 ISSN: 3107-6513

Eye Blink Communication System for Paralyzed Patients

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Abstract:

Opti-Blink is an intelligent assistive communication system designed for individuals with severe motor disabilities, paralysis, or speech impairments. The system uses real-time eye-blink detection via computer vision and converts intentional blinks into Morse code. The decoded text is displayed through a virtual keyboard and converted into speech using a Text-to-Speech (TTS) engine. Enhanced features such as emergency call initiation, WhatsApp messaging with live location sharing, intelligent predictive text using NLTK, and Sleep Mode improve communication speed, usability, and safety. Opti-Blink operates using only a standard webcam and a computer, eliminating the need for costly hardware. Experimental results demonstrate that users can efficiently generate text and initiate emergency communication with high precision, making Opti-Blink an accessible, low-cost, and reliable assistive solution.

Keywords—Eye Blink Detection, Morse Code, Assistive Technology, Computer Vision, Paralysis, Virtual Keyboard, Text-to-Speech, Emergency Alert System

I. INTRODUCTION

Communication is essential to human expression, emotional well-being, and independence. However, individuals affected by complete paralysis or severe neuromuscular disorders such as Amyotrophic Lateral Sclerosis (ALS), Locked-In Syndrome, spinal cord injuries, cerebral palsy, and post-stroke paralysis lose their ability to speak or perform voluntary physical actions. This inability to communicate even basic needs often results in emotional distress, loss of autonomy, and dependence on caregivers for survival. Existing assistive communication systems attempt to bridge this gap but remain either too complex, too expensive, or poorly suited for continuous home or hospital use. Opti-Blink addresses these challenges by providing an affordable, software-driven communication system that enables users to convey messages through intentional eye blinks. The system employs real-time computer vision to detect facial landmarks using MediaPipe, calculates the Eye Aspect Ratio (EAR), and classifies blink duration to distinguish between short and long blinks. These patterns are translated to Morse code, decoded into text, and converted into speech through an integrated Text-to-Speech (TTS) engine. Additional features such as predictive typing using NLTK, Sleep Mode, and emergency support (WhatsApp messaging with live location and automated call triggers) enhance communication efficiency and safety.

II. EASE OF USE

A. System Configuration

The Opti-Blink system is configured to operate on standard computing platforms using a webcam and basic processing hardware. The system supports deployment on commonly used operating environments without requiring specialized configurations. Default parameters are pre-defined to ensure consistent performance across different setups, enabling easy installation and reliable operation in home and clinical environments.

B. User Comfort and Interaction Reliability

To ensure reliable interaction, Opti-Blink employs Eye Aspect Ratio (EAR)-based blink detection combined with temporal thresholding to accurately distinguish intentional blinks from natural eye movements. This improves input accuracy and prevents unintended character selection. Additionally, a Sleep Mode feature is incorporated to temporarily suspend blink detection, allowing users to rest without triggering commands. Predictive text assistance further reduces the number of required blinks, thereby decreasing fatigue and improving communication efficiency. Overall, the system maintains consistent performance while prioritizing user comfort and interaction reliability.

III. SYSTEM ARCHITECTURE

The overall architecture consists of five primary layers: Input Acquisition Layer, Processing & Detection Layer, Morse & Text Layer, Communication & Safety Layer, and User Interface Layer.

A. Input Acquisition Layer

1) Uses a standard webcam connected to a laptop or PC.

2) Frames are captured using OpenCV (cv2.Video Capture) and pre-processed (resizing, grayscale conversion) to reduce computational load.

3) This layer provides continuous image frames to the detection module at a sufficient frame rate for smooth interaction

B. Processing & Blink Detection Layer

1) MediaPipe identifies key facial points around the eyes.

2) The Eye Aspect Ratio (EAR) is computed using landmark coordinates to determine if eyes are open or closed.

3) Based on EAR threshold and duration of closure, the system classifies the event as:

Short Blink → . (dot)

Long Blink → -(dash)

4) Debouncing and temporal thresholds are applied to avoid counting involuntary or natural blinks.

C. Morse Code and Text Management Layer

Once blinks are classified, they are passed to the Morse engine:

1) A Morse buffer stores the current sequence of dots and dashes for a character.

2) When a pause or separator condition is detected (e.g., no blink for a fixed time), the sequence is matched against a predefined Morse code dictionary to obtain the corresponding character.

3) Characters are appended to form words and sentences in a text buffer.

4) Special blink patterns or delimiters can be used for operations like space, delete, or confirmation.

This layer provides a standardized, language-agnostic way for users to communicate using only blinks.

D. NLP and Predictive Text Layer

To reduce the number of blinks required for communication, Opti-Blink incorporates a natural language processing layer:

1) xUses NLTK to provide word prediction and auto completion based on the partially typed word and previous context.

2) Suggested words are displayed on-screen, and users can select a suggestion using specific blink patterns instead of typing each character .

3) This significantly improves typing speed and reduces fatigue, especially during long sentences.

IV. CORE FUNCTIONAL MODULES

A. Real-Time Video Acquisition Module

This module initializes the webcam and continuously captures live video frames using OpenCV.

The frames undergo pre-processing including grayscale conversion and resizing to optimize computational performance. Accurate and stable video stream acquisition is critical for real-time responsiveness and smooth blink detection.

B. Eye and Facial Landmark Detection Module

This module uses MediaPipe or dlib to detect facial features and track eye region landmarks. The Eye Aspect Ratio (EAR) is calculated to determine whether eyes are open or closed. By analysing variations in EAR values across frames, intentional blinks are identified while filtering out normal involuntary blinking. Accurate landmark tracking ensures robust detection under varying lighting and head-position conditions.

C. Blink Classification & Morse Encoding Module

This module classifies each detected blink as either a short blink (dot) or a long blink (dash) based on eye closure duration. Short blinks indicate dot (.) and long blinks represent dash (-). Sequences of dots and dashes are stored in a buffer and interpreted as Morse code, which is then mapped to alphanumeric characters using a lookup dictionary. This allows users to generate text strings using minimal physical input.

D. Text Formation & Predictive Typing Module

Decoded characters are appended to form words and sentences. To improve typing speed and reduce user fatigue, an NLP-based predictive text mechanism implemented using NLTK suggests probable words based on context and partially typed input. Users can select suggested words using specific blink patterns. This significantly reduces communication time and enhances usability for long conversations.

E. Export Functionality

The Opti-Blink system includes a dedicated data export module that enables users and caregivers to save generated conversation logs, emergency contact activity, and session level blink-tracking data for documentation, medical review, or research analysis. The data generated during each communication session—including decoded text, timestamps, Morse sequences, predictive suggestions used, and emergency trigger logs—can be exported into standard formats such as CSV, TXT, and JSON for offline viewing or integration into other healthcare systems.

V. PERFORMANCE EVALUATION

A. Response Time Analysis

The performance of the Opti-Blink system was evaluated based on the response time of its core functional processes, including blink detection, Morse decoding, predictive text suggestion, TTS conversion, and the triggering of emergency actions. Response time is a critical parameter in assistive technologies as it directly affects usability, communication speed, and user comfort, especially for patients relying entirely on eye-based interactions.

TABLE I — RESPONSE TIME PERFORMANCE METRICS

System Operation	Average Response Time (ms)	Maximum Observed (ms)
Real time frame capture & eye detection	45 ms	70 ms
Blink classification & morse decoding	120 ms	180 ms
Word formation & predictive text suggestion	240 ms	310 ms
Text-to-speech (TTS) conversion	480ms	650 ms
Emergency sos trigger (WhatsApp)	700 ms	1050 ms
Sleep mode activation/ wake control	530 ms	680 ms

The results demonstrate that Opti-Blink offers low-latency real time interaction, ensuring natural and efficient communication for paralysed users. Blink classification and Morse decoding occur within approximately 120 ms, enabling smooth continuous text formation without noticeable delay. Predictive typing takes slightly longer due to NLP evaluations but significantly reduces total typing time when forming full sentences.

VI. CONCLUSION

Opti-Blink presents an innovative and accessible assistive communication system designed to empower individuals suffering from paralysis, Locked-In Syndrome, ALS, spinal cord injuries, and other severe motor impairments. By leveraging real-time computer vision and eye-blink detection, movement. Unlike existing systems that require expensive hardware, calibration equipment, or wearable sensors, Opti Blink operates entirely through a standard webcam, making it affordable, portable, and practical for both home and clinical environments. Overall, Opti-Blink successfully addresses the limitations of earlier assistive technologies by providing a reliable, low-cost, and user-centered solution capable of restoring independent communication. The system has great potential for deployment in rehabilitation centers, hospitals, assisted living facilities, and home-care environments. Future enhancements include integration of multilingual voice output, mobile and IoT-based deployment, deep-learning-based blink pattern adaptation, and improved personalization for user-specific blink characteristics. With continued development, Opti-Blink can serve as an essential assistive technology for millions of individuals worldwide who struggle with communication disability.

ACKNOWLEDMENT

The authors would like to express their profound gratitude to Dr.Ciyamala Kushbu.S, Project Guide, Department of Information Science and Engineering, CMR Institute of Technology, Bengaluru, for his invaluable guidance, encouragement, and continuous support throughout the development of this project. Her insightful suggestions and technical expertise greatly contributed to the successful completion of this work.
The authors also extend their heartfelt thanks to Dr. Jagadishwari V, Head of the Department, Department of Information Science and Engineering, CMR Institute of Technology, for her motivation, constant encouragement, and for providing the necessary resources and facilities. The authors are equally thankful to all the faculty members of the department for their cooperation and moral support during the course of this project.

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the system enables users to communicate effectively through Morse-code-based input without relying on speech or physical

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