Design and Implementation of Brain Computer Interface Based Robot Motion Control

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Abstract. In this paper, a Brain Computer Interactive (BCI) robot motion control system for patients' assistance is designed and implemented. The proposed system acquires data from the patient's brain through a group of sensors using Emotiv Epoc neuroheadset. The acquired signal is processed. From the processed data the BCI system determines the patient's requirements and accordingly issues commands (output signals). The processed data is translated into action using the robot as per the patient's requirement. A Graphics user interface (GUI) is developed by us for the purpose of controlling the motion of the Robot. Our proposed system is quite helpful for persons with severe disabilities and is designed to help persons suffering from spinal cord injuries/ paralytic attacks. It is also helpful to all those who can't move physically and find difficulties in expressing their needs verbally.

1 Introduction

The field of Brain Computer Interaction (BCI) has made possible new avenues to send signals from brain to the external world through non-neurological channels. The research in the BCI field has received a boost in last few years after realizing its necessity to serve people with disabilities as an assistive technology. The BCI devices enable the people, who are paralyzed, to lead their life independently without the help from any care taker. Today, BCI technology is broadly dependent on following principles: P300 [1], SCP (slow cortical potential) [1], SMR (sensorimotor rhythm), etc [1]. They translate the activities in brain in real-time into commands that operate a computer display, wheel chair, prosthetic arm or other device. Hence, both the user and the BCI system need to adapt to each other iteratively using the appropriate feedback mechanism till the optimum performance is obtained. The performance measure of the BCI systems depends on their speed and accuracy.

There are many BCI neuroheadset devices currently available for acquisition of the brain signals. One among those devices is the Epoc neuroheadset built by Emotiv, USA [12]. Though the device was meant to be used primarily for computer games, it could also be used as health equipment. It can assist patients with serious disabilities

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to communicate their expression and thoughts, move around independently without any support or care taker to do their daily activities through BCI technology.

2 Related Works

The EEG classification was used for control of application software on computers as far back as 1991[1]. They successfully created a system that allowed a user to control a cursor using EEG signals. Later, Wolpaw explored the area and published his work in a series of papers describing the state of the art throughout the early 2000s [11,17]. These works were further carried forward in [8], where a large, high resolution EEG was used to control a robotic arm. These studies highlighted the importance of EEG, but unfortunately did not address the issues of cost and difficulty of use for the end-user.

The need for an easy-to-use and cost effective neuroheadset has been met out by Emotiv EPOC neuroheadset. The Emotiv EPOC has been used in a variety of applications, due to its accessibility for consumers and researchers. The device was validated [1] where it was found to be useful for the control of computers by patients with no voluntary muscle control. These patients were able to access computer based assistive technology and navigate a virtual space using two discrete thought patterns, all with a greater than random chance of success. The Emotiv EPOC was found to be effective methods for computer control, having the subjects of their experiments perform a 3D rotation task in virtual space [9]. The Emotiv EPOC has also been used in the area of controlling robotic systems through non-invasive BCI. In [10] Emotiv EPOC was used to teleoperate a remote humanoid robot. Their system allowed for the remote control of an Aldebaran Robotics Nao humanoid robot , which the user was able to direct with EEG commands to move forward, turn left, and turn right. It was found that their system was effective to navigate a small course. In [11] the Emotiv EPOC was used to control a Lego NXT robot. They used the Emotiv Emokey software to send key commands to a java program. The Emokey software is provided by Emotiv, and allows a user to select different keystrokes to virtually actuate based on EEG data, with up to four outputs being trained [12]. The authors in [13] showed the use of the Emotiv EPOC for the control of robotic arms through EEG.

3 System Design

3.1 Objective

According to the American Spinal Injury Association Impairment Scale (AIS)-A, the patients suffer from most impairments in which their voluntary muscles don’t work. So for those patients, moving around freely and independently without any aid to accomplish their daily needs becomes a big challenge. They need their involuntary muscles to translate their needs or thoughts to a mobile device like electric wheel chair or robotic arm.

The main objective of designing the BCI based Robot motion control system is to help the persons with severe disabilities. This serves as an assistive technology for patients. The robot needs to move in all possible directions and execute all types of motion a patient would require. The same are shown in the written and pictorial form in a GUI containing nine elements in subsequent sections of this paper. When the person needs something he/she will focus on that element. Due to his/her facial expressions and thoughts the specific element being focused on is pressed. Thus, the previously programmed wheel chair or any other mobile device (here, FIRE BIRD V robot) moves as per the person's wish.

3.2 Signal Acquisition

Our system design uses the EPOC neuroheadset for extracting data from the patient's brain. The working principle of the EPOC neuroheadset is described below.

Taking the facial expression and thoughts of the user as input, the device accesses a computer and presses switches on scanning software. The neuroheadset has 16 sensors (out of which there are 2 reference sensors). It is worn on the head in such a way that these make contact with the scalp. It works by detecting electrical signals that are generated naturally by the human brain.

The neuroheadset SDK has three main features like:

1.''Expressiv'' suite which analyses the signals captured from the 16 electrodes of the EMOTIV EPOC neuroheadset to recognize 12 separate facial expressions such as ''blink'', ''smile'' or ''look left' 'etc.

2. ''Cognitiv'' suite interprets changes in this signal in order to detect 13 specific thoughts (such as ''push'' and ''pull'').

3. ''Affectiv''suite also analyses the EEG signal, but instead detects the user's level of engagement. [1]

3.3 Design Steps

The main steps of the design include: Signal acquisition, Feature extraction, and Feature classification, Feedback, Testing and Feature Recognition. In other words, the working principle of our BCI system includes: acquiring and processing EEG data, translating that data into device output, and giving a feedback to the user (Figure 1). Implementation of this above said EEG-based BCI system includes the feature extraction and classification of EEG data in real-time.

Step1: This step is concerned with Signal Acquisition from the human brain through a set of sensors. In the current design the EPOC neuroheadset is used for signal acquisition from the patient's brain.

Step 2: The Feature extraction deals with separating relevant EEG data from noise and other disturbances and simplifying that data by reducing the redundancy so that it can be further used for the classification process. Several other feature extraction techniques (i.e. PCA, ICA, CSP etc) [7] can also be used in the system.

Step 3: In the classification part, we decide what output classes the extracted feature corresponds to. Classification is done using the standard techniques such as:

LDA, SVM, ANN algorithms and various other types of pattern recognizers are employed to try to match the input data to known classes of EEG functional model. Recently unsupervised learning algorithms are used predominantly to find natural clusters of EEG data that are indicate certain kind of mental activities with varying degree of successes.

Step 4: Feedback is essential in BCI systems as it allows users to know the types of brainwaves they just produced and to learn behavior that can be effectively classified and controlled. The optimal form which the feedback should take is yet to be found out. [2][3]

Step 5: In the testing part we run some applications. Out of different classifications of EEG based BCIs; Synchronous systems (driven by the computer) are easier to implement as compared to asynchronous (are driven by the user) have so far been the major way of operating the BCI systems. [4] Here, the user is given a clue to perform a certain mental action and then the user's EEG patterns are recorded in a fixed time-window. The accuracy or success rate of using the application depends on the precision of training, the quality of contact of the neuroheadset with the person's scalp(in case of non-invasive EEG), the climatic condition, day and time on which the action is being performed and many more factors.

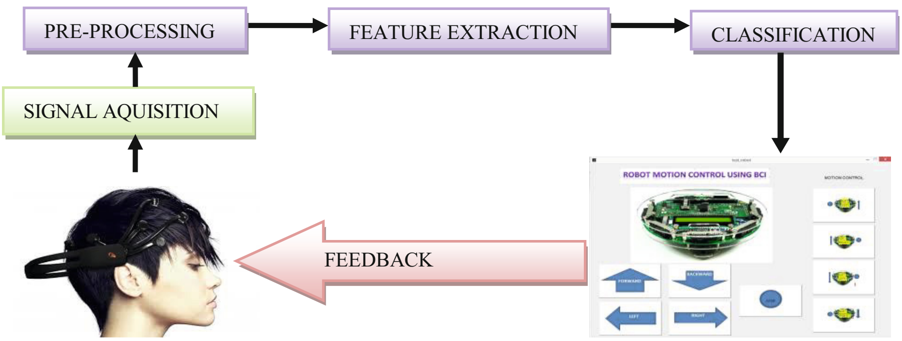

Fig. 1. BCI System

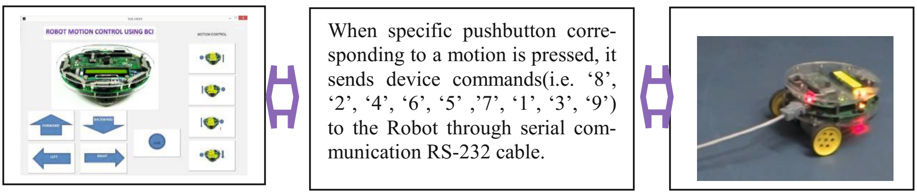

Fig. 2. Communication between GUI and Robot

4 Implementation

The implementation of the designed BCI system was done using the Emotiv Epoc neuroheadset, FIRE BIRD V Robot (developed by NEX ROBOTICS) (Refer Fig. 3a, 3b). The DB9 pin male female straight through RS232 Serial cable, computer system with Intel Xeon processor @3.4GHz, 16 GB RAM, and 64-bit Windows 8 operating system was used.

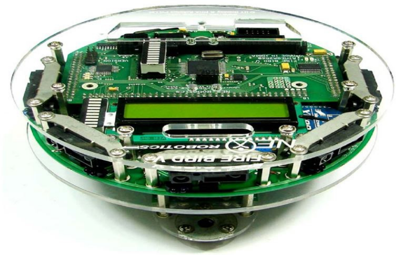

Fig. 3. Fire Bird V Robot

The various soft wares used in this work were: the AVR studio 8 from ATMEL [5], WIN AVR open source C compiler, Khazama AVR programmer, Terminal software for serial communication, Emokey software for mapping different actions with the keypad/mouse buttons. After writing and compiling the program in AVR Studio 8 ".hex" file was generated. This ".hex" file was then loaded to the FLASH buffer and then written on the ATMEGA 2560 microcontroller chip contained in the FIRE BIRD V robot and verified using Khazama AVR In System Programmer. This software does not contain digital signature and hence was blocked by Windows 8 OS. So, the digital signature needs to be deactivated before reading the chip signature. For serial communication between Computer and FIRE BIRD V Robot we used "terminal software". In terminal software, we selected baud rate as 9600 and communication port as COM1 for communication. Then, the program verification was done by pressing the appropriate keys from the keypad and checking whether the Robot was functioning appropriately or not. For example, as per our program when key '8' is pressed from the keypad the robot should move in the forward direction. The user was trained so as to use the neuroheadset. The quality of contact of each sensor was verified according to the color displayed (black: no contact, red: very poor contact, orange: poor contact, yellow: fair contact, green: good contact) in the Control Panel software supplied by Emotiv. Then the user was trained with each of the 12 facial expressions and 13 thought actions to determine which action could trigger strong signals without being disturbed by the unwanted actions. The sensitivity of the action was changed to get the best performance as per the necessity. It was observed that 'Blink' action has the greatest accuracy of detection as compared to other actions. Here after, the training is done for the user using universal signature. Then the 'left click' button of the mouse was mapped with the 'blink' action using the Emokey software.

The user then accessed a MATLAB GUI –"Robot motion control GUI" which was created using MATLAB R2012b. The cursor control feature is associated with the Emotiv Control panel under 'mouse emulator' option. Thus we can navigate through the computer screen by rolling our eyes. We selected the appropriate button in the GUI and the robot moved accordingly.

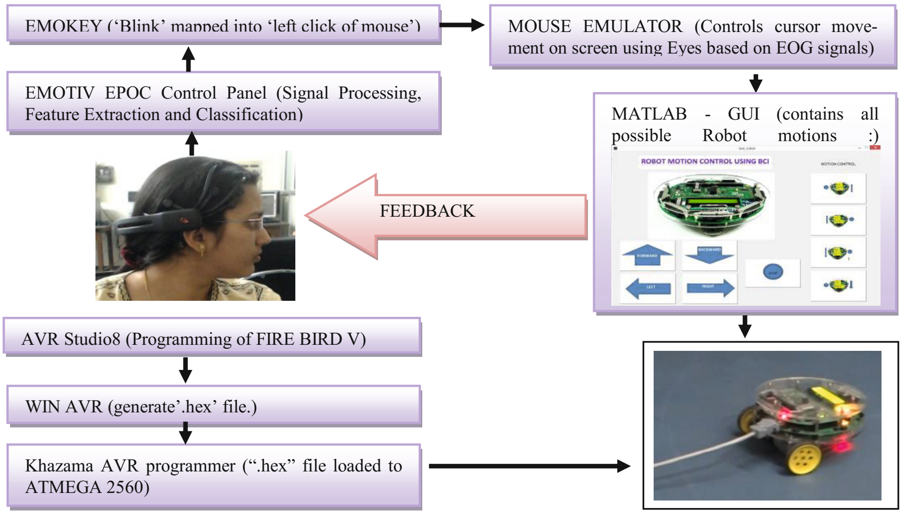

Fig. 4. Flow Diagram of implementation

This GUI has 9 control buttons (forward, backward, left, right, stop, soft left 1, soft right 1, soft left 2, and soft right 2). When the push button is pressed the necessary command is passed on to the device FIRE BIRD V through serial communication (Fig. 5).

Here, the robot motions were controlled using BCIs. All possible robot motions in Fire Bird V include:

i. Forward (both the motors move forward),
ii. Backward (both the motors move backward),
iii. Left (left motor moves backward and Right motor moves forward),
iv. Right (left motor moves backward and right motor moves forward),
v. Stop (both the motors stop),
vi. Soft left 1 (left motor stops and right motor moves forward),
vii. Soft right 1 (left motor moves forward and right motor stops),
viii. Soft left 2 (left motor moves backward and right motor stops),
ix. Soft right 2 (left motor stops and right motor moves backward).

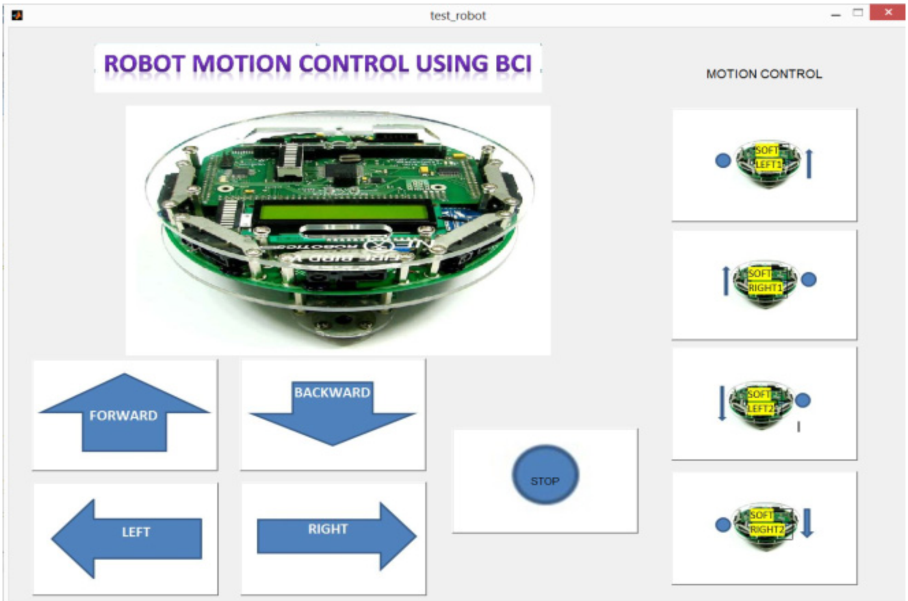

Fig. 5. Robot motion control GUI

The above events were generated as per the pin configurations and hex codes in hardware manual [5]. The pins PA0, PA1, PA2 and PA3 of ATMEGA 2560 microcontroller chip were interfaced with pin7, pin2, pin 15 and pin10 of L293D respectively[6]. Then the robot motion Forward, Backward, Left, Right, Stop, Soft Left1, Soft Right1, Soft Left2, SoftRight2 were carried out when the device commands ‘8’, ‘2’, ‘4’, ‘6’, ‘5’ ,’7’, ‘1’, ‘3’, ‘9’ were send to the robot through serial communication.

5 Conclusions

This paper presented the design and implantation details of a BCI based robot motion control system for assisting the patients. The system used the Fire Bird robot, AVR studio 8 from ATMEL, WIN AVR open source C compiler, Emotiv EPOC API, Khazama AVR programmer, Terminal software for serial communication, Emokey soft wares for the purpose. A GUI was developed. The performance and accuracy of the system after testing was found to be good. Thus, our designed system comes as bliss for all those patients with disabilities who can easily fulfil their immediate needs/wishes without moving any body part. The accuracy of the EMOTIV EPOC for the robot motion control using nine actions (blink, smile, neutral, raise brow, look left, look right, push, pull, smirk) was found out to be less than 40%. But when we reduce the number of actions from nine to two, the accuracy increased to 99%. Moreover, this inexpensive system is easy-to-use, fast, and accurate and furthermore, no adjustments are required to make it work.

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