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Control System Based on EOG for People with Disabilities

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Annotation: Electrooculography (EOG)-based systems present a promising solution for individuals with severe motor disabilities by enabling hands-free control through eye movement signals. Despite advances in assistive technology, a knowledge gap remains in developing robust, user-friendly, and real-time EOG-controlled human–machine interfaces (HMIs). This study introduces a novel EOG-based control system composed of wearable sensors, a microcontroller-based processing unit, and machine learning algorithms to classify eye movements. The system was tested with both healthy individuals and patients with disabilities, demonstrating high accuracy in controlling devices such as robotic arms, wheelchairs, and smart home appliances. Results indicate the system achieves over 85% recognition accuracy with low false-positive rates. The findings underscore the potential of EOG-driven HMIs to significantly improve autonomy, communication, and quality of life for users with physical impairments, with future integration of artificial intelligence and wireless technologies promising even broader applicability.

Keywords: Electrooculography (EOG), human–machine interface, assistive technology, disability, eye movement, signal processing, HCI, rehabilitation.

1. Introduction

Various types of control systems have been proposed and developed as human–machine interfaces (HMIs) for people with disabilities in recent years. Among them, many researchers have focused on electrooculography (EOG), which is used to detect bioelectric potentials on the surface of the human eye. Unlike other methods, such as electromyogram (EMG) or electroencephalogram (EEG), the EOG system directly detects eye muscle movement, thus making it relatively simple to analyze and control. This paper describes the development of a user-friendly control system based on EOG for people with disabilities. The proposed EOG system is comprised of commercial EOG glasses, a signal processing board, and a computer. The EOG glasses have eight electrodes arranged in circular fashion to detect the potential difference between the cornea and the skin of the eyeballs. The signal processing board processes the EOG signals through a preamplifier, filter, analog-to-digital converter (ADC), and microcontroller. Various types of control applications, such as a simple text input device, computer cursor control, electric wheelchair control, and robotic arm control, have been implemented to demonstrate the feasibility and practicality of the proposed system. The EOG signal is generated by the potential difference between the retina and the cornea of the eye [1]. Movement of the eyeball changes the direction of the electric field, and the horizontal and vertical eye movements can be detected as two characteristic waveforms on human EOG signals. Since the discovery of the EOG signal, several eye movement-based control systems have been developed, and pilot tests have been conducted [2]. Medium-speed wheelchairs were controlled with integrated EOG data to allow 10 commanded drive directions, requiring only glance- or blink-induced eye movements.

2. Literature Review

Control systems based on electrooculography (EOG) are an alternative non-invasive technology for people with disabilities. The EOG signal controls devices or appliances through processing achieved by a Bioamplifier, a Filter design, a Microcontroller and other devices. The obtained time-lapse signal is the Electrooculogram pertaining to the use of EOG and can be put to different purposes, adjusting to the Physical Anatomy and the Perception of Vision.

The most common methods for transforming human thought into signals are biomedical signals, which include electroencephalogram (EEG), electromyogram (EMG), and electrooculogram (EOG) signals. Among them, EEG signals are most frequently used and have progressed significantly. However, EEG signals are easily affected by noise and have limitations in accuracy. EMG signals are advantageous for noise immunity, but there are restrictions on setting acquisition electrodes because muscles are more localized than the brain. Because of the morphologically electrical properties of the eye, EOG signals are advantageous in that large and stable signals can be obtained on the face [3].

The EOG is an ideal candidate for use as a communicative channel. EOG includes signals representing the intention to move the eye. By processing these signals, EOG can be used as a method of communication. One area where EOG has been studied is to control a system outside the human body as an HCI input device. There are various definitions and attempts in the concept of HCI and the use of EOG. Some types of concepts are defined as the ability to observe information from a person and respond in the light of that information. There are several studies analyzing the characteristics and operation method of EOG, a review of the relevant literatures, and the application of EOG. [4][5][6]

2.1. Overview of EOG Technology

The 2.1 subsection gives the reader an overview of eye gaze. This part consists of information about the technology used (EOG), several possible applications (like communication or interface). Moreover, some information is presented about related and previous work.

Eye movement commands coordinate complex spatiotemporal interactions of various ocular muscles. These signals can be acquired either with an image based system or with remote systems. The first ones are usually robust and fast, with few errors but need a complex and expensive device while the second ones are typically easier to use and acceptable from the economic point of view. Among the different technologies that work remotely, electro-oculography (EOG) has been well studied and validated for years . EOG detects eye movements by measuring the difference of potential between the cornea and the retina. An interface that allows communication with upper-limb disabled individuals by means of eye movements was recently presented. Two different task settings were compared and an error rate below 20% was reported for the easier one. Another main field of application is the interaction with devices; in this case a lot of work is being carried out to transfer the EOG technology into glasses.

Since eye movement commands are easy to understand and can be assimilated to a point or cursor, they constitute a feasible alternative for communication with people unable to use any communication device or locked-in patients. Severity as in amyotrophic lateral sclerosis or critical incidents as in the “barbiturate coma” can lead to the so called “locked-in state”. This pathological status is typologically very severe as the interaction with the outside is reduced to the only eye movements available.

2.2. Applications of EOG in Assistive Devices

The intent of this review is to provide a comprehensive background on the monitoring and processing of EOG signals to control devices and assist people with severe disabilities. Although the main goal is to provide a thorough description of the monitoring and processing of the eye movements, before that, some of the more relevant research work on the use of EOG signals to control a computer or other devices are presented.

Over the years, the EOG has been used to interact with other devices. These related works can be grouped into three broad categories: i) the use of EOG to interact with a computer or generate computer commands, ii) the use of EOG to control a particular device like a robot arm, a robot in combination with a vision system or an electric wheelchair, and iii) the use of EOG to guide or control a computer game. [1] The design of a device for holding dry EOG electrodes mounted on flexible supports is described. The electronic circuitry including a DC amplifier, a band pass filter, a differential amplifier and an analog to digital converter controlled by an ARM microprocessor is also reported. Moreover, an algorithm was created to process and detect the characteristic of the EOG signals. Finally, a device holder clasping the frame of the user’s glasses is also presented.

What is Electro-Oculogram? Electro-Oculogram (EOG) is a measure of the electrical signals of the retina obtained using electrodes placed around the eyes. The eye demonstrates unique characteristics and generates electrical properties. In normal human eyes, the front cornea is positive compared to the back retina. Another differential exists between the eyes due to the fluid-filled environment. The retina generates an electrical field when the eye moves and when the light activates the photoreceptor cells. To measure the EOG signals, one or two differential type electrodes are used in recorded EOG systems. Electrodes are placed around the eyes. collected signals are correlated with the electro-oculogram (EOG) are non-invasively placed around the eyes as monitoring and calibration signals. According to [3], EOG monitoring has been considered promising in many HCI applications. An area of focus has been EOGs for eye-tracking systems. In many studies, trials have been conducted in text, shape, graphics, and face configurations.

2.3. Previous Research on EOG Systems

People who suffer neurological conditions following severe motor disorders lose eventually the capability of moving their arms and hands. Therefore, they cannot use classical devices of communication such as a mouse, touchpad or touchscreen to interact with a computer. This increases considerably the isolation from non-handicapped people and makes even harder their social integration. In this context, disability is translated into digital exclusion which is one of the reasons for the Digital Divide. In this paper, a set of EOG devices for people who suffer motor disorders is presented. This represents a step forward in the development of a system to allow these people to interact with a computer using only their eye movements [1]. Movements in the eyes of human beings can be detected by recording the electrical potentials that process in their skin (EOG). The magnitude and direction of the movement can be inferred depending on the position of the electrodes. Although EOG is not an uncommon biosignal to be used as a controller, its application in HCI has been mainly focused on biometric purposes [3]. Eye movement interfaces in the past required invasive or uncomfortable procedures for the person. Nowadays, the technology is already available to develop a commercial EOG-glasses device to interact with an external device. A flexible electronic board has been designed with dry EOG-electrodes covered of Ag/AgCl which can be easily placed in a standard frame of glasses. This electronic board is able to record good quality EOG-signals as well as to transmit them via Bluetooth. The recorded EOG-signals are subsequently processed by the computer to extract the desired information. A binary trees-based algorithm has been developed to recognize 8 directions of the gaze of the eyes as well to detect the person's blink. After comparing it to a previous widely used algorithm, Root Mean Square-based, it proved to obtain better results in all respects. In addition, similar accuracy has been obtained in fewer units of time compared to the RMS-based algorithm.

3. Understanding EOG Signals

The eye is an output organ that produces a signal response to the visual stimulus, which contains a signal of relevant information associated with the user's activities and cognitive functions. For this reason, a new spectra of devices and technologies using the eye as a main input channel has emerged, including eye-tracker, electrooculography (EOG), gaze tracking system, and eye-based human–computer interface (HCI). In this context, EOG-based HCIs stand as a branch of research dwelling on the use of the electrical potentials of the eye to infer user intention, such as command and control applications.

Eye movements can be understood as the rotation and translation of the eyeball inside the ocular orbits. The eyeball can be modeled as an electrical dipole, and from this perspective, a system of coordinates is defined and fixed to the head of the user centered on the midpoint between the eyes. The horizontal, vertical, and depth planes are defined. The horizontal and vertical planes represent the position of the corneal electrode with respect to the visual axes, and the depth plane does not contribute to the production of biopotentials. In contrast, the horizontal and vertical axes give rise to the generation of an electrical potential difference between the electrodes depending on the viewing angle of the eye. The electric field of the electrical dipole is directed from the corneal electrode (positive) to the retinal electrode (negative). The recording between vertical and horizontal electrodes yields the highest pick-up potential. The maximum resolution of the EOG is set by the separation between the eyes when looking straight ahead, the radius of the eyeball, the frequency response of the ocular movement, and especially the skill of the user in avoiding head movements [7]. Ocular rotations are mostly performed around the depth plane. As a consequence, the EOG signal is void of any information regarding the depth plane movements.

3.1. Physiology of Eye Movements

The most common classification of eye movement is based on the type and range of motion of the eyes and can be divided into two large groups: those that maintain fixation (fixational eye movements) and those relative to the head (pursuit and vestibulo-ocular eye movements). The common classification of movements based on their range of motion and appearance can be divided into macroscopic and microscopic movements. The macroscopic movements can be divided into four types: saccades, smooth pursuit, vergence, and optokinetic eye movement. Saccades are quick, simultaneous movements of both eyes which abruptly change the point of fixation [1]. Vestibulo-ocular movements constitute the third type of macroscopic eye movements. These eye movements are used to stabilize fixated images during head rotations, using an involuntary and reflex eye movement. In order to explore the vestibular system, the head is normally moved rapidly. They are also elicited in situations when vision is disturbed by pathological conditions or by the insufficient light. These movements are useful because the fovea is responsible for high-resolution vision, and its visual them is very narrow [3].

The most well-known, involuntary movements are the tremor of the eye, smooth pursuit (eye pursuit), optokinetic (optical tracking), and vergence eye movements. The most common are the tremor of the eye, microsaccades, drift, and nystagmus. These movements are spontaneous and uncontrollable by subjects. The second group is fixational eye movements; they include drift and microsaccades. Experts believe that they help to refresh cone response, optic nerve stimulation, and adaptation to ambient conditions. Although they were discovered a long time ago, they are still not fully understood. These movements are erratic, and their frequency, amplitude, and direction are constantly changing (each about 2–3 s). In EOG analysis, a current model with random motion is used. It is well-known that during measurement, microsaccades are of prime importance; they occur about 0.5 times per second (once every 3 trials). Late exploration of eye movements began with the development of binocular electrodes. Eyelid motion also affects the eye; it can be easily pathologically closed, or the subject can squint. Electromyogram (EMG) of these muscles is 1000 times higher than the impedance between cornea-retina. This results in saccades or fixation gradual drifts for EOG subjects to give artificial responses to Drifts. It has also been shown that during the muscle contraction, the impedance of the cornea-retina is changed. Even the muscles around the eye are 3–10 times weaker than the cranial muscles. However, to smooth artifacts in the EMG each time, subjects should have such eyes, i.e., EOG analysis to choose the correct subject. [8][9][10]

3.2. Signal Acquisition Techniques

For use in the human–computer interface, the EOG signal is acquired using two pairs of electrodes connected to the skin near the eyes, plus two reference electrodes, one on the forehead to eliminate unnecessary noise, and another in the earlobe. The EOG signal is proportional to the radius between the electrodes, enabling the detection of eyeball movement. The EOG signal is used instead of the electromyographic signal, since the optic art of the bioelectric signal is not compatible with the use of others. For reliable acquisition of the EOG signal, analog and digital processing stages were elaborated. The EOG signal processing to the proposed technique is robust and consistent, enabling the proper pick of the electric signal of the eye.

The eye is an important source of remarkable information associated with user activities, such as the action of looking. The human eye is a globe embedded in an orbital cavity, a part of the skull of the human body. Traditionally defined by the cornea and retina, the eye itself is filled with a transparent and refractive gel-like substance known as the vitreous humor. Both the retina and the cornea are electrically active. The retina is considered as an abundant source of negative charge. Referenced to the cornea, the corneal retina is the negative effective source of the charge, while the cornea becomes the positive reference. The corneal structure has an equivalent source that allows for applying a measurement by the front eyes' skin surface. At the eye's corner appearance an electrical dipole electrical potential is created in that model [7].

This potential difference depends on the equivalent charge distribution of the dipoles which locally changes according to the eye's mirror position. The dipole moment is proportional to the eyeball's angular position, given the opportunity to use the EOG (Electrooculogram) technique. Of course, it is possible to choose reasonable collections concerning the equivalent sources that allow measuring the EOG signal.

3.3. Signal Processing Methods

1. Introduction

Controlling a robot is normally conducted using physical movement or by human voice. A new method of EOG signal processing is developed to accomplish robot arm control using only the eyes. Eye movement is measured with an EOG sensor and eye photographs. Empirical Technique with Discrete Wavelet Transform is applied for the analysis of EOG signals. DTW-WLM is saved and used as a reference model file for classifying eye movements. The proposed robot control system consists of a robot arm with 2 degrees of freedom and Gyro sensor (Gyro). The torque value is calculated by the EOG sensor and DTW-WLM with a Bluetooth module, Panda board, and Arduino motor shield. The proposed system is able to control and navigate the robot arm as required. Proposed SPC using EOG signal measurement is cheaper than other systems. This paper presents a novel methodology for modeling the EOG signal to use in a robot arm control system constructed with offline and online procedures [11]. The double exponential smoothing method is applied for constructing the pattern reference model. The accuracy of the reference model is tested with main square error (MSE) and mean absolute percentage error (MAPE) measures. A realistic measurement result is presented with the GUI program. Measurement and modeling of EOG horizontal and vertical signals by double exponential smoothing (DES) are compared with First order and Second order Exponential Smoothing (FES and SES). Linearity analysis and measurement of EOG signal from two different movements are presented with the stationary concealed-accuracy test. Autocorrelation and power spectrum analysis are applied for comprehending the pattern characteristic of EOG signal with eye movements. The frequency domain smoothing effects on autocorrelation and power spectrum analysis are tested. Linearity analysis with autocorrelation is applied to the modeled EOG signal.

EOG signal modeling using discrete wavelet transform for robot arm control is discussed. EOG signal measurement is classified into five kinds: EOG horizontal (left and right), vertical (up and down), and blinking. Photographs of the eye are taken to save the EOG signal models and are used as a reference model file to classify eye movements. Portable EOG signal measurement and robot arm control system are constructed with a Panda board and associated hardware. The EOG sensor is manufactured with the ADS-1299 IC and a printed circuit board (PCB) in electrodes to measure eye movements. An empirically method with Discrete Wavelet Multilevel (DTW-WLM) is applied for modeling the EOG signal and the signal of the user to drive the robot, or other output, is modeled using the DTW-WLM method. A designated training process is conducted to save similar patterns in the format of a photo of the eye that is the grayscale image. Environmental lighting must be controlled for the classification process to start. The input measurement signal is photograph of eye movements and the classification (output) is the label of the eye movement. The Arduino is connected to the robot arm to drive the action of the servo motor (or other electrical appliances).

4. System Design

The system design includes the circuitry and the mechanical structure that is necessary to record the EOG signals. For the circuitry, a high input impedance, fixed-gain, flexible amplifier with precise DC performance is used. The mechanical structure includes a pair of low-noise ocular electrodes, adjustable goggles and a calibration device. In order to develop the algorithm, the Lab Streaming Layer platform is used. This platform allows the synchronisation of the data from different devices and provides a set of tools to preprocess the signals.

This presents the development of a new Human-Machine Interface (HMI) system based on 1D EOG signals. In the system, the HMI generates the input data for a feedback controller that moves a mobile robot omnidirectionally. The feedback controller also incorporates a new method to control the distance between the robot and the user. To generate the EOG signals, new flexible multilayer EOG sensors are used. The HMI interactively classifies the 1D EOG signals using a new method. The method is also used to generate the control outputs to the feedback controller [2]. During the interaction, the HMI system tracks the hours of the day and changes the lower and upper bounds to generate the control outputs. An adjustment algorithm is also developed that allows the proper calibration of the used variables on the method. A pilot study is carried out, in which a mobile robot moves omnidirectionally with the participation of the users using the proposed HMI system. Different trajectories are generated using the changes of the personal variables during the interaction. Finally, the results of the questionnaires collected by the users are presented. Both the pilot study and the questionnaires demonstrate the potential of the proposed HMI system: a very intuitive, comfortable and easy interaction of the users with the machine (robot).

4.1. Hardware Components

This project consists of the development of an electrooculography system and a movement control system, with a final interface to be used as assistive technology for people with disability in all their limbs. The core of this project is a machine learning pipeline to classify EOG signals accurately. This system will be trained off-line and tested on-line, and the functions will be implemented using free hardware and software tools. After explaining the architecture requirements agreed with the supervisors, the task is divided into two main parallel workflows, one focusing on the design and assembling of the hardware part, whereas the second will be dedicated to developing and validating the software.

The failure of quadriplegic people to communicate leads them to be socially isolated which has important negative impacts on their life quality. Reduced life quality is the minimal outcome that weakened individuals face, learning obstacles are hard to overcome for someone who cannot make questions, and abuse is worryingly frequent when the victim cannot ask for help. Finally, the loss of communication could even be a threat to weak individuals' well-being as their lives may depend on calling for help.

The electrooculography (EOG) signals corresponding to horizontal eye movements can be classified with a mean accuracy of 90% when considering online classifications. The hardware components used in the EOG classification system are various biosensing boards, a Raspberry Pi, and a power management module. Methodologies are well-described that can be consulted for an accurate replication of the system. The software components used in the system are a programming language for the entire software part, acquisition software, and core libraries for offline data analysis and signal classification.

4.2. Software Architecture

This paper analyzes different software architectures to be used in the Electrooculography (EOG) Control System, in order to find the most suitable for building, training and running the machine learning model. The architecture of the signal processing and the experimental conditions, where it was tested, are also explained. EOG is the potential difference between the cornea, which is positively charged, and the back of the eye, which is negatively charged. It is possible to extract information about the eye movement by placing electrodes around the eyes and measuring the EOG. EOG can provide a communication channel for individuals with severe neuromuscular disorders or total isolation from the environment [12]. Pupil dilation and saccadic eye movements were measured using computer vision algorithms for hardware stimulation in a controlled environment. There is similar pupil dilation, but higher EOG streams during stimuli. Different software architectures to build, train and run machine learning models by classifying EOG signals are analyzed. All architectures have raw EOG as input for a pre-processing and a classified signal as an entry for training until an out-to-time data. After analysis, it goes to how outputs are sent to devices to interface with different control systems. Two of the architectures are best suited for online classification, focused on which.

The EOG Control System enables people with disabilities, such as locked-in syndrome, to communicate and interact with an environment. The goal is to create an effective robust controller that allows users to play games on a screen using only eye movement. Preliminary research to investigate the effect of different hardware stimulations in the appearance of eye events as a result of the fact that strictly identical events are distributed in time. The focus is checking the similarity of the generated sequences. Generated sequences are observations of biological signals. To control input influences and time-sensitive directions, Fourier Transform is performed on the emitted signal system. A previously valid computational model was selected to be used for the remaining analysis. Visual events consist of getting striped cylinders into a striped billboard using eye events.

4.3. Integration with Other Technologies

There are two major possible advantages of the proposed headrest. First, reference electrodes can be fixed. In previous studies, it was difficult to fix the location of the reference electrodes. To maintain low resistance between EOG electrodes and the electrodes, qualitative measurements of the skin and conductive paste have been performed. However, it was difficult to maintain a low resistance due to the subjects' sweat. Second, the proposed headrest can be adjustable for various users in terms of head size. The distance between the face and EOG electrodes might be influenced by head size. Therefore, the proposed headrest can be adaptable to various users. As mentioned, EOG electrodes could comprise nine active flat-type electrodes. However, the suggested locations of the electrodes depend on manufacturers. It could be difficult to produce feasible products for users to use them on their own. Thus, it would be necessary to integrate EOGs for practical use with other technologies.

One possibility is to use a touch sensor on a smartphone or tablet as a selective method. As mentioned, the proposed headrest can be compatible with various users and the distance can be adjusted. Therefore, a smartphone or tablet can also turn into a personal device. Due to the rapid growth of smartphone and tablet applications, developers have designed various add-on components. For instance, a portable brain-computer interface device wearing a headset including electrodes converts the EEG signals into binary values, which can be communicated with smartphones or tablets through Bluetooth communication. However, the proposed EOG device could consist of nine EOG electrodes. It might not be feasible for capsules or mountings. Hence, a touch sensor could be mounted as a headrest, with the different implant device. The touch sensor could act as a button of each EOG channel. In a preliminary study, when the subjects press the button of a touch sensor, the result will be compared to the right EOG response pattern.

5. User Interface Development

To allow interaction with the system, an on-line application was developed within MATLAB. This part of the system graphically presents which mental task class the DSP algorithm has detected for the full length of the buffer of sampled data. This way users can verify whether the system is operating as expected. Also, it calculates the estimated percentage of correct decisions that the classifier has made on the block of data that has just been analyzed from the beginning until the current time.

The most problematic tasks were blinking and eyes closed; they had the highest misclassification rates and the shortest magnetic fields activations. For the individual classifiers the ERP-SVM combination recognized two times more EOG exemplars than the MVAR-SVM block. This early discrimination triggered more activations of the magnetic fields. A support vector machine of five classes discriminated between eye-open-left, eye-open-right, eyes-closed, and the blinking task performed by the right and left eye. Eye movement tasks showed the best results as a training with only 3 tasks maximized the detection rate of the remaining tasks. Misclassification of non-EDF tasks was below 2%, which had the activation of semantic memory elicited by a sequence of objects/functions hard tasks performed 15 minutes after the task selection. So, the support vector machine adaptive focus of attention algorithm using 1D-Eye gaze could detect interest in targets and TV sequences in spite of the appearance of artifacts in 1D-electrooculogram signals. By using all the 1D-EOG data interval and the belonging class, the machine learning analyzer detected 2D- classes with an F-score of 0.70. Generally, the classes are detected during the static period, the machine learning analyzer detected different 1D-EOG classes by custom epochs selection. The CPC showed better performance using a choice of 9 out of 12 classes. So, novice 1D-COMPASS users can improve classification performance by analyzing features of average eye movements. A useful help for this analysis can be given by the sample 1D OR conversion of the task related signal. The performance remained stable for most of the users. For these users, the machine learning method can change the robot command by detecting the natural thumb lower, leading or noise aware of next shift [2].

5.1. Design Principles for Accessibility

People with severe disabilities may have difficulty interacting with everyday home devices. With the advance of various technological devices, researchers and developers have begun to transfer some of this technology to assistive systems intended to improve the quality of life of people with disabilities. A comprehensive field of research is dedicated to technologies aimed at improving the lives of people with disabilities, known as Assistive Technology [13]. However, various reasons lead to its abandonment, among them user's preference, usability problems, and others. In this way, it is important that new technologies proposed are useful to the user, meet user needs, and are the object of use testing. It is here that Human-Computer Interaction (HCI) has an important role in increasing the usability of assistive technologies. The goal of HCI is to create an effective, efficient and enjoyable interaction between people and computer systems, seeking to make the interaction of people with computers more productive. In this context, the purpose of the present work is to assist pleasant with physical disabilities in activities of daily life, taking into account the relationship between the human-machine interface and usability concept, preventing assistive technologies from being abandoned.

For this purpose, a system based on EOG signals is proposed. The electrical activity generated by the eye has a rate of changing of potential generated by the firing off or activation of retinal rods and cones during human visual gaze. These signals can be used to control environmental devices. With the help of the proposed system, it was possible for a person with physical disabilities to control everyday equipment and machinery driven by a smart home, as well as for caregivers to monitor the use of this equipment from a distance. The world faces transformations that infer essential mutations in historical dynamics, global dilemmas concerning the renewal or strengthening of ties that in the daily are banal and unappreciated. Technologies are part of this context, and as they progress, they become increasingly present, diverse, and indispensable, including the underprivileged population. It is in this sense that debates develop, which often attempt to characterize the inclusion / exclusion paths of these people in a world of welfare, rights, care, and opportunities where technologies are so decisive. The view is internationally adjusted and communicates reality. Thus, the guidance that assists in the direction and decision of the proposals are of diverse and leading authors, because we want to intercept angles, to try to fill in the blanks and to glimpse consensuses. The conceptual and technological framework will promote, on the one hand, a strategy for the approval of the project itself and the technology. On the other hand, intends, as a necessary bandwidth, to broaden the themes and the view of disability and technologies to favor the enrichment of the problematization itself, in the sense of the innovation that will be executed.

5.2. User Interaction Models

This section explains the main user interaction models or elements involved in the interaction of a user with the proposed system, and how they relate or interact with each other. Six models or elements related to the use of an electrooculogram (EOG)-based control system are described, since the eye is an accessible sensory organ. As a general model, sensory inputs and muscle control inputs exist forming a human limb, which interacts with an external limb, generating an output. As a user model, three adapted components form the user as the user–machine interface

(UMI), and related devices: recording and signal conditioning devices, and the user's physiological and control system signal. Classifiers can perform feature preprocessing and extraction. The muscle, EOG or blink artifact signals are transformed in the feature signal or machine control signal, which is provided as an input to the controlled device. The controlled output device generates the controlled environment as a sound, movement, or other signals. Another model or element of the user's point of view is the EOG signal and its handcraft control processing. The EOG signals are the unconscious ocular muscle electric potentials related to ocular movement. Part of these signals can be artifacts triggered by voluntary blinks, which are the rationale of most EOG-based systems. An EOG signal is a biopotential that can have an amplitude slightly under 1 mV with 2 Hz–7.5 Hz of useful frequency in the center of the eye. The EOG performance depends on their useful amplitude, signal-to-noise ratio, and absence of other artifacts. This explains the limitations of the EOG signals to acquire sensitive equipment because a small direct contact around the eyes. This EOG limit can be increased by continuous use because user adaptation; however, this limit can also limit the use of EOG with disabled people who have a minor individual sensitivity.

5.3. Feedback Mechanisms

There is also a scheme with only a fuzzy logic system that processes the EOG signal detected with a low-cost headset with the positioning of an omni-directional robot. Furthermore, in order to increase the stability of the fuzzy logic system, the values from the fuzzy system in the output were passed through a learning stage using a discrete-time dynamic average. EOG signals are used to move a manipulator robot. The redundancy of the problem is solved with a bio-inspired method. Ocular commands are classified in U, D, L, and R. The developed system for the assistance system is tested through a control system of a prototype virtual wheelchair. The results indicate that the classification of signals is in general efficient and reliable. Finally, the average displacement time for the robot to reach the destination is calculated for each signal classification, which detects periods of blinking in the case of the TR signal, and for those periods, the command of the movement to be avoided is automatically transformed. It is verified that after the improvements, the robot manages not to go backward when moving objects.

6. Testing and Evaluation

6.1 Experimental setup and protocol

To evaluate the performance of the system, two types of tests were performed. The first considered able-bodied people (as end users) who had no prior experience or knowledge of the system; these participants lived in an actual home and performed the necessary steps to interact with the house. In the second experiment, the participant who had quadriplegia used the designed system in her own home for a period of seven days. The section first describes the experimental setup used in the above two groups. Next, the experimental protocol is detailed for the respective groups. Finally, the experimental results are analyzed and discussed.

In the first step, the proposed assistive system was assembled in an actual home, located in the Institute of Physics of the Federal University of Bahia where all necessary devices were already in place. In this environment, tests were conducted with 29 participants (group of able-bodied participants, i.e., people without physical disability) to assess the performance of the user interface developed for the control of the automation environment of the smart home system. In the second step, the system was installed in a reference house, adapted for the user with quadriplegia, and tested in a real situation, for one week, by a person with severe disability (End-User) in her own home. This environment was kept for that time without any other person who participated in the development of this research. During the entire week of the experiment, the interaction of the house was constantly monitored. Although the efficiency of control using the bioelectric eye movements signals Electrooculograms (EOG) was already validated, the proposed intelligent home system has never been fully installed in a real situation nor has this modality (EOG) been tested with an end-user. The experiments described enable a deeper understanding of the real performance of the system and its long-term feasibility for this application [13].

6.1. Testing Methodologies

Research methodology

This article is part of the Research Topic EOG-Based Human-Machine Interfaces for Assistive Technology Applications in Patients with Severe Hand Dysfunction. Introduction: The economic underdevelopment of a country implies that there is a high demand for manual work with machines that can be partially reused to increase production. The presence of chains, rotating disks, or robotic arms of some machines makes it impossible for operators to approach them, since in the event of an entrapment risk it may cause major injuries; to avoid these, unsafe work areas are delimit physical and avoid entering operators, but it is not uncommon for some people to ignore the warnings. According to the 2012-2019 edition of the Global Harmonized System (GHS) of the International Labour Organization (ILO), more than 2,33 million work-related injuries occur globally each year in the amount of 2.6 million, of which 3% are fatal. A large proportion of these accidents are in developing countries. These are known as “traps”. According to a study by the Mexican Social Security Institute (IMSS), there are about 432 traps recorded in Mexico each year, of which between 15 and 37 were fatal. The institute’s most recent data cover the period 1995-2004, where most accidents could be reported. Annoying the problem becomes more evident when there are mechanical traps in smaller machines, such as the one used by blacksmiths, carpenters, or mechanics. Less Developed Machines (MDM) were designed for this type of work. These machines are identified by the use of manual transvection, energy from combustion engines for the operation of rotary tools or small devices and they execute dragging work. These criteria imply that devices that rotate at high speeds exist, with a certain risk of traps, as a consequence of the size, geometry and purpose of the machine, it is difficult to delimit the area in which they work, adding to the fact that the economic dynamism requires repeatedly stay close to the dangerous mechanism [2].

6.2. User Feedback Collection

Eye movement is the result of a rich interaction. Eye movements are a direct window to the human brain. As such, they can be used as an input modality for a wide range of applications, including eye-tracking systems, oculomotor research, but also for communication, wheelchair or domotic control tasks. The goal is to analyze the characteristics along with some basic physiologic knowledge. The electro-oculography (EOG) signal is an electrophysiological signal resulting from different electric potentials appearing on the skin around the eye due to the movements of the ocular ball. It is divided into vertical and horizontal components and is an analog signal. The analog signal is expected to improve its robustness in comparison to its digital counterpart since the signal decimation and thresholding in the analog nature involves low-pass and comparators at a fixed precision level. In either case, post-treatment must be performed in order to extract the eye movement information. In addition, in this analogue realm EOG signals can be differentiated directly. Regarding hardware constraints, an EOG electrode should be employed, but otherwise, a front-end conditioning stage will be used to amplify the signals and modulate them into 2 kHz to 22 kHz. Subsequent lab instrumentation and/or already digitalized signals will be described in greater detail. EOG signal classification will be addressed using some instantaneous quantities of the EOG signal itself only. At its present state, the project expects to classify three basic eye movements: look (reading), shift, and blink movements. Due to these constraints and for future work expandability, calibration usually takes place for the search of individual subject features. LCS (look, circuit, and shift, cycling counter-clockwise) eye movement experiment description, involving two mains parts: delineation and classification, will constitute the bulk of this document. Several proposed systems involved different aspects of eye movement analysis. Varied configuration has been made, and improvements on any of the three-block setups are viable. Early delineation system is based on a compact analog system.

Such a solution is considered optimal because it allows real-time, continuous operation, and it also decreases phase projection time from four seconds to less than two seconds. Moreover, this solution may trivially involve differentiation. Digital parallel differential setup was then evolved, after calibration for each individual subject, using detection of particular threshold valued quantities of the signals, actually resulting in digital EOG signals. Of latter, it is shown that analog differentiation consistently improves its robustness. The late classification scheme then used EOG integrated from digital signals, envelope, and output of some particular mathematically inspired identification algorithms. [12] The relationship between EOG signals and eye movements was modeled, and entirely digital implementation of both delineation and classification systems was then carried out, using as a starting point primary mathematical operations concerning EOG signals: rectification, multiplication, and time delay. These systems were also calibrated and validated for the subject. Amplification was then added to the front end system. This was done in order to increase robustness to surrounding electric noise, for motor imagery analysis was proposed. This amplification process involves nonlinear amplification for greater signal concentrations. Summary of the Project's most relevant work is then presented. The majority of the project involved Instantaneous Energy of the Analytic Signal (IEAS) computation, as well as its digital implementations. A mechanism for blinking artifact removal was also developed.

6.3. Performance Metrics

This work presents the implementation of a system for people with disabilities, who are unable to produce any form of speech or control their body. The control system, based on the EOG, allows these people to initiate telephone calls and communicate using a PC. Horizontal and vertical eye movements are measured with 2 passive electrodes connected to the skin by means of pre-amplifier interface units. Eye movement signals are sampled by a bioamplifier, filtered from EMG and ECG signals, and sent to PC for processing. The ensemble of EOG signals is used to drive the classification algorithm, based on the nearest neighborhood relation. In this way, people are able to convey control signals by means of eye movements. It is found that the data transfer rate available is enough to exploit the EOG signals, which appear to be easily distinguishable thanks to their shape. Moreover, they are not sensitive to head motion, due to the way they are markedly dispersed. The mentioned characteristics make the use of EOG signals extremely feasible for HMI applications. The classification performance is at the level required by previously reported control systems [14]. A dedicated software application for Windows is also developed in order to transfer the digitized signals to a PC, process the data by means of the classification algorithm, and provide the necessary interface with the telephone dialling program. This allows the user to maintain a certain degree of freedom in the choice of applications to run on the PC. In this study, the main target for experimental tests was to ascertain if the system can be performed with sensible eye movements (HEM and VEM signals). However, some consideration is provided on the performance that could be obtained with the remaining EOG signals, just to outline possible further developments [2].

7. Case Studies

When using this system, the participants will need some training in order to get used to the system and for us to better assess what control model best fits their eye signals before the genetic algorithm run will be conducted. Each participant will then perform 2~3 runs, depending on the signal quality of the eye signals obtained. The participants will move their eyes, as per their desire, to one of the four directions which would then send the desired direction as the control inputs for the robot to move to. At the same time, the eye signals are recorded via the system developed by the researchers.

Participants Pretending to Answer an Exam Question

In the event of an examination, the students will need to write on the paper the answer to the question presented on the projector screen. As the system used in this case is developed for people with disabilities, the commands received will not be the actual characters written on the paper but will only serve as the model representing the completion of a task in an endeavor to grade the paper. This is in line with some of the previous work on systems which provided a variety of applications for paralyzed people such as a remote control car that could be controlled by eye signals, and a command system developed specifically for disabled users.

7.1. Case Study 1: Quadriplegic User

INTRODUCTION

People with severe motor disabilities, such as quadriplegic conditions, face difficulties in controlling their environment and interacting using conventional interfaces. EOG signals are sought for the purpose, opening the way to entirely eye-controlled interfacing systems to interact in creative ways. This proposed system structure defines a framework based on EOG signal identification that can accommodate innovative and custom-applications systems efficiently and effectively, regardless of the overall architecture's complexity.

OBJECTIVES

There are three main objectives. The first objective is to identify the main EOG control system components. The second objective is to present a study with a disabled individual focusing on quadriplegic disability conditions showing the challenges and opportunities for the directed application of an EOG-based system. The third objective is met by devising a clearly structured method.

LITERATURE REVIEW

Very notable experiences feature control systems based on EOG eye electrophysiological signals. Specific case studies illustrate, on the one hand, the efforts for system design and response for people impaired in the normal motor functions fulfilling their locomotive needs and, on the other hand, the enhancement of the related technology due to eye-movement control system improvements expanding the control on the wheelchair-mounted robot [15]. These experiences shed light on the structure definition process for the proposed control method and EOG use in selected applications. Infrastructures for EOG measurement interpretation and their interface with the powered system that go beyond a narrow description on the related literature are disclosed.

7.2. Case Study 2: Visually Impaired User

In the chapter entitled "Human–Machine Interface: Multiclass Classification by Machine Learning on 1D EOG Signals for the Control of an Omnidirectional Robot", the electrooculogram (EOG) signal is studied and implemented in a human–machine interface (HMI) composed of an omnidirectional mobile robot (OMR) and a control box for a visually impaired user. The control box is only used to acquire the EOG signal, and it has a microcontroller and a human–machine interface extending the EOG signal to a computer through the serial port. From the EOG signal, three 1D channel signals are obtained: one for the vertical displacement of the eyes and two for the horizontal displacement. A fully connected neural network is designed for multiclass classification, giving an accuracy of 69.86% by using the spectrogram of the downsampled 1D EOG signal as input. The EOG signal is generated by the potential difference between the retina and the cornea of the eye. HMI has been implemented using EOG since its acquisition is less invasive and tedious compared to electroencephalography (EEG). EOG signals have been classified with artificial intelligence algorithms, applied to the control of wheelchairs, orthotics, assistance robots, and HMI [2]. For example, the horizontal EOG channel is used to generate control commands for a lower limb orthosis, detected in a three-second sampling window. A search engine is also developed using horizontal and vertical EOG signals, obtaining user impulses by deriving the signal with a prediction algorithm of words. A hybrid brain–computer interface (hBCI) for detection of P300 potentials combines

EOG and EEG, with the EOG signal being used to eliminate noise on EEG acquisition (blinking and eye movement artifacts). An HMI method to improve letter selection on a virtual keyboard is proposed, where an EOG-guided mouse points to interactive buttons. Another system is also developed to classify EOG signals using fuzzy logic to compare the user's parameters with established commands. Fuzzy PD control is applied to the horizontal EOG channel to generate a wheelchair's rotation. A computer-based writing and communication system is designed for people with disabilities, determining the shape of the letters based on the user's parameters that are the movements of the eyeball, using EOG signals. The EOG has also been applied in industrial robotics, working with speed control systems. [16][17][6]

7.3. Case Study 3: ALS Patient

Many studies since the middle of the last century have shown that the electrical potentials across the human eye during its movement can be utilized in medical systems. Patients suffering from Amyotrophic lateral sclerosis (ALS) often lose all voluntary muscle functions, but their nervous system remains intact. Such patients may no longer have full capacity for the intricacies of speech or of the nerves controlling facial muscles. In addition, for all such diseases it can be safer to avoid the wires and needles piercing the body of the patient: in these cases only the electrodes attached to the patient's skin can be applied. An important way to open a window on the external world and to increase the quality of life of these patients is the use of an efficient alternative channel for communication, without any need of both speech and intricate hand movements. For this category of patients suffering from ALS, there is a general concern to develop tools suitable to help or to improve their communications and daily living. EOG is the measure of the corneo-retinal standing potential that is affected by the extrinsic eye muscles. On eye movement, the corneo-retinal voltage changes rise/fall, depending on the direction of the of the movement of the eye: up/down for vertical movements, and left/right for horizontal ones. Due to the portion of the muscles involved, oblique movement gives rise to a combination of these two signals. The corneo-retinal potential can be easily detected in open loop by five or more electrodes, due to the high resistance to the electric current of the eye tissues. The penetration of the exciting electrodes is only few tenths of millimeters, and it is suitable for the electrodes glued to the skin [14]. We have developed a Man Machine Interface (MMI) application for wheelchair driving, fully controlled by EOG. In more detail, EOG biosignals are classified, in real time, by means of an Artificial Neural Network (ANN) for a movable robot used on closed loop. The robotic vehicle moves when the patient's eyes moves too. There are two parameters defined: the speed, which depends from the distance of the car from the eyes, and the rotation arc, which depends from the vertical space orientation of the eyes and the head. The experimental results show good performance. The vehicle moves fast and very precisely after few seconds from the beginning of the system.

8. Challenges and Limitations

Due to that, designed system’s small and user-friendly interface, it can be worn under clothing and can be put on more easily. The designed system consists of a configured laptop computer, a 7 V battery supply, 9 Ag/AgCl electrodes, and a biological amplifier. By recording the horizontal and vertical raw EOG signals with these electrodes connected to the eye, the recorded differential data are transferred to the laptop computer by the digital converter at a 256 sample per second transfer rate. The acquired EOG signals are presented to a series of digital signal processing and binary decision algorithms. By running the algorithms on the acquired EOG signals, two types of binary decisions are made. One of these is to detect when the bedridden user looks at the nurse. The other is to detect and count when the bedridden user makes a large head movement. The EOG signal processing and binary decision applications presented on the laptop computer are observed by experimental study to work in the real time and in an online way. That is, the bioamplifier-acquired EOG signals presented to the decision module are processed immediately and decisions are made. When HEOG and VEOG signals are processed together, the first type of decisions to be detected is found to be successful at an average of

85.94% in the experiments with the data of study subjects. And the second type of decisions to be detected is found to be successful at an average of 73.84%. A current study's primary goal is to present HEOG and VEOG signals to practical and effective signal processing and analysis algorithms and methods in real time and in an online way. A developed EOG processing and analysis paradigm allows 2 different successful decisions to be made on the basis of calculations performed with horizontal and vertical eye movements. Using the designed algorithms, valuable situations, such as the bedridden person's contact with the nurse or large head movements, are detected. Successful decisions allow nurses or staff to perform caregiving or treatment tasks. After the satisfactory results given by the experiments and decision algorithms, a simple on-line interface is developed. This interface can be transformed into a suitable form for bedridden people and worked with so long battery / accumulator-powered at any desired place. With the developed software algorithm, it can be run on any computer platform. The user-friendly interface makes it easy to use. In addition, signal analysis results can be saved to demonstrate state authorities or experts when needed. In conclusion, the developed software interface represents a practical and effective environment based on EOG signals. While this environment can be used for useful purposes of bedridden people, it is also considered a quite important and beneficial application from the perspective of the real-time, online, and remote patient-care. The EOG signal processing and decision paradigm can be used to carry out even more advanced studies and applications.

8.1. Technical Challenges

This section will describe the control and implementation of an HMI system for either an orthosis or an omnidirectional robot using EOG signals through the PD plus fuzzy controller. It is also complemented with the issues in human–machine interaction (HMI) using EOG that have been previously addressed. In [2], a system is designed for classifying EOG signals from five categories using a combination of mechanical and ParaCavities theoretical model, vocalist. The theoretical model is used to calculate the position and time of the VF and the mechanical model determines the performance of the vibrator.

An EOG signal is a bioelectric signal that originates in the eyes. This specific signal is generated by the potential difference between the retina and the cornea of the eye by means of superficial electrodes. The EOG is generated by ocular movements: when the eyes move upward, a potential difference is created between the cornea and the retina that can be detected. Similarly, horizontal movements of the eye laterally to the electrodes generate a voltage difference. Three types of eye movement can be detected: horizontal (left and right), vertical (up and down), and oblique. The EOG signal has received considerable attention in developing systems for HMI for many purposes, including moving orthotics, a synthesis by machine learning (ML) of class HMI between an omnidirectional wheelomial (OMN) robot, and the ocular signal of electric oculorum gram (EOG). The basis of the HMI has been the control of various implements or robots through the acquiring ocular signals relative to them ([7]). HMI has been implemented using EOG since its acquisition is less generation functional invasiveness compared to other methods, such as electroencephalography (EEG). For the control of a lower limb orthosis, such a system is implemented using the EOG eye signal corresponding to the horizontal channel. The HMI-EOG orthosis system is composed of three main elements: a set of electrodes, signal conditioning electronics, and a PD and Fuzzy control strategy. The mechanical orthosis consists of an exoskeleton with a set of active joints. Each joint has a motor driven by a drive belt. If the motor receives PWM signals, which through a gear mechanism, they move the human limb in a cyclic manner.

8.2. User Acceptance Issues

Eye tracking technology can be used to develop systems to improve the quality of life of people with severe physical disabilities. One possible application is the development of an environmental control in which commands to activate and deactivate home appliances are sent by the user's eyes using an electrooculogram-based eye tracker. The user sits in front of a camera, to which the eye tracker is attached. The camera is connected to a computer, which processes the images and calculates the voltage proportions using software. The consequently obtained analogue signals are sent by Bluetooth to a microcontroller that processes them and activates transistors connected to relays, which close the circuit of a specific appliance. Once this system was designed to be used by a person with severe disability, it was observed that a pointer to show the percentage of error in calibration in the graphical user interface would be interesting because, if the user's eyes are completely out of range, it will not be possible to send commands to the system; in this case, it may be necessary to relocate the eye tracker and recalibrate it.

During a calibration process, a sentence is shown to the user in 9 different positions. The first position is always shown in the center of the screen and the others are shown in a 3 × 3 grid. The user should keep the eyes open and at each position follow a square oscillating its gaze, paying attention to each corner of the screen. In special cases, however, after finishing the calibration trial, the eye tracker cannot differentiate which position the user is looking at indicating a percentage of error close to 100%. In this case, a graphical user interface, shown next to the webcam image, displays a pointer that informs the percentage of error. This functionality aims to provide feedback to the participants, indicating that the calibration should be redone and, if that happens, a button will reinitialize the calibration process.

8.3. Ethical Considerations

In this work, a Human–Machine Interface (HMI) of six classes was developed based on Machine Learning for the classification of electromyographic (EOG) signals obtained by Potentiometers Kemp and a wireless system designed by the authors. Classification is from the EOG signal by applying a pre-processing, features extraction, and selection. Since the EOG signal is acquired on a scale of millivolts and with noise, it is necessary to first apply a band-pass filter (0.1–4 Hz) and to eliminate those intervals in which the power of the signal is below 1% in the band of interest to avoid the system from identifying as part of the EOG signal electric noise.

Certainly, on a computer Windows environment having: Intel i5 processor and 6 GB of RAM, Python 3.6 and MATLAB 2017b are required to run the codes developed in this work. The methodology begins by amplifying the EOG signal providing sensors, A, anti-aliasing filtering it, acquiring the EOG and performing a preprocessing that involves eliminating the power line noise and scaling the ADC in bits. After obtaining the filtered EOG, the signal has noise and could not be directly utilized, so clean EOG is acquired. Finally, the EOG is detected by the EOG acquisition system wirelessly designed by the authors, which is connected to a computer with a Windows operating system on which the interface was successfully implemented and tested [2].

9. Future Directions

1. This paper reviewed the developments of previous studies on the EOG-based control system that can be directly used in life applications for those who have disability to use the hands or other body parts, and organized the issues for future study. For people who have difficulty in using both the hands and the voice due to neuromuscular disorders, a control system based on EOG signals is recently under development for controlling electric wheelchairs and manipulator robotic arms by measuring the eyeball movements and processing the acquired EOG signals, which can be applied in various fields. However, the applications of such an EOG-based control system are still limited, and the HEOG may be more valuable as the saccade movement is less influenced by the eyelid movement compared to the VEOGs that reflect the resting position of the eyeball. Therefore, a HEOG-based control system will be proposed with a higher discrimination accuracy to distinguish the saccade direction using a machine-learning-based thresholding scheme that determines four thresholds for five EOG signals commonly, and the acquired EOG signals through the saccade direction classification and the moving average-based hysteresis are converted to the four directional commands including 'right,' 'left,' 'up,' and

'down'.

2. The performance of the proposed HEOG-based control system was compared with that of the static threshold, worked well on previous studies, using simulation results. The average accuracies of the HEOG and the VEOGs are 85.8% and 82.1%, respectively, which have improved by 5.5% and 7.6% compared to those of the VEOG obtained with the static threshold. In addition, the implementation of the EOG-based control system for controlling a mobile robot will be pursued. A hardware system includes eye-wearable EOG electrode, microcontroller, Bluetooth module, motor driver, and DC motors, and a software system for transferring the classified directional commands to the motor driver through wireless transmission, and controlling the DC motors of a mobile robot is designed. The effectiveness of the EOG-based control strategy is verified by realizing a mobile robot.

9.1. Advancements in EOG Technology

The way a human looks at things and processes visual information is fundamental to study attention, memory, language understanding, and more. In HCI and assistive technologies, eye tracking has grown steadily because it provides rich information about the user's intention. To fabricate eye-tracking systems, fabric-based electrodes were integrated into the textile surface. The fabric electrodes were designed such that they measure from the proximity of the eye's corners, where EOG signals are significantly stronger [18]. The fabric cable delivers the EOG signal to the processing unit, which amplifies the biopotential signal, filters out high-frequency noise, and transmits it to the computer or smartphone via Bluetooth.

The visual world is composed of multiple objects generating information that is processed in the human brain. Humans control most of their needs through visual information processing, while comparing data received from different sensory systems, and predominantly that data which is visual. Based on the patterns, it accumulates information. Among others, it is a mechanism for processing information in an open platform. The arrival and assessment of an inclusive order process depends on the different platforms and a high degree of network interconnection. The architecture's modulation is that it involves extensive information sharing amongst worker ecosystems [1]. Attention ripple networks that could imitate human behavior led to vast advances in architectural comprehension. A major benefit of EOG technology is ambitious networking. EOG connects to the margins of such extensive neural field disturbances, allowing inducting and egressing global information signals that did not operate interfaces for biometric brain-communication to date. Similar to the current understanding of PID and traveling wave, the POM task cannot be switched off.

9.2. Potential for AI Integration

Introduction to the theme, how it has been addressed and the information that will be provided. Eye tracking is a niche technology that involves various different methods but each is designed to track the movement of the eye. In its most basic form subtle changes in the neurology of the eye movements (saccades I made by looking at different sides, vertical or diagonal) and fixings on certain points [2]. A simple example would be when a person is reading move of their eyes a tracked line to the right by a few degrees (saccade) and then move back in (fixation) and repeating this process. As the oculomotor system breaks down, eyes fatigue can become more common with more fixations, slower saccades and jerky movements (nystagmus).

9.1. Basic Concept of the Control System Human-machine interfaces (HMI) have been of great interest in recent years due to their wide variety of applications from automation to robotics, where it is used to control devices or systems [19]. Since eye movements are one of the few remaining movements in those with tetraplegia, it has enormous potential when applied to HMIs. Based on the acquisition of the eye movement electrooculography (EOG) signal, it is possible to perform tasks such as the control of wheelchairs, orthotics, or applications dedicated to assisting robotics with severely disabled people; For any application, a short training period is required depending on the functionality provided by the system (generating a movement for a movement, controlling the end-effector, the speed or the direction defined by a point of interest).

9.3. Expanding User Base

Today the population of people with physical, mental, visual or auditory disabilities continues to rise, derived from accidents, chronic diseases, neurodegenerative diseases and congenital malformations. In response, it is necessary to have a standardized guide to carry out the design and development of electronic, robotic, biomechatronics and bio-mechanics systems that use electrooculographic (EOG) signals generated by the left, up, right and down eye movements. This will be useful for certain procedures, therapeutic interventions, rehabilitation and as a research tool, promoting the improvement of the quality of life. Starting from the monitoring of the relevant state variables and the design of the appropriate control strategy, and after the implementation of the methodology mentioned here, it is expected the development of devices for people with disabilities, remote surveillance with EOG, mobile robotics and data acquisition systems. There are two types of eye movements, saccades and fixations. A saccade is a rapid movement of the eye between two points and a fixation is a pause between saccades. From the study of eye movements, the electrooculogram or electrooculographic (EOG) signal can be obtained. To date, many researchers have made EOG an effective tool simple, inexpensive, portable, non-invasive, practical and accurate to implement a wide variety of mechanisms for a wide variety of potential persons with and without disabilities. This new approach proposes the multi. The control of the mechanics of the human eye using the EOG signal is intended. The system consists of a cart on wheels driven by a PID controller where the gross movement is governed by the left-right eye according to the gaze direction. The mobile head support system consists of a mechanical structure that guides vertical movements up and down of the head regarding the pulse signal. The monitoring is performed by the real time acquisition of the EOG signal where the relevant state variables are: LE, RE, UP and Down. Knowing the rise time (TR) of the left eye other transfer function to design the discrete proportional band (PbDis) and multiplier factor (MF). In order to supervise the effectiveness of the developed mechanism, control systems were implement to the neck, head, wrist and cervical area, and verified the tolerance bands monitoring the negations (O) and affirmations (X) of preset patterns horizontal and vertical. [2] [20][6][21]

10. Conclusion

The new HCI device presented here for the classification of EOG signals could allow the user to write a five-letter word on average in 32 sec. A five-lettered word can be written by 26 seconds by visually normal healthy individuals, and by 220 seconds by the ALS patients based on hand movement processing of EEG intentional motor actions. The new HCI device could offer the same performance with the hand movement. Therefore, HCI represents an efficient pathway for patients toward a significant amelioration in the communicative and environmental vigilance aspects. However, widespread applications of EEG intentional motor actions for HCI might be elusive, hence the interest in the performance evaluation of the proposed new device online, studied over five days in five different sessions.

In study isolated left, right, up, down eye movements and blink EOG s were processed in real time by a dynamical threshold algorithm and the usability of the device is proven in real subjects. EOG signals are thinks to be a good alternative for communicating. A computer mouse is interferes based on EOG signals and a number of off-line processing steps. The results show a correct recognition of EOG signals in about 80% of the attempts. EOG is tested on both ERP s and spontaneous eye artifacts such as blinks. This puts the groundwork for additional off-line and real time experiments with several advantages.

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