 DOI:10.3217/978-3-85125-260-6-92

Dry and Wireless EEG-Based Brain-Computer Interfaces for Real-World Applications

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Abstract. This study develops successively high-density, wearable, wireless and portable EEG-based BCI devices that address laboratory-grade data acquisition, long-term comfortable wear, quick user set-up, and high portability. The new BCI devices feature amplifier-embedded active dry EEG sensors, head circumference adapted mechanical designs, miniature supporting electronics, wireless telemetry, and mobile apps for real-time signal processing. Results from initial applications show promise for rapidly enhancing our ability to assess human brain activity in real-world scenarios.

Keywords: Electroencephalogram, dry electrode, Brain computer interface, Congnitive applications

1. Introduction

Electroencephalogram (EEG) is a powerful non-invasive tool widely used in both medical diagnosis and neurobiological research as it provides high temporal resolutionin neuroimaging. Another important advantage of EEG is that it involves sensors light enough to allow near-complete freedom of movement of the head and body, making EEG the clear choice for brain imaging of humans performing normal tasks in real-world environments. This study develops several form factors of dry and wireless EEG-based Brain-Computer Interfaces (BCIs). This study also demonstrates the applications of the proposed Brain-Computer Interface (BCI) systems for real-time cognitive-state monitoring and gaming.

2. Material and Methods

The objective of this study is to design dry, wireless EEG systems that address laboratory-grade data acquisition, long-term comfortable wear, quick user set-up, and high portability. This study first develops amplifier-embedded active dry sensors to acquire augmented EEG data avoiding the need of skin preparation and gel application to ensure good conductivity between the electrodes and skin (Liao et al, 2012; in press). Then, the state-of-the-art sensor technology was combined with a novel head circumference adapted mechanical design to support comfort, fast set-up, and improved stability.

3. Results

Several dry and wireless EEG/BCI devices (MINDO®, Taiwan) have been developed and used to acquire user’s EEG signals continuously (Fig. 1A-D). The active dry sensors amplify measured signals at very early stage to improve signal-to-noise ratios.

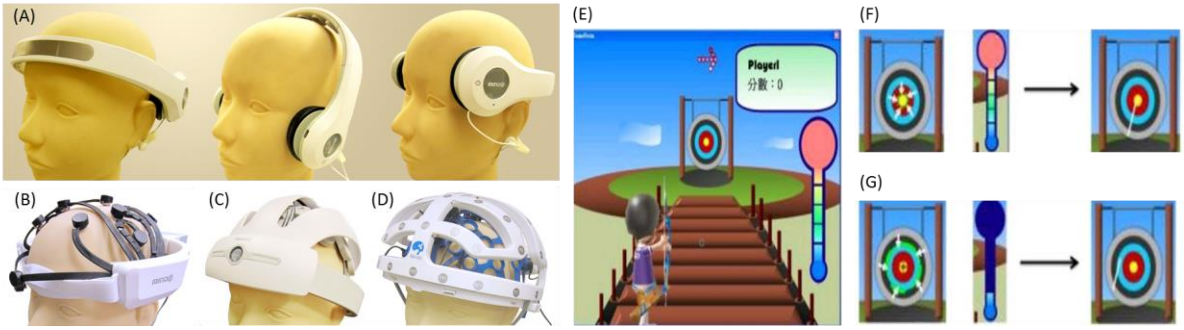

Figure 1. *Dry and wireless EEG devices with successively higher-density (A) 4 channels, (B) 16 channels, (C) 32 channels and (D) 64 channels. (E) A brain-controled application uses the proposed EEG-based BCI systems. The BCI detects the user's attentional level (measured by EEG power) to control the release of the arrow in a Brain Archery game (F) As the attention level increases, the arrow reaches the center of the target and gets a high score. (G) The arrow misses the target center when the player is distracted.*

The novel head circumference adapted mechanical design reduces user set up time and extends the duration of system wearability. Wireless telemtry allows ubiquitous brain monitoring and increases user mobility. The system can easily be used by technicians with limited experience and naïve participants. Figure 1E shows a brain-controlled video game, Brain Archery, in which the player manipulates their attentional level, measured by EEG power, to control the arrow release. A higher attentional level yields a higher score (Fig. 1F). Results of this study showed that most of participants can quickly learn strategies to control their attentional levels and improve their scores, without any training or practicing.

4. Discussion

This study demonstrated truly portable, lightweight, and readily wearable BCIs featuring dry EEG electrodes, a miniaturized DAQ, wireless telemetry and online signal processing. The main goal of the design and development of dry and wireless BCIs is to maximize their wearability, mobility, usability and reliability in real-world environments. We expect that the truly dry, wireless and user-acceptable BCI developed under this study will significantly improve the practicality of real-life applications of BCI for users actively behaving in and interacting with their environments.

Acknowledgements

This work was supported in part by the National Science Council, Taiwan, which established the "International Research-Intensive Centers of Excellence in Taiwan" (I-RiCE Project, NSC 101-2911-I-009-101); and U.S. Army Research Laboratory (W911NF-10-2-0022).

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