Gaze Connect Communication System for Locked-In Syndrome Patients

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Abstract - Locked-In Syndrome (LIS) is a rare neurological condition where individuals lose voluntary muscle control but remain fully conscious and mentally aware, making communication extremely difficult. To assist such patients, the Gaze Connect Communication System is designed to enable interaction using eye blinks detected through a webcam. The system employs OpenCV and dlib for real-time eye blink detection, while a PyQt5 interface displays a virtual keyboard and activity board for easy communication. Once a selection is made through blinking, the Google Text-toSpeech (gTTS) module converts it into audible speech. This system provides an efficient, affordable, and user-friendly solution to help LIS patients express their needs and emotions independently.

Key Words: Locked-in syndrome, eye blink detection, gaze-based communication, OpenCV, dlib, PyQt5, virtual keyboard, assistive technology, gTTS

1.INTRODUCTION

Locked-In Syndrome (LIS) is a rare and severe neurological disorder in which individuals experience near-total paralysis of all voluntary muscles while remaining fully conscious and mentally alert. Unlike coma or vegetative states, patients with LIS retain complete awareness and cognitive function but are unable to move or speak due to the disconnection between the brain and the body's motor pathways. Communication becomes extremely limited—typically restricted to eye movements, such as vertical gaze and blinking—which serve as the only means through which patients can interact with the outside world. This condition often results from damage to the ventral pons area of the brainstem, commonly caused by stroke, traumatic brain injury, tumors, infections, or neurodegenerative diseases such as amyotrophic lateral sclerosis (ALS). Although their mental abilities remain intact, LIS patients are trapped within their own bodies, unable to perform even the simplest physical actions. Because these individuals cannot communicate on their own, they often experience emotional difficulties such as fear, frustration, and isolation, which also affects their caregivers. Since the condition is rare and not widely recognized, diagnosis and proper communication support are often delayed, reducing the quality of care and the patient's well-being. Creating a reliable method for expressing needs and feelings is therefore essential. To address this, the Gaze Connect Communication System is introduced, offering an easy, affordable, and noninvasive way for people with Locked-In Syndrome to communicate using only eye gaze and blinks.

This approach helps bridge the communication gap that limits their daily interactions and provides a supportive platform that enhances their independence and confidence.

The system captures real-time eye movements and detects gaze direction and blinks using OpenCV and dlib libraries. A graphical interface built with PyQt5 allows users to select letters, words, or commands by simply moving their eyes. Once the desired text is selected, it is converted into speech using Google Text-to-Speech (gTTS) , enabling clear vocal communication. The Gaze Connect Communication System aims to provide an accessible, reliable, and easy-to-use communication platform for individuals with severe motor impairments. By enabling interaction through eye movements and blinks, it helps restore independence, improve social connection, and significantly enhance the overall quality of life for Locked-In Syndrome patients.

2.METHODOLGY

2.1 System Architecture

The Gaze Connect Communication System is designed to support individuals with Locked-In Syndrome (LIS) by enabling communication using only eye gaze and blink signals. The architecture follows a three-stage pipeline consisting of Input, Processing, and Output modules. In the Input Module, a standard webcam captures continuous real-time video of the user's face, focusing on eye and eyelid movements, which are processed using OpenCV for image analysis and dlib for 68-point facial landmark detection. These landmarks determine eyelid distance, eye width, and pupil position for blink and gaze estimation. Eye blinks are detected using the Eye Aspect Ratio (EAR) method, where short blinks are interpreted as selection or confirmation commands, while long blinks are used for cancellation actions. In the Processing Module, gaze tracking determines left, center, or right eye movement to navigate the PyQt5-based virtual keyboard and activity panel. The highlighted interface option changes according to gaze direction, and selections are made through blinks. The system enables the user to type letters, form words, or choose predefined actions such as "Help," "Water," "Yes/No," or "Emergency." Finally, in the Output Module, the selected text is processed through the Google Text-to-Speech (gTTS) engine, generating a corresponding audio message that is played through the system's speakers. The complete workflow—from video capture, blink detection, and gaze-based selection to speech output—allows LIS patients to communicate effectively and independently using only eye movements..

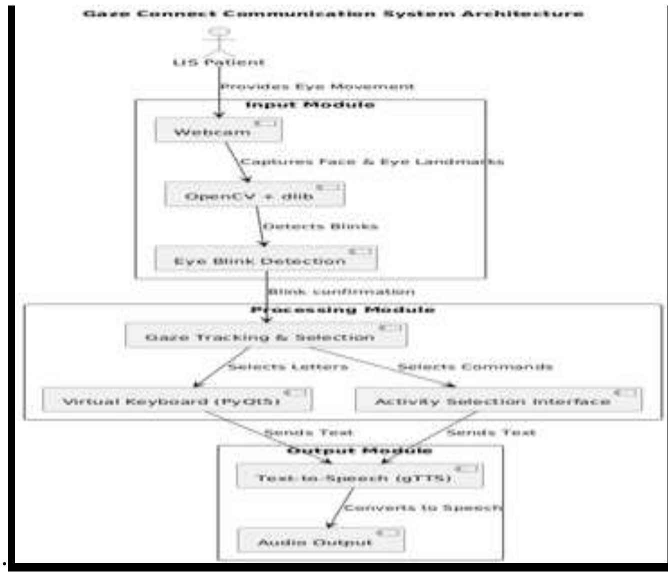

Fig. 1 System Architecture

2.2 Software Implementation

This chapter explains the development and the way the Gaze Connect Communication System was built and organized using the modular structure discussed earlier. The system was implemented to help Locked-In Syndrome (LIS) patients communicate through eye blinks and gaze interactions. Python was chosen as the main programming language due to its simplicity and strong support for computer vision. Libraries such as OpenCV, dlib, PyQt5, and gTTS were used to integrate video capture, blink detection, gaze tracking, interface design, and speech output. Modular programming ensured easy testing and scalability throughout the development process. The final system successfully turns eye actions into clear communication within a simple and easy-to-use interface.

Fig. 2 Software Implementation

2.3 Working Module

The system detects the user's eyes in the webcam feed and highlights them with green bounding boxes. Once detection is stable, the visual keyboard becomes active and displays selectable icons. The user focuses on an icon, such as the water symbol, which gets highlighted. A deliberate blink is then recognized as a selection command, allowing the user to choose the option without any physical movement. This output demonstrates the core eye-gaze and blink-based interaction process.

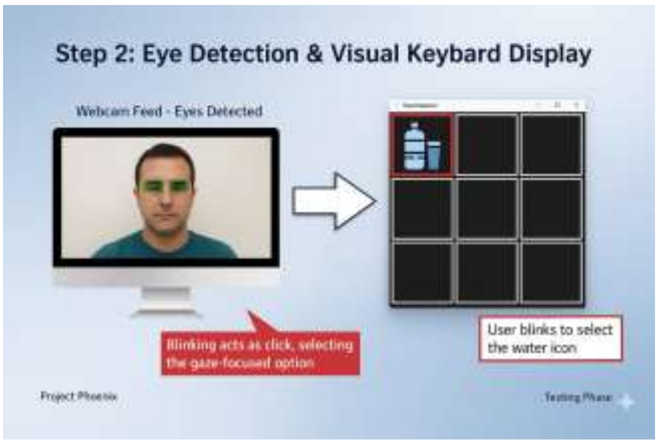

Fig. 3 Working Module

2.4 Monitoring System

Fig. 4 Monitoring System

The monitoring system displays the live webcam feed and continuously detects the user's face and eyes. When detection is accurate, green boxes appear around the eyes to confirm proper tracking. If the system cannot detect the eyes, a warning message is shown on the screen. The virtual keyboard highlights icons based on where the user is looking. When the user focuses on an option, it becomes highlighted in real time. A blink is then detected and treated as a selection command. The chosen item appears on the interface as confirmation. This output shows that the system reliably tracks gaze, detects blinks, and supports smooth user interaction

2.5 Key Components

2.5. 1. Sensors and Hardware

The system requires only a standard webcam to capture real-time eye movements, making it simple and low-cost. A computer processes these video frames and runs all algorithms without external devices. Speakers are used to deliver audio output through text-to-speech. Overall, the hardware setup is minimal and fully non-intrusive.

2.5.2 Software and Algorithms

The system is built using Python with OpenCV for image processing, dlib for facial landmark detection, and PyQt5 for the user interface. Algorithms such as Eye Aspect Ratio (EAR) and gaze estimation interpret blinks and eye direction. gTTS converts selected text into speech for communication. Together, these components create a smooth and functional interaction system.

2.5.3 Data Processing

Video frames from the webcam are preprocessed to detect facial landmarks and extract the eye region. EAR values determine blink actions, while pupil position identifies gaze direction. These inputs are mapped to the virtual keyboard for selecting letters or commands. The final text is processed and converted into speech output.

2.6 Advantages

The system is low-cost, requiring no physical sensors or specialized hardware. It is non-intrusive, making it comfortable for long-term use by Locked-In Syndrome patients. Real-time detection ensures quick and responsive communication. Its simplicity and affordability make it practical for home and clinical environments.

CONCLUSIONS

The Gaze Connect Communication System was developed to assist individuals with Locked-In Syndrome (LIS) in communicating effectively using eye blinks. By integrating OpenCV and dlib for eye detection, PyQt5 for a simple graphical interface, and gTTS for speech conversion, the system provides a smooth and user-friendly experience. It operates in real time using a standard webcam, without requiring any external hardware, making it both affordable and accessible. This project successfully demonstrates how computer vision and assistive technology can be combined to restore communication, independence, and confidence among patients with severe motor disabilities.

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