

3D Segmentation for High-Resolution Image Datasets Using a Commercial Editing Tool in the IoT Environment

Koojoo Kwon* and Byeong-Seok Shin*

Abstract

A variety of medical service applications in the field of the Internet of Things (IoT) are being studied. Segmentation is important to identify meaningful regions in images and is also required in 3D images. Previous methods have been based on gray value and shape. The Visible Korean dataset consists of serially sectioned high-resolution color images. Unlike computed tomography or magnetic resonance images, automatic segmentation of color images is difficult because detecting an object's boundaries in colored images is very difficult compared to grayscale images. Therefore, skilled anatomists usually segment color images manually or semi-automatically. We present an out-of-core 3D segmentation method for large-scale image datasets. Our method can segment significant regions in the coronal and sagittal planes, as well as the axial plane, to produce a 3D image. Our system verifies the result interactively with a multi-planar reconstruction view and a 3D view. Our system can be used to train unskilled anatomists and medical students. It is also possible for a skilled anatomist to segment an image remotely since it is difficult to transfer such large amounts of data.

Keywords

Segmentation, Large-Scale Image, Photo Editing, Visible Korean, Volume Rendering

1. Introduction

Diagnostic visualization is a useful research area in medicine that provides greatly increased knowledge of normal and diseased anatomy for medical research [1,2]. The increasing size and number of medical images requires the use of a computer to facilitate processing and analysis. Computer algorithms that can be used describe anatomic structures and other regions of interest are increasingly important to assist with and automate specific radiation tasks.

During the last few decades, we could only imagine 3D biological structures by using 2D images and illustrations. In recent years, we have seen the development of numerous systems that provide digital anatomic resources to enhance the teaching of, and learning about, human anatomy, such as the Visible Human (VH) project [3-5], Chinese Visible Human (CVH) [6,7] and Visible Korean (VK) [8]. Segmentation methods are important for identifying meaningful regions in these digital resources.

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Corresponding Author: Byeong-Seok Shin (bsshin@inha.ac.kr)

* Dept. of Computer Engineering, Inha University, Incheon, Korea (mysofs@naver.com, bsshin@inha.ac.kr)

Research into segmentation of computed tomography (CT) and magnetic resonance (MR) images is a challenging area, and to date, there are no fully automated methods. Segmentation techniques developed for grayscale images are inadequate for color images [9]. In CT and MR imaging, because an anatomic structure has the same or a similar physical property, we can identify regions using scalar values. Therefore, in general, color images are segmented by skilled anatomists. For this reason, manual and semiautomatic methods are used to segment color images. In addition, the results of segmentation may not be accurate since segmentation is only performed on the axial plane. Additionally, there are some inconveniences in verifying the results of segmentation using 3D images interactively. In this paper, we present a 3D segmentation assistant tool for large-scale high-resolution color images. An image data management system between main memory and the hard disk to handle the huge amounts of image data is devised. In the rendering step, a subsampled volume data is used. In the segmentation, however, the original-resolution color images are used. We interactively compute the indices between volume data and color images. We verify the correctness of segmented images using multi-planar reconstruction (MPR) and 3D rendering features while performing segmentation.

In Section 2, we briefly introduce segmentation of color image data. Our segmentation assistant tool is described in detail in Section 3. Some results are shown in Section 4. Lastly, we summarize and conclude our work.

2. Segmentation of Color Images

The VK dataset is designed to serve as a common reference for the study of Korean anatomy. It is a set of common public-domain data that can be used to help with medical imaging. The VK dataset is currently being compiled according to the following steps. Color images from inside a real human body are stored in a personal computer to generate anatomic images. The anatomic structures of these color images are segmented. These types of anatomic images will help to create more accurate and realistic 3D rendered images. Furthermore, these anatomic images, created with thin intervals and a small pixel size (0.2 mm), will be able to show small anatomic structures. The additionally segmented images can help to easily generate 3D images.

The detection of an object's boundary is very difficult in a color anatomic image in comparison to a grayscale image because the color image contains multiple scalar values. Therefore, we segment organs using a color value or shape in the pre-processing stage. To segment organ areas in a color image, we use a segmentation algorithm after converting the color image to a grayscale image or separating it into several color channels. However, a skillful anatomist is required for accurate segmentation because the human anatomic structure is very complicated.



Fig. 1. VK heart images. A segmented image represented in the coronal plane (left), a rendering of a geometric model (center), and a 3D volume rendering image (right); some irregularities in a segmented image can cause bumpy geometric models and volume rendered images.

Image segmentation is defined as partitioning an image into non-overlapping constituent regions that are homogeneous with respect to certain characteristics. Some segmentation methods for 2D and 3D space, such as region-growing [10-12], thresholding [13,14] and deformable-surface [15,16] methods, are also presented. However, these methods are not suitable for color anatomic 3D volumes because these color volume are large in size and consist of complex color values. Only an expert with anatomic knowledge can find and segment organs in a color image. However, these types of manual segmentation methods have problems. Fig. 1 shows a problem in VK heart images. When we generate the geometric model (middle) and 3D volume rendered image (right) using a segmented image, we can observe blocky and irregular surfaces. Since manual segmentation is based only on the axial plane, it does not guarantee accuracy in the coronal and sagittal planes.

3. Out-of-Core Segmentation System

3.1 Volume Rendering for Color Anatomic Images

Visualization of a realistic color image using the volume rendering method is difficult because the volume dataset is composed of scalar values, such as the density and temperature of materials. If we want to distinguish a special material from the entire object, we use a pseudo-color that is mapped into scalar values using a color transfer function.

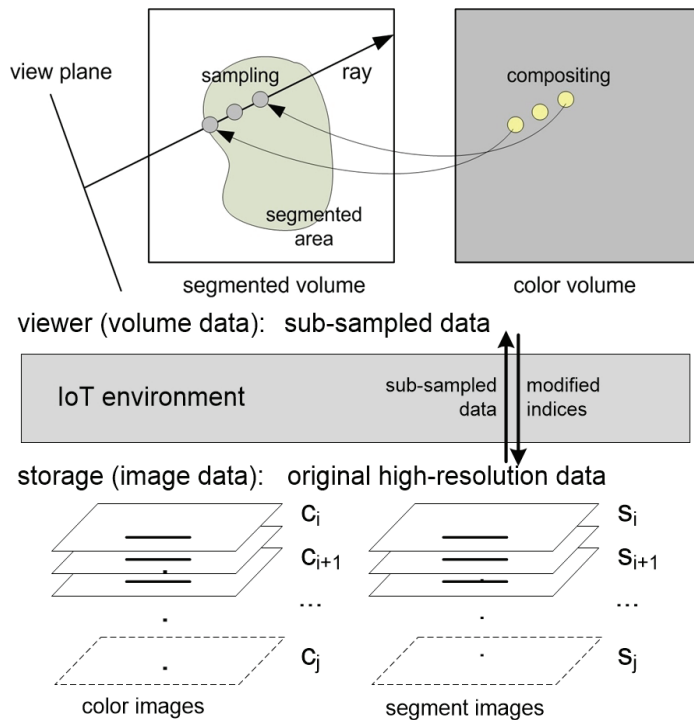


Fig. 2. Color volume data visualization method using segmented volume data (viewer), and storage of the original high-resolution images.

During volume rendering of color volume data, detection of an object's boundary is very difficult in comparison to grayscale volume data, which contains scalar values. Therefore, we segment organs using the color value or shape in the pre-processing stage. After segmentation, we calculate and composite the color values during the ray casting stage using both color and segmented volume datasets in the viewer.

The volume data can be updated when we manage the original high-resolution images by transferring the indices of the modified region (see Fig. 2). We can use a change volume with a small amount of information transfer.

3.2 A 3D Segmentation Assistant Tool for Color Anatomic Images

Dimensionality means that the segmentation method is performed in the 2D image domain or in the 3D image domain. However, some methods, such as the deformable model, Markov random field, and area expansion, incorporate spatial information, which can work differently depending on the dimensions of the image. The 2D image-based method is applied to 2D images and 3D image-based method is applied to 3D images. In some methods, the 2D method is applied sequentially to slices of 3D images for practical reasons, such as ease of implementation. Since the VK data have a large number of high-resolution images, they can only be stored in terabytes (TB). Therefore, we can only segment the 2D image domain. To reduce the size, data can be segmented in a 3D domain with a sub-sampled volume. However, the resolution of the segmented result is too low.

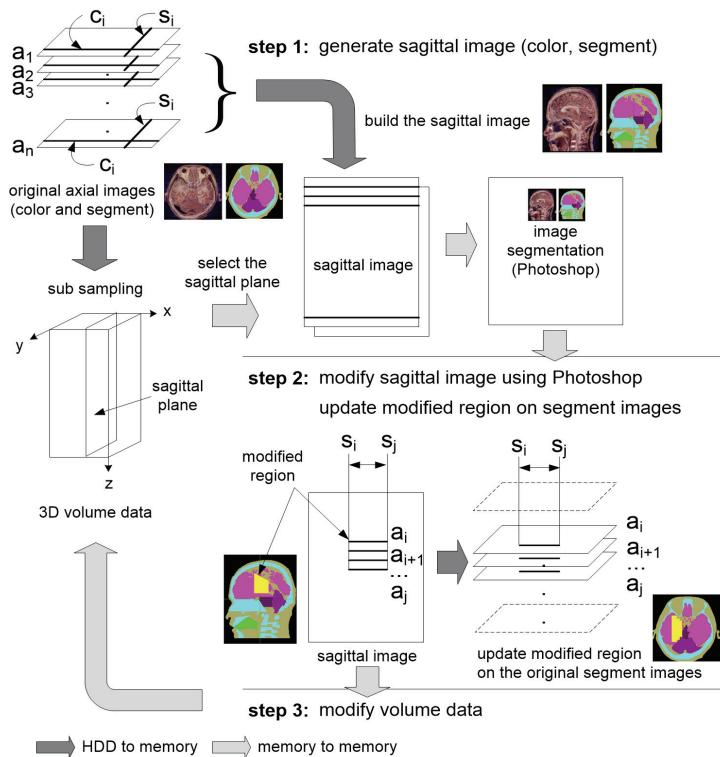


Fig. 3. An example of modifying a sagittal image with our scheme. The sagittal (coronal) image is reconstructed from axial images on the fly. A user modifies a region on the sagittal image. Our system searches for the indices of the influenced axial images and applies the changes to them.

We present two types of 3D viewing methods in our system: multi-planar reconstruction and volume rendering. A user can perform segmentation on a color image and check the results in three MPR views. Additionally, we can verify the 3D shape of an organ using volume rendering. The system provides several viewing methods, such as rotation by free angle, zooming, and dragging, which helps to verify the correctness of the segmentation.

Our system is performed in the following three steps:

- (1) The selected coronal or sagittal image (both color and segment images) are passed to Adobe Photoshop using the object linking and embedding (OLE) automation feature.
- (2) The user modifies erroneous regions with Photoshop and applies them to the original segmented images stored on the hard disk.
- (3) The volume data are also modified by reflecting new segmented images.

Volume rendering methods exploit sub-sampled volume data from the original data since the system memory is too small to accommodate the original data. We use the sub-sampled volume data when we make a 3D rendered image and MPR images. We use the original color and segmented images during segmentation. In this case, we have to know the relationship between the volume data and original images in storage.

Fig. 3 shows an example of manipulating a sagittal image with our image data management method. Assume that a user selects the sagittal image (s_i) in a volume dataset; our system constructs full-resolution sagittal images (color and segmented images) by gathering the pixel values indexed by the s_i scan lines in all of the axial images. Then, the sagittal color image and segmented image are sent to Photoshop, and the user modifies them with a couple of segmentation features. After modification, we obtain all of the indices of the influenced region, s_i-s_j and a_i-a_j , as shown Fig. 3. Finally, the axial images between a_i and a_j are changed by the sagittal lines s_i-s_j . The volume data are also changed by the newly segmented images, and the 3D rendering image is refreshed by the changed volume data. This procedure works interactively. We can segment color images on the coronal and sagittal planes using our system.

4. Experimental Results

Our system was implemented on a personal computer equipped with an Intel Core i7 Processor (3.6 GHz) and 8 GB of main memory. The volume datasets are from the VK (see Table 1). We can manipulate and modify the axial, coronal, and sagittal segment images.

Table 1. Features of the color and segmented images of the VK whole body and head dataset

Data	Interval (mm)	# of slices	Resolution	Bit depth (bits)	Size (GB)
Whole body color images	0.2	8,508	2468×1407	24	88.7
Whole body segment images	0.2	8,508	2468×1407	8	29.5
Whole body color volume	1.0	1,702	494×282	24	0.72
Whole body segment volume	1.0	1,702	494×282	8	0.24
Head color images	0.2	790	1080×1110	24	2.8
Head segment images	0.2	790	1080×1110	8	0.95
Head color volume	1.0	158	216×222	24	0.02
Head segment volume	1.0	158	216×222	8	0.008

Fig. 4 depicts the images resulting from our system. Fig. 4(a) is anatomical image from the sagittal view near the ear. The segmented image (Fig. 4(b)) shows horizontal stripes on the skull and in the brain, since it is segmented only on the axial plane. Fig. 4(c) shows the revised image resulting from our system. The regions of the skull and brain in the right-hand image represent the organ more smoothly than the middle image.

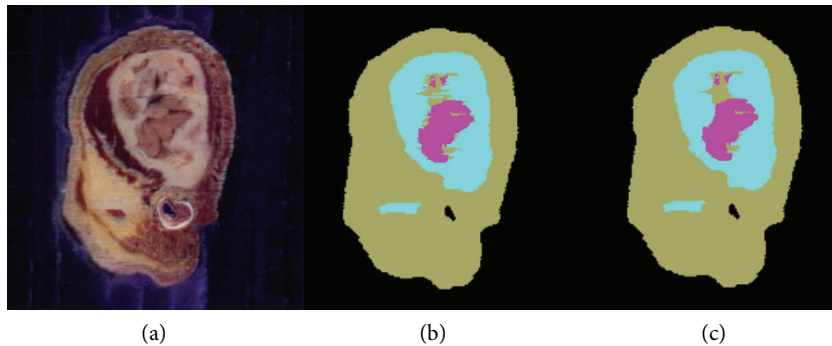


Fig. 4. Color and segmented images in sagittal view. A color image (a), sagittal image using manually segmented axial plane (b), and sagittal image produced by our system (c).

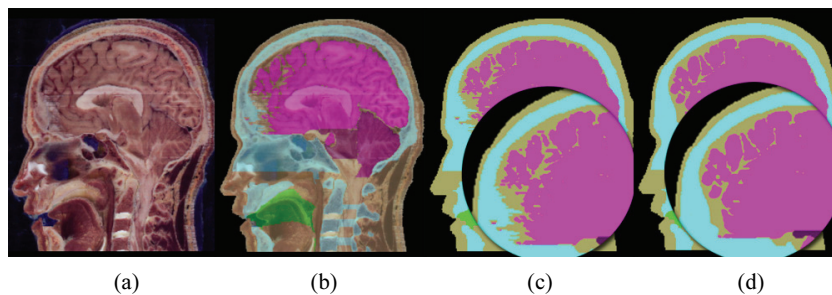


Fig. 5. The resulting images from a sagittal slice in our system. From left to right, a color image (a), semi-transparent segment image over the color image (b), segment image before applying our method (c), and segment image applying our method (d).

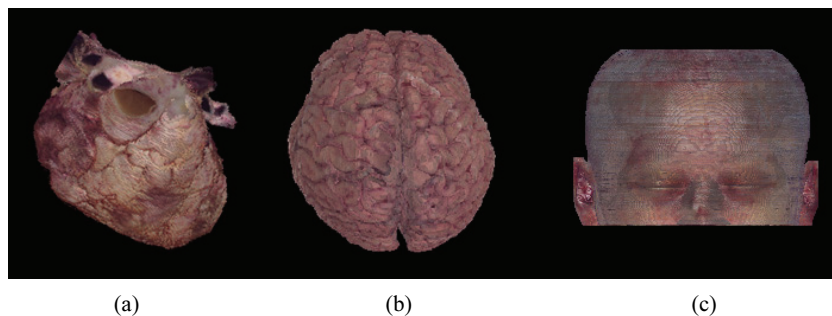


Fig. 6. A 3D rendering image from our system: heart (a), brain (b), and head (c).

Fig. 5 shows sagittal images using the VK head dataset. We find the mismatched region in the circle on the third image; we can adjust the sagittal image as shown in the circle on the fourth image. Using our method, a user segments the three-dimensional full-scale color image. Our system works interactively since the result of segmentation is immediately reflected in the 3D rendered image, and the resulting image from our segmentation method is more accurate since our method is executed on three planes (axial, coronal, and sagittal).

Fig. 6 shows 3D rendered images of VK organs, including the heart, brain and head. We can verify that the shape of each organ is rendered clearly since the boundary of the organ is segmented properly.

The average execution time for segmentation of the coronal and sagittal planes is approximately two minutes when we use the VK head dataset. When we render organs using segmented images, the average rendering speed is more than 60 fps and the size of the view plane is 800×600 . In the school of medicine at Ajou University, anatomists and medical students use our system for their research, and most of them are satisfied with the results from our method.

5. Conclusion

A 2D segmentation is a conventional method that is used by anatomists to classify an organ on medical images. 3D segmentation provides more accurate results, but it is difficult to interactively verify the segmentation result. We propose a segmentation assistant tool for large-scale high-resolution 3D color images. We segment images on the axial, coronal, and sagittal planes in three directions. Our system interactively verifies the results of segmentation with MPR and 3D volume rendering views. Using our system, the structure of an organ can be segmented more accurately via 2D image segmentation methods. The accurate structure of an organ can be important in clinical practice. We can help unskilled medical students practice organ segmentation on color images. Additionally, our system can be used by skilled anatomists to segment images remotely since it is difficult to transfer such large amounts of data.

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Koojoo Kwon <http://orcid.org/0000-0002-2467-5809>

He is a research professor in Inha University, Korea. His research interests include medical imaging and hardware-based rendering. He received B.S. degree in Computer Science & Engineering from Woosuk University. He received M.S. and Ph.D. degrees in Computer Science & Engineering from Inha University.



Byeong-Seok Shin <http://orcid.org/0000-0001-7742-4846>

He is a professor in the School of Computer Engineering, Inha University, Korea. Current research interests include volume rendering, real-time graphics, virtual reality, and medical imaging. He received his B.S., M.S., and Ph.D. in Computer Engineering from Seoul National University, Korea.