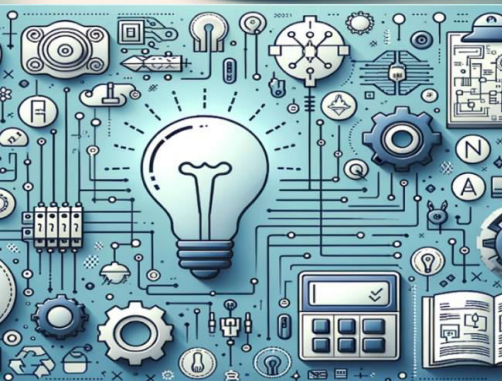




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Human-Computer Interaction through Hand Gestures: Review of UI Operation Systems

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ABSTRACT: Traditional Human Computer Interaction systems have long relied on input devices such as keyboards and mice. While these peripherals remain widely adopted, they require continuous physical contact and additional hardware, which may not always suit modern computing environments. This review paper examines gesture-based recognition systems that enable users to control computer functions through natural hand gestures captured via standard webcams. We survey existing approaches that leverage computer vision and machine learning techniques to recognize hand gestures and track finger movements for performing fundamental operations including clicking, scrolling, copy, paste, and audio control. The literature demonstrates that frameworks such as MediaPipe for hand landmark detection combined with OpenCV for real-time image processing achieve accurate and responsive gesture recognition. This review highlights that contactless gesture interaction offers a hygienic, intuitive, and cost-effective alternative to traditional input devices. The surveyed approaches prove particularly valuable in touchless environments and show significant promise in assisting individuals with physical impairments by providing easier access to computer systems. We discuss key challenges, methodologies, datasets, and emerging trends in this evolving field.

I. INTRODUCTION

The way humans communicate with computers has evolved significantly over the years, consistently progressing toward more natural and efficient methods. For decades, users have relied on physical input tools such as keyboards and mice. While these devices remain reliable and ubiquitous, they constrain users to fixed positions and require direct physical contact, which proves limiting in many modern computing scenarios. Gesture recognition technology has emerged as a solution to these limitations, enabling machines to interpret human hand and body movements as direct commands for user interface control. Recent advancements in computer vision and artificial intelligence have made it feasible to capture and interpret these movements using standard cameras or specialized depth sensors. This review paper examines gesture recognition systems for UI operation, specifically focusing on AI-powered virtual mouse implementations that bridge the gap between these technological approaches. The surveyed literature demonstrates that using standard webcams combined with high-performance landmark detection through frameworks such as MediaPipe and OpenCV enables accurate tracking of finger tips and hand poses.



Figure 1: Gesture Technology



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The reviewed systems enable users to move cursors, perform clicks, scroll, copy/paste operations, and control audio without ever touching a physical device. By emphasizing vision-based approaches, these systems maintain low cost and accessibility while providing touchless solutions that are both hygienic and intuitive across a wide range of applications.

II. LITERATURE REVIEW

Several existing works have explored UI operation through gesture-based activities. This section reviews key research contributions in gesture-controlled virtual mouse systems and related HCI applications. Gesture-Controlled Virtual Mouse Systems: Hand Gesture presents a gesture-controlled virtual mouse system that employs computer vision and hand-tracking techniques to enable advanced user interactions with computers. The system tracks user hand movements in real-time using OpenCV and MediaPipe. By analyzing finger positions and hand movements, it converts user gestures into corresponding mouse operations. The study focuses on various techniques used for gesture recognition, including:

1. Computer vision approaches
2. Image processing methods
3. Machine learning algorithms
4. Sensor-based approaches

These techniques aim to replace traditional mouse devices. The paper highlights several challenges that affect system performance

K. Bhardwaj, G. Verma, D. Chouhan, S. Sureliya, S. Chourawar and S. Munshi G proposed Gesture Based Live Mouse Control [1]. The evolution of human-computer interaction has witnessed significant contributions from gesture-based virtual mouse systems. Development a gesture-based live mouse control system that utilizes computer vision and hand-tracking techniques to provide advanced user interactions with computers. This system tracks user hand movements in real-time using OpenCV and MediaPipe, converting finger positions and hand movements into corresponding mouse operations with high accuracy

Relevance to current Research

In this paper, the author proposed a model in which Hand gesture-based virtual mouse method that primarily focuses on improving user convenience and providing a touch-free interaction environment. Their work emphasizes the practical implementation of gesture recognition for replacing traditional mouse devices in everyday computing scenarios.

N.R.Sathish kumar, Vyankateshwar Reddy, Anil kumar, Pavan Kalyan Reddy, shashank Kumar reddy proposed [3] "Hand Gesture-Based Virtual Mouse with Advanced Controls Using OpenCV and Mediapipe "(2024 International Conference on Power, Energy, Control and Transmission Systems (ICPECTS)), Authors presented a Model for the covers the issues including the accuracy, time delay, and reliability of real-time gesture recognition under various lighting environments and backgrounds. The objective is to design a system where it has to perform efficient and effective in a highly structure denvironment yet organize itself well in highly dynamic environment. This means that the hand detection and gesture recognition should be tuned properly so as to maintain good response time at different working conditions.

Relevance to current Research

The proposed method for performing the work differs from existing gesture-based systems by achieving real-time mouse control using only a standard webcam without additional sensors, gloves or markers.

Syed Mohammad Haris, Syed Mohd Arham, Samta Rani proposed [4] Gesture-Driven Virtual Mouse for Human Computer Interaction, 2026 in their paper has discussed a system which Its performance under the versatile and resilient nature of the approach was tested in various conditions of light and under different user conditions. The system eliminated is not the case because of the necessity of physical or wearable devices but also cheap but at the same time scalable, particularly where hygiene, safety or are necessary available, like amid the COVID-19 pandemic, in hospitals, or by users who are mobiles impaired. The suggested Virtual Mouse shows a first of this kind system exploiting the advantages of method to Human-Computer Interaction (HCI) face recognition by computer vision methods.



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Relevance to current Research

Computer vision-based methods have limitations such as requiring good lighting conditions, appropriate background, and additional hardware devices, which may be inconvenient or impractical for some users. These limitations must be considered to ensure the proposed solution is effective and accessible for all users. Khush Sushil Poddar, Ameya Bajarang Jadhav, Harshal Chandrakant More, Nikil Vijay Kunder, Namita Pulgam [5] GesturePitch: A Smart Presentation System Utilizing Hand Gestures, 2023

GesturePitch is a smart presentation project that uses hand gestures to control and navigate through presentations. It overcomes the limitations of traditional presentation methods and provides an interactive and engaging experience to the users. This system is developed using advanced technologies and a self-segmentation module to overcome the limitations of traditional presentation tools. The real-time background removal feature, as well as the ability to set a threshold above which the hand will not be recognized, add to the tool's functionality and ease of use. The hand detector module is responsible for detecting the user's hand through the webcam and identifying the corresponding gestures.

Relevance to current Research

R.V.R.K Akhilesh, T. Sravanthi, G. Siddeshwar Rao, M Rajashekar proposed A Real-Time Hand Gesture and Voice-Driven Virtual Mouse System Using Convolutional Neural Networks and Media pipe Framework, 2025 [6]

This paper proposes a real-time, gesture and voice- controlled virtual mouse system designed to enhance user interaction without relying on traditional input devices. The system leverages MediaPipe for hand landmark detection and Convolutional Neural Networks (CNN) for gesture classification. Mouse operations such as movement, clicking, scrolling, volume control and brightness adjustment are mapped to static and dynamic hand gestures, while voice commands enable system-level actions such as launching applications, copy-pasting, and searching the web. The integration of PyAutoGUI enables smooth and responsive cursor control, and Speech Recognition with voice assistant module. Unlike conventional solutions, the proposed system functions without specialized hardware such as gloves or sensors and runs efficiently on a standard webcam and microphone for minimizing the computational overhead. They performed encryption only for some bits out of the entire block of file. As a result, at the side of client the overhead was lowered and thus the scheme was more accepted by the users.

Relevance to current Research

The work presented in this paper takes due care of the data which is kept on cloud as it not only provides the integrity check but also security for the data as well. This lets us to test the integrity at the moment of retrieving the stored data from Cloud.

No.	Paper Title	Author Name	Key Points	Remark
1	Gesture Based Live Mouse Control	K. Bhardwaj, G. Verma, D. Chouhan, S. Sureliya, S. Chourawar, S. Munshi	Developed a virtual mouse using hand gesture recognition and computer vision. Enables cursor movement, clicking, and scrolling without a physical mouse.	Provides a low-cost and touchless human-computer interaction system but offers limited advanced gesture functionalities.
2	Hand Gesture-Based Virtual Mouse with Advanced Controls Using OpenCV and MediaPipe	N. R. Sathish Kumar, Vyankateshwar Reddy, Anil Kumar, Pavan Kalyan Reddy, Shashank Kumar Reddy	Uses OpenCV and MediaPipe for real-time hand tracking. Supports advanced controls such as left click, right click, scrolling, drag-and-drop, and system operations.	Improved accuracy and responsiveness through MediaPipe landmarks; suitable for real-time applications.



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3	Gesture-Driven Virtual Mouse for Human Computer Interaction	Syed Mohammad Haris, Syed Mohd Arham, Samta Rani	Implements gesture-based cursor control and mouse operations using computer vision techniques. Focuses on enhancing natural interaction between users and computers.	Provides an intuitive user experience but may be affected by lighting conditions and camera quality.
4	GesturePitch: A Smart Presentation System Utilizing Hand Gestures	Khush Sushil Poddar, Ameya Bajarang Jadhav, Harshal Chandrakant More, Nikil Vijay Kunder, Namita Pulgam	Uses hand gestures to control presentation slides and presentation-related actions. Eliminates the need for presentation remotes.	Specifically designed for presentation environments; demonstrates practical application of gesture recognition technology.
5	A Real-Time Hand Gesture and Voice-Driven Virtual Mouse System Using Convolutional Neural Networks and MediaPipe Framework	R. V. R. K. Akhilesh, T. Sravanthi, G. Siddeshwar Rao, M. Rajashekar	Combines CNN-based gesture recognition with MediaPipe hand tracking and voice commands. Supports cursor movement, clicking, scrolling, and voice-assisted operations.	Offers higher recognition accuracy and multimodal interaction but requires greater computational resources.

In summary, the reviewed literature highlights significant advancements in gesture-based systems using computer vision and machine learning techniques. Building upon these contributions, the proposed system aims to enhance usability, responsiveness, and real-time performance by leveraging MediaPipe and OpenCV frameworks.

III. EXPERIMENTATION

A. Hardware Requirement

- 1) WebCam: To detect the Images, webcam is required
- 2) Windows OS: computer system required with basic OS configuration.

B. Software requirement

- 1) Python: Code written in Python ,focused on computer vision application, its more responsive and easier to implement because python is simple language and flexible too.
- 2) OpenCV: It is an open-source computer vision library used for image processing, video capture, object detection, and real-time frame analysis.
- 3) MediaPipe: MediaPipe is a framework which is used for applying in a machine learning pipeline, and it is an open source framework of Google. The MediaPipe framework is useful for cross platform development since the framework is built using the time series data. The MediaPipe framework is multimodal, where this framework can be applied to various audios and videos.



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IV.METHODOLOGY OF PROPOSED SURVEY

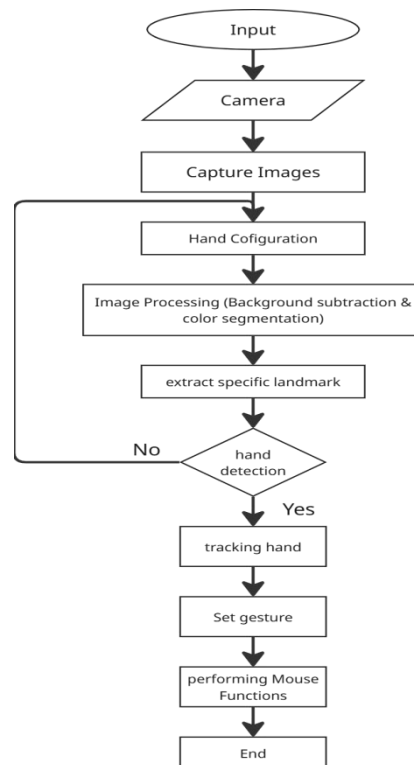


Figure1: Flowchart

Image /Video Capturing:

The webcam is used to continuously capture images video frames. OpenCV is used for capturing frames and for processing the frame. The captured image is converted to RGB format before going it to the hand detection module.

Hand Detection:

This system uses the MediaPipe for detecting hands by gesture in real time. The framework identifies finger tips and generates 21 landmark points for each detected fingers, fingertips, joints, and wrist positions for further analysis. Also detecting both hand major and minor

Landmark Processing:

After gesture detection, the coordinates of the landmarks are extracted. The x, y, and z values of the landmarks are used to calculate distances and finger positions. The distance between fingertips and finger joints is measured to determine whether a finger is open or closed. Euclidean distance method is used for measuring the distance between extracted landmarks

Finger State Identification:

The state of each finger is identified by comparing the distances between finger joints and fingertips. If the distance extended, it is considered that finger is open otherwise it is considered as a closed. Finger state represented using binary

Gesture Recognition:

The recognized finger patterns are mapped to predefined gestures. The system supports multiple gestures such as: Palm gesture, Fist gesture, Pinch gesture, Two-finger gesture.



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Special gestures are identified by measuring:

1. Distance between fingers
2. Relative finger movement
3. Direction of finger motion

To avoid false detection caused by noise or sudden movement, gesture stabilization is applied. A gesture is accepted only when it remains stable for a few consecutive frames.

Cursor Movement:

The hand position is mapped to screen coordinates for controlling the mouse pointer. The cursor movement is based on the position of hand landmarks. To reduce sudden jumps in cursor movement, smoothing techniques are applied. The movement speed is adjusted dynamically according to hand displacement.

Mouse Operation:

Types of gestures are assigned to different mouse operations.

1. Left Click: A predefined finger gesture is used for performing a left mouse click.
2. Right Click: A separate gesture is assigned for right-click operation.
3. Double Click: Two-finger closed gesture is used for double-click functionality.
4. Drag and Drop: The fist gesture is used for drag-and-drop operations.

Scroll Control:

Using Pinch gesture Vertical and horizontal scrolling are performed. Upward movement and downward movement performs upward scrolling and downward scrolling respectively. Horizontal scrolling is implemented using key combinations and mouse wheel events.

Brightness and Volume Control:

The system controls screen brightness and audio volume using pinch gestures. The brightness control module uses the screen brightness control library, while the volume control module uses the Pycaw library.

Multi Hand Interaction:

The system supports the use of both hands for different operations. The major hand is mainly used for cursor movement and mouse operations, while the minor hand is used for scrolling and system controls.

V. CONCLUSION

In the conclusion, this project demonstrates the feasibility and effectiveness of Gesture Recognition system for UI operation which interaction using computer vision and hand gesture recognition techniques. To detect hand landmark and recognize gesture in real time, system utilizes a standard webcam, OpenCV, and MediaPipe. By mapping identified gesture to computer operations such as cursor movement, clicking and dragging, scrolling, volume control and brightness adjustment. The use of gesture stabilization helps the system recognize hand movements more consistently and reduces incorrect detections that may occur due to small, unintended hand motions. In addition, supporting both hands for interaction increases the range of available functions and voice assistant. This approach makes the system more flexible and convenient for users.

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