A smartphone interface for a wireless EEG headset with real-time 3D reconstruction

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Abstract. We demonstrate a fully functional handheld brain scanner consisting of a low-cost 14-channel EEG headset with a wireless connection to a smartphone, enabling minimally invasive EEG monitoring in naturalistic settings. The smartphone provides a touch-based interface with real-time brain state decoding and 3D reconstruction.

Introduction

Functional brain imaging techniques including fMRI and PET provide moving picture access to the living human brain, however, relying on complex, heavy hardware they offer limited comfort for the user, and thus can not be used under naturalistic conditions. This induces largely unknown biases into the current state of the art brain scanning, thought to be particularly problematic for studies of emotion and social cognition [1]. While cap-based EEG systems are less constraining, their wiring typically limits comfort and movement. There are obvious advantages of brain monitoring under naturalistic conditions, to study how we perceive our surroundings in mobile real-life settings [1]. Here, we demonstrate a minimally invasive and mobile brain monitoring system (see Fig. 1) offering real-time brain state decoding and 3D cortical activity visualization within a low-cost highly mobile smartphone environment. The system can quantify brain states, e.g. emotional responses, and the 3D visualization can be used for bio-feedback. Such feedback can have significant behavioral effects including improvements in reaction times, emotional responses, and musical performance, while clinical applications include attention deficit, hyperactivity disorder, and epilepsy [2]. Such applications will benefit from a low-cost and easy-to-use personal brain monitor.

System Architecture

Our system constitutes a fully portable EEG based real-time functional brain scanner including stimulus delivery, data acquisition, logging, brain state decoding and 3D activity visualization. The raw EEG data is acquired with a wireless Emotiv 14 channel 'Neuroheadset' with a sampling rate of 128Hz and electrodes positioned at AF3, F7, F3, FC5, T7, P7, O1, O2, P8, T8, FC6, F4, F8, AF4 (the

Fig. 1. (left) The system with Emotiv EPOC wireless EEG headset (1), Receiver module with USB connector (2), USB connector and adapter (3+4), and Nokia N900 (5). (right) Touch-based interaction with a 3D model of the brain using the smartphone.

international 10-20 system). The headset transmits the EEG data to a receiver module connected to a Nokia N900 smartphone. Custom-made software for the phone transmits the EEG data to a server or processes it locally, enabling real-time brain state decoding and a rich bio-feedback signal for the user in the form of a 3D rendering of the active cortical EEG sources. The user can interact with the 3D brain model by touch gestures (see Fig. 1).

Evaluation

A major concern in mobile real-time systems is the power consumption, hence battery life. Our experiments with local logging of EEG data allowed 7.5 hours continuous usage, whereas remote logging allowed 3.5 hours. The 3D brain model contains 1028 vertices and 2048 triangles and is stored in the mobile application. Brain activity is reflected by changing colors, allowing rendering performance of approximately 30 fps and fluent touch-based interaction with the 3D model. The current design of the system has a delay of approximately 150 ms. between the signal emerging in the brain and being visualized on the smartphone. We have performed brain state decoding experiments including simple finger tapping and more complex affective stimuli (IAPS picture viewing). In both cases we have found that the system decodes at error rates significantly less than a random baseline model. In conclusion, our early tests of the system indicate the potential of minimally invasive and low-cost EEG monitoring in naturalistic settings.

Supporting Material. http://milab.imm.dtu.dk/eeg

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