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EVALUATION OF SEVERAL COST FUNCTIONS FOR MIN-CUT-SEGMENTATION OF FIBER BUNDLES IN THE HUMAN BRAIN

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Introduction:

Intraoperative imaging and multimodal navigation improved glioma surgery in the last decades. Functional data, integrated in the neuronavigation procedure, has contributed to maximum safe resection for lesions located near eloquent brain structures. Functional MRI (fMRI) and magneto encephalography (MEG) have been integrated into the navigation to identify eloquent cortical brain areas. In addition, visualising white matter tracts is now possible by diffusion tensor imaging (DTI) segmentation (Fig. 1). To optimize the displayed objects, a new graph-based segmentation method for fiber bundles and different cost functions for graph construction are presented in this paper.

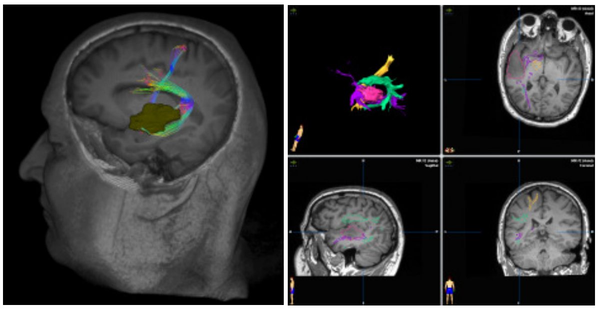


Figure 1. Left figure shows a patient with a tumor (olive) lying close to the reconstructed left cortico-spinal tract and the language pathways. Right figure shows the pre-operative planning system for using neuronavigation during intervention with segmented tumor (pink), corticospinal tract (yellow), language pathway (green) and visual pathway (purple).

Methods:

Based on a centerline of the fiber bundle derived form fiber tracking, rays are sent out and sampled in different planes perpendicular to the centerline. Then, a directed and weighted graph is created containing all evaluation points and a sink and a source node. Besides infinit-weighted edges connecting the nodes, different cost functions are used to weigh the edges to source and sink (Fig. 2). Finally, a minimum cost closed set is computed via a polynomial time s-t-cut, which creates an optimal segmentation of the fiber bundle. This result is transformed into a 3D object by triangulation and voxelization [1]. As cost functions, the scalar measures fractional anisotropy (FA), mean diffusivity (MD) and relative anisotropy (RA) are used.

The algorithm has been implemented in C++ within the MeVisLab [2] platform on an Intel Core2Quad CPU, 3 GHz, 6 GB RAM.

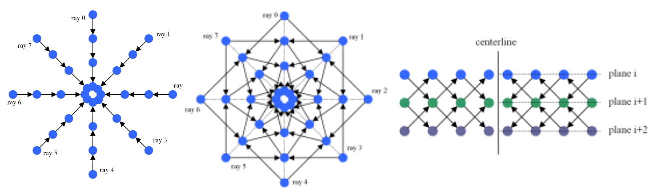


Figure 2. Graph-based approach: construction of ∞-weighted edges of different types
Type 1: edges connecting points along each ray of each plane
Type 2: edges connecting points of neigh-bored rays of the same plane ($\Delta x = 1$)
Type 3: edges connecting points of the same ray of neighbored planes ($\Delta y = 1$)

Results:

The evaluation is based on DTI data sets of several software-phantoms (portion of torus with different noise levels, anatomical phantom with modelled corticospinal tract) [3,4] to have ground truth data (fiber location, course) to compare against (Fig. 3,4). As our quality measure, the Dice Similarity Coefficient (DSC) [5] is calculated. Using the same parameter combination for all determinations, the cost function using FA yielded an average DSC of 78.73±4.08%, while the average DSC of using MD was 79.16±3.74% and for RA it was 77.05±1.48% (Fig.5).

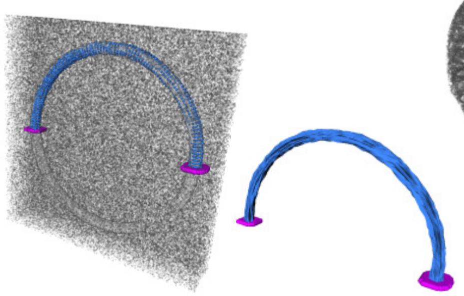


Figure 3. Torus-shaped software-phantom: calculation of boundary points (left), 3D object generation (right)

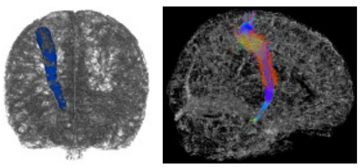
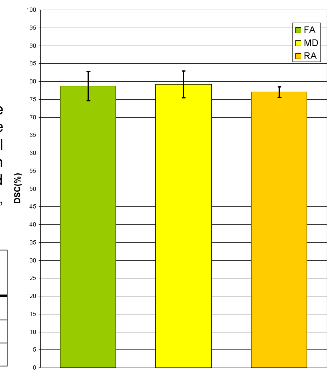


Figure 4. Anatomical phantom with modeled right corticospinal tract: phantom with modeled tract in blue (left), calculation of boundary points between start and end region (right)

Figure 5. Results of the three scalar parameters for the weighting function: fractional anisotropy (FA, green), mean diffusivity (MD, yellow) and relative anisotropy (RA, orange)



	average DSC (%)	standard deviation of DSC (%)
FA-weighting	78.73	4.08
MD-weighting	79.16	3.74
RA-weighting	77.05	1.48

Conclusions:

A new graph-based min-cut-segmentation for fiber bundle segmentation was evaluated by using different cost functions for graph construction. In conclusion, exact and automatic segmentation of the fiber bundles in the human brain obtained by our novel approach is useful in glioma resection, leading to safe tumor resection for lesions located near eloquent brain structures.

References:

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