A low cost Human Computer Interface for Disabled People based on Eye Blink detection using Brain Signal

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Abstract*—In the society, most of the disabled people especially completely movement impaired ones live like burdens and suffer from severe depression as they have to depend on others for day-to-day activities and cannot contribute to the community. These people may not be able to move their arms or legs but they can certainly think. If their ability to think and make decisions can be utilized in decision making situations and also if they can further be included in industrial automation structure, they will no longer be burden rather they will become man-power to the society. One of the major challenges of involving these people in such processes is making a low cost device that is affordable by the mass, made with locally available components and also interprets the person's choice accurately. As these people are physically disable, comprehending their electroencephalogram (EEG) signal for blink detection can be an effective solution for translating their choices. EEG-based controlling devices are mobile and can serve as powerful aids for severely disabled people in their daily life. In this work, a low cost EEG sensor is made with readily available components and a framework is developed to detect voluntary eye blinks. A graphical user interface (GUI) is also developed which is suitable for the impaired person. The eye blinks of the person act as bridge between a set of choices pointed in the GUI and his/her selection interest and thus help the person control home appliances, wheel chair and even computer without depending on others.

Keywords—automation, EEG, blink, low cost, graphical user interface, integrated

I. Introduction

In today's world, the highly advanced civilization believes a person's potential and power are not confined in only physical ability and strength rather it sees a disable person as none but a differently able person. It is also believed that no man's potential should be wasted. The rapid growth of technology and development of sensing devices have created opportunities for physically impaired people to translate their interests in various ways where they usually cannot do many routine tasks in the conventional way. For utilizing the intellectual potential of these people, distinctive human computer interfaces (HCI) or human mobile interfaces (HMI) are needed. In an HCI or HMI, the communication between human user and computer depends mainly on keyboard, mouse, touchpad or touchscreen. But a person with limited or no movement capacity cannot use these means. It leads to the urge of creating an alternative method that can interpret their choices. Detecting blink can be considered an effective way because the last voluntary action a disabled person loses control of is eye-blinking [1]. Spontaneous eye blinks come subconsciously from psycho-physiological state while voluntary eye blinks depend on the person's decision to blink. So through voluntary eye blinks, the disable person can deliver information. People suffering from diseases resulting muscle control loss, e.g. ALS, Palsy, Botulism, Guillian-Barré syndrome, cannot use their hands or speak to communicate [2]. So, an eye-blink based HCI system can utilize their capacity of critical thinking to make decisions especially for industrial automation purposes.

Eye blinks are important in various more ways. A significant application is identifying driver drowsiness from blink rates. As eye blinks are very fast and continuous, advanced apps in cellular mobile phones exploit this feature to choose between options or take pictures. Moreover, in smart home automation systems, blinks are getting attention to be a controlling input. Therefore, developing successful blink detection system has drawn special attention of researchers for a long period.

A lot of techniques and methods have been reported to the literature on ways of detecting eye blinks. Most of them involve continuous monitoring of the facial image and extracting features from it through different algorithms. Arai et al. present Gabor filter-based method for blink detection in [3]. Gabor filter is a linear filter that extracts position and pattern of contours within the eye. The distance between top and bottom eyelid changes during an eye blink; this feature is utilized in this method by first detecting the arcs in eye region through the filter and then measuring the distance between top and bottom arcs. Another method of detecting blinks is analyzing the optical flow and tracking eyelid motion based on matching scale-invariant feature transform (SIFT) descriptors computed on GPU [4]. During blinks, the dominant motion is in vertical direction. So first, the motion region is distinguished through threshold frame differences and then used to calculate the optical flow. Besides, a work regarding intensity evaluation of pixels located in eye region is presented in [5] Here, variance map that specifies distribution of intensities from the mean value in an image sequence is used in detection process. Moreover, blink detection via correlation for immobile people is presented in [6]. The image of the actual eye is compared against an open eye image. As someone closes eyes during the blink, similarity between the images decreases, so does the correlation coefficient. The main challenge that the above mentioned methods have is massive GPU requirement by the continuous image processing tool. Also, false positive detections occur due to gaze lowering, vertical head movements and failure to track the eye position.

Again, IR sensor based blink detection methodology has been explained in [7] where standard safety glasses were equipped with an infrared (IR) emitter/detector pair oriented horizontally across the palpebral fissure, creating a monitored IR beam that become interrupted when the eyelids close.

Researchers in recent years have found that electroencephalography (EEG) signals can be promising in detecting eye blinks [8]. Though EEG signal analysis is now an established method for blink detection, present EEG capturing modules are too costly to be used by the mass. The modules with least price that are available in the existing market are NeuroSky MindWave [9] and Muse [10] which are shown in Fig.1.

Fig. 1. Muse [10] and NeuroSky MindWave [9]

II. METHODOLOGY

A. EEG Capturing

At first the brainwaves need to be captured through electrodes. For this reason, three disposable foam pad electrodes are placed in three different positions as shown in Fig. 2. Two voltage nodes are placed in O2 and A1 positions as shown in the figure. The EEG signal is taken from the electrode placed at the Fp2 position [11].

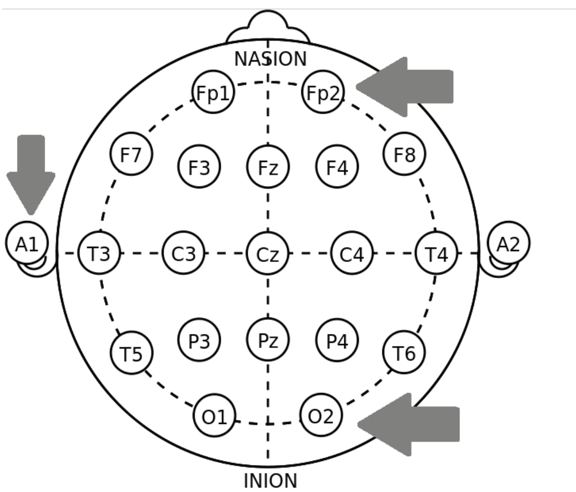

Fig. 2. 21 electrodes of International 10-20 system for EEG, including the position of the electrode set up here [12]

The electrode can be connected directly with the high-impedance and non-inverting input of the amplifier. This configuration has a feature that the DC voltage level from the electrode appears at the output with a unity gain. In practice, the offset voltage is used to determine if a good connection is being made with the scalp. Voltages less than an absolute value of 25 mV are typical for good connections, while poor connections will result in larger voltages. Thus, with this configuration it is possible to read the DC level of the output voltage and determine with some confidence if a good connection is being made. This DC level can be easily subtracted by software once data from the sensors is recorded.

The value of the captured voltage through the electrode is very small. So, an amplification circuit is designed to intensify the captured signal which is depicted in Fig. 3. As can be seen from Fig. 3, the difference signal is first amplified using an instrumentation amplifier (IC AD620). It takes two input voltages and the output is the difference between them which is multiplied by some gain, G. However, instrumentation amplifiers are not perfect. On real amplifiers, the output is slightly skewed if both input voltages are offset by same amount. A perfect amplifier would take as inputs 2.1V and 2.2V, and output 0.1V*G.

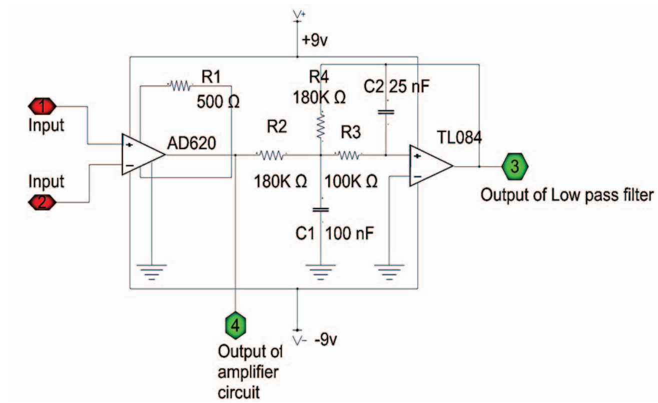

Fig. 3. Circuit diagram for EEG signal conditioning

Next, the output of the amplifier is fed into a low pass filter circuit. The biggest source of noise in the system is centered at 50 Hz, due to power line interference. Even if batteries are used to power up the circuit, the circuit will still experience noise. For this reason, a low pass filter circuit is constructed to cut out as much interference as possible from the amplified signal, that is to eliminate more interference that has been picked up by the circuit.

B. Blink Detection

The filtered signal is fed into the Arduino. Arduino is used to sample and quantize that particular signal. When the subject blinks, an observable peak is obtained which is shown in Fig. 4. The vertical axis shows the normalized value ranging from +6 to -6 and time in seconds is shown in the horizontal axis.

Here, the value of the signal at a certain time is compared to the value in the previous instant. If the subtraction of these two values is greater than a given threshold, then blink is detected. This threshold has to be set up according to the subject, as it might vary from one subject to another.

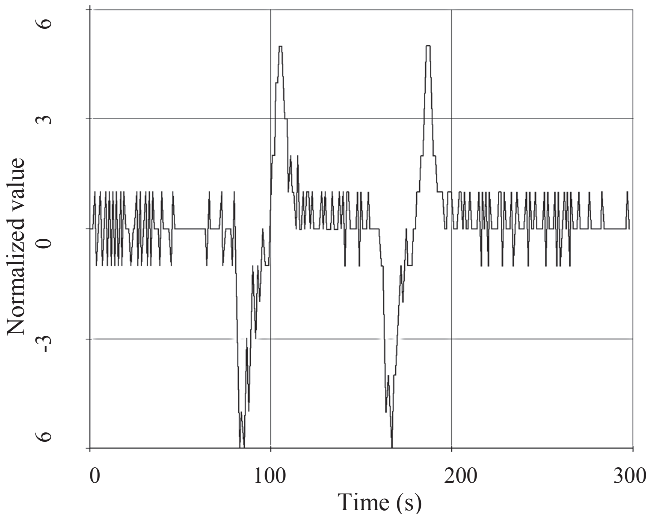

Fig. 1. Two peaks representing two blink

C. *Human implementation with GUI*

Detection of blink can be used in various applications some of which are mentioned earlier. In this paper, the targeted subjects are the disabled people who are not able to perform tasks using their hands or legs. A graphical user interface (GUI) suitable for such handicapped people is developed which is shown in Fig. 5.The GUI is displayed on a screen where options of several tasks are available. Till now, six different tasks - light on and off, switch on and off, fan on and off are considered which can be performed and controlled through eye-blinks using the GUI.

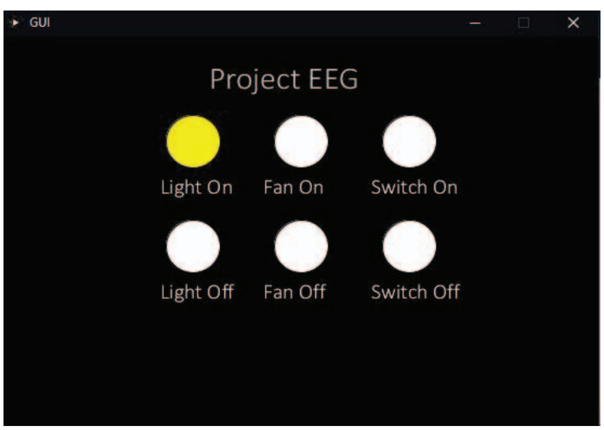

Fig. 5. GUI shown in a display

At first, all the aforementioned tasks are shown in the display screen. Next, the user needs to blink once to select one of the task which is shown in yellow cursor. In order to perform that selected task, the user needs to blink once more within a certain time limit and a green cursor is seen. If the user does not blink within this time limit, the selector will remain on that option idly (yellow cursor). The user has to blink again to move to the next task. The whole process can be repeated and the user can perform any task according to his/her own will. The system responds to blink immediately without any loss of time. The whole system is built to be handy and portable so that it can be carried around with the user.

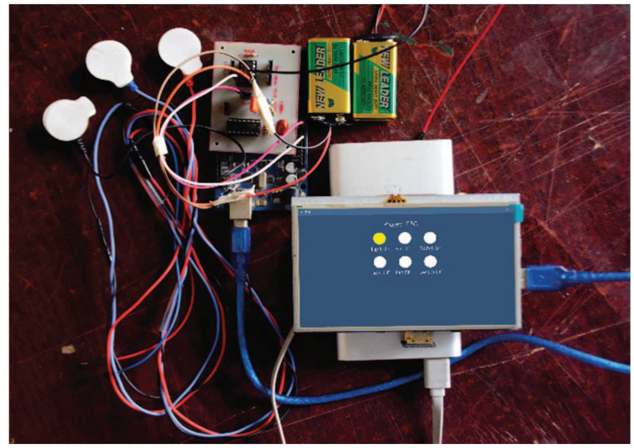

Fig. 6. The complete assembled setup

The final module is shown in Fig. 6 where all the parts are integrated. It comprises sensor pads, the preprocessing circuitry, microcontroller, power sources and a screen to show the graphical interface.

Finally, the complete assembled hardware setup is mounted on a wheelchair as shown in Fig. 7. This wheelchair can be used by the disabled person to carry on their day to day activities much more easily.

Fig. 7. Hardware mounted on a wheelchair

III. Result

The system is able to independently select and control three pairs of functions presented in the GUI. This procedure provides a faster way of EEG capturing and blink detection at the same time. The whole process is implemented on few healthy subjects and an accuracy of blink detection is deduced. Here, accuracy is defined as,

$$Accuracy = \frac{Number\ of\ blinks\ detected}{Total\ number\ of\ blinks}$$

Table I shows the accuracy of the system that has been implemented on 25 healthy males and females including their age range.

TABLE I. ACCURARY WITH AGE RANGE

Gender	Age Range	Accuracy(%)
MALE	20 to 30	98.7
FEMALE	20 to 30	97.5

IV. Humanitarian Impact

The designed system can help the disabled people control digital system, home appliances such as lights, fans etc. and even computer interface just through voluntary eye blinks, thereby helping them become independent and perform day to day activities on their own. Thus the barrier set in front of them can be removed.

In large industries, there are many subsystems where someone is appointed to monitor the workflow of that section and notify if any discontinuity is occurred or threshold is exceeded. This person in most cases offer intellectual service through making decisions and requirement of physical efforts is minimal. This type of work can be efficiently performed by physically handicapped people through the system presented in this paper. This system can be merged to operate machines in industries and can be integrated with various other control systems as well. Thus, the disabled can be able to contribute to the workforce, in industries and in local firms, with the help of this technology. So, the large disabled population can turn themselves into human resources instead of being burden to the community.

This device is also economically friendly for being cheaper compared to the existing devices in the market. The cost of the total setup is $150. It has to be noted that the total cost includes the EEG capturing components and the interfacing device as well. The interfacing device used here is the raspberry pi 3 and raspberry pi display. Muse and NeuroSky MindWave are the devices that captures the EEG signal and interpret its components but they do not have a built-in interface to view these various components of the EEG signal directly. So the proposed device of this paper is cheap compared Muse and NeuroSky MindWave which are shown in TABLE II.

TABLE II. COMPARATIVE ANALYSIS [9] [10]

Instrument	Cost without Interfacing Device (USD)	Cost with Interfacing Device (USD)
NeuroSky MindWave	192	254.90
Muse	95	157.90
Proposed	87.10	150

V. Conclusion

A low cost brain signal based eye blink detection interface for controlling devices by disabled people is developed in this work. The blink detection technique presented here has a very simple algorithm and does not require any sort of image processing or graphics processing unit (GPU) support. The accuracy of the system lies in the range of 98%-99% which is high enough. The system uses readily accessible low cost component which ensures scalability of the work. The final module is reliable, sustainable, compact, user friendly and very simple to operate; therefore, the project can easily be adapted in any community around the world and can be very prospective considering industrial application as well.

Acknowledgment

The authors would like to show a humble gratitude to the Department of Electrical and Electronic Engineering, Bangladesh University of Engineering and Technology (BUET) for providing all the necessary experimental platform for this research, so that the target can be accomplished successfully.

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