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EEG Clustering Based on Phase Synchrony for Self-paced BCI Development

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Introduction: Task-dependent neural synchronization is a general phenomenon which has been theoretically and empirically linked to the dynamic organization of communication in the nervous system [1]. Hence, the study of phase synchrony patterns over time during a specific mental task might be useful to determine if such a task is suitable for self-paced BCI control. This work presents a method for analyzing the dynamics of instantaneous phase between EEG channels over a single trial via clustering using circular statistics for directional data over varying frequency ranges. Time-Frequency-Topography (TFT) maps [2] are used to visualize the distribution over the scalp of clusters of channels that are considered highly phase-locked.

Material, Methods and Results: The clustering method consists of the following steps: a) computation of the continuous wavelet transform of each channel with a complex Morlet wavelet at varying frequencies, b) extraction of phase information per epoch, c) generation of clusters (channel wise) according to phase-locking calculation for each time *t*. In order to gauge the degree of phase-locking and formation of clusters, we used the length of the so-called mean resultant vector $\bar{R}$, which is the foremost quantity for measurement of circular spread in directional statistics [3]. Length of $\bar{R}$ is close to 1 when EEG channels are highly phase-locked; it is close to zero otherwise (Fig. 1a). d) Construction of the TFT maps over specified time windows. Each topographic map represents the cluster modes of all samples for each electrode within the time window (Fig. 1b).

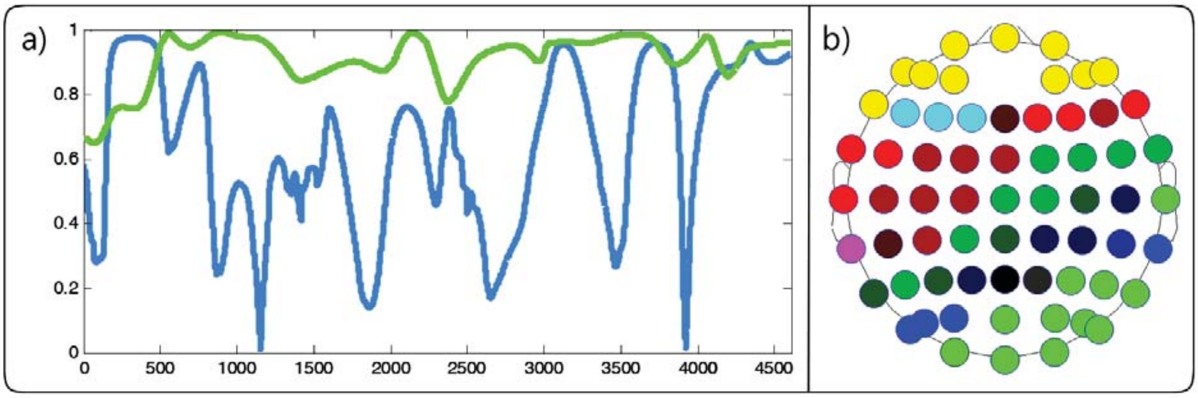

Figure 1. *a) Comparison between length values of $\bar{R}$ for each time t in a 18 seconds epoch of baseline (blue) and during imagined singing (green) for a group of EEG channels, centered at 12 Hz. b) Example of a TFT map, at 500 ms, centered at 7 Hz.*

Discussion: Our method provides a feasible way to address the analysis of phase-locking of EEG signals within single trials and characterizing their variability over time. As observed in Fig. 1a, it seems that values of vector $\bar{R}$ could be an effective feature for classification, which are clearly distinct between both conditions (baseline & imagined singing). We have developed a toolbox for both MATLAB and GNU Octave that implements our method and generates TFT maps, among other functionalities for asynchronous BCI design.

Significance: The majority of phase-locking measures so far suggested in literature, such as Phase-Locking Value (PLV) or Phase Cross Coherence (PCC) are calculated between two signals. The proposed method is an alternative for studying the behavior of the phase synchronization between all EEG channels at once in a given time window, within different bandwidths of interest.

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