Interactive Diffusion Tensor Imaging Fiber Data Visualization via Multiple Devices

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Abstract

Diffusion Tensor Imaging (DTI) reveals subtle abnormalities associated with stroke, multiple sclerosis, schizophrenia and dyslexia, which has a broad application prospect in the medical field. The densely sampled 3-D DTI fiber tracts in biological specimens have high geometric, spatial and anatomical complexity. To provide users with more immersive and convenient interactions in exploring DTI fibers, we design specific interactions based on the APIs of Leap Motion and Oculus Quest. Leap Motion and Oculus Quest are devices focusing on hand tracking and 3-D somatosensory interactions. We design four different interaction modes for users to analyze the data in different interaction stages and scenarios, in order to better explore the DTI fibers which users are interested in by Leap Motion gestures. They are Normal Mode, Box Basic Interaction Mode, Box Logic Operation Mode, and Cluster Exploration Mode. Compared with the explorations through traditional input devices, the evaluation tests show that the proposed approach is more intuitive and efficient in 3-D explorations and provides an immersive experience for users to explore the DTI fiber data.

1 Introduction

Diffusion Tensor Imaging (DTI) is a special form of magnetic resonance imaging (MRI) which has a broad application prospect in the medical field. The densely sampled 3-D DTI fiber data have high geometric, spatial and anatomical complexity. It is difficult for users to analyze it without any auxiliary tools.

Traditional hardware interaction devices for DTI fiber explorations include mouses, keyboards, touch screens, etc. However, the operating space of them is limited in the 2-D space of the screen. They show poor performance in terms of depth-direction moving and hybrid interactions. As a result, users cannot get an immersive experience. Except for the traditional 2-D interaction devices, there are some 3-D somatosensory interaction devices. In this paper, we use Leap Motion and Oculus Quest (VR glass) to explore DTI fiber data, considering their high accuracy and immersive experiences . We implemented the basic interactions via hand gesture recognition with Leap Motion, with *Scaling Gesture* to scale, *Rotation Gesture* to rotate, *Translation Gesture* to translate, and *Pat Gesture* to add new boxes. Users can explore the DTI fibers in four different modes. Switching between them depends on the *Mode-Change Gesture*.

Firstly, users can conduct traditional manipulations over the whole DTI fiber data via gestures in *Normal Mode*. Secondly, in *Box Basic Interaction Mode*, boxes can be added to filter DTI fibers, each group of filtered fibers named a tract [3]. Next, expression-based queries are designed to get logic set operations based on multiple boxes in *Box Basic Interaction Mode*, e.g, the intersection, union and complement of boxes. Complex logic combination queries are allowed to perform to reduce visual clutter and help users explore DTI fibers more precisely. In *Cluster Exploration Mode*, DTI fibers can be classified by clustering them into spatially and anatomically related tracts and then different clusters can be explored individually by designed gestures.

To evaluate the proposed approach compared with the traditional method, we conduct two evaluation test tasks: depth-direction moving task and hybrid interaction task. The evaluation result shows that the proposed approach via Leap Motion can move boxes in depth direction more efficiently and provide hybrid interactions consist of multiple basic interactions. Users can get an immersive and intuitive experience when conducting complex interactions on DTI fibers. More importantly, the interactions via Leap Motion are more accurate than those implemented by the mouse. It further promotes efficiency and reduces exploration time.

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2 Our Method

DTI is a technique that measures the speed and direction of water diffusion in biological tissues which have a high degree of geometric and spatial complexity. The use of box and clustering techniques can filter out specific fiber tracts and facilitates the exploration for users. However, the traditional interactive devices used to explore DTI data have some limitations in the interaction process. The introduction of Leap Motion and Oculus Quest can availably break these limitations. More importantly, the expression-based queries are implemented to perform complex logic set operations on multiple boxes. Besides, DTI fibers can be grouped by fiber clustering into spatially and anatomically related tracts and then different related tracts can be explored individually by designed gestures.

Figure 1 shows the pipeline of the proposed approach. The exploration of DTI fiber data is conducted in four modes. First, in the *Normal Mode*, the whole DTI fibers can be adjusted to an appropriate size and angle by *Scaling Gesture*. Second, users can enter the *Box Basic Interaction Mode*. In this mode users are allowed to place multiple boxes and adjust them to the appropriate size and position. Fibers going through the selected box will be shown in a different color. Third, in the *Box Logic Operation Mode*, users can input a logic expression to query. The resulting image can also be scaled and rotated to an appropriate size and angle. Fourth, the classified fibers can be produced and further explored in the *Cluster Exploration Mode*.

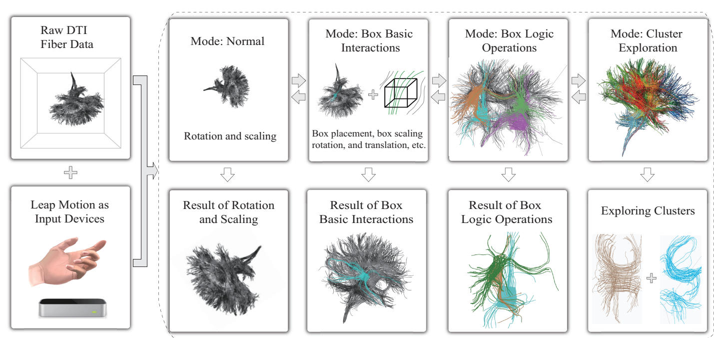

Figure 1: The pipeline of the proposed approach. The system is divided into four modes, and users can use a series of operations to control the DTI fibers through the gestures which are mainly captured and detected via Leap Motion. Each mode will get a corresponding result.

2.1 Basic Interactions by Leap Motion and VR Head Show

The *Normal Mode* is designed to conduct overall operations on DTI fiber data. The traditional method uses the mouse to operate the fiber data. Using the proposed method, we can not only achieve the same result, but also show better effect in some terms such as depth-direction moving and hybrid interactions.

When Leap Motion captures the *Scaling Gesture*, it gets the distance between two hands, and then we zoom in or out the DTI fiber accordingly. When users perform a *Rotation Gesture* and rotate the hand, it can get the change of normal vector of the hand, and calculate the rotation angle. While adjusting the fiber data, the result is vividly shown in the Oculus Quest in real-time.

2.2 Expression-based Box Queries to Filter DTI Fibers

When the Leap Motion detects the *Mode-Changing Gesture* , the exploration will enter the *Box Basic Interaction Mode* from the *Normal Mode*. In this mode, a box is usually placed to the position of a tissue or an organ to view the tracts passing them. Boxes can be added, removed, scaled and translated. Users can select an individual box to filter fibers, each group of filtered fibers named a tract [3]. Users can use *Translation Gesture* to move either the whole DTI fiber or an individual box. Accordingly, *Scaling Gesture* is employed to box scaling, and *Circle Gesture* is used to choose the previous or the next box.

2.3 Box Logic Operation Mode

The *Box Logic Operation Mode* is based on the *Box Basic Interaction Mode*. In this mode, we use Leap Motion and keyboard to achieve some logic combinations of basic box queries. We design expression-based box queries which support selecting multiple boxes to conduct complex logic combinations of queries. They are *intersection*, *union* and *complement* on multiple boxes. We use the symbol '+', '*', '/' to represent them respectively. For example, the expression 1*2 shows DTI tracts that passing through Box# 01 and Box# 02 simultaneously, while 1+2 means the queried DTI tracts passing through either Box# 01 or Box# 02 simultaneously. More importantly, more complex logic combinations are supported, such as "`(1*2)+(3*4)`". The parentheses here mean the operation priority similar to the arithmetic expression.

2.4 Exploring Classified Fibers by Leap Motion and VR Head Show

Domain experts often require to explore the DTI fibers which follow similar shapes or patterns. Previous method classifies DTI fibers into fiber clusters in the white matter region. However, the rendering of the cluster tracts will be affected by occlusion (i.e, one cluster obscuring another). Our method enable users to explore each classified fiber tract in *Cluster Exploration Mode*. Each classified fiber tract can be displayed separately, which avoids one cluster obscuring another. Users can switch between different clusters by *Mode-Changing Gesture*.

3 Result and Evaluation

To demonstrate the effectiveness of our method, we test our method on medical data include dataset BRAIN and dataset HEART provided by Chen et al. [2] and conduct two evaluation tasks including the depth-direction moving and hybrid interactions. The experiment codes of the paper are developed based on the open-source codes provided by Chen et al. [1].

In our experiment, as shown in Figure 2(a), one box has been added to a given position to filter the fibers passing through them. As shown in Figure 2(b) and Figure 2(c), when two boxes are added to the given positions, the fiber tracts are marked in red which pass through Box #01 and marked in blue for Box #02.

The proposed approach also provides logic combinations based on an arbitrary number of box queries. Figure 2(e) Figure 2(f) shows the results queried by a simple expression-based logic combination. The queried results are highlighted in yellow. For example, users can query the DTI fibers passing through both Box #01 and Box #02, together with the DTI fibers passing through both Box #03 and Box #04. The individually queried fibers are marked in red, blue, green and purple for Box #01, Box #02, Box #03 and Box #04, respectively. The corresponding expression is "`(1*2)+(3*4)`", as shown in Figure 2 (e) and Figure 2 (g). The fibers in yellow are the queried results from dataset BRAIN and dataset HEART. Besides, we use another expression "`/1*2`" to show the queried fibers passing through Box #02 without passing through Box #01 for dataset HEART shown in Figure 2 (f). More importantly, as shown in Figure 2 (d) and Figure 2 (h), the results can be shown in a more immersive way via Oculus Quest.

We conduct a user study to evaluate the interactive visualization performed by Leap Motion and Oculus Quest compared with the traditional input devices. We conduct two evaluation tasks including the depth-direction moving and hybrid interactions.

In the experiment of depth-direction moving (Task I), users are required to move a box along the depth-direction of the screen. If they use the mouse, they need to rotate the DTI fibers with an appropriate angle (90-degree). Then they can translate the box along the axis to accomplish the

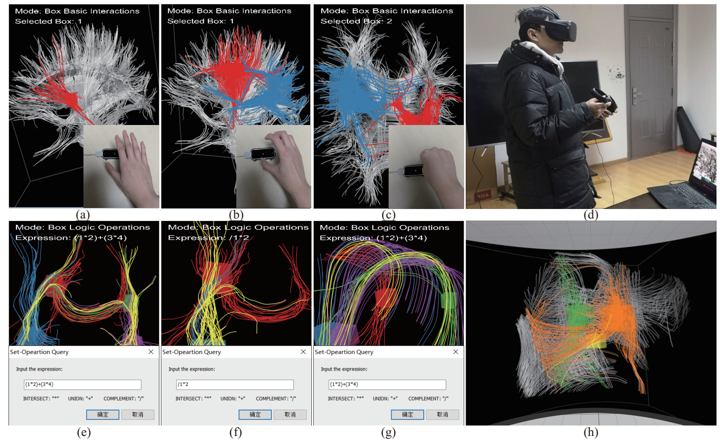

Figure 2: The results of placing two boxes through Leap Motion and complex logic combinations based on an arbitrary number of box queries. The fiber tracts selected by boxes are marked by corresponding colors predefined in the framework. The whole fibers can be rotated, scaled, translated by different gestures detected by Leap Motion. (d) The queried result by the expression "(1*2)+(3*4)"in dataset BRAIN. (e) The queried result by the expression "/1*2" in dataset BRAIN. (f) The queried result by the expression "(1*2)+(3*4)" in dataset HEART.

depth-direction moving task. However, users can achieve the task just by a simple gesture of moving inward in our method. The error of the operation is often not too high. The second task is called hybrid interactions (Task II). In this task, participants need to move the box and scale it at the same time. In traditional method (by mouse), users are required to perform it by at least two steps. It is hard for users to click multiple buttons to finish this task. However, it is easy to finish it by Leap Motion, because it is easy for users to move their hands and scale the scope of the fingers. This gesture can significantly improve operational efficiency.

In our study, we measured and recorded the time of each experiment. Every experiment is tested three times, and we calculated the average timing results for two tasks with two input devices. The experimental results show that it takes 2.6 times of the time in Task I and 1.8 times in Task II through a mouse compared with Leap Motion.

The results and evaluations demonstrate that the Leap Motion is more efficient and effective than the mouse to explore DTI fiber data. Leap Motion can be used to achieve common interactions in an immersive way. Besides, it can be used to perform some complex tasks, for example, the depth-direction moving and hybrid interactions. We also design expression-based box query to filter DTI fibers through an arbitrary logic combinations based on individual box queries. In addition, it allows users to use a gesture to explore each classified fiber tract. The interactions are real-time without obvious delay.

Nevertheless, there are some limitations on the accuracy due to the characteristics of the device. First, we are unable to fine tune the target objects. Second, the gesture identification errors sometimes may occur during the interaction. Third, the types of gestures would be still limited especially when there are a large number of different interactions should be designed in some scientific data visualization. In this paper, we design four interaction modes to enlarge the number of gestures, which solves the problem to some extent.

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