Statistical Issues in Accessing Brain Functionality and Anatomy

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Among the imaging techniques used in neuroscience there are two, functional MR imaging (fMRI) and diffusion weighted MR imaging (DWI), that especially boosted the research field in the last two decades. Both noninvasive methods allow for an in-vivo analysis of brain activity and brain anatomy.

fMRI focuses on localizing cognitive functionality within the brain gray matter. In a typical designed experiment the proband/patient is exposed to specific stimuli. The recorded data then consists of time series of three-dimensional image volumes where in some voxels (volume elements) a signal response corresponding to the stimuli is observed. This response is related to brain activity via the blood oxygenation level dependent (BOLD) effect. Statistical issues in the fMRI data analysis include adequate modeling, multiple testing, noise reduction and comparisons in groups of subjects, to name just a few.

DWI probes microscopic structures well beyond typical image resolutions through water molecule displacement. It can be used in particular to characterize the integrity of neuronal tissue in the central nervous system. Diffusion weighted data can be viewed as five-dimensional, i.e., living on a 3D grid of voxels with information on water diffusivity measured in N_{grad} directions on the sphere, characterized by two angles. The most common model for such data is the diffusion tensor model (DTI). This model is used to describe main direction of diffusivity and to derive clinically relevant diagnostical quantities. Generalizations focus on modeling and estimation of an orientation density function (ODF) at each voxel. Information from both the tensor model and ODF based models can be used for fiber tracking, characterization of fiber bundles and finally in connection with results from fMRI studies for accessing brain connectivity.

We will illustrate some of the statistical problems that arise and show how they can be addressed within R using packages **fmri** and **dti**. Some open problems will also be discussed.

References

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