Design of a Real Time Evaluation System for Multiple Neuro-Biological Signals

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Abstract

This paper introduces the design of a real time evaluation system for multiple neuro-biological signals. In this system, multiple types of neuro-biological signals can be automatically processed in a single system in real time, including EEG, EMG, EOG, ECG, etc. It not only can display the wave shapes of these signals both in online and offline, calculate the feature parameters, but also can evaluate these signals based on different criteria. Therefore, it is possible to provide information about multiple types of neuro-biological signals simultaneously, which will provide great assistance for doctors to interpret neuro-biological signals for judging the diseases and for engineers to define the control signals for BCI device using different types of neuro-biological signals. This system will be an open system that can integrate more kinds of neuro-biological signals. New functions can be easily added into this system according to different requests.

1. Introduction

At present, there already have plenty of researches on the processing and evaluation of neuro-biological signals and the applications of these signals for the interpretation of these signals and control of Brain-Computer Interface (BCI) devices. The main methods include Fourier analysis, brain mapping, feature extraction and pattern recognition [1–3]. However, it is lack of an effective system which can process and evaluate multiple types of neuro-biological signals in a single system in real time, so that it is possible to provide information about several types of neuro-biological signals simultaneously. Therefore, it can be adopted to assist doctors to interpret neuro-biological signals for judging the diseases and assist engineers to define the control signals for BCI devices. In this research we want to develop a new real time evaluation system for multiple neuro-biological signals, such as electroencephalogram (EEG), electromyogram (EMG), electrooculogram (EOG), electrocardiogram (ECG), and so on.

So far, we have already carried out a lot of works for developing this system, such as summarizing the methods of processing and evaluating neuro-biological signals, developing a prototype of this system for EEG [4], designing some types of BCI devices [5][6], and so on. In this research, we design a real time evaluation system for multiple neuro-biological signals based on our previous works. In the paper, we will introduce the structure, main functions, operation of this system. In the discussion part of this paper we will introduce the possible applications of this system and the future research on this system.

2. System Structure

In the real time evaluation system for multiple neuro-biological signals, as illustrated in Fig.1, it mainly has the following modules: (1) human-friendly interface module; (2) real time pre-processing module; (3) evaluation module; (4) output module for the interpretation of neuro-biological signals and the design of controlling signals for BCI device.

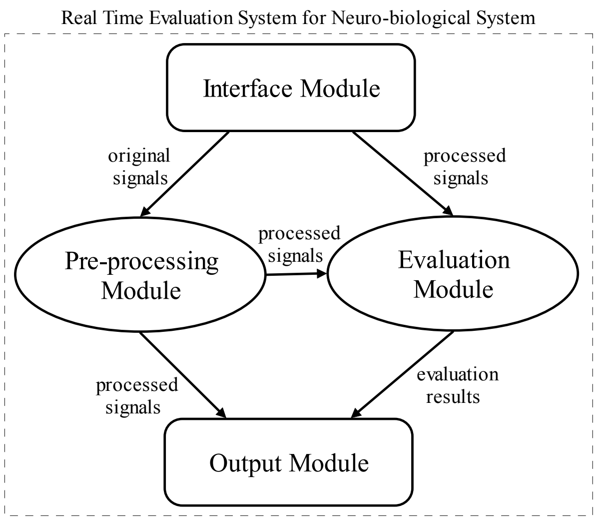


Fig.1 System structure of real time evaluation system for multiple neuro-biological signals

Each module contains the following parts.

(1)Interface module: a human-friendly windows-type menu, displaying wave shape region, displaying processing and evaluation results region, etc.

(2) Pre-processing module: judgement of types of

neuro-biological signals, segmentation of signals, elimination of noise in the signals, selection of qualified signals, etc.

(3) Evaluation module: calculation parts for different types of signals, comparison parts among segmentations of multiple signals, generating evaluation reports, etc.

(4) Output module: output control signals through I/O interface of computer, printing signals as well as evaluation reports, etc.

The system structure is designed for implementing the functions introduced in the following section. Actually, it can be extended according to the requests on this real time evaluation system for multiple neuro-biological signals.

3. System Functions

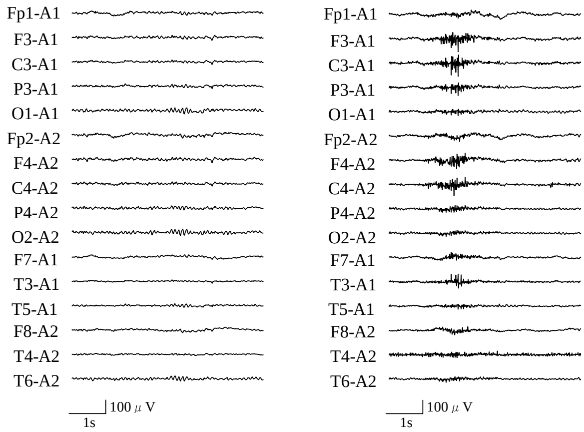
The real time evaluation system for multiple neuro-biological signals mainly has the following three functions: (1) real time pre-processing; (2) evaluation of multiple neuro-biological signals; (3) output for interpretation of signals and controlling BCI devices using information from multiple neuro-biological signals. In the following parts, these three functions are explained in detail.

3.1 Pre-processing of multiple neuro-biological signals

The purpose of pre-processing of multiple neuro-biological signals is to obtain qualified signals. First of all, it needs to automatically judge which type of signals will be processed. Since the basic features of various neuro-biological signals are quite different, it will be easy to judge the type of signals. For example, for each type of neuro-biological signal, one specific frequency region is defined as the judgement criterion. In the system, to determine the type of signals, it is only needed to check the specific frequency region.

Secondly, there always have a large mount of neuro-biological signals. According to the request, they can be divided into each segment. For example, a continuous 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 or offline.

Thirdly, in the pre-processing of signals, one of the important jobs is to obtain qualified signals. The so-called qualified signal is based on the requirement. For example, Fig.2 (a) illustrates the qualified EEG signals and Fig.2 (b) the qualified EMG signals. The selection of qualified signals is based on the calculation of feature parameters. In addition, the noise contaminated in the signals should be eliminated. There are two ways to eliminate the noise. One is to eliminate them when recording the signals in real-time. Another is to pick up the segments contaminated with noises offline from the existed signals. Any ways are both important to obtain the qualified signals..



(a) (b)

Fig.2 Example of wave shape displaying on the screen, (a) A qualified EEG signal, (b) A qualified EMG signal.

When selecting the qualified signals and eliminating the noise, feature parameters are quite important. For example, the features of EEG records in each channel can be expressed by the periodogram parameters, including:

- Amplitude: $A_z(x) = 6\sqrt{S_z(x)}$
- 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: $F_z(x) = f_z^c(x)|_{P_{\max}} \cdot P_{\max} = \max_{f_{lower} \le f_z(x) \le f_{upper}} P(f_z(x))$
- 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 Fp_1, F_3, C_3, P_3, O_1, Fp_2, F_4, C_4, P_4, O_2, F_7, T_3, T_5, F_8, T_4, T_6; *z* denotes the respective EEG components: L(0–0.5 Hz), δ(0.5–4 Hz), θ(4–8 Hz), α(8–13 Hz), β(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 EEG components calculated by the summation of periodogram with the frequency band of *z* in channel *x*;

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

Based on the above parameters and relative criteria of judgement, the qualified EEG records can be selected. Due to the limitation of space, we will not introduce the criteria of judgement.

3.2 Evaluation of multiple neuro-biological signals

One of most important functions of the real time evaluation system for multiple neuro-biological signals is to evaluate various types of neuro-biological signals. Therefore, for this purpose the system should be able to carry out calculation, comparison and making report.

The evaluation of neuro-biological signals is also based on the feature parameters of neuro-biological signals. For different types of neuro-biological signals, the evaluation items and equations are quite different. For example, based on the following criteria, the technical artifacts in EEG can be evaluated.

- Electrode:
  - $A_\delta(x) \geq 25\mu V$,(*x*: respective electrdes on one side)
  - $\sum P_\delta(x,y)/11 \leq 30\%$, (*x*, *y*: respective neighborhood electrode on one side of the scale)
  - $\sum P_\delta(x,y)/8 \leq 50\%$, (*x*, *y*: a pair of homologous electrodes on both sides)
- Base-line drift:
  - $A_L(x) \geq 60\mu V$, (*x*: respective electrodes)

With the same way, various types of neuro-biological signals can be evaluated for different items.

3.3 Output of the system

The output is an important function of the real time evaluation system for multiple neuro-biological signals because it is related with the application of the system. In this system, it has two types of output ways. Some information will be displayed on the screen of the computer. Some information can be directly output through I/O interface of computer so that it can be adopted to control the BCI devices.

Concerning the output of information by displaying on the screen, as illustrated by Fig.3, it could be the signal recordings, control signals, evaluation reports, etc., for multiple neuro-biological signals.

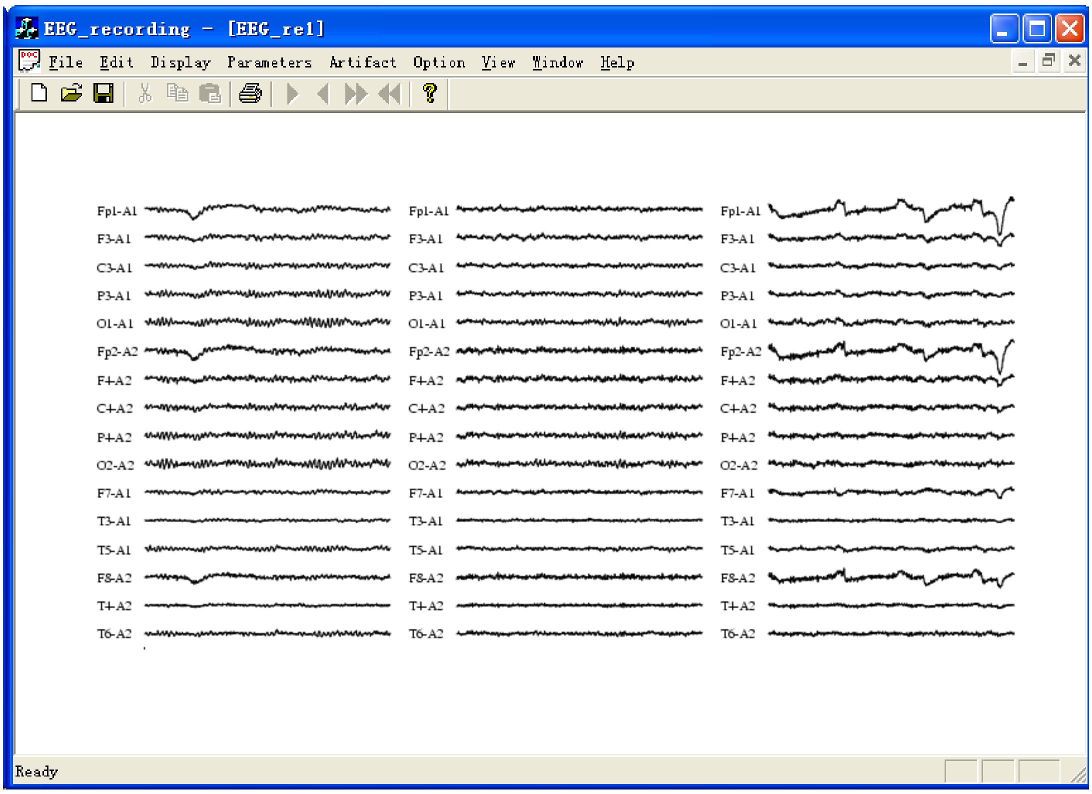


Fig.3 Output of information by displaying on the screen of computer

Concerning the output of information through I/O interface of computer, it can be directly adopted to control BCI devices. For example, a developed meal assistance robot has been directly controlled by the signals generated by EOG [5]. Besides, considering the requirement from users, based on the above system, multiple neuro-biological signals can be processed and adopted simultaneously to control BCI devices.

4. System Operation

Since the real time evaluation system for multiple neuro-biological signals has a human-friendly interface, the operation of the system is easy by use of its menu. Based on its different functions, its operation has three stages.

Stage 1: Pre-processing:

For per-processing, the operation procedure is as below:

Step 1: Input data;

Step 2: Select pre-processing mode: online or offline;

Step 3: Start pre-processing program;

Step 4: Display the pre-processing results.

Stage 2: Evaluation

For this stage, the operation procedure is as below:

Step 1: Input the processed data;

Step 2: Select the evaluation items;

Step 3: Start the evaluation program;

Step 4: Display the evaluation reports.

Stage 3: Output

For this stage, the operation procedure is as below:

Step 1: Input the processed data;

Step 2: Select the output mode: displaying or outputting control signals;

Step 3: Start the output program;

Actually, in the system there also have many other items, which can be executed by use of menu of the system. In the near future, we will also extend the functions of the system.

5. Discussion

The proposed real time evaluation system for multiple neuro-biological signals has many attractive applications. Basically, it can be adopted for doctors to interpret the neuro-biological signals and therefore diagnose the diseases. Particularly, it can provide enough information from multiple neuro-biological signals. In addition, the output of the system can be directly used to design the control signals to control the BCI devices. Besides, the proposed system can be used for other situation. For example, when using the online processing of neuro-biological signals, engineers can assist doctors to obtain qualified signals during the course of getting the neuro-biological signals. In addition, with this system we can create a neuro-biological signals database for each specific subject. This system not only can be regarded as a tool to process the multiple neuro-biological signals, but also can be regarded as a platform for interpretation of neuro-biological signals and controlling BCI devices.

6. Conclusions

This paper introduces the design of a real time evaluation system for multiple neuro-biological signals. This system not only can pre-process various types of neuro-biological signals online or offline, but also can evaluate the signals based on the user's requirement. The output of the system can be possibly adopted to assist doctors to interpret neuro-biological signals for judging the diseases and define the control signals for BCI devices. In the near future, we will continue to develop this system and extend its functions.

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