THE SSVEP-BASED BCI SYSTEM WITH HIGH TRANSFER RATE

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The Lab of Medical Information Engineering is a research division under the Department of Biomedical Engineering, School of Medicine, Tsinghua University, Beijing, China. Our research scopes include the detection, processing, analysis, recognition, transmission and management of medical information in various biomedical signals and images. Currently, the most active research areas in the lab are: (1) Brain and neural information engineering; (2) Medical Imaging and image processing. In addition, the general theory of biomedical signal processing is also a subject of our long-term research.

In the area of brain and neural information engineering, our interests fall mainly around ***3D dynamic imaging of brain electrical activities*** and ***brain-computer interface***. The research projects cover the extraction of transients in EEG, single trial and dynamic analysis of EP and ERP, dipole localization in the brain, high- resolution EEG, independent component analysis (ICA) of EP and ERP nonlinear dynamics, and approximate entropy (ApEn) analysis of EEG. In addition, to develop novel signal processing methods, some applied software has also been developed, such as the epileptic discharge wave detection, brain-computer interface (BCI), sleep analysis, perception and cognition analysis.

Since 1999, we have been engaged in brain computer interface research. We have developed a BCI system based on steady state visual evoked potentials (SSVEPs). Our first paper published in this area is in the first joint meeting of BMES and EMBS, in Atlanta, 1999. The title of the paper is "An EEG-based cursor control system".

To develop a practicable EEG based BCI system, we seriously consider the following problems:

(1) The information transfer rate.
The information transfer rates of current BCI devices are rather low. If this rate could be increased, BCIs might become a useful tool for people to interact with their environment.

(2) Requirements for training.
Long time training is always not expected. BCIs based on evoked potentials may require less training.

(3) The medical invasiveness.
The less invasive the technique is, the more likely it can be used in a wide range of applications.

(4) Least number of electrodes for data acquisition.
To mount a large number of electrodes on scalp will be time consuming and tiresome. The strategy of using a small number of electrodes in the system will be welcome in practice.

(5) System should be easy to carry and easy to use.

Based on the above considerations, we have developed a SSVEP-based BCI system which bears the advantages of high transfer rate, minimal training and noninvasiveness. The system focuses on EEG activity that occurs at a specific frequency and specific location of cortex. These characteristics simplify the feature extraction procedures and the necessary training.

We have applied our SSVEP-based BCI prototype system to control cursor movements, home electrical appliances and to make phone calls. The main features of our system are:

(1) Larger number of inputs. One can pick up a specific target out of as many as 40 candidates.
(2) Fewer electrodes for data acquisition. Only two active electrodes are used in a wireless EEG system.
(3) Higher transfer rate: the average transfer rate over all testees was 27.15 bits/min, the higher one is over 50 bits/min.

Future work will seek to develop a compact and portable system and put it to practical use. Also, increasing the input accuracy and the applicability to a larger range of users are necessary.

ON-LINE MEASURMENT OF MENTAL WORKLOAD

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Perhaps the most basic issue in the study of cognitive workload is the problem of how to actually measure it. Here, we review our long-term program of research aimed at developing cognitive workload monitoring methods based on EEG measures. This research program began with basic studies of the way neuroelectric signals change in response to highly controlled variations in task demands. The results yielded from such studies provided a basis on which to develop appropriate signal processing methodologies to automatically differentiate mental effort-related changes in brain activity from artifactual contaminants, and for gauging relative magnitudes of mental effort in different task conditions. These methods were then evaluated in the context of more naturalistic computer-based work. The results obtained from these studies provide initial evidence for the scientific and technical feasibility of using EEG-based methods for monitoring cognitive load during human-computer interaction.

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