A BCI-based Car Control System with Video Feedback

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Abstract—**We propose a real-time car control system which is controlled by BCI commands. In the system, we develop an algorithm to analyze the EEG signals and extract features in frequency-domain with proper window. It can classify two states of motor imaginary with higher accuracy in BCI module. The system contains wireless communication, video feedback, and driver module. The wireless communication transfers both BCI commands and video, the subjects make corresponding response by watching the video feedback. The results of the experiments show that the proposed real-time car controlling system has a good performance both in terms of accuracy and robustness.**

I. INTRODUCTION

In human brain EEG, it is well-known that when a person wants to move a limb, event related potentials are observed in EEG. Especially, they can be observed even he only intends to move his limb without actual movement. These facts show that information about changes of human brain activity in cognitive process or movement decision process can be identified in the observed EEG so that extracting the information can help us to guess what he is going to do. Based on this principal, Brain Computer Interface (BCI) [1,2] actualizes computer interface and allows people to communicate or control the external world using the brain's normal output channels. An important application of BCI is to facilitate the people who suffer from Amyotrophic Lateral Sclerosis (ALS), brainstem stroke after a crash, spinal cord injury, cerebral palsy and so on, so that the subject can communicate or control the external world under his or her willing. Thus, successful application of BCI can reduce the heavy personal, family, social, economic burdens of the disabilities[3-5].

Typically, BCI application involves the following procedure: 1) collect EEG data from the brain of a person who performs some kind of task; analyze and identify those signals which are only related to the task; translate the idea into some command; send the command to the related equipment, e.g., the car to carry out the control plan.

For smart car control, traditional methods usually contain several series of control algorithms to navigation[6] and add video as feedback[7]. However, in this paper, we use BCI specifically based on motor imaginary so that the "idea" can "drive" the real car model to move smoothly along the designated road. The proposed method can be directly applied to the wheelchair with self-control solutions for disabled, remote driving and so on. Hence, it has very prospective social benefit in future application.

II. SYSTEM OUTLINE

According to the real-time video feedback of the car, the subject decides to move the car by motor imaginary. At the same time the EEG signals are collected by the scalp electrodes. After sampling, filtering, feature extraction and proper translating algorithm, finally we get the intent command of the subject. The car receives the command and control the motor and servo to accomplish the system control.

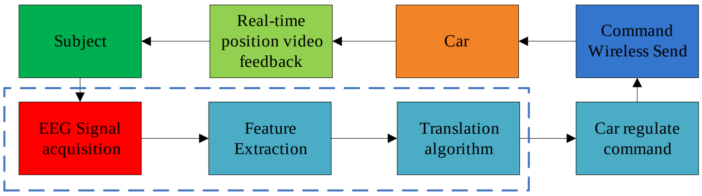

Fig.1. The whole BCI system

So the whole system consists of the following components: subject, BCI, feedback video, real car, and wireless communication.

The working flow can be described in detail as follows: the subject performs motor imaginary task to produce EEG signals, BCI module translates EEG signals into commands, wireless communication carries both commands and video between car and BCI module, and the car can be moved after receiving the commands. The system block diagram is shown in Fig. 1.

III. HARDWARE MODULES

Hardware modules in the system consist of wireless video transmission module, EEG acquisition and analysis module, wireless command transmit module, car's bottom driver module. See Fig. 2 for hardware modules in detail.

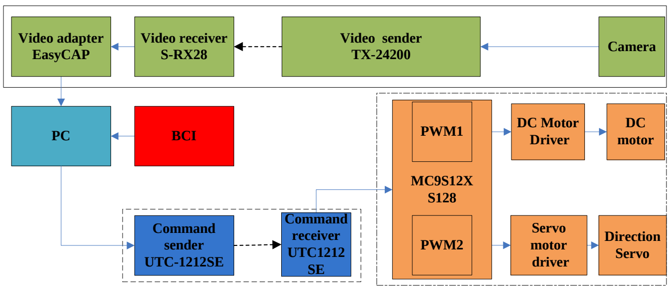

Fig.2. Hardware modules

A. EEG Acquisition

The subject used a g.tech amplifier to acquire EEG signals with eight scalp electrodes referred to a linked-ear reference (see Fig. 3). The sampling frequency is 256Hz. In this case, The subject was sitting in a comfortable armchair in front of computer screen, at the beginning of a trial (t=0s), a red box will appear on the left side of the computer screen, meanwhile, the subject was asked to think the movement of his left hand . After several seconds, the subject was asked to take a break. Then a red box will appear on the right side of the computer and the subject was asked to think the movement of his right hand. The process of the experiment is as follows: left->break->right->break->stop.

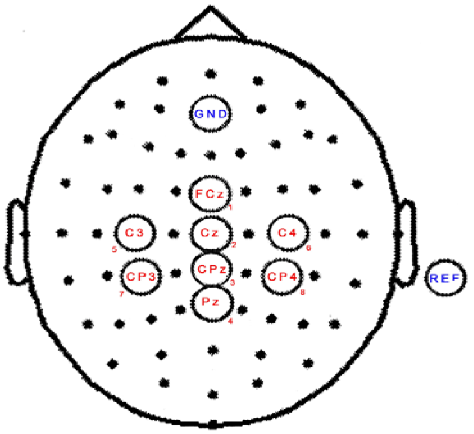

Fig.3: EEG cap montage

B. *Wireless Communication module*

We use a RF module to transmit both real-time video of the scene in front of the car and BCI commands. It has the advantages of interference robustness, transmission speed, transmission distance, etc. The module is working at 2.4GHz, its transmission efficiency reaches 2Mbps and transmission distance is about 600 meters. The video is translated as CVBS format and easy to display on the computer with the video adapter EasyCAP. As a result, the subject decides where to go according to the feedback video. Transmitter and Receiver technology parameters are shown in Table 1.

After signal processing, we get the car commands: turning left, or right. Then send them to the car through the PC serial port by RF module achieving remote control. This module works at 433MHz and the transfer rate is enough for controlling the car in real-time. Tx & Rx technology parameters also see Table 1.

C. *Car driver module*

The size of car module is about 7cm×16cm×8cm, it is free to assemble. It is mainly composed of motor, servo, tires, battery, driver and MCU, so on. Its max power is up to 26.5w, and it can last running 2 hours at the speed of 0.5m/s. It receives the commands from BCI module and is processed by the Freescale's MCU MC9S12XS128. The MCU use PWM to control the motor forward or back and the servo turning. Driver is a push-pull circuit consisting of two pieces of BTS7960B (High Current PN Half Bridge made by Infineon Technologies) with low power consumption and high current output. Through the microcontroller output PWM controls the switch of the bridge to drive the DC motor, PWM changes the

Table.1. Technology Parameters for wireless communication

Transmitter: TX-24200	Receiver: S-RX28	RX&TX: UTC-1212SE
2.4GHz, broadband FM transmitter	2.4GHz,broadband FM reception	Operating frequency 430-440MHz
size: 17.8 * 18.2 * 4.5mm	Size: 36 * 23.5 * 6mm.	1kbps-40kbps transfer rate
operating voltage: 3.3-5.5V	Low clutter leakage: meet CE, FCC requirements.	UART interface support a min 1200 max 57600 baud rate
Low power consumption: 3.3V 200mA	Low power consumption: 3.3v 110mA.	Low power consumption: the current of Sx1212 is 3mA,at low-power sleep state is 1.5uA.
High output power: 23dBm	High receiver sensitivity: -90dBm	Transmit power -8.5dbm to 12.5dbm
Two-channel input, Eight working channels	output CVBS format audio and video signals.	FSK Modulation, high sensitivity, and uses CRC error correction coding college, anti-interference
High stability internal frequency PLL	High stability internal frequency PLL	Once send and receive max support FIFO bytes 256 bytes

effective voltage of the DC motor to adjust the speed, the car's max speed can reach 5m/ s or more.

IV. BCI METHOD

A. *Methods for feature extraction*

After we have obtained the EEG signals with 2 different kinds of motor imaginary tasks, we first use BCI2000[8] software to analyze the eight channels' signals with power spectrum offline. We find that under 2 different motor imaginaries, the power spectrum in channel 7 and 8 varies mostly. So channel 7 and 8 are the interesting channels for

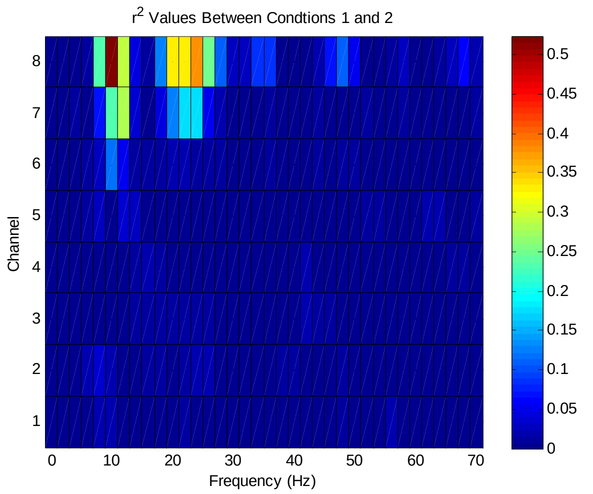

Fig.4: r^2 value between left and right states

feature classification (see Fig.4 for r^2 value which is the mean proportion of multi-trial variance between left and right imaginary task), these two channels are CP3 and CP4 respectively.

Next we describe the method in more detail. We analyze the CP3 and Cp4 with FFT[9,10], find that when the subject thinks the movement of left hand, there will be an obvious gap for both CP3 channel and CP4 channel at 10-12 HZ in frequency domain, and the power of CP3 is much higher than that of CP4, see Figure 5 (top); when he thinks the movement of right hand, there also will be an obvious gap for both CP3 channel and CP4 channel at 10-12 HZ in frequency domain, but the power of CP3 is much lower than CP4, see Figure 5 (bottom). Based the analyzed results, one feature for classification of motor imaginary is to choose the power spectrum at certain channels (CP3&CP4) and certain frequency band (10-12HZ). The formation can be written as follows:

$$Feature=Power_{10\text{-}12HZ}(CP3)-Power_{10\text{-}12HZ}(CP4)$$

Detailed explanation is as follows: if Feature>0 then we conclude that the subject is thinking of the movement of his/her left hand movement, otherwise we conclude that the subject is thinking of the movement of his/her right hand. In car control system we can send different real time commands according to the value of Feature. Hence, the algorithm flow chart can be described as in Figure 6.

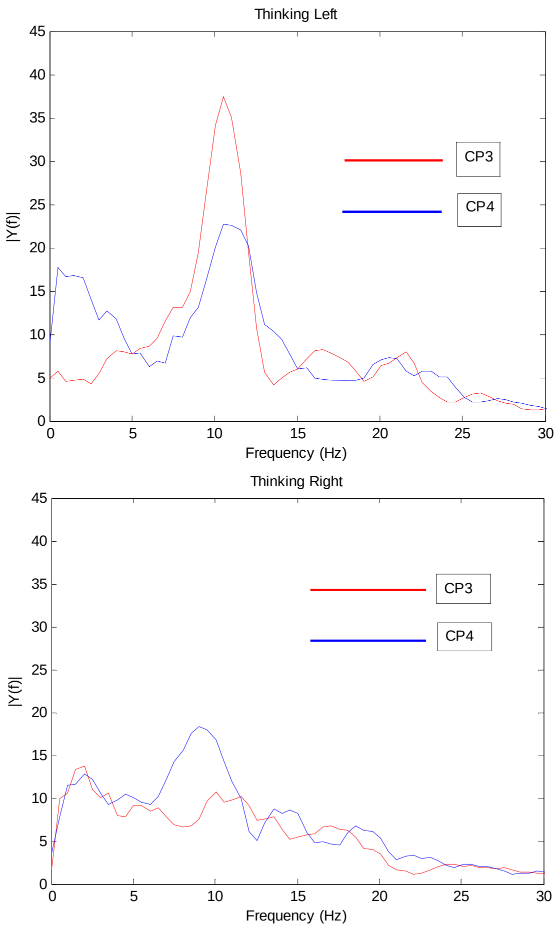

Fig.5: The power spectrum of CP3 and CP4 when the subject thinks left and right hands

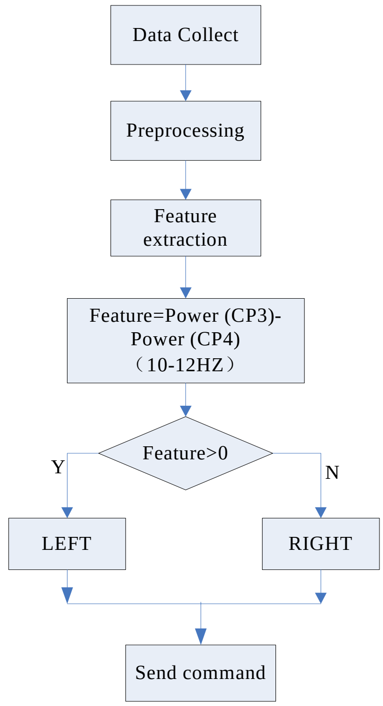

Fig.6 Algorithm Flow Chart

Remark:

(1) Preprocessing

Remove the average reference;

(2) Feature extraction

- Step1：Make Fast Fourier Transform for signals of CP3 and CP4 channels.
- Step2: Compute the power spectrum for CP3 and CP4;

(3) Compute Feature as follows:

$$Feature= Power_{10\text{-}12HZ}(CP3)-Power_{10\text{-}12HZ}(CP4)$$

Send control commands according to the Feature value via wireless communication.

B. Results of classification

We collected five datasets from one subject in our laboratory who is the best trained subject for motor imaginary. As Fig.3 shows, we acquire EEG signals with 8 channels, in despite of the interested channels were CP3 and CP4. It is helpful to use other channels’ signals constructing average reference to reduce noise disturbance. Then, we used previous methods for feature extraction and got the following results:

Table 2 The result of classification

Dataset	Classification accuracy
KWZS002R01.mat	95.31%
KWZS002R02.mat	98.41%
KWZS002R03.mat	96.86%
KWZS002R04.mat	89.06%
KWZS002R05.mat	98.44%

What we can conclude from Table 2 is that we can obtain higher accuracy (almost all dataset can get more than 90%

correction rate) by using our method. Of course, 2 channels system including CP3 and Cp4 can also work, but the performance will not be as good as 8channels. Besides, because our method does not have to make a lot of computation, so it can be easily used in the case of real time control.

V. CONCLUSIONS

We have presented a vehicle driving system which is controlled by BCI and contains a real-time video feedback which can help the subjects to adjust to control the vehicle in real environment rather than virtual environment. The method for feature extraction in the system is to apply FFT for the collected scalp EEG and compares the obvious different interesting power spectrum feature in 10-12Hz range for EEG from right and left side of brain. The performance of the BCI system from the subject is shown well.

It should be pointed out that the performance of such kind of BCI system based on motor imaginary mainly depends on the training effect on the subjects. Hence, it is the future research direction how to develop an easy or no-training BCI system.

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REFERENCES

[1] G. Pfurtscheller, G. R. Muller-Putz, A. Schlogl．15 Years of BCI Research at Graz University of Technology：Current Projects． IEEE Transactions on Neural Systems and Rehabilitation Engineering, 2006, 14：205-210

[2] L. Qin, L.Ding, B. He．Motor Imagery Classification by Means of Source Analysis for Brain Computer Interface Applications．Neural Engineering, 2005, 2(4)：65-72

[3] J. R. Wolpaw, N. Birbaumer, D. J. McFarland, G.Pfurtscheller, T. M. Vaughan, Brain–computer interfaces for communication and control, Clinical Neurophysiology 2002, 113 :767-791

[4] L. Qin，B. He．A wavelet-based time-frequency analysis approach for classification of motor imagery for brain-computer interface applications．Neural Engineering，2005，2：65-72

[5] Y. Wang，B. Hong，X. Gao．Implementation of a Brain-Computer Interface Based on Three States of Motor Imagery．Proc．of the 29th Annual International Conference of the IEEE Engineering in Medicine and Biology Society，Lyon，France，2007,5059-5062

[6] C. L. Hwang, L. J. Chang, “Internet-based Smart Space Navigation of a Car-Like Wheeled Robot Using Fuzzy-Neural Adaptive Control”, IEEE Transanction On Fuzzy Systems, 2008, 16(5):1271-1284.

[7] Z. X. Wang, and Y. X. Liu, “Design of Road Tracing Navigation Control for Smart Car Use CCD Sensor,” in International Conference on E-Health Networking, Digital Ecosystems and Technologies, 2010,345-348

[8] G. Schalk, J. Mellinger: "A Practical Guide to Brain-Computer Interfacing with BCI2000", Springer, 2010

[9] P. Duhamel, and M. Vetterli, “Fast Fourier transforms: a tutorial review and a state of the art” , Signal Processing 1990,19: 259-299.

[10] N. Yamawaki，C. Wilke，Z. Liu．An enhanced time-frequency–spatial approach for motor imagery classification．IEEE Transaction on Neural System Rehabilitation Engineering, 2006, 14(2):250-254