A Post Smoothing Algorithm for Vessel Segmentation

Jiangtao Li, Hyo Jong Lee*
Div. of Electronics and Information Engineering
Center for Advanced Image and Information Technology
Chonbuk National University, Jeonju, Korea
e-mail : {nelfy, hlee}@chonbuk.ac.kr

ABSTRACT

The segmentation of vessel including portal vein, hepatic vein and artery, from Computed Tomography (CT) images plays an important role in the therapeutic strategies for hepatic diseases. Representing segmented vessels in three dimensional spaces is extremely useful for doctors to plan liver surgery. In this paper, proposed method is focused on smoothing technique of segmented 3D liver vessels, which derived from 3D region growing approach. A pixel expand algorithm has been developed first to avoid vessel lose and disconnection cased by the next smoothing technique. And then a binary volume filtering technique has been implemented and applied to make the segmented binary vessel volume qualitatively smoother. This strategy uses an iterative relaxation process to extract isosurfaces from binary volumes while retaining anatomical structure and important features in the volume. Hard and irregular place in volume image has been eliminated as shown in the result part, which also demonstrated that proposed method is a suitable smoothing solution for post processing of fine vessel segmentation.

1. Introduction

CT images are often preferred by diagnosticians since they have high Signal-to-Noise ratio and good spatial resolution, thus giving accurate anatomical information about the visualized structures [1]. The Segmentation of liver vessel from CT images is particularly valuable for diagnosis assistance and surgery planning. To construct 3D perfect vessel model becomes an inevitable and necessary research field. With the development of computational ability of personal computers, 3D guided vessel surgery becomes more and more useful and practical.

A number of vessel segmentation techniques have been proposed by researchers. Nain et al. [2] have presented a segmentation method for vessels using an implicit deformable model with a soft shape prior, it basically using level set kernel to obtain accurate segmentation. The advantage of using level set based segmentation is to achieve smoother segmented volume because of it takes care of the curvature of evolving interfaces. Deschamps et al. [3] also provided vessel segmentation by means of level-set methods. However, most of their works rely on computational segmentation techniques such as level set, deformable models etc. With the development of CT devices and contrast medium, the intensity values of liver vessels in CT images are totally distinguishable from liver body and other adjacent organs. Thus, in our previous work, liver segmentation approach is based on modified region growing method, which highly reduces the time of volume preprocessing and segmentation, to obtain more efficiency in practical application.

The output of adopted region growing algorithm is binary 3D image. Generated isosurfaces from the segmented volume, as shown in the left part of figure 2, are not smoothed enough as the output of level set algorithms. That is because of adopted region growing algorithm does not care the curvature of surface, and there is no interpolation operation between two further connected voxels.

In this experiment, we have developed an Improved Aliasing Artifacts Removing (IAAR) algorithm to make the surface smoother without losing vessel information. Section 2 described the algorithm in detail. And the result and conclusion are presented in section 3 and section 4, respectively.

2. Vessel Volume Smoothing

Since Osher and Sethian [4] have introduced level sets as a mechanism for computing moving wave fronts, numerical schemes for computing the differential equations has been widely used in the field of image processing, computer graphics and physical simulation. The level set method evolves a contour or a surface (in three dimensions) implicitly by manipulating a higher dimensional function, called the level set function $\varphi(x, t)$. A more comprehensive review of level-set methods is given by [5].

Whitaker [6] have implemented a solution of reducing aliasing artifacts for binary data based on a narrow band level set method. It recovers grey-scale embeddings from binary data by introducing a regularization that picks the feasible solution with the least surface area. Inspired by this work, we implemented the method for binary 3D volume aim to smooth the result of previous vessel segmentation. It can removes aliasing artifacts of a volume especially in the edge of it. However, vessels in the segmented 3D volume are fine tubular which only occupy few voxels, some vessels thus turned disappeared and disconnected after applying the Aliasing Artifacts Removing (AAR) algorithm as shown in the middle of Figure 2.

To solve this problem, we expand edge-voxels according to its vector field of normal to make the model one voxel larger than original model before applying AAR, as shown in figure 1.

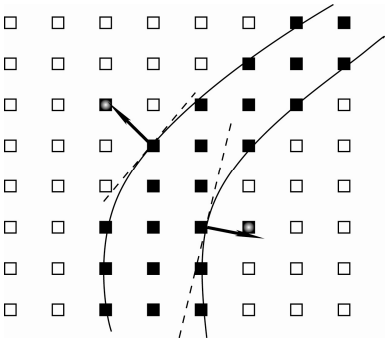

Figure 1: Voxel expanding according to normal direction

In the edge of the segmented volume, each voxel $P(x, y, z)$ will be expanded along with its normal n. The intensity value of nearest voxel in the direction will be marked as the segmented result. Finally the vessel will be enlarged with a reasonable range.

3. Result

The original liver vessels segmented by region growing method are shown in the left part of Figure 2. Some Vessels in it are grudgingly connected. The result of directly applying AAR is shown in the middle of figure 2. And the right part of Figure 2 is the result of IAAR algorithm. The comparison of whole vessel structures is shown in Figure 3.

4. Conclusion

In this paper, with the implementation of AAR algorithm, an improved algorithm to avoid losing vessels has been developed. It uses the normal feature of original segmented result and expand the edge voxels according to it. This operation compensated the voxel contraction when removing aliasing artifacts. The results demonstrated that the method is reasonable for the segmentation of fine tubular, especially in vessel segmentation.

References

[1] P.Campadelli, E.Casiraghi. “Liver segmentation from ct scans: A survey”. LNCS 4578, pp.520-528, Springer Berlin. 2007.

[2] D. Nain, A. Yezzi, and G. Turk, “Vessel Segmentation using a Shape Driven Flow,” in International Conference on Medical Image Computing and Computer-Assisted Intervention (MICCAI’04), vol. LNCS 3216, pp. 51–59. 2004.

[3] T. Deschamps, P. Schwartz, D. Trebotich, P. Colella,D. Saloner, and R. Malladi, “Vessel segmentation and blood flow simulation using level-sets and embedded boundary methods”. International Congress Series: Computer Assisted Radiology and Surgery (CARS), 1268, 75–80, 2004.

[4] S. Osher and J. Sethian, “Fronts propogating with curvature dependent speed: Algorithms based on Hamilton-Jacobi formulations”. Journal of Computational Physics, vol. 79, pp. 12–49, 1988.

[5]J. Sethian, “Level Set Methods: Evolving Interfaces in Gometry”. Fluid Mechanics, Computer Vision, and Material Sciences. Cambridge University Press, 1996.

[6] R. Whitaker. “Reducing Aliasing Artifacts in Iso-Surfaces of Binary Volumes”. IEEE Volume Visualization and Graphics Symposium, pp.23-32, 2000

Figure 2: Surface reconstruction result. Left: original data. Middle: AAR applied data. Right: IAAR applied data.

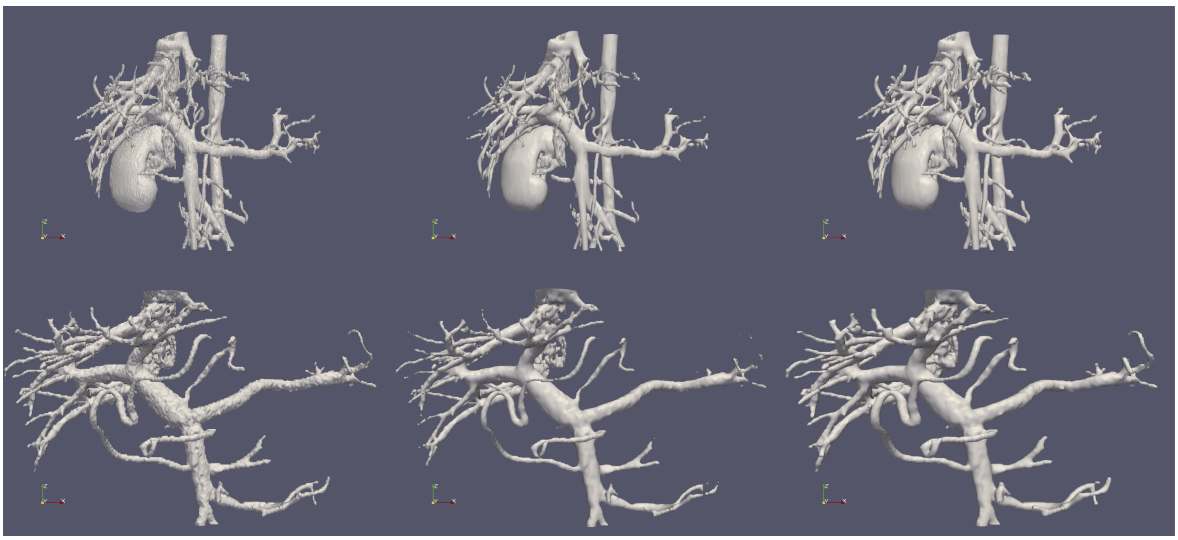

Figure 3: Comparison of the overall result of original, AAR and IAAR.