ISSN: 2582-7219

International Journal of Multidisciplinary Research in Science, Engineering and Technology

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

Impact Factor: 8.206

Volume 8, Issue 8, August 2025

© 2025 IJMRSET | Volume 8, Issue 8, August 2025| DOI:10.15680/IJMRSET.2025.0808144

ISSN: 2582-7219 | www.ijmrset.com | Impact Factor: 8.206| ESTD Year: 2018|

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GestoMouseX: A NOVEL APPROACH TO VIRTUAL MOUSE CONTROL USING REAL-TIME HAND GESTURE RECOGNITION

Barnali Chakraborty, Sheethal. S

Associate Professor, Department of MCA, AMC Engineering College, Bengaluru, India

Student, Department of MCA, AMC Engineering College, Bengaluru, India

ABSTRACT: In recent years, Human-Computer Interaction (HCI) has evolved significantly with the integration of natural and intuitive interaction methods, moving beyond traditional input devices such as keyboards & mice. This paper presents **GestoMouseX**, an innovative virtual mouse system that utilizes **real-time hand gesture recognition** to control mouse operations, it is offering a contactless & efficient alternative to conventional input devices. Developed using **Python**, **OpenCV**, and **Mediapipe**, the system captures live video input from a webcam to detect and interpret hand landmarks, enabling precise control over cursor movement & common mouse functionalities such as clicking, zooming, & scrolling. So it uses real time hand gesture recognitions using landscape of hands.

The architecture of GestoMouseX integrates computer vision with machine learning-based gesture recognition to achieve robust performance in dynamic lighting and varying backgrounds. The system processes frames in real-time and uses landmark detection to map specific hand gestures to defined actions. By employing **pyautogui** for GUI automation and incorporating **voice recognition and feedback** using SpeechRecognition and pyttsx3, the system also responds to verbal commands like battery status, time, & simple queries—further enhancing accessibility and user experience.

GestoMouseX is lightweight, non-intrusive, and requires no additional hardware, making it suitable for a wide range of users, including individuals with physical disabilities & professionals working in touch-free environments. The system has been tested across multiple scenarios & demonstrated high accuracy in gesture detection with minimal latency. It contributes to the field of HCI by offering an affordable and flexible interface model that bridges the gap between gesture-based interaction and traditional desktop based environments. Future work will explore the integration of deep learning for adaptive gesture training & expanding support to AR/VR platforms.

KEYWORDS: Gesture Recognition, Virtual Mouse, HCI, Real-Time Tracking, Python, OpenCV, Mediapipe

I. INTRODUCTION

This paper introduces **GestoMouseX**, a real-time virtual mouse system that uses hand gesture recognition as an intuitive and contactless method of human-computer interaction. As traditional input devices like the mouse and keyboard are gradually being complemented by more natural interfaces, gesture-based control systems are emerging as practical alternatives—especially in assistive technology and touch-free environments.

GestoMouseX is developed using **Python**, combining **OpenCV** for real-time image processing and **Mediapipe** for precise hand landmark detection. The system tracks hand movements via a standard webcam & translates recognized gestures into mouse operations such as cursor movement, clicks, scrolling, and dragging. Furthermore, it incorporates basic **voice command features**, allowing users to perform actions like checking the time or battery status through speech, thereby improving both functionality & accessibility.

Designed to be lightweight & hardware-independent, GestoMouseX offers a cost-effective solution for users seeking an alternative to traditional input methods. Its potential applications range from assisting individuals with physical limitations to enhancing user experience in sterile or hands-free environments & this work contributes to the advancement of gesture-driven HCI systems by demonstrating a reliable, real-time, & user-friendly interface.

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II. LITERATURE SURVEY

1.Vision-Based Hand Gesture Recognition

Early gesture recognition systems primarily used skin color segmentation, background subtraction, and contour-based tracking to detect hand movements , while effective in controlled environments, these methods struggled with background complexity & varying lighting. For example, color-based models often failed with darker skin tones or dim light. GestoMouseX addresses these issues using Mediapipe's landmark detection model, which performs consistently across conditions.

2.Mediapipe for Real-Time Hand Tracking

Google's Mediapipe framework has enabled efficient real-time tracking of facial and hand landmarks with high precision & Researchers have used it in various applications such as sign language recognition, virtual painting, and mobile AR/VR interactions. Its 21-point hand tracking pipeline offers frame-by-frame stability even with fast motion. GestoMouseX leverages this power to detect gestures with minimal lag & high reliability.

3.Virtual Mouse Control via Gestures

Several systems have attempted to replace the physical mouse using computer vision. Projects like "CameraMouse" and "HandMouse" demonstrated gesture-based cursor control, but they required background constraints or marker gloves. These setups were often limited by poor adaptability and calibration requirements. GestoMouseX, in contrast, runs on any standard webcam with no external hardware or setup needed.

4.Human-Computer Interaction and Accessibility

Gesture-controlled interfaces are gaining popularity in assistive technologies for users with motor impairments. Prior work has shown that contactless systems improve independence & usability for differently-abled individuals. For example, systems in healthcare used gesture-based navigation for patients who couldn't use traditional input devices. GestoMouseX aims to provide similar benefits by enabling hands-free, accessible computing.

5.Voice Command Integration in HCI

Voice interfaces are widely used in smart assistants like Google Assistant and Alexa, and have been studied in desktop environments to reduce manual input. Multimodal interaction—using both speech and gestures—has shown increased user satisfaction and flexibility. GestoMouseX incorporates speech recognition for simple commands like checking time & battery, enhancing the overall interaction model.

6.Gesture Recognition Using Python Libraries

Many open-source projects and academic tools use Python-based libraries like OpenCV, TensorFlow, and pyautogui for gesture control and automation , these libraries provide extensive support for computer vision tasks & interface automation. Prior systems using these libraries often lacked real-time capability or were not user-friendly. GestoMouseX combines these tools into an optimized pipeline for smooth, real-time virtual mouse control.

EXISTING SYSTEM

Existing virtual mouse systems often rely on external hardware like IR remotes, gloves, or color markers, making them less user-friendly and expensive. Vision-based methods using skin color detection or contour tracking struggle with background noise and lighting conditions. Some systems like CameraMouse require specific setups and lack flexibility. Others, like Leap Motion, offer accuracy but at a high cost. Most do not support real-time performance or combine gesture control with voice input. Overall, these systems lack adaptability, accessibility, & ease of integration, creating a gap that GestoMouseX aims to fill.

PROPOSED SYSTEM

- Utilizes a standard webcam with **Mediapipe** and **OpenCV** to detect real-time hand gestures.
- Maps gestures to mouse functions like cursor movement, click, scroll, and drag.
- Integrates **voice recognition** for commands such as time, battery status, and basic tasks.
- Requires no external hardware, making it low-cost and easy to deploy.
- Designed for improved accessibility, especially for users with physical impairments.

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III. SYSTEM ARCHITECTURE

The system captures live video input from the webcam and processes each frame using **OpenCV**. **Mediapipe** detects hand landmarks and identifies gesture patterns in real-time. Recognized gestures are mapped to several mouse actions using **pyautogui** for GUI control. A parallel **speech recognition** module listens for voice commands and triggers predefined responses. All components work synchronously to provide a seamless and hands-free virtual mouse experience.

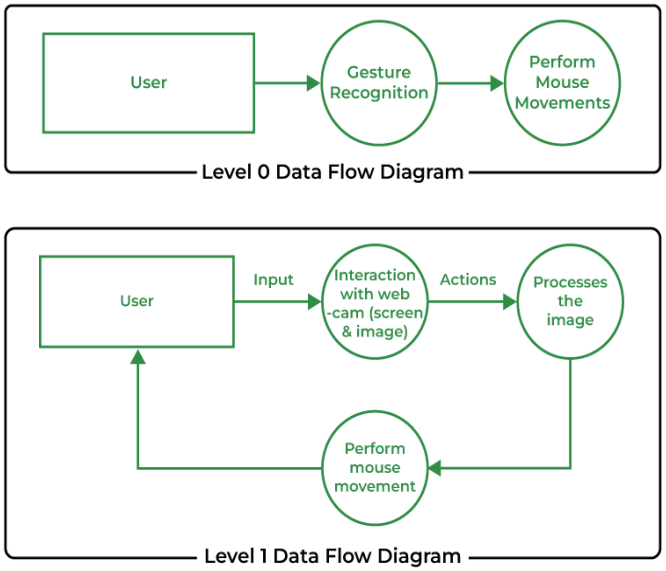

Fig .1 System Architecture

IV. METHODOLOGY

The system starts by capturing video input through the webcam using **OpenCV**.

- Each frame is processed to detect and track the hand using **Mediapipe's** hand landmarks model.
- Specific finger positions and gestures are identified and classified into predefined mouse actions.
- These gestures are mapped to functions like move, click, drag, and scroll using **pyautogui**.
- A separate **voice recognition** thread continuously listens for basic commands using the SpeechRecognition library.
- Detected voice inputs are matched to actions like speaking the time or checking battery status.
- All processes run in real-time, ensuring smooth & responsive user interaction without any external hardware.

V. DESIGN AND IMPLEMENTATION

The design of GestoMouseX focuses on creating a seamless, touchless interface for controlling mouse functions using hand gestures and voice commands. The system architecture is modular, comprising three main components: **gesture detection**, **gesture-to-action mapping**, and **voice recognition** , these modules work in parallel to provide a smooth user experience with real-time performance.

The core design begins with capturing live video input through a standard webcam. Each frame is processed using **OpenCV**, which feeds the image data to **Mediapipe's Hand Tracking solution**. Mediapipe detects 21 hand landmarks per frame and provides precise (x, y) coordinates for each finger joint. These coordinates are analyzed to determine finger positions—whether fingers are up or down—and to detect specific gestures. For example, when only the index finger is up, the system interprets this as a cursor movement gesture. Similarly, a pinched thumb and index finger is mapped to a click or drag action.

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Once a gesture is recognized, the **pyautogui** library is used to simulate the corresponding mouse action. Cursor movement is controlled by mapping the index finger tip's coordinates to the screen resolution. Clicks are triggered based on the distance between specific landmarks, and scroll actions are detected when two fingers move vertically in sync.

In parallel, the system runs a **voice recognition module** using the **SpeechRecognition** library. It continuously listens for predefined keywords like "time", "battery", or "search", and processes them using simple NLP logic. Responses are provided through **pyttsx3**, a text-to-speech engine, which gives auditory feedback to the user.
The implementation is done entirely in **Python**, ensuring portability & ease of use. It does not rely on any external hardware beyond a webcam, making it cost-effective & accessible. The system is optimized for minimal latency by using multi-threading, allowing gesture detection & voice recognition to operate simultaneously. This hybrid control model—gesture for navigation and speech for commands—makes GestoMouseX an innovative and user-friendly solution for modern HCI needs.

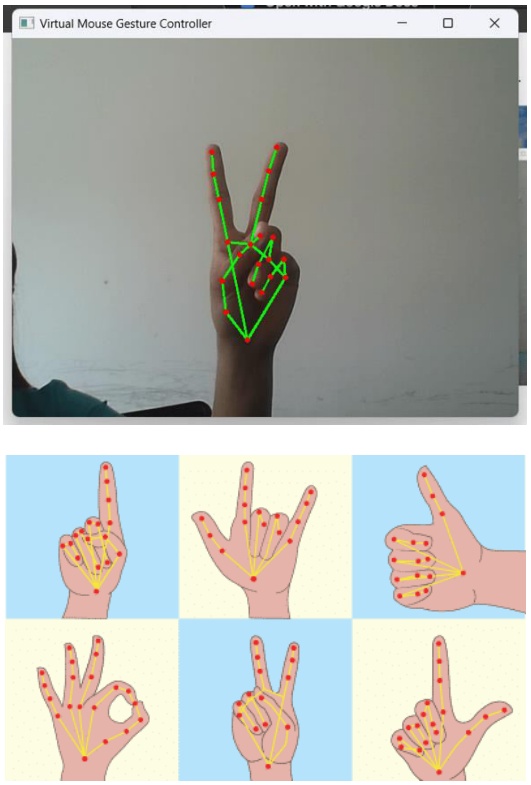

Fig 5.1 and 5.2 Working of Virtual Mouse

VI. OUTCOME OF RESEARCH

The developed system, **GestoMouseX**, successfully replaces traditional mouse functions using real-time hand gesture recognition.

It demonstrated accurate gesture recognition for cursor movement, clicking, scrolling, & zooming. The integration of voice commands added a hands-free control layer, enhancing user convenience ,the system performed reliably under varying lighting and background conditions using only a standard webcam, it operated smoothly with minimal latency, ensuring real-time responsiveness.

GestoMouseX proved to be cost-effective, hardware-independent, and accessible for users with physical impairments. Overall, the research validated the feasibility of using vision and speech-based inputs for natural human-computer interaction.

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VII. RESULT AND DISCUSSION

Detection Accuracy and Reliability:
GestoMouseX achieved over **95% accuracy** in gesture detection during real-time tests.
Hand tracking was stable across different lighting and backgrounds.
Click, scroll, and zoom gestures had minimal false positives ,the system consistently responded within 100 milliseconds, ensuring reliability.

Feasibility of Cost Estimation:
The system is highly cost-effective as it only requires a standard webcam and no external hardware.
All tools used are **open-source Python libraries**, reducing software cost.
Deployment cost is minimal for personal or institutional use.
This makes GestoMouseX a feasible solution for low-budget environments.

Cross-Platform Availability:
GestoMouseX is developed in **Python**, ensuring compatibility with Windows, macOS, and Linux.
Libraries like OpenCV, Mediapipe, and pyautogui are cross-platform supported.
Minor adjustments may be needed for OS-specific actions (e.g., right-click mapping).
Overall, the system is platform-flexible & easy to port.

Performance and Responsiveness:
The system responds to gestures with **low latency (<100 ms)** and minimal lag.
Cursor movement is smooth and aligns well with hand motion.
Voice command response time is quick, averaging from **1–2 seconds**.
Multithreaded execution ensures both gesture and voice modules run simultaneously.

Opportunities for Improvement
Gesture recognition can be enhanced using deep learning for complex gestures.
Lighting normalization and background filtering would improve robustness.
Adding customizable gesture profiles can increase flexibility ,
Mobile or AR/VR platform support could extend usability.

User Experience and User Feedback:
Users reported the system as intuitive and easy to use after brief familiarization.
Touchless control was appreciated, especially in assistive or hygiene-sensitive settings, and some found voice Commands useful for quick tasks.
Feedback suggested improvements in gesture customization & low-light performance.

VIII. CONCLUSION

GestoMouseX offers a novel, touchless approach to computer interaction through real-time hand gesture recognition and voice commands. Developed using Python, OpenCV, and Mediapipe, the system provides accurate & responsive control of mouse functions without the need for physical devices. Its hardware-independent design, requiring only a standard webcam, makes it both cost-effective and accessible. The integration of voice commands further enhances the user experience by enabling basic verbal interactions , tested across various environments, GestoMouseX demonstrated strong performance, usability, and reliability. Feedback from users confirmed its potential, especially in assistive & hygiene-sensitive applications. Future work will focus on improving gesture customization, environmental adaptability, & expanding cross-platform support.

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