ABSTRACT

Computer-assistance has reached virtually every domain within the field of medical imaging. But, even after four decades of intensive medical image analysis research, most of the fully automated methods have not been adopted for clinical routine use. Dedicated computer-aided-diagnosis tools with proven clinical impact exist for a narrow range of applications, including mammography and chest imaging, both x-ray and CT. Interestingly, neuroimaging is where many of the modern image analysis methods have pioneered, but also where computer-aided diagnosis in its narrower sense does not play a major role today. Clinically used tools rather relate to computer-supported delineation and quantification of brain lesions in CT and MRI, perfusion analysis from dynamic imaging, localized analysis of diffusion properties, reconstruction of white-matter tracts from a series of diffusion-weighted MR images, and quantification of brain atrophy. We provide an overview of quantitative image analysis techniques including their evaluation based on phantom and patient data, and discuss future prospects regarding dedicated computer-aided diagnosis in the brain.

In neuroimaging, one of the questions that computers can answer more reliably than humans is how much did it change? The control of brain atrophy has numerous indications when studying the course of neurological disorders such as Multiple Sclerosis or Alzheimer's disease. Besides the absolute volumes, the spatial distribution of brain atrophy is of major interest. We describe different approaches to brain volume quantification and present results from a methodological comparison.

Similarly, in oncologic neuroimaging, computer-assistance often relates to measuring growth or shrinkage of tumors, for example alongside of chemotherapy or also as a decision aid during the wait-and-see period. Such task becomes especially challenging for gliomas, where the tumor is known to expand beyond the blurred visible boundary. We present a case where the combination of multi-modal and serial image fusion can provide insight into local growth processes.

Lesion quantification also plays a role in staging and treatment evaluation in, e.g., Multiple Sclerosis or vascular dementia. While the total lesion load is a standard measure for disease progression, currently used methods are prone to errors that arise mainly due to partial volume effects. We present strategies to minimize volumetric errors based on neighborhood histogram modeling. As a first step, such strategies could also be combined with conventional supervised lesion delineation.

Diffusion imaging provides a promising approach to analyzing the white matter structure. While neurosurgeons use diffusion tensor images to preoperatively visualize major fiber bundles such as the corticospinal tract, there is hope to develop diffusion-based quantitative tools that are sensitive to demyelination, tumor infiltration, and other localized pathological processes that afflict white matter integrity. A major difficulty, however, arises from the intrinsic heterogeneity of brain tissue and the related low specificity of cross-sectional diffusion quantification. New paradigms for microstructural imaging might overcome these limitations.

In the future, dedicated computer-aided diagnosis systems might play a more prominent role in neuroimaging than at present. Current approaches might be extended towards full classification of neurodegenerative diseases, such as Alzheimer's or ALS based on MRI and PET, possibly based on new tracers. Likewise, specific patterns of abnormal cortical thinning might be related to populations with a high probability to develop schizophrenia. Epilepsy patients will benefit from a comprehensive and detailed analysis of available morphological and functional information. Lesions loads and, possibly even more important, locations will be characterized and quantified robustly, such that larger imaging studies can be analyzed without human observation. To this end, the individual image quality will have to be monitored automatically and images below a certain quality threshold excluded from analysis. Not least, specialized computer systems for the emergency room might integrate knowledge for a reliable diagnosis in stroke and trauma cases. In such situations, where critical decisions must be reached within a very short time span, CAD in a broader sense receives significance far beyond classical detection and classification tasks, by relating expert knowledge about available treatment options to the sum of available imaging findings.