Abstract

Brain Computer Interface (BCI) or Brain Machine Interfaces (BMI), has proved the feasibility of a distinct non-biological communication channel to transmit information from the Central Nervous System (CNS) to a computer device. Promising success has been achieved with invasive BCI, though biocompatibilities issues and the complexity and risks of surgical procedures are the main drive to enhance current non-invasive technologies.

Electroencephalography (EEG) is the most widespread method to gather information from the CNS in a non-invasive way. Clinical EEG has traditionally focused on temporal waveforms, but signal analysis methods which follow this path has been overshadow in BCI research.

This thesis propose a method and framework to analyze the waveform, the shape of the EEG signal, using the histogram of gradient orientations, a fruitful technique from Computer Vision which is used to characterize image local features. Inspiration comes from what traditionally electroencephalographers have been doing for almost a century: visually inspecting raw EEG signal plots.

The validity of the method is verified by identifying and detecting Visual Occipital Alpha Waves and Motor Imagery Rolandinc Mu rhythms. It is also applied on P300 ERP detection and used to implement a P300-Based Visual Speller application. Experimental protocols to produce these cognitive patterns were designed and own datasets produced and published using both commercial-grade and research-grade EEG devices. Obtained results on public and own datasets are outlined and described, and comparisons performed against similar procedures.

The benefits of the approach presented here are twofold, (1) it has a universal applicability because the same basic methodology can be applied to detect different patterns in EEG signals with applications to BCI and (2) it has the potential to foster close collaboration with physicians and electroencephalograph technicians because this direction of work follows the established procedure of the clinical EEG community of analyzing waveforms by their shapes.

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This technique can be outlined in five steps, (1) signal preprocessing, (2) signal segmentation, (3) transformation on a channel by channel basis of each signal segment into a binary image of a signal plot, (4) assignment of keypoint location on a position over the newly created image depending on the physiological phenomena under study and finally (5) the calculation of the histogram of gradient orientations using finite differences from the image around this keypoint. This method generates a feature, a normalized 128-dimension descriptor. This feature is used to compare the signal segments that were used to generate them, hence to analyze the underlying cognitive phenomena.

The validity of the method was verified by studying three cognitive patterns. First, Visual Occipital Alpha Waves are analyzed. An experimental protocol is designed and a dataset is produced using a commercial-grade EEG device. Additionally, the ability of the method to capture oscillatory processes is verified by analyzing a public dataset. Moreover, this methodology is extended to study a related oscillatory process: Motor Imagery

Rolandic Mu rhythms. The performance of the method to discriminate right vs left motor imagery against a public dataset of healthy subjects is verified. Results are informed and reported. Finally, the method is modified to capture transient events, particularly the P300 Event Related Potential. A minute description on how to extract the ERP from the EEG segment is offered, and a detailed description of how to implement a P300-Based BCI Speller application is outlined. It's performance is verified by processing a public dataset of ALS patients and contrasted against an own dataset produced in house replicating the same experimental conditions.

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