Accurate Liver Extraction Using a Local-Thickness-Based Graph-Cut Approach

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Abstract— *This article presents an accurate and automatic approach to extract a liver from CT images for oncologic surgery planning. Our algorithm exploits graph cut segmentation, which perform global optimization. The quality of graph cut segmentation strongly depends on the edge image that gives prior knowledge about locations of foreground and background regions. In order to get a good edge image, a liver candidate region is extracted based on three types of liver structure models: intensity model, shape model, and blood vessel model. Moreover, the "local-thickness" image of the liver candidate region is used as the edge image. The experimental results show that the use of local-thickness edge image can avoid the over-extraction of anatomical structures surrounding the liver.*

Keywords: Medical imaging, 3D simulation analysis, anatomic hepatectomy, local thickness

1. Introduction

For liver cancer surgery, 3D simulation before surgery operations, recently, is getting one of the crucial tasks since a liver has complex structure. Liver segmentation from CT images is a challenging task since the variations of the liver shape is large and since there exist some other anatomical structures with the CT values similar to the liver around the liver. For example, Fig. 1(a) shows a CT image. Rib muscle contacts Liver partly, and they have almost similar CT values. There have been several researches on liver extraction[1]-[5]. The researches [1] and [2] use, respectively, statistical shape models and probabistic atlases, and both methods suffers from large variations of liver shapes. The active contour approach [3] are dependent on image gradient, and leads to over-extraction into organs with CT values similar to the liver. Moreover, its quality strongly relies on the location and shape of the initial contour. The intensity-based approach [4] usually exploits a simple intensity model, and miss the vessels and non-homogenous texture regions inside the liver. The structure-model-based approach[5] exploits a shape and vessel models as well as an intensity one. Although it successfully extracts the major volume of liver, there is still over-extraction at regions touching the liver tightly like rib muscle as shown in Fig. 1.

2. Algorithm

Figure 2 shows the total flow of extracting a liver region. For simplicity, we use 2-D images in the figure although a 3-D image is used in fact. First, a liver candidate region is extracted from CT images using structure-model-based method[5]. The upper-left and upper-right figures shows a CT image and the liver candidate region. Readers can see rib muscle is mis-extracted as the liver region. Next, for the liver candidate region, the thickness feature is measured by computing “Local Thickness“ [6], where the local thickness of a point is defined as the diameter of the largest sphere that fits inside the object and contains the point. The lower-right figure of Fig. 2 shows the local-thickness image of the liver candidate image. Generally speaking, the core region of the liver has a large LT value whereas mis-extracted regions surrounding the liver tends to have a small LT value. This observation indicate that the local thickness image is a good metrics to give the possibility which voxel is foreground(or background) one. Figure 3 shows the difference between the binary and LT images of the liver candidate region. In the binary image, the mis-extracted region like rib muscle has the same weight value as correctly-extracted region. In the LT image, the mis-extracted region has smaller weight value than the correctly-extracted region. Finally, graph cut segmentation is done using the LT image as the edge image as shown in the lower-left figure. The graph-cut segmentation [7]-[9] is a energy-based approach which allow much more robust segmentation than simple techniques such as region growing or split-and-merge. The CT image and the LT image are used as inputs for the graph-cut segmentation. The graph-cut segmentation works in such a way that regions with small LT values are segmented into background.

3. Experimental results

For programming, we use the Java-based image processing platform called ImageJ[10]. ImageJ has a lot of plugins like a DICOM reader, basic 2D/3D image processing and visualization, and can be extended easily by adding use-defined plugins. Moreover, ImageJ runs on multi-platforms like Microsoft Windows, Linux and MacOS since it is based on Java. To be specific, we use Fiji, one distribution of ImageJ, since it has much more plugins such as graph cut

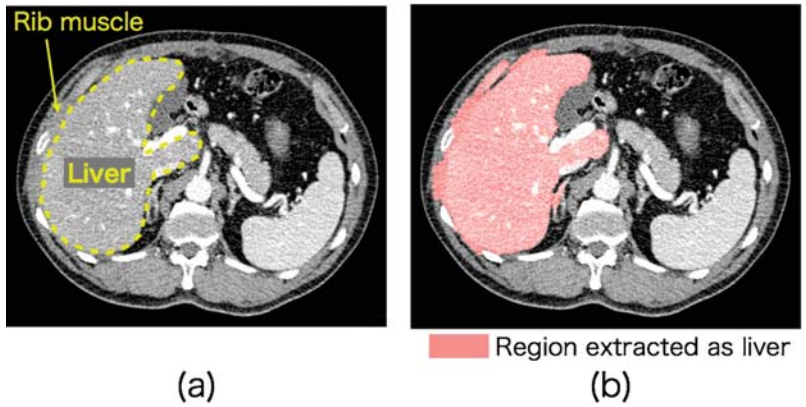

Fig. 1: CT image including the liver and extraction result of conventional approach[5].

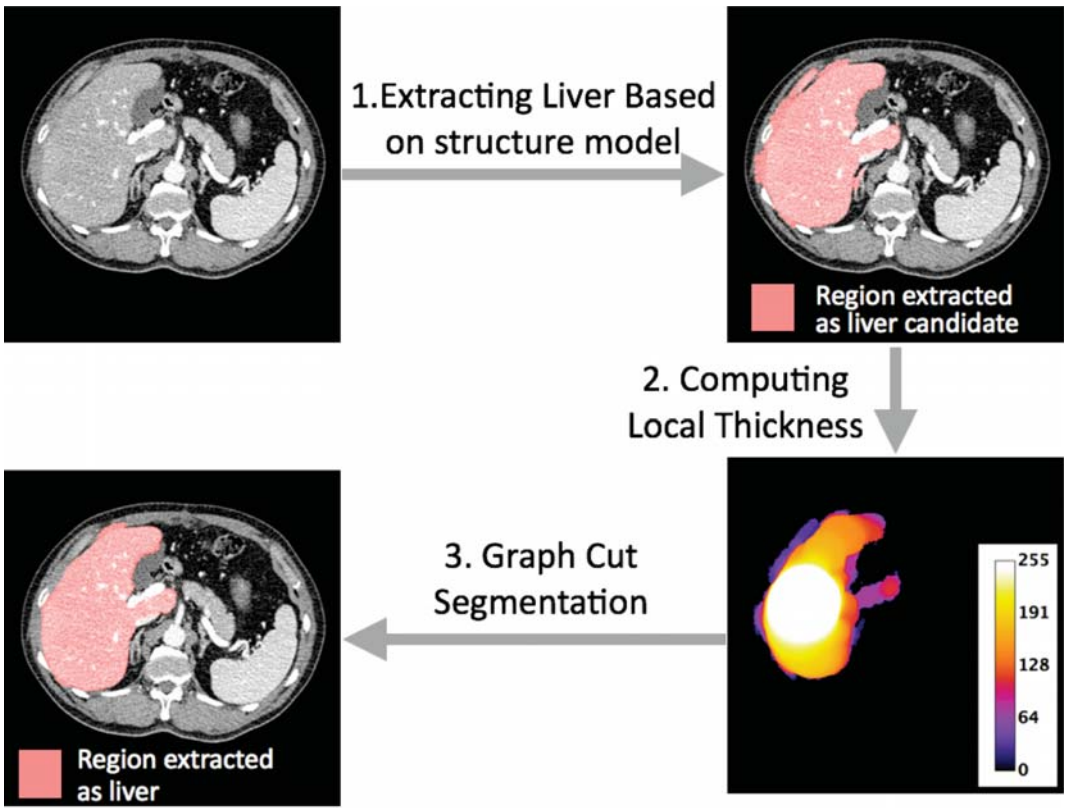

Fig. 2: Flow of extracting the liver regions.

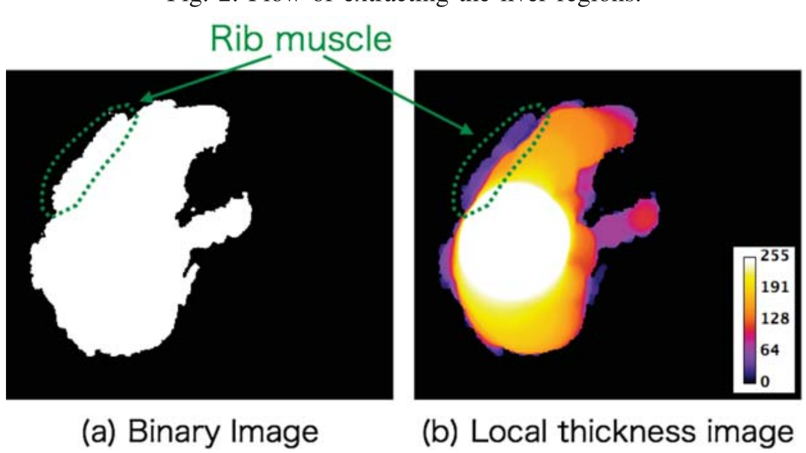

Fig. 3: Edge images: binary image and local-thickness image.

segmentation than original ImageJ. For the experiments, we use the plugin of graph cut segmentation which is implemented based on [8]. This plugin has for parameters to be preset as follows:

- the expected numbers of foreground pixels,
- the smoothness of the segmentation,
- the influence of the edge image,
- the variance of the edge image.

We adjust these parameters as needed.

Let us compare the proposed method(graph-cut segmentation using LT edge images) with segmentation based on structure models[5], and with graph-cut segmentation using binary edge images. Note that the segmentation based on structure model is used to obtain the liver candidate region in our extraction flow shown in Fig. 2. The comparison results are shown in Figures 4-6; the regions bounded with dotted lines indicate the mis-extracted regions; note that there are only over-extracted regions in this experiments. Each of these figures have (a) Grand truth, (b) Extraction based on structure model, (c) Graph-cut segmentation using binary edge images, and (d) Graph-cut segmentation using LT images(proposed). In these results, there are over-extracted areas in (b), and they are improved in the proposed method (d). In contrast, the results of (c) are almost same as those of (b) in Figs. 5 and 6, and is even worse in Figure. 4. The another advantage of the proposed method is that it is less sensitive than the Graph-cut segmentation using binary edge image.

4. Conclusion

The proposed method can obtain the accurate boundary of liver region based on the information of local thickness. As future work, setting parameters automatically is important issue. Moreover, simultaneous recognition of other organs around the livers is on-going to improve the accuracy.

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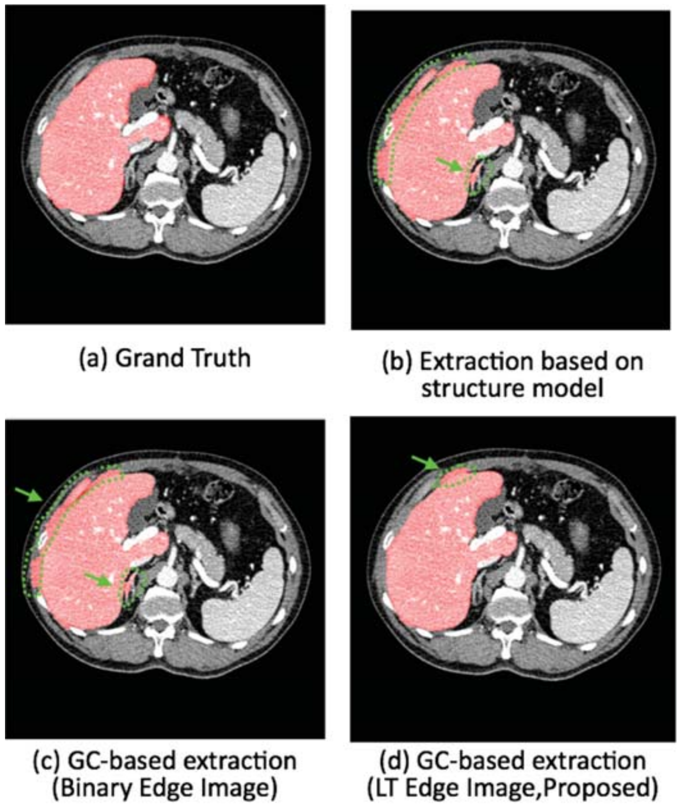

Fig. 4: Comparison 1.

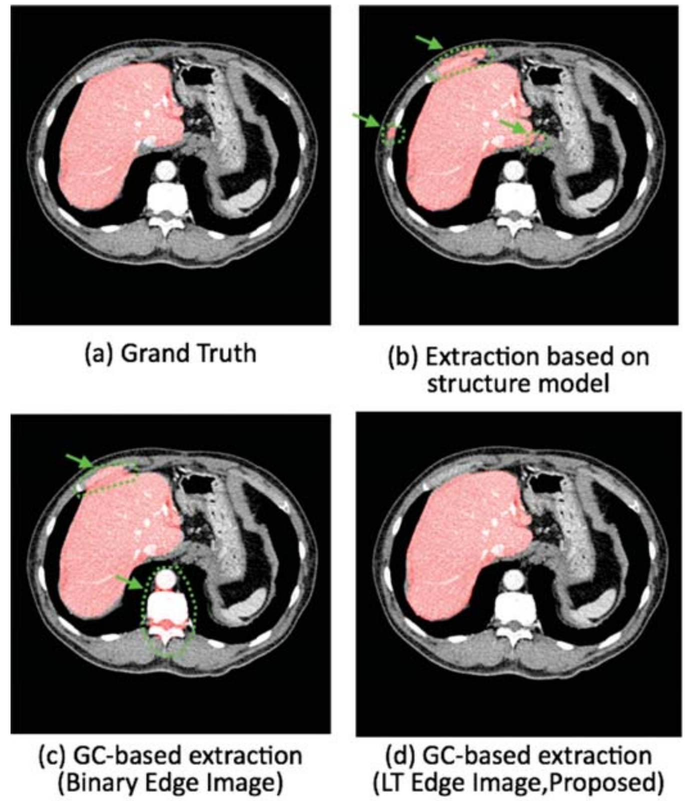

Fig. 5: Comparison 2.

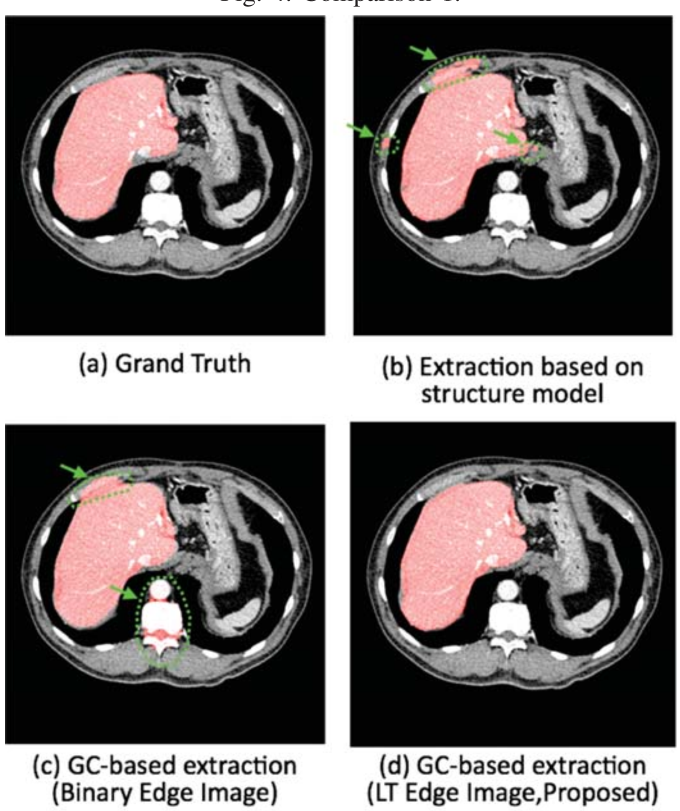

Fig. 6: Comparison 3.