An Intelligent Brain Computer Interface of Visual Evoked Potential EEG

Shih-Chung Chen  Shih-Chang Hsieh  Chih-Kuo Liang
Institute of EE, Southern Taiwan University
chung@mail.stut.edu.tw; m9520113@webmail.stut.edu.tw; liangck@mail.stut.edu.tw

Abstract

The goal of our research is to design an EEG BCI (Brain Computer Interface) system and develop techniques for helping the serious disabled with spine/central nerve injury, motor neuron disease or without upper limb/foot. In our research, the brain wave amplifier we used is the NuAmps amplifier and the acquisitive/analytic software for EEG is named “Scan 4.3”. Both of them were developed by NeuroScan Company. The other software we used to implement the human-machine interface and on-line analysis functions is LabVIEW 8.2.1 version developed by National Instruments. We programmed TCP/IP communication protocol to connect Scan 4.3 with LabVIEW. In the experiments, we focused on VEP (Visual Evoked Potential) to design the EEG BCI system. There are four directional arrows (up, down, left, right) shown on the monitor randomly for stimulating the subject. Regarding data analysis, we used ICA (Independent Component Analysis) to filter the artifact of EOG/EMG, and calculate the average value after the summation of all trials of EEG signals. Therefore, we found some special phenomena and regarded them as VEP EEG features. We applied these VEP EEG features to design a directional examination for 5 male subjects. The average of recognition ratio of EEG resulted from VEP is over 90 % if the subject can be concentrative during the test.

2. Material and Methods

The whole system design can be divided two parts: (a) VEP EEG acquisition and pre-processing system, the architecture is shown in figure 1 and (b) EEG BCI system, the architecture is shown in figure 2. In the VEP EEG acquisition and pre-processing system, we utilized visual stimulus mainly, meanwhile, recorded all EEG signals during the test and then acquired EEG signals were analyzed off-line. Once EEG signals were acquired in VEP EEG acquisition system, the EEG signals can be pre-processed for analysis and feature extraction. Then the EEG BCI system can on-line recognize the VEP features in EEG on-line measurement referring to the feature extraction of VEP EEG and the recognition result can be transferred into command for controlling the assistive devices.

1. Introduction

Many kinds of assistive devices and medical equipments are developed rapidly because the medical technologies are getting better. However, there are still many problems regarding how to develop an effective assistive system for the serious disabled with spine injury, central nerve damage, motor neuron disease or without upper limb/foot. These so-called the serious disabled are the impaired people whom we have no other better methods to communicate with, except EEG application [1, 2]. It is a big challenge to help the serious disabled to communicate with normal people.
port of the user’s computer. NuAmps amplifier can receive both of the event code and EEG signals. Event code and amplified EEG signals were transmitted together to Scan 4.3 software in the second computer after digitalization. In the mean time, the exact time of visual stimulation event can be mapped for EEG signal in time domain.

Regarding the flowchart of EEG BCI system in figure 2, the amplified EEG signals from NuAmps were received and pre-processed by the band pass digital filter. The EEG signals after band pass digital filter were further filtered again by ICA (Independent Component Analysis) functions as described in the equation (1). The mixed matrix \( W \) in equation (1) can be calculated. Each independent component in \( y \) multiplied by \( W^{-1} \), mapping to each electrode on the scalp in \( x \) can be found. These artifacts included in EEG signals can be cancelled.

\[
x = W^{-1} y
\]  

(1)

Figure 2. the architecture of EEG BCI system

2-1. Data acquisition

The software we used to acquire brain wave is Scan 4.3 developed by NeuroScan Company. The other software we used to design the human-machine interface and on-line analysis functions is LabVIEW 8.21 developed by National Instruments Company.

We adopted LabVIEW to implement TCP/IP communication protocol program to communicate with Scan 4.3 which can receive the EEG data from NuAmps amplifier because NuAmps amplifier can’t be controlled by LabVIEW directly.

The flowchart of EEG BCI system we mentioned in figure 2, first step, the computer produced a visual stimulation event to stimulate the subject and encode the event. The event code was sent to NuAmps brain wave amplifier by printer port of computer and the subject’s EEG signals were also acquired by NuAmps amplifier in the meantime.

Next, the amplified EEG signals from NuAmps amplifier were digitized and transmitted to Scan 4.3. Then, Scan4.3 can transmit the digitized EEG signals to human-machine interface of EEG BCI system programmed in LabVIEW language for data analysis and feature extraction with the help of TCP/IP communication protocol.

2-2. Signal processing, analysis and control

When we start to proceed with the EEG BCI test, first step is to load the subject’s VEP EEG features as reference analyzed in VEP EEG acquisition and pre-processing system. Next, EEG BCI system starts to generate visual stimulation and measure the subject’s EEG signals. The measured EEG signals will be on-line filtered by the band pass filter and ICA for data pre-processing and artifact cancellation. Third step, the EEG BCI system will integrate the visual stimulation time and sum up of each trial of EEG signal to calculate the average of VEP. Once the average of VEP is calculated on-line, we can analyze the correlation parameter between VEP reference and the average of on-line VEP. After correlation analysis, we can find out the linear dependence correlation parameter value. If the correlation parameter is over the threshold value we defined, BCI system will execute command to control the devices. Otherwise, BCI system will do nothing.

3. Experimental methods

There are two kinds of EEG experiments finished that will be discussed in the following context. All related setting parameters of NuAmps, for example, sample rate, recording channels of amplifier, reference channel, the frequency range of band pass filter and notch filter etc. are as follows:

- Sample Rate: 1000 Hz
- Record Channel: EOG(V), EOG(H), C3, Cz, C4, P3, Pz, P4
- Reference Channel: A2
- BandPass Filter: 0.1 ~ 30 Hz
- Notch Filter: 60 Hz

The first EEG experiment is designed for the subject’s VEP measurement and analysis. The visual stimulation patterns are shown in figure 3. There are four directional arrows showing up, down, right and left respectively. These four directional arrows can be blinking in a random order [4, 5, 6]. Each directional arrow represents a stimulating event. Each stimulating event can be encoded as up:1, down:2, right:3, left:4
and transmitted to NuAmps amplifier by the printer port of computer.

The subject will be asked to follow the rule: gazing at the designated directional arrow and neglecting the residual three other directional arrows during the first kind of VEP EEG experiment. The subject will be also asked to be concentrative and count the appearance times of the designated directional arrow.

4. Results and Discussion

5 subjects accepted the first and the second experiment tests we mentioned above. The whole test includes 25 directional questions. The direction assignment can be designated in random order by computer automatically. We recorded the answer of each directional question for every subject. We gathered statistics in Table 1. We can see that 4 subjects can on-line recognize the direction designated by computer more than 90% correct ratio referring to the VEP feature extraction in the first experiment. The average of total accuracy is about 94.4%. It is a satisfactory result that makes us feel confident to finish EEG BCI application.

<table>
<thead>
<tr>
<th>Q</th>
<th>S</th>
<th>Up</th>
<th>Right</th>
<th>Down</th>
<th>Left</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>S1</td>
<td>2/4</td>
<td>6/6</td>
<td>3/4</td>
<td>9/11</td>
<td>80 %</td>
</tr>
<tr>
<td>2</td>
<td>S2</td>
<td>3/3</td>
<td>9/9</td>
<td>6/7</td>
<td>6/6</td>
<td>96 %</td>
</tr>
<tr>
<td>3</td>
<td>S3</td>
<td>9/9</td>
<td>4/4</td>
<td>3/3</td>
<td>9/9</td>
<td>100 %</td>
</tr>
<tr>
<td>4</td>
<td>S4</td>
<td>5/5</td>
<td>5/6</td>
<td>10/10</td>
<td>4/4</td>
<td>96 %</td>
</tr>
<tr>
<td>5</td>
<td>S5</td>
<td>11/11</td>
<td>2/2</td>
<td>7/7</td>
<td>5/5</td>
<td>100 %</td>
</tr>
</tbody>
</table>

Q: questions for 4 kinds of directions
S: subjects
?/?: correct ratio, correct answers/questions

5. Conclusion

We had implemented the TCP/IP communication protocol program, EEG signal analysis software and EEG BCI system by LabVIEW. We also designed two different VEP related experiments to prove that VEP feature extraction technique can be utilized to implement EEG BCI control. The high average of recognition accuracy (more than 94%) in Table 1 lets us feel confident to further apply the VEP EEG technique to control the assistive devices in the near future. It will be the good news for the serious disabled.

However, there are still many problems waiting for solutions. For example, it still needs 1~2 hours to set up the whole equipments. The whole system is very expensive. In spite that the recognition rate is high, the recognition time of each direction test cycle still needs over 40 seconds. All the problems we have now will be considered to find the better solutions. After all, practice makes perfect. Heaven always help those who help themselves. We believe that we can have the advanced research result in the future.
6. Acknowledgement

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7. References


