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Utilization of EEG Signal as Virtual Keyboard for Physically Disabled

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Abstract— **The use of Electroencephalogram (EEG) signals in the field of Brain Computer Interface (BCI) has obtained a lot of interest with diverse applications ranging from medicine to entertainment. This paper is concentrated on developing a BCI system, a Virtual Keyboard using the LabVIEW platform which establishes a real-time interaction between the user and the outside world. BCI is designed using electroencephalogram (EEG) signals where the subjects have to think of only a single mental task. The EEG signal contains the technical artifacts (noise from the electric power source, amplitude artifact, etc.) and biological artifacts (eye artifacts, ECG and EMG artifacts).Eye blinks is one of the important aspects of EEG signal. Hence they act as control signals to select the block /characters in the virtual keyboard. The kurtosis coefficient and amplitude characteristics of the eye blink signals are used to detect the control signals.**

Index Terms— **Brain Computer Interface (BCI), EEG, Eye blinks, Data Acquisition, Lab VIEW.**

I. Introduction

Motor neuron diseases like ALS (Amyotrophic lateral sclerosis) are a form of progressive, fatal, neurodegenerative disease caused by the degeneration of motor neurons, the nerve cells in the central nervous system that control voluntary muscle movement. The disorder causes muscle weakness and atrophy throughout the body as both the upper and lower motor neurons degenerate, ceasing to send messages to muscles. The patient may ultimately lose the ability to initiate and control all voluntary movement.

Electroencephalograph (EEG) was first recorded by Berger In 1929 by externally attaching several electrodes on the human skull. Such signals generally deliver in indirect way information about physiological functions, which are related to the brain. Possible applications using such signals are very numerous. They are for example integrated in the design of new technological devices with embedded intelligence and allow for Brain-Computer-Interfaces.

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BCI is composed of signal collection and processing, pattern identification and control systems. In healthy adults, the amplitudes and frequencies of such signals change from one state of a human to another, such as wakefulness and sleep.

The EEG signal of ALS patients will have the least EMG (Electromyography) artifact content (EMG is a technique for evaluating and recording the electrical activity produced by skeletal muscles). The eye event signals can be easily detected and can be effectively used as controls in BCI applications.

The main artifacts in EEG can be divided into patient-related (physiological) and system artifacts .The patient-related or internal artifacts are body movement-related, EMG, ECG (and pulsation), Sweating etc. The system artifacts are 50/60 Hz power supply interference, impedance fluctuations, cable defects, electrical noise from the electronic components and unbalanced impedances of the electrodes.

There are five major brain waves called delta (δ), theta (θ), alpha (α), beta (β), and gamma (γ) distinguished by their different frequencies ranging from low to high that are listed as follows:-

Brainwave Type	**Frequency range**	**Mental states and conditions**
Delta (δ)	0.1Hz to 3Hz	Deep, dreamless sleep, non-REM sleep, unconscious
Theta (θ)	4Hz to 7Hz	Intuitive, creative, recall, fantasy imaginary, dream
Alpha (α)	8Hz to 12Hz	Relaxed, but not drowsy, tranquil, conscious
Low Beta	12Hz to 15Hz	Formerly SMR, relaxed yet focused, integrated
Midrange Beta	16Hz to 20Hz	Thinking, aware of self & surroundings
High Beta	21Hz to 30Hz	Alertness ,agitation
Gamma (ɤ)	30Hz to 100Hz	Motor Functions, higher mental activity

Table 1: **Brainwave Types**

Eye blinks are normally considered as physiological artifacts in the EEG. But if we consider in a BCI point of

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view, these signals, although artifacts, can be used as good control signals. Eye blink signals can be used in BCI applications like virtual keyboard while the eye close and eyes open signals can be used for folding and opening electric foldable hospital beds.

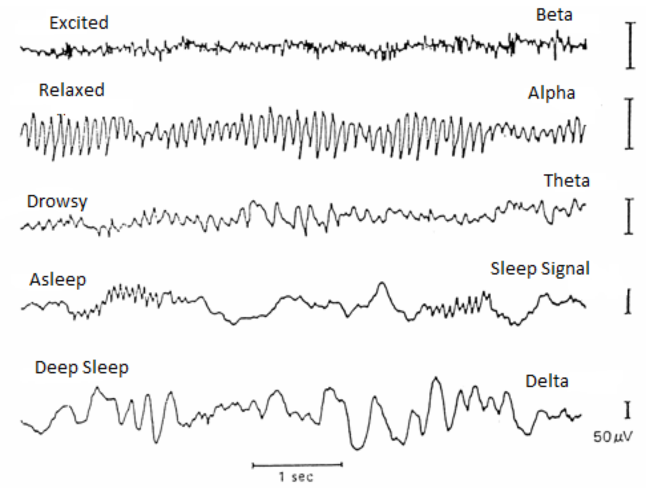

Fig 1: EEG waves [7]

II. Brain Computer Interface

BCI acts as communication channel between the human brain and the computer. Mental activity leads to changes of electrophysiological signals like the EEG. The BCI system detects EEG signal changes and transforms it into a control signal which can be used to motion control of a wheel chair, controlling of a video game, Folding and opening electric foldable hospital beds etc. One of the main goals is to enable completely paralyzed patient to communicate with their environment. The machine should be able to learn to discriminate between different patterns of brain activity as accurate as possible and the user of the BCI should learn to perform different mental tasks in order to produce distinct brain signals.

A BCI is a communication and control system that is independent of brain's normal neuromuscular output channels. The user's intent is conveyed by brain signals and these brain signals do not depend for their generation on neuromuscular activity.

Furthermore, as a communication and control system, a BCI establishes a real-time interaction between the user and the outside world. The user receives feedback reflecting the outcome of the BCI's operation, and that feedback can affect the user's subsequent intent and its expression in brain signals.

The first step in developing a BCI paradigm is to determine suitable control signals from the EEG. A suitable control signal has the following attributes: it can be precisely characterized for an individual, it can be readily modulated or translated to express the intention, and it can be detected and tracked consistently and reliably [1]. The EEG eye blink signals have all the above three attributes and hence can be used as a control signal.

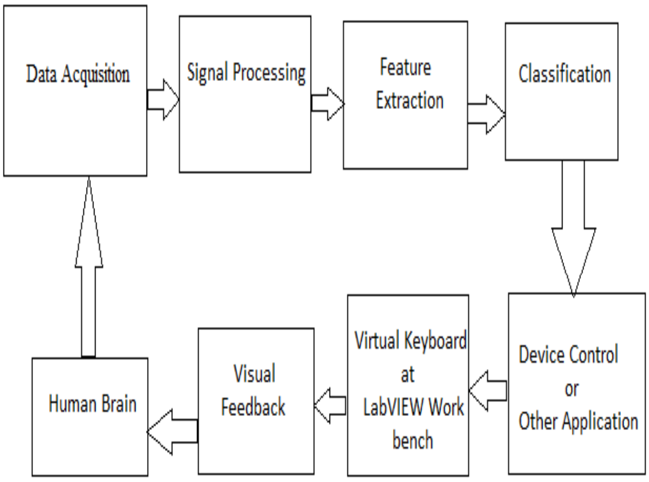

Fig 2: Block Diagram of BCI system

III. Eye Blink Characteristics

Eye blinks are typically characterized by peaks with relatively strong voltages. There is also some variability in the amplitude of the peaks of a specific individual, more variability between different subjects. Eye blinks can be classified as short blinks if the duration of blink is less than 200ms or long blinks if it is greater or equal to 200ms.

Eye blinks can be classified into three types: reflexive, voluntary and spontaneous. The eye blink reflexive is the simplest response and does not require the involvement of cortical structures. In contrast, voluntary eye blinking (i.e. purposely blinking due to predetermined condition) involves multiple areas of the cerebral cortex as well as basal ganglion, brain stem and cerebella structures. Spontaneous eye blinks are those with no external stimuli specified and they are associated with the psycho-physiological state of the person.

A. Amplitude

The eye related signals will be predominant in the frontal and prefrontal regions of the brain. In the prefrontal lobe, say FP1-F3 or FP2 -F4 electrode pairs, a downward peak in the negative region shows an eyes-open event and a positive peak shows an eyes-close event. Also the amplitude of these peaks will be significantly higher compared to the rhythmic brain activity. An eye-blink signal can be detected by its positive and negative peak occurrences.

IV. Signal Processing & Data Acquisition

A. Signal Processing

In signal processing, electrodes are used for sensing EEG signals generated in human brain. EEG electrodes are generally of the direct-contact type. They work as transducers converting ionic flow from the body through an electrolyte into electron current and consequentially an electric potential

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measured by the front end of EEG system. These transducers, known as bare-metal or recessed electrodes, generally consist of metal such as silver or stainless steel, with jelly electrolyte that contains chloride and other ions. Another end of EEG electrodes are connected to the instrumentation amplifier (AD620) which amplify the signal.

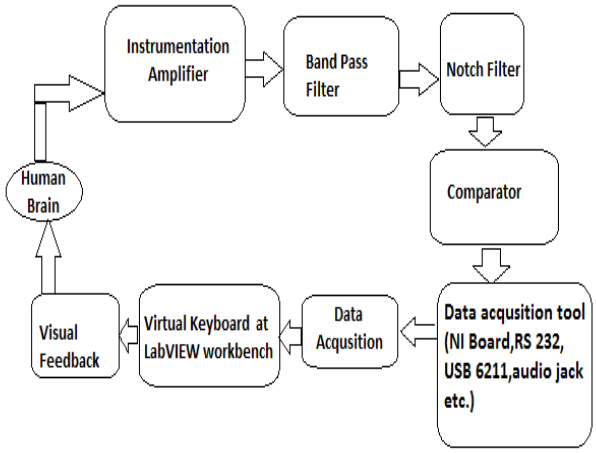

Fig 3: EEG Amplifying Circuit

The amplified signal is applied to band pass filter. It passes the require frequency from 0.5-15 Hz and attenuates rest of frequency. The filtered signal is fed to narrow band rejection filter (Notch Filter).

The notch filter used for rejection of signal frequency such as 50 Hz Power line frequency hum from signal. Then the signal is applied to comparator which is continuously compares the input signal captured with reference voltage applied to inverting input. The output will go high saturation each time when the input signal rises over the reference level. According to the peak and low obtained comparator signal, the virtual keyboard operates.

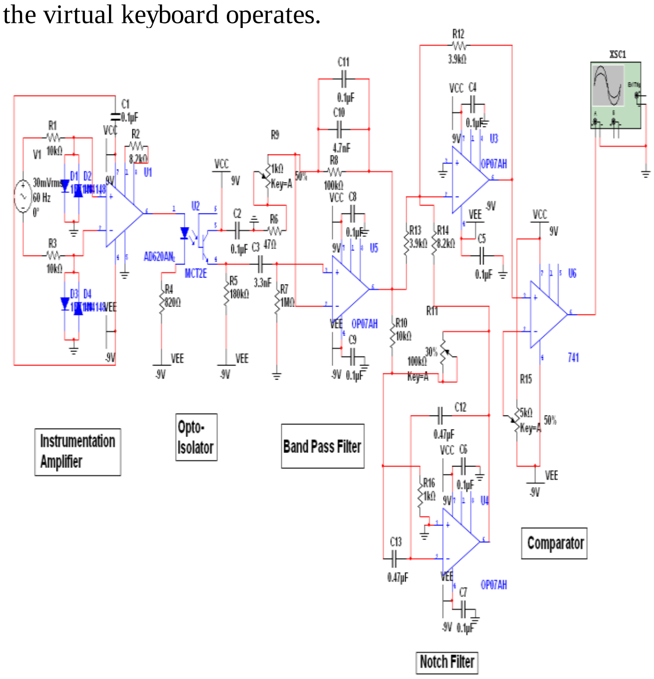

Fig 4: Schematic of the EEG amplifying circuit simulated in the Multisim.

B. Data Acquisition

The EEG amplifying circuit records the movement of muscles due to eye blinks. It can also record information about our physiological state which comes from the scalp electrodes placed on both side of forehead.

The EEG signal is acquired using the EEG amplifying circuit. The comparator output of EEG amplifying circuit is connected to the data acquisition tools like NI USBs, NI board, RS232 etc. we are using NI USB 6211. The comparator output is connected to the Channel 1 (CH-1) of NI USB 6211 which is further connected to the computer. This USB is interfaced with the computer using NAQ mx driver at LabVIEW. In LabVIEW we fix the sampling frequency set at 200 samples per second.

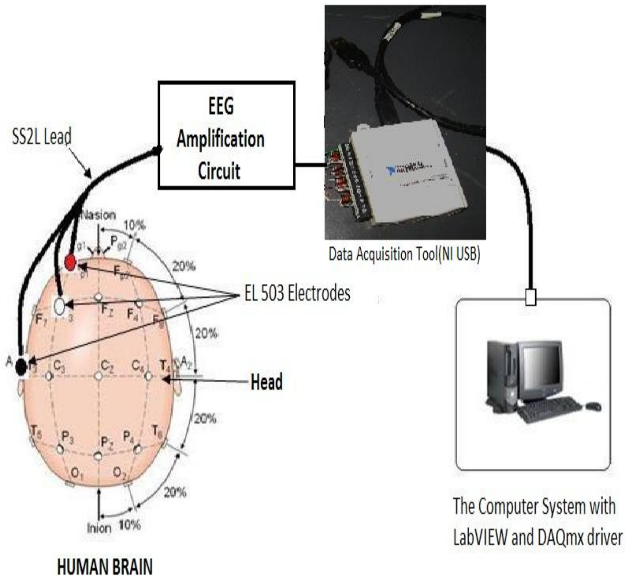

Fig 5: Data Acquisition System [6]

Eye blinks are used as inputs or control signals in this BCI. The user of the BCI has to produce an eye blink in the specified time interval, i.e. 5s interval. The input is of binary nature. The BCI detects in this 5s interval whether an eye blink is present or not.

A single selection can be done in 20s. In every 5s interval the user should make an eye blink. So in effect at the end of 20s interval the BCI will detect one of the following events.

• In the first 5 sec it will detect whether Single eye blink occurred
• In the next 5 sec it will detect whether two eye blinks occurred
• In the last 5 sec it will detect whether three eye blinks occurred.
•. After 20 sec it will detect and display the character.

The entire alphabets (A - Z) and the space character (--) are the characters available in the Virtual Keyboard. The total 29 characters are divided into three blocks having 9 characters each.

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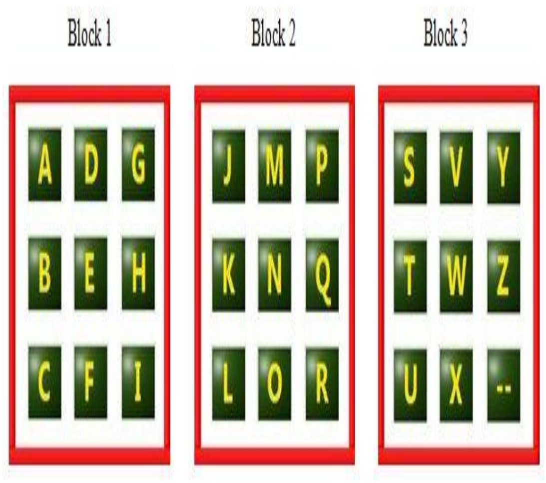

Fig 6: Various blocks of characters[6]

V. WORKING

The Block 1 contains the characters A – I, the Block 2 contains the characters J – R and the Block 3 contains the characters S – Z and space (--) character. The user can select the Block 1 by producing a single eye blink. The selection of a block is accompanied by glowing the characters in the block for a small time interval. This is considered as a visual feedback to the user. Similarly the user can select the Block 2 and Block 3 by producing two eye blinks and three eye blinks respectively. The corresponding block selected is glowed for a small time interval.

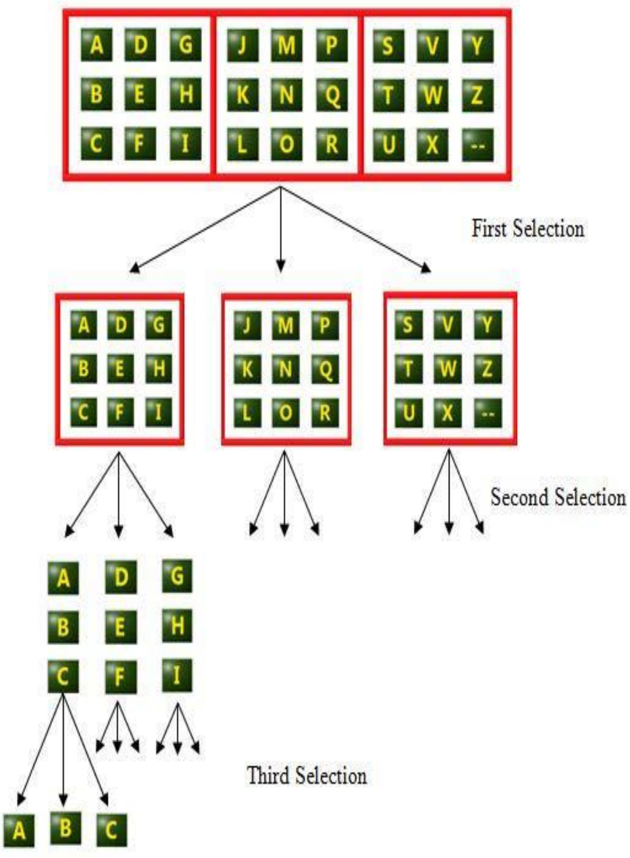

Fig 7: Selection scheme in the Virtual Keyboard [6]

After the first selection the user can select one of the three columns in each block by producing the next set of eye blinks. The first, second and third column can be selected by one, two and three eye blinks respectively.

After the selection of a particular column, a particular character in that column can be selected using the next set of eye blinks. Every column has three characters. The first, second and third character can be selected using one, two and three eye blinks respectively. After selecting a character the entire process continues again to select the next character and so on.

VI. DEVELOPING VIRTUAL KEYBOARD IN LAB VIEW PLATFORM

LabVIEW is a system design platform and development environment for a visual programming language and provides powerful graphical development environment for signal acquisition, measurement analysis, and data presentation. LabVIEW programs are called virtual instruments (VIs).Each VI has 3 components: a block diagram, a front panel, a front panel and a connector panel.

For developing a program in LabVIEW, the user has to go through the following processes:-

- Designing the Front Panel
- Developing the Block Diagram code

After developing the program it can be used in real world applications.

A. Front Panel

The front panel shows the display of the Virtual Keyboard (Virtual Instrument) using the LEDs representing the various character. It consists of 27 LEDs, one for each character. When a block/character is selected these LEDs glow.

B. Block diagram

The actual programming in LabVIEW is the development of the block diagram. The block diagram code describes the utility of a front panel object (a control or an indicator). In the block various loops and structures are used to develop complex algorithms.

The signal is read from the file using *Read from spread sheet file* function. A *while loop* in combination with a *for loop* and other functions calculates the kurtosis value, maximum value and minimum value. A comparison of these values with the pre-set values gives a decision, whether eye blink is present or not. The *while loop* gives the number of eye blinks output. This value is used to select the *case structure*. According to the code in the *case structure* the decision is taken to select a block/character.

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VII. Results And Discussion

The Virtual Keyboard developed is a Virtual Instrument (VI). A character selection rate of 1 character/min is obtained with the current settings. A single selection of the block is obtained in 20s, the column in the block is selected in the next 20s and the character is selected in the next 20s. Every selection by the user is accompanied by giving a visual feedback to the user by glowing the corresponding block/column/character in the Virtual Keyboard. Every selection of a character will show the corresponding character in the screen in the Virtual Keyboard.

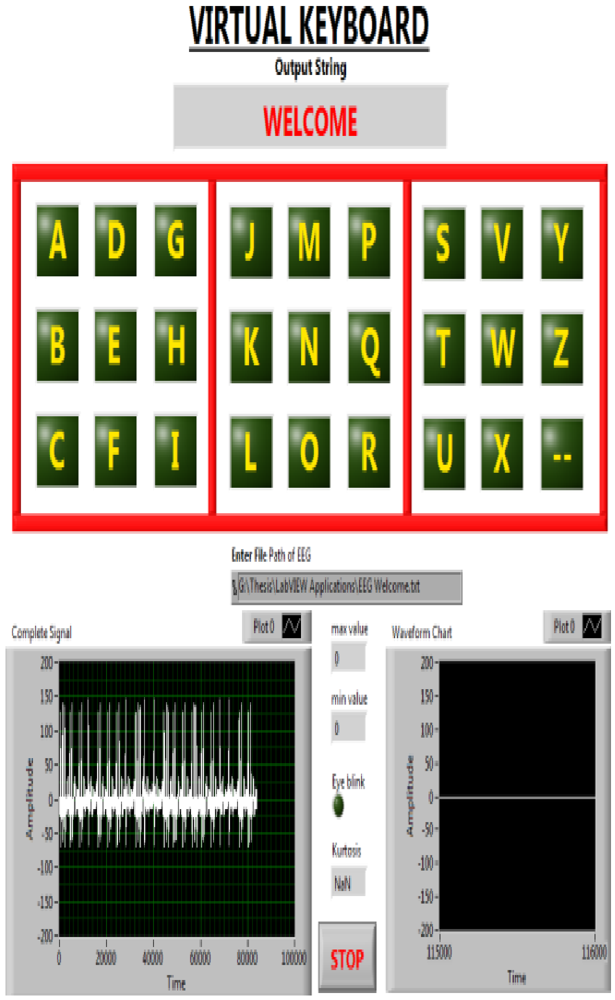

Fig 8: Front Panel of Virtual Keyboard[6]

VIII. Conclusion

While the electroencephalograph was invented nearly a century ago, it is only recently that researchers have begun to apply it to problems outside the medical and neuroscience domains such as the brain computer interface systems. The role of signal processing is crucial in the development of a Brain Computer Interface system.

Hence we can conclude that with the help of a BCI system we have aimed to create a virtual keyboard using eye blinks. Eye blinks are used as control signals in this BCI and kurtosis coefficient, maximum amplitude and minimum amplitude in a sample window are successfully used to detect the eye blinks from non-eye blink signal.

The BCI developed can be used for communication purposes, which use eye blinks as control signals, especially for locked-in patients like those suffering from motor neuron diseases. The Virtual Keyboard developed obtained a correct spelling rate of 100 characters/ min which is excellent. The spelling rate can be improved by reducing the time given to produce the eye blink.

IX. Future Work

The practical use of BCI technology depends on an interdisciplinary cooperation between neuroscientists, engineers, computer programmers, psychologists, and rehabilitation specialists, in order to develop appropriate applications, to identify appropriate users groups, and to pay careful attention to the needs and desires of individual users.

The prospects for controlling computers through neural signals are indeed difficult to judge because the field of research is still in its infancy. Much progress has been made in taking advantage of the power of personal computers to perform the operations needed to recognize patterns in biological impulses, but the search for new and more useful signals still continues.

If the advancement of the 21st century matches the strides of the next few decades, direct neural communication between humans and computers may ultimately mature and find widespread use. Perhaps newly purchased computers will one day arrive with biological signal sensors and thought-recognition software built in, just as keyboard and mouse.

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