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Automatic liver segmentation for volume measurement in CT Images

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Abstract

Computed tomography (CT) images have been widely used for diagnosis of liver disease and volume measurement for liver surgery or transplantation. Automatic liver segmentation and volume measurement based on the segmentation are the most essential parts in computer-aided diagnosis for liver CT as well as computer-aided surgery. However, liver segmentation, in general, has been performed by outlining the medical image manually or segmenting CT images semi-automatically because surface features of the liver and partial-volume effects make automatic discrimination from other adjacent organs or tissues very difficult. Accordingly, in this paper, we propose a new approach to automatic segmentation of the liver for volume measurement in sequential CT images. Our method analyzes the intensity distribution of several abdominal CT samples and exploits a priori knowledge, such as CT numbers and location of the liver to identify coherent regions that correspond to the liver. The proposed scheme utilizes recursively morphological filter with region-labeling and clustering to detect the search range and to generate the initial liver contour. In this search range, we deform liver contour using the labeling-based search algorithm following pattern features of the liver contour. Lastly, volume measurement is automatically performed on the segmented liver regions. The experimental measurement of area and volume is compared with those using manual tracing method as a gold standard by the radiological doctors, and demonstrates that this algorithm is effective for automatic segmentation and volume measurement method of the liver.

Keywords: Liver segmentation; Volume measurement; Morphological filtering; Deformable contouring; Computer-aided diagnosis

1. Introduction

The liver cancer is one of the most common internal malignancies worldwide. The hepatocellular carcinoma is common in Asia and metastasis is common in the West. The liver cancer is also one of the leading death causes. Currently, the confirmed diagnosis used widely for the liver cancer is needle biopsy. The needle biopsy, however, is an invasive technique and generally not recommended [1]. Therefore, computed tomography (CT)

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and magnetic resonance imaging (MRI) have been identified as accurate non-invasive imaging modalities in the diagnosis of the liver cancer. These medical images are interpreted by radiologists. However, image interpretation by human beings is often limited due to the non-systematic search patterns of themselves, the presence of structural noise in the image, and the presentation of complex disease states requiring the integration of vast amount of image data and clinical information.

Recently, computer-aided diagnosis (CAD), defined as a diagnosis introduced by a radiologist who uses the output from a computerized analysis of medical images as a "second opinion" in detecting lesions, assessing extent of disease, and making diagnostic decisions, is being used to improve the interpretation components of medical imaging [2,3]. In addition, computer-aided surgery (CAS) that is the future technology in surgery is performed on computerized surgical planning and image-guided surgery by analyzing region-of-interest (ROI) in the medical image. Volume measurement is also of major importance in different fields of medical imaging where physicians need some quantitative assessments for surgical decisions.

Research in CAD for both mammogram and chest radiographs is rapidly growing; however, CAD research for liver cancer is to be insufficient because the liver segmentation that plays an important role for CAD is difficult. This is mainly due to the two following facts. The first one is the proximity of the liver and other organs or muscles with the similar intensity. It makes difficult to resolve by observation of intensity discontinuity alone since partial-volume effects (PVE) cause the discontinuity to weaken where the structures touch. The second one is the variation in both shape and scale across patients even on the same patient [4].

There are many approaches for image segmentation, such as feature thresholding, contour based techniques, region based techniques, clustering, and template matching. Each of these approaches has its advantages and disadvantages in terms of applicability, suitability, performance, and computational cost [5]. Particularly, no one who did not consider above characteristics of the abdominal CT image can meet desirable results on liver segmentation. In addition, the traditional method of getting volume of the liver is to perform a by-hand 2D segmentation of parallel cross-sectional CT slices and to multiply all voxels of the stacked slices by their size while the procedure is often time consuming and non-systematic [6]. Therefore, to address above problems, we present an automatic liver segmentation algorithm in abdominal CT images using the combination of region-based and contour-based approaches. Our algorithm exploits both medical priori knowledge, for example, the general shape, location, and gray level of the liver, and deformable contour method using labeling-based search algorithm. Finally, total liver volumes were calculated from segmented areas of the liver to evaluate the patients for entire or partial liver transplantation and CAS.

This paper is organized as the following. In Section 2, we propose a new segmentation algorithm applicable to CT image, and we describe volume measurement in Section 3. After experimental results and analysis are presented in Section 4, we conclude the paper in Section 5.

2. Automatic liver segmentation

Mainly, the liver is approximated to muscle and gastrointestinal tract. Since adjacent organs have similar intensity with the liver as shown in Fig. 1, a direct liver-extraction approach without preprocessing may also extract undesirable boundaries resulting from its adjacent organs as fault positive/negative errors [1]. To cope with the problem, we present a new segmentation scheme with three stages. The first stage is image simplification as preprocessing; the second stage detects a search range detection with initial liver contour by using morphological filter; and the last stage is contour-based segmentation using labeling-based search algorithm that refines the initial liver boundary obtained in the second stage.

The overall framework of our proposed scheme is illustrated in Fig. 2. The input for algorithm is contrast enhanced, abdominal CT image of 512×512 pixels with gray level.

2.1. Image simplification

For image simplification, we consider a priori knowledge of the liver on abdominal CT image, such as shape, location, and intensity value. First of all, we decide ROI region. To identify ROI blocks, we divide the abdominal CT image into non-overlapping blocks of 64×64 pixels. Then, we discard the right-bottom region ('Rd' region except 'd1' block in Fig. 3) that is from a priori knowledge—the liver cannot be located