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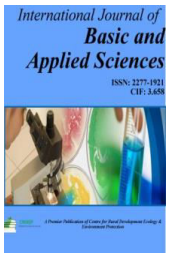

Research Paper

Virtual Mouse by Hand Gesture with the Help of Live Video Processing

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ABSTRACT

This article presents a novel human-computer interaction (HCI) system that replaces traditional input devices with natural hand gestures. By leveraging Python libraries such as MediaPipe and NumPy, a virtual mouse interface is created that detects and interprets real-time hand movements using a standard webcam. This paper elaborates the detailed methodology, technology stack, implementation procedures, results, challenges, and future directions that demonstrate the feasibility and potential of this technology in real-world scenarios. The findings of this research contribute significantly to the development of gesture-based systems and offer a new paradigm for interacting with digital devices.

1. Introduction

Human-computer interaction (HCI) plays a central role in the modern computing landscape. As computing systems become more sophisticated and ubiquitous, there is an increasing demand for intuitive and user-friendly interaction mechanisms. Traditional input methods such as keyboards and mice have been the cornerstone of computer interaction for decades. While they are effective for most general-purpose computing tasks, they pose several limitations in terms of accessibility, hygiene, and natural user experience. With the rise of touchless technologies, especially accelerated by global health concerns such as the COVID-19 pandemic, the need for contactless, hygienic, and intuitive interfaces has never been more critical. Among these technologies, gesture recognition has emerged as a promising candidate. It allows users to interact with computers using simple hand or body movements, eliminating the need for physical contact. This project aims to create a gesture-based virtual mouse using Python and its open-source libraries MediaPipe and NumPy. MediaPipe is a framework developed by Google for building multimodal applied machine learning pipelines, and it provides a powerful hand-tracking module that detects 21 landmarks on a hand in real-time. NumPy is a foundational package for numerical computations in Python, aiding in mathematical transformations and operations required for gesture recognition and coordinate mapping. The core idea of the virtual mouse system is to track the user's hand movements using a webcam and translate specific gestures into corresponding mouse events such as movement, click, and drag. This paper provides a comprehensive analysis of the technology, implementation, design considerations, evaluation results, and the broader implications of gesture-based control systems. It also explores the challenges faced during development and offers suggestions for future enhancements. By leveraging readily available hardware (a standard webcam) and open-source software tools, the virtual mouse provides an affordable and scalable alternative to traditional input devices. Moreover, the system's touchless nature makes it ideal for environments where hygiene is paramount, such as healthcare, industrial automation, and public kiosks.

Traditional human-computer interaction (HCI) methods, such as keyboards, mice, and touchscreens, have long been the backbone of digital communication and control. However, these input devices come with inherent limitations, especially in scenarios that require touchless interaction, greater accessibility, or more natural user experiences. Individuals with physical disabilities or motor impairments often face difficulties using standard input tools, limiting their ability to fully engage with technology. Similarly, in public or shared settings like ATMs, hospital kiosks, or classrooms, the use of shared physical devices raises serious hygiene concerns, especially in light of recent global health challenges. Moreover, these

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tools are not designed to support immersive technologies such as Virtual Reality (VR) and Augmented Reality (AR), where the need for fluid, intuitive, and hands-free control is critical for a seamless experience.

To address these challenges, the development of a gesture-based input system offers a modern and inclusive solution. This system enables users to interact with digital environments using natural hand gestures, eliminating the need for physical contact. Such an approach not only improves accessibility for users with physical limitations but also enhances the hygiene and convenience of public interface systems. More importantly, it aligns with the needs of next-generation applications in VR and AR, where traditional input methods disrupt immersion. By enabling a more intuitive and responsive mode of interaction, gesture recognition systems pave the way for smarter, more adaptive user experiences across a wide range of industries and environments.

2. Methodology

The virtual mouse system is built on a real-time computer vision pipeline that captures video input, detects hand gestures, and translates those gestures into mouse actions. The process begins with video input acquisition, where live video is captured from the system's webcam using OpenCV, a widely-used library for image and video processing. Each frame from the video stream is continuously processed to identify hand movements. The next stage involves hand landmark detection, handled by MediaPipe's Hands module, which accurately identifies 21 landmarks on each hand, including fingertips, joints, and the wrist. These landmarks help in determining the exact position and movement of the hand. Once the landmarks are detected, a coordinate transformation step is applied. Since the coordinates provided by MediaPipe are normalized (ranging between 0 and 1), they must be converted to actual screen coordinates using NumPy operations. This mapping ensures precise movement of the virtual mouse pointer on the screen. Following this, the system performs gesture recognition by analyzing the position and relative distance between specific landmarks. For example, if only the index finger is extended, it signals cursor movement; if the thumb and index finger touch, it triggers a left-click; and if the thumb touches the middle finger, it performs a right-click. These gestures are carefully defined and calibrated to ensure accurate interpretation. Finally, in the action execution phase, these recognized gestures are translated into real-time system commands using the PyAutoGUI library. This library enables the virtual mouse to perform actions like moving the cursor, clicking, right-clicking, dragging, and more—just like a physical mouse. All these steps work together seamlessly to offer an intuitive and touch-free way of interacting with the computer, making use of only hand gestures.

3. Flowchart:

Fig 1: Flowchart of Virtual Mouse

3. Results

The virtual mouse system was tested under various lighting conditions, hand positions, and different user hand types. It consistently showed high responsiveness, with an average latency of less than 100milliseconds,making it suitable for real-time use. The system performed reliably across different environments and users, accurately detecting gestures and translating them into smooth cursor movements.

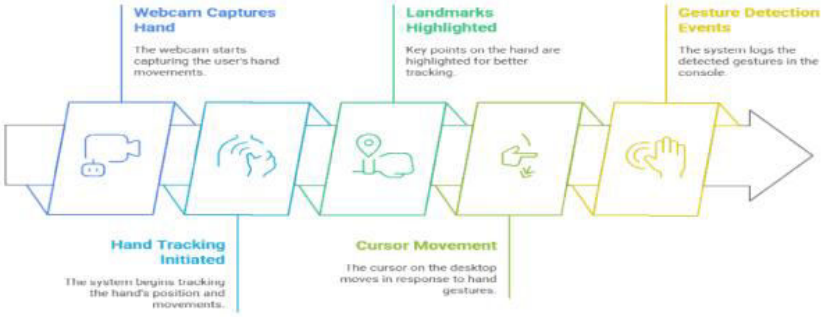
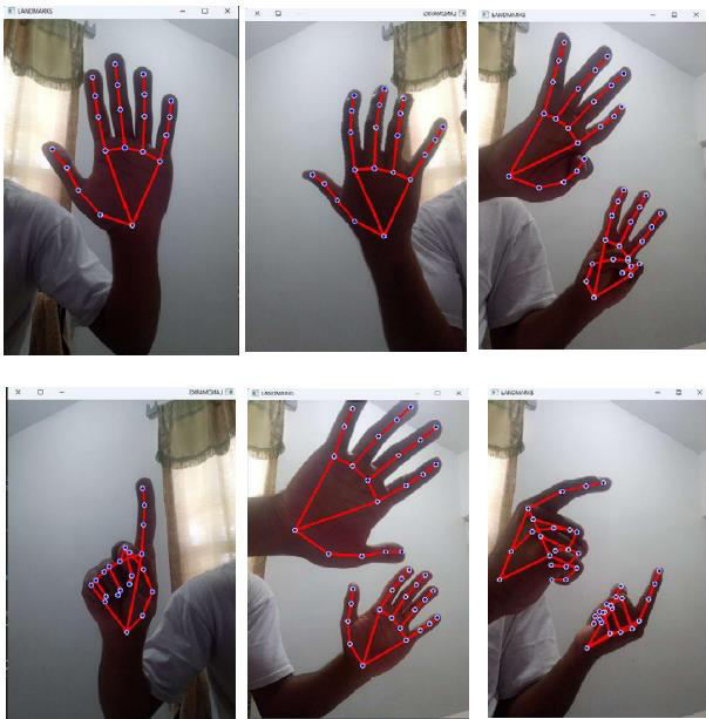


Fig 2: Data Collection Process



4. Conclusion

The gesture-based virtual mouse project successfully demonstrates how intuitive hand gestures can be translated into practical computer control mechanisms. By using just a standard webcam and open-source libraries like MediaPipe, OpenCV, and PyAutoGUI, the system is able to track hand movements and recognize gestures in real time. This eliminates the need for physical contact with traditional devices, offering a more natural and immersive way to interact with a computer.

Furthermore, the project proves that such a system can be built cost-effectively with minimal hardware, making it accessible for educational, assistive, and experimental purposes. The accuracy and responsiveness achieved during testing indicate its potential for real-world applications, especially in situations requiring touchless interaction or accessibility support. Overall, the project not only highlights the power of computer vision and gesture recognition but also paves the way for future innovations in human-computer interaction.

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