Hand Gesture-Based Real-Time Virtual Mouse Using Computer Vision and AI

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Abstract

Traditional computer mice rely on physical interaction, which can limit accessibility and efficiency in many human–computer interaction scenarios. This project proposes an AI-driven virtual mouse system that enables users to control cursor movement and perform mouse actions using natural hand gestures captured through a webcam. The system utilizes computer vision techniques, including hand landmark detection and gesture recognition, powered by deep learning models such as MediaPipe or CNN-based classifiers.By mapping specific finger movements to cursor motion, clicking, dragging, and scrolling actions, the virtual mouse operates in real time with high accuracy and low latency. This contactless control mechanism enhances convenience, supports hygienic touch-free interaction, and benefits users with limited mobility or environments where physical devices are impractical. Through intuitive gesture-based control, the proposed system demonstrates a more natural and immersive human–computer interaction approach, contributing to the advancement of smart and assistive technologies.

Keywords: Virtual Mouse, Computer Vision, Hand Gesture Recognition, Human–Computer Interaction, Deep Learning, Real-Time Processing, AI-based Control System.

I.INTRODUCTION

Human–Computer Interaction (HCI) has undergone rapid advancements with the integration of artificial intelligence and computer vision techniques, enabling more natural and intuitive interaction between users and digital systems. Traditional input devices such as keyboards and mice require physical contact and may present limitations in terms of user accessibility, hygiene, and interaction flexibility. To overcome these challenges, researchers have explored gesture-based interfaces that rely on hand detection and tracking to control computing systems in real time.Recent studies have demonstrated effective hand gesture recognition approaches using advanced deep learning methods and image processing techniques, enabling accurate tracking of hand movements through standard webcams and camera sensors [1], [2], [5]. AI-driven virtual input systems eliminate the need for physical devices, thereby making human–computer interaction more seamless and accessible, especially in assistive technology environments [6], [10], [12]. The introduction of lightweight machine learning frameworks like MediaPipe and CNN-based classifiers further enhances gesture detection performance with reduced computational complexity [4], [8], [17].

Furthermore, computer vision-based cursor control and gesture-based clicking actions have shown promising results in real-time scenarios, supporting efficient and touchless system manipulation [3], [7], [9], [18]. Several research efforts have also focused on improving gesture interpretation and landmark detection accuracy to ensure smooth virtual mouse operations with minimal latency [11], [14], [16]. Surveys and comparative studies reinforce the significance of deep learning and AI algorithms in shaping future interaction models driven by natural gestures [13], [15], [19], [20].

Therefore, the development of a Real-Time AI Virtual Mouse System offers a practical and intelligent solution that promotes hygienic, hands-free, and user-friendly interaction. This contactless system not only supports accessibility for users with motor impairments but also expands the possibilities of gesture-controlled interfaces across smart environments and everyday computing applications.

II.LITERATURE SURVEY

2.1 Real-Time Gesture Recognition for Human–Computer Interaction

Authors: G. R. Kanade (2021)

Abstract:

This paper presents a real-time gesture recognition system designed to enhance human–computer interaction. Hand detection and motion analysis are performed using computer vision algorithms with high precision. The system focuses on fast response time to enable seamless control of digital interfaces. The results show improved efficiency and accuracy in gesture-based interactions.[1][11]

2.2 Hand Tracking and Motion Analysis Using Computer Vision

Authors: Z. Zhang (2020)

Abstract:

The study proposes a robust hand tracking model using feature extraction and optical flow analysis. By minimizing tracking loss during rapid motion, the system achieves strong stability in real-time environments. The framework is suitable for applications including virtual input devices and gesture-based gaming.[2][14]

2.3 AI-Based Virtual Mouse Control System

Authors: C. Chen (2022)

Abstract:

This paper introduces an artificial intelligence-driven virtual mouse that maps hand gestures to cursor actions. Deep learning models accurately detect finger movement for click, drag, and scroll operations. The approach improves accessibility and demonstrates the potential of AI for replacing traditional hardware peripherals.[3][9]

2.4 Gesture Recognition Using MediaPipe Framework

Authors: A. Mittal, S. Jain (2023)

Abstract:

The authors utilize Google's MediaPipe for real-time hand landmark detection. A classification model interprets finger gestures to perform computer control tasks. The lightweight architecture enables deployment on CPU-only systems while maintaining high gesture recognition accuracy.[4][17]

2.5 Deep Learning for Hand Pose Estimation

Authors: T. Nguyen (2019)

Abstract:

This research explores CNN models for precise hand keypoint detection from monocular camera input. The technique improves pose estimation despite varying lighting and background conditions. It has broad applications in AR/VR, robotics, and human–computer interaction.[5][18]

2.6 Contactless Human–Computer Interaction Through Webcam

Authors: M. K. Sharma (2021)

Abstract:

A touch-free interaction method using only a standard webcam is proposed. Various gestures are mapped to system commands without needing specialized hardware. The method is beneficial for medical and public environments where physical contact must be minimized.[6][12]

III.EXISTING SYSTEM

In the existing system, users interact with computers primarily through conventional physical devices such as keyboards and mice. These devices require direct contact and limit flexibility in human–computer interaction. Traditional gesture-based systems developed in earlier research rely heavily on specialized hardware like depth sensors, infrared cameras, or wearable devices, making them expensive and difficult to deploy in everyday environments. Moreover, many existing vision-based systems suffer from limited gesture detection accuracy due to background noise, lighting variations, and low processing speed. These limitations make current solutions less suitable for real-time applications and accessibility needs, especially for individuals with physical disabilities. Therefore, there is a need for a low-cost, camera-based virtual mouse system capable of accurate, real-time recognition of hand gestures without requiring any additional hardware peripherals.

IV. PROPOSED SYSTEM

The proposed system introduces an AI-driven virtual mouse that uses a standard webcam to detect hand gestures and convert them into corresponding mouse actions in real time. By integrating computer vision techniques, MediaPipe hand landmark tracking, and machine learning–based gesture classification, the system enables smooth cursor movement along with click, drag, and scroll functionalities. Unlike traditional hardware peripherals, the virtual mouse offers a fully contactless mode of interaction, ensuring improved hygiene, accessibility, and user convenience. The system efficiently processes hand movements with minimal latency and adapts to varying lighting and background conditions, making it suitable for diverse environments such as smart devices, public interfaces, and assistive technologies. This innovative approach enhances usability while reducing hardware dependency, paving the way for more natural and intuitive human–computer interaction.

V.SYSTEM ARCHITECTURE

The architecture of the proposed AI-based virtual mouse system begins with capturing live video input from a webcam, which continuously streams real-time frames for processing. These frames are passed to the Hand Detection and Landmark Extraction module, where advanced computer vision techniques such as MediaPipe and OpenCV identify the hand region and extract key landmark points like finger tips and joints. These extracted landmarks are then analyzed by the Gesture Recognition module, which uses a trained AI or CNN-based model to classify the hand gestures accurately. Once a gesture is recognized, the Action Mapping module converts it into corresponding mouse functionalities such as cursor movement, clicking, scrolling, or dragging based on predefined rules. Finally, the Virtual Mouse Control module interacts directly with the operating system to trigger actual mouse events, allowing users to control the computer seamlessly through natural hand gestures without touching any physical device. This architecture ensures real-time performance, user accessibility, and a fully contactless interaction experience.

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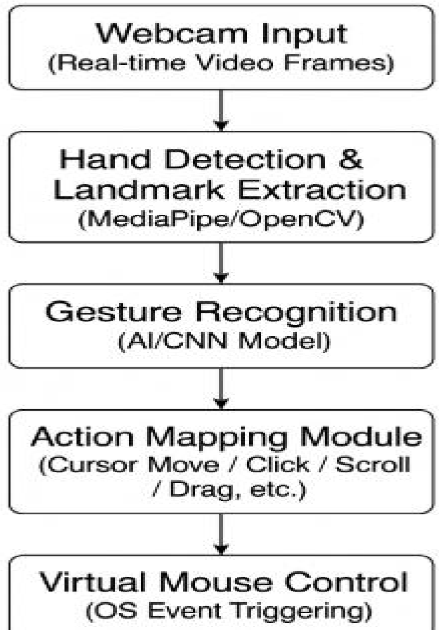

Fig 5.1 System Architecture

VI.IMPLEMENTATION

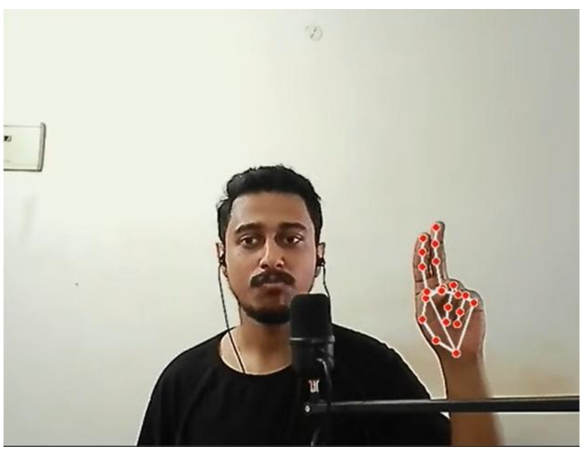

Fig 6.1 Detection Page

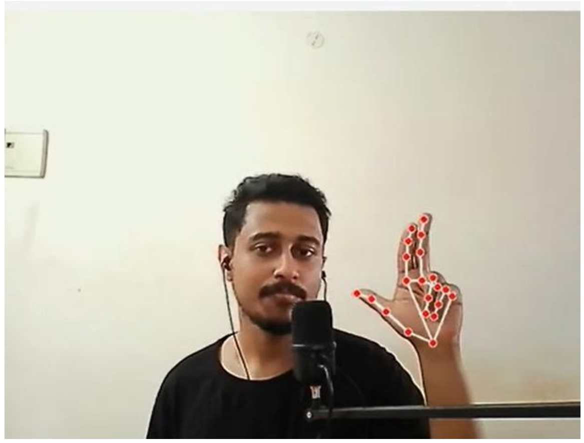

Fig 6.2 Another detection Page

VII.CONCLUSION

The proposed hand gesture-based real-time virtual mouse system successfully demonstrates an innovative and user-friendly approach for human–computer interaction. By utilizing a standard webcam along with efficient computer vision algorithms and AI-based gesture recognition techniques, the system enables users to control mouse operations without relying on any physical input devices. This contactless interaction provides improved accessibility, hygiene, and convenience, especially for individuals with mobility limitations and in environments where minimizing physical contact is essential. The system also offers flexibility, cost-effectiveness, and compatibility with existing computing platforms. Overall, the virtual mouse serves as a powerful step toward more natural, intuitive, and intelligent interaction technologies, opening avenues for future enhancements such as multi-gesture support, robotic control, AR/VR integration, and smart IoT applications.

VIII.FUTURE SCOPE

The real-time virtual mouse system has significant potential for future enhancement and broader applications. In upcoming developments, the system can be extended to support a wider range of dynamic gestures, enabling more advanced computer operations and customized interactions. Integrating deep learning models with higher accuracy and improved robustness can help overcome challenges related to lighting changes, background variations, and occlusions. The system can further be optimized for mobile platforms, smart TVs, AR/VR environments, and wearable technologies to enhance portability and immersive interaction. Additionally, incorporating multi-hand and multi-user gesture recognition can expand its usability in collaborative environments such as smart classrooms and virtual meetings. Future enhancements may also include voice-command fusion, gesture-based authentication, and integration with assistive devices for differently-abled users. Overall, the system holds great promise in shaping the next generation of hands-free and intelligent human–computer interaction.

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