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Relevant Frequency Estimation in EEG Recordings for Source Power Co-Modulation

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Introduction: Non-invasive neuroimaging techniques as EEG and MEG allow measuring oscillatory sources related to different cognitive processes. On the sensor level, these techniques deliver a mixture of the underlying source activity, which is caused by volume conduction and impedes the analysis and interpretation of measured brain data. Spatial filters determined by the Source Power Co-modulation algorithm (SPoC) [1] allow to extract sources whose band-power values correlate with a given target variable in single trial. However, SPoC requires prior knowledge about the frequency band of interest, which may contain such co-modulating sources. As brain signals vary between individuals, prior knowledge about optimal frequency bands may not be available or require a full search over the spectrum.

As a remedy, we present the SPEC-SPoC algorithm, following the idea of the SPEC-CSP algorithm introduced in [2]. SPEC-SPoC co-optimizes not only spatial filters as in standard SPoC, but in addition it determines a spectral filter, which defines a suitable frequency band. SPEC-SPoC is tested on EEG data of a steady-state auditory evoked potential (SSAEP) paradigm, for which the optimal frequency is known.

Material, Methods and Results: SPoC optimizes a set of spatial filters by first weighting the trial-wise spatial covariance of the EEG signals with the target variable and then decomposing it into its main components. This first step allows to extract the components or sources which have the strongest (anti-) correlation between their band-power and the target variable. To estimate the frequency of interest, this SPoC-step is alternated with second step to computation for each frequency bin the correlation between the band-power of the decoded sources and the target variable. As the frequency bins of the original data are re-weighted using the obtained relevance value, this second step enhances the most relevant frequency components and suppresses irrelevant ones. The described two-step procedure is repeated until convergence. For the SSAEP datasets collected from seven healthy subjects, the target variable corresponded to the loudness of the auditory stimuli, whereas the ground truth frequency of interest was the SSAEP stimulation frequency of 40 Hz.

Fig. 1(a) exemplifies the spatial and spectral patterns for one of the subjects (S1), where the spectral pattern shows that the identified relevant frequency is exactly at 40 Hz. Furthermore, Fig. 1(b) compares correlation coefficients of sources yielded by SPEC-SPoC (red) versus those obtained by standard SpoC (blue), which was applied after a 40 Hz band pass filter.

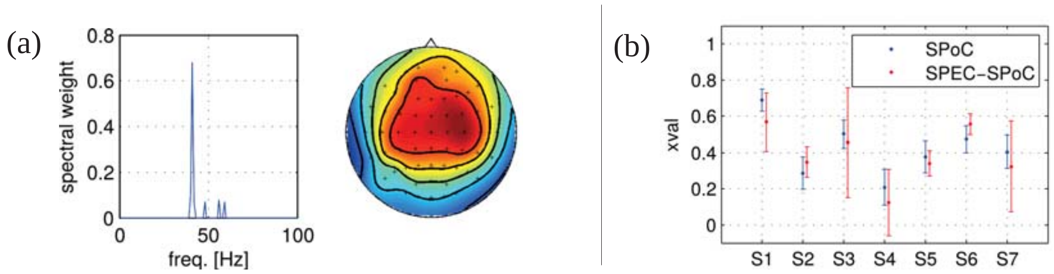

Figure 1. *(a) Example of spectral filter (left) and spatial (right) pattern obtained via SPEC-SPoC for subject S1. The target frequency (40 Hz) is successfully identified. (b) Mean correlation values and standard deviations of sources with the performance metric, achieved by SPoC (blue) and SPEC-SpoC (red), for each of the studied datasets. Performance of SPEC-SPoC is comparable to the one achieved by SPoC, with SPEC-SPoC inferring the relevant frequency band from the data.*

Discussion and Significance: Determining the frequency band informative for a phenomenon under study is a problem which has not been addressed for the SPoC algorithm. With SPEC-SpoC, the automatic tuning of a spectral filter to identify the optimal frequency band becomes possible in a purely data-driven approach. SPEC-SPoC yields results which are not statistically different to those obtained by SPoC ($p=0.8048$). While the latter makes use of *a-priori* knowledge about the informative frequency-band, SPEC-SPoC was able to infer this information from the data. Compared to a brute-force grid search, the new algorithm may reduce run time and the need of user interaction, thus contributing to more accurate, faster and reliable results.

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