Segmentation and Volume Rendering of Human Brain Cryosections

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Abstract

1. Introduction

As datasets become larger and more detailed, they can no longer be segmented exclusively by interactive methods or by hand. Real-color RGB images, such as cryosections, contain much more information than CT or MRI data: the resolution is usually higher (150-500 dpi as opposed to 25 dpi, leading to a data volume increase of 20^3=8,000), and the color information provides some additional cues. Therefore, we propose an automated segmentation pipeline, which allows us to apply different filters and image processing algorithms to separate the tissue from the surrounding material. The images can be rendered interactively at very high quality.

2. Human Brain Data Set

The Human Brain Data Set (courtesy of Art Toga, Ahmanson-Lovelace Brain Mapping Center, UCLA) has a resolution of 1472 x 1152 and consists of 753 cryosections. The data set provides real-color RGB information, 16 bits per channel. Due to the nature of the cutting technique used for image generation, the data are different from conventional CT or MRI data. Cavities or gaps in the brain reveal structures that are actually located in "deeper" layers. These parts of the image need to be eliminated and replaced by a transparent region. Also, the brain must be separated from the surrounding matter, i.e., from the ice and the background (figure 1). We have been working on segmenting the images to construct a "cleaned" 3D volume data set.

3. Segmentation

3.1 Exploring Color Cues

The brain can be easily distinguished from the ice and the background by using color information. By using a different color model, such as RGB, HLS, HSV, grayscale, and YIQ, we can make use of the fact that the red and light brown components are much more dominant in the brain than in the rest of the picture. We have found that the YIQ color model works best for selecting this brown color (the I component detects both the red component and the intensity).

Figure 2(a) shows a result image (slice #100). The brain has been nicely segemented. However, the image still shows holes inside the brain and some noise around the brain. To fill these holes, to smooth the contour and to remove the noise, we apply filtering after YIQ thresholding.

3.2 Filtering

In figure 3, the rectangles show the filters that were used to fill the holes and smooth the contour, and the ovals show the filters used to remove the noise.

The result of this process is shown in figures 2(b)-(e). Each process shows some progress, but after using a dilation filter, some of the ice appears again close to the contours. An RGB color threshold was used to remove these artefacts.

The segmentation pipeline consists of these steps:

(1) Median filter (5 x 5 window, remove holes, smooth contours);

(2) Region growing (8 directions, check for background pixels, remove noise if below size threshold);

(3) 2D morphology (9 x 9 window, dilation);

(4) RGB thresholding (removal of iced area); and

(5) 3D morphology (9 x 9 x 9 window, erosion).

Some algorithms require several thresholds (YIQ: 3, region growing: 6), because the structure of the image changes across the dataset. However, it is much easier to select a set of thresholds than to segment the entire data set by hand.

4. Volume Rendering

The segmented images are volume rendered in hardware using three sets of textures, each set aligned to one of the principle axes. With a Pentium III 550 Mhz and a 32M Nvidia GeForce™ video card, a downsampled 128^3 volume fits in texture memory and can be rendered at over 15 fps. A 256^3 volume does not fit in texture memory and can be rendered at approximately 2 fps. The user can interactively rotate the volume, and apply multiple axis aligned cutting planes to quickly visualize specific regions of the brain (figure 4).

5. Conclusion

The presented segmentation pipeline allows us to segment a large-scale data set semi-automatically with minimal user intervention. The parameters must be chosen carefully in order to obtain optimal results. Future research will focus on automated image analysis to determine segmentation parameters automatically. We are currently implementing analysis techniques based on image coherence within a slice and between adjacent slices. The quality of the rendered images is much better than the one obtained by using a conventional transfer function.

(See color plate for original, filtered, and rendered images.)

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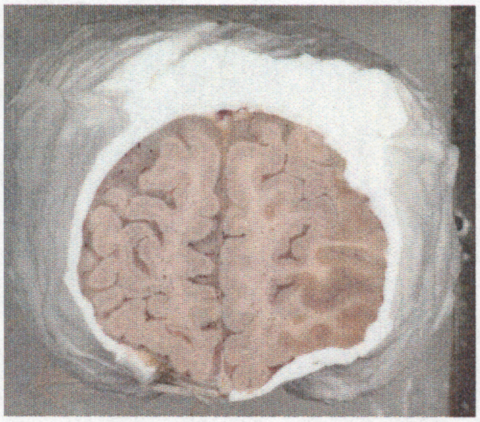

Figure 1: Original image

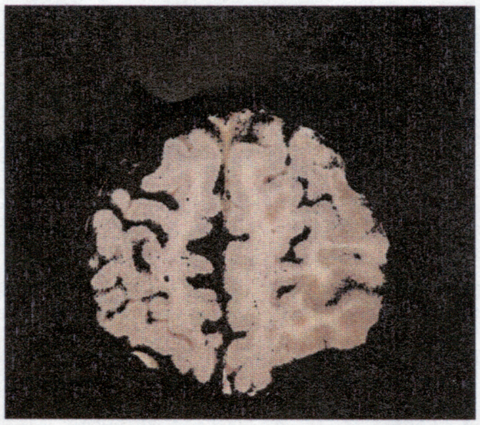

Figure 2(a): YIQ thresholding

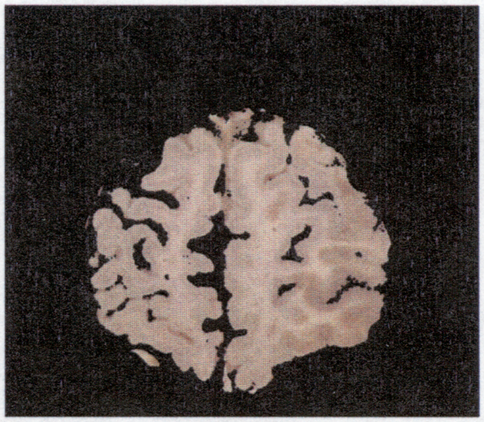

Figure 2(b): Median filter

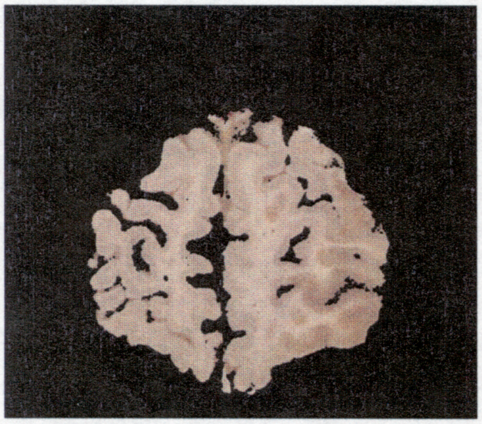

Figure 2(c): Region growing

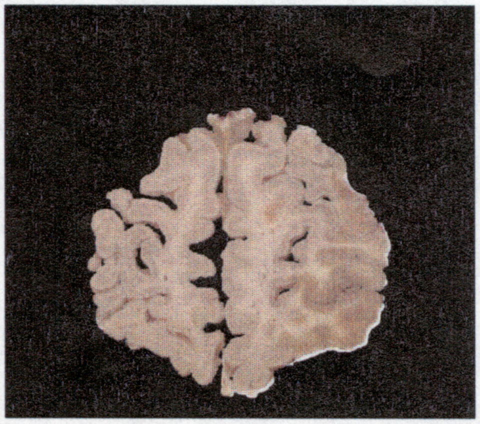

Figure 2(d): 2D morphology (dilation)

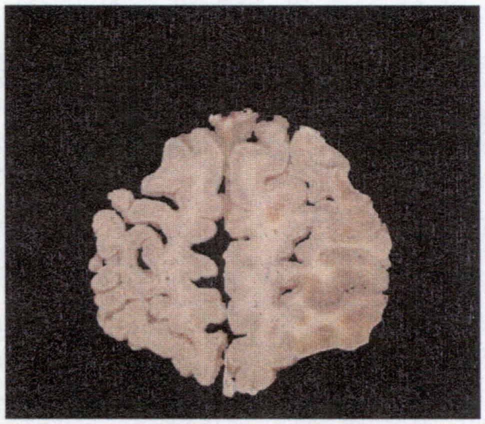

Figure 2(e): RGB thresholding

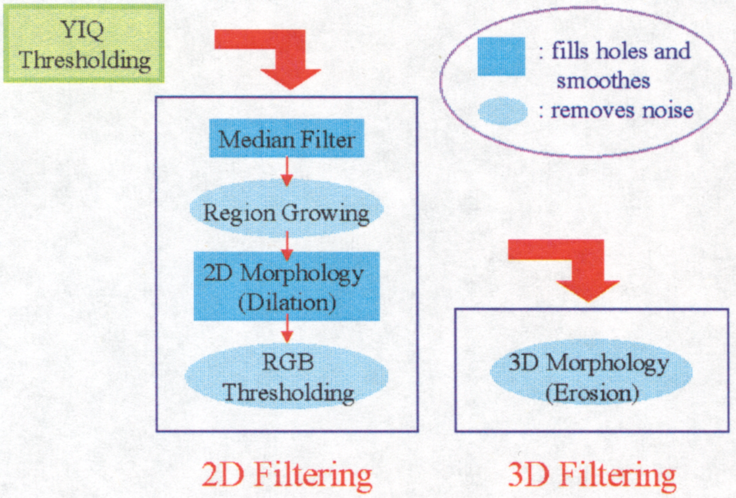

Figure 3: 2D/3D filtering

Figure 4: Volume rendering