EEG Based Brain Computer Interface

Syed M. Saddique[1] and Laraib Hassan Siddiqui[2]
[1]Department of Electrical Engineering-CECOS University of IT and Emerging Sciences
Peshawar, Pakistan
Email: rsaddique@hotmail.com
[2]Department of Electronics Engineering-NUST-School of Electrical Engineering and Computer Science
Islamabad, Pakistan
Email: laraib.hassan@yahoo.com

***Abstract* – Brain-Computer Interface (BCI) has added a new value to efforts being made under human machine interfaces. It has not only introduced new dimensions in machine control but the researchers round the globe are still exploring the possible uses of such applications. BCIs have given a hope where alternative communication channels can be created for the persons having severe motor disabilities. This work is based upon utilizing the brain signals of a human being via *scalp Electroencephalography* (*EEG*) to get the control of a robot's navigation which can be visualized as controlling one's surrounding environment without physical strain. In this work when a person thinks of a *motor activity*, it gets performed. The procedure includes acquisition and analysis of brain signals via EEG equipment, development of a classification system using AI techniques and propagating the subsequent control signals to Lego-robot via parallel port. This has been depicted in [1] as a generic block diagram.**

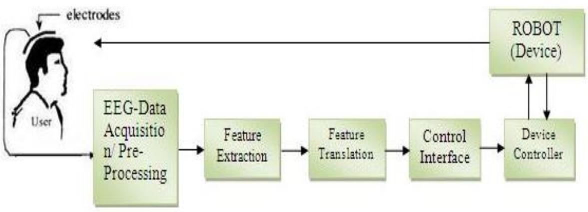

Figure 1: Functional Model of a BCI system [1]

I. Introduction

"Mind Control is generally regarded as scary. But recent refinements of brain- machine interfacing (BMI) may redefine the expression to mean totally different". [2] The need of new communication channels was strongly felt for the disabled people, who can't move their muscles, can't communicate with the outside world, so that they can also be able to lead an independent life. Thus, the idea is why not to use one's brain to control one's own environment.

It is now a proven fact in medical sciences that the blockage of neural pathway between the cognitive part of brain (the signal generator) and the part which has to respond causes paralyses. [3] Though the signals are being generated in most of the cases but somehow or the other are not communicated properly because of disorder. So, if such an artificial system could be devised which can use electrophysiological signals of brain to perform the task which brain is trying to instruct, will truly be BCI system. The underlying magic is that the electrodes sense the electrical activity of the brain (a conductive gel is used for the purpose of providing an electrical contact between the surface of the *scalp* and electrode plates, this improves signal strength), which may be up to the microvolt level, and carry it to amplifiers [4]. The signals after being amplified several thousand times are fed to a computer via analog to digital convertor for further processing. The computer then based upon the devised mechanism generates signals to accomplish the control accordingly. Thus scalp EEG based systems are flexible, easy to use and provide quick, repeatable analysis.

The recording procedures in various researches have proved that the EEG signals do vary as any movement is just being planned studied under movement-related desynchronization (or MRDs in short). But MRDs are tiny, rarely bigger than a few tens of micro volts and are often buried beneath other signals. It is therefore needed to use advanced pattern recognition methods, such as neural networks, to detect the MRD signals.

The issue is that such systems will be useful if signals are acquired non-invasively. But because of poor signal-to-noise ratio of signals via scalp electrodes as compared to implanted electrodes (into cerebral cortex), amplification and filtration is unavoidable. [5]. If this is done, then power concerns also may arise.

II. Background Research:

This domain is quite fresh and is still growing acquiring different shapes since it emerged no later than 30, 35 years back in 1970's. The research subjects, initially, were animals (rats and monkeys) but then it took a dramatic shift in 1990's when first working implant in humans occurred successfully. By now not only damaged eyesight, hearing, impaired movements' etc. can be restored but researchers could now conceivably attempt to produce BCI that augment human functions rather than simply restoring them.

In order to meet the growing needs and technology expansion, some sort of standardization was required not only for the guidance of the future researchers but also for the validation and testing of the new developments with other systems as well. Thus, a general purpose system was developed named as BCI 2000 for systematic studies. It has made the analysis of brain signals easy by defining the recording method, output formats and operating protocols to facilitate the researchers in developing any sort of application.

These BCI systems gauge specific features of brain activity and translate them into device control signals. The features used in studies to date include slow cortical potentials, P300 evoked potentials, sensorimotor rhythms recorded from the scalp, event-related potentials recorded on the cortex, and neuronal action potentials recorded within the cortex.

It has been confirmed through laboratory tests that the frequencies of stimulation and the number of stimulating patterns (in addition to factors such as speed of the computer, used, its memory capacity and the Operating System (OS)) determine the level of software implementations. A good design reduces the dependence on these factors by providing a stable operation even for a large number of patterns.

III. Systematic Approach:

Much of the progress on this project has been dependent upon technical developments in advanced pattern recognition. These have included developing measures of signal complexity, calculating error bars on neural network predictions, assessing model selection methods, developing methods for combining network predictions and investigating the use of dynamic models.

Implementing such an innovative project at the commercial level would not only be an immense learning experience but indeed, it gives a sense of contribution towards the society by designing such thing which is of enormous and harmless usage for the human society. It's not only a new step towards automation but it can also be adapted to turn the miserably painful lives of the persons lying with severe motor disabilities into heavens. Further, this work can be extended to various scenarios where security and safety is a big issue.

IV. System Implementation:

It has been split into three major modules

- Data Acquisition and Analysis
- Feature Extraction and Classification
- Feature Translation for Control Application

A. Observing the EEG patterns

Data has been acquired by applying non-invasive technique i.e. scalp *EEG*. For this purpose *NIHON KOHDEN EEG-1100* has been used as data acquisition unit. Dataset for various subjects under different test cases and scenarios has been analyzed and waveforms of two subjects (Laraib and Shoukat) have been collected during motor imageries (through training sessions).

Analysis of similar tests on different subjects helped reaching the conclusion that the brain wave patterns of adults are not much different from each other corresponding to a particular activity. However, since infants have delta waves superimposed on the scalp EEG patterns which cause their patterns to vary from those one of normal adults. Thus, this encourages the development of a generalized system that can be applicable to a number of persons.

In this paper the work presented is limited to the implementation of few motor controls because of inherent complexity of brain waves as multiple processes are running at a time and it's tough to determine the desired signal out of the highly damped signal received over the scalp. Figure 2 shows the data acquisition unit for this work.

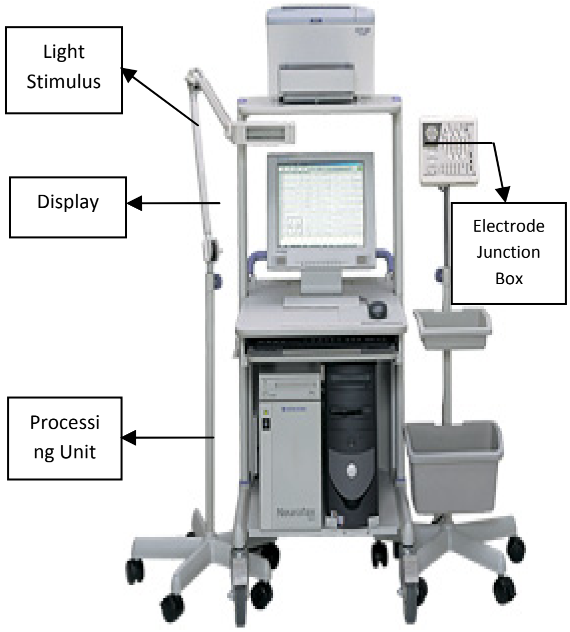

Figure 2: Nihon Kohden Neurofax-21 channel Electroencephalograph

The results have been studied and variance/changes have been analyzed as slightly different stimulus was presented to the subjects. Figure 4, 5 and 6 show various mental states of the subject under test.

Figure 3: Subject Laraib under Test

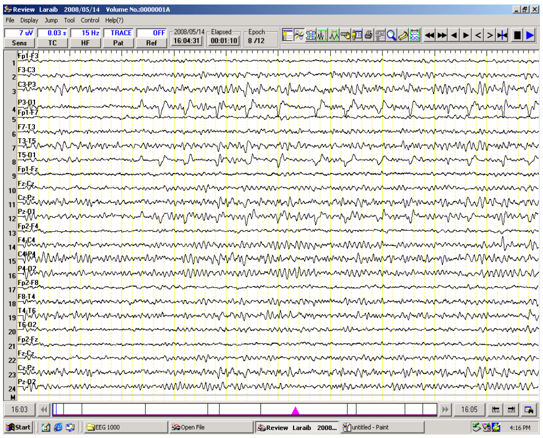

Figure4: Planning for Left movement with eyes closed

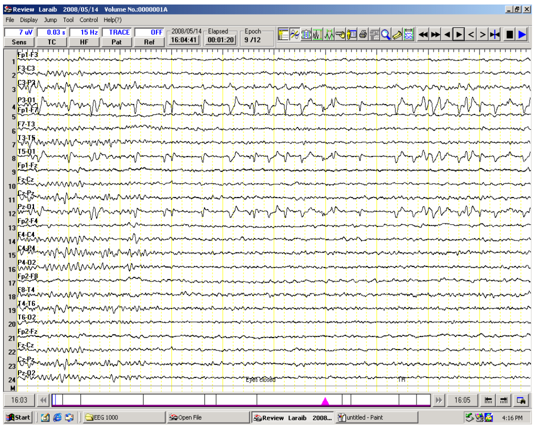

Figure5: Planning for Right Movement with eyes closed

Likewise, effect of opening and closing of eyes has also been studied.

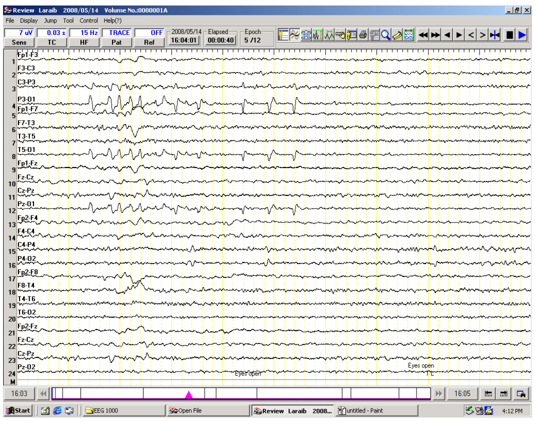

Figure 6: Planning for Left Movement with Eyes open

B. Extracting and classifying the information:

After data acquisition and analysis, the next task is to identify the feature presented to the system and generate the control signals accordingly. Since, machines don't understand analog waveforms, so this data has been converted to ASCII format and imported into the MATLAB, figure [7] which read the files.

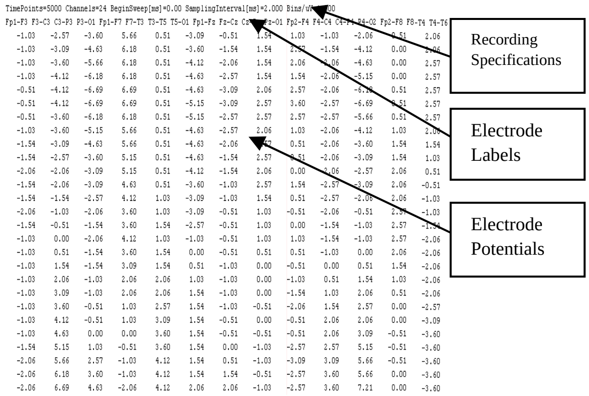

Figure 7: Data imported into MATLAB

Since motor imageries are concerned with the frontal part of brain, so 6 electrodes peculiarly associated with frontal regions contained the signals of the concerned activities, a routine has been defined to access the entire dataset and pick the required data. Next routine has been defined to set the target values for the classification system which are used to train the system. Multiple neural networks (with different layers and neurons) have been created to analyze the response. Training results are as follows:

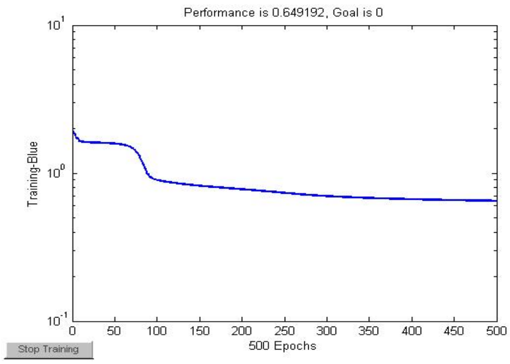

Figure 8: Net1 with one hidden layer consisting of 50 neurons

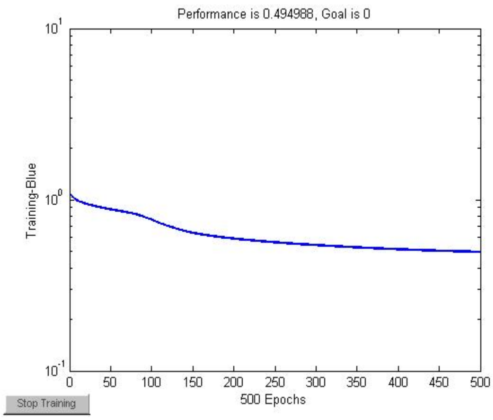

Figure 9: Net2 with one hidden layer consisting of 100 neurons

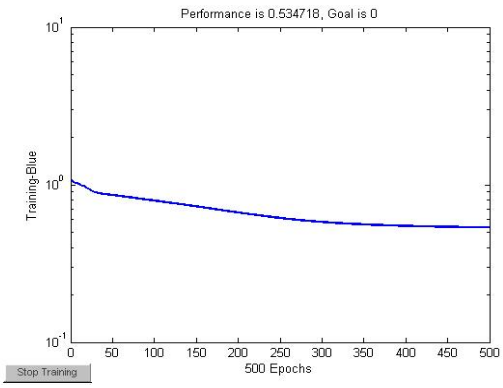

Figure 10: Net3 with two hidden layers of 50 neurons each

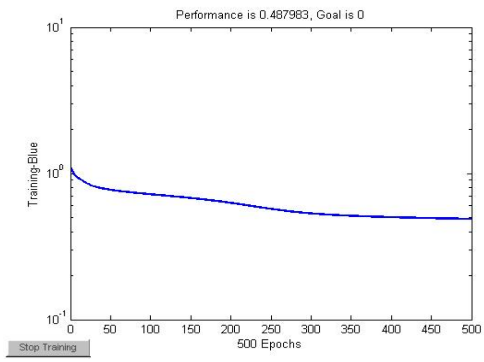

Figure 11: Net 4 with two hidden layers of 100 neurons each

Finally, all the routines and scripts have been integrated into one file which displays the information in a GUI window which allows the user to select or import the data. Then, after classification, it generates the control signals as shown in figure [12] which are being written to the parallel port of the PC.

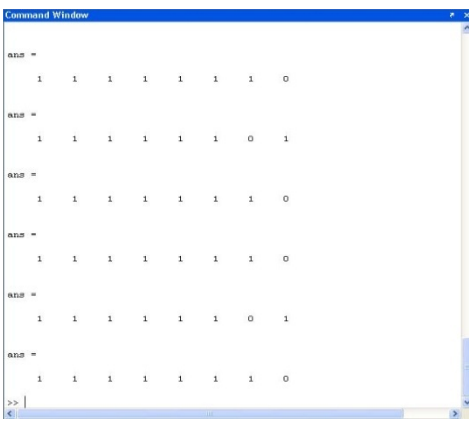

Figure 12: Output of the Classification System

V. APPLICATIONS

The spectrum of applications has been widening. BCI has strengthened neurobiology and provided the hope that mind, which is still an abstract concept, can possibly be read. Some of the key applications, which are more obvious now, include:

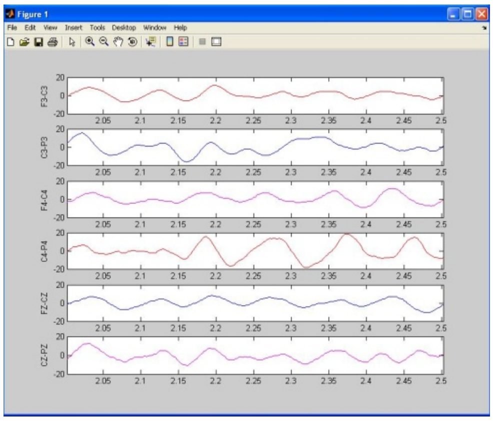

Figure 13: Plot of the selected data

1. To achieve complete cursor control (clicking icons, opening/closing files/folders etc.) over a graphical display without any physical strain/movement.
2. To restore the vision, hearing, muscle activity etc. of the diseased persons.
3. To develop applications (web browsers etc.) such that the disabled persons can stay in touch with the world and enjoy the blessings of technology.
4. To get a highly automated system.
5. Gamers will have fun now shortly by interacting with the virtual world just by using their thoughts and emotions.
6. Development of equipment for such defense applications which require critical and instantaneous action.

VI. CONCLUSION & DISCUSSION

“BCI for a Robot”, has, indeed, been a great learning opportunity. It has helped in developing the critical aspect of “*Thinking out of the Box*”. Following conclusions have been drawn out of this project after analyzing the results closely.

- **Movement related aspects** of brain waves can easily be identified and observed by EEG, hence can be classified
- **Analytical thought process** is still almost impossible to classify, since emotions can’t be predicted via *scalp EEG*
- **Influence of A**rtificial **N**eural **N**etwork **(ANN) Topology**: The more the number of neurons or layers the better the classification is but at cost of memory and processing power.
- **A trade-off**. Improved signal recognition vs. slow performance of the system. The choice depends upon the designer of the system based upon the level of user.

VII. RECOMMENDATIONS FOR FUTURE WORK

Since, this technology is still quite new, residing over the initial rise of the famous *s-curve*, so it has lot of opportunities for the innovative minds to explore and expand the scope of technology. Few areas have been highlighted above under applications, just to give the glimpse of wide-spread of this domain. This section describes as to how this world can be much better place to live by providing directions towards the path of future work.

- **Wireless BCI**- Paradigm shift from wired media to wireless in order to make system more adaptive and user friendly
- **Self Adaptation**- Processing load to be shifted towards computers rather passing individuals through intense trainings. For this purpose, processing algorithms should be improved. [6]
- **Flexibility**- Flexibility should be the hall mark of any BCI system. So, multiple sensory inputs can be exploited for control applications. For example, mu waves, a type of EEG signal related to motor function, may be used for cursor control while using the P3 component as a mouse click. Another modality such as eye tracking may be used in order to control the computer during flights to avoid plane hijacking etc. Different users may need to use different muscles or EEG signals for optimal use.

REFERENCES

[1] Steven G. Mason, Member, IEEE and Gary E. Birch, Member, IEEE, "*A General Framework for Brain-Computer Interface Design*" , VOL. 11, NO. 1, MARCH 2003

[2] Michael J. Riezenman, "*Melding Mind and Machine*"- IEEE publications, issue June 2008

[3] http://www.answers.com/topic/paralysis

[4] Janne Lehtonen, "*EEG-based Brain Computer Interfaces*", May 2002

[5] Pasi Jylänki, "*Classification of single-trial EEG for online brain-computer interface*", June 2006

[6] Jessica D. Bayliss, "*A Flexible Brain-Computer Interface*", University of Rochester, 2001