# Brain Computer Interface-based Multimedia Controller

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*Abstract*—**Music is a way of expressing our feelings and emotions in daily life. Suitable music can affect people in a positive way. However, current multimedia control methods, such as manual selection or automatic random mechanism which is now applied broadly in MP3 and CD player, cannot adaptively select suitable music according to the user's state. In this study, we proposed a novel brain computer interface (BCI)-based multimedia controller to help people to select suitable music according their cognitive states. In our system, a multimedia control MIDlet program built in the mobile phone was developed to recognize the user's cognitive state and select suitable music according his/ her cognitive state. A wireless multi-channel electroencephalograph (EEG) acquisition module was also designed for monitoring the user's EEG. By the property of selecting suitable music type according to the user's cognitive state, our BCI-based mobile multimedia controller provides a novel prototype of multimedia controller.**

***Keywords-brain computer interface, electroencephalograph, multimedia controller***

## I. INTRODUCTION

Music is a way of expressing our feelings and emotions in daily life, which helps us to calm down and reduce the stress of the daily routine. Nowadays, music has also been approved as a significant approach to help and enhance people in not only physiology but also psychology.

Furthermore, some researches concentrated on the relationship between music listening and performance. Listening music could positively enhance software design performance [1] and workers benefit work satisfaction, productivity, and concentration from listening music [2]. In the contrary, people can be distracted and get worse performance by background sound while working, especially by high arousal music [3], and other proposal denoted music brings both positive and negative affect to users [4]. However, Cassidy and MacDonald [5] proposed that performance is largely optimised if people could select music depending on preference. Some studies applied rhythm of music as rule to recommend suitable music for appropriate activities [6] or used social tags to assist selection [7]. Thus, it is reasonable to consider performance of people could be directly affected by music in a positive way if listeners choose suitable music on their own cognitive states. For example, activities, such as exercise and working that people require alert cognitive state, are more suitable for quick tempo music; On the other hand, relaxing and sleeping that people are under drowsy state are appropriate for slow tempo music.

However, current multimedia control methods, such as manual selection or automatic random mechanism which is now applied broadly in MP3 and CD player, cannot adaptively select suitable music according to the user's cognitive state. In order to achieve this aim, a novel Brain Computer Interface (BCI)-based mobile multimedia controller is proposed in this study. Different from manual selection or automatic random mechanism, our BCI-based multimedia controller can select suitable music type according to the user's cognitive state. Brain computer interface provides a feasible and non-invasive way for the communication between the human brain and external devices Various kinds of BCI-based multimedia controllers have been proposed in previous studies [8]-[10]. Lalor et al. proposed MindBalance system to control videogame [8]. Leeb et al. developed Graz-BCI system for virtual reality control [9]. Shyu et al. proposed a Field-Programmable Gate-Array (FPGA)-based Steady State Visually Evoked Potential (SSVEP) BCI multimedia control system [10]. However, the above BCI-based multimedia controllers require the user's active mental command to control multimedia, but cannot select music automatically and adaptively according to the user's current cognitive state. Moreover, most of BCI systems require bulky and expensive EEG machines, personal computers, and commercial software to real-time process EEG. This also limits the feasibility of BCI-based multimedia controller for daily applications.

With rapidly increasing popularity of mobile phones, using mobile phones as assistive technology device of music listening becomes feasible and convenient. Mobile phones contain small-volume and light-weight properties. In particular, recently mobile phones trend to offer more advanced computing ability, connectivity, and music efficiency. In the proposed BCI-based multimedia controller, a commercial mobile phone is used as the development platform. A multimedia control MIDlet program built in the mobile phone, which contains a cognitive state detection algorithm used to detect the user's cognitive state, was also developed. The program can continuously monitor EEG signal acquired from external EEG machines, and then recognize the user's cognitive state. When the playing music is toward the end, the multimedia control MIDlet program will decide the next music type according to the user's cognitive states. Moreover, a novel wireless multi-channel EEG acquisition module was also designed in this study. Difference from other bulky EEG machines, the portability of our wireless multi-channel EEG acquisition module is more suitable for daily applications. This paper is organised as follows. The system architecture is described in Section II. In Section III, this paper describes the system software design. More discussion is conducted in Section IV. Conclusion of this project is given in Section V.

## II. SYSTEM ARCHITECTURE AND DESIGN

The system hardware, illustrated in Fig. 1, contains a wireless multi-channel EEG acquisition module and a commercial mobile phone. Here, the wireless multi-channel EEG acquisition module is designed to acquire multi-channel EEG signals simultaneously and then transmit these EEG signals to the commercial mobile phone wirelessly. A multimedia control MIDlet program with a cognitive state detection algorithm is built in the commercial mobile phone. It will receive and analyze the acquired EEG signal, and then store the estimated cognitive states continuously. Four types of music are stored in the four different folders of the commercial mobile phone. When the playing music is toward the end, the suitable type for next music will be decided according to the user's cognitive states. The wireless multi-channel EEG acquisition module is shown in Fig. 2. Fig. 3 shows the GUI screenshot of the multimedia control MIDlet program.

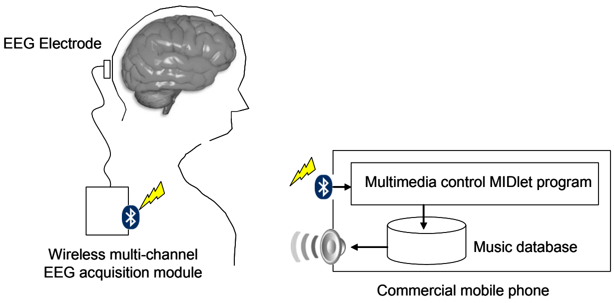


Fig. 1 Basic scheme of proposed mobile multimedia controller by using brain computer interface

## III. SYSTEM SOFTWARE DESIGN

### A. *Cognitive State Detection Algorithm*

The changes of the cognitive state and memory performance usually are reflected from EEG spectra in theta rhythm (4~7Hz) and alpha rhythm (8~11Hz) [11]-[13]. According to the above mentioned property, Pal et al. proposed an unsupervised subject- and session- independent approach to detect drowsiness departure from alertness [13]. Moreover, they also found that EEG spectra in alpha and theta rhythm, obtained from the occipital midline (the location Oz, O1, O2 in the international 10–20 EEG system), can provide discriminating power and have high correlation with the user's cognitive state. The flowchart of the cognitive state detection algorithm proposed by Pal et al. is shown in Fig. 4.

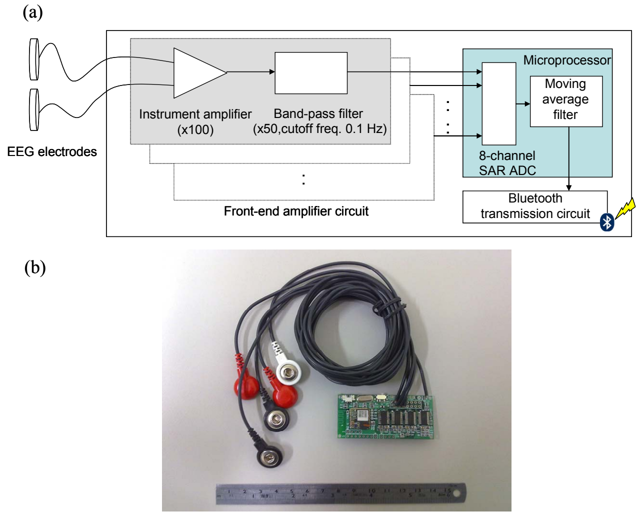


Fig. 2 (a) System architecture and (b) photograph of wireless multi-channel EEG acquisition module

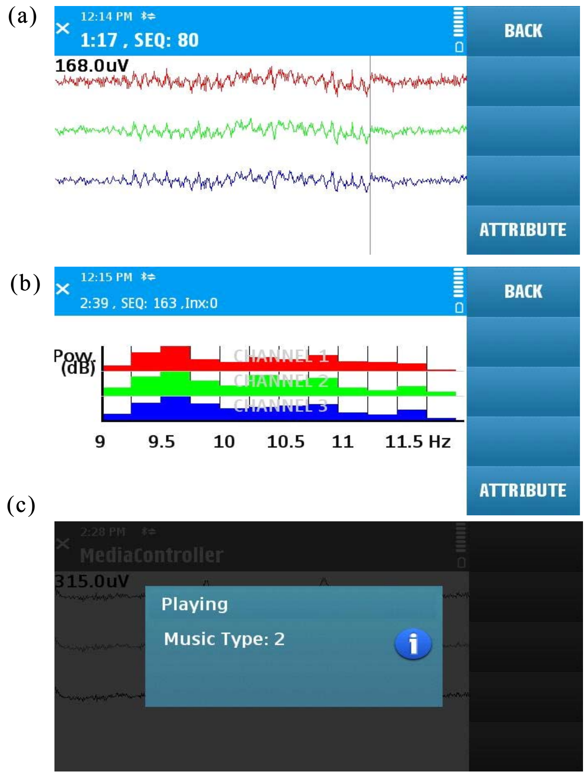


Fig. 3 Screenshot of multimedia control MIDlet program: (a) displaying raw EEG signals, (b) displaying EEG spectra, and (c) selecting music type

First, EEG signals recorded from the location Oz, O1, O2 by using the wireless multi-channel EEG acquisition module will be preprocessed. EEG data will be down-sampled to 64 Hz of sampling rate to reduce the computation load, and 512-point FFT with 448-point overlap will be used to obtain EEG spectra. The model for alert state can be derived by EEG recorded during the first few minutes under the assumption of that the user should be in an alert state during the first few minutes.

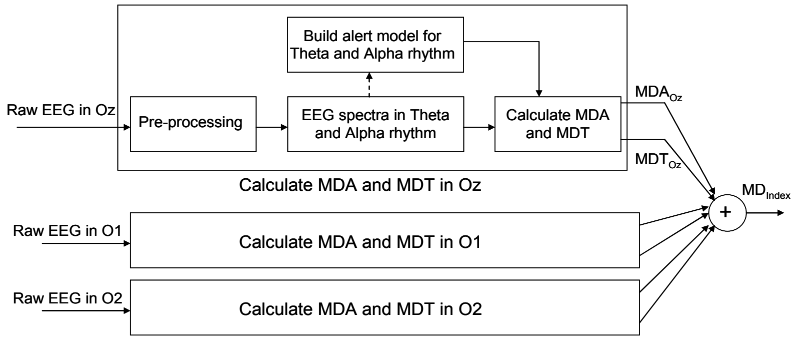

Fig. 4 Flowchart of cognitive state detection algorithm

If the user remains alert, his EEG spectra in theta and alpha rhythm should match the alert model; otherwise, if the user is under drowsy state, his EEG spectra should be diverge from the alert model. Here, the first three-minute EEG spectral data is used to derive the alert model. The multivariate normal distribution $N(\mu, \Sigma^2)$ is used to characterize the model of the alert state. Here, $\mu$ and $\Sigma$ denote the mean vector and variance-covariance matrix respectively. We use $(\mu,\Sigma^2)_{Oz-A}$ and $(\mu,\Sigma^2)_{Oz-T}$ to represent the alert models for alpha and theta rhythms in the location Oz. Next, the Mahalanobis Distance from the alert mode for Alpha rhythm (MDA) and for Theta rhythm (MDT) will be calculated directly from the following EEG spectra. Let $\mathbf{EEG_{Oz-A}}$ and $\mathbf{EEG_{Oz-T}}$ be EEG spectra obtained from Oz in alpha and theta rhythms respectively at some time instant, the deviation from the alert model can be calculated by

$$MDA_{Oz}(\mathbf{EEG_{Oz-A}}) = \sqrt{(\mathbf{EEG_{Oz-A}} - \mu)^T (\Sigma^2)^{-1} (\mathbf{EEG_{Oz-A}} - \mu)}$$

$$MDT_{Oz}(\mathbf{EEG_{Oz-T}}) = \sqrt{(\mathbf{EEG_{Oz-T}} - \mu)^T (\Sigma^2)^{-1} (\mathbf{EEG_{Oz-T}} - \mu)} \quad (1)$$

Next, a linear combination $MD_{Index}$ of MDT and MDA is used to compute a combined measure of deviation as

$$MD_{Index} = MDA_{Oz} + MDT_{Oz} + MDA_{O1} + MDT_{O1} + MDA_{O2} + MDT_{O2} \quad (2)$$

where $MDA_{O1}$, $MDT_{O1}$, $MDA_{O2}$, and $MDT_{O2}$ are the Mahalanobis distance for alpha rhythm and theta rhythm in O1 and O2 respectively. If $MD_{Index}$ is large, the user's cognitive state trends to drowsy; otherwise, if $MD_{Index}$ is small, the user's cognitive state trends to alert. This approach does not need a labeled training dataset with information, and can adapt for baseline shifts and the variations in EEG spectra due to changes in recording conditions in different sessions.

### *B. Multimedia Control by Using Cognitive State*

In order to select the suitable music type for the user, it needs to consider the relationship between music type and his/her cognitive stats. Therefore, according to the four levels of cognitive state, music selection should depend on from case to case. There are some applications of the proposed BCI-based multimedia controller. First, retaining constant level of alertness is difficult because most people are easy to be drowsy after long monotonous work such as driving. Then, listeners could set loud, strong bass, quick tempo such as metal to type 3 in order to remind listeners as quickly as possible and prevent from accidents [5], [15]. Second, in the case of relaxing and going to sleep, world music and new age are recommended to set in type 3 while relaxing and folk and classical are set at type 1 when the system detects drowsiness level and enhance listeners the quality of sleep [15]. On the other hand, Levtin and McGill [5] suggested that, in the situation of household chores or walking that only needs light alertness, music with near 100 Beats Per Minute (BPM) or higher could be set into type 2. Furthermore, activities in alertness level are categorized to dynamic and static, dynamic activities such as exercise are recommended to apply the BPM of music is double to the frequency of action of exercise to type 4 and set low tempo music in type 2 to moderate arousal state after exercise [16]. As for static activities, like studying, classical music, jazz, and bluegrass would be effective.

## IV. Results and Discussions

In this study, fifteen participants attended this experiment. In order to obverse the variation trends of both $MD_{Index}$ and the user's cognitive state, the average of $MD_{Index}$ and the user's response time during the previous three minutes was calculated. The experiment results show that the variation trends of $MD_{Index}$ is highly correlated with that of the user's response time. Therefore, the value $MD_{Index}$ actually corresponds to the user's cognitive state.

Under the assumption of that $MD_{Index}$ is related to the user's cognitive state, we select the music type according to $MD_{Index}$. There are four types of music in the database of our mobile phone. Because the cognitive state is relative, we applied linear mapping to divide $MD_{Index}$ into four levels corresponding to four levels of cognitive states. Here, we defined the four levels of cognitive states as alertness, light alertness, light drowsiness, drowsiness. It has to be noticed that the above four cognitive states are just relative to each other, but not correspond to the real alert or drowsy state of human. We defined the average of $MD_{Index}$ as the threshold of the middle cognitive state level. The average and standard deviation of all $MD_{Index}$ , whose response time is about 1 second, for fifteen participants is 24.81 $\pm$ 1.8. Therefore, we define the $MD_{Index}$ threshold for four cognitive states (alertness, light alertness, light drowsiness, drowsiness) are 0, 12.4, 24.8, and 37.2 respectively.

## V. CONCLUSIONS

In this study, a novel brain computer interface-based mobile multimedia controller was proposed. A novel wireless multi-channel EEG acquisition module for daily applications, which contains small-volume, wireless and low-power consumption properties, was also designed in this study. In this system, a commercial mobile phone is used as the music platform. A multimedia control MIDlet program built in the mobile phone, which contains a cognitive state detection algorithm, was developed to select suitable music type according the user's cognitive state. Different from other BCI-based multimedia controllers that require the user's active mental command to do multimedia control, our system can control multimedia automatically and adaptively according to the user's cognitive state. Moreover, different from other BCI-based multimedia controllers that require burly and expensive personal computer and EEG machines, our system is small, light, and more suitable for music therapy and other daily applications. The concept of the modular design is also used to develop both the hardware and software of our multimedia controller system. The wireless multi-channel EEG acquisition module can easily communicate with any kind of commercial mobile phones via Bluetooth communication. The multimedia control MIDlet program can also be applied on other commercial mobile phones easily. By the above properties of modular design, our system becomes more acceptable for the general users, and can be a good prototype of BCI-based multimedia controller.

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