Research and Implementation of Adaptive Control Method Based on EEG

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Abstract. The appearance of BCI (Brain-Computer Interface) [2] provides people with a new foreign exchange of information and control method. The project we studied is just the application of this technology. We use TGAM module, a dry electrode detecting weak EEG from brain and making result of attention, meditation and so on, to design our car control system. Based on numerical analysis and researches about the raw EEG signals and attention, we propose an adaptive EEG processing algorithm to design the car by a complete set of control scheme. Finally, we test the system and get a good result that the car moves under the control as we expected.

Introduction

EEG (Electroencephalography) signal is one of the most common of nature signals. It exists in the brains of human beings and animals. According to different frequency, these spontaneous EEG signals are divided into the Delta wave (0.1 Hz - 3 Hz), Theta waves (4 Hz - 7 Hz), Alpha waves (8 Hz - 12 Hz), Beta waves (12 Hz - 30 Hz) and a variety of other types such as Gamma waves [3].

BCI is a way of human-computer interface that implements the communication and control between brains and computers or other external devices, which focuses on the study of obtaining EEG signal characteristics. Its application fields involve biometric, the control of prosthetic device, auxiliary communication, military applications, video games and robot control, etc[4].

At present, BCI technology can be divided into three categories: invasive BCI[5], part invasive BCI, non-intrusive BCI [6]. Because of the minimal damages of non-invasive BCI for brains, it becomes a most widely used method. TGAM, a kind of EEG acquisition devices we used, also belongs to this type. Differing from traditional EEG acquisition devices, it contains a built-in single dry electrode TGAM module. The weak brain electrical signal can be collected from brain, and the noise around and other power interference can be filtered only through a dry electrode. Further more, the EEG signals will be processed by filter, amplifier, A/D conversion and MCU. Then the module outputs NeuroSky’s eSense meter for attention, meditation, and other future meters, which is suitable for small project’s second development.

System Structure

We mainly combine TGAM EEG acquisition module, arduino board and motor to form a new whole. The arduino board and TGAM module are connected through Bluetooth for communication, and arduino board receives and processes information from the TGAM. Then arduino board analyzes and processes the data to control the running state of the car. The structure of system is shown in Fig. 1.
EEG Acquisition Module

NeuroSky TGAM module we used is a brain waves acquisition head phones with 512Hz sampling frequency. The EEG analog data is converted to digital signals in TGAM module. The raw EEG data and the processing data are encapsulated into two packages, which are large package and small package. Then these two kinds of data packets are transmitted via Bluetooth. With the raw data and checksum in the small packet, we judge the correctness of data transmission and analyse the raw data. Large package packet contains the signal of strength signal, Attention, Meditation and eight EEG Power values, etc. Large data packets are extracted from the raw brain waves out of the characteristic signal, and the characteristic values are simple and convenient. Useful data stream with signal parameters is shown in Fig. 2:

Bluetooth Transmission Module

TGAM module has its own low-power Bluetooth module. In the arduino development board, the wireless transmission of data is realized through a low-power bluetooth module.

Arduino Board

Arduino board with the serial interface can receive the data transmitted from TGAM via Bluetooth. Through the numerical analysis, discriminant and forming instruction operation, the result is achieved to control the motor driving.

Specific Implementation

Overall Design Scheme of the Arduino Programming

The raw brain wave is produced by the current whole brain operation. So it is not easy to analyse the raw brain waves and realize "mind control". Especially for a single electrode brain wave acquisition module, the analysis of the law of the brain is more difficult. Therefore, we expect to use some of the data which are generated directly by the processing module TGAM. These data include Attention, Meditation, eight related EEG Power as well as the raw EEG signal values. The eight related EEG power values as a whole are used to test people's mental state, while the value of any single cannot fully describe a person under the different mental state. The sum of the eight indicators is Attention and Meditation given by TGAM module. The test result shows that we can
control the change of the Attention. But during this time the Meditation reflecting the individual spirit is loosened and is short-term difficult for better control. Therefore, we decide to use Attention value to control the state of the car. However, only using the single variable is unable to control the four movements around. So, the use of the blink of an eye signals to control the car model are available. It is classified as before and after a movement pattern, as another movement patterns around, in a blink of an eye to achieve two modes to switch. Two cases in each kind of model is controlled by the Attention of high and low.

For example, the default mode is a car for the initial forward and backward, at a high level when the car forward. When the attention is at a low level, the car back. When the twice-blink signal arrives, the car changes to the second movement pattern. In the second movement mode, the car turns left when the degree of attention at a high level, and the car turns right when the attention at a low degree. As shown in Fig. 3:

![Figure 3. Whole scheme design.](image)

Then, blink signal extraction problem appeared. How do we accurately extract the blink signal value from the raw EEG signal. By a large number of experimental observations collected, we find that the normal state of mind blink signal is typically raw EEG data with large fluctuations. The fluctuations vary in the size and different people in different blink signal mental state. In this regard, we have to take into account the use of an adaptive algorithm in order to meet its requirements, it will be described in detail below.

**Blink Value Extraction**

We sum 512 packets of raw EEG signals received each second and then average it to determine their expectations. The expected value represents the value of a certain brain wave in current mental state, and then it is attached to a fixed value from statistics which indicates the fluctuation value at the moment of blink. Principle is shown in Fig. 4.

![Figure 4. Adaptive algorithm of extracting the blink signal.](image)
Adaptive threshold of blink signal is calculated as follows:

\[ \text{Sum} = \sum_{i=0}^{511} \text{rawdata}[i]. \]  
(1)

\[ \text{Aver\_data} = \text{sum}/512. \]  
(2)

\[ \text{Aver\_c} = \text{aver\_data} + c. \]  
(3)

If the current rawdata value is greater than the value of aver\_c in one second, the blink signals arrive, otherwise not. In order to reduce the instantaneous noise, we test several times that rawdata value greater than aver\_c signal value, then identify the blink of an eye comes.

**Attention Processing**

For the Attention we use the similar method. Five Attention values before the current time is calculated and a mean is done to obtain a threshold value. Then the current received Attention is compared with this threshold value. And the value of the summation of Attention beginning with the most recent attention is replaced, so the cycle can be always maintained adaptive ability.

Adaptive threshold computation formula of attention extraction is as follows:

\[ \text{Sum} = \sum_{i=5}^{i+5} \text{attention}[i]. \]  
(4)

\[ \text{Aver\_attention} = \text{sum}/512. \]  
(5)

The initial value of variable \( i \) is 0, then 1, 2, 3, 4…… Attention to time of the next replaces the youngest of the five serial numbers, and is chosen as a threshold after expect. Subsequent attention are compared with the threshold, and the bigger attention have a way to control the car, as well as the smaller attention have another way of movement.

**Results Test and Analysis**

The raw EGG signal waveform figure for the same person measured and the attention and meditation, which are shown in Fig. 5, Fig. 6 under different mental.

![Waveform of raw EGG signal, attention and meditation at mental state 1.](image-url)
Which can be seen from the above two figures, the fluctuation amplitude of the raw EEG waveform has a little difference under different mental state. The Fig. 5 shows that when Attention is generally less than 50, lack of focus leading to the range of the raw EEG waveform slightly larger. In addition, lack of focus may leading to the big change on facial expression, and the blink of eyes will also be mixed into the raw EEG waveform. The two combined will cause a larger fluctuation. On the contrary, it is concentrated in Fig. 6 that the larger fluctuation of the raw EEG waveform only comes when the eye blinks. The result of the latter is much better than the former.

Fig. 7 shows that the fluctuation of slow blink is slightly different from normal blink, but the amplitude of them is almost the same. Although facial expression change has an impact on the amplitude of fluctuation, we are still able to extract the blink signal correctly. After repeating test and preliminary estimate statistics, the probability of accurately extracting the blink signal is about 60%.

We have finished 20 times experiments to test the situation that the EEG signal can drive the car correctly. In some detail, we randomly control the car to move to the left, to the right, backward and forward, and record the spent times of repetition that the car move towards the direction as "mind control" correctly, and the results are listed in the following table:

Table 1. The times for the correct direction.

<table>
<thead>
<tr>
<th>sequence</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
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<tr>
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<td>backward</td>
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<td>backward</td>
<td>left</td>
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<tr>
<td>times</td>
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<tr>
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<tr>
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<td>5</td>
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<td>1</td>
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</table>

According to the statistics, in 20 times experiments, to make the car move towards the direction as “mind control”, we totally use 55 times operation. Finally, we figure out the accuracy of correct movement, 20/55*100%=36%. The result shows in Fig. 8.
In our test, there are two aspects which influence the car’s movement state. One is whether the blink of an eye is extracted from EEG signal accurately or not. Another is whether the processing of Attention value is under the control of the human brain changes timely and effectively. It has analyzed that the extraction accuracy of the blink signal of an eye is high, but it may be influenced by other noise so as to cause misjudgment. As for processing the adaptive Attention, as a result of referring to previous Attention value, several Attention value we collect before will influence the current judgment to car’s movement.

Meanwhile, single dry electrode acquisition device have some error and noise which is impossible to be filtered. What’s more, the position that different people put the acquisition device on is different, and different degree of dry skin also have certain interference. Furthermore, the different people’s EEG signals are different in different time. Superposition of the above situation, it causes that we can’t always control car’s movement by EEG signal accurately. Although the car’s movement changes, it might be a variety of misjudgment added together, which are all we need to improve.

Summary
This paper gives the system we designed, which is based on NeuroSky's single electrode TGAM module. First, we describe the design and the specific implementation of the system, given some of the ways we deal with the collected EEG. Next, use brain waves via bluetooth terminal connected to the Arduino board. And then we process the Attention and the raw EEG value in the development board. The processed data is used by programming to change the car in motion. In the end, make some tests and analysis of the whole system. Through the brain electrical signal analysis and processing. We basically realized to control the car to change direction. But this is just a preliminary overall brain signals generated by the resolution of brain activity. And there is a big gap to realize "mind control" in the true sense. For now, we should improve the control of a single electrode, optimize the algorithm, and continue to study more deeply the laws of electroencephalograms.

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