Eye Gaze Controlled Keyboard With Predictive Text

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Abstract*— A gaze-controlled virtual keyboard offers an unobtrusive communication channel for people with severe physical disabilities. The technology utilizes real-time gaze and blink detection to enable it to read eye movement and blinking patterns to effectively navigate and select keys on a virtual keyboard. The system offers smooth vertical navigation between keyboard rows using adaptive wink identification, utilizing the application of the left and right eye winks, while horizontal navigation relies on the direction of the gaze. Integration of predictive text optimizes typing efficiency by presenting the most probable words based on the application of a personalized frequency-based dictionary stored in a light text file. It also features an embedded emergency trigger button that, upon activation by a sustained blink, transmits an alert SMS via the Twilio API, thus increasing the security of the user during emergency use. The system constantly processes input from a webcam, hence offering constant responsiveness without manual intervention. It offers a reliable, accessible, and intelligent communication system, giving the user precise, eye-controlled text entry and emergency alerting functionalities.

Index Terms*— Gaze Tracking, Blink Detection, Virtual Keyboard, Assistive Technology, Predictive Text, Eye-Controlled Interface, Emergency Alert System, Twilio API, Wink Recognition

I. INTRODUCTION

People with severe speech and motor impairments often face extreme barriers to communication. Traditional assistive technologies can be slow, intrusive, or ineffective in real-world use, prompting a shift toward gaze-based systems that enable natural, hands-free interaction.

Recent advancements have led to the development of intuitive, eye-based communication systems tailored for individuals with speech limitations. One such system is NETRAVAAD, which enables users to select letters and phrases using only eye movement, greatly enhancing accessibility [1]. Further innovations have explored the recognition of eye-writing patterns using deep learning models such as dilated causal convolution networks, offering improved accuracy and responsiveness [2].

To enhance gaze estimation, event-based cameras have been introduced, capturing high-speed visual data for real-time, robust tracking performance [3]. Blink-based communication systems, such as Blink-To-Live, have also proven effective by using voluntary eye closures as input triggers for composing and transmitting messages [4]. These approaches collectively highlight the potential of eye activity as a reliable medium for human-computer interaction.

In the realm of gaze detection, deep learning-based automatic gaze analysis has gained traction, with models trained on large datasets enabling precise prediction of eye focus points even in dynamic conditions [5]. Systems designed for assisted living environments benefit from uncertainty-aware gaze tracking, which ensures consistent performance despite variability in lighting or user posture [6]. Eye-controlled interfaces now support real-time interactions, providing fast and natural control mechanisms for individuals with limited mobility [7]. Lastly, non-intrusive facial alignment methods have enabled real-time gaze tracking without specialized hardware, further reducing the barrier to adoption [8].

Building upon these foundational works, this project presents a comprehensive gaze-controlled virtual keyboard that integrates predictive text suggestions, real-time blink detection, and an emergency alert system using Twilio. The goal is to create a lightweight, adaptive, and user-friendly interface for people with severe physical disabilities.

II. RELATED WORK

The domain of gaze-based human-computer interaction and communication for individuals with speech or motor impairments has seen notable advancements in recent years. Researchers have explored a range of solutions, from simple blink-based systems to sophisticated real-time gaze tracking integrated with deep learning techniques.

One of the prominent works is by Megalingam et al. [1], who developed NETRAVAAD, an interactive eye-based communication system tailored for individuals with speech issues. The system uses eye movements for text input and voice output, offering real-time assistance for communication. Similarly, Ezzat et al. [4] introduced Blink-To-Live, a blink-triggered communication system that enables users to convey messages via controlled blinking, offering an accessible interface without relying on speech or hand gestures.

The recognition of eye-writing as a novel interaction method was investigated by Bature et al. [2], who proposed a Dilated Causal Convolution Network to classify eye-drawn patterns. Their work highlights the potential of pattern-based recognition in enhancing communication accuracy. Likewise, Li et al. [3] presented E-Gaze, a system utilizing event-based cameras for efficient and high-speed gaze estimation, which reduces latency and improves temporal resolution in gaze detection systems.

Deep learning approaches have also influenced the field substantially. Ghosh et al. [5] conducted a comprehensive survey of CNN and GAN-based methods in automatic gaze analysis, emphasizing their capacity for learning complex features and improving robustness. However, these models often face challenges like data scarcity and high computational demands. To address environmental uncertainties, Her et al. [6] introduced an uncertainty-aware gaze tracking model, which improves gaze estimation reliability in assisted living environments.

In addition to tracking and recognition, real-time interaction remains a core focus. Chen et al. [7] demonstrated a gaze-based HCI framework for industrial applications, showing how eye movements can substitute for touch or voice in machine control. Similarly, Leblond-Menard and Achiche [8] designed a non-intrusive real-time eye-tracking system using facial alignment techniques, which proved effective in assistive technologies without requiring specialized hardware.

Advanced intent prediction models were developed by Koochaki and Najafizadeh [9], who proposed a data-driven framework for interpreting eye movements to predict user intentions in assistive systems. Their approach opens up possibilities for proactive system responses. Meanwhile, Chakraborty et al. [10] created an eye gaze-controlled virtual keyboard, demonstrating how gaze direction and fixations can be used for precise text entry.

Survey efforts by Zhou et al. [11] and Nguyen and Tran [18] summarized the field's progress in gaze-based assistive control systems and augmented reality (AR) interactions, respectively, outlining key challenges like calibration, drift correction, and the need for personalized interfaces. Specific to gesture recognition, Smith and Huggins [12] focused on blink-based communication gestures, analyzing noise resilience and gesture ambiguity in practical use.

Efforts to support speech impairment recovery were discussed by Lee et al. [13], who explored the intersection of eye tracking and speech therapy, identifying beneficial modalities for rehabilitation. Similarly, Tanaka and Yamaguchi [14] developed real-time gaze-controlled interfaces, aiming for low-latency communication in fast-paced environments. Ohashi and Nakamura [15] extended this idea to AR environments, proposing gaze recognition techniques optimized for wearable display systems.

In virtual and adaptive systems, Wang et al. [16] showcased real-time gaze tracking in VR setups, enabling immersive and intuitive user interactions. Finally, Kim and Park [17] introduced an adaptive gaze-controlled communication system, which dynamically adjusts to the user's attention span and eye fatigue, ensuring usability across long sessions.

These existing works collectively demonstrate that while traditional gaze systems offer basic functionality, emerging techniques involving deep learning, adaptive models, and multimodal inputs hold the potential to create more robust, accurate, and user-friendly communication platforms. The proposed system in this work aims to build upon these foundations by integrating blink, wink, and gaze cues with predictive text to deliver a seamless, efficient, and intelligent communication interface.

III. METHODOLOGY

A. Proposed System Overview

Existing communication systems for individuals with motor and speech impairments leverage various modalities such as blinking, gaze direction, and eye winks. Many of these systems utilize eye-tracking technology to simulate keyboard input or trigger predefined messages. Early implementations focused on detecting blinks to navigate and select interface elements, offering basic message composition. More recent approaches integrate machine learning for improved gaze estimation and adaptive user experience. Deep learning models like convolutional neural networks have been employed to estimate gaze direction under varying lighting and head positions. Predictive text algorithms have also been embedded into gaze-based keyboards to reduce typing time and cognitive load. Additionally, some systems include emergency response features triggered by specific blink patterns or prolonged gaze, enabling real-time alerts to caregivers. While effective, these systems often face challenges related to calibration, accuracy, and real-time responsiveness in diverse environments.

B. Software and Hardware Requirements

To implement the proposed gaze-controlled virtual keyboard system, both hardware and software components are carefully selected to ensure real-time responsiveness, accuracy, and ease of integration. On the hardware front, a standard webcam with a resolution of at least 720p is required to capture the user's facial and eye movements with sufficient clarity. A system with a multi-core processor and a minimum of 8GB RAM is recommended to support the computational load of real-time video processing and predictive text generation. For user interaction, a standard monitor or laptop screen is used to display the virtual keyboard interface.

On the software side, Python serves as the primary programming language due to its extensive libraries and support for computer vision and GUI development. OpenCV is used for real-time image capture and preprocessing, while the gaze_tracking library facilitates gaze direction and blink detection. PyQt5 is employed for designing the interactive virtual keyboard interface, offering flexibility in layout and styling. For predictive text suggestions, a txt document was created with the most frequently used English language words. Additionally, Twilio is used for sending alerts to the caretaker's mobile phone through SMS. The entire system is developed and tested on a Windows 10 environment, though it is compatible with other platforms that support Python and webcam access.

C. System Architecture

The proposed system follows a modular architecture where each module plays a distinct role in enabling efficient and intuitive interaction for users with severe physical disabilities. The modular approach allows for easy development, maintenance, and future scalability. Below is a detailed description of each module:

1) Camera Module: The Camera Module acts as the primary input source, capturing real-time video of the user's face and eyes. This continuous video feed serves as the basis for all further processing in the system, especially for detecting eye movements and blinks.

2) Gaze and Blink Detection Module: This module analyzes the video stream to detect the user's gaze direction—whether left, right, or center—and identifies eye gestures such as winks and blinks. It uses image processing and facial landmark tracking techniques to determine the visibility and position of pupils. The output from this module informs both navigation and selection mechanisms in the system.

To detect blinks, the Eye Aspect Ratio (EAR) is used. EAR is calculated using six key facial landmarks around the eye:

$$EAR = \frac{\|P_2 - P_6\| + \|P_3 - P_5\|}{2 \cdot \|P_1 - P_4\|}$$

where P_1 to P_6 are the coordinates of the eye landmarks. A blink is detected when the EAR value falls below a predefined threshold (e.g., 0.20) for a short duration.

Gaze direction is estimated using the gaze ratio, which compares the average pixel intensity of the left and right regions of the eye:

$$Gaze\ Ratio = \frac{\text{Average intensity in the left half of the eye}}{\text{Average intensity in the right half of the eye}}$$

Gaze direction is interpreted as:

$$\begin{cases} \text{Looking Right} & \text{if } Gaze\ Ratio < 1 \\ \text{Looking Center} & \text{if } Gaze\ Ratio \approx 1 \\ \text{Looking Left} & \text{if } Gaze\ Ratio > 1 \end{cases}$$

3) Virtual Keyboard Module: The Virtual Keyboard Module provides a graphical user interface where keys are arranged in rows and columns. It highlights the keys based on the user's gaze direction, allowing the user to navigate across the keyboard without physical interaction. The highlighted key indicates the current focus, which can be selected using a blink.

4) Selection Mechanism: This module interprets blink patterns to confirm user choices. A prolonged blink, typically lasting two seconds, is considered a selection signal and inputs the currently focused key into the text area. This blink-based selection eliminates the need for physical input devices and provides a reliable mechanism for interaction.

5) Predictive Text Module: To enhance typing speed and ease, the Predictive Text Module suggests three word predictions dynamically based on the letters typed so far. It leverages a frequency-based dictionary or lightweight language model to display the most probable completions. Users can gaze and blink on one of the predicted words to insert it quickly.

6) Emergency Button Module: This module is a safety feature built into the system interface. A fixed-position emergency button is monitored continuously, and if the user gazes at it and performs a prolonged blink (e.g., three seconds), the system interprets it as an emergency and triggers a predefined alert, such as sending an SMS to a caretaker or guardian.

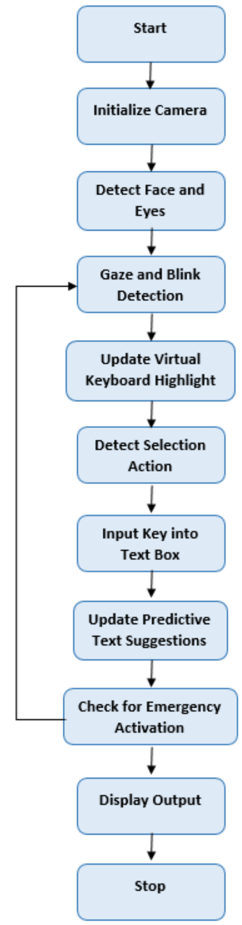

Fig. 1: System Flowchart

D. *System Flowchart*

Fig. 1 visually represents the operational sequence of the gaze-controlled virtual keyboard. It begins with the initialization of the camera, followed by real-time face and eye detection to track the user's gaze direction and eye gestures such as winks and blinks. Based on the gaze input, the virtual keyboard highlights the corresponding key, while a prolonged blink confirms selection. The selected key is then added to the text area, and predictive text suggestions are updated accordingly. The flowchart also includes an emergency detection branch, where a fixed emergency button is triggered through a focused gaze and prolonged blink, sending an alert to a caregiver. This modular flow ensures seamless and efficient user interaction through eye-based input.

E. *Deployment Setup*

The gaze-controlled virtual keyboard system is packaged as a standalone `.exe` executable file for ease of deployment and distribution. This eliminates the need for users to install Python or manually configure dependencies. The application is developed using Python and converted into an executable using tools like `PyInstaller`, which bundles all required libraries—including OpenCV, `gaze_tracking`, PyQt5, and

Twilio—into a single file. Once the `.exe` file is generated, it can be executed on any Windows system with a webcam, without requiring an internet connection for normal operation. The executable initializes the webcam on startup, loads all modules in sequence, and provides a user-friendly interface for real-time gaze and blink-based interaction. This setup ensures portability, ease of installation, and quick launch, making it accessible for end-users with minimal technical expertise.

F. Pseudocode of the Proposed System

Algorithm 1 Gaze-Controlled Virtual Keyboard System

```
Initialize webcam and load required libraries
Load virtual keyboard interface and predictive text dictionary
while System is running do
    Capture video frame from webcam
    Detect face and eyes in the frame
    Estimate gaze direction: Left, Right, or Center
    Detect eye state: Open, Left Wink, Right Wink, or Blink
    if Left Wink detected then
        Move focus one row up in keyboard
    else if Right Wink detected then
        Move focus one row down in keyboard
    else if Gaze is Left or Right then
        Move focus left/right across current row
    end if
    if Prolonged Blink (≥ 2 seconds) detected then
        Select and type the currently focused key
        Update typed word buffer
        Generate predictive text suggestions based on typed prefix
    end if
    if Emergency Button is focused AND prolonged blink (≥ 3 seconds) detected then
        Trigger emergency alert (e.g., send SMS)
    end if
end while
```

IV. RESULTS AND DISCUSSION

A. Experimental Setup

The proposed gaze-controlled virtual keyboard system was tested on a standard Windows 10 laptop equipped with an Intel Core i7 processor and 8GB of RAM. The webcam was used to capture real-time video of the user's eye movements. The webcam was positioned approximately 40-50 cm away from the user's face to ensure optimal gaze and blink detection. The test environment involved moderate indoor lighting, which provided satisfactory performance.

B. Performance Metrics

The performance of the proposed gaze-controlled virtual keyboard system was evaluated based on the accuracy of gaze direction and eye gesture detection. The system was tested under normal lighting conditions and at a distance of approximately 40–50 cm from the webcam. The detection accuracies for each gaze and gesture type are presented in Fig 2.

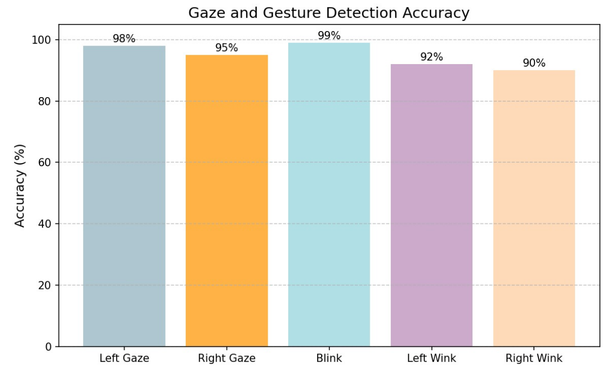

Fig. 2: Home Page Interface

C. User Experience and Feedback

To evaluate the practical usability of the gaze-controlled virtual keyboard, informal testing was conducted with a small group of users. The following observations were made based on their feedback:

- **Ease of Use:** Users found the system intuitive, with minimal training required to operate the keyboard using only their eye movements and blinks.
- **Responsiveness of the System:** The system responded quickly to changes in gaze direction and accurately registered blinks and winks, providing a smooth interaction experience.
- **Comfort Over Extended Use:** Most users reported that the system remained comfortable to use over short to moderate durations. However, some eye strain was observed during prolonged usage sessions.
- **Usability Observations:** While no formal usability survey was conducted, informal feedback highlighted the system's potential for daily communication tasks, especially in controlled lighting conditions.

This user feedback suggests that the system is a promising assistive tool, with scope for further ergonomic and usability improvements in future iterations.

D. System Interface

The system consists of a virtual keyboard displayed on the screen, where keys are highlighted based on the user's gaze direction. The interface dynamically responds to left, right, and center gaze inputs for navigation, and registers selections through blinks or winks. In addition to standard character input, the interface includes a predictive text panel that offers word suggestions, and an emergency button feature for quick alerts. Visual feedback and minimalistic design ensure ease of use and reduce cognitive load during interaction.

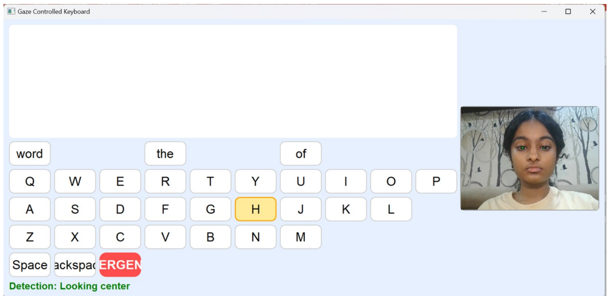

Fig. 3: Virtual Keyboard

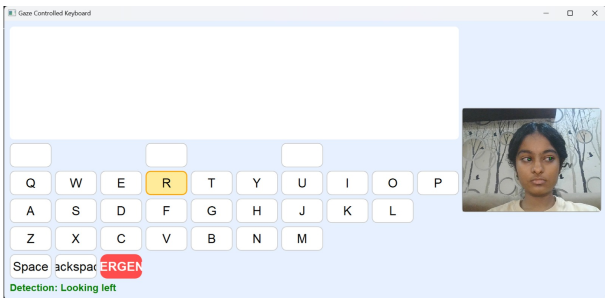

Fig. 4: Looking Left

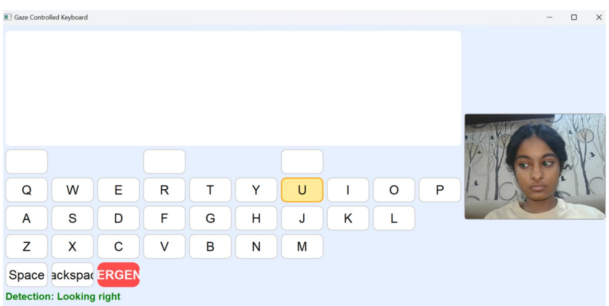

Fig. 5: Looking Right

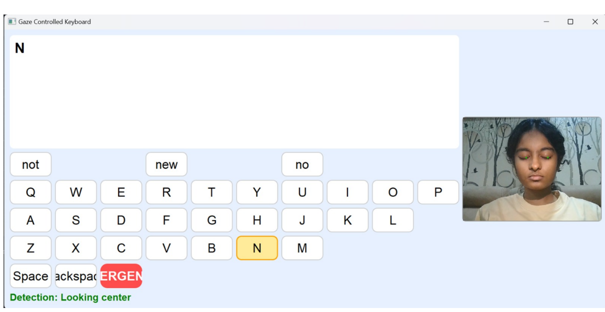

Fig. 6: N is typed as the user blinks on it

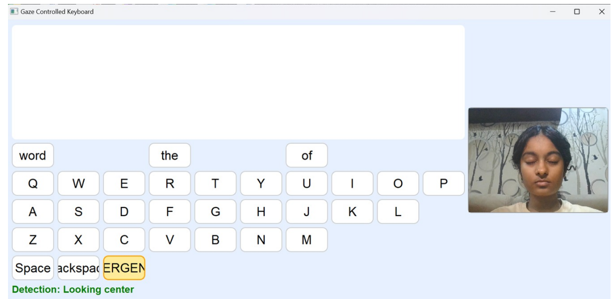

Fig. 7: The user blinks on EMERGENCY button

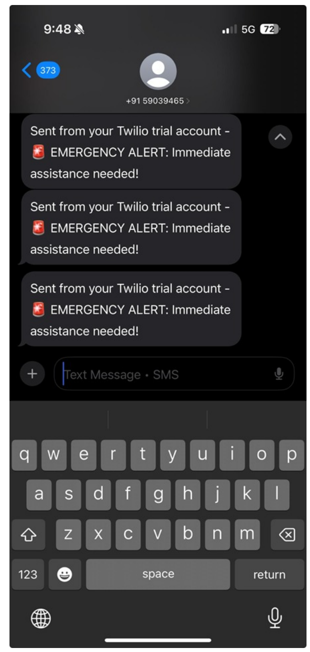

Fig. 8: The alert message

V. FUTURE SCOPE

While the system performs effectively under controlled conditions, there are several areas that offer potential for future improvement. Currently, the accuracy of gaze and blink detection can be affected by poor lighting conditions. Enhancing the system's robustness under variable illumination using adaptive brightness correction or infrared-based tracking could significantly improve usability in real-world settings. Additionally, incorporating head pose estimation could allow more accurate gaze localization, especially for users with involuntary head movements. Future iterations may also explore integrating deep learning-based gaze estimation models to further improve precision. Expanding the interface to include additional features such as customizable layouts or multi-language support could enhance accessibility. Finally, deployment on mobile or embedded platforms would make the system more portable and suitable for daily use by individuals with physical disabilities.

VI. CONCLUSION

In this paper, we presented a gaze-controlled virtual keyboard system designed to assist individuals with severe physical disabilities in communication. The system uses real-time gaze direction and blink detection to navigate and select characters on a virtual keyboard. Through accurate tracking of eye movements and simple blink-based confirmation, users can type effectively without the use of hands or speech. The system also integrates predictive text suggestions and an emergency alert mechanism to enhance usability and safety. Experimental results show high accuracy in detecting gaze directions and eye gestures, validating the reliability of our approach. Overall, this work demonstrates a promising assistive technology that can be further refined and extended to support broader accessibility needs.

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