Spatiotemporal Bayesian Brain Source Imaging

A Hierarchical Multiscale Bayesian Framework with Decoupling Properties

Ali Hashemi

joint work with Stefan Haufe, Gitta Kutyniok, and Klaus-Robert Müller

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Abstract

Understanding the brain structure as the ultimate neural network architecture in nature (10^{12} neurons with 10^{15} synaptic connections) and the way that brain works (process 10^{12} Giga-bits of information per second), is a promising field of research, which is highly motivated by biomedical applications as well as the outstanding success of deep learning frameworks in real-world applications. *Electroencephalography* (EEG) is a noninvasive technique which is highly desirable for brain electrical activity monitoring due to its wide range of advantageous such as its high temporal resolution. The major challenge, however, lies in its poor spatial resolution since the number of brain sources ($32 \sim 256$) is much larger than the number of EEG sensors ($10^3 \sim 10^4$).

In the first part of the talk, we are going to have a brief review of EEG brain source imaging forward and inverse problem and present different regularization techniques in order to deal with the ill-posedness of its inverse problem. Next, we will particularly point out to the very sensitive performance of the presented algorithms in the situations where the design matrix (consisting of forward model, sensing matrix and the dictionary) does not have certain favorable properties. In order to come up with a strategy for addressing this challenge, we will continue our talk by explaining a probabilistic approach for solving inverse problems and describe two major categories in this field called *type I* and *type-II MAP* estimation. We will analyze the *type-II MAP* estimation approach in details, in particular, its multi-scale property which maps the original optimization problem into the form with desirable features. In addition, we will also explain multi-loop procedures in order to solve the resulting optimization problem. Finally, we will finish this part by intuitively focusing on concepts such as non-factorial (non-separable), dithering, decoupling, and coherence-compensation, which has been achieved by having a hierarchical multiscale Bayesian perceptive.

We introduce our contributions in the second part of the talk. First, by connecting *type-II MAP* estimation algorithms to the re-weighted schemes, we will propose a unification perspective on presented algorithms in the preceding part of the talk, based on the *majorization-minimization* (MM) algorithms. We continue by extending the whole framework to cover temporal correlation and finding tight convex upper-bounds for improving the performance of MM algorithms in certain settings. If time permits, we will show an interesting connection between multi-loop algorithms (such as *type-II MAP* estimation techniques) to the recurrent neural network (RNN) architectures with memory, e.g. LSTM, in addition to their unfolding strategies. (This section is done in collaboration with Hector Andrade Loarca).

Finally, in order to have some discussions and getting some technical comments and feedback, I am going to present some of my preliminary rough ideas regarding the multi-level structures as well as decoupling properties in the context of "Plug and Play" algorithms and "Fusion Frames" structures.