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BrainKey: A Virtual Keyboard controlled using Eye Blinks

Chirag Bellara, Raj Madheshia, Pranali Patil, and Mrs. Vinita Mishra

Department of Information Technology
Vivekanand Education Society Institute of Technology
{2016.chirag.bellara, 2016.raj.madheshia, 2016.pranali.patil, vinita.mishra}@ves.ac.in

Abstract: Dysarthria Syndrome and Amyotrophic Lateral Sclerosis (ALS) Syndrome are some of the diseases that result in complete paralysis of the body, taking away the ability to communicate with the people around. This paper focuses on using the concept of Brain-Computer Interface (BCI) to establish a way of communication for such patients using signals from their eye blinks. Electroencephalography, or EEG, is a method to record the electrical signals generated by the human brain via electrodes that are placed on a person's head. This paper aims at establishing the usage of an EEG device to control a virtual keyboard using the signals from the person's eye blinks. The user will be able to write a complete word, alphabet by alphabet, on our electron js based desktop application, and with the help of continually updating a list of most probable words, thereby resulting in a medium of communication that will aid all such patients to communicate again.

Index Terms: Brain Computer Interface, Electroencephalogram, Neurosky Mindwave Mobile 2, Eye blink, Virtual Keyboard, Electron JS.

1 Introduction

Amyotrophic lateral sclerosis, or ALS, is a neurological system disease that affects nerve cells and spinal cord, causing loss of muscle control on body moments and failure of voluntary muscle movements. ALS gradually deteriorates, or degenerate motor muscles and causes the death of motor neurons. Eventually, ALS affects control of the voluntary muscle movement in which individuals lose control of move, speak, eat, and breathe. According to worldwide statistics, more than 200,000 people around the world are suffering from ALS disease. Dysarthria is neurological damage that may occur due to neuron degeneration causes motor speech disorders that occur as a result of muscle weakness and poor articulation of phonemes. People with dysarthria have neurological damage that weakens the muscle component of the motor–speech system. An EEG machine is a device that captures the electrical signals from the brain. It contains electrodes that can detect brain activity in the form of potential differences across various points in the brain when placed on a a person's scalp. The electrodes placed on the scalp surface record the brain wave patterns in the form of electrical signals and send signal data to a computer or cloud server. EEG machine captures five major types of brain waves distinguished by their different frequency ranges of each wave. Each brain wave belongs to fixed range from low to high frequencies respectively and is called delta (δ), theta (θ), alpha (α), beta (β), and gamma (γ). Eye blink signals can be used as good control signals. Eye blink signals can be used in BCI applications like virtual keyboard while the eyes closed, and eyes open signals can be used for switching on and switching off several electronic devices.

2 Motivation and Related Works

Eye blinking is a partially autonomic and rapid closing of the eyelid Although it is the essential function of the eye that helps spread tears across and remove irritants from its surface, it can also play an important role in the human computer interaction. Several pieces of research have been done in the field of Brain-Computer Interfaces. Many of these researches focused on the topic of using Brain-Computer Interface technology to the advantage of humans in assisting them with daily activities.

In recent years, a great number of BCI systems have been developed to provide an alternative communication tool for people with severe neuromuscular disorders or any other kind of speech disability. Hundreds of BCI research articles were published [1]. A lot of implemented BCI applications are associated with different areas, i.e.: mental speller [2] mouse control [4], robot arm control [3], drowsiness detection system [5], etc. There have been previous attempts to create a brain-controlled keyboard, we gain inspiration from them [6] and try to improve on the procedure followed and the way the output is presented. The aim of this work was to propose a new method of typing using eye blinking with the support of EEG signals and word prediction.

3 Tools

This section highlights the various hardware tools used in the development of the system.

3.1 Mindwave Mobile Headset

Electroencephalography (EEG) is a monitoring method to record the electrical activity of the brain. Wearable EEG headsets position electrodes along the scalp[7]. EEG electrodes pick up brain waves and record the electrical signal of a person's brain. The gathered signals are amplified and digitized then sent to a computer for storage and processing purposes. For our purpose, we have used the Neurosky Mindwave Mobile Headset 2[9]. Neurosky provides good quality EEG headset for an affordable price. Mobile Mindwave 2 is connected to the desktop application via a simple Bluetooth connection.

Neurosky Mindwave Mobile Headset 2 device consists of a headset, an ear clip, and a sensor arm[9]. The headset's reference to adjust on the head and ground electrodes ear clip is attached to the ear lobe and the EEG electrode sensor arm resting on the forehead above the eye of the person. The Mindwave Mobile measures brain waves by using the potential difference between sensor arm and ear clip and give the outputs the EEG power spectrum (alpha waves, beta waves, etc.) which then send to connected computer or mobile. The sensor arm of the Neurosky Mindwave Headset also includes an EMG sensor[7] that allows users to pick up and measure the blink strength. The data thus, measured by the headset is sent to a Bluetooth connected computer for further analysis and processing.

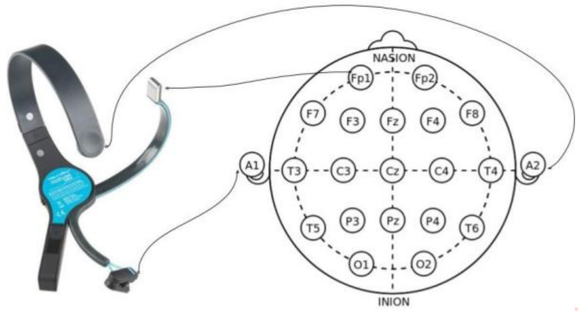

Fig.1. Positioning of Mindwave Mobile headset electrodes

4 Brain Computer Interface

A brain-computer interface (BCI) is a computer-based system that allows communication between a wired human brain and external device technology. This interface act as a component that can capture brain wave signals and can send it to hardware devices. BCI interface can also act as a key component to send signals to the brain from external hardware technology.

Human brains are filled with millions of neurons, and nerve cells connected to one another by axons and dendrites. When human body move, eat, speak, or remember something our nerve cells or neurons play a key role in this. To send information from one neuron to another electrical signal is used. Electric signals that zip from neuron to neuron as fast as 250 mph, generated by ions on the membrane of neurons by creating the potential differences. This is used in BCI to work with brain signals. Communication with the BCI depends on brain wave signals and not on the generation of peripheral nerves of the human body and therefore control system does not depend on neuromuscular outputs channels.

Real-time connection for communication between the user brain and the outside world can be established using BCI. The user receives feedback for his or her actions as an outcome of the operations of the BCI and this feedback can further influence the actions performed by the user. In a way, the BCI acts more or less like a sense organ, reacting to stimulus and giving feedback for actions.

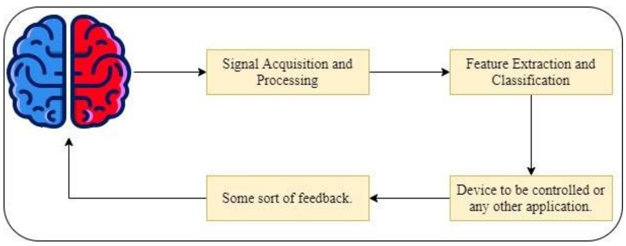

Fig.2. Basic functioning of a Brain Computer Interface.

5 Methodology

To implement Brain Interfaced Keyboard, we have used Neurosky Mindwave headset Mobile 2 which helps to capture the EEG signal from a single channel. With the usage of eye blinks as gestures, our idea is to develop a Brain-Computer Interface (BCI). The idea is to create a Brain Interfaced Keyboard (desktop app) which is connected with the machine model that helps to distinguish between different types of blink which allow a person to communicate via eye blinks.

5.1 Low Level Design

The system comprises of two main components, which are, the Neurosky Mindwave Mobile Headset and the Electron JS desktop application. Figure 2 shows how the main components are connected and how they function in a very brief manner The Neurosky Mindwave Mobile headset is connected to the client machine using Bluetooth. The desktop application first tests the connection and only when the connection is made, can the user type anything via eye blinks.

5.2 Working of the system

The system aims at the usage of some voluntary actions done by these patients to provide some kind of means of communication with the outside world. With the usage of eye blinks as gestures in the form of the voluntary action and brain computer interface as the mode of communication, the system presents an idea for helping any patient suffering from any kind of motor neuron disease or speech paralysis to communicate with the outside world by using their eye blinks. The system operates in the following steps:

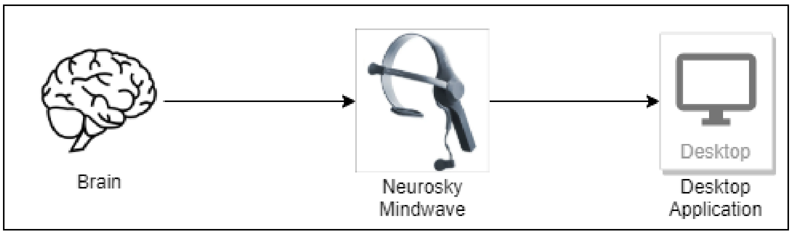

Fig.3. Low Level Design

1. First the system waits for the headset to automatically connect to the application.
2. Once the headset is connected to the application and ready to send the data, the application reads the data points of brain waves sent by the EEG device which in this case is the Neurosky Mindwave Mobile Headset 2.
3. Processing the incoming data and filtering out the data that corresponds to intentional eye blinks.
4. If the blink is intentional then an alert is sent to the keyboard.
5. Depending on the sequence of blink, the appropriate step of character selection is carried out by the application.
6. The aim of the application is to minimize the time consumption and still be very accurate. In order to achieve this, the keyboard design is optimized to type any character with a maximum of three blinks.
7. To further reduce the overall time to write a word and subsequently a sentence and maintaining user-specific dictionary that would constantly update itself on encountering a new occurrence, thereby making the process of writing sentences less tedious.
8. Since the system is designed for patients, an exclusive help button is placed and can be accessed with three immediate yet intention eye blinks.
9. Help button which raises an alarm in the case of an emergency.
10. Four provisional buttons are also provided which can be customized to speak complete sentences that the user uses often.

Further, we analyze the reason behind the usage of each any every aspect, from eye blinks to the keyboard pattern, in the system.

5.3 Character Selection Process

The final keyboard layout consisted of horizontally divided, alphabetically arranged, characters in groups of three. The below figure shows the final keyboard layout. The character selection process would take place using three blinks[6].

1. First blink will select the row that has the desired character.
2. Second blink will select the side of the row (left or right) that has the desired character.
3. Third blink will select the desired character.

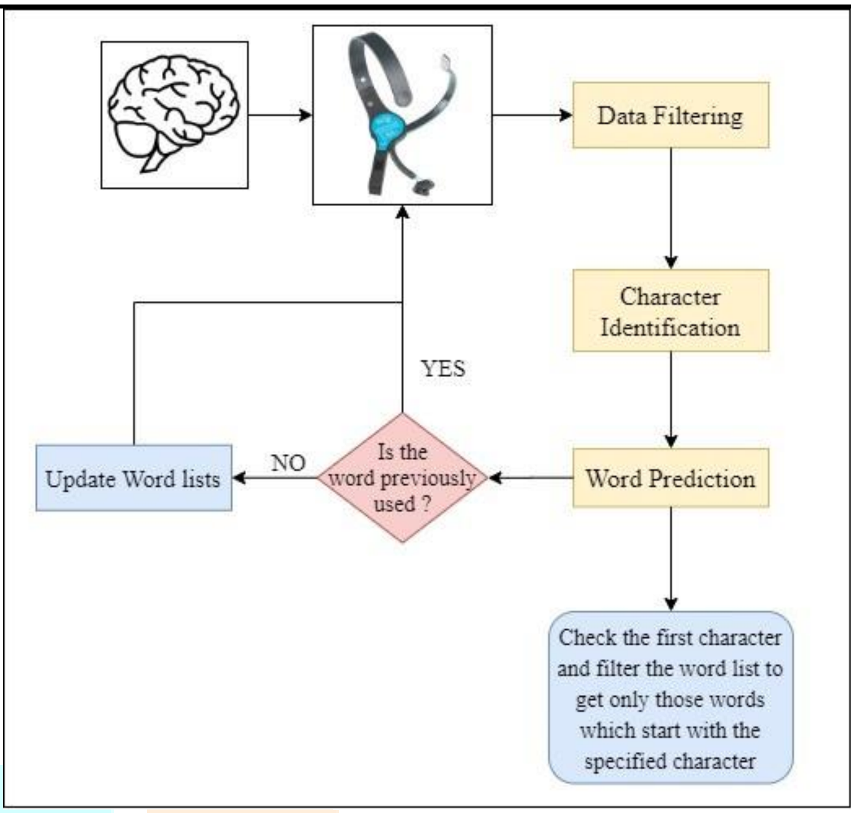

Fig.4. System flow diagram.

Once the character is selected, it will be displayed on the screen and probable words starting with the selected character are displayed [8].

5.4 Virtual Keyboard Application

The desktop application developed using Electron JS. The application consists of the virtual keyboard, word predictions, and several utility buttons that can come in handy. The desktop application indicates if the headset is connected or not and if it is sending any data to the computer or not. These features help to understand the connection status of the application and Neurosky Mindwave headset. The application requires 3 blinks to type any characters from the virtual keyboard [10].

The layout of the keyboard is so designed that minimum 3 blinks are required to reach any alphabet/function. In the virtual keyboard, there are 6 rows and 6 columns. This keyboard layout consists of 6 function buttons, 26 alphabets and 4 customized sentence buttons. In the first row, there are all the essential and important function buttons. While designing the layout, the high usage and priority functions are made available in the first row. Each function button in the first has its own significance.

5.5 Significance of keyboard layout

Help button: The system developed is for a patient who are not able to communicate. So, for the patient to notify, the helper/anyone around them, there is a help button on the virtual keyboard. The help button is located in the first row of the keyboard. On selecting the help button, an alarm bell is rang.

Switch button Besides the keyboard, there is a prediction box. To switch from keyboard to the prediction box this button is used.

Speak button: The speak button is to speak all the that is present in the textbox [8].

Customized sentence buttons: In the last row of the keyboard, there are 4 buttons which can be programmed as per the user's requirement. On selecting these buttons whole sentence is spoken out without any need of user typing the whole sentence.
For example, Hi button in last row and third column is programmed to speak: *Hello,Hi.How are you*?
In the same way, sentences can be configured as per the user.

6 Comparative Study of Keyboard Designs and Signaling Mechanism

Alternatives to Eye Blinks In this system, the eye blink serves as a means to generate some sort of voluntary action that can act as the stimulus to the EEG device. For the same purpose, we could have chosen any muscle that is completely in control of the individual, but we are considering the worst of the cases, that is, in cases of complete paralysis.

Alternatives to Keyboard Design The keyboard structure of the desktop application is made in order to ensure that the user is able to type characters with the minimum number of eye blinks [6]. We considered the following possible keyboard layouts for the purpose of our application.

1. Alphabetically arranged characters in a single row. A single row of All Alphabets, arranged in alphabetical order, is shown on the screen and the user has to select the character as the cursor moves linearly.
   Though this approach is easier to implement and the user always gets to select any character in just one blink, it is very time consuming to wait for the cursor to reach the character the user wants to select.
2. Alphabetically arranged characters in multiple rows. This approach extended the earlier approach and divided the 26 characters of English language into 6 rows. Now, the user uses the first blink to select the row and the second blink to select the character in that row.
   This approach was slightly better because the overall waiting time of the user was decreased, especially in the case of selecting the last few characters. But there could have been a better approach, that would potentially save more time, and help the user to select the characters with optimal number of blinks.
3. Division of alphabets into groups. This time, the alphabets were divided into groups of three. The user would have to select the group with the first blink and the alphabet inside that group with the second blink.
   This approach would have reduced the overall time of selection and so this was considered as the base approach and the final approach was built on top of this.

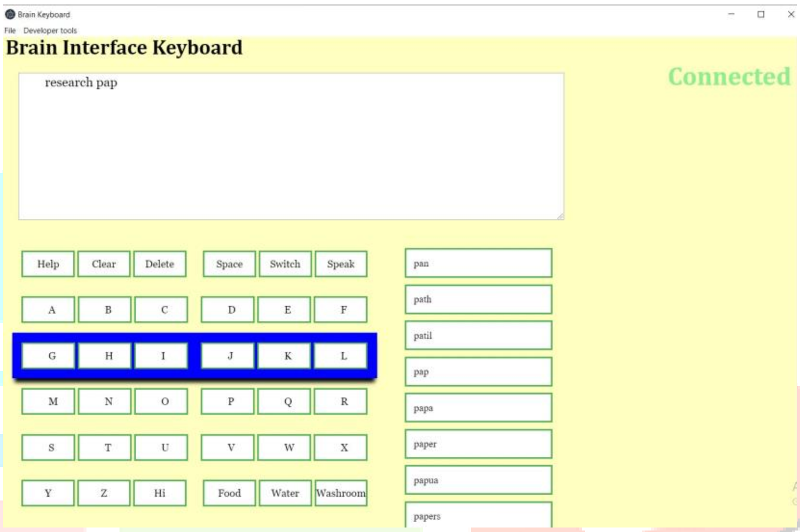

Fig.5. The final result being displayed on the application.

7 Conclusion and Future Work

The proposed system uses the Neurosky headset to capture eye blinks. The system described in the paper uses eye blinks as a communication medium between the software interface and the user. The software interface consists of the virtual keyboard. The design of the keyboard is done considering the user and to reduce the time. The maximum of 3 blinks is used to reach to each character.

The help button assists the user to raise an alarm. The prediction box eases the word typing by predicting the probable word by using the already printed characters. The placement of the important functions as the top row of the virtual keyboard reduces the time of the user. The basic sentences that a user will be using frequently can be programmed in the custom buttons. This facilitates as the whole sentence will be spoken without the need of writing any word sentence.

The proposed system was designed taking into consideration the difficulties faced by the people suffering from any kind of disabilities. The data, whether the movement is an eye blink or not, is being retrieved from the Neurosky headset and this information is used to allow a user to type in characters. As the user went on typing characters, word completion suggestions were given, and each character was converted to a speech output. The user will be able to sound an alarm in case of an emergency.

The proposed system is extremely beneficial for people with any kind of disability and has a wide variety of variations to be considered as scope of work in the future. The proposed system can be upgraded to be user specific, having a user specific blink strength threshold and a personalized dictionary. There is also a scope of adding multiple language support in the system. This system can also be upgraded to support games and activities that help enhance attention and meditation capabilities of the user.

Moreover, the whole system can be used as a base for the development of future applications that allow full control of multiple interfaces merely by the usage of brain waves. Looking at the way the BCI is experiencing a boost of interest, there is definitely a possibility of having direct neural communication between humans and computers. Perhaps, we may also witness the development of computers with biological sensors and thought recognition soft wares.

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