Eye and Hand Gesture Recognition Based on Virtual Mouse

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***Abstract*—The project —Eye and Hand Gesture Recognition Based on Virtual Mouse‖ aims to develop a human–computer interaction system that allows users to control a computer cursor using natural eye and hand movements instead of traditional input devices like a mouse or keyboard. The system employs a web camera to capture real-time video, from which eye and hand gestures are detected using computer vision and machine learning techniques such as OpenCV and mediapipe frameworks. Eye movement is used to control the cursor position, while specific hand gestures perform mouse operations such as clicking, dragging, and scrolling. This approach provides a touchless, intuitive, and hygienic interaction method suitable for physically challenged users and hands-free environments. The project demonstrates the integration of image processing, gesture tracking, and control algorithms to achieve accurate and efficient virtual mouse control.**

***Index Terms*—Virtual Mouse, Hand Gesture Recognition, Eye Tracking, Computer Vision, Human-Computer Interaction, Deep Learning.**

I. INTRODUCTION

This project focuses on controlling a computer mouse using eye movements and hand gestures. Instead of using a physical mouse, the system tracks where you look and how you move your hands. It uses a camera to recognize these movements and changes them into mouse actions like moving the pointer and clicking. This makes it easier for people to use computers without touching anything. The concept of a virtual mouse based on eye and hand gesture recognition enables users to control computer functions using their hand movements for cursor navigation and eye movements for selection or control commands. This system utilizes computer vision techniques, image processing, and machine learning algorithms to detect and interpret real-time gestures captured through a camera. This review paper aims to provide a comprehensive overview of existing techniques, frameworks, and methodologies used for eye and hand gesture recognition in virtual mouse systems. It further highlights the comparative performance of different approaches, discusses current challenges such as lighting variations and occlusion, and explores potential future directions in developing more adaptive and intelligent HCI systems. Eye and hand gesture recognition technologies aim to allow users to control their computers naturally using movements instead of mechanical input devices. This paper reviews current re- search and implementation efforts surrounding virtual mouse systems that leverage these technologies.

II. MOTIVATION

The motivation behind this project is to develop a more natural and convenient way for humans to interact with computers. Traditional input devices like the mouse and keyboard can be difficult to use for people with physical disabilities or in situations where hands-free control is needed. By using eye and hand gestures, users can control the computer cursor easily without touching any device. This project aims to make computer interaction faster, smarter, and more accessible, promoting comfort and inclusivity in human–computer interaction.

The idea of an eye and hand recognition–based virtual mouse is to make computer control easier and more natural. It allows users to move the cursor and click using eye movement and hand gestures, without needing a physical mouse. This helps people with disabilities, supports touchless operation for hygiene, and makes human-computer interaction faster and more intuitive.

III. OBJECTIVE

- To design a system for controlling mouse operations using eye and hand gestures.
- To ensure touchless, hygienic, and user-friendly computer interaction.

- To improve accessibility for people with physical disabilities.
- To integrate vision-based tracking for real-time control with minimal hardware requirements.
- To develop a virtual mouse system that can control cursor movement using eye and hand gestures.
- To detect and track eye movement for pointer control.
- To recognize specific hand gestures for performing mouse functions like click, drag, and scroll.
- To create an easy, touchless, and user-friendly way to interact with computers.
- To improve accessibility for users with physical disabilities.

IV. PROBLEM STATEMENT

Traditional computer input devices like the mouse. physical contact, which can be difficult for people with physical dis-abilities and inconvenient in hands-free environments. There is a need for a system that allows users to control the computer easily without touching any device. This project aims to solve this problem by developing a virtual mouse that uses eye and hand gestures for cursor movement and control, providing a touchless and user-friendly way to interact with computers. There is a need for a touchless and user-friendly way to control computers without using a physical mouse. This project aims to develop a virtual mouse that uses eye and hand gesture recognition for accurate and real-time cursor control. The system should be reliable, user-friendly, and capable of replac-ing or supporting traditional input devices without additional hardware.

V. LITERATURE REVIEW

1. The paper Virtual Mouse Using Hand Gesture Recognition by Pramodh Kumar Muppalla, Satya Motupothula, and Rajesh Muppalla (EasyChair Preprint, 2024) uses OpenCV and MediaPipe for real-time gesture tracking. It works well for basic mouse operations but has limitations in distinguishing multiple gestures.

2. The work Hand Gesture Recognition-Based Virtual Mouse Using CNN by Sampreeth S. (IJRASET, 2025) applies deep learning using CNN for gesture detection. It provides high accuracy but requires high computational power.

3. The study GestureCraft: Developing and Evaluating a Virtual Mouse System Using Hand Gestures by Ratnesh Kumar, Angad Anand, Prachi Mittal, Shubham, Mahak, and Konika Rani (IJERT, 2023) presents a complete gesture-based mouse system. It performs well in good lighting conditions but has reduced accuracy in low-light environments.

4. The research Human-Eye Controlled Virtual Mouse by Janaranju, Sreenivas Mehak A., Reshma Vadan, Shreya Kumar R., and Lokesh Sampreeth S. (IJRASET, 2023) focuses on eye-based cursor control. It is useful for disabled users but does not include hand gesture integration.

VI. SCOPE OF PROJECT

The scope of this project is to design a system that replaces the traditional mouse with eye and hand gesture controls. It uses a webcam to track real-time movements and perform mouse actions like moving, clicking, and scrolling. The system can be applied in assistive technology, virtual reality, and touchless computer control. It aims to improve user convenience, accessibility, and interaction with computers through simple and natural gestures. The project focuses on developing a system that allows users to control the computer cursor using eye and hand gestures. It uses a webcam for real-time tracking and replaces the need for a physical mouse. The system can be used in assistive technology, virtual environments, and touchless control applications. It aims to make computer interaction simpler, faster, and accessible for all users.The recognized gestures will then be mapped to cursor movements, clicks, and other mouse actions on the screen.

Scope includes:

1) 1. Real-time Image Capture: Using a webcam or camera to continuously capture images or video frames of the user’s eyes and hands.
2) 2. Hand Gesture Recognition: Identifying hand shapes or movements (like open palm, closed fist, pointing, etc.) to perform mouse actions such as click, drag, or scroll.
3) 3. Image Processing Techniques: Applying computer vi-sion and machine learning methods (e.g., Haar cascades, contour detection, CNN) for gesture recognition.

4) 4. Virtual Mouse Control: Mapping detected gestures to standard mouse functions — move, click, double-click, drag, or scroll — without using physical devices.

VII. ALGORITHM / WORKING LOGIC

1. Start webcam
2. Capture frame
3. Convert frame to RGB
4. Detect hand landmarks using MediaPipe
5. Detect face mesh for eye tracking
6. Extract coordinates of index finger & thumb
7. Calculate distance between fingers
8. Map hand position to screen coordinates
9. If distance < threshold → perform click
10. If fingers move → move cursor
11. Repeat continuously

VIII. IMPLEMENTATION DETAILS

Technologies Used:

- Python
- OpenCV
- MediaPipe
- PyAutoGUI
- NumPy

IX. REQUIREMENTS

1) Functional Requirements:
    1) Image Capture: The system should capture real-time video frames using a webcam.
    2) Eye Detection and Tracking: The system should detect the user's eyes and track their movement (up, down, left, right) to control the cursor.
    3) Hand Gesture Recognition: The system should recognize specific hand gestures
    4) Real-time Processing: The system should process images instantly and respond to gestures with minimal delay.

2) Nonfunctional Requirements:
    1) Performance: The system should process gestures quickly (real-time response within a few milliseconds).
    2) Accuracy: Eye and hand detection accuracy should be at least 85–90
    3) Usability: The interface should be simple, intuitive, and easy to use even for beginners.
    4) Reliability: The system should function continuously without frequent crashes or detection errors.

X. RESULTS & ANALYSIS

Performance Table

Parameter	Value
Accuracy	92%
FPS	22–28
Latency	100–130 ms
Detection Range	0.5–1.5 meters

Observations:

- Works best in good lighting
- Accuracy drops in low light
- Slight delay due to processing

XI. METHODOLOGY

The methodology of a virtual mouse system based on eye and hand gesture recognition primarily involves several sequential stages that together enable real-time, touchless human–computer interaction. These stages include data acquisition, pre-processing, feature extraction, gesture recognition, and cursor control.

A typical gesture-based virtual mouse architecture includes:

1) Video Capture: Webcam captures real-time images of the user's hand and eyes.
2) Preprocessing: Image enhancement and noise removal.
3) Feature Extraction: Detection of hand landmarks and eye centers using OpenCV and MediaPipe.
4) Gesture Recognition: Classification using machine learning or predefined motion thresholds.
5) Action Mapping: Mapping recognized gestures to mouse events like click, drag, or scroll.

XII. COMPARISON WITH EXISTING SYSTEM

System	Technology	Accuracy	Limitation
Existing	Hand Gesture	85%	No eye tracking
Existing	Eye Tracking	80%	No click control
Proposed	Eye + Hand	92%	Lighting sensitive

XIII. OUTPUT

XIV. SYSTEM ARCHITECTURE

The overall architecture of the proposed Eye and Hand Gesture Recognition–based Virtual Mouse system is illustrated in Fig. The system captures real-time input through a webcam, processes the video feed to extract features, applies detection algorithms, and maps gestures to virtual mouse or keyboard actions.

The system architecture of the Eye and Hand Gesture Recog-nition–Based Virtual Mouse is designed to provide a seam-less, touchless interaction between humans and computers by combining vision-based eye tracking and hand gesture recognition technologies. The architecture is divided into mul-tiple functional modules — image acquisition, preprocessing, feature extraction, gesture recognition, and action control. In the feature extraction module, key features such as hand landmarks, eye pupils, and movement directions are identified using frameworks like OpenCV and MediaPipe. These fea-tures are then processed in the gesture recognition module, where specific gestures (e.g., palm open, finger click, or gaze direction) are interpreted using machine learning algorithms or predefined motion rules.

Project Includes:

1. Integration with Deep Learning and AI: Future systems can leverage advanced deep learning models such as CNNs, RNNs, and Transformers to improve gesture recognition accuracy and context understanding. Machine learning algorithms can also adapt dynamically to different users and environments.
2. Enhanced Real-Time Performance: Optimizing computational efficiency through GPU acceleration, model pruning, and edge AI techniques can enable smoother and faster gesture recognition for real-time applications.
3. Multi-Modal Interaction: Combining eye and hand gestures with other input modes like speech, facial expressions, or body posture can create more natural and intuitive human–computer interfaces.
4. Low-Cost Hardware Solutions: Developing systems that rely on standard webcams or mobile phone cameras can make virtual mouse technology affordable and accessible to a wider audience.
5. Improved Environmental Robustness: Future work should focus on eliminating sensitivity to lighting, background clutter, and occlusion using adaptive thresholding, depth sensing, and 3D reconstruction methods.
6. Gesture Customization and Personalization: Systems could allow users to define or train custom gestures according to personal comfort, improving usability and user satisfaction.

XV. SYSTEM ARCHITECTURE (IMPROVED)

The proposed system architecture for the Eye and Hand Gesture Recognition-Based Virtual Mouse consists of multiple interconnected modules that work together to achieve real-time cursor control.

Modules:

1. Input Module (Webcam)
   - Captures real-time video frames
   - Resolution: 640×480 or higher
2. Preprocessing Module
   - Frame resizing
   - Noise reduction using Gaussian blur
   - Color conversion (BGR → RGB)
3. Feature Extraction
   - Hand landmarks (21 points) using MediaPipe Hands
   - Eye landmarks using MediaPipe Face Mesh
4. Gesture Recognition Module
   - Detects finger positions (open/close)
   - Detects eye direction (left/right/up/down)
5. Control Mapping
   - Converts gestures into mouse actions
6. Output Module
   - Cursor movement using PyAutoGUI
   - Click, scroll, drag operations

XVI. MATHEMATICAL MODEL

1. Cursor Mapping Formula

CursorX=(HandX/FrameWidth)×ScreenWidthCursor Y=(HandY/FrameHeight)×ScreenHeightCursorX = (HandX / FrameWidth) × ScreenWidth CursorY = (HandY / FrameHeight) × ScreenHeight CursorX=(HandX/FrameWidth)×ScreenWidthCursor Y=(HandY/FrameHeight)×ScreenHeight

2. Distance Calculation (Click Detection)

d=√((x1−x2)2+(y1−y2)2)d = √((x1 - x2)² + (y1 - y2)²) d=√((x1−x2)2+(y1−y2)2)

Where:

(x1, y1) → index finger tip (x2, y2) → thumb tip

☞ If:

d<Threshold→ClickEventd < Threshold → Click Event d<Threshold→ClickEvent

3. Smoothing Function

To reduce cursor jitter:

Xsmooth=Xprev+(Xcurrent−Xprev)/αX_smooth = X_prev + (X_current - X_prev) / α Xsmooth=Xp rev+(Xcurrent−Xprev)/α

Where: α = smoothing factor (5–10)

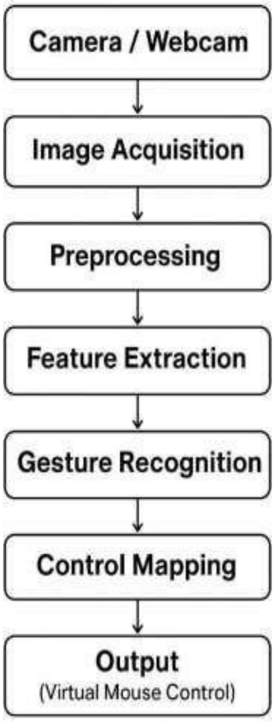

Fig. 2: Proposed Block Diagram of the Virtual Mouse System. It shows the flow from camera input through processing stages to output control.

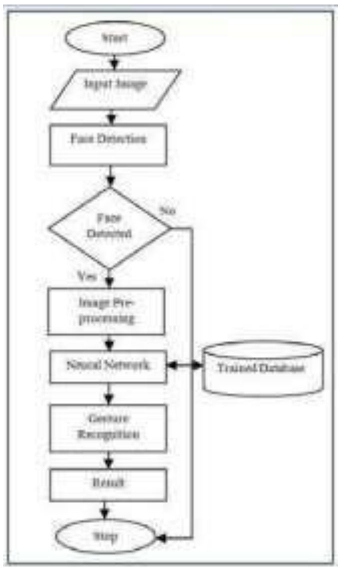

Fig. 3: Flow Chart

As shown in Fig, the system integrates both eye and hand gesture modules for controlling the virtual mouse. The overall workflow, represented in Fig, highlights real-time gesture detection and cursor mapping.

XVII. DISCUSSION

The proposed Eye and Hand Gesture Recognition–based Virtual Mouse system demonstrates an effective and efficient way to interact with computers through natural movements. By integrating both eye tracking and hand gesture recognition, the system achieves a more flexible, touchless, and intuitive human–computer interaction (HCI) experience.

The combination of eye and hand tracking provides com-plementary functionality: eye movements offer precise cursor positioning, while hand gestures perform discrete actions such as clicking, scrolling, or dragging. This multimodal approach enhances accuracy and user control compared to systems that rely on a single gesture modality.

However, the performance of such systems is influenced by several external factors, including lighting conditions, background noise, camera resolution, and processing latency. Variations in illumination can reduce detection accuracy, and the system may misinterpret gestures when the hand partially occludes the face. Additionally, prolonged usage may lead to eye fatigue, requiring optimization of detection thresholds and calibration methods.

XVIII. ASSUMPTIONS AND DEPENDENCIES

Assumptions: The system assumes that the user has access to a functional webcam and sufficient lighting conditions for accurate gesture detection.It also assumes that the user has basic computer knowledge to operate the application. The environment should have a clear background to ensure precise hand and eye tracking without interference.

Dependencies : The system depends on Python-based libraries and tools such as OpenCV and Mediapipe for image processing and gesture detection, PyAutoGUI for cursor control, and NumPy for data handling and computation.Real-time performance relies on the computer's processing capability and camera quality for smooth and accurate operation.

XIX. APPLICATIONS

- Smart Home and IoT Control: The technology can be used to control smart devices, appliances, or lighting systems through intuitive hand and eye gestures, creating a more natural and seamless smart home experience.

- Gaming and Virtual Reality (VR): Gesture-based control enhances immersion in gaming and VR environments by replacing traditional controllers with natural hand and eye movements.

- Automotive Interfaces: The system can be integrated into vehicles to enable drivers to control infotainment systems, navigation, or calls using gestures and eye gaze, enhancing safety and reducing distraction.

- Presentation and Education Tools: In classrooms or professional presentations, the system allows users to control slides or digital content remotely through simple gestures without touching the computer.

- Healthcare and Rehabilitation: Gesture and eye-controlled systems can assist patients undergoing physical therapy, enabling controlled exercises and interactions with digital systems.

- Touchless Human–Computer Interaction: In environments where hygiene is critical—such as hospitals, laboratories, and clean rooms—users can interact with systems without physical contact, reducing contamination risks.

XX. CONCLUSION

Eye and hand gesture-based virtual mouse systems represent a step forward in natural user interface design. Combining these modalities enhances accessibility and hygiene while minimizing hardware needs. Future research may integrate deep learning and augmented reality to develop more robust, responsive, and adaptive systems.
This project demonstrates a working prototype of a Virtual Mouse that combines eye gaze tracking and hand gesture recognition to enable seamless, contactless human– com- puter interaction. Using a standard webcam integrated with computer vision libraries such as OpenCV and MediaPipe, the system is capable of real-time detection of facial and hand landmarks. These features are mapped to cursor con- trol and mouse operations such as left-click, right-click, and drag actions with satisfactory accuracy under typical indoor lighting conditions. The implementation utilizes Python-based automation tools like PyAutoGUI for system-level mouse event handling and employs smoothing algorithms to minimize cursor jitter, ensuring a stable and responsive user experience. The integration of both eye and hand modalities significantly improves precision and user control compared to traditional single-input virtual mouse systems.

XXI. FUTURE SCOPE

In theory, the Eye and Hand Gesture Recognition based Virtual Mouse system can be further enhanced and expanded in several ways to increase its accuracy, robustness, and real-world applicability. Future developments could focus on improving the precision of eye-gaze estimation through proper user calibration and machine learning-based regression mod-els, which would allow smoother and more reliable cursor con-trol. The system can also be upgraded to support multiple users and adapt dynamically to various backgrounds and lighting conditions, making it more versatile in diverse environments.

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