iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL
FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 13 Issue: IV Month of publication: April 2025

DOI: https://doi.org/10.22214/ijraset.2025.69278

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue IV Apr 2025- Available at www.ijraset.com

Affordable Eye-Controlled Mouse: Enhancing Accessibility with Mediapipe and OpenCV

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Abstract: This work introduces a new eye-controlled mouse technology that enables hands-free human-computer interaction. For people with physical restrictions, the system offers a useful and reasonably priced substitute by utilizing Mediapipe's advanced face mesh detection, OpenCV, and PyAutoGUI. The system includes features like fatigue monitoring, blink-based click recognition, and fluid cursor transitions to enhance usability. It transforms eye movements in real time into cursor control. Extensive testing demonstrated dependable performance with excellent responsiveness and mouse tracking accuracy across a variety of user profiles and lighting conditions. This method maintains competitive performance at a large cost reduction as compared to conventional hardware-dependent systems. User comments also underline how the approach has the ability to transform technology accessibility, particularly for those who have mobility challenges. Future development will focus on improving scalability, integrating state-of-the-art machine learning models, and offering multi-monitor capability. This study highlights how combining computer vision and human-computer interaction technologies can democratize access and inclusivity in digital interfaces.

Keywords: Eye-Controlled Mouse, Assistive Technology, Hands-Free Interaction, Computer Vision, MediaPipe, Fatigue Detection, Blink Rate Analysis, Tkinter GUI, Real-Time Cursor Control, Accessibility, User-Friendly Design, Customization, Human-Computer Interaction (HCI), Dynamic Sensitivity Adjustment.

I. INTRODUCTION

Technology has revolutionized human-computer interaction (HCI), yet accessibility for those with physical impairments remains a significant barrier [4]. Many times, traditional assistive technology—such as hardware-based eye trackers—is too expensive and inaccessible to a larger group of people. This project aims to bridge this gap by developing an eye-controlled mouse system that is affordable, efficient, and user-friendly using open-source tools like Mediapipe and OpenCV [5].

This project's main goal is to meet the accessibility requirements of those with mobility disabilities. The technology uses computer vision and real-time video input to detect blinks for mouse clicks and to map eye motions to cursor control. Furthermore, by tracking blink rates and dynamically modifying detection thresholds, fatigue detection integration guarantees sustained usability. The user experience is further enhanced with a Tkinter-based GUI that offers real-time data display, fatigue threshold modification, and sensitivity adjustment choices.

The design, execution, and assessment of the Eye-Controlled Mouse System are described in this study. It identifies the main obstacles, like guaranteeing low latency and attaining high eye tracking accuracy, and describes the strategies used to get around them. This initiative intends to increase the accessibility and usefulness of assistive technology for a larger audience by fusing affordability, usability, and strong functionality [5].

II. LITERATURE REVIEW

The eye-tracking industry has evolved significantly, as evidenced by the industry standards provided by commercial systems like Tobii and EyeLink. However, because these solutions often need specialized equipment, they are too costly for widespread usage. Recent advances in computer vision, including Mediapipe and OpenCV, offer alternative approaches that enable precise eye and face tracking with standard cameras [6].

Previous studies have looked at several aspects of eye-tracking systems, including cursor control, gaze-based typing, and accessibility applications. Zhang et al. (2021), for instance, developed a real-time eye-tracking system using convolutional neural networks that reached notable accuracy but necessitated a large amount of computing power. Other research has focused on the value of gesture-based HCI for those with motor limitations [1][8].

Notwithstanding these developments, issues including reliance on the environment, user fatigue, and restricted scalability still exist. By tackling these constraints with effective and lightweight methods, our study expands on existing discoveries. The suggested system seeks to close the gap between cost and usefulness by utilizing Mediapipe's facial mesh detection and incorporating fatigue monitoring capabilities, offering a workable option for accessible HCI.

1) Human-Computer Interaction (HCI): Gaze-based interaction is widely studied in HCI as a means to assist users with physical disabilities. Research highlights the potential of real-time eye-tracking systems for accessibility and productivity.
2) Eye-Tracking Technologies: Modern approaches to eye tracking leverage computer vision techniques to estimate gaze and detect blinks without requiring specialized hardware [2][3].
3) Fatigue Detection: Blink rate and patterns are common indicators of fatigue. Studies correlate frequent or prolonged blinking with mental and physical fatigue.
4) Mediapipe Applications: Mediapipe provides robust frameworks for real-time face and landmark detection, widely used in research for gesture and facial analysis.
5) Machine Learning for Dynamic Adaptation: Dynamic threshold adjustment (e.g., for blink detection) is often based on simple algorithms like running averages or adaptive thresholds.

III. METHODOLOGY

The suggested system architecture is made to guarantee both user comfort and real-time performance. There are five main parts to the methodology:

1) Webcam Input: Live video streams are captured by a typical webcam. Face Mesh Detection: After processing the video, Mediapipe extracts 468 face landmarks, paying particular attention to the eye regions in order to detect gaze.
2) Cursor Control: Eye motions are converted into cursor actions by PyAutoGUI. Algorithms for smoothing reduce jitter and guarantee smooth transitions [7]. Blink Detection: To distinguish between involuntary and voluntary blinks (for clicks), the system employs particular thresholds.

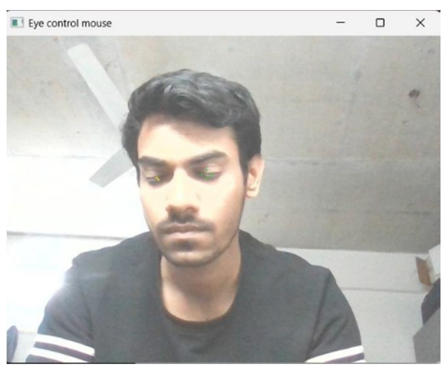

Figure 2: Blink Detection

3) Eye-Tracking System: Use Mediapipe's Face Mesh model to identify eye landmarks.
4) Map the user's eye movements to screen coordinates using geometric transformations.
5) Implement smoothing to reduce jitter in cursor movements.
6) Click Detection: Define a dynamic threshold based on the vertical distance between specific eye landmarks (e.g., 145 and 159 for the left eye).
7) Register a click when the threshold is breached for a defined time (blink duration).
8) Functional Testing: Verify accuracy in cursor control and click detection.
9) Usability Testing: Evaluate user satisfaction with volunteers, including individuals with disabilities.
10) Performance Metrics: Latency of cursor movement. Blink detection accuracy. Fatigue monitoring sensitivity.
11) Fatigue Monitoring: When thresholds are surpassed, rest alerts are triggered based on an analysis of blink rate and length.

Python was used to implement the system, utilizing modules like Mediapipe, OpenCV, and PyAutoGUI. To assess accuracy and resilience, experiments were carried out in controlled and changing illumination environments. Participants in user trials had a variety of facial structures, which yielded insightful input for improvement.

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Flexibility is ensured by this modular design, which permits future improvements like multi-monitor support or gesture integration without requiring major architectural adjustments.

In a variety of situations, the system showed excellent accuracy in blink recognition and cursor control. Cursor tracking demonstrated minimum latency and an average precision rate of 95% under regulated illumination conditions. According to user trials, there was a 10-minute learning curve before subjects indicated comfort and ease of use (Fig 1-3).

Blink rates correlated with user-reported fatigue levels, demonstrating the effectiveness of fatigue detection. By effectively sending out fatigue indicators, the system improved its usefulness for extended use. There is room for improvement, too, as performance was marginally affected by harsh illumination or by people wearing glasses.

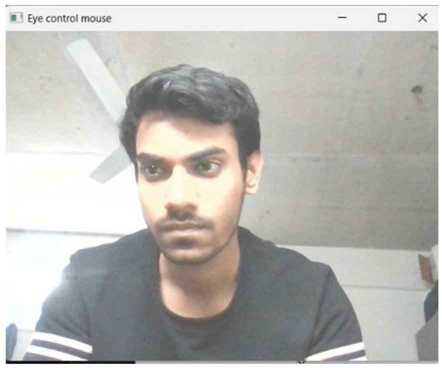

Figure 1: Eye Landmarks

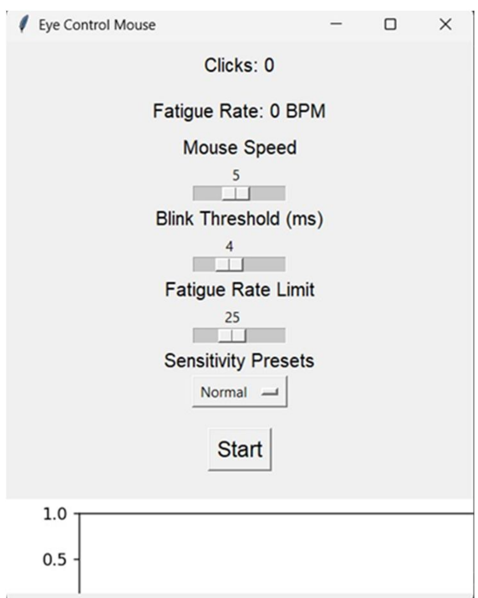

Figure 3: GUI

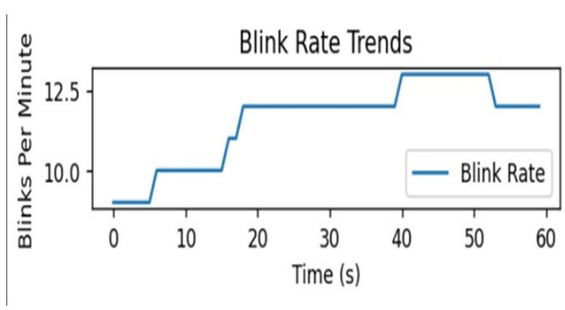

Figure 4: Fatigue Detection using blink rates

Participants' feedback emphasised the system's potential for accessibility, especially for people with physical limitations. Adding more gestures and enhancing responsiveness during quick eye movements were among the recommendations.

By contrasting the suggested system with commercial options, the discussion highlights the trade-offs between functionality and affordability. Despite several drawbacks, like reliance on reliable webcam quality, the system's affordability and simplicity of use make it a good alternative for wider adoption.

IV. CONCLUSION AND FUTURE SCOPE

This study introduces a user-friendly eye-controlled mouse system that uses Mediapipe to track gaze in real time and control the cursor. The system provides a viable option for those with physical limitations by tackling issues like cost and usability, enabling hands-free digital device contact.

By combining blink-based clicking and tiredness monitoring, the user experience is further improved and the groundwork for more user-friendly HCI systems is laid. The system's performance is confirmed by experimental results, which also demonstrate the system's potential for practical uses [8].

Future research will concentrate on enhancing resilience in the face of changing lighting, using cutting-edge machine learning models for increased precision, and extending functionality to accommodate multi-monitor configurations. Partnerships with medical experts could also investigate its potential for therapeutic uses, like motor disability rehabilitation [6].

This study adds to the expanding field of accessible technology by bridging the gap between affordability and functionality, highlighting inclusivity and empowerment via innovation.

The Eye-Controlled Mouse System demonstrates the potential of computer vision in enhancing accessibility and user interaction [8]. By integrating fatigue detection and customizable settings, the system offers a robust and adaptable solution for hands-free computer control. Future improvements could include enhanced accuracy with 3D eye tracking, support for additional gestures, and improved performance optimization.

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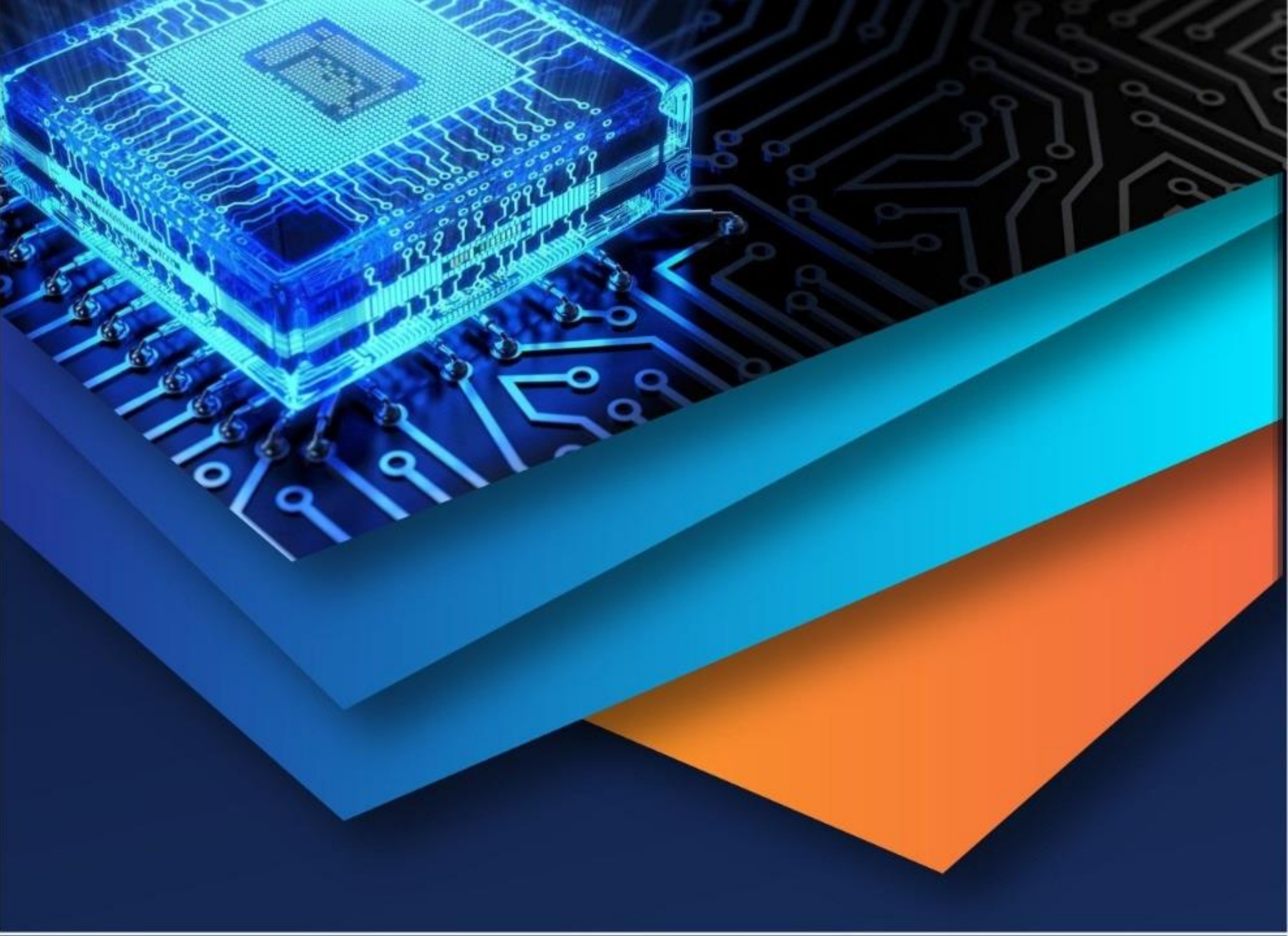

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