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Research Article

Design of a LabVIEW-Based Virtual Instrument for the Disabled

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Abstract

The eye is a prominent organ with complex functions that play a crucial role in our daily lives. The ability to perceive objects from varying distances and angles is vital for navigation, interaction, and understanding the world around us. The coordination of multiple muscles to move the eye allows us to focus on specific points of interest and gather visual information effectively. The concept of using the electrical signals generated by eye movements, known as the electrooculogram (EOG), has been studied in this research. EOG signals can be captured by placing electrodes around the eyes and measuring the potential differences generated as the eyes move. It was noted that a limited number of studies were carried out on EOG-based designs. However, continued research and development in this area have the potential to enhance the quality of life for individuals with disabilities and contribute to our understanding of both the visual system and human-computer interaction. This paper focuses on addressing the relatively underexplored areas of vertical and horizontal eye movements, as well as eye blinking, in the context of electrooculogram (EOG)-based designs. In this research, sharp EOG signals were observed in different eye movement patterns, and those signals were utilized to control assistive devices for individuals with mobility impairments with the LabVIEW software interface.

Keywords

Bandpass Filter, Electrooculogram (EOG), Electrodes, Eye Movements

1. Introduction

The term "Biosignal" refers to a chemical or physical signal that characterizes a feature or condition of human biology [1]. The signal may originate from a molecular, cellular, systemic, or organ level. Biosignals such as EOG, EEG, EMG, and ECG are electrical activity representations of the eyes, brain, muscles, and heart that can be captured with the help of electrodes placed on different bodily areas. Such electrodes provide information on the human body's anatomy and how it works and are capable of detecting impulses at incredibly low voltages [2, 3].

Scientists have conducted tests to gain an improved comprehension of electrooculograms, or EOG, among the occurrences that can help to understand the functions of the eye. The standing potential of corneal-retinal, or the potential

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difference between the front and rear of the human eye, can be found using the EOG technique [4-6]. In this method, eye movements are recorded by measuring the difference in electrical potential between two electrodes that are implanted in the surface of each aspect of the eye. The eyeball resembles a miniature battery because it has positive and negative poles on the cornea and retina, respectively [4, 7].

When determining eye movement identifications and monitoring, there are many alternative approaches. Eye tracking using sensors (EOG) and eye tracking with computer vision are the two primary categories of eye movement identifications and monitoring systems [8]. Eye tracking using sensors (EOG) systems that are described above monitor and examine eye movements by determining the electrical potentials in the vicinity of the eyes. In computer vision-based eye-tracking methods, eye movements are captured by focusing a camera on either one or both eyes. Eye tracking with computer vision emphasizes two areas in particular. Localization of the eye, commonly referred to as eye recognition, is the first thing that an image looks at. Determining the direction of one's gaze is known as eye tracking, and it falls under the second category. Using the data gathered through processing and analyzing the detected ocular region, It is possible to compute the direction of the eye glance. When real-time eye-tracking devices are utilized, the data are either tracked over successive video frames or utilized directly in the application [8-10].

Eye identification and tracking are still challenging tasks with such systems because of a variety of issues, including how much of an eye-opening, variance in the position of the head and the size of the eyes, etc. [8]. Therefore, depending on the application, many strategies may be employed for determining eye detection and tracking.

2. Literature Survey

In recent years, a limited amount of research has been done on the creation of various systems and devices through eye movement detection. Among them, studies that are very close to this field can be found, and they have been highlighted in this section.

An interface control mechanism for humans and machines based on EOG was developed in 2013. Control signals to operate the wheelchair were produced using EOG signals. As part of this work, A method of recording EOG signals was developed. The prototype motorized wheelchair was then moved using these control signals. Some very similar literature can be seen on these kinds of human– machine interface designs based on Eog [11-13].

A low-cost eye-tracking system that allows measuring the rotational angle of the eye and gaze direction in healthy individuals was designed and implemented in 2014. This system comprises an EOG circuit made up of basic components that can measure eye movement in both horizontal and vertical directions [7]. Several studies similar to this research can be seen, and vertical and horizontal eye movements have been studied [14, 15].

A team led by Lydia Yuhlung developed a signal processing system in 2015 that can handle EOG signals and be applied to a variety of tasks. LabVIEW was a graphical development environment for this work, with built-in features for simulation, data acquisition, instrument control, measurement analysis, and data presentation. Because signals vary from person to person, it could be difficult to acquire and interpret the signal in this system [4, 16].

In 2017, a technique was investigated for analyzing EOG data for distinct eye motions and tiredness detection using a PIC Microcontroller. Depending on the values of the EOG signal magnitude and frequency, the sleepy and awake states were determined. When fatigue begins to occur, an alarm is sounded. Obtaining a precise outcome from these efforts can be difficult due to the value fluctuating based on the individual accounting to the potentials of action generated by that individual eye [2, 17, 18].

A study on the identification of eye movements utilizing EOG was conducted for interaction with impaired people in 2017. A decision on horizontal eye movement was made according to four characteristics in connection with the identified peak. Horizontal eye movement was extracted via signal processing. These studies have a limitation in that the single axis of ocular motion is explored, specifically just horizontal eye movement [19, 12].

In January 2018, a study into electrooculography signal processing was conducted using National Instruments LabVIEW. Through this effort, a novel method for mechanical devices used by physically immobile impaired people was created. Blinks and motions of the eyes in both directions have all been detected via electrode placement. These indications were sent via a biopotential amplification, and LabVIEW was used to process and modify the output [20].

Because of the work that Samina and her colleagues did, information is presented regarding a study project completed in April 2021 concerning adding a new dimension to electrooculography. That effort was made to develop an electrooculography (EOG)-based interface for computer cursor control. People who might not be able to control a computer with a regular mouse, for instance, people with motor impairments or those who have suffered limb loss, are specifically focused. EOG readings were obtained from the right eye through the mechanism to move a pointer to precise points on the computer screen. LabVIEW VI was developed to transform receiving potentials from eye movements into horizontal and vertical cursor motions [21, 3, 6].

3. Materials and Methods

Biopotential amplifier circuits, EOG electrodes, and virtual instruments are the main components of this eye movement detection and virtual instrumentation system.

3.1. EOG Gel Electrodes

The EOG signals were detected using Ag-AgCl electrodes because they are inexpensive, widely accessible, and reusable electrodes for fusing electronics with living things. Typically, the electrodes are made of a conducting gel that is inserted in the center of a self-adhesive pad onto which cable clips are attached [4]. Three gel electrodes were used for detecting horizontal and vertical eye movements and eye blinking. As illustrated in Figures 1 and 2, two of these three electrodes can be used both vertically and horizontally, with the third electrode serving as the reference in both situations.

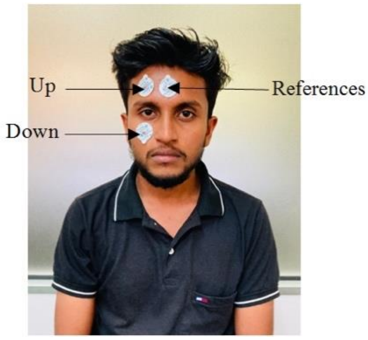

Figure 1. *EOG electrode placement in the vertical direction.*

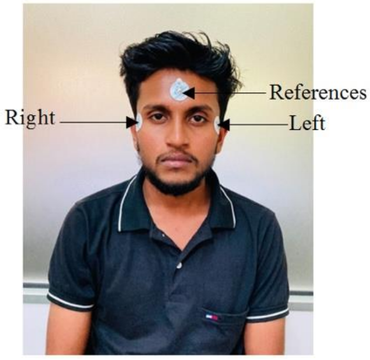

Figure 2. *EOG electrode placement in the horizontal direction.*

3.2. Biopotential Amplifier

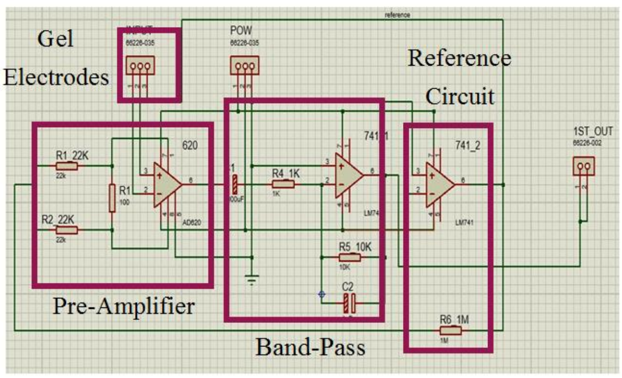

Figure 3. *The biopotential amplifier's schematic design.*

The EOG signals that were observed were passed to the amplifier which is called the biopotential amplifier. As illustrated in Figure 3, the biopotential amplifier was created with an instrumentation amplifier and A pair of operational amplifiers to lessen noise and increase the EOG signal amplitude. AD620 was chosen because it was an instrumentation amplifier with excellent precision and minimal cost, with a gain of one to ten thousand that can be established with just one external resistor. The bandpass filter circuit was built using an amplifier called UA741 because it has several useful properties, such as both output and input overload protection, the common mode range is surpassed without latching up, and no oscillations [4, 22, 23].

The amplitude of the EOG signal ranges from 100 to 3500 microvolts and a range of 0.1 to 20 Hz in frequency. A minimum 2000 voltage gain is needed. [12, 24]. As a result, greater attention was given to the aforementioned points when building the biopotential amplifier circuit, and additionally, other circuit computations were performed using the formulae below.

$$Gain_1 = (49.4 \times 10^3\ \Omega)/(Rg)) + 1 \quad (1)$$

$$Gain_1 = (49400\ \Omega)/(Rg)) + 1$$

$$Gain_1 = (49400\ \Omega)/(100\ \Omega)) + 1$$

$$Gain_1 = 494 + 1$$

$$Gain_1 = 495$$

To get the Rg value of 100 Ω, pins one and eight of the instrumentation amplifier were linked via a resistor. The theoretical gain ($Gain_1$) for the AD620 instrument amplifier was 495. The high-pass filter was used to filter out noises at low frequencies such as head motions, electrode positioning as well as electrode-skin contact. Using the low-pass filter, the electricity line was eliminated, and there was no aliasing. Some calculations were made to align the EOG signal's frequency with the lower cutoff frequency (f_{Lower}) and upper cutoff frequency (f_{Upper}) since the bandpass filter was developed as both a high-pass and a low-pass filter combined. The circuit was then devised.

$$\text{Lower cutoff frequency } (f_{Lower}) = 1/2\pi RC \quad (2)$$

$$f_{Lower} = 1/(2\pi \times 10 \times 10^3\ \Omega \times 1 \times 10^{-6}\ F)$$

$$f_{Lower} = 15.9154\ Hz$$

$$\text{Upper cutoff frequency } (f_{Upper}) = 1/2\pi RC \quad (3)$$

$$f_{Upper} = 1/(2\pi \times 1 \times 10^3\ \Omega \times 1000 \times 10^{-6}\ F)$$

$$f_{Upper} = 0.1591\ Hz$$

The gain ($Gain_2$) of the bandpass filter was also estimated theoretically because it was crucial to determining the overall gain of the circuit.

$$\text{Gain}_2 = \text{RH/RL} \quad (4)$$

$$\text{Gain}_2 = 10000\ \Omega/1000\ \Omega$$

$$\text{Gain}_2 = 10$$

The two previous gains were multiplied to determine the biopotential circuit's total gain (Gain_T).

$$\text{Total Gain } (\text{Gain}_T) = \text{Gain}_1 \times \text{Gain}_2 \quad (5)$$

$$\text{Gain}_T = 495 \times 10$$

$$\text{Gain}_T = 4950$$

In this work, a simple circuit with driven right legs that is reminiscent of an electrocardiogram (ECG) served as a circuit of reference. By using it, the safety of the patient is increased, and disruption is decreased. In this instance, the neck and forehead were used in place of the right leg. The forehead was connected to the output of an auxiliary amplifier rather than the ground. The common-mode voltage was obtained by averaging the 22 k resistors and then supplied back to the reference probe. Through undesirable feedback originating from the reference circuit, the voltage in common mode was decreased [25]. A single PCB was used in the design of the preamplifier, band-pass filter, and reference circuit. Two batteries (Nine volts each) were integrated into the circuit, providing dual power for all devices. The oscilloscope received the EOG signals to obtain a graphical representation of the signals [26].

3.3. Virtual Instrument

The Virtual Instrument was designed and developed by using LabVIEW. The Front Panel was used to develop the User Interface (UI), while the Block Diagram was utilized for coding. Several While Loops were used for display outputs. The Data Acquisition loop can be seen in Figure 4.

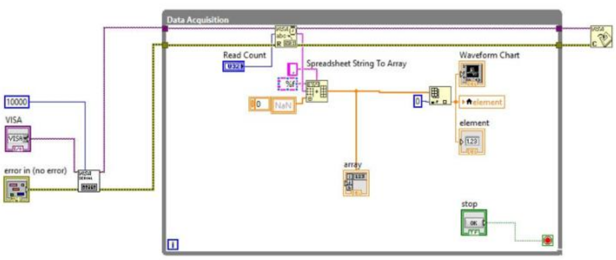

Figure 4. *Data acquisition loop.*

4. Results

First, blinking, as well as vertical and horizontal eye motions were detected and analyzed by using an oscilloscope. EOG signals were obtained and repeated for several students, and the same shapes could be obtained for the particular EOG signals, but different amplitudes were contained.

The EOG signals that were obtained over the two episodes of blinking of the eyes both voluntarily and involuntarily can be seen in Figures 5 and 6. In the voluntary scenario, a larger amplitude was obtained, and a reduced amplitude in the case of involuntary. These differences should be considered when developing EOG-based new creation systems.

Figure 5. *EOG signal of involuntary eye blink.*

Figure 6. *EOG signal of a voluntary eye blink.*

EOG signals were also observed when the eyes were focused independently up and down. The waves have distinct features even if their V_{pp} and V_{avg} levels were near. The oscilloscope's observations of the EOG signals are shown in Figures 7 and 8.

Figure 7. *EOG signal of upward eye motion.*

Figure 8. *EOG signal of downward eye motion.*

In vertical eye movements, a combination of the above eye movements was observed. This means from up to down eye movement and from down to up eye movement. The oscilloscope was used to obtain the EOG signals that can be seen in Figures 9 and 10.

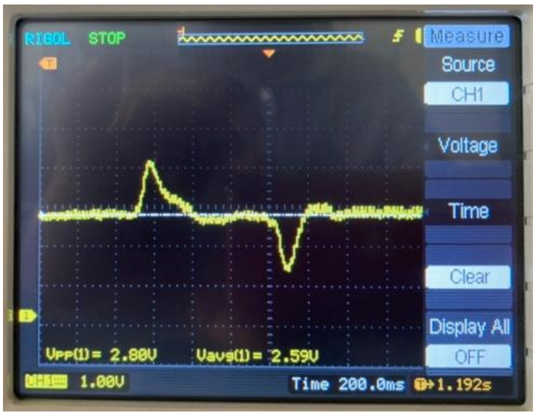

Figure 9. *EOG signal from up to down eye movement.*

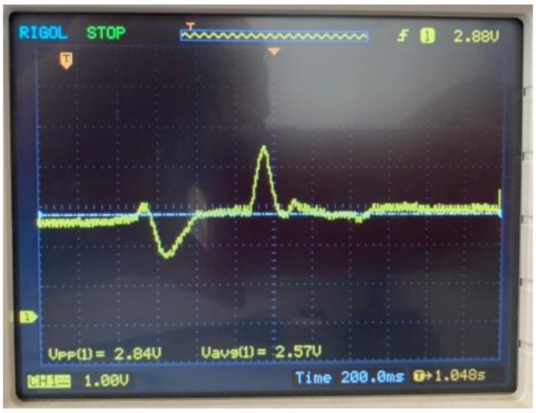

Figure 10. *EOG signal from down to up eye movement.*

When looking left and right, EOG signals were recorded (horizontal eye movement), which is similar to vertical eye movement. When the eye is moved up and down, there is a discernible variation in the EOG signal's shape. Figure 11 and Figure 12 below show how it was seen using the oscilloscope.

Figure 11. *EOG signal of left eye motion.*

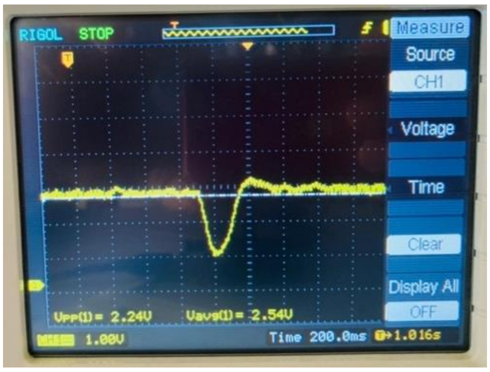

Figure 12. *EOG signal of right eye motion.*

Figure 13. *EOG signal from left to right eye movement.*

Figure 14. *EOG signal from left to right eye movement.*

In horizontal eye movements, a combination of the above eye movements was observed. This means from left to right eye movement and from right to left eye movement. The EOG signals were obtained by using the oscilloscope that can be seen in Figures 13 and 14.

A summary of the average values of Vpp and Vavg regarding both voluntary and involuntary eye blinking, additionally to both horizontal and vertical eye motions of 20 random individuals aged 20-40 years can be seen in Table 1.

Table 1. *The average value of the V_{PP} and V_{AVG} for eye motions in both the horizontal and vertical directions and involuntary, voluntary eye blink.*

Kind of movement or blinking of the eyes	Vpp (V) (Average value)	Vavg (V) (Average value)
Involuntary	2.64	2.40
Voluntary	4.16	2.68
Up	2.72	2.52
Down	3.42	2.64
Left	1.80	2.56
Right	2.36	2.50

The EOG signals for eye blinks were identified separately and displayed corresponding messages for the aid of the disabled. The system displays the message "Please Blink Your Eye" under normal conditions or at the beginning. It can be seen in Figure 15 below.

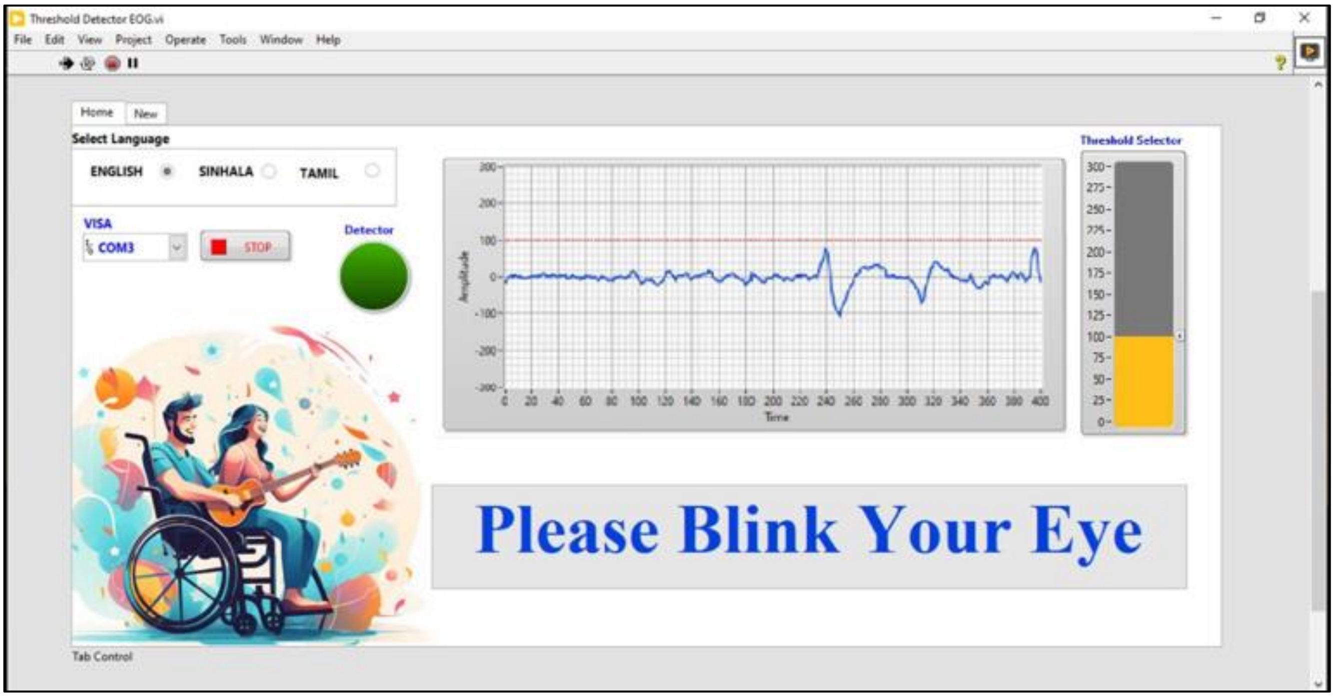

Figure 15. *Virtual instrument output for involuntary eye blinks.*

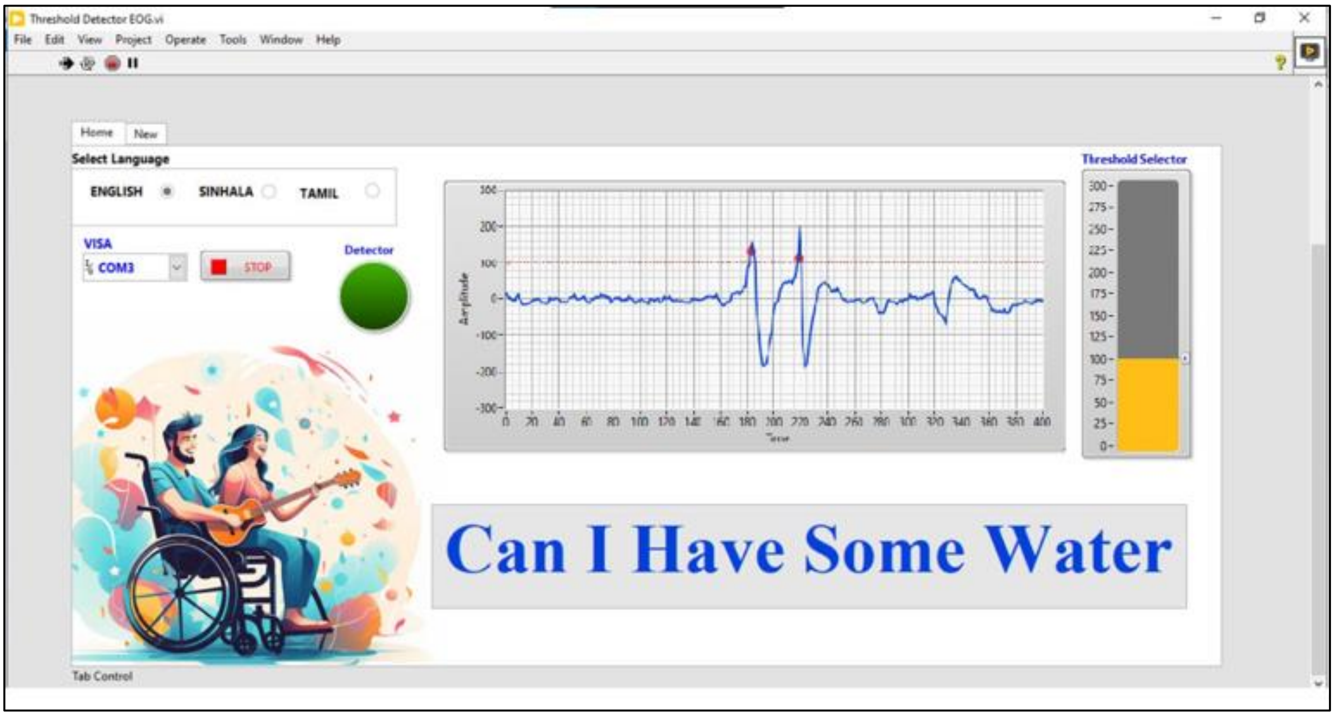

Figure 16. Virtual instrument output for two eye blinks.

Five messages can be displayed with the voice by using this virtual instrument system. Three messages can be seen in Figures 16, 17, and 18 for two, three, and four eye blinks, respectively.

Figure 17. Virtual instrument output for three eye blinks.

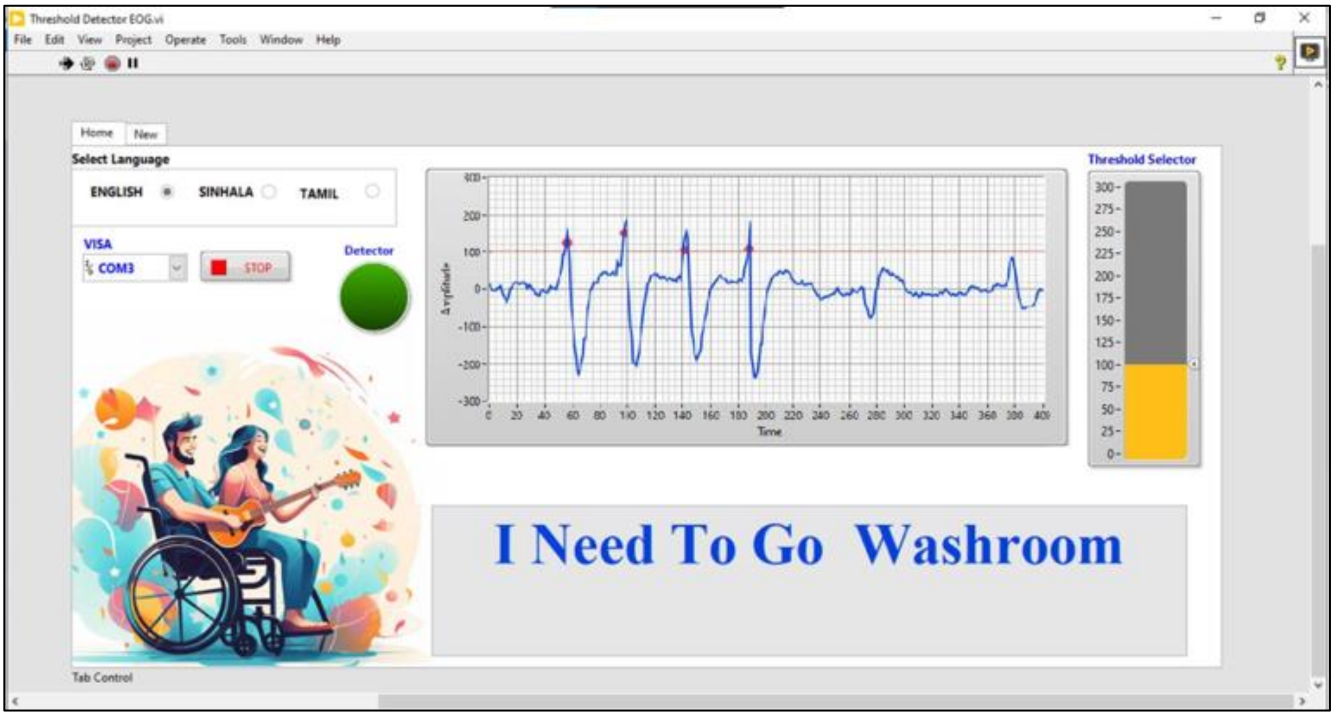

Figure 18. *Virtual instrument output for four eye blinks.*

5. Discussion

It is worth noting that while EOG-based systems offer exciting possibilities, they also come with challenges. These include the need for accurate signal processing algorithms, individual calibration, noise reduction, and adaptation to variations in eye movement patterns among different users. These factors should be considered when developing EOG-based new creation systems such as drowsiness detection systems, control computer cursors, virtual instrumentation systems for the disabled, and control systems for motorized wheelchairs.

In this system, output messages were created for eye blinks only. It is possible to modify the threshold value according to the amplitude of the EOG signal of the particular person. The message is displayed on the display in light of the threshold value. As soon as the EOG electrodes are attached, the system operates in a way that prevents the presentation of any unique gestures. Additionally, nothing appears on the system a particular communication message, not even when only one blink is activated. Thus, the primary reason why a single blink is not used to transmit a communication message is that when a single blink happens naturally, the system detects it and always displays a message with sound.

Consistent shapes of EOG signals were obtained across different individuals, indicating a level of consistency in the patterns of eye movement and blinking, which is significant for the development of various applications. While the shapes of the EOG signals are similar, the differences in amplitude between individuals need to be considered. This variability could be due to factors such as individual physiology, electrode placement, and signal-to-noise ratios. Understanding and accounting for these amplitude differences are crucial for the accurate interpretation and application of EOG signals. Robust signal processing techniques will be crucial for accurately extracting meaningful information from EOG signals, despite amplitude differences. Techniques such as filtering and feature extraction could help in achieving this goal.

6. Conclusions

The goal of this project was to create a virtual device that could detect and analyze electrooculogram signals to identify eye movements and display a message with a voice to assist disabled people such as deaf dumb and paralyzed in communicating. The product's importance lies in the fact that using it requires less effort and has made it easier for patients to express their basic needs. Furthermore, the development of this portable system can be accomplished affordably.

This system can be used to illustrate basic needs in English, Tamil, and Sinhala languages. Thus, these messages are easily understood by anyone proficient in one of these three languages. This system's unique feature is its ability to gradually increase the number of messages that can be input for basic needs in relation to the number of blinks. Additionally, a combination of eye blinks and vertical and horizontal eye movements can be used to increase the number of messages. It will be possible to successfully address the communication difficulties the disabled encounter when utilizing this technology in practice.

Abbreviations

EOG	Electrooculogram
EEG	Electroencephalogram
EMG	Electromyography
ECG	Electrocardiogram
PIC	Peripheral Interface Controller
PCB	Printed Circuit Board
UI	User Interface

Conflicts of Interest

The authors declare no conflicts of interest.

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