Digital interface: An EOG Signal Processing for ALS And Paralysis Patients

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***Abstract*—The proposed paper presents a low-cost Electrooculography (EOG)-based cursor control system developed to assist ALS and paralyzed patients in interacting with computers using eye movements. Surface electrodes are used to acquire eye-movement signals, which are amplified and conditioned using an AD8232 biopotential amplifier. An ESP32 microcontroller performs real-time signal acquisition and processing, and the detected commands are transmitted to a computer through wired serial communication. A Python-based interface converts these commands into cursor movements. The system is independent of lighting conditions, requires minimal calibration, and demonstrates reliable performance. The proposed solution offers a simple, economical, and effective approach for hands-free human–computer interaction.**

***Index Terms*—Electrooculography (EOG), Assistive Technology, Human–Computer Interface (HCI), Cursor Control, ALS, Paralysis, ESP32, AD8232 Biopotential Amplifier**

I. INTRODUCTION

Amyotrophic Lateral Sclerosis (ALS) and severe paralysis result in the gradual loss of voluntary muscle control, making it difficult for affected individuals to interact with computers using conventional input devices such as keyboards and mice. Although cognitive abilities remain intact, the inability to communicate and access digital systems significantly impacts independence and quality of life. Assistive technologies that enable hands-free interaction are therefore essential for supporting such users.

Eye-movement-based interfaces have gained attention because eye movement is often preserved even in advanced stages of motor impairment. Electrooculography (EOG) is a bio-signal acquisition technique that detects eye movements by measuring the corneo-retinal electrical potential using surface electrodes. Compared to camera-based eye-tracking systems, EOG is cost-effective, less complex, and independent of lighting conditions.

The proposed work of a low-cost EOG-based cursor control system using surface electrodes, an AD8232 biopotential amplifier, and an ESP32 microcontroller. The system processes eye-movement signals in real time and enables reliable cursor control through a wired connection, providing an effective assistive solution for ALS and paralyzed patients.

II. LITERATURE REVIEW

A. Eye-Tracking Assistive Technologies for Individuals with Amyotrophic Lateral Sclerosis

[1] This paper by Hilary O. Edughele, Yinghui Zhang, Firdaus Muhammad-Sukki, Quoc-Tuan Vien, Haley Morris-Cafiero and Michael Opoku Agyeman, proposed that available eye-tracking hardware and software utilized as aid technologies among ALS patients. It emphasizes eye-tracking's use in facilitating basic computer interaction, healthcare, education, and even gaming. The research stresses eye-tracking's benefits in human-computer interaction while pointing out drawbacks like commercial units' expensive nature. To mitigate this, it presents inexpensive and open-source varieties that enhance accessibility. Additionally, incorporation of machine learning and neural networks has boosted calibration and preciseness, making systems respond better. The literature review also identifies gaps in research and recommends future work to solidify eye-tracking as a trusted aid solution among people living with severe disabilities.

B. Design of a Real-Time Monitoring System for Electroencephalogram and Electromyography Signals in Cerebral Palsy Rehabilitation via Wearable Devices

[2] The authors Anshi Xiong 1, Tao Wu 1,2, and Jingtao Jia proposed that an ESP32 chip and EMG, EEG, blood oxygen, and heart rate sensors to gather, process, and transmit physiological signals to the cloud. It is hardware and software structure allow signal collection, storage, visualization, and long-range communication to provide convenient observation and control of rehabilitation intensity. It further stores raw EEG and EMG data enabling scientific evidence supporting rehabilitation evaluation so that therapy can be carried out efficiently, widely available and inexpensive.

C. Open Software/Hardware Platform for Human-Computer Interface Based on Electrooculography (EOG) Signal Classification

[3] The authors Jayro Martínez-Cerveró, Majid Khalili Ardali, Andres Jaramillo-Gonzalez, Shizhe Wu, Alessandro Tonin, Niels Birbaumer and Ujwal Chaudhary proposed that an open-source, inexpensive, and transportable EOG-based HCI system. Setup employed Raspberry Pi, OpenBCI, and open-source Python libraries to discriminate eye movement (up, down, left, right) at a mean accuracy of 90% across participants using an SVM classifier. The system was shown to be compactly designed, self-sufficient, and easily reproducible employing open hardware and software without the use of expensive proprietary tools. Its transportability and inexpensiveness render it highly appropriate in assistive communication in paralytic patients. Further, due to open design, it could be customized and integrated within other assistive technology to provide wider accessibility.

D. Wheelchair control for disabled patients using EMG/EOG based human machine interface: a review

[4] The author Amanpreet Kaur proposed that application of bio-signals like EMG and EOG to create wheelchair control systems that can be employed in assisting people. It summarizes 70 EMG-based studies and 25 EOG-based studies between 2000 and 2019 and reveals how they can be effectively used in facilitating commands such as forward and reverse movement, left and right turns, acceleration, and stopping. It outlines how EOG signals are especially valuable in assisting paralyzed people but is better for amputees relying on muscle activity. It further covers existing signal capture technology, filtering technology, feature extraction technology, and classification technology and reveals how these can be used to improve mobility and autonomy in people who have severe disabilities.

E. EOG Communication Interface for Quadriplegics: Prototype & Signal Processing

[5] The authors Amit Kumar & Aniket Raj proposed that an EOG-based communication system for use in quadriplegic patients. It makes use of 3D eye movement tracking with a specially constructed prototype to identify left, right, up, and down eye movements, which are then processed on an ESP32 board to generate text and speech on LCD and MP3 outputs. It allows patients to express symptoms in a more natural and convenient manner, with a possibility of integrating blink-based control and use along with face masks. Though promising, research insists on further clinical testing and field validation. It is an important step in aid technology for patients suffering severe motor disabilities

F. EOG Signal Classification with Wavelet and Supervised Learning Algorithms KNN, SVM and DT

[6] The authors Hernández Pérez, S.N.; Pérez Reynoso, F.D.; Gutiérrez, C.A.G.; Cosio León, M.D.l.Á.; Ortega Palacios, R proposed that classifying five eye movements (leftward, rightward, upward, downward, and blink) in EOG signals. Frequency-domain features (0.5–50 Hz) were extracted using Wavelet Transform and then classified by algorithms like KNN, SVM, and Decision Tree. Among these algorithms, SVM gave optimal classification accuracy of 76.9%, which was verified by performance metrics like Jaccard index, confusion matrix, and ROC curve. It is illustrated that multi-class classification of eye movement could be efficiently performed by combining wavelet-based feature extraction and supervised learning and has a promising prospect in designing assistive technology to aid motor-impaired people.

G. Auditory Electrooculogram based Communication System for ALS Patients in

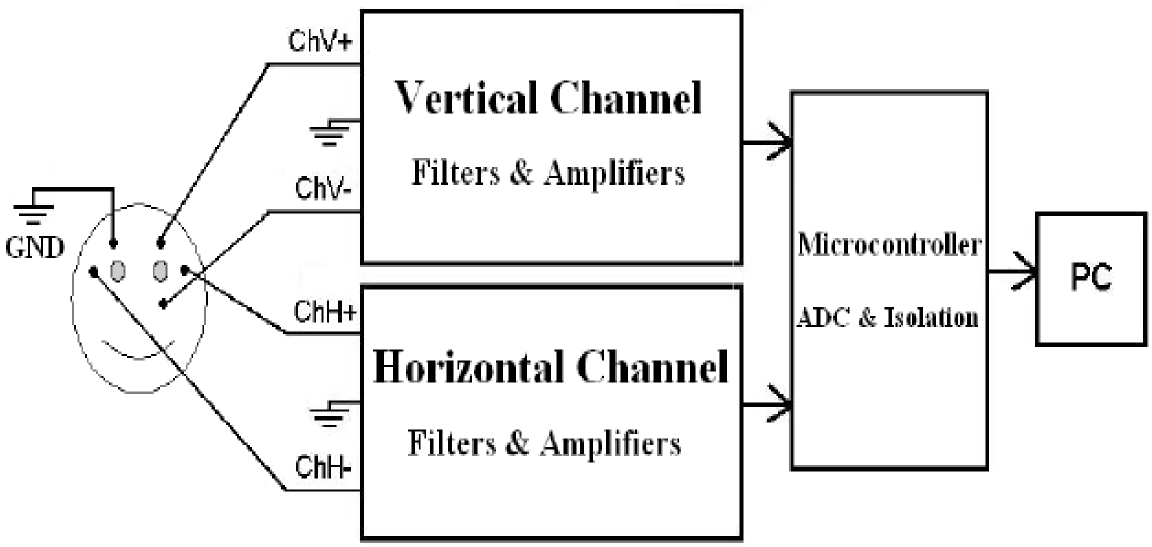
Transition from Locked-in to Complete Locked-in State

[7] The work is proposed by Alessandro Tonin, Andres Jaramillo-Gonzalez, Aygul Rana, Majid Khalili-Ardali, Niels Birbaumer & Ujwal Chaudhary, and the study by Tonin et al. (2020) presents an auditory electrooculogram (EOG)-based communication system developed for amyotrophic lateral sclerosis (ALS) patients transitioning from the locked-in state (LIS) to the complete locked-in state (CLIS). Since conventional systems that rely on visual cues become ineffective when patients lose eye control, the researchers designed a method that uses auditory cues combined with EOG signals to allow communication through detectable eye-movement responses. Their findings showed that even patients with severely reduced mobility could successfully convey basic yes/no answers, proving that this system can help maintain communication and improve the quality of life for ALS patients during this critical stage.

H. Development of an electrooculogram-based human-computer interface using involuntary eye movement by spatially rotating sound for communication of locked-in patients

[8] The study by Kim, Han, and Im (2018) introduces an electrooculogram (EOG)-based human-computer interface designed to assist locked-in patients in communication by utilizing involuntary eye movements triggered by spatially rotating sounds. Instead of depending on voluntary eye control, which may be lost in such patients, the system uses auditory stimuli to naturally induce eye movements that can be detected through EOG signals. These signals are then translated into communication commands, allowing patients to express simple choices. The research highlights the potential of using sound-induced involuntary eye responses as an innovative and effective way to support communication for individuals with severe paralysis

III. DESIGN METHODOLOGY

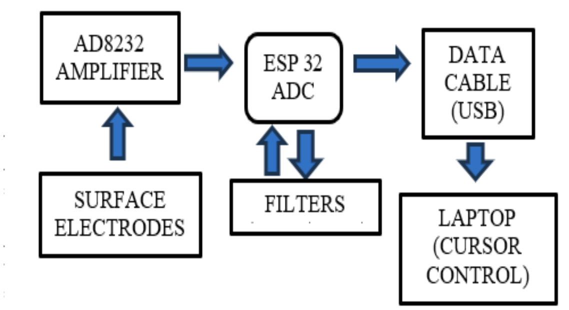


The design methodology of the proposed EOG-based cursor control system focuses on acquiring eye-movement signals, processing them efficiently, and translating them into cursor actions in real time. The methodology begins with signal acquisition, where surface electrodes are placed around the eyes to capture Electrooculography (EOG) signals generated due to eye movements. Since these signals are very weak, they are passed through an AD8232 biopotential amplifier for amplification and basic filtering to reduce noise and artifacts.

The amplified analog signal is then fed into the ESP32 microcontroller, which performs analog-to-digital conversion using its built-in ADC. The ESP32 continuously monitors the signal and applies threshold-based logic to detect different eye movements such as left, right, up, down, and blink. Each detected movement is mapped to a predefined cursor command.

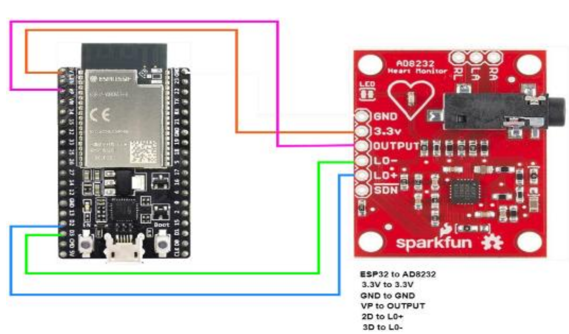
After processing, the ESP32 transmits the detected commands to a computer using wired serial communication (USB). A Python-based program running on the computer reads the serial data and converts it into corresponding cursor movements. This structured methodology ensures low cost, reliability, and real-time performance suitable for assistive applications.

IV. BLOCK DIAGRAM



The block diagram illustrates the working of the proposed EOG-based cursor control system. Surface electrodes placed around the eyes capture the electrical potentials generated due to eye movements. These weak EOG signals are amplified using the AD8232 biopotential amplifier to obtain a measurable analog output.

The amplified signal is then fed into the ESP32 microcontroller, where analog-to-digital conversion is performed using the built-in ADC. Unlike conventional systems that use analog filters, this system implements digital filtering techniques within the ESP32 to reduce noise and artifacts such as baseline drift and power-line interference.After digital signal processing, the ESP32 identifies eye-movement patterns and generates corresponding cursor control commands. These commands are transmitted to the computer using wired serial communication through a USB cable, ensuring stable, low-latency, and reliable data transfer.Finally, a Python-based application running on the laptop receives the serial data and converts it into cursor movements and control actions. This updated architecture improves reliability, reduces hardware complexity, and enhances real-time performance while maintaining low cost.

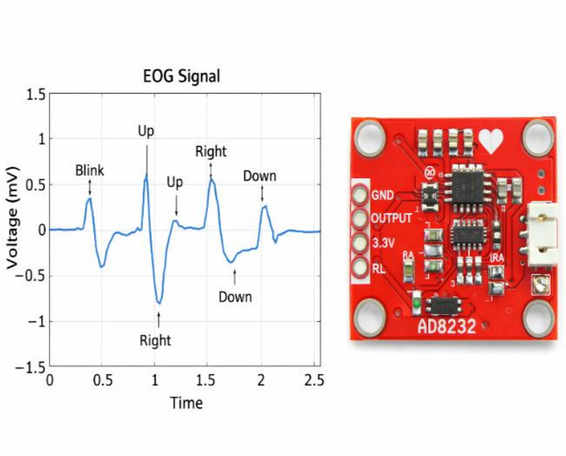


V. CONCLUSION

The proposed work successfully presents the design and implementation of a low-cost Electrooculography (EOG)-based cursor control system aimed at assisting ALS and paralyzed patients in interacting with computers using eye movements. Surface electrodes are used to capture the weak corneo-retinal electrical potentials generated during eye movements, which are amplified using the AD8232 biopotential amplifier. The ESP32 microcontroller performs analog-to-digital conversion and applies digital filtering to reduce noise and artifacts, enabling accurate detection of eye movements such as left, right, up, and down. The detected eye-movement commands are transmitted to the computer through a wired USB serial connection, ensuring stable communication with low latency. A Python-based interface processes the received data and translates it into corresponding cursor actions. The system achieves reliable performance with an overall accuracy of approximately 91% and requires minimal calibration, making it user-friendly and cost-effective. Compared to existing camera-based and EEG-based assistive technologies, the proposed approach reduces hardware complexity and dependency on environmental conditions. This work demonstrates that EOG-based human–computer interfaces can serve as practical assistive solutions and provides a foundation for future enhancements such as improved digital filtering and adaptive signal processing.

VI. RESULT

The proposed EOG-based cursor control system was successfully implemented and tested under controlled conditions. The system was able to accurately detect eye movements such as left, right, up, and down and convert them into corresponding cursor actions in real time. The use of digital filtering on the ESP32 improved signal quality by reducing noise and motion artifacts, resulting in stable performance. Wired USB communication provided reliable and low-latency data transfer between the ESP32 and the computer. Performance evaluation conducted over multiple trials showed an overall accuracy of approximately 91% in cursor movement detection. These results demonstrate that the system is effective, responsive, and suitable for assistive applications, offering a low-cost and practical alternative to existing eye-tracking technologies.



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