InBox: In-situ Multiple-Selection and Multiple-View Exploration of Diffusion Tensor MRI Visualization

Haipeng Cai*
University of Southern Mississippi
Jian Chen†
University of Southern Mississippi
Alexander P. Auchus ‡
University of Mississippi Medical Center
Stephen Correia§
Brown University
David H. Laidlaw¶
Brown University

ABSTRACT

We present InBox, an *in-situ* multiple-selection and multiple-view interface for interactive exploration of dense tube-based diffusion tensor magnetic resonance imaging (DTI) visualization. Optimal experience for such exploration demands concentration on the tract of interest (TOI). InBox facilitates such concentration by designing interaction *within* the three-dimensional (3D) model context. It leverages the use of screen space for splitting actions. The primary interface is for box-based selection featured by DTI model sculpturing. Multiple boxes can function together using two working modes (select and removal) and two associative logics (AND and OR) to support a rich set of operations. Results from a pilot study showed that our design of InBox was on the right track and users were inclined to use one-dimensional (1D) input. A high efficacy of selection was also observed specially within non-DTI participants.

Keywords: Diffusion tensor MRI, fiber tracts, 3D interaction, visual interface

Index Terms: J.3 [LIFE AND MEDICAL SCIENCES]: Medical information system; I.3.8 [COMPUTER GRAPHICS]: Miscellaneous

1 INTRODUCTION

The 3D tractography of diffusion tensor magnetic resonance imaging (DTI) usually produces a set of integral curves or fiber tracts. If the fibers are constructed from a large volume of DTI, the display can get very cluttered making it difficult to get insight into the data. One way to solve the problem is to only select tracts of interest (TOI), which becomes difficult in the dense DTI visualizations.

Existing approaches to the interaction with DTI visualizations permit effective selection with various means from intuitive virtual reality (VR) (e.g., box selection in BrainApp [7]) or pen-based input (e.g., brush-based interface in CINCH [1]) to the use of two-dimensional (2D) embedding [4] or projection [5]. These methods permit more efficient selection compared to 3D multi-model settings, especially when the targets are known. Problems exist however. The 2D embedding is not anatomically meaningful, thus the users would have to examine both the 3D and 2D views to do the selection. In addition, our collaborators reported that there was a lack of fast removal method. Medical doctors often work on a subregion of the brain and purely selection-based interface would be less efficient to reach those regions. They would like to quickly *sculpt away* pathways not relevant to their task.

*e-mail: haipeng.cai@eagles.usm.com
†e-mail: jian.chen@usm.com
‡e-mail: aauchus@umc.edu
§e-mail: stephen_correia@brown.edu
¶e-mail: dhl@cs.brown.edu

Built on existing techniques and suggestions provided by our DTI collaborators, our approach makes use of conventional desktop setting ([4]) to enable users to *stay in the flow* of focused attention. This work is based on the assumption that focusing on the current working window can facilitate more precise selection by engaging the users in their tasks. We call our interface InBox to stand for in-situ box selection (Figure 1).

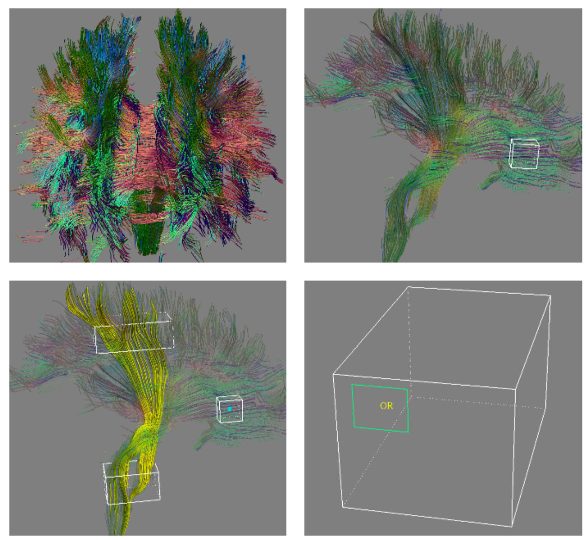

Figure 1: Outlook of the InBox selection interface: a whole brain model initially loaded (top left); rough region containing the corticospinal tract (CST) fibers sculpted out from the initial whole brain (top right); then accurate selection of CST fibers made by two AND selection boxes added to the sculpted model (bottom left); and hover-over widgets on a box face where the "OR" widget is used for toggling between the "AND" and "OR" logic association between boxes (bottom right).

The main contribution of this work is an *in-situ* sculpturing interface prototype for DTI fiber selection through boxes maneuvering boolean logic combined with complementary modes and hover-over widgets minimizing mode switching. In addition, the multiple view environment supporting synchronization of both actions and data enables more effective exploration of multiple DTI models.

2 RELATED WORK

Sherbondy et al. design box widgets to define TOIs on which dynamic queries are constructed to locate specific structures in neural pathways [6]. Both Chen et al. [4] and Jianu et al. [5] use a compound interface that integrates a 2D embedding to assist the 3D exploration; here the user can select embedded points on a 2D plane in order to select the corresponding 3D fiber tracts. Blaas et al. proposed a geometry-based approach for selection by use of multiple convex objects to yield reproducible bundles [2]. The three-box method is more efficient mostly for selecting major or regular bundles but less for bundles consisting of jagged fibers due to imperfect tractography often seen in practice. Brushes and strokes have also been applied to 3D selection. CINCH allows to select the 3D pathways using pen strokes [1]. In this pen-based interface, TOIs are defined by arbitrary marks drawn by a trackball. Multiple-view visualizations have also been used to support simultaneous view of multiple models [5, 4].

In InBox we focus on extending the DTI visualization interface through an *in-situ* modality allowing user to concentrate on the model context since interactions are put together following the user's data focus. It also enables boxes for selecting, removing or erasing fibers to collaborate with boolean logic combinations thus provides a novel prototype for DTI model sculpturing. Here removing is different from erasing in that removed fibers can be selected back again by moving away the removal box while erasing fibers is to sculpt them away.

3 Methods

3.1 Box Interaction

By default, a selection box is shown when the program is loaded. The size of the selection box is equal to the size of the bounding box of the DTI data. The box can be resized flexibly through left dragging any of its vertices, edges or faces. Besides, congruent scaling by right dragging is also available for a quicker resizing. InBox also provides a widget-based interface for a set of other operations. Hovering over any front face of a box will activate a group of hover-over widgets. Additionally, multiple boxes can be added to a view. When added, they can be associated using two logics: AND or OR. Each box can exist either as a selection box (or select) or a removal box (or removal), and this selection mode is easy to switch with a box widget.

3.2 Sculpturing

InBox provides continuous removal of fibers (erasing or brushing fibers) towards a sculpturing approach to TOI selection. The sculpturing can be particularly useful when the selection targets are known, especially when they are located in the inner regions. Users can simply remove those that are blocking their views. Our collaborators also reported that their tasks are often related to a small region of a brain and that they would like to sculpt TOI out from dense tubes while holding the whole brain model in mind. Sculpting can become handy for removing the large chunk of irrelevant fibers thus help achieve their goals (see Fig. 1).

3.3 Multiple View Interaction

InBox can synchronize actions besides dataset selection. When actions are synchronized, transforming data in one view could introduce simultaneous transformations in other views. Selection and box widget operations can also be synchronized. When the user operates in any of the views, interactions are mirrored to all other views. In this prototype interface, the action synchronization between different tractographies produced from a same or similar brain model is achieved by geometry-wise pre-calibration. For disparate models, asynchronous adjustment for individual model will be needed.

4 Results and Discussion

We invited two group of users to test InBox. The DTI expert group included a radiology professor and two medical students, and the non-DTI expert group had two computer scientists. Our pilot study results suggest that the InBox design goals are on the right direction. Participants found that the interface was useful for examining the white matter pathways and the anatomical structures in the brain, and that the removal mode was effective. In this initial pilot test, small sample size did not suffice for a formal quantitative measure thus a table or figure is not presented for now.

Participants were inclined to use 1D input. Our log data showed that the participants were mostly inclined to resize the box using 1D face movement ($> 30\%$), perhaps due to its low movement cost. The users do not have to modify two or more planes simultaneously when a higher dimension manipulation is activated. This finding is consistent with what people operate in VR [3].

High efficacy within the non-DTI participants The average task completion time was 2.2 minutes for the non-DTI participants with a relatively high selection accuracy. However, we need to interpret this result carefully when compared to other tools in experiments with different sampling population, sample size and test settings. As expected, the participants reported that the hover-over widget provided quick and accurate selection.

Comments from the DTI Experts Several extensions have been suggested by the DTI-expert group. One expert participant suggested the design of a spherical widget in a polar coordinate. Then the selection can be performed by placing the center of the sphere within the TOI. Thus the initial scene would be less clutter. Increasing the size of the sphere enlarges the selection context to show more fibers of interest. In addition, users reported that they rarely examined the whole brain, thus loading a good initial default (such as a sub-volume of the brain) could further simplify TOI selection.

5 Conclusion and Future Work

We have presented InBox, an in-situ interface for the interactive exploration of dense DTI tubes. InBox extends many well-known techniques (box-based selection, brushing-and-linking, multiple view, and widget-based interface) to allow actions to be performed within the model context. It also contributes with the prototype of sculpturing-based interaction and the multiple synchronized view for the ease of selection. We have reported results from a pilot study. A formal study with more brain experts is planned to compare our interface with the 2D separated views to learn if ours helps reduce the cognitive barrier between examining 3D while selecting in 2D.

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