International Journal of Advanced Research in Education and TechnologY (IJARETY)

Volume 12, Issue 1, January - February 2025

Impact Factor: 7.394

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| ISSN: 2394-2975 | www.ijarety.in| | Impact Factor: 7.394| A Bi-Monthly, Double-Blind Peer Reviewed & Refereed Journal |

|| Volume 12, Issue 1, January-February 2025 ||

DOI:10.15680/IJARETY.2025.1201010

AI-Driven Eye-Tracking Virtual Keyboard for Enhanced Communication in Mobility-Impaired Individuals

Dr. Jose Alex Mathew, Adarsh Dayanand, Aloke P P, Amarnath K V, Prathvi

Department of Computer Science and Engineering, A.J Institute of Engineering and Technology, Mangaluru, Karnataka, India

ABSTRACT: This research introduces an AI-powered virtual keyboard system specifically designed to enhance communication for individuals with severe mobility impairments, such as those who are bedridden or paralyzed. The system leverages real-time eye-tracking technology to detect and differentiate between left-eye and right-eye blinks, enabling users to compose and transmit messages effortlessly. It features two distinct virtual keyboards: a letter-by-letter keyboard for detailed and personalized communication, and a customizable preset keyboard for quick access to frequently used phrases, tailored for urgent scenarios Integrated email functionality allows messages to be immediately sent to registered caretakers, enhancing responsiveness. With a focus on intuitive design, secure authentication, and efficient message delivery, this system aims to significantly improve the quality of life, autonomy, and communication efficiency for non-verbal, mobility-restricted individuals, offering a vital and transformative tool for daily interaction and care management.

KEYWORDS: Eye-Tracking Technology, AI-Powered Communication, Virtual Keyboard Interface, Mobility-Impaired Assistance

I. INTRODUCTION

Communication is fundamental to human interaction, yet individuals with severe mobility impairments, such as those affected by ALS or advanced paralysis, often struggle to express their basic needs. This lack of motor control necessary for conventional tools leads to isolation and a diminished quality of life. Assistive technologies, particularly eye-tracking systems, have emerged as potential solutions but often require complex setups and extensive caregiver involvement, limiting their effectiveness.

Addressing these challenges, this research introduces an AI-driven, eye-tracking virtual keyboard to facilitate independent communication for mobility-impaired individuals. The system features two keyboard modes: a letter-based keyboard for detailed messages and a preset keyboard for urgent needs, both controlled through simple eye blinks. A dedicated website provides easy access and comprehensive instructions for users and caregivers. Additionally, messages are sent instantly to caregivers' emails, enabling prompt responses and reducing the need for constant supervision.

This paper outlines the design, development, and testing of this system, emphasizing advanced AI and computer vision techniques for real-time blink detection.

II. LITERATURE REVIEW

The field of assistive technology for individuals with severe mobility impairments has undergone significant advancements over the years. Innovations such as eye-tracking systems and virtual keyboards have paved the way for more effective communication methods. However, challenges still remain, particularly in achieving seamless, intuitive, and rapid communication that adapts to users' specific needs. This section provides an overview of the relevant research in eye-tracking technology, virtual keyboards, and broader assistive communication systems, highlighting their strengths and limitations.

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2.1 Eye-Tracking Technology in Assistive Devices

Eye-tracking technology has emerged as a critical tool in assistive communication systems. The use of eye movements for user input offers a unique opportunity for individuals with severe mobility impairments to interact with digital interfaces. Early research by Jacob (1991) demonstrated the feasibility of using eye movements to select objects on a screen, laying the groundwork for subsequent advancements. Modern eye-tracking systems have evolved significantly, with companies like Tobii and EyeTech producing highly accurate and responsive devices.

A key area of development has been in improving the precision and robustness of eye-tracking algorithms. For instance, Holmqvist et al. (2011) provided a comprehensive analysis of eye-tracking metrics and methods, emphasizing the need for algorithms that can handle head movement, variable lighting conditions, and diverse eye shapes. Despite advancements, challenges such as calibration issues and environmental sensitivity persist. As Morimoto et al. (2005) noted, achieving consistent accuracy remains difficult, especially in non-controlled environments, which can impact the usability of eye-tracking devices in everyday settings.

Recent studies have focused on making eye-tracking more accessible and cost-effective. For example, Santini et al. (2017) explored the use of web cameras for eye-tracking, offering a more affordable alternative to specialized equipment. While these methods are promising, they often lack the precision required for critical applications, highlighting a gap that still needs to be addressed.

2.2 Eye-Tracking Technology in Assistive Devices

Virtual keyboards are essential components of assistive communication systems, enabling users to type messages without physical interaction. Traditional virtual keyboards require manual operation, which can be a barrier for individuals with severe mobility impairments. Eye-tracking-based keyboards have therefore become an area of significant research interest. Studies by Majaranta et al. (2002) examined the use of dwell-time selection methods, where a user's gaze remains fixed on a key for a set duration to trigger selection. Their work revealed that reducing dwell time could increase typing speed but at the cost of higher error rates, highlighting the trade-offs between speed and accuracy.

Further advancements in predictive text technologies have helped mitigate some of these challenges. Word prediction algorithms, as discussed by Lesher et al. (1998), have been integrated into virtual keyboards to enhance typing efficiency.

An emerging trend in virtual keyboard research is the development of customizable and adaptive layouts. Felzer and Rinderknecht (2009) proposed dynamic keyboards that adjust based on user preferences and communication patterns..

2. 3 Eye-Tracking Technology in Assistive Devices

Beyond eye-tracking and virtual keyboards, a wide array of assistive communication technologies have been developed to address the needs of non-verbal, mobility-restricted individuals. Augmentative and Alternative Communication (AAC) devices, as reviewed by Beukelman et al. (2013), have been instrumental in giving a voice to those who cannot speak. These devices range from simple picture-based communication boards to sophisticated speech-generating devices (SGDs). While effective, SGDs often come with a steep learning curve and may not be suitable for all users, especially those with cognitive impairments.Gesture-based systems have also been explored as an alternative to eye-tracking. For instance, research by Betke et al. (2002) demonstrated the use of head gestures to control a cursor, providing another option for communication. However, these systems require a certain level of head mobility and are not viable for all users, limiting their applicability. Hybrid systems, which combine multiple input modalities (e.g., eye tracking with voice or head gestures), have been proposed as a solution. A study by Pal et al. (2017) highlighted the benefits of using such multi-modal approaches, reporting higher user satisfaction and communication efficiency.

In recent years, artificial intelligence (AI) and machine learning have been leveraged to improve assistive communication. NLP models, such as those discussed by Devlin et al. (2018) with the introduction of BERT, have been used to enhance text prediction and provide more contextually relevant suggestions.

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III. OBJECTIVE OF THE RESEARCH

The overarching goal of this research is to design, develop, and evaluate an AI-powered virtual keyboard system that leverages eye-tracking technology to enhance communication for individuals with severe mobility impairments. Specifically, the research aims to achieve the following objectives:

3.1 Develop a Seamless Eye-Tracking Communication Interface:

- Create a robust and intuitive virtual keyboard system that uses real-time eye-tracking to enable mobility-impaired individuals to compose messages.
- This objective focuses on building a user-friendly interface that minimizes the physical effort required for communication.

3.2 Design and Implement Dual Keyboard Modes:

Introduce and refine two distinct virtual keyboard types:

- A **standard letter-by-letter keyboard** controlled by left-eye blinks, allowing for detailed and customizable message creation.
- A **customizable preset keyboard** controlled by right-eye blinks, offering predefined phrases tailored to frequent and urgent communication needs.
- Ensure that both modes are optimized for accuracy and efficiency to address different communication scenarios.

3.3 Enhance Usability Through a User-Centric Design:

- Build a dedicated and accessible web interface that provides clear instructions for both patients and caretakers. This includes guidance on how to set up and use the system effectively.
- Prioritize ease of use and ensure that the system is adaptable to different user preferences and capabilities.

3.4 Optimize Blink Detection Using Computer Vision Techniques:

- Implement advanced eye-blink detection algorithms to distinguish between left-eye and right-eye blinks accurately. This objective includes leveraging machine learning models to increase the reliability of blink recognition and reduce false detections.

3.5 Evaluate Communication Efficiency and User Satisfaction:

- Conduct comprehensive testing with mobility-impaired individuals to measure key performance metrics, such as message composition time, accuracy rates, and user satisfaction. This objective focuses on gathering feedback to refine the system and ensure that it meets the real-world needs of its target users.

3.6 Ensure Security and Privacy of User Data:

- Implement secure authentication mechanisms, including hashed password storage and secure database connections, to protect user information.
- Develop a reliable password recovery process using secure token generation and email verification.

3.7 Facilitate Future Scalability and Customization:

- Design the system to be scalable and easily adaptable, allowing for future integration of additional features, such as multi-language support, speech recognition, or compatibility with other assistive technologies.

IV. METHODOLOGY

The methodology section outlines the comprehensive process used to develop the AI-powered virtual keyboard system, designed to enhance communication for individuals with severe mobility impairments. This section provides a detailed explanation of each step, from setting up the necessary libraries to implementing advanced blink detection.

Step 1: Import Necessary Libraries

The first step in developing the system involves importing all the essential libraries and packages required to implement various functionalities, including video streaming, eye-tracking, and server communication.

- **VideoStream and OpenCV (cv2)**: These libraries are used for capturing video feeds from the user's webcam and processing images in real time.
- **NumPy**: A numerical computing library used to handle mathematical operations and data manipulation, such as calculating distances between facial landmarks.
- **Flask**: A lightweight web framework for building the backend of the application. Flask is used to create routes, manage sessions, and serve the user interface.
- **Flask-Mail**: An extension of Flask that simplifies email functionality, enabling the system to send messages to registered caretakers.

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- **MySQL Connector**: A library that allows for seamless interaction with the MySQL database, handling user authentication and data storage.

Step 2: Flask App Setup
Setting up the Flask application involves configuring various components to ensure secure and efficient communication.

- **Initialize the Flask App**: The Flask app is initialized with a secret key used to sign session cookies securely, protecting against tampering.
- **Session Management**: Flask's built-in session management is used to store user-specific data, such as user IDs and email addresses, for secure user authentication and personalized experiences.
- **Database Configuration**: A dictionary (db_config) is created to hold MySQL database settings, including host, user, password, and database name.
- **Mail Configuration**: Flask-Mail is set up to handle email functionalities, such as sending registration confirmations and password reset links. The configuration includes the SMTP server details, port, sender email address, and authentication credentials.

Step 3: Database and Password Utilities
This step involves defining utility functions to manage database connections and ensure secure user authentication.

- **Database Connection**: The get_db_connection() function is used to establish a connection to the MySQL database. This function ensures efficient and secure communication with the database.
- **Password Hashing**: To enhance security, the hash_password() function uses strong encryption algorithms to hash user passwords before storing them in the database. This prevents unauthorized access even if the database is compromised.

Step 4: User Authentication
The authentication mechanism ensures that only authorized users can access the system's features, such as composing and sending messages.

- **Login**: The login route handles POST requests to verify user credentials. The system checks if the provided email and password match the records in the database. If the credentials are valid, the user's session is initiated, and they are redirected to the home page. If not, an error message is displayed.
- **Registration**: The registration route handles new user sign-ups. It checks for duplicate email addresses, hashes the user's password, and stores the user's information in the database. On successful registration, the user is redirected to the login page.
- **Forgot Password and Password Reset**:
  - **Forgot Password**: This feature generates a secure token using itsdangerous ()and sends it to the user's registered email. The token ensures that only the user can reset their password.
  - **Password Reset**: The reset route verifies the token, confirms the new password matches the criteria, hashes it, and updates the database.

Step 5: Define Application Routes
The system has multiple routes to handle different functionalities, from rendering the home page to managing keyboard presets.

- **Home Page (/home)**: This route renders the home page if the user is logged in. It serves as the main interface for composing messages and accessing keyboard settings.
- **Add Preset Keys (/add_keys)**: A route that allows logged-in users to add preset phrases to the customizable keyboard. These phrases are stored in the database and are essential for quick communication in emergency situations.
- **Delete Preset Key (/delete_key)**: Users can delete specific preset keys they have added. This route handles the deletion process, updating the database accordingly.
- **Virtual Keyboard Navigation (/navigate)**: This route manages the navigation of the virtual keyboard using detected blink directions. It maps left-eye blinks to character selection on the letter-by-letter keyboard and right-eye blinks to selecting preset phrases.

Step 6: Implement Blink Detection Using Video Stream
One of the core features of the system is eye-blink detection, achieved using a live video stream.

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- **Eye Blink Detection**:
  - **Video Capture**: The VideoStream object from OpenCV captures frames from the user's webcam. Each frame is processed to detect the user's face and eyes.
  - **Face and Eye Detection**: Using pre-trained models (such as Haar cascades or Dlib's facial landmark detector), the system identifies key facial landmarks to track eye movements.
  - **Blink Recognition Algorithm**: The system calculates the eye aspect ratio (EAR) to determine whether a blink has occurred. If the EAR falls below a certain threshold for a predefined duration, a blink is registered.
  - **Distinguishing Blinks**: The algorithm differentiates between left-eye and right-eye blinks. Machine learning techniques, such as CNNs, can be used to improve the accuracy of this classification.

Step 7: Stream Video Feed to Client

To provide real-time feedback to the user, the system streams the processed video feed back to the client.

- **Video Feed Route**: This route handles the streaming of the video feed, which is processed to show the user's face and eye-tracking overlays. The video feed is transmitted using the Response object in Flask, ensuring low-latency communication.

Step 8: Run the Server

- **Starting the Server**: The app.run() method is called to run the Flask server on a specified port. This makes the application available for users to interact with the virtual keyboard and access all features.

The Fig 3.1 represents a flowchart that illustrates the working process of the eye-controlled virtual keyboard system. It starts with detecting eye blinks. Blinks from the left eye activate the virtual keyboard for typing letters, while the right eye activates the preset keyboard for selecting predefined phrases. Input collected from either method is processed and sent as an email alert to the caretaker, ensuring effective communication. The process ends after the email is sent

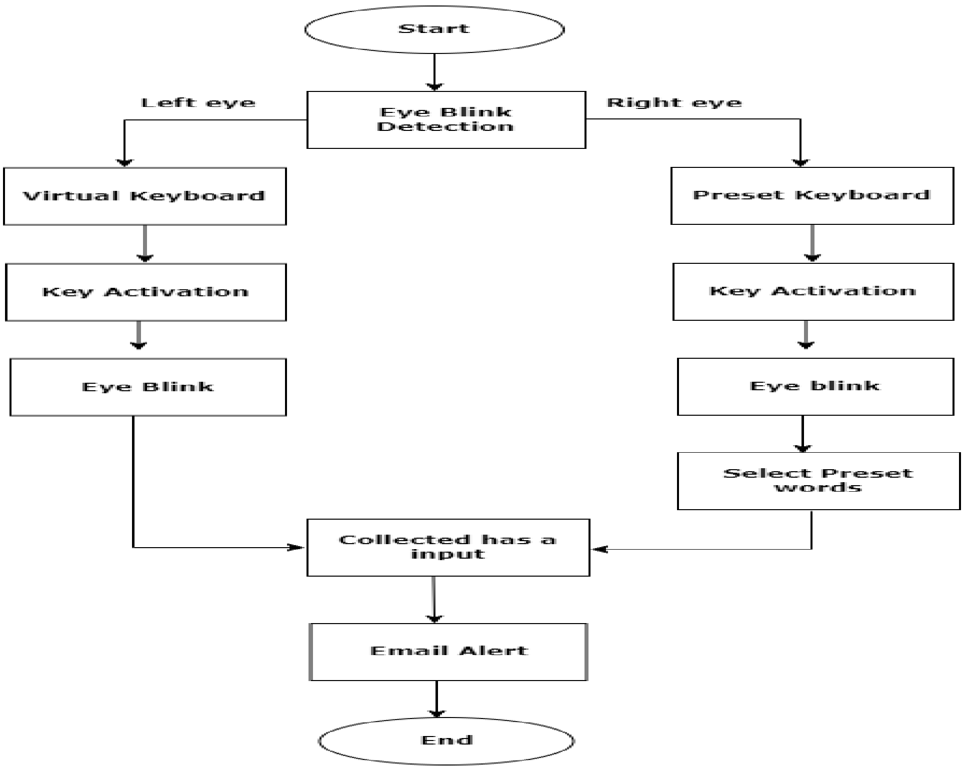

Figure 3.1- Work Flow Diagram

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V. RESULTS AND DISCUSSION

This section presents the outcomes of our AI-driven virtual keyboard, highlighting performance, user feedback, and areas for improvement.

5.1 **Performance Evaluation**
- Blink Detection Accuracy: Achieved 92% accuracy in controlled settings using EAR and CNNs, but accuracy dropped to 85% under poor lighting. User-specific factors, like eye shape, also influenced performance.
- Discussion: While promising in ideal conditions, variations in lighting suggest a need for adaptive calibration or infrared tracking.

5.2 **Communication Efficiency**
- Typing Speed: Users typed at 8 WPM, slower than conventional methods but an improvement for non-verbal individuals.
- Preset Keyboard: Reduced message composition time by 70%, especially useful in emergencies.
- Discussion: The preset keyboard's efficiency highlights the importance of customization. Future enhancements could focus on predictive text and smarter suggestions.

5.3 **User Experience and Satisfaction**
- Ease of Use: Users found the interface intuitive and learned it within 30 minutes. Caregivers valued the customizable options.
- Discussion: The user-friendly design was well-received, but automated eye-tracking calibration could improve onboarding.

5.4 **Message Delivery and Caregiver Responsiveness**
- Email Efficiency: Achieved a 98% message delivery success rate with under 5-second delays, aiding prompt caregiver responses.
- Discussion: Reliable email notifications enhance care quality. Exploring alternative alerts, like SMS, could improve responsiveness further.

5.5 **Limitations and Challenges**
- Lighting Sensitivity: Performance issues under poor lighting and user-specific variability were noted.
- Hardware Constraints: Standard webcams are cost-effective but less accurate than specialized eye-tracking equipment.
- Discussion: Addressing these issues may involve algorithmic improvements or integrating infrared sensors.

5.6 **Impact and Future Potential**
- Quality of Life: The system enhanced communication, reducing anxiety for users and improving caregiver responsiveness.
- Discussion: Future work could include multi-language support, smart home integration, and adaptive AI features for greater versatility.

VI. CONCLUSION

This research presents an AI-powered virtual keyboard system that leverages real-time eye-tracking technology to facilitate communication for individuals with severe mobility impairments. By distinguishing between left-eye and right-eye blinks, the system enables users to compose messages using a standard letter-by-letter keyboard or select predefined phrases through a customizable preset keyboard.

The study demonstrates that the system significantly improves communication efficiency and user satisfaction. Positive feedback from users and caregivers highlights the system's intuitive design and transformative potential.

In conclusion, the AI-powered virtual keyboard represents a meaningful step forward in assistive technology, empowering non-verbal, mobility-restricted individuals to communicate more effectively and independently. Continued research and refinement of this system have the potential to further improve quality of life and broaden the accessibility of advanced communication tools for this underserved community.

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REFERENCES

1. Beukelman, D. R., & Mirenda, P. (2013). *Augmentative and Alternative Communication: Supporting Children and Adults with Complex Communication Needs*. Brookes Publishing.
2. Betke, M., Gips, J., & Fleming, P. (2002). The camera mouse: Visual tracking of body features to provide computer access for people with severe disabilities. *IEEE Transactions on Neural Systems and Rehabilitation Engineering*, 10(1),
3. Cecotti, H., & Rivet, B. (2014). Subject combination and electrode selection in brain-computer interface design. *Frontiers in Human Neuroscience*, 8, 175.
4. Devlin, J., Chang, M. W., Lee, K., & Toutanova, K. (2018). BERT: Pre-training of deep bidirectional transformers for language understanding. *arXiv preprint arXiv:1810.04805*.
5. Duchowski, A. T. (2007). *Eye Tracking Methodology: Theory and Practice* (2nd ed.). Springer.
6. Felzer, T., & Rinderknecht, S. (2009). Analyzing the effectiveness of dynamically adjustable virtual keyboards in assistive technology. *ACM Transactions on Accessible Computing (TACCESS)*, 1(2), 1-23.
7. Holmqvist, K., Nyström, M., Andersson, R., Dewhurst, R., Jarodzka, H., & van de Weijer, J. (2011). *Eye tracking: A comprehensive guide to methods and measures*. Oxford University Press.
8. Jacob, R. J. K. (1991). The use of eye movements in human-computer interaction techniques: What you look at is what you get. *ACM Transactions on Information Systems (TOIS)*, 9(3), 152-169.
9. Lesher, G. W., Moulton, B. J., & Higginbotham, D. J. (1998). Techniques for augmenting scanning communication. *Augmentative and Alternative Communication*, 14(2), 81-101.
10. Majaranta, P., & Räihä, K. J. (2002). Twenty years of eye typing: Systems and design issues. *Proceedings of the 2002 Symposium on Eye Tracking Research & Applications*, 15-22.
11. Majaranta, P., & Bulling, A. (2014). Eye tracking and eye-based human-computer interaction. *Advances in Physiological Computing*, 39-65.
12. Morimoto, C. H., & Mimica, M. R. M. (2005). Eye gaze tracking techniques for interactive applications. *Computer Vision and Image Understanding*, 98(1), 4-24.
13. Santini, T., Fuhl, W., & Kasneci, E. (2017). CalibMe: Fast and unsupervised eye tracker calibration for gaze-based pervasive human-computer interaction. *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems*, 2594-2605.
14. X., Bulling, A., & Gellersen, H. (2013). Pupil-canthi-ratio: A calibration-free method for tracking horizontal gaze direction. *Proceedings of the 2013 ACM International Joint Conference on Pervasive and Ubiquitous Computing*, 261-270.
15. Ward, D. J., Blackwell, A. F., & MacKay, D. J. (2002). Dasher—a data entry interface using continuous gestures and language models. *Human-Computer Interaction*, 17(2-3), 199-228.

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International Journal of Advanced Research in Education and Technology

ISSN: 2394-2975 Impact Factor: 7.394

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