Fiber tractography and brain atlas integration in stereotactic planning: improving interactivity with multithreaded and CUDA-based solutions

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In order to support surgical planning with computationally intense tractography analyis and brain atlas fusion, it is important to find a smooth integration with multithreaded or GPU-based approaches. The available open source libraries offer solutions but the parameter intialization, intermediate data exchange, interactive visualization of results are related to surgical planning steps and remain challenging.

Fiber tractography is initiated from our Vister3D surgical planning software by command scripts calling MRtrix library functions (http://jdtournier.github.io/mrtrix-0.2/) suitable to perform multithreaded diffusion-weighted MRI white matter tractography. Selection of anatomical MR sequence initiates automatic parsing of diagnostic files to find DWI data of patient. Spherical ROIs are defined in 3D using orthographic views of anatomical sequence. Locations are mapped from radiologic (LPS) to neurologic (RAS) patient space and transformed to the scanner reference. From there the space of DWI data can be reached and streamline or probabilistic tractography are executed. The resulted fiber models transformed back to the imaging space representing patient anatomy and displayed in the surgical planning views. The fiber models are visualized during frame based stereotactic planning and also during frameless navigation in different real-time resampling modes. The tractography analysis is supported by multiply ROI selection which can involve not only the "seed" type ROI but also "exclude" and "include" type ROIs. The computations are very fast, streamline computations with single seed ROI run less than one minute and probabilistic ones with the same ROI usually less than 10 minutes (Fig.1).

Brain atlas fusion is added to Vister3D planning in interactive way by using NVIDIA CUDA-based fast, nonlinear 3D image fusion algorithm (https://sourceforge.net/projects/ezys/). The registration is limited for subvolume, position and size of it are initiated in atlas volume according to user-selected group of atlas seeds. The size of atlas subvolume and target subvolume in patient reference is kept identical but can be modified from patient volume. The center of subvolume in atlas domain is left fixed in contrast to the subvolume in patient domain where it can be relocated. This positioning can be used to find the best initial overlap for optimization. The planning software creates archives for subvolumes in atlas and patient MR domains together with parameters needed for actual registration. Weight distributions in 3D can be defined for atlas and reference volumes to amplify effects of some parts of image in computations. The fusion aligns atlas based subvolume to patient subvolume usually in few seconds. The displacement field is used to deform seeds into the patient reference. The seed voxel distribution is smoothed with 3x3x3 Gaussian filtering method in reference volume and transformed to different planning views with CT or MR modalities (Fig.2).

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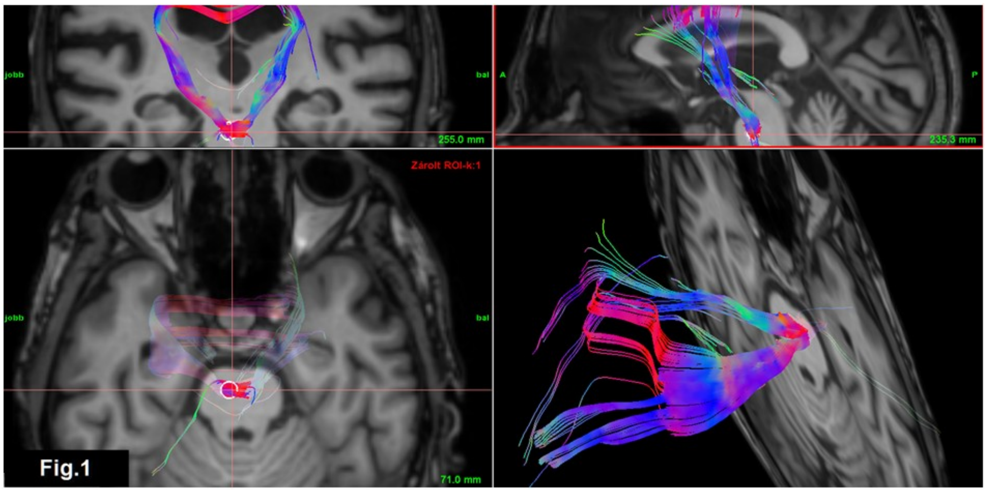

Fig.1. Fiber visualization in orthographic views of surgical planning

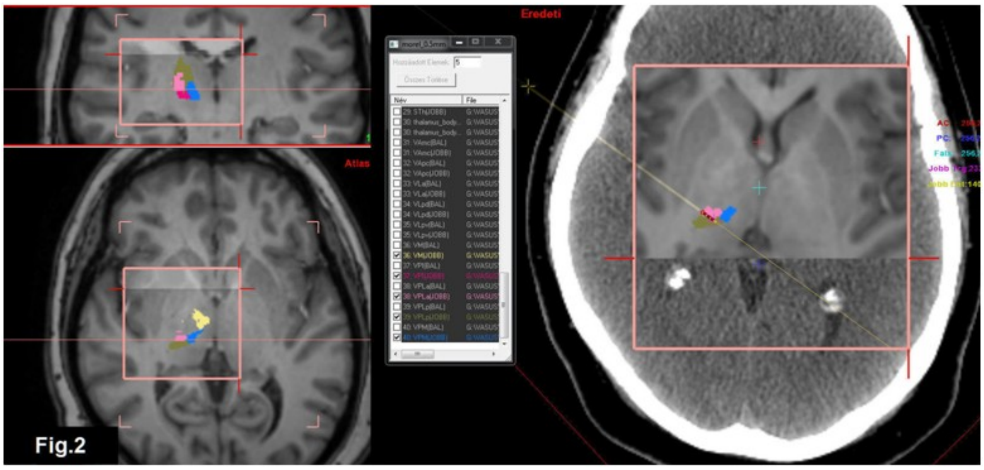

Fig.2. Fusion of atlas seeds into surgical planning views (left: patient MR with fusioned atlas, right: trajectory planning with CT/MR fusion and registered atlas seeds)