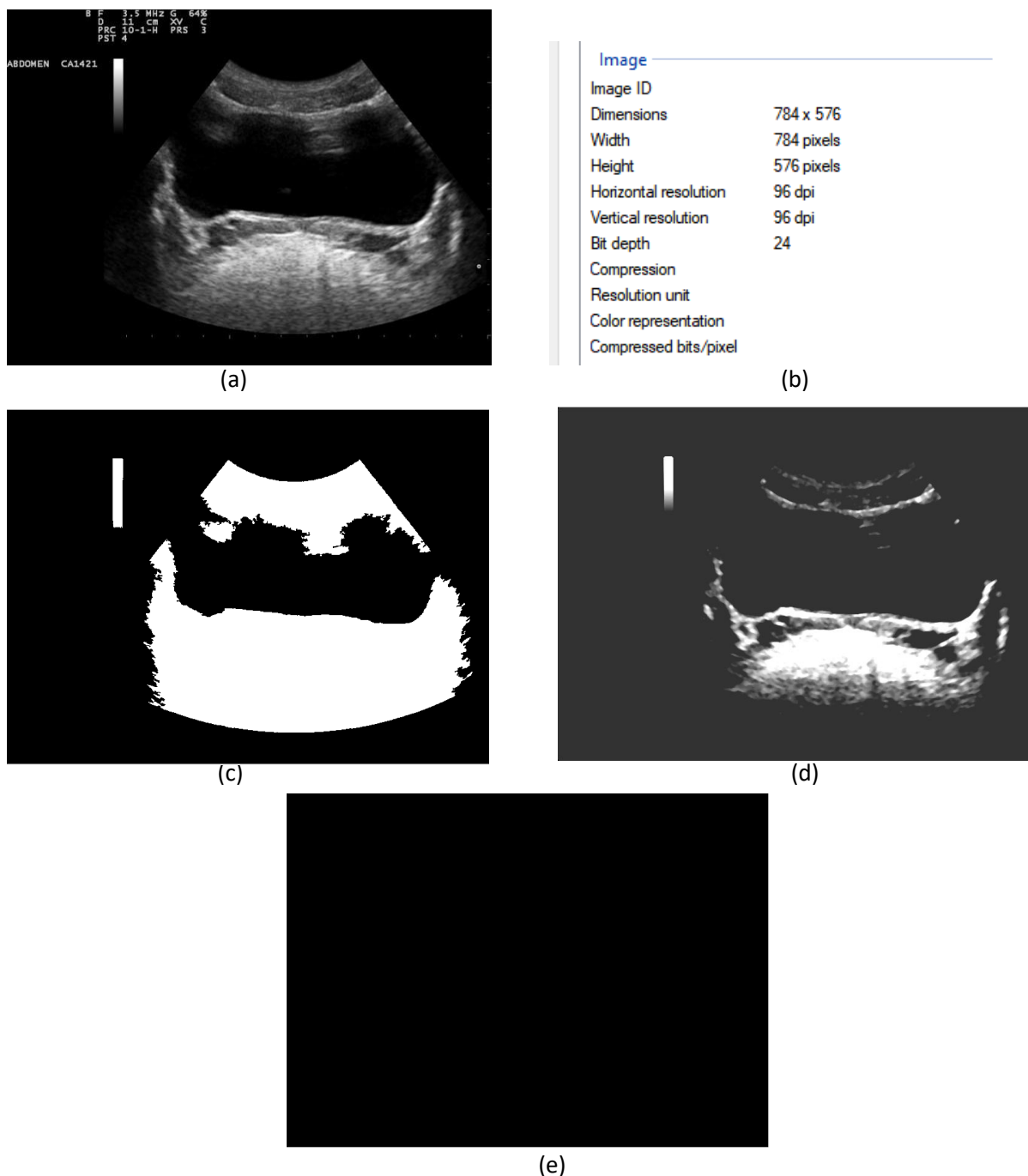


Figure 3: The Ultrasound Image B (a) the original image, (b) the properties of the original image, (c) the processed image after stage 2, (d) the processed image after stage 3, and (e) the processed image after stage 4.

It is also commonly known for operation with images at the lowest level of abstraction which includes both input and output and intensity images. Speckle noise is common in ultrasound images. Noise caused by speckles disturbs ultrasonic images [3]-[4]. During surgery, this disturbance can cause inaccurate detection of stones, damaging kidney tissues. So de-speckling noise is one of the most crucial steps in image pre-processing that improves image quality and enhances content information. This can be done through filter operations, whereby noise can be removed from images, in which it will increase, or reduce the specific details, making evaluation easier and faster. Nonetheless, choosing the appropriate threshold value is important to ensure the accuracy of the spot location is maintained [3]-[6].

4. Conclusion

In conclusion, the purpose of the project has been achieved. The proposed methods have successfully detected the presence of kidney stones in the ultrasound images at their exact location. Nonetheless, more studies must be done to make the proposed techniques applicable to any ultrasound kidney images. The current techniques require unique adjustments on the threshold values and the intensity level to successfully locate the presence of stones in the kidney. However, the output image with the exact location of the stone using a region-based segmentation technique can be integrated with other image processing to provide an alternative that can be used in the process of diagnosing the kidney stone.

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