

## A mobile and wireless brain-computer interface for communication in daily life

### Introduction

Moving a brain-computer interface (BCI) from a laboratory demonstration to real-life applications poses severe challenges to the BCI community [1][2]. Recently, with advances in the biomedical sciences and electronic technologies, the development of a mobile and online BCI has obtained increasing attention in the past decade [3]. A mobile BCI has the advantage of ultimate portability as well as a low system cost derived from using customized Electroencephalogram (EEG) recording and signal processing modules. To implement a mobile BCI with online processing, a mobile terminal such as a mobile phone or a PDA might be an ideal platform for data transmission, signal processing, and feedback presentation. In this study, we aim to integrate a wearable and wireless EEG system with a mobile phone to implement a visual-evoked potential (VEP) based BCI, which can be used to directly make phone calls based on users' EEG.

### Methods

A typical VEP based BCI using frequency coding consists of three parts: visual stimulator, EEG recording device, and signal processing unit [4]. In this study, a virtual keypad consisting of 12 flickers (indicating 10 digits, *backspace*, and *enter*) displayed on a computer monitor was used as the stimulator. The stimulus frequencies ranged from 9Hz to 11.75Hz with an interval of 0.25Hz between two consecutive digits. EEG was measured using a wearable and wireless 4-channel EEG recording module [5]. A head strap with embedded electrodes was used to fix electrode positions over the occipital area. The EEG signal digitized at 128Hz was transmitted to a Nokia N97 (Nokia Inc.) mobile phone via a wireless Bluetooth module. On the phone, a J2ME program developed using Borland JBuilder 2005 in conjunction with Wireless Development Kit 2.5 was installed to perform online procedures including frequency detection of the VEP, feedback presentation, and phone dialing.

In the experiments, the users were instructed to dial a 10-digit phone number by looking at the flickered digits sequentially. In each trial, a 512-point Fast Fourier Transform (FFT) with a 1s step was started at 4s to calculate the power spectra of the elicited SSVEP until the same dominate frequency of the VEP was detected twice consecutively. For each digit selection, the sound of the digit was delivered through the cell-phone speaker as auditory feedback and the cue for the next target. There was a 1s interval between trials for the users to rest and shift their gaze directions to the next target.

### Results

Ten healthy subjects with normal or correct-to-normal vision participated in the experiments. To facilitate system operation, only one electrode around the Oz site was used for online processing. All subjects completed the dialing task with a mean accuracy of  $95.9 \pm 7.4\%$ . The information transfer rate (ITR) of this cell-phone based BCI system was  $28.5 \pm 7.8$  bits/min, which was comparable to other VEP BCIs [4].

## Conclusions and Discussion

In this study, we proposed to design, implement and test a mobile and wireless platform for BCI. The portability of the wireless EEG hardware, the ubiquity of cell-phones, and the flexibility of the software implementation make this platform promising for BCI's real-world applications. The testing results demonstrated the feasibility of using this platform for constructing a practical wearable and wireless BCI. Directions for future work include the use of dry EEG electrode [5] and spatial and/or temporal filtering of the acquired EEG data to further improve the system performance.

## References

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