The Fourteenth International Symposium on Artificial Life and Robotics 2009 (AROB 14th '09),
B-Con Plaza, Beppu, Oita, Japan, February 5 - 7, 2009

Reliable EOG Signal Based Control Approach with EEG Signal Judgement

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Abstract

This paper proposes a reliable EOG signal based control approach with EEG signal judgement. In this method, raw bio-neurological signals (including EOG and EEG) are first extracted and segmented in the pre-processing. The processed bio-neurological signals will be then evaluated by calculating feature parameters of these signals. Since in bio-neurological signals they may be contaminated by various kinds of artifacts, by means of feature parameters of bio-neurological signals, some artifacts of bio-neurological signals can be indicated. Thus, the bio-neurological signals contaminated with artifacts can not be adopted to generate control signals and judge the correctness of control signals. In the proposed method, in order to generate reliable control signal based on the EOG signal, EEG signal is adopted to assist to make judgement about the valid of EOG signal. With the proposed method, an EOG signal based control software platform has been implemented. By use of this platform, simulation work has been carried out to control the behavior of a robot. The simulation results verified the effectiveness of the proposed method.

1 Introduction

From human body there have many kinds of bio-neurological signals, which are adopted for diseases diagnosis, such as electroencephalogram (EEG), electromyogram (EMG), electrooculogram (EOG), electrocardiogram (ECG), and so on. In recent decades of years, many researchers are engaged in a new field of study, i.e., Brain-Computer Interface (BCI). The main task of this field is to control robot by means of various kinds of bio-neurological signals [1].

There already have plenty of researches on this topic. Many proposed methods use bio-neurological signals to control different robots. For example, Craig[2] proposed a method of using EEG to control hand of the disabled. Nakamura[3] introduced a method to control meal assistant robot by means of EEG. However, most of control methods are just using one type of bio-neurological signals which has limitation to reach high accuracy of control performance, because bio-neurological signal is too week and very hard to be exact clearly signals. Therefore, the reliable control request is still a most important issue in BCI. So far, we have already carried out a lot of works for proposing effective methods to evaluate various bio-neurological signals [4]. Therefore, it is possible to improve the reliability of control by means of bio-neurological signals.

In this research, we propose a reliable EOG signal based control approach with EEG signal judgement. In this method, raw bio-neurological signals (including EOG and EEG) are first extracted and segmented in the pre-processing. The processed bio-neurological signals will be then evaluated by calculating feature parameters of these signals. Since in bio-neurological signals they may be contaminated by various kinds of artifacts, by means of feature parameters of bio-neurological signals, some artifacts of bio-neurological signals can be indicated. Thus, the bio-neurological signals contaminated with artifacts can not be adopted to generate control signals and judge the correctness of control signals. In the proposed method, in order to generate reliable control signal based on the EOG signal, EEG signal is adopted to assist to make judgement about the valid of EOG signal. With the proposed method, an EOG signal based control software platform has been implemented. By use of this platform, simulation work has been carried out to control the behavior of a robot. The simulation results verified the effectiveness of the proposed method.

In this paper, the proposed method are explained in detail in section 2, including the bio-neurological signals acquisition and pre-processing, evaluation of processed EOG signals and generation of control signals, and judgement by EEG signals. In section 3, control platform for the proposed method is introduced. In the section 4, simulation work was explained to control a robot by use of the developed platform.

2 Method

2.1 Bio-neurological signals acquisition and pre-processing

In the proposed method, it first needs to automatically record raw bio-neurological signals (including EOG and EEG) from subject and make some pre-processing. According to the standard, EOG signals can be obtained from the electrodes Fp1, Fp2, F7 and F8 pasted on the human face new eyes. EEG signals can be obtained from the electrodes Fp1, Fp2, F3, F4, F7, F8, C3, C4, P3, P4, O1, O2, T3, T4, T5, T6 pasted on the human head. According to the request, raw continuous bio-neurological signals are segmented in each short time period. For example, a continuous bio-neurological signal can be divided into a set of segments and each segment may have 5 second long. Therefore, it will be helpful to make the further processing. This segmentation work can be automatically made by the system in online.

In the pre-processing of bio-neurological signals, bio-neurological signals need to store into the data file. Additionally, it can automatically generate the name of data file, indicate the types of signals, an instruction file including important information about the signals, and so on.

2.2 Evaluation of bio-neurological signals and generation of control signals by EOG signals

In the proposed method, evaluation of processed bio-neurological signals is very important for generating control signals. In the evaluation of the processed bio-neurological signals, it needs calculate parameters, indicate artifacts and find out qualified signals.

2.2.1 Parameters calculation

The parameter calculation is essential for the evaluation of bio-neurological signals. For example, the features of bio-neurological records in each channel can be expressed by the periodogram parameters.

- Amplitude [μV]: $A_z(x) = 6\ \sqrt{S_z(x)}$
- Symmetry [%]: $P_z(x,y) = 6\sqrt{S_z(x-y)}/6\sqrt{S_z(x+y)} \times 100$
- Asymmetry [%]: $G_z(x,y) = 6\sqrt{S_z(x+y)}/6\sqrt{S_z(x-y)} \times 100$
- Extension [%]: $E_z(x,y) = 6\sqrt{S_z(y)}/6\sqrt{S_z(x)} \times 100$
- Duration [%]: $D_z(x) = S_z(x)/S_T(x) \times 100$
- Central frequency [Hz]: $F_z(x) = f_z^c(x)|_{P_{max}}, P_{max} = \max_{f_{lower} \le f_z(x) \le f_{upper}} P(f_z(x))$
- Normalization of parameter: $\Phi_z^Q(i) = (Q_z(i) - \min Q_z(i))/(\max Q_z(i) - \min Q_z(i))$

where x, y both represent each electrode of Fp1, F3, C3, P3, O1, Fp2, F4, C4, P4, O2, F7, T3, T5, F8, T4, T6; z denotes the respective signal components: L(0-0.5 Hz), (0.5-4 Hz), (4-8 Hz), (8-13 Hz), (13-25 Hz), T(0.5-25 Hz), H(35-50 Hz); $f_z(x)$ is the frequency within the frequency band of z in channel x; $f_z^c(x)$ is the central frequency within the frequency band of z in channel x and corresponding to the maximal power spectrum; f_{lower} is the lower limit of the frequency band; f_{upper} is the upper limit of the frequency band; and i is the segment number.

The following items are employed in the parameters definition:

- $S_z(x)$ is the amount of signal components calculated by the summation of periodogram with the frequency band of z in channel x;
- $S_T(x)$ is the amount of signal components calculated by the summation of periodogram with the frequency band of 0.5-25 Hz in channel t;
- $S_z(x-y)$ is the amount of signal components calculated by the summation of periodogram with the frequency band of z in channels x and y, in which the signal time series of channel y is subtracted from that of the channel x;
- $S_z(x+y)$ is the amount of signal components calculated by the summation of periodogram with the frequency band of z in channels x and y, in which the signal time series of channel x adds that of the channel y.

As the first step, in the proposed method, the parameters for EEG and EOG are calculated. When implementing the proposed method, the parameters will be displayed on the screen of computer so that the user can understand the change of the parameters in real time.

2.2.2 Artifacts indication

Based on the parameter calculation, artifacts contaminating in the bio-neurological signals can be indicated. Normally, there are two types of artifacts. One is technical artifact, including electrode artifact, base line drift artifact, etc. Another is physiological artifact, including blink artifact, EMG artifact, horizontal eye movement (HEM) artifact, etc. For each type of artifact, it has criteria to judge the existence of this artifact. For example, for EOG signals, blink artifact is one of main artifacts always existed in the EOG signals. Its criteria are as below [4].

- **Existence of δ component**:
  $A_\delta(F_{P1}) \geq 25[\mu V], \quad A_\delta(F_{P2}) \geq 25[\mu V]$
- **Symmetry of the waveform**:
  $A_\delta(F_{P1}+F_{P2}) \geq 50[\mu V], \quad P_\delta(F_{P1}, F_{P2}) \leq 55[\%]$
- **Extension to central region**:
  $E_\delta(F_{P1}, F_3) \leq 85[\%], \quad E_\delta(F_{P2}, F_4) \leq 85[\%]$
  $E_\delta(F_{P1}, C_3) \leq 78[\%], \quad E_\delta(F_{P2}, C_4) \leq 78[\%]$

When implementing the proposed method, there always use two ways to indicate the artifacts by the computer. One is using different color for the parameters displaying on the screen of computer. Another is making alarm voice to notice the user. Therefore, it will be very helpful for user to understand the artifacts in real time.

2.2.3 Control signals generation based on qualified EOG signals

Based on the above parameters and artifacts indication method, the qualified signals can be picked up. Since the qualified EOG signals will be adopted to generate control signals in the proposed method, the criteria of judgement of qualified EOG signals for generating control signals are as below. The qualified EOG signals for generating control signals do not mean that the EOG signals have no any artifacts. In contrast, the qualified EOG signals for generating control signals are defined that they should have blink artifact and HEM artifact. Particularly, these two types of artifacts should occur at the same time. It means that the subject shows this manner to express his intention to control object. If these two artifacts are existing separately in EOG signals, these EOG signals are defined unqualified records.

Concerning about the control signals generated by qualified EOG signals, it can be defined based on user's requirement. For example, it can be a kind of pulse.

2.3 Judgement by EEG signals

In the proposed method, although the control signals are generated by qualified EOG signals, it still exists the phenomenon that the subject status is not appropriate for control. For example, the status of subject is drowsy while recording the EOG signals. The EOG signals may be qualified, but the control signals generated by the current EOG signals can not be adopted to fulfill the control task. Therefore, EEG signals can be adopted to judge the status of the subject in order to determine the correctness of the control signals.

Normally, the evaluation of α wave in EEG signals is always adopted to judge the vigilance level of the subject under the relaxed situation. If the relative ratio of α wave is high, the vigilance level is high and therefore the subject status is satisfied with the requirement. The control signals generated by EOG signals at this moment are correct to control object. Due to the page limitation, the calculation method about relative ration of α wave will not be introduced in detail and you can find it in [4].

It should be noticed that the qualified EEG signals adopted for judgement can only judge the correctness of control signals generated by qualified EOG signals which are synchronized with qualified EEG signals.

3 Control platform for the proposed method

The proposed method has been implemented by developing a real time evaluation software system. This system not only can process EOG and EEG signals, but also can generate control signals by qualified EOG signals and make judgement by qualified EEG signals in real time. Fig.1 illustrates the interface of the real time evaluation system.

Basically, this system is developed by C language and includes about three functions, i.e., preprocessing, evaluation and output. For each function, it has a software module. Through AD/DA converter, this system can connected with bio-neurological signals recording machine. The recorded signals can put into the computer running the proposed system. The evaluation results can be displayed on the screen of the computer and saved into the data file in real time. As above explained, two different types of output ways can be both implemented by the proposed system. One is to store useful information into the data file. Another is directly to output control signal to control actual system, such as a robot.

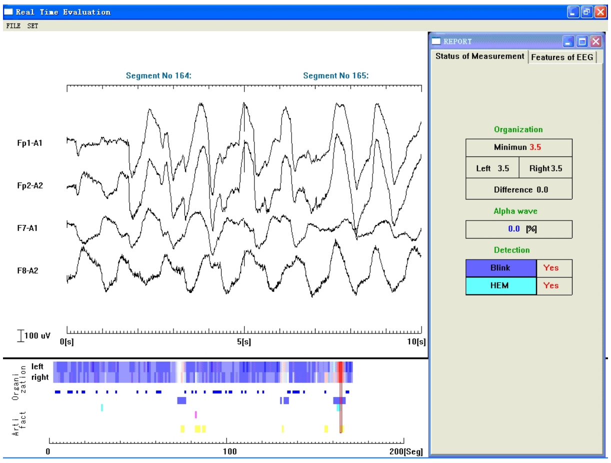

Figure 1: Interface of the control platform

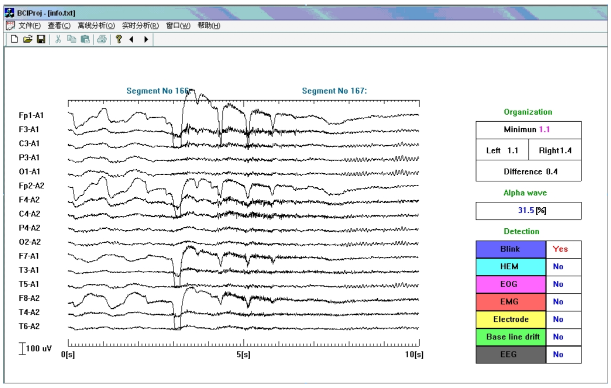

Figure 2: Unqualified EOG signals with blink

4 Simulation of the proposed method

In order to demonstrate the effectiveness of the proposed method, simulation work has been done to control the behavior of a robot by bio-neurological signals. We adopt EOG signals to control the movement of a mobile robot. If the subject blinks his eyes, the mobile robot will start to move or stop. If the subject's eye-ball is horizontal moving, the mobile robot will rotate with an angle. The following Fig.2 illustrates the unqualified EOG signals with blink. Fig.3 illustrates the qualified EOG signals.

5 Summary

This paper proposes a reliable EOG signal based control approach with EEG signal judgement. In this method, EOG signals are adopted to generate control signals. EEG signals are adopted to assist to make judgement about the valid of EOG signal. With the proposed method, an EOG signal based control software platform has been implemented. By use of this platform, simulation work has been carried out to control the behavior of a robot. The simulation results verified the effectiveness of the proposed method. Actually, the application of the proposed method can be extended to the wide fields.

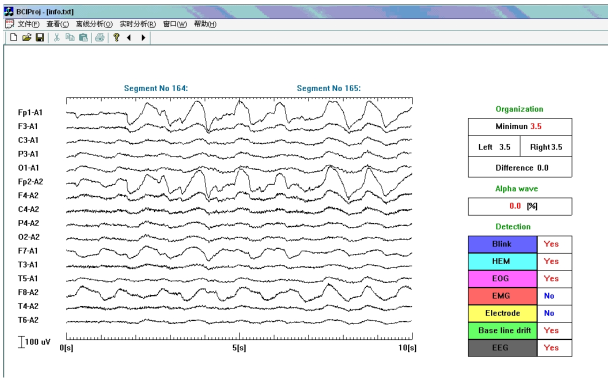

Figure 3: Qualified EOG signals for generating control signals

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