Design and Implementation of a Brain Computer Interface System for Controlling a Robotic Claw

D Angelakis, S Zoumis and P Asvestas
Department of Biomedical Engineering, TEI of Athens, Agioy Spyridonos, 122 43 Egaleo, Greece

angelakisdimitris2@gmail.com

Abstract. The aim of this paper is to present the design and implementation of a brain-computer interface (BCI) system that can control a robotic claw. The system is based on the Emotiv Epoc headset, which provides the capability of simultaneous recording of 14 EEG channels, as well as wireless connectivity by means of the Bluetooth protocol. The system is initially trained to decode what user thinks to properly formatted data. The headset communicates with a personal computer, which runs a dedicated software application, implemented under the Processing integrated development environment. The application acquires the data from the headset and invokes suitable commands to an Arduino Uno board. The board decodes the received commands and produces corresponding signals to a servo motor that controls the position of the robotic claw. The system was tested successfully on a healthy, male subject, aged 28 years. The results are promising, taking into account that no specialized hardware was used. However, tests on a larger number of users is necessary in order to draw solid conclusions regarding the performance of the proposed system.

1. Introduction
A BCI system is a computer-based system that takes brain signals, analyses them and translates them into commands that are relayed to a device to trigger a desired action. A BCI system does not use peripheral nerves and head muscles [1]. The CNS (Central Nervous System), for example, is used to measure signals produced by the central nervous system. Thus, for example, a sensor that is activated by the voice or the movement of a muscle is not a BCI system. Also an EEG is not BCI itself, because it only records brain signals but it does not produce an output that acts on the user's environment. It is also wrong to think that BCI is a mind-reader. They do not export information from unsuspecting users or users unwillingly using the system. They allow users to act in their environment when they want it by reading their brain signals rather than muscles [2]. The user and the BCI work together. The user, after a training session, produces brain signals encoded by the BCI system. The BCI then translates these commands and transmits them into an output device [1].

Brain computer interfaces have contributed to various areas of research. Applications that are about medicine, neuro-technology and smart environment, neuro-marketing and advertising, education and self-regulation, games and entertainment, as well as security and identification [3]. In this particular project the researchers focusing on rehabilitation and especially in the area of motor neuroprosthetics. BCIs focusing on motor neuroprosthetics aim to either restore movement in individuals with paralysis or provide devices to assist them, such as interfaces with computers, robot arms or devices meant to
replace missing biological functionality or cognitive modality that might have been damaged as a result of an injury or a disease (stroke, cognitive impairment after chemotherapy, brain injury after a vehicle accident etc.) [4].

2. State of the art
This paper presents a prototype of a simple BCI system that can control the opening/closing and the rotation of a robotic claw. It makes use of commercially available EEG headset, as well as of a cheap microcontroller board. Dedicated software is used to interpret the acquired EEG signals to suitable commands for the manipulation of the claw. Previous researches suggest that the Emotiv EEG can be used to differentiate between varying stimulus modalities and accompanying cognitive processes [5]. Also it have been shown that Emotiv EPOC can be a possible option but not recommended for implementing motor imagery application [6]. On a similar study by the Faculty of Mechanical Engineering, University Technology MARA Shah Alam, (Selangor, Malaysia) the researchers used LabVIEW GUI to combine EEG waves and myoelectric signals to control a prosthetic hand with a major notifying difference of having access to raw data in contrast of this study [7].

3. Method and Procedure

3.1. Hardware implementation
The hardware architecture of the proposed system is depicted in Fig. 1. It comprises:
- An EEG headset
- A PC
- An Arduino Uno
- Two servo motors
- A robotic claw

The EEG headset is the EMOTIV Epoc+, which is designed for contextualized research and advanced brain computer interface (BCI) applications. The EPOC+ provides access to dense array, high quality, raw EEG data using a subscription based software (EMOTIV Pure•EEG™). It features 14 EEG channels plus 2 reference channels and offers optimal positioning for accurate spatial resolution (Fig. 2(a)). The electrodes of the headset are placed on the head of the subject and their data are transferred wirelessly to the PC by means of the Bluetooth protocol. The PC communicates with the Arduino board, which in turn controls the servo motors to rotate accordingly the robotic claw (Fig. 2(b)). The one servo motor opens or closes the claw, whereas as the other motor turns it right or left.
3.2. Software implementation

Since, the authors did not own a licenced copy of the EMOTIV Pure•EEG™ software, that provides access to the raw EEG data, a different approach was followed. Specifically, the Emotiv Epoc+ is accompanied by a freely available software (Emotiv Control Panel) that provides the capability to analyse a subject’s brainwaves and develop a personalized cognitive signature which corresponds to each particular action, as well as the background state (neutral state) (Fig. 3). As the software learns and refines the signatures for each actions as well as neutral state, detections become more precise and easier to perform.

Figure 2. Screenshot of the accompanying software suite for the Emotiv Epoc+.

To this end, a training process takes place. Firstly, the user selects an action from a predefined list (6 directional movements (push, pull, left, right, up and down) and 6 rotations (clockwise, counterclockwise, left, right, forward and backward). The actions are related to the manipulation of a virtual object (cube), which is shown on the PC’s display. Next, when the user is ready, he/she begins to think the selected action for about 8 seconds. During this period, it is very important the user to maintain his/her focus: physical gestures, such as pushing the virtual object with one hand, may be used to heighten his/her focus on the intended action, but are not required. The user should avoid making substantial head movements training period, as these actions can interfere with the recorded EEG signal. Initially, the virtual cube on screen will not move, as the system has not yet acquired the training data necessary to construct a personal signature for the current set of actions. After Neutral and each enabled action have been trained at least once, the virtual cube will respond to the user’s thought in real time. Usually, 10 or 15 training sessions are required, in order to generate a reliable personalized cognitive signature for each user. When the training is completed, the Emotiv Control Panel is able to interpret the EEG signals of a subject.

As was mentioned above, it was not possible to access the raw EEG data, therefore a specialized software (Mind Your OSCs) was used to communicate with the Emotiv Control Panel. This software is able to encode the raw data selected from the Emotiv Control Panel into a series of OSC (Open Sound Control) messages and sends them to a network port. Open Sound Control is a protocol for communication among computers, sound synthesizers, and other multimedia devices that is optimized for modern networking technology and has been used in many application areas. The OSC messages were decoded and converted to suitable commands for the Arduino Uno board, using a dedicated application developed by the authors under the Processing programming environment using the Java language. Fig. 3 displays the software architecture.
4. Results
The system was tested successfully more than thirty times on a healthy, male subject, aged 28 year. There was four more tries on different healthy male aged 26 but was unsuccessful due the EMOTIV connectors couldn't have proper connectivity most possibly due to the morphology of the subject's skull. The movements that can be performed are right, left and opening-closing the robotic claw. It has been noticed that the acquired data from the headset are perfectly decoded on the robotic claw with a delay of 5 milliseconds. It’s an ongoing promising research that lead us on a strong conjecture for more rigorous evaluations of commercial BCI headsets in the future. The EMOTIV EPOC+ 14 Channel Mobile EEG cost is $799.00. Other well-known commercial EEG neuroheadsets set is INTERAXON’s MUSE (7 electrode-sensors) with a cost at $354.00 and MindWave (3 electrode-sensors) from Neurosky with a cost at $79.99

5. Conclusion
Human-Computer Interaction has been promising in recent years and is steadily growing. Practical applications mainly focus on the rehabilitation of cognitive or neurological lesions and on aiding people with aesthetic / motor lesions (paralysis, ALS, etc.), as well as subjects with learning disabilities or autism, observation and study of Sleep, explanation or anticipation of reactions under rest or danger. To this end, this paper presented the prototype of a system than can manipulate a simple robotic claw using a commercially available EEG headset, the Emotiv Epoc+. The system was tested on a limited number of subjects, yet providing encouraging results. Tests on larger number of subjects are required in order to be able to reliably assess its performance. Individuals depending on their skill learning rate, after some sessions can gain control of grasp and release, enabling to perform various activities of daily living, such as eating, drinking, and brushing teeth, as well as other tasks such as opening a door handle etc. Additionally, the system could be enhanced by directly accessing and using the raw EEG data and using pattern recognition techniques to extract meaningful features. These features could be used to design classifiers to interpret brain waves into suitable commands.

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