Morphological Segmentation for Identifying Backbone Area

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Abstract. Segmentation in images of abdominal CT scan is an important step in the processing and interpretation of medical images. This is not easy, because the organs are close together and the color intensity is similar. Various methods have been developed, but the problem of locating the position of the backbone is still difficult to solve. The purpose of this study is to develop a segmentation method to determine the location of the backbone using a morphological method with a binarization approach. Testing of 11 CT Scan images shows that the method developed can determine the area and position of the backbone. Thus, it can be concluded that the method of backbone segmentation using a morphological method with a binary approach is successfully developed so that it can be applied to the advanced analysis process.

1. Introduction

Kidney stones are characterized by the formation of crystals in the urine caused by the concentration of a substance or by genetic disorder. According to [1], kidney disorders caused by kidney stones showed an increase in numbers both in terms of age and sex. In the majority of kidney stone patients, the stones are detected after symptoms such as fever, low back pain, abdominal pain and urinary tract infections occur. The presence of kidney stones has been confirmed by urine testing in the laboratory and abdominal imaging, one of which is by using Computer Tomography (CT), known as CT scan. If kidney stones are found, treatment can use the ESWL (Extracorporeal Shockwave Lithotripsy) method, PNL (Percutaneous Shockwave Litholapaxy), open surgery, and conservative therapy or expulsive medical therapy (TEM). This shows that the accuracy of identifying kidney stones is an important step for making decisions on follow-up actions taken by specialists. Identifying kidney stones based on CT scan images is not easy. This is due to various factors, including the complexity of anatomy and the quality of images produced [2].

Figure 1 is an example of the complexity of abdominal anatomical structures from CT Scan images.
Figure 1. CT Scan image of Abdomen Anatomy

Figure 1 shows the parts of the abdomen including the liver, right kidney, left kidney, pancreas and backbone. Visually, the color of the organs is gray shade, so it can be stated that the separation (segmentation) of the abdomen organs is difficult.

Various methods of segmentation to identify kidneys have been developed. One of them is by Belgherbi [3], who develop semi-automatic kidney segmentation algorithms in abdominal CT images using morphology with a watershed approach. The goal is to remove the backbone so that kidney segmentation can be done. This study resulted in an average sensitivity of 95% but could be below 91% if the CT Scan was not precise and used a different machine. Campadelli [4] segmented the abdominal organs with CT images using morphology to identify the backbone. This study succeeded in segmenting the liver and pancreas, but segmentation of the backbone, kidneys, and heart required further visual examination. Myint [5] compared the effectiveness of the kidney segmentation method manually with a gradient-based approach, and semi-automatic kidney segmentation with the region growing approach. It can be concluded that the region growing technique is not better than the gradient-based approach method. From the 258 CT Scan images, the region growing technique produced an average performance of 70.5% and an average gradient-based technique of 85.5%.

Referring to the research that has been done, identifying the backbone is an important stage in identifying the presence of kidney stones. Based on these conditions, this study aims to develop a segmentation method for identifying the backbone from CT scan images with morphological methods using a binary approach.

2. Literature Review

2.1 CT scan image

CT Scan stands for Computed Tomography or Computerized Tomography Scan. Computed Tomography uses X-Ray technology to detect various conditions and diseases by synthesizing basic images and synthesis units called volume elements [6]. The x-ray tube is rotated and the light is projected in various positions. The amount of electricity received is converted into a digital scale by Analog to Digital Converter (A/DC) which is then recorded by the computer. Next it is processed using the Image Processor, and finally an image is displayed on the TV monitor screen. The resulting image can be made into a film with Multi Imager or Laser Imager [7].

2.2 Morphological Segmentation

One method of image segmentation is the morphological method, which is a mathematical function used to extract and describe the geometric structure of objects in an image [8]. Image processing with a morphological approach is usually done on binary images but does not rule out the possibility of
conducting it on gray-scale images. Morphology has two basic operators, namely dilation and erosion, which are used to extract the desired components in an image [9]. Dilation operation is a morphological process that is intended to expand the area or size of an object [10]. Dilation of the image \( f \) by the structure of the dilated \( B \) matrix element is given by equation (1) below:

\[
f \oplus B = \{ s \mid (B)_s \cap f \neq 0 \}
\]  

Equation (1) shows that the value of the dilation element will be equal to 1 if and only if there is one value of the element \( f = 1 \) which is equal to the value of element \( B = 1 \) in the same coordinate position. Accordingly, the value of the dilation element will be equal to 0 if none of the values of the element \( f = 1 \) which is equal to the value of element \( B = 1 \) in the same coordinate position.

2.3 Kidney

Kidneys have a very important role as an organ that functions to control fluid balance in the body, especially the urinary system, control salt concentration in the blood and acid-base balance of blood, and secretion of waste materials and excess salt [11]. The kidneys are a pair of nut-shaped organs, which are located on both sides of the vertebral column (backbone) [12]. In CT Scan images, the kidneys are of gray-scale color, similar to other abdominal organs such as the liver, pancreas, stomach, and others.

2.4 Backbone

Bone is a living structure composed of proteins and minerals. The mineral content of bone is calcium phosphate carbonate. Bone becomes hard due to deposition of calcium phosphate crystals [13]. The kidneys are located between the backbone precisely in the retroperitoneal space between the thoracic XII or lumbar I and lumbar vertebrae [14]. When viewed in the CT Scan image, the backbone is white like the color of the bone around the abdomen. The white color is produced from the calcium in the bones.

2.5 Kidney Stones

Kidney stones are solid objects formed by various substances dissolved in urine. The stones can be distinguished based on the composition of the substances that make them up. Based on the composition of the substances that make up the stones, they are divided into calcium stones, struvite stones, gout stones, cystine stones, xanthine stones, triamterene stones, and silicate stones [15]. When viewed on a CT scan, kidney stones produce white color because of the composition of calcium contained in the stone, just like bone color.

3. Methodology

Basically, the research stages are as shown in Figure 2.
The first step is to read the CT scan image with the DICOM format studied. The next step is to convert the DICOM image into a gray-scale image. This step is done to delete the writing or symbol that is not needed in the subsequent processing. The third stage is image enhancement which consists of (1) reversing the color of the image, this process aims to see objects around the abdomen that are not needed in the area being analyzed, (2) adjusting the intensity of the image color to make sure that unnecessary areas are eliminated. The fourth step is backbone detection by performing the binarization of gray-scale image. This step produces an image with the area sought (ROI), namely the backbone.

4. Result and Discussion

DICOM Image Reading

The input image is in DICOM (Digital Imaging and Communication in Medicine) format. The DICOM format is used for medical imaging that can be exchanged for data and quality needed for clinical use. DICOM has the format extension .dcm with a size of 512x512 pixels. An example of a DICOM format image can be seen in Figure 3.

DICOM Image Conversion

This stage aims to convert DICOM image to gray-scale image so that CT Scan images can be identified and displayed by MATLAB 2018a software. The formulation of RGB image conversion into gray-scale image can be seen in equation (3).

$$\text{gray-scale} = 0.299 \times R + 0.5876 \times G + 0.114 \times B$$

With R expressing the value of the Red component, G represents the value of the Green component, and B denotes the value of the Blue component.

The results of the gray-scale image conversion can be seen in Figure 4.
Figure 4 gray-scale image resulting from the conversion of an input image that shows that the patient data information is deleted.

Image Enhancement

Image quality improvement is needed because the image used as the research object has poor color quality, such as too dark or too bright, and to delete unnecessary information (noise). The enhancement stage in this study consisted of color reversal, and setting the color intensity of the image.

Color Reversal (Imcomplement)

The operation of reversing the color of the image aims to produce a negative image, so that it is expected to strengthen the color of the object needed and facilitate processing. The process of reversing the color of the image is done using equation (4).

\[ g(x, y) = 255 - f(x, y) \]  \hspace{1cm} (4)

with,

- \( g(x, y) \): image resulted form imcomplementing \( f(x, y) \)
- \( f(x, y) \): gray-scale value of the input image

The result of reversing the color of the image can be seen in Figure 5.

Figure 5. Color Reversal Result

In figure 5, it appears that the background of the image turns white, so that unneeded objects around the abdomen can be spotted. The abdominal area also changes according to the results of the new intensity value. Thus, the object around the abdomen is easy to remove.
**Image Color Intensity Settings**

Increasing image quality can be done by increasing the brightness so as to make the image appear brighter, and the required object becomes clearer. It is known that \( f(x, y) \) states the pixel value in gray-scale images at coordinates \((x, y)\), then the new image uses equation 5 as follows:

\[
g(x, y) = f(x, y) + \beta
\]

with,
- \( g(x, y) \): Result of image color intensity settings
- \( f(x, y) \): Gray-scale image
- \( \beta \): Variable (If the value is positive then the brightness of the image increases. If the value is negative, then the brightness of the image decreases)

The results of setting the color intensity of the image can be seen in Figure 6.

![Figure 6. Result of Image Color Intensity Setting](image)

The result of setting the color intensity of the image in Figure 6 shows that the color of the image becomes more black compared to the previous image in Figure 5, and unnecessary objects around the abdomen are clearly visible. This stage aims to clarify the area of the backbone.

**Backbone Recognition**

Backbone recognition aims to determine the ROI (region of interest) of a CT Scan image by taking the most important part of the image and removing part of the image that is not needed. Prior to making ROI steps, the binarization process is conducted. The binarization process is done by defining the threshold value \( T \) as the limit to check whether a pixel is included in the desired area or not. The formulation for the binarization process can be seen in the following equation 6:

\[
g(x, y) = \begin{cases} 
0, & \text{if } f(x, y) \geq T \\
1, & \text{if } f(x, y) < T 
\end{cases}
\]

with,
- \( g(x, y) \): Binary image
- \( f(x, y) \): Gray-scale image
- \( T \): Threshold

The threshold value \( T \) is used to determine the intensity to be converted to 0 (zero) or to 1 (one).

The ROI identified as the midpoint area is the location of the backbone. The result of the morphological approach to the image can be seen in Figure 7.
Figure 7. Morphological Results

Figure 7 shows a black area with a white background, indicating that the identification of the backbone has succeeded.

This method was tested on 11 CT Scan images and successfully carried out the identification of the backbone. The results of the study can be seen in Table 1.

Table 1. Image of Backbone Detection Result

| Image Code | CT Scan Image | ROI | Morphological Result | Image Code | CT Scan Image | ROI | Morphological Result |
|------------|---------------|-----|----------------------|------------|---------------|-----|----------------------|
| 01_02      |               |     |                      | 02_14      |               |     |                      |
| 01_08      |               |     |                      | 02_18      |               |     |                      |
| 01_35      |               |     |                      | 02_22      |               |     |                      |
| 01_44      |               |     |                      | 02_23      |               |     |                      |
| 01_48      |               |     |                      | 02_33      |               |     |                      |
| 02_01      |               |     |                      |            |               |     |                      |
5. Conclusion

From the results of trials on 11 CT Scan images, it was proven that the method developed successfully identified the backbone. Based on the results of testing in table 1, it can be stated that the development of morphological methods with a binary approach is suitable for conducting backbone recognition.

Future work

The result of the identification of the backbone will be then used as a reference to develop kidney stone identification methods in further research.

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