Analysis of noise effect on DTI based fiber tractography

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Synopsis

While tractography technique based on line propagation is a promising and widely used technique, it is known to be sensitive to noise, partial volume effect, and ROI placement. In this presentation, we analyzed the effect of noise and ROI locations and sizes on the tractography results using a high-resolution postmortem mouse brain sample. Gold standard was created from anatomical knowledge and deviation of the tracking results were measured as a function of SNR. The results confirmed that the two-ROI and brute-force approach could effectively reduce the sensitivity to the noise and ROI placement.

Introduction

It has been shown that macroscopic white matter tract trajectories can be reconstructed based on DTI data. One of the most widely used reconstruction approach is “tracking” model, in which a line is propagated from a seed pixel based on tensor orientations (conventional approach) (1-3). While it is a promising technique to understand white matter neuroanatomy and neurological disorders, it is also known that the technique is sensitive to noise, partial volume, and ROI placement. In this presentation, we tested whether two modified approaches (2) could reduce the sensitivity to the noise and ROI placement. In the first approach, multiple ROIs were defined based on anatomical knowledge (two-ROI approach). This poses strong constraints in the tractography results and is expected to reduce false positive results. Second, instead of performing tracking from one ROI, it was initiated from all pixels within the brain and tracking results that penetrate the ROI were searched (brute-force approach). The analysis was based on high-resolution, high-SNR DTI data from a fixed mouse brain. A series of datasets were created by adding Gaussian noise to the time domain data and the effects were analyzed. The ROI sizes and locations were also changed to observe the effects. The results indicated that the combination of the two approaches increased the reliability and reproducibility of the tracking results substantially by reducing the noise and ROI placement effects.

Methods

Data acquisition: An adult mouse brain was scanned in a 9.4 T GE Omega Spectrometer with tri-axis gradient set. A set of DWIs were acquired in 10 linearly independent directions with a multiple spin echo sequence. DWI parameters were: FOV=17mm/10.5mm/8mm, TE=37ms, TR=0.9s, voxel size = 0.0664×0.0625×0.0625mm, data matrix=256×168×128. A co-registered T_2-weighted image was also acquired. **Noise generation:** Gaussian noise was generated with three different sets of seed numbers. Each data set includes 28 different noise levels. Gaussian noise with mean of 0 and different standard deviations were added to both the real part and imagnary part of the original high-SNR k-space of experiment data. **Gold standard and ROIs:** We chose the anterior part of anterior commissure (AC), which is well isolated from other white matter tracts, anatomically well documented, and easily defined from T_2-weighted images. Using coronal slices, the AC was manually defined and served as the gold standard (Fig. 1). Once the AC is defined, two ROIs (#1 and #2) are placed in coronal planes at two different locations of the AC. **Tracking:** Tracking was based on linear propagation model (FACT)(1). ROI #1 with a size of 17 pixels was used for initiation points for the conventional approach. For the combined approach (two-ROI & brute force approach), tracking results that penetrate both ROIs were searched. Tracking with and without prohibition of sharp turns (inner product threshold of 0.5) were performed. No threshold for anisotropy was used.

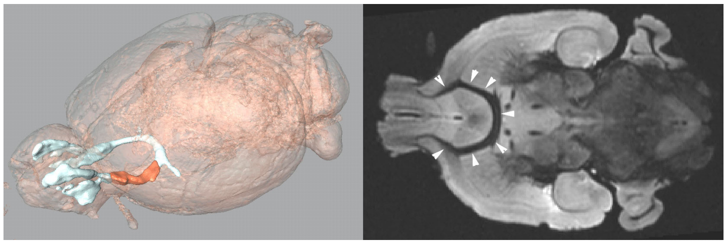

Fig. 1 Gold standard

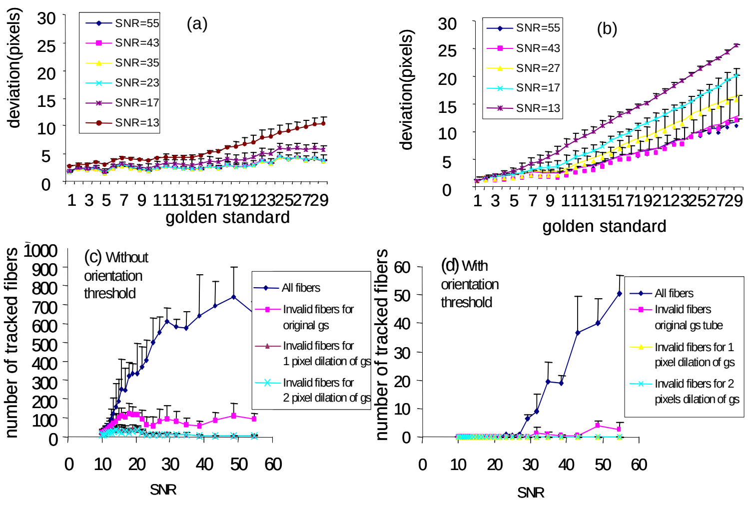

Fig. 2 Analysis results

Results

Fig.1 shows the T_2-weighted image (right panel) and the hand-segmented anterior commissure used for the gold standard (left panel). The area between two ROIs is also indicated by orange color. Fig. 2(a) shows pixel-by-pixel distance from the core of the gold standard as a function of tracking length by the combined approach and Fig. 2(b) shows the same measure by simple line propagation approach. Fig. 2(c) and (d) show the total number of tracts found by the combined approach (blue line) and the number of tracking results that deviate from the gold standard (other colored lines). From these results, several important facts can be appreciated. First, the combined approach had much smaller distance from the core of the gold standard and was less sensitive to noise compared to the conventional approach (Fig. 2(a),(b)). From Fig. 2(d), it can be seen that the tracking results of the combined approach were all within 1 pixel from the gold standard regardless of the amount of noise, while the number of the trajectories decreased as the SNR went down. The result was further improved if the inner product threshold was posed. The same results were found when the two ROIs were dilated by up to 5 pixels or placed at the different locations along the gold standard.

Discussion

The conventional approach uses one ROI, which is the only anatomical constraint. Some tracking results stayed in the gold standard and some did not. We could not conclude whether those deviated from the gold standard correctly followed one of the axonal trajectories that branched out or they were false results due to noise and/or partial volume effect. By adding the second ROI, it is unlikely that those once deviated from the gold standard happen to come back to the second ROIs, effectively removing the deviated tracts. Our results confirmed that the combined approach achieved 100 % accuracy for this particular tract used in this analysis. On the other hand, the removal of the deviated tracts results in decrease in the number of the tracts as the SNR goes down, while the accuracy stays 100 %. It is also confirmed that the dependency on ROI sizes is also low in the combined approach. These results suggest that the combined approach effectively ameliorate the shortcomings of the simple line propagation approaches; namely the sensitivity to noise and ROI placement.

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Reference: (1). Mori S. *et al.* Ann. Neurology, 45:265-269, 1999, (2) Conturo TE. *et al.* PNAS 96:10422, 1999, (3) Basser, PJ. *et al.* MRM, 44:625-632, 2000 .