Controlling the Wheelchair by Eye Movements Using EEG

Van Cam Thi Le, Nhan Thanh Le, Hai Ngoc Nguyen, Dang Cao Le, and Keiji Iramina

Abstract

In this study, we propose a method to control the wheelchair by eye movement using Electroencephalography (EEG). Firstly, we collect EEG signal by five types of eye movement: Blink, Double blink, look at Right, look at Left and Relax. These movements correspond to five directions of wheelchair motion: Go forward, Go backward, Turn right, Turn left and Stop. After that, the offline EEG signal is analyzed using MATLAB to find out the classified threshold of the signal amplitude in Alpha band and Delta band. Finally, an effective algorithm is built allowing us to identify the type of eye movement and control the external device—the powered wheelchair. As the result, the average accuracy for five motion directions (Go forward, Go backward, Turn right, Turn left and Stop) are 92.333, 93, 81.667, 86.667 and 83% respectively. With this study, we expect it can give people the help they need and be applied to many fields in the near future.

Keywords

Brainwave control algorithm • Wheelchair • Eye movement • EEG

1 Introduction

Nowadays, Electroencephalography (EEG) has become the most versatile and powerful tools not only in medical to diagnose the mental diseases or brain injury but also in technology to help disabled people who got the severe disabilities to engage with their surroundings and live more comfortable.

In many cases, the severe disabilities affect the patient's daily life, including activities of self-care and movement, causing major changes in the quality of life. Besides the physical therapy, many types of technique were applied for disabled people to help them live more comfortable. With brain control technique, they can use their own physiological signal such as EEG signal, eye movement signal to interact with external environment by the supported equipment such as wheelchair.

This study proposes a cheap and effective method to control the wheelchair with a commercially low-cost EEG headset—Emotiv EPOC Headset. This headset is easy to use with the 14 channels fixed on the scalp to collect the EEG signal and the software development kit (SDK) to process and interpret the signals [1]. In this study, the main issue is to identify the types of eye movement in EEG signal in order to control the wheelchairs. We use MATLAB language to analyze raw offline data and calculate the amplitude threshold value for each eye movement type. Thus we can use these threshold value for wheelchair application.

2 Method

Subject: One healthy female, 23 years old.
Requirements for the subject: Because the aim of this study is total paralysis patients so when we collect the data, she must do not move the body except her eyes.
EEG equipment: EPOC Emotiv headset and its packet tools.

By observing the actual experiments, we choose five types of eye movement to be the controlling commands: Blink eye (B) as Go Forward command; fast Double blink eye (D) as Go Backward command; look at Left (L) as Turn left command; look at Right (R) as Turn right command and relax or closed eye (X) such as Stop command. We collected

V. C. T. Le (✉) · K. Iramina
Graduate School of Systems Life Sciences, Kyushu University, Fukuoka, Japan
e-mail: lethicamvan273@gmail.com

N. T. Le · H. N. Nguyen · D. C. Le
BME Laboratory, Faculty of Applied Science, Ho Chi Minh City University of Technology, Ho Chi Minh City, Vietnam

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the EEG data by EPOC Emotiv headset in total 661 samples from four channels: AF3 (Fp1), AF4 (Fp2), F7 and F8 in 5 s [2]. In every 5 s sample, the subject does only one type of eye movements such as Blink, Double Blink, look at Right, look at Left or Closed eye. The data then are analyzed offline by MATLAB. After doing pre-processing by the Notch and band-pass filters to extract the desired frequencies, we use Fast Fourier Transform method to compute the power spectral density ratio (R-value).

$$R_i = \frac{P_i}{\sum P_i} \tag{1}$$

where:

R	is power spectral density ratio
P (μV^2)	is power spectral density
i	sequentially is δ, θ, α and β band

In this study, we only give the attention on two frequency regions δ and α which have the significant change in amplitude for the eye movement behaviors.

Identify X signal

As we know, when we're relaxing, the alpha wave of our brain will increase. In this case, the R-value in the alpha region of the X signal is significantly higher than the other four signals B, D, L, and R in the same region. At the same time, the R-value in the delta region of X signal is smaller than the R-value in the same region of the other four signals. Therefore, we got the sign to recognize the X signal as follow:

$$\begin{cases} \{R_{\propto X}\} > \{R_{\propto B}; R_{\propto D}; R_{\propto L}; R_{\propto R}\} \\ \{R_{\delta X}\} < \{R_{\delta B}; R_{\delta D}; R_{\delta L}; R_{\delta R}\} \end{cases}$$

Identify Blink eye (B) and Double blink eye (D) signal

Looking at Fig. 1 that shows the power spectrum of two groups B signal and D signal, we observe in the same frequency range [0.5; 4 Hz], the power spectrum of group B is gathered in one part, whereas the power spectrum of group D is tended to be divided into two distinct parts. For the sake of identification, we argue and compute a coefficient to distinguish B signal and D signal. It is ρ-value and computed by the following equation:

$$\rho = \frac{P_{[0.5\,\text{Hz};1.5\,\text{Hz}]}}{P_{[1.5\,\text{Hz};4\,\text{Hz}]}} \cdot \frac{P_{[0.5\,\text{Hz};3\,\text{Hz}]}}{P_{[3\,\text{Hz};4\,\text{Hz}]}} \tag{2}$$

With: $P_{[a;\,b]}$ is the power spectral density which is limited to the frequency segment [a; b] (Hz).

The value of $\rho_B \gg \rho_D$ in most samples. So we use this coefficient to distinguish B signal and D signal.

Identify look at Left (L) and look at Right (R) signal

The Correlation Coefficient is the powerful index that indicates the strength of the linear relationship between two random variables. To distinguish L signal and R signal, we calculate 6 correlation coefficients of 6 pairs of channel: (AF3,F7); (AF3,F8); (AF3,AF4); (F7,F8); (F7,AF4); (F8, AF4).

By calculating the correlation coefficients between the pairs of channels according to behaviors B, D, L or R, we have the distribution of correlation coefficients as Fig. 2.

From Fig. 2, we can deduce the trend of correlation coefficient as Table 1 using for the identification algorithm.

From Table 1, we divided four behaviors B, D, L and R into two groups using the correlation coefficient cr(F7,F8) and cr(F7,AF4). The first group includes B and D behaviors

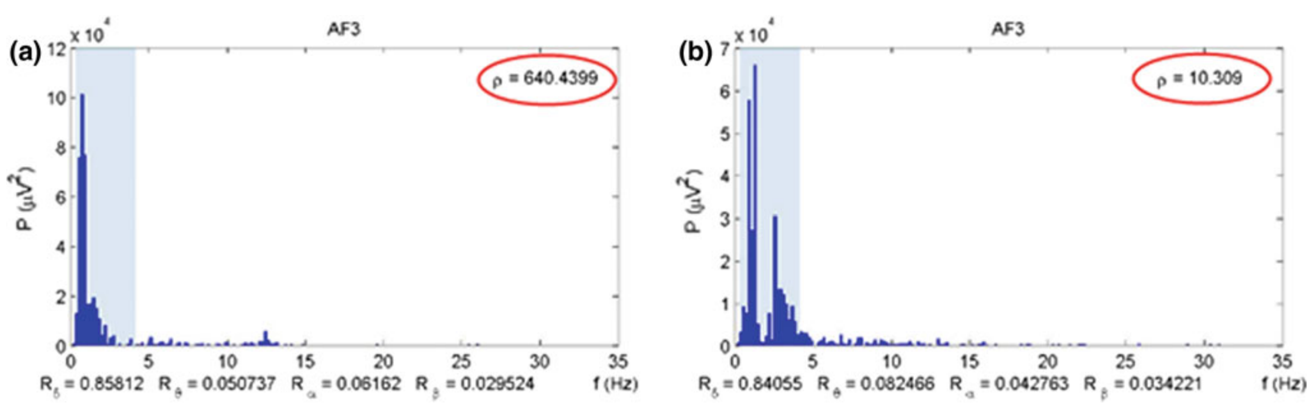

Fig. 1 ρ values of B signal (**a**) and D signal (**b**)

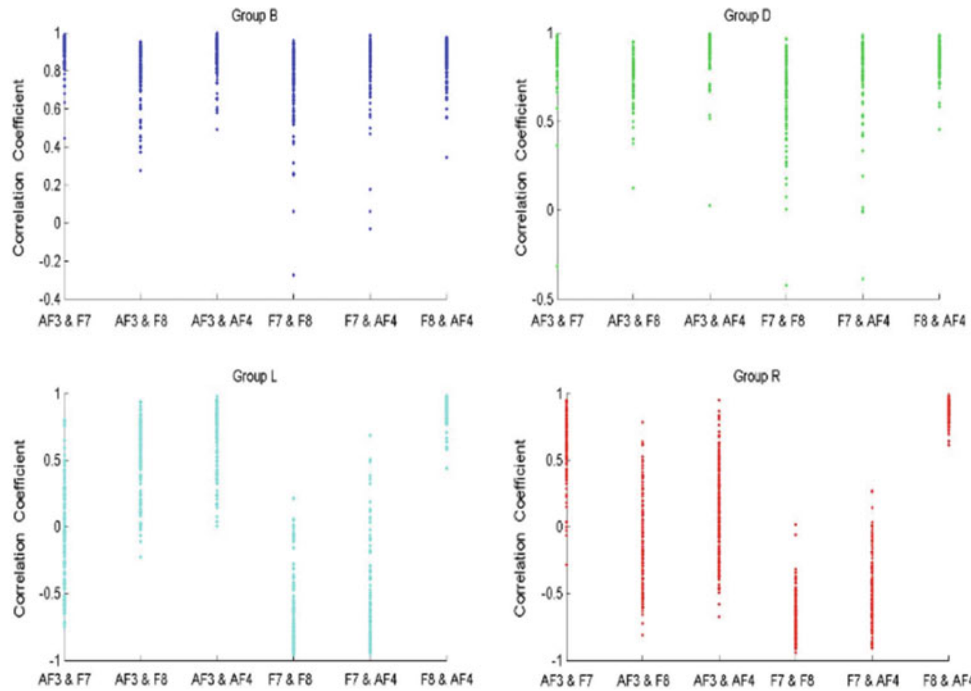

Fig. 2 The graph that distribute the correlation coefficients between the pairs of channels according to behaviors B, D, L or R

Table 1 The trend of correlation coefficients

Correlation coefficients pairs	B	D	L	R
cr(AF3,F7)	+	+	–	+
cr(AF3,F8)	+	+	+	–
cr(AF3,AF4)	+	+	+	–
cr(F7,F8)	+	+	–	–
cr(F7,AF4)	+	+	–	–
cr(F8,AF4)	+	+	+	+

because they had a positive coefficient while L and R behavior had a negative coefficient. In addition, based on the opposite trend of the correlation coefficient cr(AF3,F7), cr(AF3,F8) and cr(AF3,AF4), we can distinguish the L and R signals.

Threshold statistic

Threshold statistic is the method we built to define the threshold value of the data set R_α, R_δ, ρ and correlation coefficients. The R_α value and R_δ value are used to recognise {X} signal from {B, D, L, R}, ρ value is use to identify group {B} and {D} while correlation coefficients are used to distinguish {L} and {R} signal. In every set, there always is the opposite distribution of the data between two groups in the same value domain that we call Upper Domain (UD) and Lower Domain (LD). In particular, for the set of R_α, UD is the $R_{\alpha\{X\}}$ and LD is $R_{\alpha\{B,D,L,R\}}$, while in R_δ set, UD is $R_{\delta\{B,D,L,R\}}$ and LD is $R_{\delta\{X\}}$. Similar, in the set of ρ value, UD is $\rho_{\{B\}}$ and LD is $\rho_{\{D\}}$. For correlation coefficients, UD are cr (F7, AF4) and cr(F7, F8) of group {B, D}; cr(AF3, AF4) and cr(AF3,F8) of {L} signal; and cr(AF3, F7) of {R} signal. From that distribution, we compute the a specific value as the boundary between two domain sets, called the intersection value μ, defined by the formula below:

$$\mu = \frac{\sum_{\substack{i=\overline{1,n} \\ j=\overline{1,m}}} \left(\frac{min_{UD_i} + max_{LD_j}}{2}\right)}{m.n} \tag{3}$$

With:

min_{UD_i} the smallest value of each subsets of the upper domain.

max_{LD_j} the biggest value of each subsets of the lower domain.

Table 2 The performance of the algorithm after every test

Type of signal and command	B	D	L	R	X
	Go forward (%)	Go backward (%)	Turn left (%)	Turn right (%)	Stop (%)
The 2nd test	89	86	60	78	71
The 3rd test	88	93	92	87	93
The 4th test	100	100	93	95	85
Average	92.333	93	81.667	86.667	83

Note The first test was rejected since the mechanical problems of the wheelchair so we didn't mention it here

n The number of subsets is in the upper domain.
m The number of subsets is in the lower domain.

3 Results

The threshold values of $R_{\propto}$, R_{δ}, ρ and 6 correlation coefficients of 6 pairs of channel are calculated by statistic to identify each type of signal. Whereas the online collecting data program and control program are built on LabVIEW so that we can do the performance test for our algorithm. After every test, the performance of the algorithm is better. However, this result was dependent on every subject and the training session.

The International University in Vietnam also did the project about "An EEG-Controlled Wheelchair Using Eye Movements" using the number of blinks to control the wheelchair with the Biosemi Active Two system [3–6]. In our study, we use the direction of eye movement to be the control signal. With Epoc Emotiv headset, the subject feels more comfortable to do the test for a long time and it also saves our time with a wearable device and fixed channels. In Table 2, the performance of group B and D are almost absolute since there is a big difference of ρ-value with the ratio of ρB/ρD is always more than 10 times. After several adjustments for threshold value, the performance of Turn left and Turn right signals were improved significantly. Besides, the Stop signal is still stable. This study also gives us the effective performance with the accuracy of five motion directions (Go forward, Go backward, Turn right, Turn left and Stop) are 92.333, 93, 81.667, 86.667 and 83% respectively in indoor environment.

4 Conclusion

This current study adds an other high-productive method to help disable people control the wheelchair by eye movement via their EEG signal with five commands: Go forward, Go backward, Turn right, Turn left and Stop. The wearable EEG equipment that we use in this study—EPOC EMOTIV—brings more convenient for the subject and easy to conduct the experiment because of its light weight and quick response. In near future, we hope this algorithm will have the potential application and not only be used for motion controlling but also can expand to many equipments in other fields.

Conflict of Interest The authors declare that they have no conflict of interest.

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