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# EyeVox: A Secure Multimodal Gaze and Voice-Controlled System for Hands-Free Human–Computer Interaction

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**Abstract: EyeVox is a secure multimodal human–computer interaction system designed to enable hands-free desktop interaction using eye gaze and voice input. The system utilizes realtime iris and facial landmark detection through MediaPipe to control mouse cursor movement based solely on eye movements, eliminating the dependency on conventional input devices such as keyboards and mice. Additionally, a voice assistant module allows users to execute system commands and perform authentication using a predefined voice phrase.**

**To enhance security, EyeVox integrates dual-biometric authentication combining gaze behavior and voice recognition. Advanced security mechanisms including role-based access control, continuous authentication, intelligent threat detection, shoulder surfing resistance, and immutable audit logging are incorporated to protect against unauthorized access, spoofing attacks, and session hijacking.**

**The system is specifically designed with accessibility in mind, making it suitable for users with physical or motor impairments. Experimental evaluation on consumer-grade hardware demonstrates low latency, high authentication accuracy, and stable real-time performance. EyeVox offers a scalable, cost-effective, and secure solution for assistive computing and modern secure desktop environments.**

***Keywords:*** *Gaze Tracking, Voice Assistant, Multimodal Biometrics, Human–Computer Interaction, Continuous Authentication, Shoulder Surfing Protection, Secure Systems, Accessibility.*

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## I. INTRODUCTION

The increasing reliance on digital systems in personal, academic, and professional environments has created a strong demand for interaction methods that are both intuitive and secure. Traditional input devices such as keyboards and mice are not always suitable for users with physical disabilities and may also pose security risks in shared environments. Password-based authentication mechanisms are vulnerable to attacks such as shoulder surfing, brute-force attempts, and credential theft.

Hands-free interaction systems based on biometric inputs provide a promising alternative by improving accessibility while enhancing security. Among various biometric modalities, eye gaze and voice input are natural, non-intrusive, and well-suited for continuous interaction. However, systems relying on a single biometric modality remain vulnerable to spoofing and replay attacks.

EyeVox addresses these challenges by combining eye gaze tracking and voice recognition into a unified multimodal framework. The system allows users to move the mouse cursor using eye movements, execute commands through voice interaction, and securely authenticate using live biometric behavior. Since authentication depends on continuous gaze and voice patterns, EyeVox is inherently resistant to shoulder surfing attacks.

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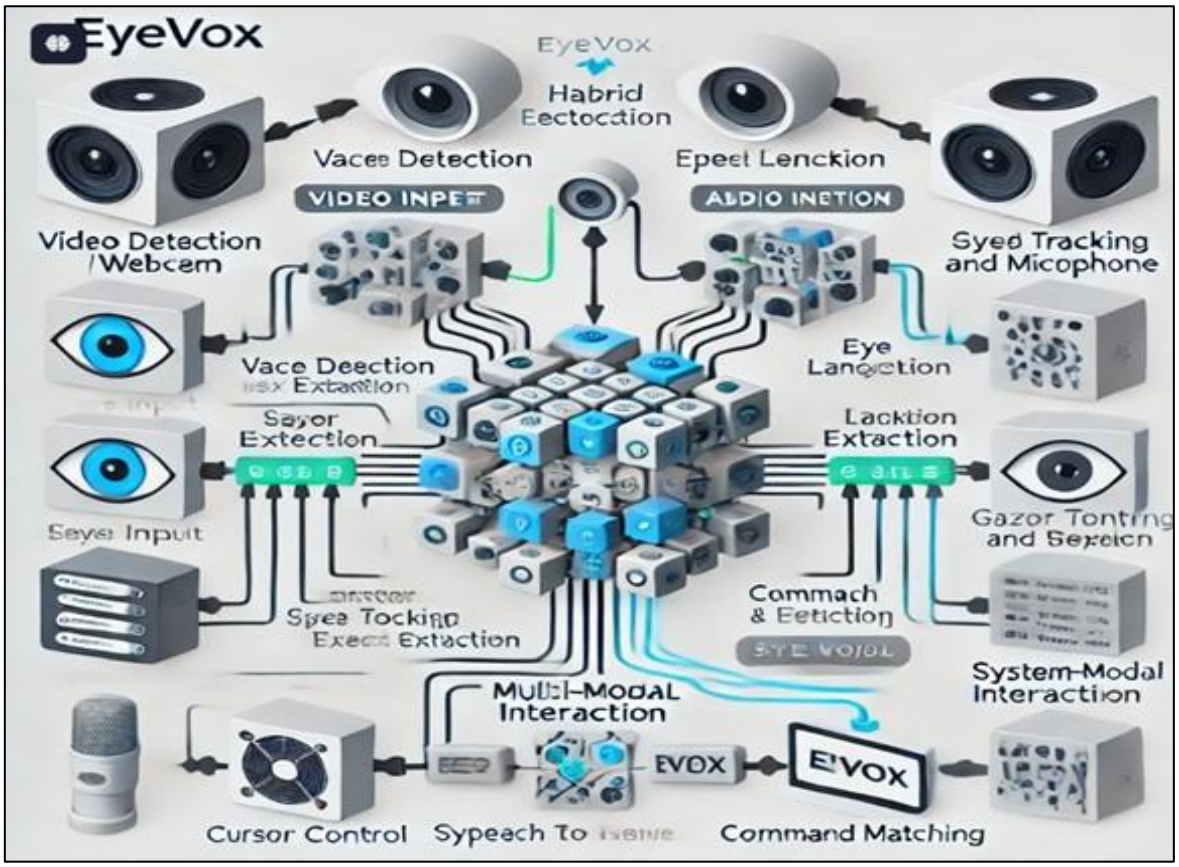

Fig 1 Overall EyeVox System Architecture

## II. RELATED WORK

➢ *Gaze-Based Interaction Systems*

Gaze-based interaction systems have been extensively researched as assistive technologies for users with motor impairments. Early systems relied on infrared sensors and dedicated eye-tracking hardware, offering high accuracy but at significant cost. Recent advancements in computer vision have enabled webcam-based gaze estimation, making such systems more accessible.

Although modern gaze tracking systems provide acceptable accuracy for cursor control, many existing solutions focus solely on interaction and do not incorporate strong security mechanisms.

➢ *Voice Assistants and Biometric Authentication*

Voice assistants such as Google Assistant and Amazon

Alexa demonstrate the effectiveness of speech-based interaction. Voice biometrics have also been explored for authentication due to their convenience. However, voice-only authentication is vulnerable to replay and deepfake attacks, necessitating the use of additional biometric factors.

## III. LITERATURE SURVEY

Multimodal human–computer interaction research indicates that combining gaze and voice improves reliability, usability, and security. Systems such as GazeSpeak demonstrate that gaze and speech together enhance interaction efficiency, particularly for users with disabilities.

MediaPipe Face Mesh enables real-time facial landmark and iris tracking using deep learning models optimized for consumer hardware. Speech recognition frameworks such as Vosk provide efficient real-time voice processing. Security literature highlights the importance of continuous authentication, behavioral biometrics, and immutable audit logging to prevent session hijacking and insider threats.

## IV. SYSTEM ARCHITECTURE

EyeVox follows a modular architecture consisting of gaze tracking, voice recognition, authentication and security management, logging, and a graphical user interface. The webcam continuously captures facial landmarks for gaze estimation, while the microphone captures voice input for command execution and authentication.

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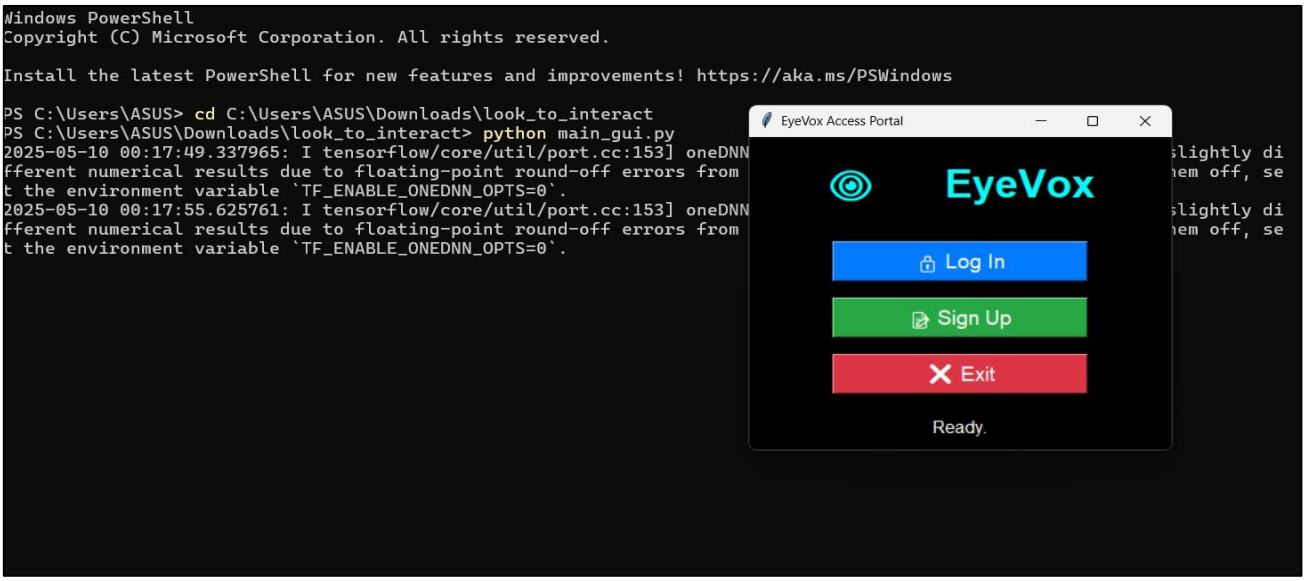


Fig 2 Gaze and Voice Interaction Flow in EyeVox

A centralized security engine coordinates biometric verification, role-based access control, threat detection, and session monitoring.

## V. METHODOLOGY

➢ *Eye-Based Cursor Control*

EyeVox uses MediaPipe Face Mesh to detect iris position and eye landmarks. Cursor movement is calculated based on the relative position of the iris within the eye region. Smoothing and sensitivity adjustment techniques are applied to reduce jitter and improve usability.

➢ *Voice Assistant Module*

Voice input is captured via a microphone and processed using speech recognition models. The voice assistant enables actions such as mouse click, scrolling, application launching, and authentication phrase recognition.

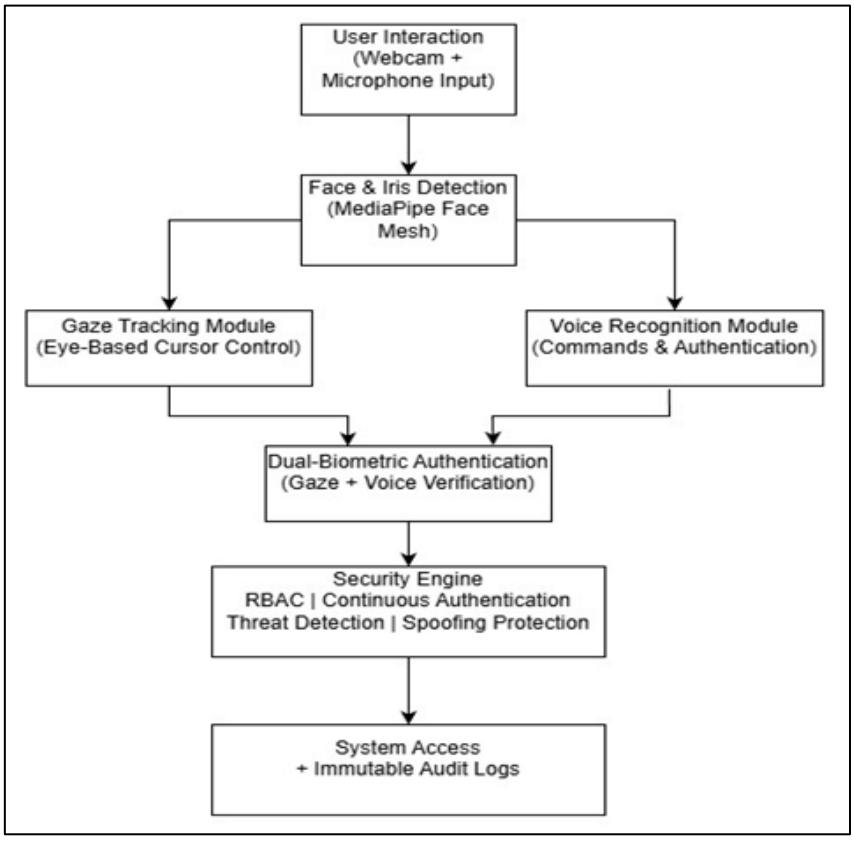


Fig 3 Methodology Workflow of the EyeVox System

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➢ *Dual-Biometric Authentication*

System access requires both correct gaze behavior and voice phrase verification. This dual-biometric approach significantly reduces spoofing, replay, and shoulder surfing attacks, as both biometric traits must be live and synchronized.

➢ *Role-Based Access Control*

EyeVox assigns roles such as Administrator, User, and Auditor. Each role has restricted permissions, ensuring that sensitive operations are accessible only to authorized users.

➢ *Continuous Authentication*

User identity is continuously verified throughout the session by monitoring gaze behavior and voice interaction patterns. Any abnormal deviation triggers re-authentication or automatic session termination.

➢ *Threat Detection and Shoulder Surfing Protection*

The system detects brute-force login attempts, deepfake voice anomalies, camera spoofing using images or videos, and repeated authentication failures. Shoulder surfing attacks are mitigated as authentication relies on live biometric behavior rather than visible credentials.

➢ *Audit and Compliance Logging*

All authentication and access events are recorded in immutable, append-only logs with timestamps. These logs support forensic investigation and regulatory compliance.

## VI. RESULTS AND PERFORMANCE EVALUATION

Experiments were conducted on a standard laptop with a 720p webcam and integrated microphone. Gaze tracking latency remained below 100 ms, enabling smooth cursor movement. Voice command accuracy averaged 92% in quiet environments. Dual-biometric authentication achieved a 95% success rate for enrolled users.

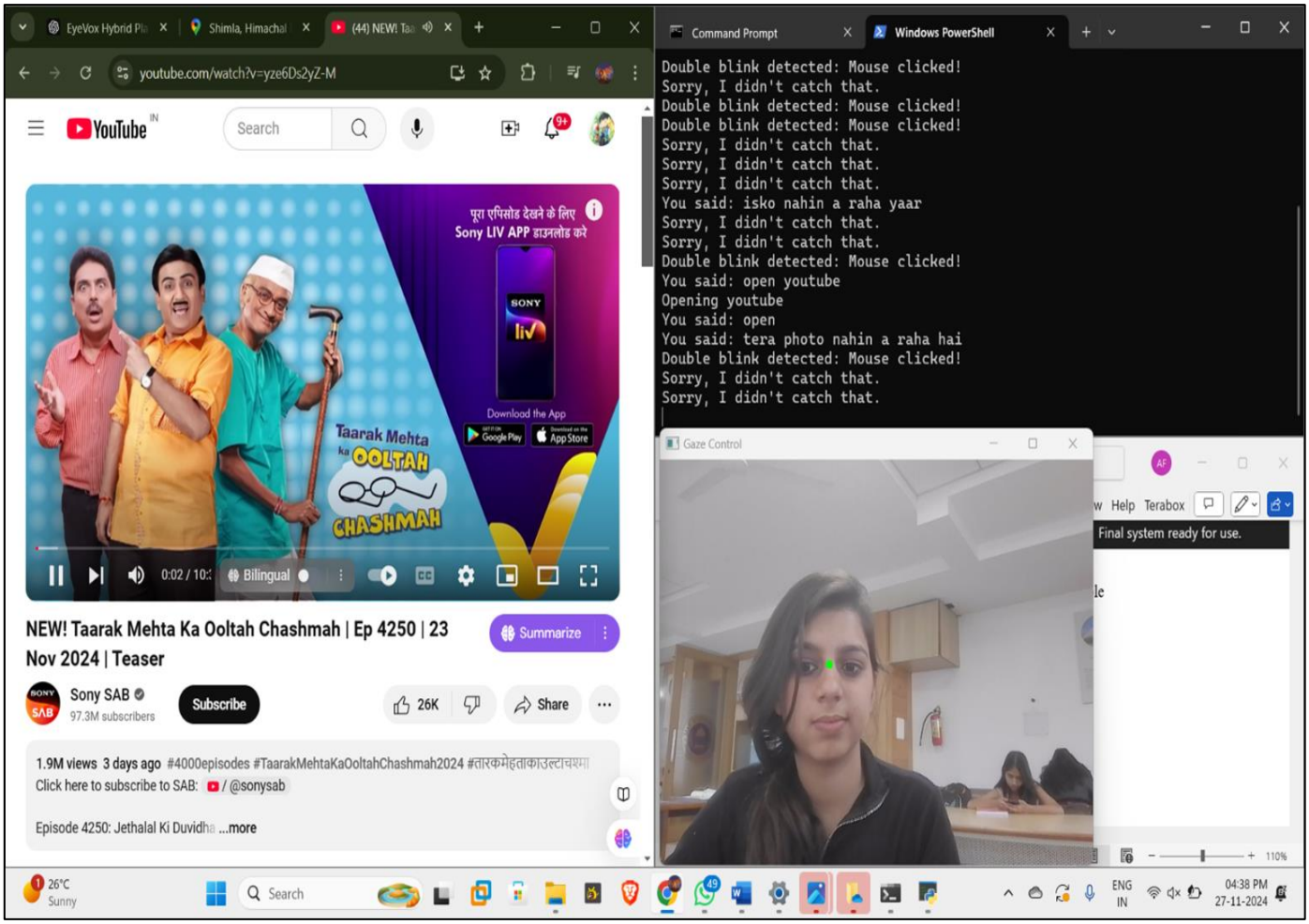


Fig 4 EyeVox Authentication and Interaction Results

User testing demonstrated improved accessibility, reduced physical strain, and high user satisfaction during extended usage.

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## VII. COMPARISON ANALYSIS WITH EXISTING METHODS

➢ *Comparison with Traditional Method*

Table 1 Comparison of Eyevox with Traditional Systems

| Feature | Traditional | EyeVox |
|---|---|---|
| Input Method | Keyboard, Mouse | Eye Gaze + Voice |
| Hands-Free Usage | No | Yes |
| Authentication | Password / PIN | Gaze + Voice |
| Shoulder Surfing Risk | High | Low |
| Spoofing Protection | Low | High |
| Continuous Auth. | No | Yes |
| RBAC Support | No | Yes |
| Audit Logs | No | Yes |
| Accessibility | Limited | High |
| Security Level | Low | High |

Traditional human–computer interaction systems primarily rely on physical input devices such as keyboards and mice, along with password-based authentication mechanisms. While these systems are widely adopted, they present limitations in terms of accessibility, security, and usability, especially for users with physical impairments or in shared computing environments. Recent advances have introduced single-modal biometric systems such as voice-based or gaze-based interaction; however, these approaches still suffer from security and reliability issues.

This section compares EyeVox with conventional and existing interaction and authentication methods to highlight its advantages.

From the comparison, it is evident that EyeVox overcomes the limitations of traditional and single-modal systems by combining multimodal interaction with advanced security mechanisms. The integration of gaze-based cursor control, voice-assisted commands, dual-biometric authentication, and continuous security monitoring makes EyeVox more secure, accessible, and reliable for modern computing environments.

## VIII. FUTURE SCOPE

Although EyeVox demonstrates effective hands-free interaction and strong security in its current form, several enhancements can be explored to further improve scalability, privacy, and robustness.

➢ *Federated Learning for Privacy-Preserving Biometrics*

Future versions of EyeVox can integrate federated learning to enable decentralized training of biometric models directly on user devices. In this approach, raw biometric data such as eye patterns and voice samples are never transmitted to a central server. Instead, only encrypted model updates are shared, significantly reducing the risk of data breaches. This enhancement would improve user privacy and ensure compliance with modern data protection regulations such as GDPR and India's DPDP Act.

➢ *Blockchain-Based Identity Verification*

A blockchain-based identity framework can be incorporated to store hashed biometric identity proofs instead of raw biometric data. By leveraging the immutability and decentralization properties of blockchain technology, EyeVox can achieve tamper-proof identity verification and eliminate single points of failure associated with centralized databases. This approach can further enhance trust and transparency in authentication processes.

➢ *Adaptive Noise and Environment Handling*

Future work can focus on improving system robustness under varying environmental conditions. Adaptive noise cancellation techniques and environment-aware calibration can be integrated to enhance voice recognition accuracy in noisy settings and improve gaze tracking performance under different lighting conditions.

➢ *Multi-User and Cross-Device Support*

EyeVox can be extended to support multiple user profiles on a single system, enabling secure and personalized interaction in shared environments. Additionally, cross-device integration can allow users to authenticate and interact seamlessly across multiple desktops or smart devices using a unified biometric identity.

➢ *Advanced Threat Detection Using Machine Learning*

The threat detection module can be further enhanced by incorporating machine learning-based anomaly detection techniques. By learning normal user behavior patterns over time, the system can more accurately detect sophisticated attacks such as deepfake voice synthesis, replay attacks, and behavioral impersonation attempts.

Overall, these future enhancements aim to transform EyeVox into a more intelligent, privacy-aware, and scalable multimodal interaction platform suitable for next-generation secure and assistive computing environments.

## IX. CONCLUSION

This paper presented EyeVox, a secure multimodal human– computer interaction system that integrates eye-

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controlled cursor movement and voice-based interaction to enable hands-free desktop usage. By leveraging real-time gaze tracking and voice recognition, EyeVox reduces dependency on traditional input devices, making it particularly suitable for users with physical impairments and secure computing environments.

EyeVox distinguishes itself through its strong security architecture, incorporating dual-biometric authentication based on gaze behavior and voice verification. The system effectively mitigates common security threats such as shoulder surfing, spoofing attacks, and unauthorized access through continuous authentication, role-based access control, threat detection, and immutable audit logging. Experimental evaluation demonstrated low latency, high accuracy, and stable realtime performance on consumer-grade hardware, validating the practicality of the proposed approach.

Overall, EyeVox demonstrates that usability, accessibility, and security can be successfully combined within a unified interaction framework. With future enhancements such as federated learning and blockchain-based identity verification, the system has the potential to evolve into a scalable and privacypreserving platform for next-generation human–computer interaction and assistive computing applications.

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