Haptics-Assisted 3D Lasso Drawing for Tracts-of-interest Selection in DTI Visualization

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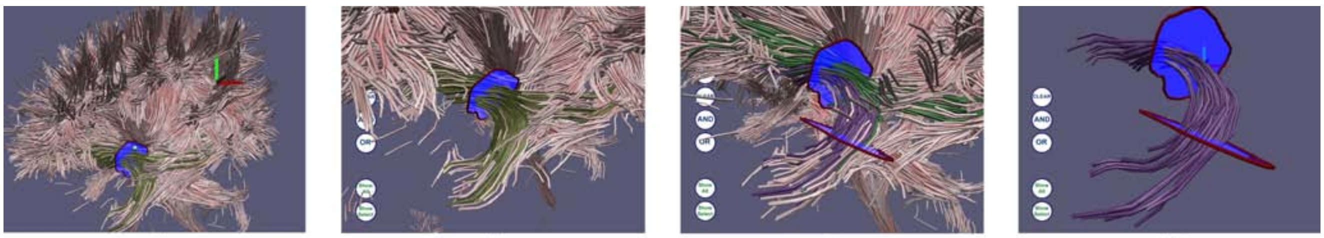

(a) (b) (c) (d)

Figure 1: Our interface selecting the uncinate fasciculus (UF) using 3D lasso: the user places two lassos around the UF and singles out the structure with an AND operation. The final result is shown in purple.

ABSTRACT

We present a new haptics-assisted 3D lasso drawing interface for selecting tracts-of-interest (TOI) in diffusion tensor imaging (DTI) in fishtank virtual reality (VR). This interface brings TOI selection tasks into 3D stereo VR with higher-input bandwidth devices. In the system, the 6D input Phantom device lets the user make selections by drawing a smooth 3D lasso with haptics constraint assistance directly in the 3D space. The hand tracker lets the user use hand gestures to rotate and zoom the model. Users also reported that making selections by drawing 3D lassos is easy, as it resembles pointing out structures to a collaborator with their fingers but has higher precision. Users also remarked that VR helped them appreciate the three-dimensional structure of the fiber tracts more easily, and they gained more confidence in identifying the structures and the area they project in the brain. Working in the VR environment reduces the navigation time of the TOI selection task, a key challenge in TOI selection tools. Users were able to segment out tortuous structures that are often time-consuming to select using traditional rigidly shaped volume-of-interest (VOI) fiber pathway selection tools.

Index Terms: J.3 [LIFE AND MEDICAL SCIENCES]: Medical information systems—; I.3.8 [COMPUTER GRAPHICS]: Applications—

1 INTRODUCTION

Diffusion tensor imaging (DTI) is a magnetic resonance (MR) imaging technique that makes possible the non-invasive exploration of fibrous white matter (WM) structures within the human brain. Understanding the WM structure is crucial for studying such diseases as HIV, Alzheimer's disease, and brain tumors. Current DTI visualization and analysis have focused on rendering fiber tracts and segmentation of WM trajectories into anatomically meaningful bundles [8]. The densely sampled fiber tracts representing WM structures tend to be visually cluttered, making it difficult for brain scientists to understand the data. Automatic segmentation methods impose a rigid, possibly inaccurate model of which WM pathways belong to which bundles. Instead, enabling brain scientists to interact with the visualization models and manually perform segmentation by selecting TOI is an important interaction on which many published clinical research studies using DTI tractography, such as [4], have relied.

Most interfaces for selecting TOI interactively depend on devices such as mice and pens, which offer only two degrees of freedom for manipulation of 3D VOI, and they also use standard 2D monitor screens to display the 3D structure of the brain. Brain scientists have noted that they must constantly rotate the brain model in order to retain their mental picture of the 3D structure presented on the 2D screen. The extensive navigation time is also a key drawback in the current TOI selection tools. Here we present a new haptics-assisted interface that uses a 3D lasso for selecting TOI in 3D stereo VR.

2 RELATED WORK

Segmentation and clustering of WM pathways by interactively selecting TOI has become a popular way for brain scientists to test their hypotheses of WM connectivity and functionality, and a number of tools have been developed for interactively assembling TOI into anatomically meaningful fiber bundles. Sherbondy et al. [7] [2] defined volume-of-interest to let users interactively group WM pathways going through these regions. Blaas et al. [3] presented a real-time fiber bundle selection system based on multiple convex selection objects. However, in these methods, the shape of the volume the user can define is rather limited, making selection cumbersome due to the curved and complex nature of WM pathways. CINCH, a 2D marking interface for selecting 3D TOI, has been developed recently [1] to alleviate the difficulties involved in selecting complex 3D structures using only commodity input devices, which offer only two degrees of freedom. However, CINCH users still find navigating and locating the desired WM structure undesirably time-consuming. It is also reported that selection using 2D plane intersection, as in CINCH, requires extensive neurological knowledge because the user loses the 3D context while working in the 2D space.

Here we describe a new haptics-assisted 3D lasso-drawing interface for selecting TOI in DTI. Our system brings TOI selection tasks into 3D fishtank VR with higher-input-bandwidth devices. Our system greatly reduced navigation time in the TOI selection task and enabled users to identify the WM structures in the brain

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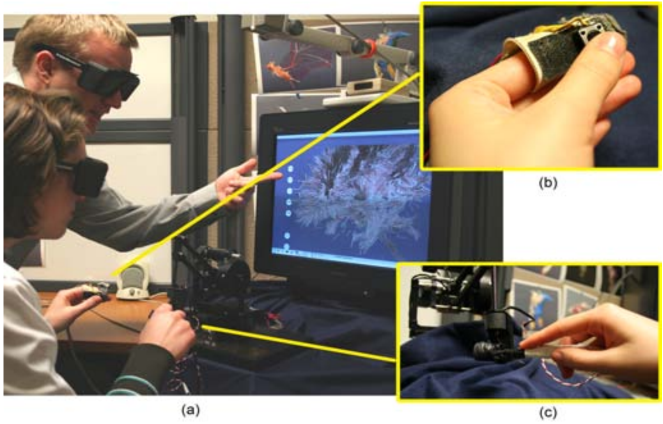

Figure 2: Users collaborating on hypotheses about WM connectivity using 3D lasso drawing selection interface in 3D stereo VR. (a) Fishtank VR setup. (b) 3D hand tracker. (c) Phantom force feedback device.

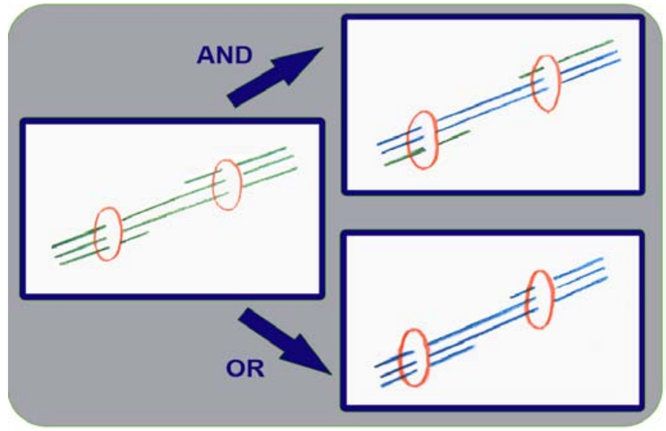

Figure 3: The two logical operations "AND" and "OR". Two lassos delineate regions-of-interest (ROI) placed on anatomic landmarks. (1) AND operation: fiber tracts that go through both ROIs are selected. (2) OR operation: fiber tracts that go through either one of the ROIs are selected. The fiber tracts resulting from the corresponding logical operations are shown in blue.

with more confidence. With the WM structures vividly apparent, users could easily lasso out tortuous structures that are often time-consuming to specify using traditional rigid VOI selection tools.

3 Methods

To approach the navigation challenges present in current TOI tools, we asked brain scientists to work in a nontraditional environment using stereo VR environment with head tracker to reduce visual clutter (Figure 2a) and a higher-degree-of-freedom input device (Figures 2b and 2c) to improve manipulation and selection.

The user wears head-tracked stereo glasses that support active stereo viewing. A 3D hand tracker is attached to the user's finger so that rotation and zooming are controlled by hand gestures. User draws 3D lassos for TOI using the Phantom force feedback device, which serves as a tangential guiding filter and makes it possible to draw a smooth lasso directly in the 3D space. We address the challenges involved in drawing the 3D lasso by integrating a dynamic dragging haptics constraint [5] [6] inspired by the dense and narrow nature of the fiber tracts.

In our interface, selection is done by drawing a freeform 3D lasso around the fiber bundle directly in the 3D space using the Phantom device (Figure 2c). Figure 1 demonstrates making a TOI selection using the tool. First, the user selects a group of fiber tracts by drawing a lasso in the space. This creates a 3D surface based on triangulation of the lasso and any fiber tracts intersecting this surface are selected. The user can then perform multiple lasso operations with logical combinations of AND and OR, as illustrated in Figure 3, to obtain the desired fiber bundle based on the characteristic trajectory. Figure 1 shows a user placing two lassos around the uncinate fasciculus (UF) and singling out the structure with an AND operation.

To evaluate our system, informal evaluations with 4 expert users visualizing two normal brain dataset were performed. The results are reported in the next section.

4 Results and Discussion

In our informal user evaluation with 4 expert users visualizing two normal brain dataset, our users reported that:

- The 3D stereo environment let them identify 3D structures much more easily, since it avoids the visual flattening of the 3D WM structure found in traditional TOI selection tools.
- Navigation time was greatly reduced by the visual aid of 3D stereo combined with simple hand gestures for brain model manipulation. The users located and identified WM structures and the area they project in the brain quickly and with high confidence.
- Selection by lasso drawing is easy to learn. The users found that the ability to directly place the simple 3D lasso in the 3D space let them easily segment tortuous brain structures, such as the uncinate fasciculus (UF), thatwith traditional VOI tools often require careful placement of multiple VOI with specific dimensions and locations.
- Users were often highly engaged in the process and noticed a reduction of the eye fatigue common in stereo interfaces.

The four brain scientists involved in this preliminary study expressed strong interest in adopting the system for their scientific analysis process in the near future.

5 Conclusion

A new TOI selection interface adopting haptics was presented that uses direct 3D lasso drawing for making the selection. Our evaluation suggests that this is a promising approach. The brain scientists who worked with the 3D lasso tool in stereo VR environment found that visual clutter was reduced and that they gained more confidence in identifying the structures; they also noted that manipulating a brain model using a higher-order input device such as the hand tracker in the stereo environment greatly reduced navigation time.

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