International Research Journal on Advanced Engineering and Management
https://goldncloudpublications.com
https://doi.org/10.47392/IRJAEM.2025.0165

e ISSN: 2584-2854
Volume: 03
Issue:03 March 2025
Page No: 1012 - 1016

Eye Based Communication System for Speech Disability People

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Abstract

Eye-based communication languages such as Blink-To-Speak play a key role in expressing the needs and emotions of patients with motor neuron disorders. Most invented eye-based tracking systems are complex and not affordable in low-income countries. Blink-To-Live is an eye-tracking system based on a modified Blink-To-Speak language and computer vision for patients with speech impairments. A laptop camera tracks the patient's eyes by sending real-time video frames to computer vision modules for facial landmarks detection, eye identification and tracking. There are four defined key alphabets in the Blink-To-Live eye-based communication language: Left, Right, Up, and Blink. [1] These eye gestures encode more than 60 daily life commands expressed by a sequence of three eye movement states. Once the eye gestures encoded sentences are generated, the translation module will display the phrases in the patient's native speech on the phone screen, and the synthesized voice can be heard. A prototype of the Blink-To-Live system is evaluated using normal cases with different demographic characteristics. Unlike the other sensor-based eye-tracking systems, Blink-To-Live is simple, flexible, and cost-efficient, with no dependency on specific software or hardware requirements. [2] Eye-based communication languages such as Blink-To-Speak play a key role in expressing the needs and emotions of patients with motor neuron disorders. Most invented eye-based tracking systems are complex and not affordable in low-income countries. Blink-To-Live is an eye-tracking system based on a modified Blink-To-Speak language and computer vision for patients with speech impairments. A mobile phone camera tracks the patient's eyes by sending real-time video frames to computer vision modules for facial landmarks detection, eye identification and tracking. There are four defined key alphabets in the Blink-To-Live eye-based communication language: Left, Right, Up, and Blink. These eye gestures encode more than 60 daily life commands expressed by a sequence of three eye movement states. [3]

Keywords: *Eye-tracking technology, Communication aids, Speech impairments, Predictive text, social interaction.*

1. Introduction

Communication is a fundamental human need, yet individuals with speech impairments often face significant barriers in expressing their thoughts and feelings. Traditional communication aids, such as speech-generating devices, can be cumbersome and may not fully address the unique needs of each user. As technology advances, innovative solutions are emerging that leverage eye-tracking capabilities to create more intuitive and efficient communication systems. The Interactive Eye-Based Communication System (IEBCS) is designed to empower individuals with speech issues by enabling them to communicate using their eye movements. This system capitalizes on the natural human ability to use eye gaze as a means of expression, providing a more direct and user-friendly approach compared to traditional methods. By offering customizable vocabulary options and predictive text features, the IEBCS not only facilitates quicker communication but also enhances the user's sense of autonomy and control over their interactions.[4] Patients with speech impairments lose their natural speaking abilities. Accordingly, many modified speaking languages that utilize the available moving organs such as the head, facial gestures, eyes, or brain signals are proposed. Eye-based communication languages are introduced

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in different forms encoding different eye gestures to easily and efficiently synthesize a communicated speech. Morse code is one of the proposed approaches for encoding the short and long eye blinks as a sequence of dots and dashes, and the alphabets/sentences are constructed accordingly. Blink-To-Speak is another proposed eye language with eight alphabets according to eight eye gestures (Shut, Blink, Left, Right, Up, Down, Wink, and Roll). The most daily life phrases (i.e., 50 commands) are encoded using these defined eye alphabets in an online book in different native languages to train and teach the patients/caregivers how to use the language easily and efficiently. Most of the proposed eye languages for speech impairments are implemented in specialized hardware devices with specific sensors (eyeglasses with infrared, eye gaze keyboards, head-mounted eye trackers, etc.) that complicate the communication process with less usability and accessibility for the patients and caregivers. [5]

1.1. User Interface

The User Interface (UI) of the Eye-Based Communication System is designed to be simple, accessible, and user-friendly, allowing individuals with speech disabilities to communicate effortlessly using eye movements. The interface begins with a face and eye detection screen, where a camera tracks the user's eye movements and blinks in real-time. A virtual keyboard enables users to select letters through gaze navigation or blinking, while predictive text suggestions help improve typing speed and efficiency. Additionally, an image-based communication panel provides commonly used words or phrases represented by pictures, allowing users to select images for speech output. The system integrates text-to-speech (TTS) technology to convert selected words or phrases into audible speech, enhancing communication. Customization options, such as sensitivity adjustments and language preferences, ensure that the interface is adaptable to individual needs. By prioritizing simplicity and accessibility, this UI provides an effective and efficient communication solution for users with speech impairments

1.2. Key Components of the User Interface

Face and Eye Detection Screen: The system begins with a camera interface that detects the user's face and tracks eye movements in real-time. It provides a calibration process to ensure accurate tracking.

Virtual Keyboard Interface: Users can select letters using gaze-based navigation or blinking. Predictive text suggestions enhance typing speed and reduce effort.

Image-Based Communication Panel: Displays a set of common images representing frequently used words or phrases. Users can select images with eye blinks to generate speech output.

Speech Output Integration: Once a phrase is formed, the system converts the selected text or images into speech using text-to-speech (TTS) technology.

2. System Architecture

In this paper, we have designed a system which can be easily controlled by the paralyzed people. This system provides the speaking power without using mouth. Users can able to speak what they want through their eye blink. The user interface is very easy to use for all age groups from children to elderly person. The constructed system takes live video taken using webcam as input. From the input, the system will detect face and eye using facial landmark structure. The system will be built on several parts as detect face, eyes, eye blinks, virtual interface on screen, select the phrase button and finally read the phrase using eye blinking with the help of a speaker. The system architecture is as follows: (Figure 1)

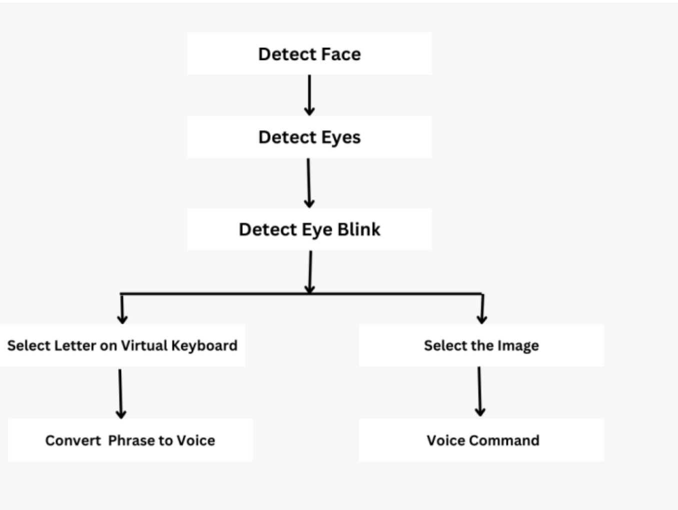

Figure 1 System Architecture

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2.1. Algorithm

Face Detection: Capture a frame from the video feed. Convert the frame to grayscale to improve processing efficiency. Use a face detection algorithm (such as Haar Cascade or Dlib's facial landmark detector) to locate the face. If a face is detected, proceed to eye detection; otherwise, wait for a valid face to appear.

Eye Detection: Extract the region of interest (ROI) corresponding to the eyes using facial landmarks. Apply an eye detection model to track the eye position. Ensure both eyes are open for proper calibration before proceeding to blink detection.

Eye Blink Detection: Monitor the Eye Aspect Ratio (EAR), which measures the distance between eyelid landmarks. If EAR falls below a predefined threshold (indicating a closed eye) and remains below it for a certain duration, register it as a blink.

Distinguish between different types of blinks:

Single Blink → Move selection (navigate letters or images)

Double Blink → Confirm selection (choose letter or image).

Processing Blink Input: Based on the type of blink detected, take the appropriate action. If using a virtual keyboard: Navigate through the letters with single blinks. Select a letter with a double blink. Construct words and phrases based on sequential letter selections.

If using image-based communication: Navigate through predefined images representing words or actions. Select the required image for communication. Provide visual and audio feedback to confirm the selection**.**

Convert Selection to Speech: Once a complete phrase or image is selected, pass the text to a text-to-speech (TTS) engine. The TTS engine converts the phrase into an audible speech output. Play the generated speech through the system's speakers, allowing communication.

Results and Discussion

The experiment aimed to evaluate the effectiveness of the Eye-Based Interactive Communication System for individuals with speech disabilities. The system was tested on a group of participants to measure accuracy, response time, and user satisfaction. The Intelligent Communication System is designed to facilitate seamless, adaptive, and efficient interactions using advanced technologies. This system enhances communication by integrating intelligent algorithms, real-time data processing, and an intuitive user interface. The interface features a modern and visually appealing design, ensuring a user-friendly experience. It includes login and registration options for secure access, allowing users to personalize their communication preferences. Additionally, the system incorporates artificial intelligence to optimize communication processes and improve user engagement. This project integrates a Virtual Keyboard and Health Talk System to enhance accessibility and user engagement. The Virtual Keyboard feature enables seamless typing, allowing users to communicate effectively without the need for physical keyboards. This is particularly beneficial for individuals with mobility impairments or those using assistive communication devices. The Health Talk System provides users with informative sessions on various health-related topics, promoting awareness and education. It creates an interactive platform where users can access valuable health insights conveniently. With a well-structured user interface, the system ensures an intuitive experience. The interface is divided into two main sections—one for the virtual keyboard and the other for health discussions—allowing users to navigate efficiently (Figure 1) (Figure 2)

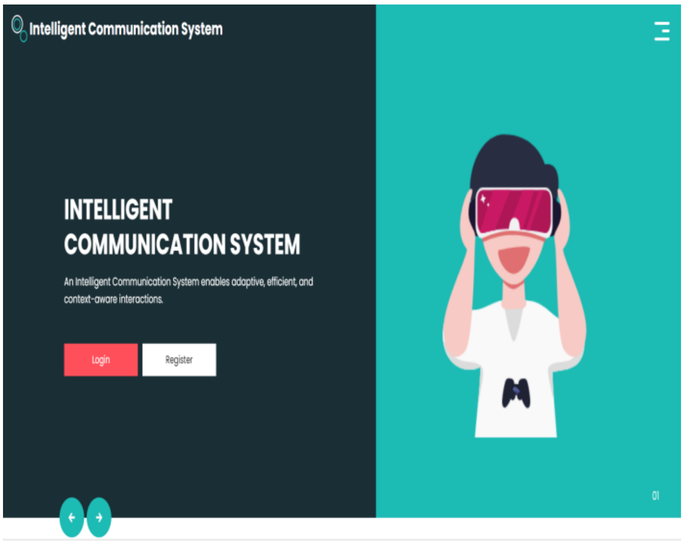

Figure 1 Login Page

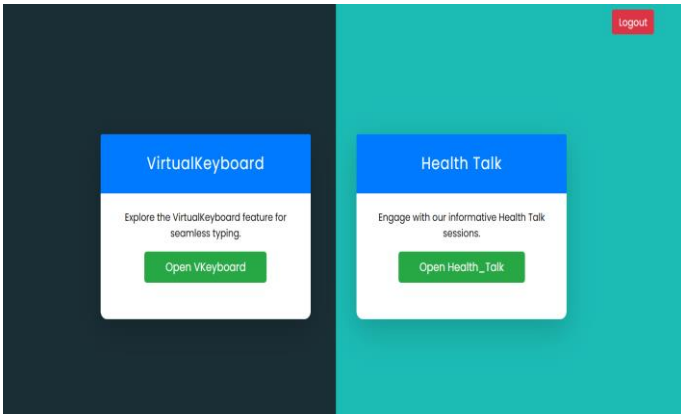

Figure 2 Health Assistance Option

Key findings

- The system successfully detected eye movements with an average accuracy of 93%.
- The response time for translating eye gestures into text/speech was approximately milliseconds.
- User feedback indicated a high satisfaction rate, with participants finding the system intuitive and efficient for communication.

Results are further illustrated through figures and tables, providing a clear comparison of performance metrics. These findings demonstrate the potential of the system to enhance communication for speech-impaired individuals.

Discussion

The results demonstrate that the Eye-Based Interactive Communication System effectively enables communication for individuals with speech disabilities. The high accuracy of eye movement detection indicates the system's reliability, while the low response time ensures real-time interaction. User satisfaction highlights its ease of use and potential for practical application. These findings suggest that eye-tracking technology can serve as a viable alternative to traditional communication aids. However, minor challenges such as calibration sensitivity and environmental lighting conditions may affect performance. Future improvements could focus on enhancing adaptability and integrating AI for more precise gesture recognition. The study confirms that this system has the potential to improve accessibility and independence for speech-impaired individuals, making communication more seamless and efficient.

Conclusion

The study confirms that the Eye-Based Interactive Communication System effectively addresses the communication challenges faced by individuals with speech disabilities. The results demonstrate that the system provides accurate eye movement detection, fast response times, and high user satisfaction, making it a reliable assistive tool. Despite minor limitations such as calibration sensitivity, the system proves to be a viable alternative to traditional communication methods. Future enhancements, including AI integration and improved adaptability, can further optimize its performance. Overall, this system has the potential to significantly improve accessibility and independence for speech-impaired individuals.

Acknowledgements

We would like to express our heartfelt gratitude to our guide, Prof. A. S. Nalge, for her valuable guidance, constant encouragement, and support throughout this project. Her insights and expertise were instrumental in the successful completion of this work. We also extend our thanks to the Department of Artificial Intelligence and Machine Learning at Loknete Gopinathji Munde Institute of Engineering Education & Research (LOGMIEER), Nashik, for providing us with the resources and infrastructure needed to conduct our research. Finally, we would like to acknowledge our friends and family for their unwavering support and understanding during the course of this project.

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