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Automated Tractography of Four White Matter Fascicles in Support of Brain Tumor Surgery

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Abstract

Knowledge of eloquent white matter fascicles is imperative to prevent the loss of sensory, motor, and linguistic abilities that can accompany diffuse cerebral edema (cortex, brainstem, thalamus), and other brain tumors. For the planning of tumor resection, neurosurgeons require detailed knowledge of white matter fascicles. However, few neurosurgeons have access to this information because data analysis requires skilled and experienced personnel [2].

Data processing pipeline

The data processing pipeline is outlined in Figure 1 for the automated tractography of the optic radiation (OR), inferior fronto-occipital fasciculus (IFOF), corticospinal tract (CST) and the arcuate fasciculus (AF). The three steps of the pipeline are outlined.

Step 1: Estimation of Regions of Interest


- Thalamic segmentation using the Morel stereotactic atlas of the thalamus [4] provides an additional 44 sub-cortical segmentations. The atlas was aligned to thalamic segmentations of SLANT for increased accuracy.

Step 2: Tumor segmentation

- Segmentation of the tumor core, tumor edge and edema was done with a convolutional neural networks approach [5] trained on Multimodal Brain Tumor Segmentation (BRATS) Challenge data of annotations of low and high-grade gliomas. The segmented tumor core provides an additional exclude region for tractography to reduce false positives.

Step 3: Diffusion-weighted tractography

- Tractography of the four bundles was performed with the MRTrix software package [6] using the constrained spherical convolution. Diffusion data was preprocessed used the preprocessing script of MRTrix, which uses FSL’s eddy.

Results

The pipeline was evaluated on the data of five patients who were candidate for brain surgery, acquired using a clinically-applicable DWI protocol (b=1500, n=50). All tracorgrams were reviewed by an experienced neurosurgeon (GR), and were found to be consistent with anatomical knowledge.

In Figure 2A (bottom-right) a mass effect can be observed where the IFOF is pushed inferiorly, but could still be successfully reconstructed. Similarly in Figure 2D the AF is pushed medially due to a mass effect. The SLANT method appeared to produce robust results even in the presence of tumor tissue, and, in all cases, did not apply a false label to the tumor core.

Conclusion

Initial investigations show that the pipeline produces robust results. As a next step, we will validate its performance in a larger group of neurosurgical patients, including patients with very prominent mass effects or edema. While (quantitative) validation of tractography results remains an open problem, indirect approaches are possible such as comparison to the results of electrorocutal stimulation [7] or post-operative functional outcome [8]. In future work the analysis pipeline will be further optimized to correct for free water in peritumoral edema, which may improve the quality of tractography results in close proximity to the tumor.

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