Bayesian Modelling of Functional Whole Brain Connectivity - DTU Orbit (01/11/2019)

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This thesis deals with parcellation of whole-brain functional magnetic resonance imaging (fMRI) using Bayesian inference with mixture models tailored to the fMRI data. In the three included papers and manuscripts, we analyze two different approaches to modeling fMRI signal; either we accept the prevalent strategy of standardizing of fMRI time series and model data using directional statistics or we model the variability in the signal across the brain and across multiple subjects. In either case, we use Bayesian nonparametric modeling to automatically learn from the fMRI data the number of functional units, i.e. parcels. We benchmark the proposed mixture models against state of the art methods of brain parcellation, both probabilistic and non-probabilistic.

The time series of each voxel are most often standardized using z-scoring which projects the time series data onto a hypersphere. This underlying manifold is often ignored and the data is modeled using Gaussian distributions. In one contribution, we show that using a mixture model based on the directional distribution, the von Mises-Fisher distribution, increase the reliability of inferred parcellations.

We develop a mixture model for modeling time-series using a Gaussian Process as a prior that is informed of the temporal dynamics of the data expected from the blood oxygenation level dependent (BOLD) signal. In two contributions, we explore the potential of this modeling framework. In the first, we show that this mixture model can delineate regions of task activation that can then be identified unsupervised. This forms a promising framework for unsupervised identification of task activated when the task design is unknown. In the final contribution, we evaluate the performance of the mixture model on the problem of clustering whole-brain fMRI. Based on both simulations on synthetic data and analysis of two fMRI datasets, we show that the model provides improved reliability of clustering compared to traditional clustering methods. Furthermore, the inferred parcellations provide the foundation for a method for increasing the reliability and sensitivity in analyses of task activation and for determining the networks of functionally connectivity in fMRI.

The proposed mixture models form promising tools for brain parcellation and we hope the methods can provide a nudge towards using probabilistic models for fMRI parcellation.

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