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Brain-Computer Interface for Controlling a Mobile Robot Utilizing an Electroencephalogram Signals

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Abstract

Brain-computer interface (BCI) system provides communication channel between human brain and external devices. The system processes and translates thought into control signals and thus enabling a user to navigate a robot from one place to another. In this context, we developed a system that enables a user to guide a robot by brain waves. The system consists of an Emotiv Epoc headset, a personal computer, and a mobile robot. The Emotiv Epoc headset attached to the head of the user and used to collect Electroencephalogram (EEG) signals. The headset picks up brain activities from 14 locations on the scalp and sends them to the computer for processing. Those brain activities can tell the system what a person is going to do in his virtual reality. Then, by using a novel application designed for this purpose, the cognitive suite supplied by Emotiv is responsible for generating the control actions needed to make the robot execute three different commands: turn right, turn left, and move forward. In this paper, hardware and software architectures were designed and implemented. Experimental results indicate that the robot can be successfully controlled in real-time based on the subject's physiological changes.

Keywords: brain computer interface (BCI), electroencephalogram (EEG), emotiv epoc neuroheadset.

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1. Introduction

As shown in figure 1, the adult human brain is divided into four lobes: frontal, temporal, parietal, and occipital lobe [1]. It weighs on average about three pounds and contains more than 100 billion neurons. Within a single neuron, information is conducted via an electric pulse that travels down to the axon terminals. The electrical pulse (action potential) is then converted to a chemical signal so as to pass the information to the target neuron. The target neuron then converts the message back to an electrical pulse to continue the process. This process enables people to think, move, and feel emotions.

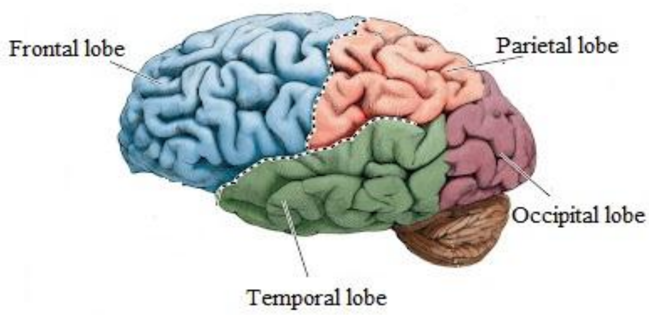


Figure 1: Anatomical Areas of the Brain

Amyotrophic lateral sclerosis (ALS), brainstem stroke, severe brain or spinal cord injury, cerebral palsy, muscular dystrophies, multiple sclerosis, and other brain disorders have locked in people into a limited environment that would be worse in there own bodies and thus they became unable to communicate with other people. Fortunately, several technologies with distinct functionalities are available nowadays for helping those with disabilities to experience relief from the difficulty that they face while trying to communicate with the outside world. Among those, Brain Computer Interface (BCI) technology is widely used and can provide an alternative method of communication and control [2].

Paralysis is the result of a block in the information pathway that travels between the brain and limbs [3]. Patients who are suffering from this severe problem do not have the ability to control any external device. This problem added a high cost for the residential care packages since another person is needed to drive the patient and satisfy his needs. This research will provide a patient who is losing the ability to control limbs or lack any muscle control to communicate with wheelchair by thought alone and thus giving him the ability to regain functions they have lost.

Brain computer interface (BCI) is a new emerging technology that processes brain activity and translates them into commands [4]. The purpose of this technology is to analyze brain electrical activity obtained via electroencephalography (EEG) and establish a direct communication channel between human brain and any computing device [2]. BCI system mainly allows an individual with severe physical disabilities or totally paralyzed to have effective control of devices such as wheelchairs, and robotic [5].

The early work of the BCI system was to detect and read brain signals invasively through a metal electrode that are implanted directly on the surface of the brain. Recently, electroencephalography (EEG) is used as a non-invasive technology in which sensors are implanted directly on scalp [6]. Although invasive technologies provide high spatial resolution, they require a complex surgery that often leads to some degree of risk. In most BCI systems, the non-invasive technology is the most popular method that presents the opportunity for inexpensive, portable, and safe devices to monitor neurological state of the patient and process them into usable data [7].

The scope of this paper is to help disordered patients to be more interactive with their environment without exerting any physical effort. The remainder of this paper is organized as follows. Section 2 presents a brief survey of the related work. In section 3, we explain the system architecture, hardware and software design. In section 4, experiments were performed and results are explained. Finally, we conclude and discuss future work in section 5.

2. Related Work

A number of researchers are interested in the BCI field; whether in the theoretical or practical part. The author in [8] proposed a BCI system, and mentioned number of brain disorders and how to help patients in order to communicate more freely with their surrounding environment. Furthermore, he clarified what is the highest transfer rate of information that BCI can reach based on different cooperating factors. In [9], the same concept was introduced, but with another name; BMI (Brain Machine Interface). Where he showed the auspicious BMI applications in future, and mentioned that instead of being sufficient only with sending commands from brain cortex area to control external devices, it could be possible to return information back to the cortex area.

Research in BCI has focused primarily on motor imagery tasks. The author in [10] aims at evaluating the possible advantages of introducing a mobile robot as a physical input/output device in BCI systems. In his research, the movements of a robot were triggered by the subject's brain activity. Consequently, the efficiency of any BCI system is affected by several factors. The author in [11] mentioned how to improve the BCI efficiency with a group of effective factors like attention, and motivation. Others described how a closed-loop protocol may enhance BCI efficiency. Although this approach seems to enhance BCI efficiency, their use is limited by the additional time needed for the exploration process.

In further research, researchers are working nowadays to develop and improve the control system of a wheelchair based on EEG signals. In [12], the author proposes a control strategy in which the motion of the wheelchair is controlled based on brain signal, and data obtained from obstacle avoidance sensors. Tanaka in [13], developed a system that is able to discriminate between left and right movement. During the training phase, the user was instructed to imagine the movement for just 20 seconds. Another system was developed by [14], for which EEG signal was analyzed every 125 milliseconds, and the system is then decided whether to turn left, right or forward.

3. System Description

In the following subsections, we will describe the system architecture, and hardware components.

3.1 System Architecture

As shown in figure 2, the architecture of the system mainly consists of six parts: Emotiv Epoc neuroheadset, Bluetooth module, personal computer, RBC program, FLYPORT Wi-Fi module, PIC16F887 microcontroller, and PICA robot. Neuroheadset measures the electrical activities within the brain and sends them for amplification and processing. It holds 14 EEG sensors and has a microchip which pre-process brain activities, and transmits data to the computer via Bluetooth. After receiving EEG data from the wireless device, the data is processed using the software provided by Emotiv. We created a software application that read commands from Emotiv software and establishes a Wi-Fi connection with the robot. Further, we created an ad-hoc protocol to exchange data between a robot and the previous application. After the connection is established between the RBC program and the robot, the commands are passed to it. Another software application was created in order to control the robot motion. Once the action is done by the user, the robot will respond to the command and move to the desired direction.

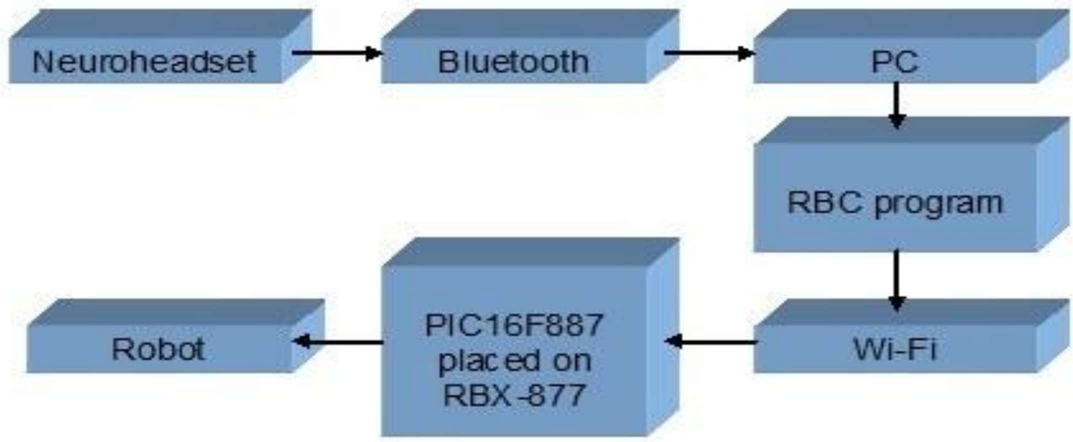
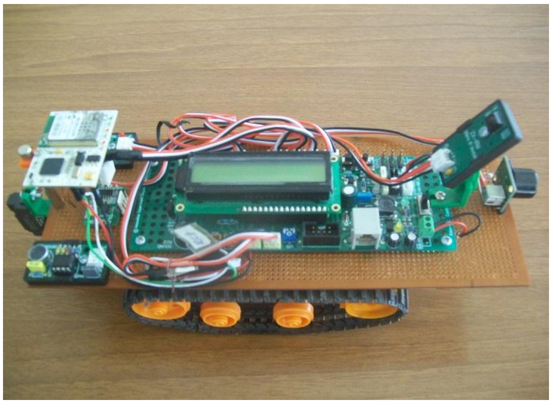
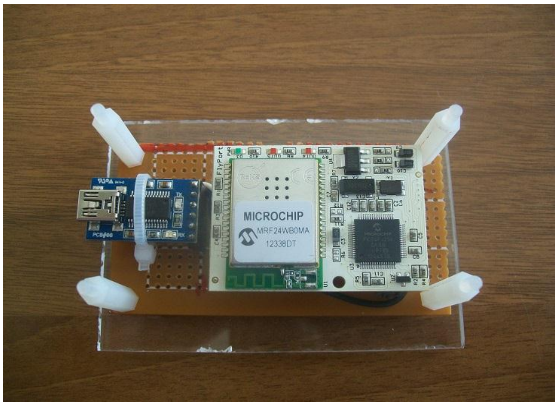


Figure2: General Architecture of a BCI System.

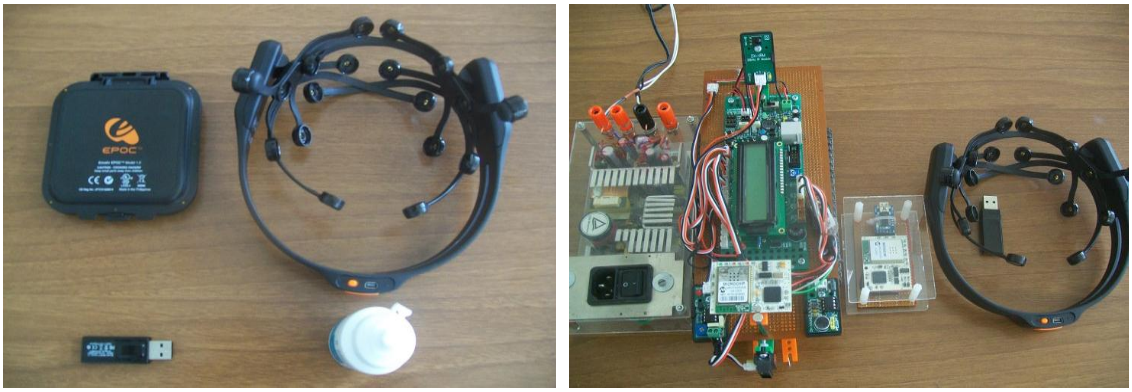
3.2 Hardware Components

As shown in figure 3. a, the structure of the robot in our case consists mainly of a commercial off-the-shelf parts which are available at low cost. The main controller board attached to the robot is based on the PIC16F887 microcontroller. A variety of sensors are mounted on the robot, including ultrasonic sensor, and accelerometer. A Wi-Fi module was also interfaced to the microcontroller. This module receives the commands from another Wi-Fi module that is shown in figure 1.b and feeds them to the microcontroller. The microcontroller is then output a PWM signal to L293D H-bridge to drive two DC motors. The system designed in this project is analogous to a powered wheelchair and will be used in the near future by disabled people in order to improve their life and maximize their communication capabilities and independences. Figure1. c shows Emotiv Epoc neuroheadset that has a microchip which pre-process brain activities, and transmits that data to the computer via Bluetooth.





(a) (b)

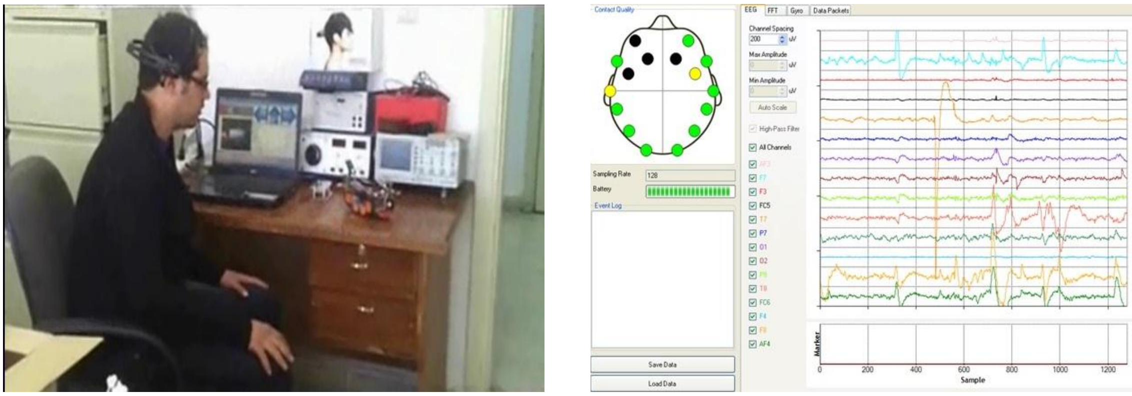


(c) (d)

Figure 3: Overview of the main components in the system design (a) PICA-Robot, (b) FLYPORT Wi-Fi module, (c) Emotiv Epoc neuroheadset, (d) System hardware components.

4. Experimental Results

In this paper, Emotive Epoc EEG headset is used for controlling a PICA robot. EEG headset consists of 14 electrodes positioned on the test person scalp. As shown in figure 1.a, a user who has been trained before, is wearing the Emotive headset that forwards brain signals to the software application. The actual task was to get some information about the user brain waves, analyze them and covert them into commands. Those commands will then be used to control the robot directions. The process of connecting three actions: push, left, and right to three directions: forward, left, and right was mainly accomplished successfully using three programs. Cognitive suite, EmoKey, and TTU_Robo_control. Cognitive suite is used to control left and right movements of a virtual cube supplied by Emotive, while Emokey allows mapping cognitive actions to keyboard input. The action push was mapped to the key (i), and the action left was mapped onto the key (l). Right action was mapped to the key (k). The keys (i), (l), and (k) were then used as a command to move the robot forward, left, and right respectively. TTU_Robo_control code was written in Microsoft Visual C#. The code is divided into two basic parts: listening for a key pressed and sending the corresponding commands to the robot. For this purpose, we have developed a Wi-Fi module that acts as an interface between the laptop and the robot. This allows us to control the robot directly from the laptop using off the shelf components. The system was trained for collected neutral data and then the user was instructed to imagine pushing the virtual cube, moving it to the left or to the right. EEG Data used in this study was recorded using the Emotive Epoc TestBench. As shown in figure 1.b, TestBench utility records the voltage across each electrode in microvolt. Further, we have added an ultrasonic sensor in order to avoid obstacles located ahead of the robot.



(a) (b)

Figure 4: Operation of the System (a) 14 Electrodes Positioned on the Test Person Scalp, (b) EEG Measurements in TestBench.

5. Conclusion

Brain-computer interface (BCI) system provides communication channel between human brain and external devices. The system processes and translates thought into control signals and thus enabling a user to navigate a robot from one place to another. In this paper, we have trained a specific user on the headset using Emotive control panel that is included with the Emotiv SDK. The user is trained on left, right, and push movements in order to control the robot's directions. Then we programmed the PIC16F887 and place it on the robot. And finally we have controlled the robot using EEG signals that are transmitted from the Emotive headset. In the current stage, we consider the simple task of operating a robot to move in three directions. In future, we aim to develop an application that is able to adjust the speed of the robot using the level of concentration in a test person, and then implement this technology to assist paralyzed or disabled people to communicate with others or control their wheelchairs using just brain waves.

References

[1]Carlson, N. R. (2002). Structure and Functions of the Nervous System, Foundations of physiological psychology. Boston, Mass, London: Allyn and Bacon, 5(3).

[2] Wolpaw, J. R., Birbaumer, N., McFarland, D. J., Pfurtscheller, G., & Vaughan, T. M. (2002). Brain-computer interface for communication and control, *Clinical Neurophysiology, 133*, 767-791,

[3] Donoghue, J.P. (2002). Connecting cortex to machines: recent advances in brain interfaces, *Nature Neurosci supp. 5*, 1085–1088,

[4] Vaughan, T. M., Heetderks, W. J., Trejo, L. J., Rymer, W. Z., Weinrich, M., Moore, M. M., Kubler, A., Dobkin, B. H., Birbaumer, N., Donchin, E., Wolpaw, E. W., & Wolpaw, J. R. (2003). Brain-computer interface technology: a review of the second international meeting, *IEEE Transactions on Neural Systems and Rehabilitation Engeneering, 11*(2), 94-109.

[5] Mak, J.N., & Wolpaw, J.R. (2009). Clinical Applications of Brain-Computer Interfaces: Current State and Future Prospects. *IEEE reviews in biomedical engineering, 2*(1), 187-199.

[6] Müller, K. R., & Blankertz, B. (2006). Toward non-invasive brain-computer interfaces, IEEE Signal Processing Magazine, *128*(1), 125-128

[7] Sajda, P., Muller, K. R. & Shenoy, K.V. (2008). Brain-Computer Interfaces, IEEE Signal Processing Magazine, *25*(1), 16-17

[8] Wolpaw, J. R., Birbaumer, N., McFarland, D. J., Pfurtscheller, G., & Vaughan, T. M. (2002). Brain-computer interface for communication and control, Clinical Neurophysiology, 133, 767-791

[9] Donoghue, J.P. (2002).Connecting cortex to machines: recent advances in brain interfaces, Nature Neurosci supp. 5, 1085–1088

[10] Tonin, L., Menegatti, E., Cavinato, M., D'Avanzo, C., & Pirini, M. (2009). Evaluation of a robot as embodied interface for brain computer interface systems, Int J Bioelectromagnetism, 11, 97-104

[11] Vaughan, T. M., Heetderks, W. J., Trejo, L. J., Rymer, W. Z., Weinrich, M., Moore, M.M., Kubler, A., Dobkin, B.H., Birbaumer, N., Donchin, E., Wolpaw, E.W., & Wolpaw, J.R. (2003). Brain-computer interface technology: a review of the second international meeting, *IEEE Transactions on Neural Systems and Rehabilitation Engeneering, 11*(2), 94-109.

[12] Rebsamen, B., Chee, T., Zeng, Q., Ang, V., Burdet, E., Guan, C., Zhang, H., & C. Laugier, (2007). Controlling a wheelchair indoors using thought, Intelligent systems, IEEE, 22, 2

[13] K. Tanaka, K. Matsunaga, H. Wang, (2005). Electroencephalogram-based control of an electric wheelchair, *IEEE Transaction on Robotics, 21*(4), 762-766

[14] Toyota Motor Corporation, (2009). Real-time control of wheelchairs with brain waves.