Extracting and discriminating selective brain signals in non-invasive manner and using them for controlling a device: a cost-efficient approach to Brain Computer Interface (BCI)

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***Abstract*—The interface through which a human brain establishes links with external devices is generally called Brain Computer Interface. Although there are some significant amounts of ongoing researches on how an overall efficient BCI can be developed are going on, making a cost-efficient approach while dealing with limitless brain patterns is found to be more challenging. In this work, feasibility of a cheaper but appropriate way of extracting and discriminating of several non-invasive EEG signals and using those for controlling devices such as a wheel chair has been proved. To assist the argument of this project, numerous experimental data has been processed to produce several signals, such as, right turn, moving forward, stop etc. for the wheel chair. In the experiment the above mentioned three signals were well distinguished from each other. A microcontroller has been used for processing the signals collected from the brain and hence sending to the wheel chair controlling motors. Despite the challenges of dealing with very low but noise sensitive brain signals, their limitless patterns, and limited scope of necessary circuitries, this work has opened up the scope of feasibility of BCI technology in practical life with a simpler and easier approach.**

Keywords—BCI, EEG, Wheel Chair, Microcontroller.

I. INTRODUCTION

In this work an approach of controlling devices by using Brain Computer Interface (BCI) technology has been demonstrated. This project was proved as successful by extracting some brain signals as responses of body movement of a human subject and controlling a device by using those signals as some selective commands. The signals were extracted by performing non-invasive EEG and hence they were processed through a microcontroller to send as control signals to the motors attached with a wheel chair. In the whole project, extensive analysis has been performed on several EEG responses such as clapping, eye blinking, movement of hands etc. Additionally, the responses from a conscious and a relaxed mind were also investigated. Extraction of some selective and well distinguished patterns from hand movement was a success to control a wheel chair in an accurate manner. Although only few brain patterns were considered despite having limitless patterns, this project exhibited a very simple and cost efficient approach. Implementing an automated system was not the primary goal of this work. The primary concern was to prove the feasibility of applicability of BCI in practical arena.

This kind of research is needed to make devices smarter and more compatible with us to make rapid use. This method can be applied to drive wheelchairs for paralyzed person, or can be used to communicate with deaf and mute persons.

II. LITERATURE REVIEW

BCI is one of the newest technologies under research that creates the communication pathway between a brain and a computer. In another sense it is also called Man Machine Interface (MMI) as brain signals are extracted to control machines. The natural process is that a brain following a person's intent sends signal via peripheral nervous system to the analogous muscles. BCI is the process where the brain activity is measured according to a person's intent and those activities are converted to control signals for the external devices. The above concept was demonstrated by Wolpaw et al. where BCI was referred as communicating and controlling device for brain which is accomplished by non-muscular networks. Invasive and non-invasive: there are two ways of how BCI can be performed. The earlier one requires surgery and the process is called Electrocorticogram (ECoG). In comparison, for the later, only some electrodes needed to be placed on the scalp to extract signals by performing the process called Electroencephalography (EEG). The electrical and magnetic activities produced by brain are sensed by those electrodes in the EEG process. A brain can exhibit different modes of activities with difference frequencies such as- delta, theta, beta and gamma wave with the ranges of 0.5-4 Hz, 4-8 Hz, 14-35 Hz and above 35 Hz respectively. EEG signals are also classified based on those modes [2]. All but Gamma waves are not taken into account for BCI research to control external devices.

In BCI approach producing certain useful brain patterns which are convertible and controllable for certain operations is called mental or experimental strategy. The most common two ways of strategies used in current BCI research are-selective attention and motor imagery. In the case of selective attention, external stimuli, either auditory [3] or somatosensory [4] are required in BCI approach. For the later case, BCI research focuses on detecting a pattern of Event Related Synchronization (ERS). Any movement or imagination of movement of muscles creates or changes activities in brain's cortex region which is called Sensorimotor Rhythm (SMR). This rhythm generates different brain waves. Any increase in brain activity in a specific frequency band is termed as ERS. In BCI research, a control signal for particular movement of a device comes from a particular pattern of ERS after detection.

III. METHODOLOY AND RESULTS

A. Extracting the Brain Wave

For extraction, two wet type passive electrodes have been used which were placed on the fore head of the subject as shown in figure 1 as only two channels were considered in the experiment.

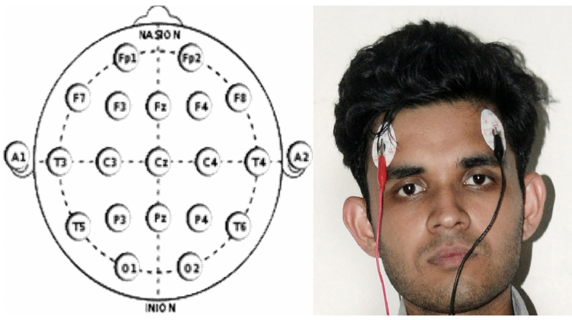


Fig. 1. Acquiring signals: position of electrodes

The necessary steps for extraction of the signals are shown in the figure 2. Before sending it to microcontroller it was needed to amplify and filter the signals as signals are of very low voltage and highly noise sensitive.

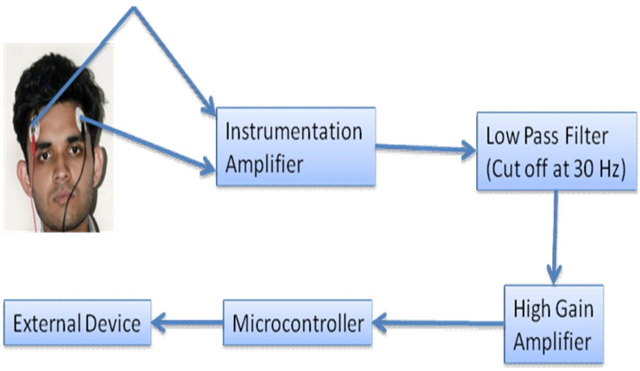


Fig. 2. Brainwave Signal Extraction

After performing some exhaustive trial and error in filtering process a fourth order Chebyshev Low Pass Filter with a cutoff at 30Hz was used. Again, a sharp roll-off -15 dB/Decade was crucial as signals were extremely noise sensitive. The circuit's lay out is shown in figure 3, whereas, gain and phase as responses are shown in figure 4. As the extracted signals were considered to be Alpha (8-13 Hz) and Beta (13-30 Hz) waves, a cutoff of 30 Hz was chosen in the filter.

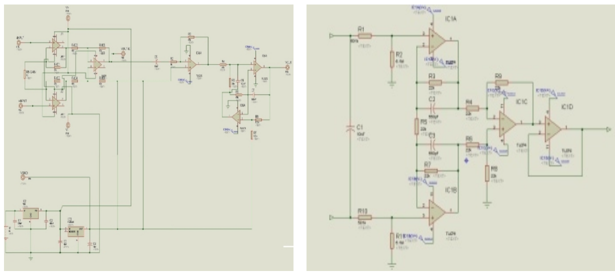


Fig. 3. Amplification and Filtering

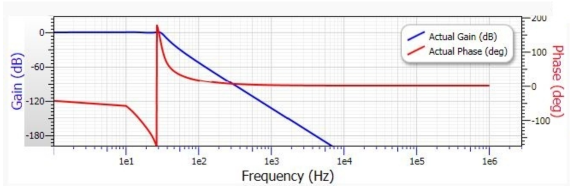
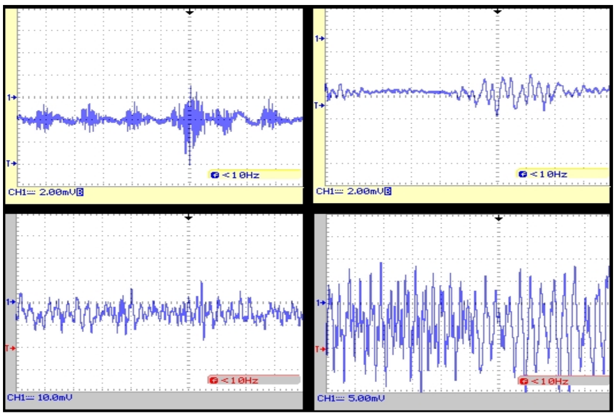


Fig. 4. Phase and Gain vs. Frequency of LPF with cut off at 30 Hz

It is important to note that even the signals are necessarily amplified and filtered, a BK Precision 2530B Digital Oscilloscope was used where all the signals were fed to that before delivering to the microcontroller. The purpose of this was to check and compare those display waveshapes with theoritical waveshapes and whether the signals have expected harmonis. Figure 5 shows the comparison where upper half shows the experimental waveshapes and lower half shows the theoritical waveshapes.



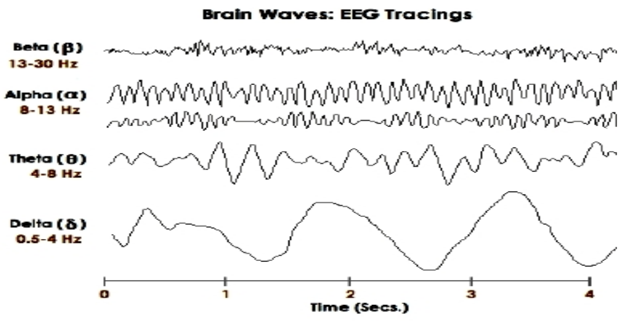


Fig. 5. Comparison between experimental (top) and theoretical results (bottom) [9]

B. LED control with brain wave

In this part of experiment the signals were justified by setting a LED on. It was peformed by waking up the subject from relaxed state which exhibited the discrimination between conscious and relaxed states. This is shown in figure 6.

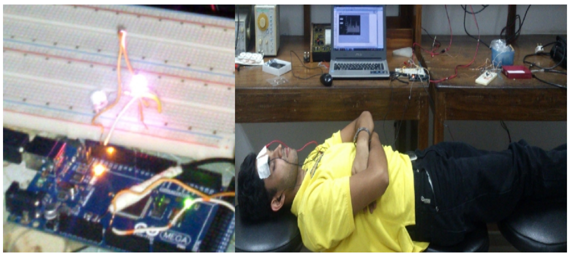


Fig. 6. LED responding to brain wave signal

The wave shapes below (figure 7) show the two states of mind mentioned above. It is noteworthy that alpha wave and beta wave represent relaxed state and conscious state respectively. In the figure below top part shows relaxed state whereas bottom one shows conscious state.

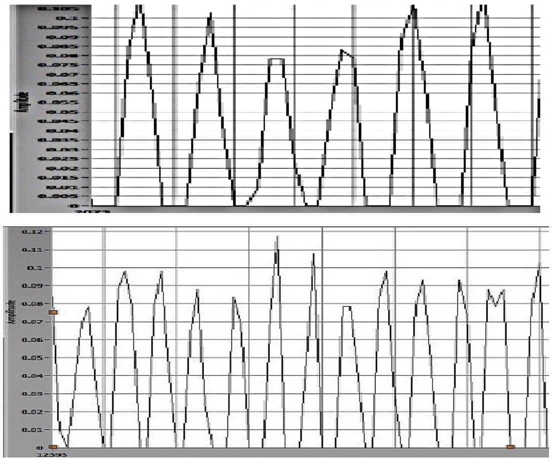


Fig. 7. Two states of mind: Relaxed (top) and Conscious (bottom)

The software named LabVIEW was used for a real-time plot of the subject. A firmware installed for the microcontroller (Arduino) enabled the microcontroller to be controlled in LabVIEW platform. This microcontroller was then programmed by "G" language for continuous sampling purpose of the signals and for varying the sampling rates (figure 8).

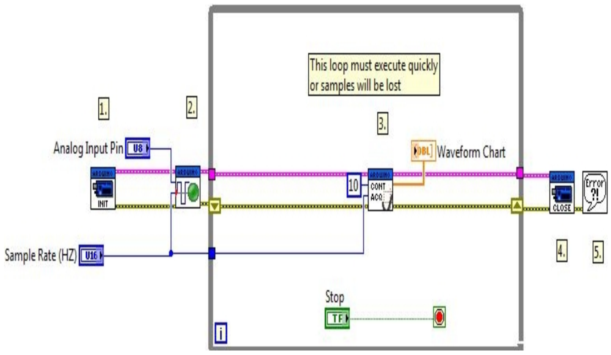


Fig. 8. Continuous Sampling Diagram (Arduino-LabVIEW interface)

LabVIEW enables Arduino to use the plotted signals from into plotting application after reading from its analog port as shown earlier (figure 8). The microcontroller continuously reads 10 samples from the input pin and then the microcontroller is disconnected. Then the loop is started unless it the application stops it. Figure 9 shows how the analog brain signals are read in analog form, converted to digital and then encoded finally.

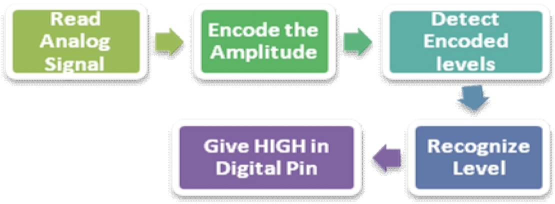


Fig. 9. Controller Block diagram

As the amplitude of the signals are in millivolt ranges, encoding was accomplished by following an algorithm. In this algorithm +5 V was quantized or divided in 1024 levels, which means 0-5 V can be represented in wider range of 0-1024. Thus the output signals were programmed where different states have shown voltage in wide range of levels.

C. Wheelchair control

In this stage the final patterns received after previous stages were used to control the wheel chair which is the ultimate purpose of this project. The challenge here is to drive a large load that draws high current. While looking for the appropriate motors, two DC gear motors have been chosen to drive the wheel chair. Before choosing the motors, high torque and minimum gear requirements were some major factors. The design finally was accomplished where the motors could drive a 100 kg load at 0.5m/s and which required only 12 V and 120 W to rotate at 180rpm. This generic design is shown in figure

10 where arrangements of gears are shown. Efficiency enhancement was the purpose of including the chain. .

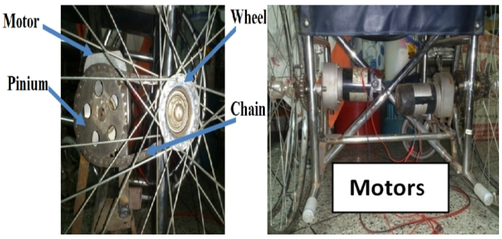


Fig. 10. BCI application: a Wheelchair modified with gears and motors

A relay was added to turn on the motors after processing the signals. Four physical inputs such as no-touch, one finger touch, one hand grip and full hand grip from the users were considered and four different directions were achieved by setting up an algorithm which are shown in figure 11, 12, 13 and 14.

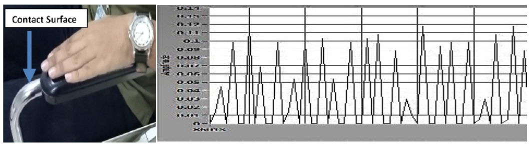


Fig. 11. Hand position: no touch mode and the corresponding wave shape

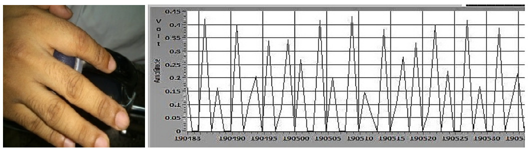


Fig. 1. Hand position: one finger mode and the corresponding wave shape

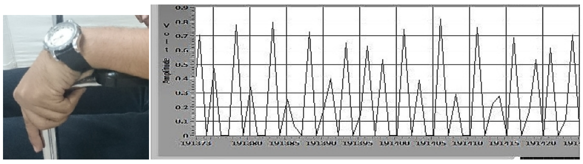


Fig. 2. Hand position: one hand grip mod and corresponding wave shape

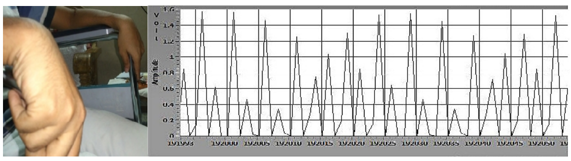


Fig. 3. Hand position: two hands grip mode and corresponding wave shape

It is noteworthy that in the whole design the wheel chair's all metallic parts was considered as the sensitive part, where, the foam pad for resting of the hands was separated from the handle bar.

It should be noted that the resting foam pad of the handle bar is isolated from the wheel chair. All the metallic parts of the wheel chair are considered as sensitive areas in this design.

In the first case (figure 11), the user was not touching the handle bar and a maximum record of 0.12 V was found from the wave shape. This did not provide any motion in the wheel chair.

In the second case (figure 12), user touched the handle bar and a maximum level of 0.45 V was recorded. In this case the level of quantization was one and the signal sent to the motors and made the wheel chair to move forward. The wheel chair stopped as soon as touch was removed.

The third mode (figure 13) exhibited a higher voltage level of 0.8 V with a quantization level of two. Here, the user had a grip on the handle bar. In this case the command received by the motor was to turn right by turning only the left motor on and again it stopped as soon as the grip removed.

In the final mode (figure 14), with a full two hands grip, the voltage level found 1.6 V and it was quantized as level 3. In this case the right motor was set on and hence, the wheel chair turned left.

CONCLUSION

Exploring the feasibility of how BCI can be applied in practical field was the main objective of this study which was performed with the aid of controlling external devices such as wheelchair. The approach was proven as very simple and cost-efficient one with the support of sufficient experimental data and the whole work has created more scopes to investigate BCI applications further. Although, only two channels EEG extraction were used, improvement on circuitries and including more channels may enhance the efficiency of the whole system. Additionally, extensive training on subjects will give a significantly improved outcome. The scopes of this work may be extended to develop a system to control prosthetic limbs, a system for military applications, a thought controlled device, bionic limbs etc. Even the wheelchair designed in this project can be further improved after extracting and discriminating more channels, and it was already suggested by some Japanese scientists that using an EEG sensor cap and a computer program that can process the EEG signals into directional signals a user's thought read wheel chair can be built [5]. Emotiv epoc headset can also be used to read EEG signals, as it claims that it can read both muscle movements and brain waves.

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