Eye Gaze Controlled Virtual Keyboard

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***Abstract*— Eye gaze technology has emerged as a transformative tool within Human-Computer Interaction (HCI), offering innovative solutions for individuals with physical disabilities. A review of the development and application of an eye gaze-controlled virtual keyboard demonstrates its potential to facilitate typing without the use of hands or fingers, empowering users with limited motor abilities. Key challenges in gaze detection, eye-blink differentiation, and interaction reliability are addressed, contributing to the fields of assistive technology and inclusive design. Experimental results validate the system's usability and accuracy, emphasizing its potential to improve the quality of life for users with mobility impairments.**

Keywords Gaze Tracking Algorithms, Pupil Detection, Landmark Detection, Visual Servoing, Optical Flow, Hough Transform, Thresholding Techniques, Neural Networks for Gaze Prediction, Eye Region of Interest (ROI), Pupil-Corneal Reflection (PCR), K-means Clustering, Camera Calibration, Head Pose Estimation, Saccadic Movements.

I. INTRODUCTION

Human-Computer Interaction (HCI) is a multidisciplinary field that focuses on the design and use of computer technology, emphasizing the interfaces between people (users) and computers. With the advancement of technology, traditional input devices like keyboards, mice, and touchscreens have become the standard modes of interacting with computers. However, for individuals with severe physical disabilities or conditions such as quadriplegia, amyotrophic lateral sclerosis (ALS), or neuromuscular diseases, using these conventional input devices is often impractical or impossible. In such cases, assistive technologies that can facilitate interaction through alternative methods are crucial.

Eye gaze tracking technology has emerged as a promising solution for enabling individuals with limited physical mobility to interact with digital devices. The human eye, especially the gaze and blinking, is a natural, constant source of non-verbal information. Researchers have recognized that eye movement can serve as an intuitive and efficient means for users to convey commands to a computer, allowing them to type, navigate, or even control a digital environment without using their hands.

II. PROBLEM STATEMENT

The goal of this project is to develop a virtual keyboard controlled by eye gaze and eye blinking, aimed at helping people with physical disabilities who cannot use their hands or fingers for typing. The system will detect the user's face and eyes using computer vision techniques, then track the movement of the eyes to select portions of a virtual keyboard. Eye blinking will be used as a selection mechanism for pressing keys. The system will assist disabled individuals in typing and interacting with computers using only their eye movements and blinks.

III. MOTIVATION

Eye gaze-controlled systems, such as virtual keyboards, are developed to assist individuals with physical disabilities who cannot use traditional input methods like typing. These systems enhance accessibility, allowing people with severe disabilities to interact with computers, continue education, and communicate. They also promote independence by enabling tasks like typing and browsing without external assistance. Advancements in technology drive the development of more inclusive Human-Computer Interaction (HCI) systems. These systems support physical and mental well-being, reduce fatigue, and help prevent isolation, allowing users to remain engaged in society.

IV. OBJECTIVE

A. **Enable Typing Without Using Hands**
The system allows users to type using only their eye movements and blinks, helping individuals with physical disabilities who cannot use their hands.

B. **Develop an Accessible HCI System**:
It creates an accessible interface for people with disabilities, providing an alternative way to interact with computers and communicate effectively.

C. **Use of Eye Gaze Technology for Efficient Typing:**
Eye-tracking technology is used to detect eye movements, allowing users to select keys on a virtual keyboard, facilitating efficient typing.

D. **Improve Independence for Physically Disabled Users**:
The system helps physically disabled individuals become more independent by enabling them to perform tasks like typing without relying on others.

E. **Develop a Real-time Face and Eye Detection System**:
It uses real-time video analysis to detect the user's face and eyes, leveraging algorithms like HoG and shape prediction for precise tracking.

F. **Minimize Errors and False Positives in Eye Movement Detection**:
The system works to reduce errors in detecting eye movements and blinks, ensuring more reliable inputs and a smoother user experience.

G. **Ensure Compatibility with Different User Profiles**:
The system is adaptable for various users, including those wearing glasses, and works well under different lighting conditions to ensure effective eye detection.

IV. APPLICATION

1. **Assistive Technology for Disabled Individuals**: Enables people with physical disabilities, particularly those with limited mobility in their limbs, to interact with computers and write without using hands or fingers.

2. **Human-Computer Interaction (HCI)**: Facilitates more accessible and intuitive interfaces, particularly for individuals with severe motor impairments.

3. **Typing for People with Severe Disabilities**: Useful for individuals who can only perform involuntary actions like eye blinking, allowing them to type using their eye gaze.

4. **Eye Tracking for Communication**: Provides a means for individuals with conditions like ALS, spinal cord injuries, or locked-in syndrome to communicate and use a computer by tracking eye movements and blinking.

5. **Security and Access Control**: Eye gaze detection can also be integrated into security systems for user authentication or surveillance, leveraging biometric traits.

6. **Virtual Environments**: Used in virtual reality (VR) or augmented reality (AR) environments for interaction through gaze, enhancing user experience.

7. **Educational Tools for Disabled Students**: Can be a vital tool for students with disabilities to continue their education and interact with digital learning platforms

V. LITERATURE SURVEY

Electrooculogram-based Virtual Reality game control using blink detection and gaze calibration
in 2016 Intl. Conference on Advances in Computing, Communication and Informatics (ICACCI).

This paper explores the design and implementation of an Electrooculogram (EOG) and gaze-based hands-free interaction system for virtual reality (VR) games. Traditional interfaces such as joysticks, keyboards, and data gloves are seen as obtrusive, hampering the immersive VR experience. To address this, the study introduces a natural interface utilizing eye blinks and gaze calibration to interact with the VR environment. The prototype game "VRrailSurfer" was developed to demonstrate the feasibility of the proposed system.

The methodology involved the detection of eye movements and blinks using EOG signals captured through six electrodes. The signals were amplified, filtered, and processed to classify specific movements like blinks, double-blinks, and directional gaze shifts using a support vector machine (SVM). Eye gaze calibration was conducted to estimate gaze direction, which enabled navigation within the game.

The "VRrailSurfer" game used eye blinks for actions like jumping on trains or collecting coins and gaze estimation for switching tracks. Ten subjects (8 male, 2 female) participated in testing, achieving an average game control accuracy of 78%. Although the system demonstrated high blink detection accuracy (96%), challenges like head-mounted display (HMD) movement affecting electrode impedance were noted.

The study highlights the potential of EOG-based controls for enhancing VR gaming by providing a natural and immersive experience. However, issues such as user fatigue due to frequent eye movements and limitations in gaze calibration efficiency need further investigation. Future work aims to improve gaze detection accuracy and expand the prototype's applicability to more complex VR games.

The paper underscores the feasibility of using EOG-based hybrid Brain-Computer Interfaces (BCIs) as a safe and effective alternative for natural VR interaction, paving the way for more intuitive gaming experiences.

Paper details : “Devender Kumar, Amit Sharma”

Computer Vision Based Eye Gaze Controlled Virtual Keyboard for People with Quadriplegia in 2021 International Conference on Automation, Control and Mechatronics for Industry 4.0 (ACMI).

Quadriplegia makes people incapable of performing even simple day-to-day activities. As the disease progresses, individuals lose most of their ability to communicate. Quadriplegia, also termed tetraplegia, affects the spinal cord, causing paralysis that prevents the brain from sending signals to the body below the shoulders. Causes of quadriplegia include accidents, spinal cord diseases, and tumors, which can result in partial or total limb paralysis. In children, the condition may arise due to oxygen deprivation during childbirth or complications from infectious diseases. This necessitates the development of assistive technology tailored to their limited voluntary movements, often restricted to the eyes.

Eye tracking serves as the foundation for the virtual keyboard proposed in this paper. Eye tracking refers to estimating the user’s gaze direction, which can help identify the object or area being focused on, such as screen coordinates. Iris detection plays a crucial role in gaze estimation. Most eye-tracking methods treat it as a circular analysis problem. Various methods, including a Viola-Jones face detector combined with a tracking

learning algorithm, have been employed for eye detection. Other approaches, such as electrooculography (EOG) or fuzzy logic-based systems, face limitations in processing time or cost.
Several eye-tracking systems have been designed for communication or control, such as the i-Riter for writing on a screen or multi-modal virtual keyboards. However, these models are often costly, require specific hardware, or are less efficient. Existing systems often lack an intuitive mechanism for gaze and blinking detection to facilitate smoother text entry. In contrast, the proposed system leverages real-time algorithms for eye-blink detection using a standard webcam. It achieves cost-effective, efficient communication for individuals with quadriplegia.

The virtual keyboard developed in this study consists of 40 keys, including letters, numbers, a space key, and a delete key. Sequential activation of keys is controlled by the user's eye gaze and blinking. Users can navigate forward or backward on the keyboard by looking right or left, respectively. When a specific key is highlighted, blinking at the correct moment types the corresponding character, with audio feedback provided for confirmation. This setup eliminates the need for specialized hardware, making it affordable and accessible.

Paper details : "Md. Robiul Islam, Md. Sazedur Rahman, Anamica Sarkar"

EyeBoard: A Fast and Accurate Eye Gaze-Based Text Entry System in IEEE Proceedings of 4th International Conference on Intelligent Human Computer Interaction, Kharagpur, India, December 27-29, 2012

The paper presents a study on the performance of a gaze-based text entry system called EyeBoard, which aims to improve text input efficiency and accuracy for users with eye-tracking devices. The hypothesis of the study is that participants would take more time to learn the EyeBoard layout but would eventually outperform other designs in terms of text entry rate and error correction after becoming familiar with the system.

Key dependent measures for the experiment include text entry rate (words per minute), uncorrected error rate, corrected error rate, and total error rate. The study involved 8 participants who completed a total of 1152 trials over multiple sessions using four different keyboard designs. The EyeBoard system showed a significant improvement in text entry rate compared to the other designs, achieving an average of 5.02 words per minute (WPM), which is 20.83% faster than the baseline Design 1. Additionally, the uncorrected error rate for EyeBoard was the lowest among the designs, with a significant difference in error rates between designs. The EyeBoard layout also achieved faster text entry speeds as users became more familiar with the system, showing a clear learning curve.

The study also included subjective evaluations, where participants reported that eye typing was easier than expected, although slower than using conventional keyboards. Despite initial challenges, participants found dynamic dwell time adjustment to be particularly important for improving performance. Additionally, there was no significant difference in terms of fatigue between sessions, and participants reported that the speed adjustment for typing was clear and easy to use.

The paper concludes that while EyeBoard achieved faster text entry rates than other designs, accuracy remained a challenge due to the trade-off between speed and errors. Despite this, EyeBoard proved to be an effective and easy-to-learn system for gaze-based text entry, and future research is suggested to focus on minimizing visual search time, reducing dwell time, and improving accuracy further through features such as spell checkers and adaptive dwell times.

Paper details : "Prateek Panwar, Sayan Sarcar2, Debasis Samanta"

VI. PROPOSED METHODOLOGY

1. Face Detection:

- **Technique Used:** Histogram of Oriented Gradients (HoG) for detecting faces.
- **Algorithm:** HoG-based face detection involves scanning sub-windows across an image to identify gradient orientations in localized regions. The system uses a combination of HoG and linear Support Vector Machine (SVM) classifiers to detect human faces.
- **Implementation:** The face is located by detecting the presence of these gradient-based patterns, making it easier to proceed with eye detection.

2. Eye Detection:

- **Technique Used:** The system uses a facial landmark detection approach, specifically the 68-point face landmark method, which pinpoints key facial features such as the eyes, eyebrows, nose, and lips.
- **Algorithm:** Developed by Vahid Kazemi and Josephine Sullivan (2014), this model identifies critical points on the face, such as:
  - Left Eye: Points (36, 37, 38, 39, 40, 41)
  - Right Eye: Points (42, 43, 44, 45, 46, 47)
- **Implementation:** Using dlib's pre-trained shape predictor model, the system is capable of detecting these points on the face to focus on the eye area, facilitating eye gaze and blink detection.

3. Eye Blink Detection:

- **Technique Used:** Eye blink detection is based on tracking the vertical and horizontal displacement of the iris when the eyes are open and closed.
- **Algorithm:** The system draws two lines, one vertical and one horizontal, across the eye. During a blink, the iris disappears (vertical line vanishes) and the upper and lower eyelids meet, signifying the blink.
- **Implementation:** The eye blink is detected when the system measures the disappearance of the vertical line, marking the transition from an open to a closed eye.

4. Eye Gaze Detection:

- **Technique Used:** The system tracks the gaze direction of the user's eye to determine the area of the virtual keyboard that the user is focused on.
- **Algorithm:** By detecting the eyeball's position and applying a threshold to the image, the system identifies whether the user is looking left, right, or center. The ratio of the gaze in the left and right eyes is used to determine which half of the keyboard to activate.
- **Implementation:** The gaze direction is calculated by analyzing the pupil's movement relative to the white part of the eye, and the system can detect three gaze points: left, center, or right.

5. Virtual Keyboard Setup:

- **Keyboard Layout:** The virtual keyboard is split into two sections: the left part contains alphanumeric keys (1-5, Q-Z, Space, Delete), and the right part contains the rest of the digits, letters (6-0, Y-P, B-N, Space, Delete), and special symbols.
- **Interaction:** The keys on the screen are sequentially illuminated. The user is expected to look at a key until it lights up and then blink to select it. The left and right sections of the keyboard are selected based on the user's gaze direction.

6. Key Selection and Typing:

- **Action Trigger:** When the user's gaze points to a specific key on the keyboard, that key lights up. The system waits until the key is illuminated, and once it happens, the user blinks to select the key.
- **Time Delay:** Each key is illuminated for a set number of frames (10 frames per key) before proceeding to the next key. This ensures that the user has enough time to focus on the key before selection.

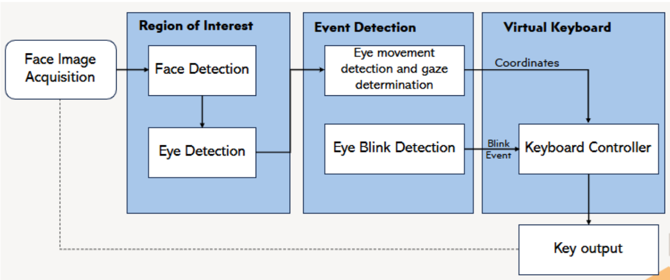

Fig 1.1 System Architecture

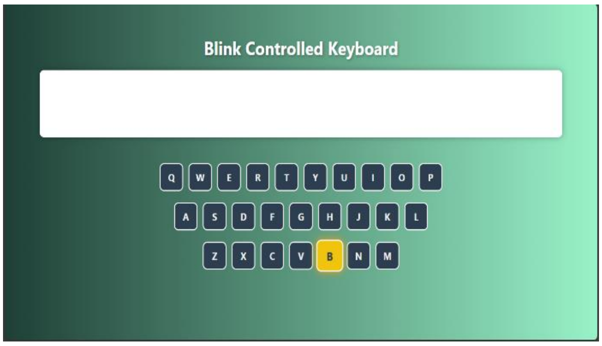

Fig. 1 Virtual Keyboard

VII.Results and Discussion

This system worked well in combining basic computer vision techniques to build a hands-free virtual keyboard. The face detection part using HoG was quite reliable when the user's face was clearly visible and in front of the camera. However, it sometimes struggled if the face was turned or the lighting was poor.

The eye detection method using facial landmarks accurately located the eyes, which helped a lot in tracking gaze and detecting blinks. It worked best when the user was still and facing forward.

Blink detection using the eye shape (when the eye opens and closes) was effective, but it could sometimes give wrong results if the user moved too quickly or only blinked slightly. Gaze detection (checking where the user is looking – left, right, or center) gave good results most of the time, but reflections or low contrast in the eye area made it harder to track.

The virtual keyboard setup, where the keyboard was split and the user could blink to choose a letter, made the system easy to use. The time delay between key highlights helped give enough time to focus and blink, but it also slowed down the typing speed.

Overall, the project shows a practical way to help people with physical disabilities type without using their hands. With more improvements, like faster blink detection and better gaze accuracy, it can become even more useful and user-friendly.

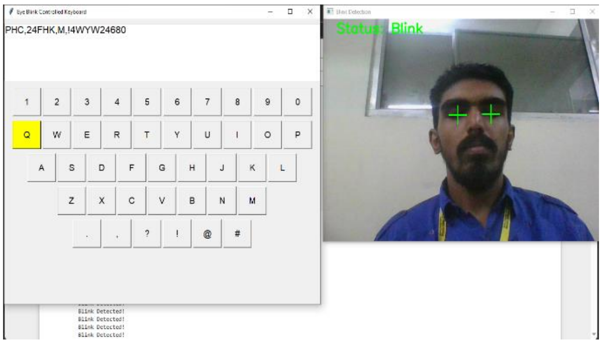

Fig.2 Blink detect and key print

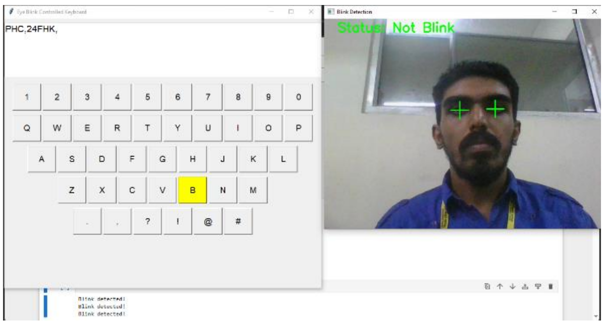

Fig.3 Not Blink and no key print

VIII.Challenges ans Limitation

- **Lighting Conditions**
  The system's performance heavily depends on good lighting. In low light or too much brightness, face and eye detection may fail or become less accurate.

- **Head Movement**
  If the user moves their head too much or turns to the side, the camera may lose track of the face or eyes, affecting blink and gaze detection.

- **Blink Detection Accuracy**
  Quick or partial blinks may not be detected properly. Sometimes normal eye movements or squints are wrongly detected as blinks.

- **Gaze Detection Limitations**
  The system only detects three gaze directions (left, center, right). It doesn't support more precise tracking, which limits control over small on-screen elements.

- **Typing Speed**
  Since each key lights up for a few frames before moving to the next, typing can be slow. Users need to wait and time their blink correctly, which requires practice.

- **Glasses and Eye Shape**
  Users wearing glasses or having unique eye shapes might face issues with eye tracking due to reflections or poor landmark detection.
- **Noisy Backgrounds**
  A cluttered or moving background can confuse the face detection system and reduce accuracy.

- **Hardware Dependence**
  The system needs a decent webcam and sufficient processing power. It may not run smoothly on older or low-performance computers.

IX.Conclusion

This project successfully demonstrates a low-cost, hands-free virtual keyboard system controlled through eye blinks and gaze direction. By using basic computer vision techniques like HoG for face detection and facial landmarks for eye tracking, the system can detect where the user is looking and when they blink to select keys on a virtual keyboard**.**

While the system works well under proper conditions, it still faces challenges like sensitivity to lighting, slow typing speed, and difficulty handling head movement or users with glasses. Despite these limitations, the project shows great potential for helping individuals with physical disabilities communicate more easily**.**

With further improvements in blink and gaze accuracy, speed, and user experience, this system could become a practical assistive tool for real-world use.

The eye blink and gaze-controlled virtual keyboard offers an innovative way for users, especially those with physical disabilities, to type without using their hands. By detecting the face, eyes, gaze direction, and blinks, the system allows users to select letters on a virtual keyboard in an interactive and hands-free manner.

Although the system works well in ideal conditions, it has some limitations like slower typing speed, sensitivity to lighting, and difficulty with head movements or glasses. Still, it proves that computer vision can be used effectively to create assistive technologies. With more improvements and testing, this system can become even more accurate, faster, and user-friendly for daily use.

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