Purpose

We present a flexible R&D platform targeted towards clinical neuroimaging that permits information fusion from multimodal imaging sources. Our main motivation is to develop software assistants to support neurosurgical planning, risk assessment, and therapy monitoring. To this end, the platform combines tools for quantitative anatomical and structural image analysis as well as interactive two- and three-dimensional visualization of relevant structures.

Material and Methods

The platform comprises software modules for neurological image analysis and visualization besides various data interfaces. Primary image data is automatically imported from various anatomical (T1 and T2 weighted native and post-contrast) and structural (diffusion weighted and diffusion tensor imaging) MRI acquisition techniques. All data interfaces and algorithms are implemented within the modular programming environment ILAB, which is dedicated to rapid application prototyping in image based diagnosis and risk assessment. Functional information is imported as secondary data from two-common software packages, namely SPM and BrainVoyager, therewith benefiting from the latest developments in fMRI analysis. Further specific algorithms are available for (i) segmentation of tumors and other lesions, blood vessels, cerebral ventricles, white and gray matter, (ii) volumetry of these structures, (iii) diffusion tensor reconstruction, (iv) quantification of anisotropy and connectivity of white matter tracts, as well as (v) functional cluster analysis and visualization. The visualization modules comprise fast direct volume rendering (DVR) and shaded surface rendering (SSD) methods for all objects segmented in the image data. Specific color coding schemes are available for functional activations, diffusion tensor directions, and slice based image fusion (cf. Fig. 1 and 2). A crucial strength of ILAB to flexibly and efficiently provide complex graphical user interfaces is exploited for the development of user-oriented software assistants.

Results

Several software assistants have been developed within the platform. We are able to fuse information from functional, anatomical, and structural imaging, and to provide the information within complex two- and three-dimensional rendering scenes. For example, a component for the preoperative visualization in neurosurgery comprises DVR of the cortical surface, multiple interactive clip planes to explore lesions and different brain structures, and SSD for tumors, blood vessels, and functional activation centers (cf. Fig. 1). Viewpoint, contrast, color, and transparency of all objects are automatically adjusted and may be modified interactively to obtain optimal visualization results. Furthermore, automatic histogram analysis is used to reproducibly quantify the volumes of white and gray matter, cerebral ventricles, and lesions. The volumetry modules are especially useful for follow-up studies, such as therapy monitoring in oncological tumor treatment. The quantitative analysis of diffusion tensor data is crucial for the preoperative identification of important white matter tracts as well as for the assessment of white matter damage after surgical treatment or radiation therapy.

Conclusion

The use of ILAB permits a high efficiency for the development of new image analysis techniques and user-oriented software assistants as well as an excellent adaptability to specific requirements of individual neurosurgical and neuroradiological departments. Further work will focus on clinical validation of the platform, development of interfaces to neurosurgical navigation systems, and integration of magnetic resonance spectroscopic imaging, e. g. for differential diagnosis and follow-up in tumors.