ISSN: 2349-6495(P) | 2456-1908(O)

Implementation of Robotic arm control with Emotiv Epoc

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***Abstract*— *Brain Computer Interface (BCI) has opened up a new hope for people suffering from severe motor disabilities, having no physical activities caused due to disease or injury to the central or peripheral nervous system. A BCI based robotic arm movement control is designed and implemented. The proposed system acquires data from the scalp of subjects a group of sensors. Emotiv EPOC a commercially available EEG headset is used, which analyzes the acquired EEG signals real time. The signals are processed and accordingly commands are issued for different movements which will be based on the characteristic patterns for various facial expressions, human emotions and cognitive actions. The idea is to combine the user intent with a robotic arm to achieve the user initiated motor movements.*

***Keywords*— Brain Computer Interface, robotic arm, Emotiv EPOC, patterns, expressions, emotions, cognition and motor movement.**

I. INTRODUCTION

The basic idea of Brain-computer interfaces (BCI) is to transform user created patterns of brain activity into corresponding commands. BCI systems bypass regular channels of communication (i.e., muscles and nervous system) to supply direct communication and management between the human brain and physical devices by translating different patterns of brain activity into commands in real time. With these commands robotic devices can be controlled[1].

BCI systems are interactive that aim at providing users with an alternative way of translating their thought into control of external devices. Their most popular applications lie within the scope of rehabilitation and motor restoration for patients with severe neurological impairment. Although BCI research is currently undergoing a transitional stage of exploratory efforts, commercial applications of BCI are beginning to emerge. The use of brainwaves to control robotic devices has produced promising clinical results in terms of feasibility. Advances in biomedical signal processing, especially the EEG signal, and mobile robot control have allowed the development of robotic wheelchairs or a hand orthosis commanded by brain-computer interfaces , use some EEG characteristics, such as potentials from an imaginary motor task or evoked potentials, in their development[2]. Restoration of a certain degree of motor functions and high accuracy control of robotic prosthetic arms using invasive BCI has been proved. Such BCI controlled robotic applications would find more acceptability with the use of noninvasive, portable, and relatively low-cost systems is considered during development. Given these recent technological advances, research efforts are focused in noninvasive,minimally intrusive, and low-cost BCI. Control of electromechanical robotic arm to investigate the capabilities and limitations in combining these technologies for biomedical applications is attempted. The movements of robotic arm are designed to match the natural movement of a human operator's arm. The following factors were considered in the development of the interface: portability, scalability, and relatively low cost [3].

The execution of motor control in the body is planned, processed and memorized in the brain. The development in the area of BCI has focused on improving resolution and speed whilst minimizing health risks and user training times. Electroencephalography (EEG) has met all of the above criteria effectively. Thus facilitating multiple users and Virtual Rehabilitation scenarios. EEG functions by recording the electrical activity of neurons in the brain by placing electrodes over a patient's scalp. Because electrode placement is external, there is no need for invasive surgery or implants that would otherwise interfere with brain function, or corrode and release fragments and material by-products into the blood. However, EEG functions by measuring the integration of all outgoing signals for neurons instead of initial action potentials. Therefore, it trades specificity for speed, and has a lower spatial resolution compared to functional Magnetic Resonance Imaging (fMRI). EEG data also needs to be filtered by software to remove signals not associated with brain activity, including heart rate, eye movements, voluntary muscle activity, and noise from surrounding electronic equipment. These can be removed reliably through software due to frequency ranges during specific states of rest or activity, and by positioning electrodes as close to the scalp surface as possible[4].

A brain-computer interface (BCI) translates complex patterns of brain activity into commands that can be used to control a computer and other electronic devices. Thus, a BCI can provide a communication and control channel, which by-passes conventional neuromuscular pathways involved in speaking or making movements to manipulate objects. BCI systems are anticipated to play an important role in the development of assistive and therapeutic technologies for paralyzed patients, for prosthesis or orthosis control, and in movement rehabilitation, e.g., after stroke or spinal cord injury. Many BCI systems are based on the electroencephalogram (EEG), which provides a noninvasive measure of electrophysiological brain activity. There has also been growing interest BCI systems using magnetoencephalogram (MEG) signals, which have a higher spatial resolution compared with EEG. Notwithstanding the fact that MEG systems are not portable, MEG signals could be useful for providing enhanced feedback during training for EEG-based systems and for non-ambulatory BCI applications[5].

Non-invasive Brain Computer Interface like Electroencephalography (EEG) which directly taps neurological signals, is being widely explored these days to connect paralytic patients/elderly with the external environment. However, in India the research is confined to laboratory settings and is not reaching the mass for rehabilitation purposes. An attempt has been made here to develop a prototype of low cost robotic Arm using cost effective and portable headset unit Emotiv EPOC. The Emotiv EPOC neuroheadset was an ideal platform for the robotic arm control device. Though it is originally intended for computer gaming, a developer/research suite is provided which allows to explore the API and view real time EEG waveforms. Through a program using the Emotiv APIs the interpretation of EEG recordings was done. The output of this program was sent as a command to the robotic arm.

II. EEG HEADSET NEUROHEADSET AND ARM

A conclusion section must be included and should indicate clearlThe selection of a commercially available BCI headset depended on the number of sensing channels, signal quality, price, and ease of use. The medical EEG equipment causes inconvenience to the subjects by the application of conductive gel to the scalp and the preparation routine is also time consuming.

After surveying for wireless user friendly EEG headsets, we found the following headsets most suitable for research as they also provided raw EEG data.

1.Mindwave: 1 electrode, 2 mental states, cost around $99.95 and uses bluetooth technology.

2.Emotiv EPOC: 14 electrodes , 3 mental states, costs around $299. Also uses bluetooth.

3.Muse : 4 electrodes, trained apps provided to reduce stress. Cost $299[6].

Furthermore, the ideal BCI headset would need to meet the requirements of multiple data acquisition channels, low weight, and low cost. Frequency-based automatic classification of mental states by the hardware device and the ability to export the raw EEG signal were considered, the former being a strong factor for preference, the latter a decisive requirement. The capacity of a commercial system to automatically detect multiple mental states was considered an indirect indication of the quality and breadth of its sensing capabilities.

Two low cost, commercially available headsets, the Emotiv EPOC and NeuroSky MindWave were considered initially. Both devices export raw EEG as well as processed, automatically classified mental state data. Between them, sensing capabilities were considered, where the NeuroSky MindWave uses one sensor that can provide only three values: attention, meditation, and eye blinking. The Emotiv EPOC uses a series of 14 sensors plus 2 references, which are capable of detecting specific conscious thoughts, levels of attention, facial expressions, and head movements (the latter using the embedded gyroscope). The sampling frequency of the Emotiv EPOC is 4 times greater than the NeuroSky MindWave making it comparable to more complex EEG devices. Occasional unreliability of signal quality, is noticed with both the devices because of the use of dry electrodes. For this reason, the designers of the Emotiv headset suggest that users further improve skin conductance by the moistening of the sensors using a saline solution. We selected the Emotiv EPOC for use in our robotic arm design, since it integrates the largest number of sensors at the highest sampling rate among all portable low-cost BCI headsets available in the market[3].

2.1 THE EMOTIV EPOC OVERVIEW

The Emotiv EPOCTM EEG Headset [7] is an input peripheral released in September 2009, created by Emotiv Systems. Using a series of 16 electrodes, the EPOCTM can measure conscious thoughts, levels of attention and facial expressions to wireless control software or physical devices. Cost of developer edition is $299, it is one of the first low cost, portable, wireless EEG systems compared to those available prior to it. Whilst the number of electrodes is comparable to a standard medical EEG system, which uses 16-25 electrodes, the EPOCTM does not require a moistened cap to improve conduction. The sampling rate is also comparable to existing EEG devices used for virtual robotic movement with an internal sampling rate of 2048Hz. The EPOCTM utilizes 3 Suites for detection of different signal inputs: ExpressivTM, which reads facial expressions; AffectivTM, which reads the user’s emotional state; and CognitivTM, which reads conscious intent for movements. The CognitivTM Suite was the primary choice for use in robotic arm Training due to the imaginary movements[4].

Fig.1: Emotiv EPOC headset

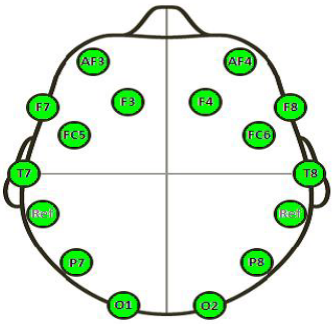

Fig.2: Electrode Placement

Emotiv EPOC uses gold-plated contact-sensors that are fixed to flexible plastic arms of a wireless headset as seen in Fig. 1. The headset included 16 placements, aligned with the 10–20 system: AF3, F7, F3, FC5, T7, P7, O1, O2, P8, T8, FC6, F4, F8, FC4, M1(Ref), and M2(Ref) as in fig. 2. One mastoid (M1) sensor acted as a ground reference point to which the voltage of all other sensors was compared. The other mastoid (M2) was a feed-forward reference that reduced external electrical interference. The signals from the other 14 scalp sites (channels) are high-pass filtered with a 0.16 Hz cut-off, pre-amplified and low-pass filtered at an 45 Hz cut-off. The digital signals are filtered using a 5th-order notch filter (50–60 Hz), low-pass filtered and down-sampled to 128 Hz. The effective bandwidth was 0.16–43 Hz[8]

2.2 ROBOTIC ARM

We have considered the TechnologyUncorked OctaMotion Robotic (TUOM) arm with degree of freedom 6. The TUOM Robotic Arm DIY Kit arm was procured from ebay [9] with the following key features as seen in fig. 3. It contains 84 parts required to construct 4-wheel All Terrain, pick and place platform The platform can support Forward, Reverse, Left and Right Motion The Gripper can support Open, Close, Up and Down movements Includes six high torque DC motors, spanner and screwdriver along with mechanical parts for the assembly. We have made modifications in the arm, as we did not need the pick and place facility shown in fig.4. The wheels from the chasis were removed and instead a stable base was provided, where grip open and grip close, up and down movements of the arm and left and right motions were considered.

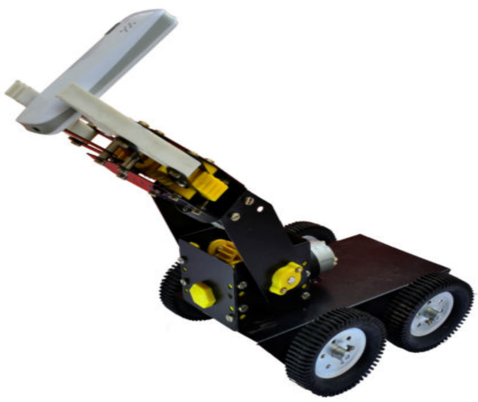

Fig.3: TUAM arm from ebay

Fig.4: Our prototype arm.

III. AVR MICROCONTROLLER

ATmega16 is used microcontroller for the arm. The ATmega16 is a low-power CMOS 8-bit microcontroller based on the AVR enhanced RISC architecture.The AVR development board is shown in fig. 5. By executing powerful instructions in a single clock cycle, the ATmega16 achieves through puts approaching 1 MIPS per MHz allowing the system designer to optimize power consumption versus processing speed.

The ATmega16 provides the following features as in fig. 5: 16K bytes of In-System Programmable Flash Program memory with Read-While-Write capabilities, 512 bytes EEPROM, 1K byte SRAM, 32 general purpose I/O lines, 32 general purpose working registers, a JTAG interface for Boundary scan, On-chip Debugging support and programming, three flexible Timer/Counters with compare modes, Internal and External Interrupts, a serial programmable USART, a byte oriented Two-wire Serial Interface, an 8-channel, 10-bit ADC with optional differential input stage with programmable gain (TQFP package only), a programmable Watchdog Timer with Internal Oscillator, an SPI serial port, and six software selectable power saving modes. The Idle mode stops the CPU while allowing the USART, Two-wire interface, A/D Converter, SRAM, Timer/Counters, SPI port, and interrupt system to continue functioning. The Power-down mode saves the register contents but freezes the Oscillator, disabling all other chip functions until the next External Interrupt or Hardware Reset. In Power-save mode, the Asynchronous Timer continues to run, allowing the user to maintain a timer base while the rest of the device is sleeping. The ADC Noise Reduction mode stops the CPU and all I/O modules except Asynchronous Timer and ADC, to minimize switching noise during ADC conversions. In Standby mode, the crystal/resonator Oscillator is running while the rest of the device is sleeping. This allows very fast start-up combined with low-power consumption. In Extended Standby mode, both the main Oscillator and the Asynchronous Timer continue to run.

The ATmega16 AVR is supported with a full suite of program and system development tools including: C compilers, macro assemblers, program debugger/simulators, in-circuit emulators, and evaluation kits.

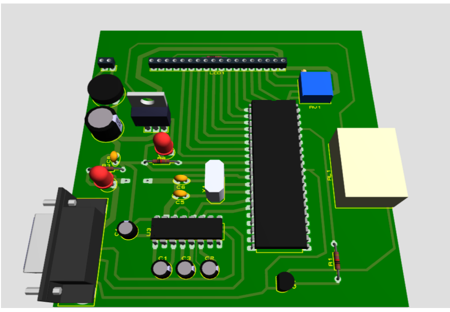

Fig.5: AVR Development Board

IV. DESIGN AND IMPLEMENTATION

The power supply consists of a step down transformer 230/12V, which steps down the voltage to 12V AC. This is converted to DC using a Bridge rectifier and it is then regulated to +5V using a voltage regulator 7805 which is required for the operation of the microcontroller and other components.

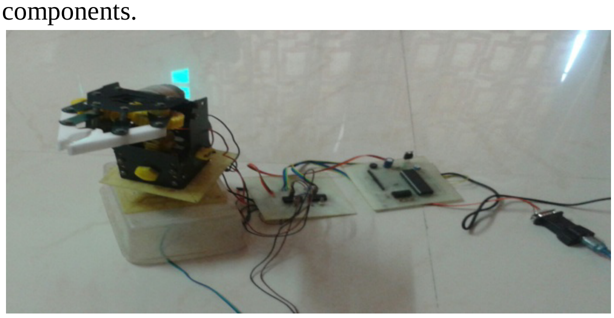

Fig.6: Implementation of prototype arm.

Implementation of designed system as in fig. 6, was done using Emotiv Epoc neuroheadset, arm,DB9 pin male female straight through RS 232 serial cable, laptop with processor @ 2.20GHz, 4GB RAM and 64 bit windows 10 PRO operating system. Software used was the tool provided with Emotiv, Emokey for mapping different actions with keypad, AVR studio 8 from ATMEL, Terminal software for serial communication.

The program was written and compiled in AVR studio 8, A .hex file was generated, which was then loaded to flash buffer and written on Atmega 16 microcontroller used to control the arm. Atmega 16 pins were interfaced with l293D to get the required movement.

The verification process was done using serial communication between the laptop and arm with the help of Terminal software.

In Terminal the baud rate selected was 9600, bit parity 8 and communication port was com1. Program verification was done by pressing different keys from the keyboard to check whether the arm was working properly or not. For example when keystroke 1 is pressed the arm should open, 2 for close, 3 for up and 4 for close.

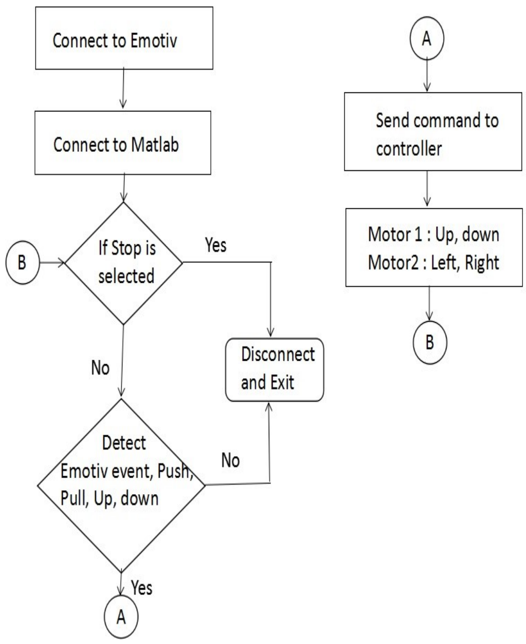

Fig.7: Working of prototype arm.

In the experimental setup, the subject was seated out of the movement range of the TUAM robotic arm to avoid being hurt or inconvenienced by proximity movements, and the TUAM robotic armis positioned to allow full movement range in each tested axis to avoid collisions with its surroundings.

Training was imparted to the users regarding the use of the neuroheadset. The sensor activation in the headset was checked and only if activation was noticed in all the sensors the readings were considered.The flow of events is shown in fig.7. Initially users were trained for 12 expressive and 13cognitive actions to get the best outcome. Out of these 4 events of Cognitiv suite were selected for four movements namely

1.Open grip
2.Close grip
3.Up
4.Down

Matlab was used for user interface. When particular button was pressed then necessary command is passed to the arm through serial communication.

V. CONCLUSION

The prototype robotic arm and Emotiv EPOC intend to provide users with an alternative way of translating their thought to control of external devices. Here only 4 commands were considered. In future more events would be considered. A more natural appearing robotic arm with natural human like movements can be considered in future.

ACKNOWLEDGEMENTS

We would like to thank the department of Computer Science and Information Science, Dr. Babasaheb Ambedkar Marathwada University, for providing the infrastructure for conducting the research.

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