Electroencephalography (EEG) provides a measure of brain activity and has improved our understanding of the brain immensely. However, there is still much to be learned and the full potential of EEG is yet to be realized. In this thesis we suggest to improve the information gain of EEG using three different approaches: 1) by recovery of the EEG sources, 2) by representing and inferring the propagation path of EEG sources, and 3) by combining EEG with functional magnetic resonance imaging (fMRI). The common goal of the methods, and thus of this thesis, is to improve the spatial dimension of EEG.

The main topic of this thesis is the localization of the EEG generators. This entails solving both a forward and an inverse problem. The inverse problem maps the EEG signal recorded on the scalp to its origin in the brain. It is a highly ill-posed problem which we tackle by employing a sparsity promoting 'spike and slab' like method augmented with physiologically relevant source priors. The incorporated temporal and spatial priors exploit coherence between neighboring time samples and between neighboring source locations, respectively. We show that these augmentations effectively increase the source recovery ability.

The forward problem describes the propagation of neuronal activity in the brain to the EEG electrodes on the scalp. The geometry and conductivity of the head layers are normally required to model this path. We propose a framework for inferring forward models which is based on the EEG signal and a low dimensional representation of forward models. The representation is built by principal component analysis of a corpus of forward models. The method can be used to recover subject-specific forward models when structural scans and/or conductivity estimations are not available.

Finally we investigate the extraction of EEG components having bandpower dynamics correlated with fMRI components. We show that adding anatomical information to the inference scheme improves the recovery of correlated components compared to only using functional information. The anatomical information is incorporated through the EEG forward model and assumes that the activity of the fMRI component overlaps spatially with the origin of the coupled EEG component.