

Diffusion MRI: Clinical Application in Radiotherapy Planning of Intracranial Pathology

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Abstract : In clinical practice, and especially in stereotactic radiosurgery planning, the significance of diffusion-weighted imaging (DWI) is growing. This makes the existence of software capable of quickly processing and reliably visualizing diffusion data, as well as equipped with tools for their analysis in terms of different tasks. We are developing the «MRDiffusionImaging» software on the standard C++ language. The subject part has been moved to separate class libraries and can be used on various platforms. The user interface is Windows WPF (Windows Presentation Foundation), which is a technology for managing Windows applications with access to all components of the .NET 5 or .NET Framework platform ecosystem. One of the important features is the use of a declarative markup language, XAML (eXtensible Application Markup Language), with which you can conveniently create, initialize and set properties of objects with hierarchical relationships. Graphics are generated using the DirectX environment. The MRDiffusionImaging software package has been implemented for processing diffusion magnetic resonance imaging (dMRI), which allows loading and viewing images sorted by series. An algorithm for "masking" dMRI series based on T2-weighted images was developed using a deformable surface model to exclude tissues that are not related to the area of interest from the analysis. An algorithm of distortion correction using deformable image registration based on autocorrelation of local structure has been developed. Maximum voxel dimension was $1,03 \pm 0,12$ mm. In an elementary brain's volume, the diffusion tensor is geometrically interpreted using an ellipsoid, which is an isosurface of the probability density of a molecule's diffusion. For the first time, non-parametric intensity distributions, neighborhood correlations, and inhomogeneities are combined in one segmentation of white matter (WM), grey matter (GM), and cerebrospinal fluid (CSF) algorithm. A tool for calculating the coefficient of average diffusion and fractional anisotropy has been created, on the basis of which it is possible to build quantitative maps for solving various clinical problems. Functionality has been created that allows clustering and segmenting images to individualize the clinical volume of radiation treatment and further assess the response (Median Dice Score = $0.963 \pm 0,137$). White matter tracts of the brain were visualized using two algorithms: deterministic (fiber assignment by continuous tracking) and probabilistic using the Hough transform. The proposed algorithms test candidate curves in the voxel, assigning to each one a score computed from the diffusion data, and then selects the curves with the highest scores as the potential anatomical connections. White matter fibers were visualized using a Hough transform tractography algorithm. In the context of functional radiosurgery, it is possible to reduce the irradiation volume of the internal capsule receiving 12 Gy from 0,402 cc to 0,254 cc. The «MRDiffusionImaging» will improve the efficiency and accuracy of diagnostics and stereotactic radiotherapy of intracranial pathology. We develop software with integrated, intuitive support for processing, analysis, and inclusion in the process of radiotherapy planning and evaluating its results.

Keywords : diffusion-weighted imaging, medical imaging, stereotactic radiosurgery, tractography

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