

Hand Gesture Recognition System for Mouse Control

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ABSTRACT

This paper presents a novel web-based application that enables intuitive, touch-free control of a computer's mouse cursor using real-time hand gesture recognition via a standard webcam. Leveraging computer vision and gesture recognition techniques, the proposed system translates specific hand gestures into mouse actions, such as cursor movement, clicks, and freezing, providing an accessible and hygienic alternative to traditional input devices. The application is developed in Python and features a modular architecture, with dedicated components for gesture detection, mouse control, and user management. The platform includes two primary modules: an Admin module for secure user and content management, and a User module for registration, login, and interactive gesture-based mouse control. Experimental results demonstrate the system's responsiveness and accuracy in diverse environments, highlighting its potential to enhance accessibility for individuals with mobility challenges and to reduce physical contact in shared or public computing scenarios. This work showcases the integration of modern computer vision into web applications, paving the way for more natural and inclusive human-computer interaction.

Keywords: *Hand Gesture, Open CV, MediaPipe, TensorFlow, Keras*

I. INTRODUCTION

The evolution of human-computer interaction (HCI) has steadily aimed to make technology more accessible, intuitive, and inclusive for diverse user groups. Traditional input devices such as the mouse and keyboard have been the cornerstone of computer interaction for decades. However, these devices present significant challenges for users with mobility impairments, individuals working in sterile or public environments, and situations where hands-free operation is preferred. Recent global health concerns have further underscored the importance of minimizing physical contact with shared devices, accelerating the demand for alternative input

methods that enable touch-free interaction. Gesture recognition, empowered by advances in computer vision and machine learning, has emerged as a promising solution to these challenges by interpreting natural human movements and translating them into computer commands. The widespread availability of affordable webcams and the increasing computational capabilities of consumer devices have made real-time gesture recognition both feasible and practical for everyday applications.

Over the past decade, there has been considerable research and development in gesture recognition and its integration into HCI systems. Early

implementations often relied on specialized hardware such as data gloves or infrared sensors, which, while accurate, were expensive and cumbersome, limiting their adoption. More recent approaches have leveraged standard webcams combined with sophisticated image processing algorithms to detect and interpret hand gestures in real time. Commercial products like Microsoft Kinect and Leap Motion have popularized gesture-based interaction, particularly in gaming and virtual reality. However, these systems typically require dedicated hardware and are not easily adaptable to web-based platforms or existing workflows. Academic research has explored various techniques including skin color segmentation, contour analysis, and deep learning-based landmark detection to improve the robustness and accuracy of gesture recognition. Frameworks such as OpenCV and MediaPipe have facilitated the development of efficient pipelines capable of running on standard computing devices with real-time performance. Despite these advances, there remains a gap in accessible, web-based solutions that allow users to control their computers using hand gestures without additional hardware, especially with integrated user management and administrative control.

This paper addresses the limitations of traditional input devices and existing gesture recognition systems by proposing a web-based application that enables users to control their computer's mouse cursor through simple hand gestures detected via a webcam. The system is designed to provide an intuitive, touch-free alternative to the mouse and keyboard, enhancing accessibility for individuals with mobility challenges and offering a hygienic

option in environments where physical contact with devices should be minimized. The application leverages widely available hardware and open-source software libraries such as Python, OpenCV, MediaPipe, TensorFlow, and Keras to ensure broad compatibility and ease of adoption. The platform is modular, featuring distinct Admin and User modules to facilitate secure user management, content administration, and interactive gesture-based control. The system aims to deliver real-time performance and high accuracy in gesture recognition, even in diverse and dynamic environments.

II.RELATED WORK

Hand Gesture-based Virtual Mouse using OpenCV, Authors: Gayatri Jagnade, Mitesh Ikar, Nikita Chaudhari, Maithili Chaware,

The paper presents a contactless virtual mouse system that enables users to interact with computers through hand gestures, eye blinks, mouth openings, and object detection. By leveraging MediaPipe and OpenCV, the system allows functionalities such as cursor movement, scrolling, and volume control without physical contact. Aimed particularly at aiding people with disabilities and promoting hygiene during pandemics, this innovation provides a practical and accessible human-computer interaction method.[1]

Hand Gesture-Based Virtual Mouse with Advanced Controls Using OpenCV and Mediapipe, Authors: N. R. Sathish Kumar, A. Venkateswara Reddy, B. Anil Kumar, B. Pavan Kalyan Reddy, A. Shashank Kumar Reddy, machines, and decision trees for classification.

This research introduces a gesture-controlled virtual mouse system that enables users to interact with computers through hand gestures without physical contact. By utilizing OpenCV and Mediapipe, the system detects real-time hand landmarks via webcam and interprets specific gestures to perform actions like cursor movement, clicking, and scrolling. The goal is to enhance accessibility, particularly for people with disabilities, and to promote hygienic, touchless interaction in various environments. This approach reflects a significant advancement in Human-Computer Interaction (HCI) by enabling intuitive, hands-free control.[2]

Mouse Cursor Control Using Dynamic Hand Gesture Recognition, Authors: Darryll Fonseca, Tanmoy Majumder, Banita Mitra, Arpita Das, Biswajit Das, Anirban Bhowmik,

This paper proposes a dynamic hand gesture-based interface for controlling mouse cursor movements using real-time color segmentation and gesture recognition. The system supports operations like dragging files, left and right clicking, and scrolling, all performed through hand gestures. By calibrating colors to avoid background interference, the interface ensures accurate tracking and interaction. This work aims to replace traditional input devices with a more natural, intuitive method of human-computer interaction, making it especially suitable for evolving technologies like virtual reality and assistive systems.[3]

System Control using Hand Gesture, Authors: Gaurav Bhole, Digvijay Bhingare, Rajas Bhise, Sakshi Bhegade, Sohan Bhokare, Amol Bhosle,

This paper presents a gesture-based system control interface that enables users to interact with a

computer using hand movements detected via a webcam. By leveraging Python 3.7, OpenCV, MediaPipe, and PyAutoGUI, the system performs cursor movement, clicking, volume control, and brightness adjustment without a physical mouse. The virtual mouse interprets fingertip tracking and hand gestures using computer vision and AI, offering a cost-effective, touch-free alternative for human-computer interaction. This technology is particularly valuable for accessibility, immersive environments, and next-gen UI design.[4]

A Six-Degree-of-Freedom Virtual Mouse Based on Hand Gestures, Authors: Xingfeng Wang, Kaihuai Qin,

This paper introduces a six-degree-of-freedom virtual mouse system that utilizes hand gestures for real-time human-computer interaction using a standard USB webcam. The system employs motion detection, skin color recognition, and finger tracking to enable intuitive mouse functionalities. It is particularly notable for its accessibility, offering potential use by individuals with severe disabilities who may not be able to bend their fingers. The experimental results demonstrate the system's capability for effective, real-time input, highlighting its usefulness in enhancing both traditional and assistive computing environments.[5]

Design and Development of Gesture Recognition Based Virtual Mouse System, Authors: Shashwat Srivastava, Richa Tiwari, Ananya Garg, Rishu, Rohit Tiwari.

This paper proposes an AI-based virtual mouse system that enables touchless computer control through hand gestures detected by a webcam. By applying computer vision and deep learning

techniques, the system interprets gestures for mouse actions like cursor movement, clicking, and scrolling, offering an alternative to traditional hardware-based interaction. Designed to reduce dependency on physical devices, this system is particularly relevant in contexts like airports and hospitals, where hygiene and contactless interaction are essential. The study shows that the virtual mouse achieves performance comparable to physical mice, providing an intuitive and practical solution for modern human-computer interaction.[6]

Vision-Based Gesture Recognition for Mouse Control, Authors: Paolo G. Estavillo, Dale Joshua R. Del Carmen, Rhandley D. Cajote,

This paper presents a vision-based gesture recognition (VGR) system designed for efficient mouse control through hand gestures. The proposed system meets three critical requirements: reliable hand tracking, recognition of both static and dynamic gestures, and efficient computational performance. Using RGB images and hand skeleton data, the authors developed an algorithm capable of real-time gesture detection and classification. Evaluated on the IPN dataset, the system demonstrated improved performance in both isolated and continuous gesture recognition, achieving 61.30% Levenshtein accuracy in continuous tasks—marking a significant advancement in gesture-controlled human-computer interaction. The paper presents a real-time sign language recognition system aimed at bridging the communication gap between hearing-impaired individuals and the general public. Using deep learning and Convolutional Neural Networks (CNN), the system translates American Sign

Language (ASL) alphabet gestures captured through a camera into readable text. This approach eliminates the need for a human translator and empowers deaf and mute individuals to interact more confidently with society. The system contributes toward developing an effective Human-Computer Interaction (HCI) tool for inclusive communication.[7]

Virtual Cursor Control System Using Artificial Intelligence, Authors: Barath A., Dr. C. Priya, This paper introduces a virtual cursor control system leveraging computer vision and artificial intelligence to enable hands-free mouse interactions through real-time camera input. The system uses color recognition and image processing to detect hand positions and gestures, mapping them to various mouse functions like clicking and cursor movement. By replacing traditional input devices with gesture-based controls, the solution promotes more intuitive and accessible human-computer interaction (HCI), especially useful in scenarios like human-robot interaction and touch-free environments. The study emphasizes the system's applicability in broader HCI domains, including gaming, sign language interpretation, and natural user interfaces.[8]

This Hand Gesture Recognition Based on Computer Vision: A Review of Techniques, Authors: Munir Oudah, Ali Al-Naji, Javaan Chahl

This paper provides a comprehensive review of hand gesture recognition methods based on computer vision, exploring both static and dynamic gestures used in applications like sign language, robot control, and human-computer interaction (HCI). It discusses key approaches, comparing

glove-based sensor methods with vision-based systems, and analyzes their strengths and limitations. The review also evaluates techniques for hand segmentation, classification algorithms, gesture types, datasets used, and camera specifications. The study concludes that vision-based gesture recognition, while challenging, offers a promising path toward more natural and intuitive interaction systems across diverse domains.[9]

Implementation of Virtual Mouse Control System Using Hand Gestures for Web Service Discovery,
 Authors: G. V. Bhole, Shrikala Deshmukh, M. D. Gayakwad, P. R. Devale, This research proposes a virtual mouse control system driven by real-time hand gesture recognition for enhancing web service discovery. The system uses computer vision techniques such as color segmentation with MediaPipe, OpenCV, and Python to interpret hand movements and map them to mouse actions like clicks and scrolling. It is particularly beneficial for users facing accessibility issues or physical limitations, offering a hygienic and touchless interface that minimizes the spread of infections. The application not only improves user experience and interaction but also contributes to modernizing Human-Computer Interaction (HCI) environments.[10]

III. METHODOLOGY

The methodology for the proposed web-based hand gesture-controlled mouse system integrates real-time computer vision, deep learning, and intuitive user interface design to enable seamless, touch-free interaction with a computer. The process begins with live video acquisition using a standard webcam, followed by hand detection and

segmentation through skin color filtering. Hand landmarks are then extracted using MediaPipe, and these key points are processed as feature vectors. A deep learning model, trained on a variety of hand gestures, classifies the input in real time. Recognized gestures are mapped to specific mouse actions—such as movement, clicks, or freezing the cursor—using a dedicated controller module. The system is structured with modular software components, including separate interfaces for users and administrators, ensuring both usability and maintainability. The entire pipeline is implemented in Python, leveraging libraries such as OpenCV, MediaPipe, TensorFlow, and PyAutoGUI, and is validated through real-time testing in diverse usage environments.

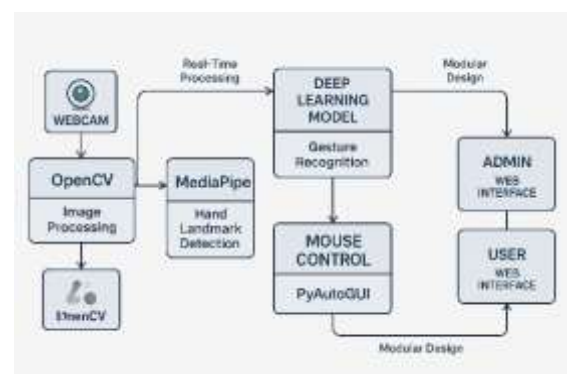


Fig 3.1. Proposed Methodology

1. **Data Acquisition and Preprocessing:** The system initiates with continuous video capture from the user's webcam. Each frame is processed using OpenCV to resize and convert the image to the HSV color space, facilitating robust skin color segmentation. This step isolates the region of interest (ROI)—the user's hand—by applying thresholding techniques, effectively filtering out background noise and ensuring accurate hand detection even in dynamic or cluttered environments.

2. **Hand Landmark Extraction:** Once the hand region is segmented, the MediaPipe library is employed to detect and track 21 key landmarks on the hand, such as fingertips and joints. These landmarks are represented as NumPy arrays of spatial coordinates, forming the basis for gesture recognition. Additional preprocessing, such as normalization and smoothing, may be applied to enhance the reliability of landmark detection.

3. **Gesture Recognition Using Deep Learning:** The extracted hand landmarks are processed as feature vectors and input into a deep learning model. The model, typically a Convolutional Neural Network (CNN) or Long Short-Term Memory (LSTM) network, is trained on a labeled dataset of hand gestures to classify both static and dynamic gestures. The output is a gesture class label, which is mapped to a corresponding mouse action.

4. **Mouse Control and Action Mapping:** Recognized gestures are translated into mouse actions using the PyAutoGUI library. For example, an open hand gesture allows for cursor movement, a closed thumb freezes the cursor, and specific finger configurations are mapped to click or drag events. To prevent unintended repeated actions, debounce mechanisms or short delays are implemented after certain gestures.

5. **Modular System Architecture:** The application is organized into modular components for maintainability and scalability. The main logic for video capture, gesture detection, and recognition is separated from the controller module responsible for executing mouse commands. The web interface comprises two modules: an Admin

module for user and FAQ management, and a User module for registration, login, and gesture-based control.

6. **Implementation and Testing:** The entire system is developed in Python, with dependencies managed via a requirements.txt file. Real-time testing is conducted in various environments to validate the system's responsiveness and accuracy. The modular design allows for straightforward extension, such as adding new gestures or accessibility features, ensuring the system's adaptability for different use cases.

IV. TECHNOLOGIES USED

The implementation of the web-based hand gesture-controlled mouse system leverages a suite of modern technologies from computer vision, machine learning, and web development to deliver robust, real-time gesture recognition and seamless user interaction. The system relies on a standard webcam for data acquisition, OpenCV for image processing and hand segmentation, MediaPipe for precise hand landmark detection, and deep learning frameworks such as TensorFlow and Keras for gesture classification. Mouse control is achieved through PyAutoGUI, while the web application itself is structured using Python-based backend logic, with modular components for both user and admin interfaces. This combination of technologies ensures high accuracy, responsiveness, and accessibility, making the solution practical for a wide range of users and environments.

1. Webcam and Video Capture:

A standard webcam serves as the primary input device, capturing live video streams of the user's hand gestures. This approach enables vision-based

gesture recognition, which is more intuitive and accessible than sensor-based methods, and eliminates the need for specialized hardware.

2. OpenCV for Image Processing:

OpenCV, a widely used open-source computer vision library, is responsible for real-time image capture, color space transformation, and skin color segmentation. These processes isolate the user's hand from the background, ensuring accurate detection and minimizing noise in diverse environments.

3. MediaPipe for Hand Landmark Detection:

MediaPipe, developed by Google, is utilized for detecting and tracking 21 key landmarks on the hand in real time. This framework provides robust, high-speed landmark extraction, which is crucial for both static and dynamic gesture recognition and serves as the foundation for feature extraction and classification.

4. TensorFlow and Keras for Deep Learning:

The extracted hand landmarks are processed as feature vectors and fed into deep learning models built with TensorFlow and Keras. These frameworks enable the training and deployment of Convolutional Neural Networks (CNNs) or Long Short-Term Memory (LSTM) networks for accurate gesture classification, supporting both static and dynamic gestures.

5. PyAutoGUI for Mouse Control:

PyAutoGUI is a Python library used to translate recognized gesture commands into system-level mouse actions, such as cursor movement, clicks, and drag events. This allows for seamless and natural

control of the computer interface using only hand gestures.

6. Python and Modular Software Architecture:

Python serves as the primary programming language, chosen for its extensive libraries and ease of integration across computer vision, machine learning, and automation tasks. The software is organized into modular components, separating gesture detection, classification, and mouse control, as well as providing distinct interfaces for users and administrators.

7. Web Application Structure:

The application features a user-friendly web interface with separate modules for users and administrators. The User module enables registration, login, and access to gesture-based mouse control, while the Admin module provides tools for user management and FAQ administration. This structure ensures both usability and maintainability.

By integrating these technologies, the system achieves real-time, accurate hand gesture recognition and intuitive mouse control, making it highly suitable for accessibility applications, public kiosks, and environments where touch-free interaction is essential.

V. CONCLUSION

In conclusion, the proposed web-based hand gesture-controlled mouse system demonstrates the potential of combining computer vision, deep learning, and intuitive interface design to create a practical, touch-free alternative to traditional input devices. By leveraging widely available hardware

and robust open-source technologies, the system delivers real-time, accurate gesture recognition and seamless mouse control, significantly enhancing accessibility and hygiene in various environments. Its modular architecture and user-friendly web interface make it adaptable for diverse use cases, from assisting individuals with mobility challenges to enabling contactless interaction in public or shared spaces. This work highlights the promise of gesture-based interfaces in advancing more natural, inclusive, and innovative human-computer interaction.

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