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# Effective Kidney Segmentation Using Gradient Based Approach in Abdominal CT Images

Moe Moe Myint[1], Theingi Myint[2]
Department of Information Technology Engineering, Yangon Technological University, Insein Township, Yangon, Myanmar
[1]moe2myint.mdy@gmail.com, [2]drtgim@gmail.com

***Abstract***: *Kidney image segmentation of medical images is an essential role for diagnosis and treatment of kidney diseases using medical image technologies. However, accurate kidney image segmentation is a challenge due to the difficulties in finding the object boundaries in medical images. This paper proposes an effective segmentation method for 2D abdominal Computed Tomography (CT) images of the human kidneys. Therefore, a novel kidney segmentation algorithm in CT images using gradient based approach is presented. The involved primary steps are taking image sequences as input, preprocessing and kidney image segmentation with nearest morphological structures. Segmentation is implemented by specifying region of interest (ROI) to get the accurate kidney volume, shape and texture. The ROI is extracted using the statistics of geometric location of kidney on the abdomen area. The effectiveness of this method is demonstrated through experimental results on complex abdominal CT slices compared with manual segmentation based on gradient or edge based approach and semi-automatic segmentation based on region growing approach. It is tested on dataset of 2D images obtained from patients of clinical abdominal CT scan by medical image processing tools, like MATLAB.*

***Keywords:*** *computed tomography, kidney segmentation, gradient based approach, morphological structure, region of interest.*

## 1. Introduction

Nowadays, medical image processing plays a valuable tool in diagnosis therapy, surgical planning, preventing the diseases and complications of various body organs such as brain, heart, kidney, liver and so on [1]. In most cases, tissue segmentation in medical images is the first step in analyzing these images. However, the interpretation of medical images currently depends on the knowledge and experience of radiologists. There are two main reasons for the use of computer aided segmentation: one is to improve upon the conventional user-guided segmentation and the other one is to acquire segmentation prior to visualization or quantification for the analysis of medical images [2]. In recent years, many computer aided diagnosis (CAD) system is developed by using medical image processing techniques. Internal images of a human body can be easily provided by X-ray, Ultrasound, CT and MRI devices [3]. These devices have good resolution on soft tissue of a human body and have fast computation capability. However, the major difference between the other medical imaging equipment and CT is that it is safer, low cost, non-invasive and non-traumatic. The diagnostic CT machines become more popular than the other diagnostic tools [4].

In recent years, many CAD systems have been developed to assist in the making of precise and objective diagnoses for lung cancer, liver tumour and breast diseases. However, kidney image segmentation is a

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challenging task. The main factors are unclear borders between the kidneys, the liver and the spleen, image acquisition artifacts, image noise, and various pathologies, such as tumours and nephrolithiasis [5].

The objective of the system is to demonstrate the advantages of the ROI approach and develop a manually and semi-automatic system for kidney image segmentation on a parallel series of abdominal CT images. A wide variety of prior knowledge regarding anatomy and image processing technique has been incorporated. The major features of the proposed system are 1) pre-processing of the CT image for reducing the noise by using filtering technique and preparing the images for further processing, 2) an elliptic candidate kidney region extraction with progressive positioning of the gradient detection on the consecutive CT images, 3) a more reliable kidney region point identification and 4) specifying region of interest controlled by the properties of image homogeneity. The user interface of segmentation and visualization is implemented to provide a slice by slice observation for each series of the CT images.

This paper is organized as follows. The system design is detailed in Section 2. Experimental results are also shown in Section 3. Finally, Conclusion is presented in Section 4.

## 2. System Design

The overview of the proposed system for kidney image segmentation is shown in Fig. 1. This system is implemented a program in MATLAB to segment the left and right kidney from 2D abdominal CT images. In the proposed system, nearly 75 individual slices of images are acquired as a result.

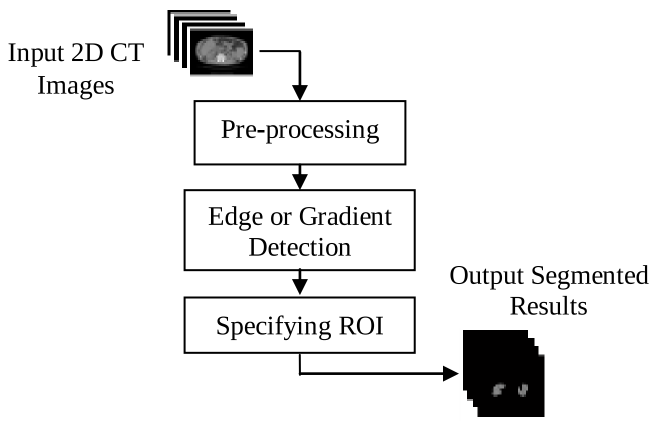



Fig. 1: Block diagram of the proposed kidney image segmentation system.

Segmentation is the process of classifying pixels in an image or volume. Kidney image segmentation is not an easy task. It is one of the most difficult tasks in the visualization processes. For reconstruction of medical 3D surface and volume, interest tissue boundaries are necessary to distinguish the required region of interest on all the image slices. For volumetric rendering, in spite of the surface properties of the tissues being simple visualization, their inner properties are more important. For these purposes, segmentation results are used for further processing before reconstruction of medical images.

A typical abdominal CT image is very complicated. It may contain kidney, liver, spleen, vertebral column, fat, and pathologies. The abdominal cavity is first delineated by kidney image segmentation algorithm. Segmentation methods automatically delineate anatomical structures and other regions of interest for later analysis by human or automated processes. Segmentation algorithms for gray scale images are based on the two basic properties of active contour models according to the force evolving the contours: similarity (region growing approach) and discontinuity (edge-based or gradient-based approach). This experiment covers the edge or gradient based approach than region growing.

## 2.1. Region Growing Approach

Region growing relies on intensity differences, but includes the notion of spatial proximity of pixels, and a seed point for the region. Because of the homogeneous area, RG method is based on neighbourhood grey levels to expand an initial seed to obtain a final mask. RG method is known as a simple and fast algorithm to segment an image. It is compared the initial seed pixels with the unassigned pixels and is considered the speed of segmentation for user convenience in segmenting the images from a Digital Imaging and Communication in Medicine (DICOM) file [6]. A fast segmentation will make the application more user-friendly in displaying a series of images. In this method, a global threshold is defined based on the initial seed and the region is expanded by comparing the neighbourhood pixel intensity with the global threshold, instead of using statistical region calculation. The evaluation of the performance is measured based on the time required to segment an image.

Since the kidneys are homogeneous area, these are almost exhibit similar intensity to other organs. Once the appropriate seed is located, it proceeds with the region growing starting with this seed. The homogeneous criterion is destined to $|f(x, y) - \theta_{local}| \leqslant t_0, \forall (x, y) \in R_k$ where f(x, y) is a pixel satisfying the 8-connection around the seed. The region growing operation terminates when the surrounding area is not homogeneous $|f(x, y) - \theta_{local}| > 50$. The choice of a threshold of 50 is based on this observation of training images. However, the system exhibits weakness in kidney region seed point searching, especially when they appear to the pathologies.

In this case, noise is the sharp pixel intensity transitions which present in the homogeneous regions. Therefore, it is impossible to use region growing-based approaches because the kidney exhibits almost similar intensity to other organs. In some images, we cannot even identify the region of kidney because it is in physical touch with nearest morphological structures. The results of region-growing cannot use the kidney image segmentation because of the homogeneous regions. Therefore, only edge-based or gradient based approach will work in this experiment. Fig. 2 shows the segmented left and right kidney using region growing approach.

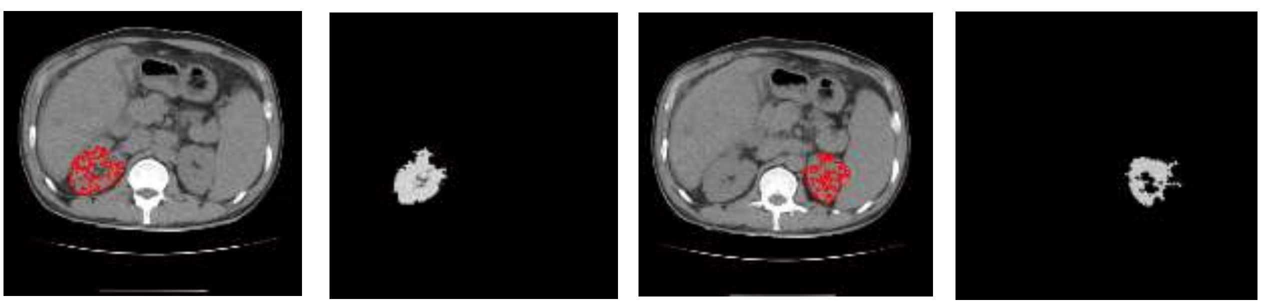
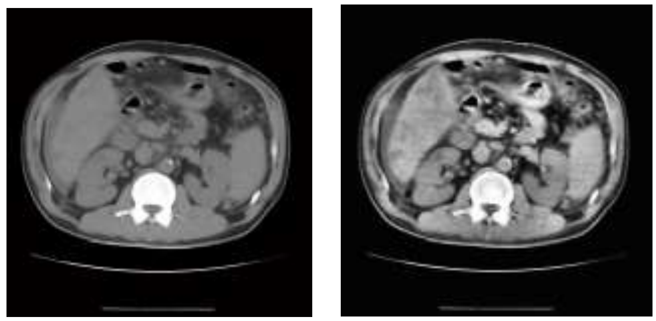


Fig. 2: Kidney segmentation using region growing approach.

## 2.2. Gradient or Edge Based Approach

Gradient or Edge detection is the most common approach for detecting meaningful discontinuities in intensity values. This method widely use as an essential part before segmentation of medical images. After acquisition of CT images, image data is recorded in DICOM file. DICOM files in Medical Image Processing and Analysis System (MIPAS) can convert the image contents of JPEG file using ImageJ. To find out a transformation between slices of images precisely, it is necessary to do the pre-processing for the ROIs extraction of left and right kidneys to improve the medical image qualities.

Generally the structures of both kidneys are not complete or prominent in CT images and it is very hard to segment these structures correctly due to the speckle noise. Therefore, we need to do the pre-processing before kidney segmentation. The gray level of each pixel is replaced by the median of the gray levels in its neighbourhood, instead of using the average. And then, histogram is the basis for numerous spatial domain processing techniques. Histogram manipulation can be used effectively for image enhancement. Histogram manipulation can be used for image enhancement. Therefore, images will go into the operation of image contrasting. Fig. 3 illustrates the resultant image after noise removal and the enhancement of image contrast using histogram equalization.



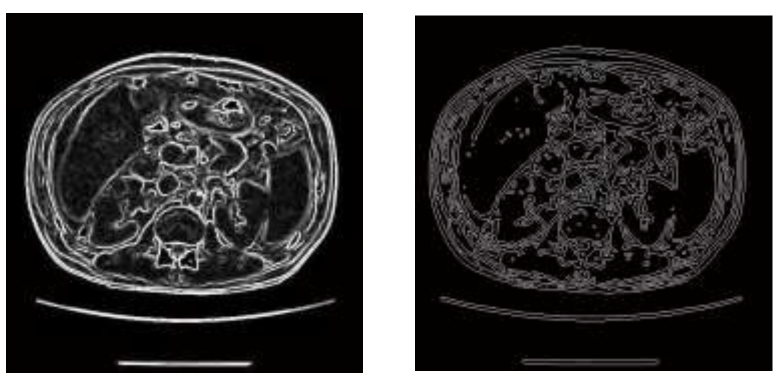
(a) (b)

Fig. 3: Pre-processing step: (a) Image after median filtering and (b) Image after contrasting.

## 3. Experimental Results

To validate the proposed methodology, it is gathered a set of two-hundred and fifty-eight abdominal CT images from 20 different patients in the dataset of normal cases, proceeding from 128 multi-slice CT scanners. An expert radiologist selected the largest 2D longitudinal kidney section from each CT sequence (sequence length ranging between 14 and 73 images), and subsequently produced a manual outline of the organ.

All the organs visible in the CT have similar intensity and texture. Some morphologies exhibit even stronger boundaries or edges than kidneys. Therefore, it is necessary to eliminate unwanted structures other than the morphologies from the image and then to trace the edges using gradient based thresholding. After the edges have been detected (see Fig. 4 (a)), threshold function is used to eliminate weak edges. At this stage, borders are displayed as thick lines. To perform next step, these lines has to be thinned to the width of one pixel. This was done by canny edge detector (see Fig. 4 (b)). Fig. 4 demonstrates the resulting of gradient image and edge image.



(a) (b)

Fig. 4: Edge or gradient steps: (a) Image after gradient and (b) Image after edge detection.

A region of interest (often abbreviated ROI) is a selected subset of samples within a dataset identified for a particular purpose. An ROI can be taken literally as a polygonal selection from a 2D map and defined the borders of an object under consideration. Filling is a process that fills a region of interest (ROI) by interpolating the pixel values from the borders of the region. It is defined an ROI by creating a binary mask, which is a binary image that is the same size as the image with pixels that define the ROI set to 1 and all other pixels set to 0. Fig. 5 illustrates the extraction of ROI from each slice.

(a) (b)

Fig. 5: A left and right kidneys delineate the contour with two blue closed lines (a) Image after selected ROI for left and (b) Image after selected ROI for right.

This experiment describes how to create binary masks to define ROIs. However, any binary image can be used as a mask provided that the binary image is the same size as the image being filtered. The results of computer-aided kidney image segmentation from one of the patients are shown in Fig. 6.

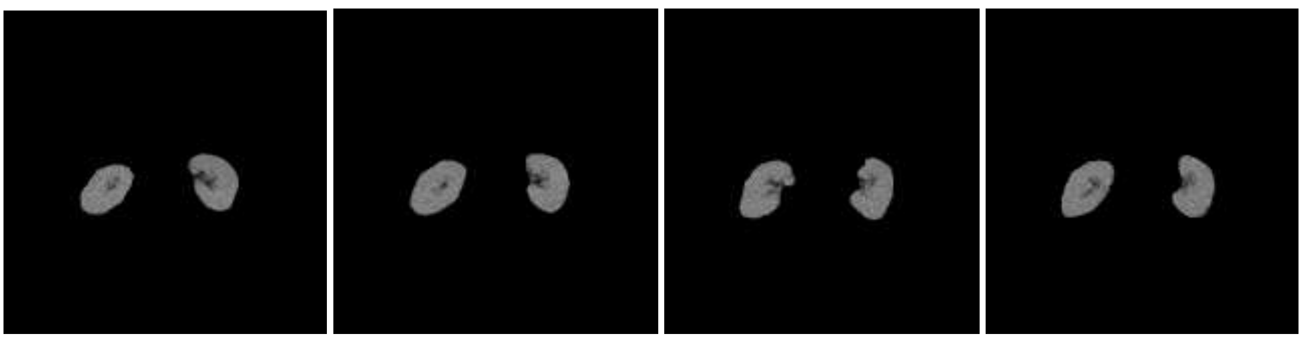


Fig. 6: Some accurate kidney image segmentation results.

To compare the kidney segmentation performance, the average segmented kidney rate is calculated according to the following equation:

$$\text{Segmentation Rate}=(\text{Number of correct segmented images} / \text{Total tested images})\times 100\%$$

In TABLE I, the segmented rates for left and right kidneys show that region growing technique is not better than the gradient based approach in noisy images where images are difficult to detect.

TABLE I: Experimental Results of Kidney Image Segmentation

| Method | Left Kidney | Right Kidney |
|---|---|---|
| Region Growing | 67% | 74% |
| Gradient Based | 82% | 89% |

## 4. Conclusion

It has presented an effective gradient-based approach rather than region growing approach for kidney segmentation in 2D abdominal CT images. Given a set of training images with segmentations, the proposed method computes the kidneys texture based on specifying ROI estimation of the current image. It is demonstrated the performance of kidney image segmentation on both kidneys and provided a region modification strategy so as to accomplish accurate extraction. Experimental results show that the proposed method is accurate, robust, an easy to use and provides relevant clinical measurements for many applications.

Ultimately, we intend to develop a fully automated segmentation approach by exploiting the additional information available in 3D CT and plan to apply the proposed method to other organ segmentations from various imaging modalities.

## 5. Acknowledgements

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