Real-Time Fiber Tractography: Interactive Parameter Tuning for Neurosurgical Interventions

Maxime Chamberland\textsuperscript{1,2}, David Fortin\textsuperscript{2,3}, Maxime Descoteaux\textsuperscript{1,2}
\textsuperscript{1}Sherbrooke Connectivity Imaging Laboratory (SCIL), Computer Science,\textsuperscript{2}Surgery department, Université de Sherbrooke, Sherbrooke, Canada \textsuperscript{3}Centre de Recherche Clinique Etienne Le Bel

Introduction

Fiber tractography has started to be commonly used in neurosurgical planning [3, 8]. Typically, fiber tractography is performed with a fixed set of parameters; either from everywhere in the white matter based on a fractional anisotropy (FA) threshold or starting from a specific region of interest (ROI). In both cases, the produced fiber tracts are shown to the neurosurgeon in a visualization tool such as the Fiber Navigator [2, 8], amongst others [3, 4]. However, it is well known in the diffusion magnetic resonance imaging (dMRI) community that fiber tractography is sensitive to the tractography parameters used [7]. Moreover, in neurosurgery applications, the input dMRI datasets are very different from one subject to the other and thus, parameters are subject-dependent. Hence, an expert usually has to prepare the fiber tracts datasets by manually editing and segmenting the tracts of interests [1]. Or, whole-brain fiber tracts are shown to the neurosurgeon under different fiber tractography parameters; for example, fiber tracts using a conservative FA threshold (e.g. FA < 0.2 [6]) versus fiber tracts using a more aggressive FA threshold (e.g. FA < 0.1 [1]). This is far from optimal for the neurosurgeon having to analyze these fiber tracts. Hence, real-time fiber tractography (RTT) has recently appeared [3, 5, 6]. This work describes such a real-time tractography algorithm integrated to the Fiber Navigator [2], which we confront and illustrate in a neurosurgical planning application for the first time in the literature.

Methods

Datasets are collected on a Siemens 1.5 Tesla (T) scanner using a single-shot echo-planar (EPI) spin echo sequence (TR/TE = 12500/95 ms), with b-value of 1000 s/mm\textsuperscript{2}, the default 12 directions for Diffusion Tensor Imaging (DTI) and 3 averages
By placing a ROI box, the user can tune a series of parameters that can be modified during the tracking process (Fig. 1). He can then start the fiber tractography algorithm and move the selection box freely around. Currently, the fiber tractography algorithm implemented is the popular and robust tensor deflection (TEND), as in MedINRIA and other public software [4]. Every change to the parameters, or to the size of the box, or its position causes the computation and instantaneous update and display of new tracts.

**Results**

As seen in Figs. 2-4a), a selection box filled with 1200 seed points is placed within the glioma area. No fiber pathways are found using an FA threshold of 0.15 whereas in other regions of the brain, this threshold is preferred by the neurosurgeon. By adjusting the threshold to 0.10 and using the same parameters as mentioned above, relevant fiber tracts projecting towards the frontal lobe are detected on Figs 2-4b). Those fibers are anatomically possible and resecting them could lead to severe post-operation deficits. This brings lights on the uncertainty of fiber tracking parameters and indicates that they should be used with precaution. Without this additional information on the field, a neurosurgeon might have made the wrong choice during the operation, had he based its decisional algorithm solely on this data. These results also emphasize the importance of defining adequate validation strategies before the standard clinical use of DTI in assisting neurosurgery.

**Conclusions**

Real-time fiber tracking provides information on the fly about uncertainty and DTI limitations which are well-known. It appears mandatory to have the right tool and the ability to adjust parameters depending on the subject and the neurosurgical case. We believe that this new feature can bring awareness to the neurosurgeon about the hidden parameters in fiber tractography and emphasize some of the current limitations, thereby avoiding the use of tracking algorithms as dangerous “black box”. It is part of our ongoing work to implement a streamline high angular resolution diffusion imaging (HARDI) algorithm and have a GPU-based implementation as well.
Fig. 1) RTT parameters

- Properties:
  - Realtime tracking: dti.nii.gz

- Realtime tracking parameters:
  - Min FA: 0.10
  - Max angle: 60.0
  - Step: 1.0 mm
  - Puncture: 0.2
  - Min length: 8.0 mm
  - Max length: 400 mm
  - Use random seeds
  - Interpolation

Fig. 2) T1 + tensors main axis

a) FA threshold: 0.15

b) FA threshold: 0.10
References


