A Framework for Volume Segmentation and Visualization Using Augmented Reality

Takehiro Tawara*
RIKEN

Kenji Ono†
RIKEN

ABSTRACT

We propose a two-handed direct manipulation system to achieve complex volume segmentation of CT/MRI data in Augmented Reality with a remote controller attached to a motion tracking cube. At the same time segmented data is displayed by direct volume rendering using a programmable GPU. Our system achieves visualization of real time modification of volume data with complex shading including transparency control by changing transfer functions, displaying any cross section, and rendering multi materials using a local illumination model.

Our goal is to build a system that facilitates direct manipulation of volumetric CT/MRI data for segmentation in Augmented Reality. Volume segmentation is a challenging problem and segmented data has an important role for visualization and analysis.

Index Terms: K.5.1 [Information Interfaces and Presentation]: Multimedia Information Systems—Artificial, augmented, and virtual realities; K.5.2 [Information Interfaces and Presentation]: User Interfaces—Interaction styles; I.3.6 [Computer Graphics]: Methodology and Techniques—Interaction techniques

1 INTRODUCTION

Volume segmentation is a challenging problem, and it includes many individually difficult problems: scanning, filtering for noise removal and enhancement, and edge detection. Segmentation is followed by visualization and analysis.

Although many algorithms to automatically extract shapes have been proposed for 2D and 3D datasets [3], existing methods tend to depend only on geometrical features. Moreover existing automatic methods control extraction by parameters, and such parameters often affect extraction globally. Thus, even for users that are familiar with the algorithm, it is difficult to predict the final shape to be extracted. However the user's decision becomes more important for ambiguous input data which is common for scanned data. Moreover the user may want to perform semantic segmentation as shown in Figure 1, which shows a functional map of a human brain and doesn't depend on geometric features. Our system allows the user to control shape extraction with intuitive manners.

To achieve this goal, we propose a framework for volume segmentation and visualization using Augmented Reality. Augmented Reality superposes virtual objects on a display with a correct perspective as if they placed in the real world [2]. We develop a two-handed direct manipulation to perform complex segmentation in Augmented Reality with a remote controller attached to a motion tracking cube shown in Figure 3. We exploit Augmented Reality to track the motion of our controller and visualize real time modification of volume data on the user's hand.

Although similar concepts for a two-handed manipulation [1] and segmentation with the haptic device [4] have been proposed, our system can be built by very reasonable, common devices such as a web camera and a wii remote controller.

*e-mail: takehirotwr@riken.jp
†e-mail: keno@riken.jp

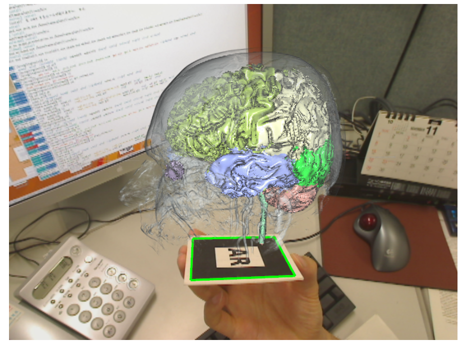

Figure 1: An example of segmentation of a human head. The user can easily extract parts of a human head by the guide of geometric features: cerebrum, cerebellum, spinal cord, and eyes. The cerebrum is further segmented to smaller parts per functionality of a human brain by the user's decision: frontal lobe, parietal lobe, occipital lobe, and temporal lobe. Such semantic segmentation without depending on geometric features can be achieved by an interactive system as we have proposed.

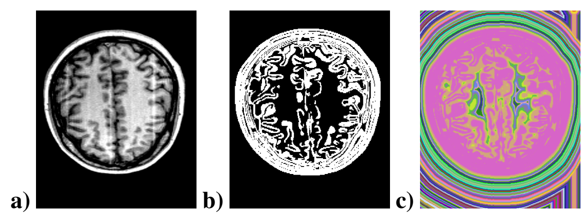

Figure 2: The cross section of a MRI volume data in the pre-process: **a)** input, **b)** binary, and **c)** the distance function visualized by pseudo colors.

2 OUR FRAMEWORK

Our system is composed of pre-processing, locating a seed point, and growing a region. In the pre-process, input volume data is filtered, amplified, and binarized by the magnitude of gradients of the data. Then a distance function is generated from the binary data. Figure 2 visualizes the cross sections of a MRI volume data in the pre-process. The next, the user puts a seed point at the tip of the virtual needle indicated by the controller in the region which the user wants to extract. Then the user can grow the region with the guide of the distance function mentioned above. We locally limit the expansion of a boundary surface by changing a speed function depending on the distance from the tip of the virtual needle. By using this technique, the user can freely expand regions to extract desired shapes. The combination of existing marker based motion tracking and region growing guided by geometrical features makes a success of intuitive and precise volume segmentation.

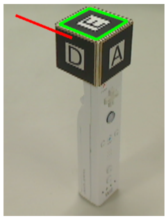

Figure 3: Our manipulator; a motion tracking cube is attached at the top of a wii remote controller. The virtual needle is drawn in the red line. The tip of the virtual needle is defined as the relative position from one of markers. The detected marker is shown as the green square.

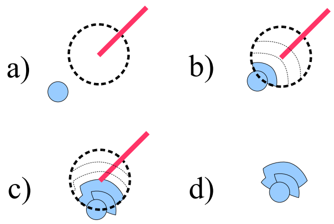

Figure 4: The procedure of expansion: **a)** no expansion, **b)** and **c)** expansion, and **d)** the final shape to be extracted. The red line represents a virtual needle, and the dotted circle at the end of the line depicts an effective area of expansion.

2.1 Region Growing

There are several efficient region growing techniques including the fast marching method and the level set method [3]. Such methods define a speed function F which represents the evolution of a boundary surface. However our motivation is to give the user the control of expansion. So we want to locally modify the extracting shape. Therefore we limit the effective area of expansion by indicating using our controller.

Once a seed point locates in the 3D space, the region is growing from that point. The boundary surface in an effective region centered at the tip of the virtual needle gradually extends toward outside. The user can easily expect the next step of an extending shape, and stop or continue growing until the user satisfies.

Figure 4 illustrates the procedure. In Figure 4a, a seed point and an effective area don't overlap at all. Therefore no expansion performs. In Figure 4b, the part of an effective area overlaps to a seed point. In the region inside an effective area, the boundary surface expands toward the normal direction in a fraction of time $\triangle t$.

During regions are overlapping, a boundary surface will expand until the whole area of the effective sphere will fill up. Of course, the user can freely move the controller during expansion, resulting complex shape extraction as shown in Figure 4c. Figure 4d shows the final shape of extraction.

During expansion, there are two restrictions: only the boundary with a selected material ID will expand. Thus, the user can expand only one region at a time. Another restriction is the voxel to be filled must be far enough from the wall. The distance of the voxel from the nearest wall is retrieved from the distance field generated in the pre-process. When the distance is more equal than one, the boundary surface can be expanded. We consider six neighbors of the boundary voxel for expansion.

3 Results

Using our system, the user can freely extract volumetric shapes such as left and right cerebrums, cerebellums, corpus callosums, medulla and eyes with visualization of a MRI head data on a desktop through a HMD mounted a USB camera. Each part of a MRI head data can be extracted in a few seconds to a minutes in real time using Geforce 8800GTX class GPU. Figure 5 shows the image sequence of the real time demonstration of extraction.

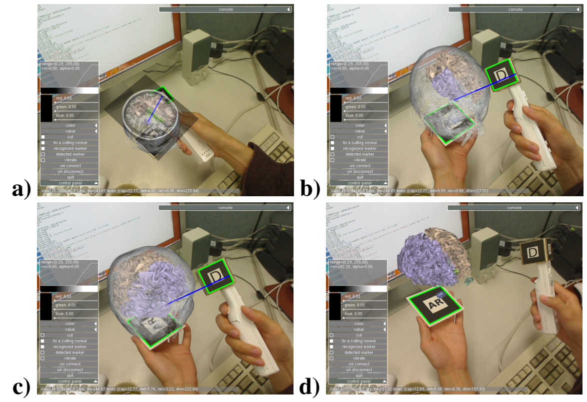

Figure 5: The image sequence of volume segmentation. The image **a)** shows locating a seed point. The following images represent the extraction of the right brain colored by purple.

We implemented a very basic region growing algorithm, which doesn't take into account smoothness of extracting shape and leaking during operations. Such problems are well studied in automatic segmentation algorithms, and we could introduce such sophisticated algorithms in our system. However, our main focus of this paper is user's intervention for 3D volume segmentation.

4 Conclusion and Future Work

Although many automatic volume segmentation algorithms have been proposed, such algorithms suffer from the try–and–error approach to find the best parameter for desired shape extraction. We proposed an intuitive volume segmentation framework which gives the user a great controllability. As shown in Figure 1, such semantic segmentation can be handled by only user's interaction. Moreover, our system can be built with very reasonable prices to handle complex volume segmentation exploiting a marker based motion tracking technique [2] and a wii remote controller.

We will include more sophisticated region growing algorithms in future. More robust motion tracking algorithms and devices are also worth to investigate. Additionally, more case studies help to confirm the effectiveness of our framework.

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