

3D Reconstruction of Abdominal Organs from 2D Slices

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Abstract

For medical diagnosis, visualization, and model-based therapy planning three-dimensional geometric reconstructions of individual anatomical structures are often indispensable. Since internal anatomical structures cannot be measured optically or mechanically in vivo, three-dimensional reconstruction of 2D image slices remains the method of choice. This calls for an effective volumetric image reconstruction method to find the correspondence among a sequence of 2D images and recover the 3D coherence that is lost in the sampling process. In this work, we reconstruct a 3D volumetric model of abdominal organs from 2D slices. A two step process is used to accomplish this (i) Segmentation of organ (ii) 3D volume reconstruction. Segmentation is done using seeded region growing. 3-D reconstruction is done with the help of a fast volume render application which uses OpenGL surfaces developed using MATLAB. 3D reconstruction helps in better quantitative evaluation on 3-D physical peculiarities of abdominal organs which can be very useful for better treatment planning.

Keywords: 3D reconstruction, segmentation, region growing, surface rendering, volume rendering

Introduction

Traditional visualization of the data by displaying 2D transverse images in a grid on screen or scrolling through the 2D slices of the volume by paging up and down is yet a reliable and accurate method in most cases. Even though this method is still the first choice of many radiologists in daily practice, it becomes more and more time consuming as the amount of data increases from 20-30 images per patient to several hundreds, and more recently up to 2000-3000 images (1-1.5GB) per patient[1]. Thus arises the need for 3D reconstruction.

Accurate 3D reconstruction from 2D data sets requires an accurate segmentation method for pathology zone detection and extraction. Usually, to perform the manual segmentation medical technicians need to sketch the contours slice by slice using pointing devices such as a mouse or a trackball. This procedure is very time-consuming and the results may suffer from intra- or inter-observer variability. In the past few decades, many algorithms have been proposed to perform the computer-aided segmentation. These methods usually involve complex programming and mathematics that researchers are not trained

to perform. Furthermore, these algorithms are designed to perform segmentation in a specific anatomical region and therefore are not easily extended to the segmentation of a different region due to their complex nature. Thus a simple but accurate method for segmentation is necessary.

3D visualization of the segmented region of interest is the second step of 3D reconstruction. It involves arranging the 2D slices with real spatial positions to produce the data volume. Rendering techniques are applied on the data volume to produce 3D image. Rendering is done by either using surface rendering or volume rendering. Surface rendering produces low quality images. Volume Rendering produces good quality images but it has a serious drawback of high computation cost and the difficulty in appreciating 3D relationships in very transparent volume-rendered images.

The goal of 3D image visualization is to formulate and realize concepts of an efficient architecture for productive use of medical image data. In this work we try to explain the concepts and methods of 3D reconstruction. In addition to this, a methodology is presented to perform 3D reconstruction of abdominal organs from 2D slices.

Methodology Used

The general principle of 3D reconstruction is composed of following steps

- Step 1: 2D data slices need to be read and arranged exactly with the real spatial positions, the result is a data volume. This data volume is saved in any memory of computer.
- Step 2: Use rendering techniques to visualize data volume as 3D image. Usual rendering techniques are Indirect Volume rendering or Surface rendering and Direct volume rendering.

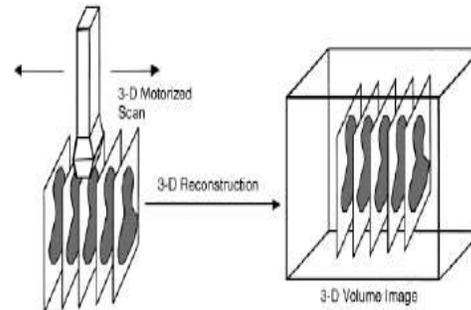


Figure 1a: Parallel Slices[2]

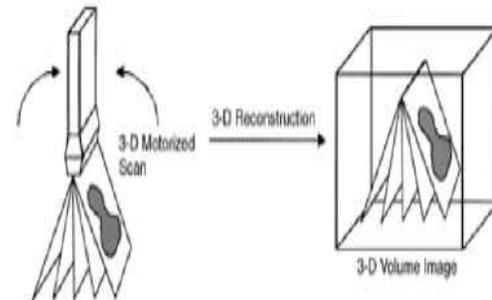


Figure 1b: Divergent Slices[2]

Thus we see that effective segmentation followed by efficient rendering of the segmented slices are the key steps in 3D reconstruction. The block diagram representation of the used methodology is shown in figure 2.

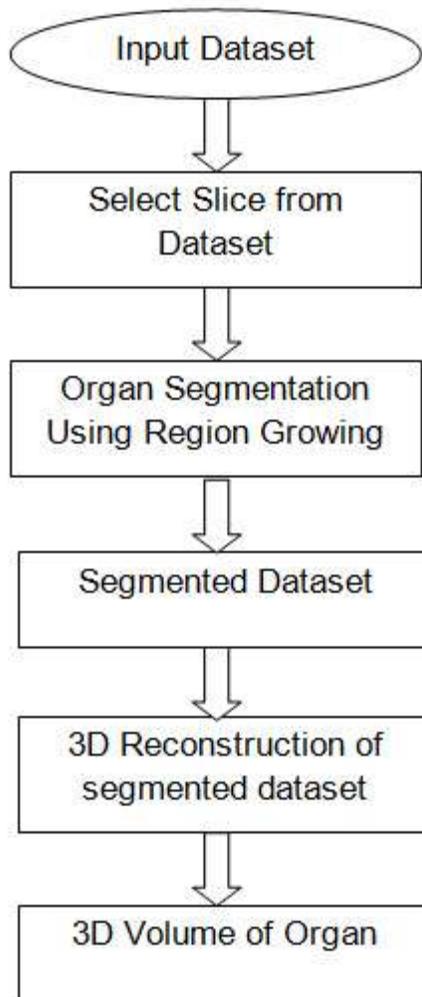


Figure 2: Steps involved in proposed methodology

In this work, seeded region growing (SRG) method is used to segment an organ from the clinically acquired abdominal CT and MRI images. Seeded region growing has characteristics like robustness, rapidness and is also free of tuning parameters which makes it suitable for large range of images. The general steps in SRG algorithm can be as follows:

1. Determine seed to start the segmentation process.
2. Determine the criteria to grow the region. In case of multiple regions, clearly the characteristic of regions should be

mentioned, so that no ambiguity exists to place the pixel in particular region.

3. The candidate pixels to include in the region, it should be 8-connected to at least one of the pixel in the region.

4. Cross-check is to be done to ensure all the pixels are tested for allocation and then label has to be given to all regions.

The characteristics that considered for the test of homogeneity of the region are gray level, intensity, shape etc.

3D Volume Reconstruction

The final step in proposed methodology is 3-D volume construction from 2-D images. This is primarily used for visualization and quantization of abdominal organs. Volume construction reduces inter observer variability. The method used is a fast volume render application which uses OpenGL surfaces. OpenGL is the premier environment for developing portable, interactive 2D and 3D graphics applications. It is simple, multiplatform, stable and reliable and gives high visual quality and performance.

The 3D Volume Rendering program is developed in MATLAB. The input to the code is a volume data that is created from the segmented slices. The input volume data is arranged to form a stack volume. Surface of the stack volume is created with the help of OpenGL.

Experimental Results

The proposed method is applied on two types of dataset (i)MR slices of abdomen (ii)CT slices of abdomen. Figure 3 shows the result of segmenting kidney from various MRI slices of abdomen. The 3D volume visualization of the segmented kidney, from different angles, is shown in figure 4.

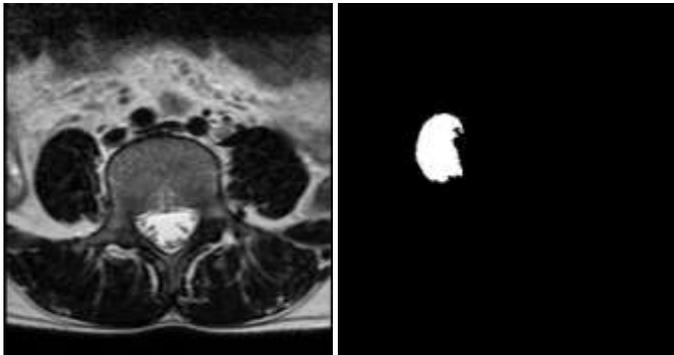


Figure 3(a): Input Slice Figure 3(b): Mask

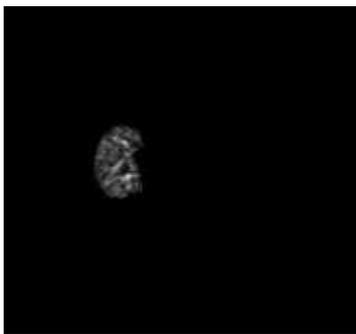


Figure 3(c): Kidney



Figure 4.2: Different views of 3D reconstructed Kidney

Figure 5 shows the result of segmenting liver from various CT slices of abdomen. The 3D volume visualization of the segmented liver, from different angles, is shown in figure 6.

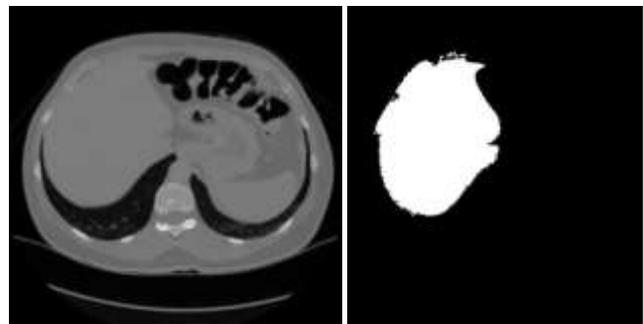


Figure 5(a): Input Slices Figure 5(b): Mask

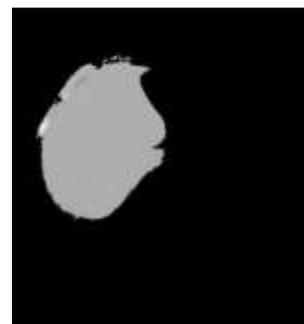
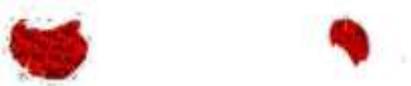


Figure 5(c): Liver



Future Scope

In future work this semiautomatic method can be improved by making it fully automatic to avoid user interaction. Furthermore, slices across a single plane are used for reconstruction. So only the top and bottom surface of the organ are constructed properly. Slices from frontal, sagittal and transverse planes can be used together to construct all the surfaces accurately. Therefore the future research work can be focused on the improvement of smoothness of model.

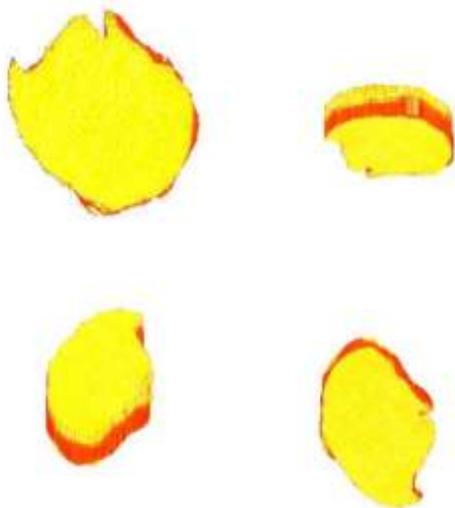


Figure 6: Different views of 3D reconstructed Liver

Discussion and Conclusion

A methodology is designed in the proposed work to construct 3-D volume of abdominal organs from MRI and CT images. It focuses on the two major steps of 3D reconstruction namely segmentation and 3D visualization. Segmentation is a fundamental preprocessing step for accurate volume construction. An effective segmentation technique is proposed and efforts are made to overcome the major challenge of determination of correspondence between segmented slices. The quality of reconstruction, completeness and accuracy are main aspects which are considered. The technique developed for 3D reconstruction should produce comparable results for both MRI and CT images unlike other techniques which produce better results for CT.

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