Emotional BCI Control of a Smart Wheelchair

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Abstract

In this paper, an emotional BCI control system to drive a smart wheelchair is proposed. The proposed BCI control system permits to the user to select one of four commands to drive the wheelchair. Once a command is selected, the control system executes the selected command and, at the same time, monitors the emotional state of the user. While the user is satisfied, the selected command is still executed and when the user becomes unsatisfied, the control system will stop the wheelchair and ask the user to select another command.

Keywords: *Smart Wheelchair, Control, BCI, Emotional State.*

1. Introduction

Electrical wheelchairs are widely used to help disabled people moving around their environments. However, many of them have difficulties to drive their wheelchairs especially in narrow places [1]. To overcome this problem, several techniques were proposed to assist people in driving their wheelchairs [2-5].

Brain Computer Interfaces (BCIs) is one of these techniques that help users controlling their wheelchairs by brainwave signals [6-11]. However, these techniques require the concentration of the user all the time in external stimuli in order to generate a recognized metal state that limits the use of these techniques practically.

In the other hand, emotions are important communication ways with the users. Recent studies proposed new methods to recognize the user's emotional state from measured brainwave signals [12-16].

In this paper, we propose an emotional BCI control system to drive a smart wheelchair. The proposed BCI control system permits to the user to select one of four commands to drive the wheelchair: move forward, move backward, turn left, and turn right. Once a command is selected, there is no need for the user to concentrate in external stimuli. The control system executes the selected command and, at the same time, monitors the emotional state of the user. While the user is satisfied, the selected command is still executed and when the user becomes unsatisfied, the control system will stop the wheelchair and ask the user to select another command.

The rest of the paper is organized as follows. In Section 2, a brief description of BCI systems is given. In Section 3, the proposed emotional BCI control system is explained. Experiments and results are given in Section 4. Section 5 is devoted to concluding remarks and future works.

2. BCI Systems

Brain Computer Interfaces (BCIs) are compound techniques that permit a direct communication with brainwave singles. A BCI system is usually composed of three main units: signal acquisition unit, signal analysis unit, and action unit [17].

Signal acquisition unit consists of electrodes and signal processing unit. The electrodes are distributed on the scalp according to an international system such that meaningful signals can be acquired [18]. The signal processing unit amplifies the acquired signals and removes noises and possible artifacts from the acquired signals [19].

The signal analysis unit extracts features from input signals and classifies them into distinct classes according to extracted features. A wide range of feature extraction methods and classification methods were proposed and used in literature [20].

The action unit converts classified signals into discrete control signals that can be used to control an external application and give a feedback to the user.

3. Emotional BCI Control System

In this section, the proposed emotional BCI control system is described in detail. A general description of the proposed system is depicted in Fig. 1.

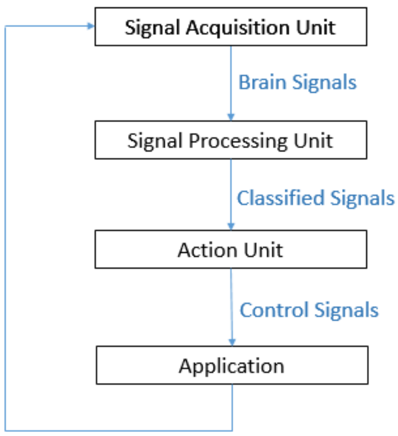

Fig. 1 Proposed system.

3.1 Signal Acquisition Unit

The signal acquisition unit used in our system is the Emotiv EPOC headset shown in Fig. 2. The headset has 14 electrodes located over 10-20 international system positions AF3, F7, F3, FC5, T7, P7, O1, O2, P8, T8, FC6, F4, F8, and AF4 using 2 reference electrodes as shown in Fig. 2. The headset aligns, band-pass filters, and digitizes the signals at 128 Hz and transmits wirelessly to a windows PC [21].

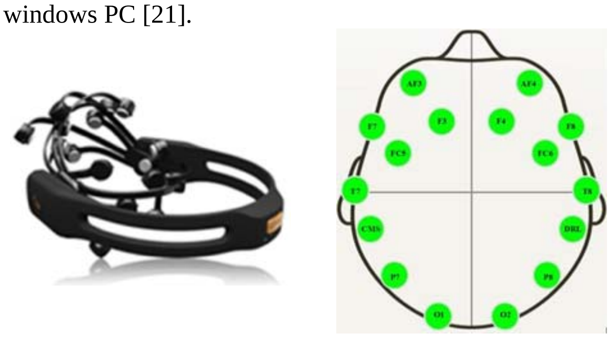

Fig. 2 Signal acquisition unit: the Emotiv EPOC headset (Left) and the location of electrodes relative to the head (Right).

3.2 Signal Processing Unit

The signal processing unit used in our system is the Emotiv EmoEngine™ that runs on the PC and exposes Emotiv detection results to applications via the Emotiv Application Programming Interface (Emotiv API) [22]. The Emotiv control panel shown in Fig. 3. The Emotiv control panel provides three suites [22]: Expressiv™ Suite, Affectiv™ Suite, and Cognitiv™ Suite. In this work, the Affectiv™ Suite and Cognitiv™ Suite are used and they will be described briefly in the following.

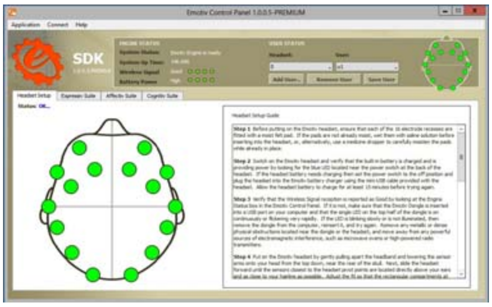

Fig. 3 Signal processing unit.

The Affectiv™ Suite reports real time changes in the subjective emotions experienced by the user. The Affectiv™ detections look for brainwave characteristics that are universal in nature and do not require an explicit training or signature-building step on the part of the user. However, to improve the affective detections, individual data is collected for each user and is saved in the user's profile while the Affectiv™ Suite runs. Adaptive interfaces can monitor user engagement, boredom, excitement, frustration, and meditation level in real time. [22].

The Cognitiv™ Suite evaluates a user's real time brainwave activity to discern the user's conscious intent to perform distinct physical actions on a real or virtual object. The detection is designed to work with up to 13 different actions: 6 directional movements (push, pull, left, right, up and down) and 6 rotations (clockwise, counter-clockwise, left, right, forward and backward) plus one additional action that exists only in the realm of the user's imagination: disappear. Cognitiv™ Suite allows the user to choose up to four actions that can be recognized at any given time [22].

In this work, the Affectiv™ Suite is used to monitor the user frustration such that when the user is frustrated the control unit will stop the wheelchair and waits for a new command from the user. In the other case, the control unit will continue executing the command previously selected by the user.

In addition to the Affectiv™ Suite, the Cognitiv™ Suite is used to allow the user to choose one of four actions by a metal activity: push, pull, left, and right.

3.3 Action Unit

The action unit takes the states produced by the signal processing unit and generates appropriate control signals. The proposed system consists of two states: frustrated state and unfrustrated state as shown in Fig. 4.

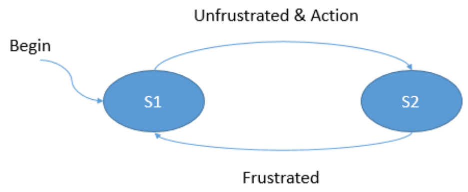

Fig. 4 State diagram of proposed system.

At the beginning, the user is in the unfrustrated state and he has to do a mental activity to choose a desired action. Once an action is recognized, the appropriate control signal is generated. The correspondence between the actions and the controls is given in Table 1. Notice that this operation needs the concentration of the user in order to generate a recognized action.

Table 1: Correspondence between actions and controls

Action	***Control***
Push	Move Forward
Pull	Move Backward
Left	Turn Left
Right	Turn Right

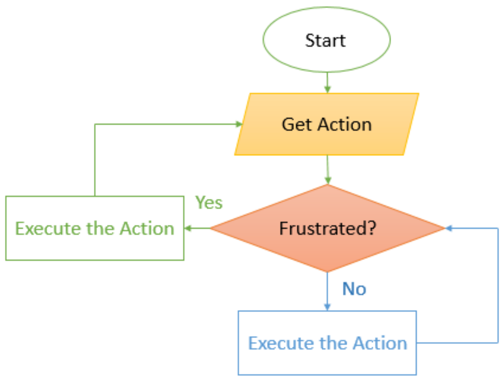

Fig. 5 Operational flowchart of proposed system.

Once an action is recognized, the system will switch to the second state. In this state, the corresponding control will be executed while the user in not frustrated. When the user becomes frustrated, the system switches to the first state and the same activities are repeated. The operation of the action unit is described in the flowchart shown in Fig. 5.

3.4 The Application

The application considered in this work is the Autonomous Vehicle for People with Motor Disabilities (VAHM-3) shown in Fig. 6 which is available at Laboratoire d'Automatique humaine et Sciences Comportementales (LASC), Université de Metz, France.

Fig. 6 VAHM-3: autonomous vehicle for people with motor disabilities.

VAHM-3 is provided with smart system that prevents it from hitting any possible obstacle when executing a control signal.
In addition to the real wheelchair, the system is provided with a simulator shown in Fig. 7 that gives a feedback to the user about the wheelchair motion and permits to the user to choose a new action.

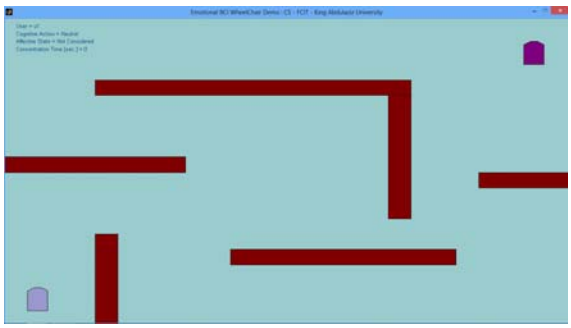

Fig. 7 Simulator of VAHM.

4. Experiments and Results

In order to test the efficiency of the proposed system, two experiments were carried out. The first one was carried out using only the metal activities of the user while the second one was carried out using the metal activities and the emotional state of the user. The concentration time is used to compare the performance of the experiments.

Before starting the experiments, the Emotiv Cognitiv™ Suite has to be trained. The user wearing the Emotiv EPOC Neuro-Headset sits in front of a PC running the Emotiv Cognitiv™ Suite. First, two actions are added, push and pull, and the user is asked to generate a metal state to push and pull and animated cube in the image. Then another two actions are added, left and right, and again the user is asked to generate a metal state to move the animated cube to left and right respectively (see Fig. 8).

Fig. 8 The Emotiv Cognitiv™ Suite.

In both experiments, after training the Emotiv Cognitiv™ Suite, the user uses the Emotiv Cognitiv™ Suite to generate appropriate actions to derive the wheelchair from a start position to a target position. However, in the second experiment the Emotiv Affectiv™ Suite is used to detect the emotional state of the user.

In the first experiment the user has to be concentrated all the time to generate appropriate actions, while in second experiment has to be concentrated only when the wheelchair executes undesired move.

Fig. 9 shows the results of first experiment for a user and Fig. 10 shows the results of second experiment for the same user. From Fig 9 and Fig 10 we can see similar behavior of the user during the driving of the wheelchair from start pose to target pose. However, the difference of concentration time is quite big. In the first experiment, the concentration time is 227.41 sec. while the concentration time of the second experiment is 74.49 sec.

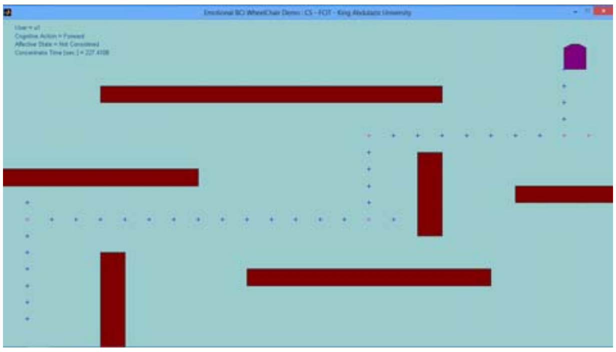

Fig. 9 Results of experiment1.

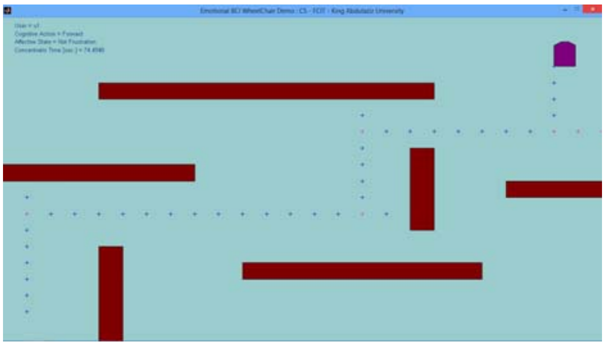

Fig. 10 Results of experiment 2.

5. Conclusions

This paper addressed the problem of integrating emotional state of the user in a brain computer interface (BCI) system. A BCI system is designed to drive a smart wheelchair using four mental activities of the user. In addition, an emotional state of the user was considered to make the user less concentrate in choosing actions when driving the wheelchair.

Two experiments were conducted to see the efficiency of the proposed system, one without considering the emotional state of the user and another with emotional state of the user. The result showed that the user needed less concentration time when his/her emotional state is considered.

In the future, we are looking to improve the detection time of the user emotional state. In addition, other emotional states will be considered.

Acknowledgments

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References

[1] L. Fehr, W.E. Langbein, S.B. Skaar, "Adequacy of Power Wheelchair Control Interfaces for Persons with Severe Disabilities: A Clinical Survey", Journal of Rehabilitation Research and Development, Vol. 37, No. 3, 2000, pp. 353-360.

[2] S.P. Levine, et al., "The NavChair Assistive Wheelchair Navigation System", IEEE Transactions on Rehabilitation Engineering, Vol. 7, No. 4, 1999.

[3] G. Bourhis, O. Horn, O. Habert, and A. Pruski, "The VAHM Project: Autonomous Vehicle for People with Motor Disabilities", IEEE Robotics and Automation Magazine, Vol. 7, No. 1, 2001, pp. 21-28.

[4] M. Sahnoun, A. Fattouh, and G. Bourhis, "Assisted Control for a Powered Wheelchair with a Force Feedback Joystick", in 8th European Conference for the Advancement of Assistive Technology in Europe", Henri Warembourg, Faculty of Medicine, Lille, France, September 6-9, 2005.

[5] F. Leishman, O. Horn, and G. Bourhis, "Smart Wheelchair Control through a Deictic Approach", Robotics and Autonomous Systems, Vol. 58, 2010, pp. 1149-1158.

[6] B. Rebsamen, et al., "Controlling a Wheelchair using a BCI with Low Information Transfer Rate", in IEEE 10th International Conference on Rehabilitation Robotics, 2007, pp. 1003 – 1008.

[7] R. Leeb, et al., "Self-Paced (Asynchronous) BCI Control of a Wheelchair in Virtual Environments: A Case Study with a Tetraplegic", Computational Intelligence and Neuroscience, Vol. 2007, 2007.

[8] G. Pires, M. Castelo-Branco, and U. Nunes, "Visual P300-Based BCI to Steer a Wheelchair: a Bayesian Approach", in Annual International Conference of the IEEE Engineering in Medicine and Biology Society, 2008, pp. 658-661.

[9] V. Khare, J. Santhosh, S. Anand, and M. Bhatia, "Brain Computer Interface Based Real Time Control of Wheelchair Using Electroencephalogram", International Journal of Soft Computing and Engineering (IJSCE), Vol. 1, No. 5, 2011, pp. 2231-2307.

[10] F. Carrino, et al., "A Self-Paced BCI System to Control an Electric Wheelchair: Evaluation of a Commercial, Low-Cost EEG Device", in Biosignals and Biorobotics Conference (BRC), 2012, pp. 1-6.

[11] R. Lievesley, M. Wozencroft, and D. Ewins, “The Emotiv EPOC neuroheadset: an inexpensive method of controlling assistive technologies using facial expressions and thoughts?”, Journal of Assistive Technologies, Vol. 5, No. 2, 2011, pp. 67-82.

[12] S. Makeig, et al., "First Demonstration of a Musical Emotion BCI", in Fourth International Conference, ACII 2011, pp. 487-496.

[13] Y. Liu, O. Sourina, and M. K. Nguyen, Real-Time EEG-Based Emotion Recognition and Its Applications, Lecture Notes in Computer Science: Springer-Verlag GmbH Berlin Heidelberg, 2011.

[14] S. P. Kvaale, "Emotion Recognition in EEG: A Neuroevolutionary Approach", M.S. thesis, Department of Computer and Information Science, Norwegian University of Science and Technology, 2012.

[15] A. A. Ghanbari, et al., "Brain emotional learning based Brain Computer Interface", IJCSI International Journal of Computer Science Issues, Vol. 9, Issue 5, No 1, 2012, pp. 146-154.

[16] G. G. Molina, T. Tsoneva, A. Nijholt, "Emotional Brain-Computer Interfaces", in 3rd International Conference on Affective Computing and Intelligent Interaction and Workshops, 2009, pp.1-9.

[17] B. Graimann, B. Allison, and G. Pfurtscheller, Brain-Computer Interfaces: A Gentle Introduction, In the book: Brain Computer Interfaces Revolutionizing Human Computer Interaction. New York: Springer Publishing, 2011.

[18] U. Herwig, P. Satrapi, and C. Schönfeldt-Lecuona, "Using the International 10-20 EEG System for Positioning of transcranial Magnetic Stimulation", Brain Topography, Vol. 16, No. 2, 2003.

[19] A. Bashashati, M. Fatourechi, R. K. Ward, and G. E. Birch, "A survey of signal processing algorithms in brain–computer interfaces based on electrical brain signals", Journal of Neural Engineering, Vol. 4, 2007.

[20] A. Cabrera, "Feature Extraction and Classification for Brain-Computer Interfaces", Ph.D. thesis, Brain-Computer Interface Laboratory Center for Sensory-Motor Interaction (SMI), Department of Health Science and Technology, Aalborg University, Denmark, 2009.

[21] Brain map image from: http://www.emotiv.com/bitrix/components/bitrix/forum.interface/show_file.php?fid=1529

[22] Emotiv Software Development Kit: http://emotiv.com/developer/SDK/UserManual.pdf

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