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A Knowledge based Technique for Segmenting Liver using Mathematical Morphology

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Abstract

Segmentation of Liver from Computed Tomography (CT) abdomen image is the most basic and important technology and a prerequisite for the diagnosis, treatment planning, and surgery planning. Manual segmentation is time consuming and tedious. To precisely segment and assist radiologist a computer assisted approach is developed. The proposed method integrates knowledge base with mathematical morphology to segment liver. Quantitative evaluation is performed and the mean score of 93% is obtained.

Keywords: Computed Tomography, Histogram Tail Threshold, Liver Segmentation, Morphological Operations

1. Introduction

In this era of modern medicine, Medical Imaging plays a vital role in diagnosis and treatment planning. Imaging modalities are greatly improved over the years to study the internal organs in the human body. Few among the modalities are X-rays, Ultrasound, Computed Tomography (CT), Magnetic Resonance Imaging (MRI), and Positron Emission Tomography (PET). Computed Tomography (CT) and Magnetic Resonance Imaging (MRI) are the most accurate as well as non-invasive image modalities in the diagnosis of liver. These medical images are interpreted by radiologist[1]. Liver is the largest glandular organ in the body and performs various significant functions such as hormone balancing, purifying body from toxins and other harmful substances[14]. The average weight of adult liver is 3 pounds (1.5 kg) and it is positioned in the upper right portion of the abdominal cavity under the diaphragm and to the right of the stomach. Medical images are widely used in clinical purposes, including diagnosis, monitoring and for treatment planning[2]. Segmentation is regarded as a major preprocessing step in all clinical and technical demands. In practice, further analysis in CT images i.e., segmentation for surgery planning is a tedious and a time consuming task for a radiologist[3]. It requires strict attention of the radiologist which results in wearisome as the time prolongs. Segmentation of liver is difficult due to the following reasons: organs inside the abdominal cavity are abutting, homogenous gray level intensities between the organs. In order to improve the diagnostic efficiency of the liver, CT image obtained with contrast media is used. For liver segmentation, knowledge about the CT images and abdomen anatomy is a pre-requisite. By removing the non-liver portions with morphological operations the liver region is segmented from the CT abdomen in this method.

The rest of the paper is organized as follows. Section 2 describes the related works. Section 3 discusses the proposed method of liver segmentation. In section 4, we quantitatively evaluate the proposed method and discuss the results obtained. The paper ends with conclusion in section 5.

General approaches for liver segmentation are reported in several previous works. Some of the conventional techniques are used for liver segmentation[4-9]. A liver segmentation method based on region growing is proposed in[5]. An improved slice-to-slice region growing method with combination of both centroid detection and intensity distribution analysis is proposed. An automated segmentation method using 2D histogram in multi-slice CT images focusing on the liver region is proposed[6]. Segmenting liver

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region based on the anatomical knowledge that the blood vessels are surrounded by the liver boundary is given in[7]. A knowledge - based technique for liver segmentation in CT data[8]. Thres holding, morphological operations and deformable contour model is used to segment liver for three dimensional visualization automatically[9].

2. Proposed Method

A radiologist performs manual segmentation based on the anatomical facts of the organs. Segmentation of Liver with similar approach is proposed here. The anatomical knowledge employed in this method is as follows: liver is present inside the rib cage, liver cross section is mainly located in the right side of the abdomen, and liver is a continuous object which is larger than other organs inside the abdomen. While undergoing normal CT scans, bone appears white, gases and most liquids appear black and other tissues can have varying shades of gray depending on its density. The contrast media improves the ability of the radiologist to view the images of the organs inside the body. The intake of contrast causes the blood vessels and organs filled with contrast to enhance and show up as white areas on the CT image. In abdomen, kidneys and liver eliminate the contrast from the blood[15], whereas stomach and intestine appears white in color.

2.1 Histogram Tail Threshold and Binarization

The method starts with the intensity analysis of the input image. In CT data set, the intensity range of abdomen organs has high variations. The histogram of the abdomen is computed. In CT abdomen, our region of Interest (ROI) is the liver. Histogram of CT slices doesn't have peak values at both ends. Histogram Tail Threshold[10] (HTT) is applied on both sides of the histogram to take out extreme regions. Right Histogram Tail Threshold (I_{RHTT}) extract bone, spine and stomach region as in Figure 1 and Left Histogram Tail Threshold (I_{LHTT}), extract the image background. Global thres holding technique Otsu[11] converts the input image into a binary image (I_B) as in Figure 2. By subtracting bone, spine and stomach from the binary image, we obtain Figure 3.

2.2 Morphological Erosion Operation

Mathematical morphology is a type of filter used in image processing for noise suppression, feature extraction etc.

Figure 1. RHTT- Rib-cage Bone, Spine and Stomach (I_{RHTT}).

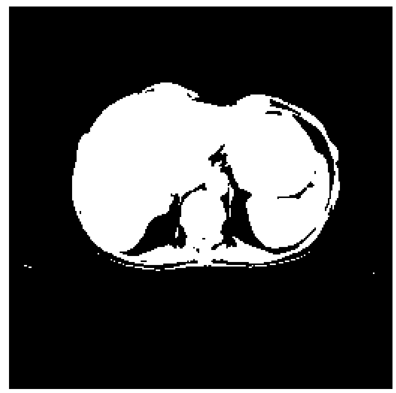

Figure 2. Binary Image (I_B).

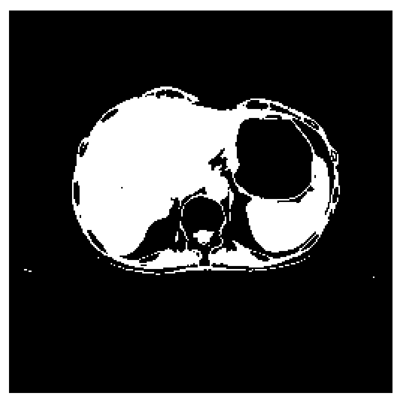

Figure 3. Resultant image (I_{BSS}) after subtracting $I_{RHTT.}$

The essence of mathematical morphology is an expression of the interaction between collection of objects and the structuring element (SE). The structuring element used in this method is a disk shaped structuring element with radius 7. The SE window is shown in Figure 4. Erosion is one of the base operations of morphological processing.

It shrinks or thins the object in the binary image. Here the input for erosion is the resultant image (I_{BSS}) obtained from the subtraction. The erosion operation is given in (1) and the eroded image (I_E) is shown in Figure 5.

$$E = I_{BSS} \ominus SE \quad (1)$$

2.3 Removing the 4th Quadrant

The input image is of 256x256 pixels (height x width). We separate the image into four quadrants as shown in Figure 6 (a). In the CT abdomen image, liver lies in the first three quadrants as shown in Figure 6 (b). So we remove the fourth quadrant of the image and the result is shown in Figure 6(c). The non-ROI portions are removed during the 4th quadrant removal is a part of spleen, kidney and fat muscles.

0	0	1	1	1	1	1	1	1	1	1	0	0
0	1	1	1	1	1	1	1	1	1	1	1	0
1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1
0	1	1	1	1	1	1	1	1	1	1	1	0
0	0	1	1	1	1	1	1	1	1	1	0	0

Figure 4. Disk Shaped Structuring Element of radius 7 (SE).

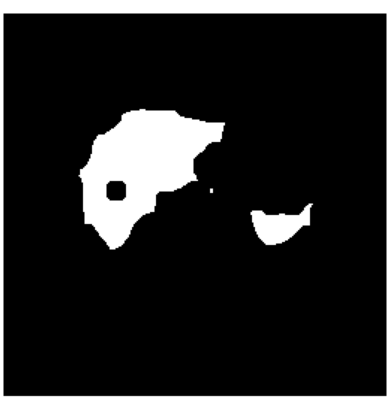

Figure 5. Eroded Image (I_E).

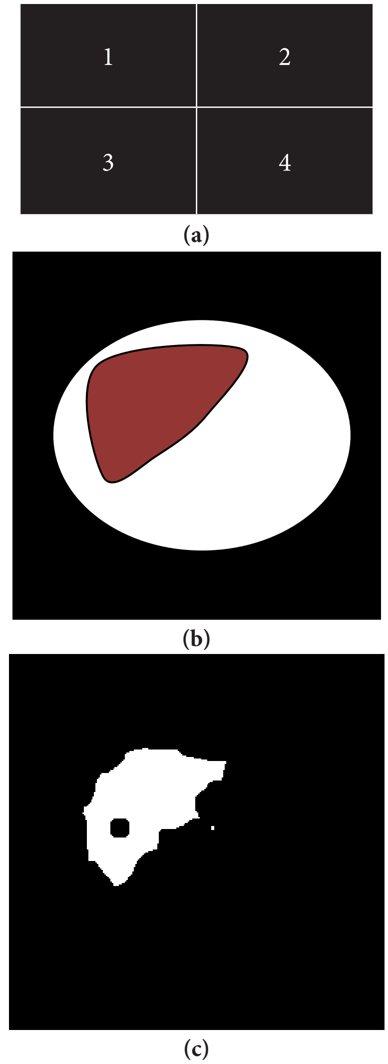

Figure 6 **(a).** Separating Image into four equal quadrants. **(b).** Image showing liver location. **(c).** Fourth quadrant removed image (I_{RFQ}).

2.4 Extracting Greatest Connected Pixels

With the known anatomical fact that liver is a continuous object and the largest inside the abdomen region, we exclude the least connected region in the image (I_{RFQ}) and extract the greatest connected pixels from the eroded image which is (I_{GCP}) as shown in Figure 7.

2.5 Morphological Dilation Operation

The (I_{GCP}) image has lost some pixels during erosion. With morphological dilation we can regain the lost pixels in the ROI. Dilation is the operation of lengthening or thickening in the binary image. The extent of thickening is controlled by the structuring element. We use the same structuring element (SE) of that is used for erosion. The dilated operation is given in (2) and image (I_D) is shown in Figure 8.

$$D = I_{GCP} \oplus SE \qquad (2)$$

When overlapping the dilated image mask with that of original image, segmented liver region is obtained as the resultant image. Results of liver segmentation in different slices are shown in Figure 10.

3. Experimental Results and Discussion

The proposed algorithm is implemented and tested with 2 volumes of CT abdomen images obtained from Medall diagnostic Scans which include more than 200 axial two dimensional slices with contrast. We implemented this algorithm in MATLAB environment. Raw abdomen images obtained from the CT scanner is shown in Figure 9 and the liver segmented results of the CT abdomen are shown in Figure 10. The strengths and weakness

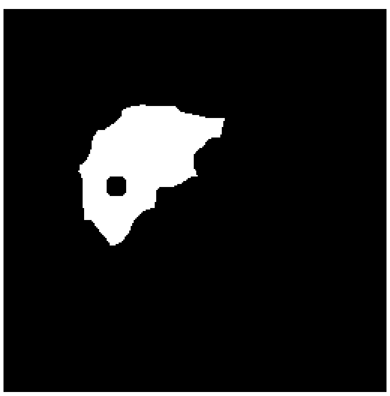

Figure 7. Extracted Greatest Connected Pixels (I_{GCP}).

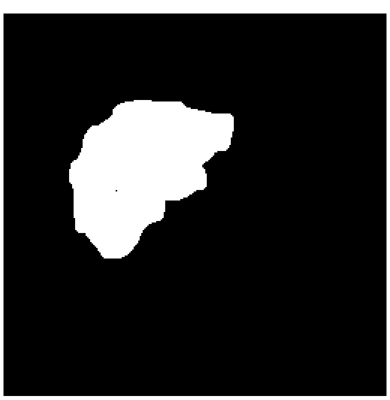

Figure 8. Dilated Images (I_B).

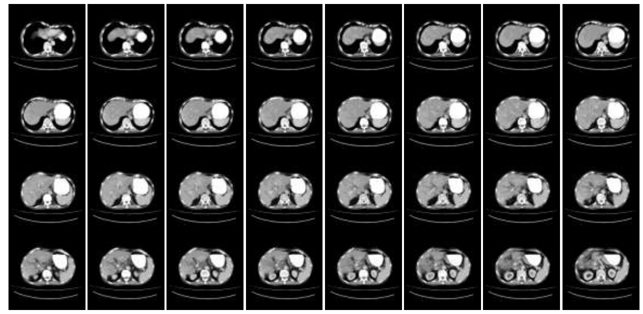

Figure 9. Raw Images from CT scanner.

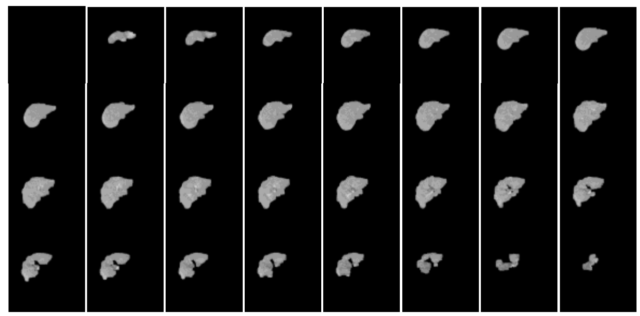

Figure 10. Results of the proposed segmentation.

of the proposed method are apparent from the figure shown. We evaluate the segmentation algorithm by comparing the segmentation results against the gold standard image segmented by the expert radiologist. The degree of similarity between the manual segmentation and machine segmentation reflects the accuracy of the segmented image. Dice similarity[12,13] co-efficient is one of the popular quantitative evaluation technique used in medical image segmentation. The dice co-efficient metric is calculated using (3),

$$Dice = \frac{2|A \cap B|}{2|A \cap B|} * 100 \qquad (3)$$

Here, A is the proposed method and B is the manual segmentation obtained from radiologist. The average value of dice co-efficient for the two volumes is 93% and the results are very satisfactory. The algorithm encounters problem with the region where liver boundary and abdominal wall intersects.

4. Conclusions

In this study, an automatic method is proposed to segment liver region from the CT abdomen images with the anatomical knowledge base of abdominal organs with its intensity properties and mathematical morphology. According to our experiments, this method can efficiently segment the normal liver invariant in terms of size and shape. The problem of over segmentation is encountered at the places where liver touches abdominal wall. Over the last decade, diagnostic radiology has grown heights with computer assisted reading of medical images. Since health care is the key for national development it is still recommended to add more features in segmentation and achieve maximum accuracy with the results.

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