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ANALYSIS OF EEG SIGNALS FOR EMOTION RECOGNITION

Doctoral thesis under the supervision of
prof. dr hab. inż. Katarzyna Stąpor

Main discipline: Computer science

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Abstract of the doctoral dissertation

The human brain contains around 86 billion neurons generating an electrical activity that is a biological foundation of learning, memory, behavior, perception, consciousness, and emotions. Revealing how billions of electric impulses map into our mind and emotions is the ultimate goal of neuroscience. This electrical activity of the brain may be measured non-invasively using an electroencephalogram (EEG). However, the EEG signals from tens of electrodes placed on the scalp of the head are impossible to decode without advanced computational methods. My thesis focuses on methods for processing event-related potentials (ERP) generated by synchronized and repeatable activity of neurons in response to emotional facial expressions.

In my dissertation, I prove that proper hardware adaptation (i.e., a custom stimuli marking circuit), a wavelet-based artifact filtration, and a robust weighted averaging (RWA) enable differentiation between ERPs induced by images of different emotional facial expressions (angry/happy vs neutral), as reflected in the early posterior negativity (EPN) ERP component, using the low-cost Emotiv EPOC+ EEG device. The proposed stimuli marking circuit allows for precise timing of brain responses in low-cost devices which is crucial in ERP analysis, and the proposed wavelet-based filtering and RWA significantly increase the signal-to-noise ratio of ERP waveforms. Additionally, I implemented improvements to the RWA method that achieved 45% lower RMSE error in the simulation study and increased robustness to outliers in real-life data.

In the second part of the dissertation, I propose proper EEG processing, including a new method of ocular artifacts filtration, for single-trial ERP analysis of neural processes of face learning as reflected in the N250 component. This component is a confounder of EPN component, so its better understanding is crucial to disentangle the processes of face familiarity acquisition and emotional face processing. Single-trial ERP analysis in high temporal resolution needs an advanced signal processing pipeline like the one proposed in my dissertation. It includes a new semi-automatic ocular artifact filtration with only one hyperparameter based on the correlation between EEG components from independent component analysis (ICA) and the electrooculography (EOG) signal. It provides a state-of-the-art improvement in signal-to-noise ratio and 25% lower standard deviations in time series of N250 component amplitudes.

All the proposed methods can be applied not only in emotion recognition but in countless different applications using ERP features, e.g., brain-computer interfaces, medical diagnosis, and psychology research. They will help neuroscientists and psychologists to design better ERP experiments, contributing to a better understanding of the human brain.