ABSTRACT OF PhD THESIS

PREPROCESSING OF LOW-CHANNEL EEG SIGNALS

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One of the crucial but as yet insufficiently addressed aspects of brain function monitoring is the issue of recording EEG signals outside of controlled laboratory conditions and without the supervision of qualified medical staff. Constant monitoring of cognitive functions in a noisy environment can be highly beneficial in the case of professions demanding highly focused and sustained attention, such as airline pilots or drivers or in the neuromarketing research. Of course, the continuous monitoring of EEG signals outside of scientific laboratories, research centres or medical clinics is not an easy task. There are numerous issues that need to be addressed, and the two with the highest priority are the low signal quality in an outside-lab environment and insufficient user comfort.

ICA (Independent Component Analysis) is a linear spatial filter often used in EEG signal analysis for tracing all kind of artifacts, e.g. ocular, muscle, electrocardiographic, or power line artifacts. Although a lot of research confirmed that ICA enhances SNR (Signal to Noise Ration) of EEG signal for high number of EEG channels, from 16, through 19-20 up to 71 and even many more, very few studies analyzed the outcomes of ICA in a low-channel setup. The reason is that in order to solve the linear ICA model two conditions have to be fulfilled: 1) the sources must be statistically independent, with at most one source of a Gaussian distribution; 2) the number of signals in the sensor domain should be at least as large as the number of sources that we want to extract

PhD thesis presents a method that enables the application of ICA in a low-sensor environment. The idea behind the approach, called MAICA, is to create artificial input signals by applying a set of zero-phase moving average filters to the recorded EEG channels and to use ICA on the dataset composed of original EEG channels and their filtered versions. The main advantage of MAICA is that it fulfils the assumption of preserving the mixtures of sources in the input matrix. By using moving average filters with the smallest possible windows, MAICA repeats most of the information that is contained in the signals recorded from sensors. In this way, not only the dimension of the input ICA matrix is extended but also the linear transformation is much more effective.

PhD thesis discusses the theoretical background of the MAICA algorithm and verifies its usefulness on three exemplary systems of different characteristic dependent components.

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The first system (purely mathematical), shows that MAICA is able to decompose two mixed signals (composed of 10 source sinusoids) into 10 components with an extremely high correlation between the sources and components (99-100%). The second system (15-seconds long real EEG data recorded from 64-channels) presents that MAICA used over only 5 channels is able to recognize similar artifacts as classic ICA used over all 64 channels. Finally, the last system (5 subjects, 200 trials, motor imagery classification) proves that MAICA is capable to work in an online mode without significant delays (the additional time needed for running MAICA for one trial was smaller than 6ms).

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