



Original Article

Gesture Control Virtual Mouse using Opencv and Mediapipe

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Abstract:

This paper proposes a virtual mouse system based on Human c-computer interaction (HCI) using computer vision and hand gestures. Techniques for establishing the process of human-computer interaction (HCI) have evolved since the invention of computer technology. The mouse is its extensive innovation in HCI (Human-Computer Interaction) technology. Wireless or Bluetooth mouse technology is still in development, but the technology is not yet completely device-free. The Bluetooth mouse requires battery power and a connection dongle. The presence of additional devices in the mouse makes it difficult to use. The proposed mouse system solves these limitations. We have written a program for Controlling the mouse movement using Python and OpenCV with a real-time camera that detects hand patterns, tracks hand gesture patterns that replaces the work of a traditional physical mouse. Gestures captured with an integrated camera or webcam are processed with recognition technology. Basically, this system lets you use your computer completely hands-free. All you need is your normal laptop camera or a regular webcam to track your hand movements live. The software cleans up the video frames so it can track your hand smoothly. Then, when you make different movements like moving your hand up or down or changing your fingers—the system instantly figures out what you want to do. It maps those gestures to real mouse actions, allowing you to move the pointer, left-click, right-click, or double-click without ever touching a physical mouse. This new mouse system removes the need for physical hardware entirely, showing how human-computer interaction (HCI) technology is evolving to make devices easier to use.

Keywords: Virtual Mouse, Mediapipe, Puautogui, Hand Tracking.

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Introduction:

The most effective and expressive means of human communication is hand gestures, which is a widely accepted language. It is expressive enough for the deaf and dumb to understand. In this work, a real-time hand gesture system is proposed. Test setup of the system using the low-cost, fixed-position web camera mounted on a computer monitor, or a fixed camera on a laptop, with the system's high-definition recording capability. The gesture control virtual mouse simplifies human-computer interaction using hand gestures. There is no need of physical contact between the user and the computer. All I/O functions can be controlled virtually by static and dynamic hand gestures.

This project uses state-of-the-art machine learning and computer vision algorithms for hand gesture recognition that works seamlessly without any additional hardware requirements. It leverages models like CNN implemented by MediaPipe that run on top of pybind11. It works directly on the hand using MediaPipe hand detection. The system was built using Python, and it uses a special tool called OpenCV to help the computer "see" and understand images or video from a camera. This system has the potential to replace the typical mouse and also the remote controller of machines. The only barrier is the lighting condition. That's why the system still can't be enough to replace the traditional mouse as most of the computers are used in poor lighting condition. This technology has numerous applications in areas such as gaming, virtual reality and accessibility quite easy for people.

The system captures video input from a camera pointed at the user's hand and uses computer vision algorithms to identify the user's

hand and track its movement. This information is given to machine learning models which have been trained to recognize specific hand gestures, such as pointing or swiping, and translate them into corresponding mouse movements, such as moving the cursor or clicking.

In the long run, this research establishes the foundation for further advancements in Gesture Control technologies, with continuous work being done to enhance system capabilities and investigate new application areas. Our technology enhances user experience in a variety of applications by combining motion control methods and gesture recognition algorithms to provide responsive and intuitive interaction.

Objective:

1. The main objective of the proposed virtual AI mouse is to furnish an alternative to the conventional physical mouse that provides mouse functions with the help of computer vision enabled computer.
2. Create a touch-free alternative to traditional physical mice using computer vision.
3. Use a webcam and machine learning to accurately track hand movements and gestures for moving the cursor, left-clicking, right-clicking, and scrolling.
4. Also we are using multiple libraries to perform this project.
5. Offer a natural, intuitive, and easy-to-learn method for navigating the graphical user interface.
6. Create an intuitive and easy-to-use interface for interacting with the virtual mouse system.



Literature Review:

Numerous studies have been undertaken to replace standard human-computer interface devices with computer vision alternatives. Controlling cursors via hand gestures dramatically increases the direct interaction loop between the user and the system.

These are the related studies that have been undertaken on the topic. There are many ways of cursor control using hand gestures. This can increase the interaction between user and system. [1] Quam in 1990 designed an early hardware-based gesture recognition system requiring users to wear a bulky DataGlove. While achieving high tracking accuracy, the architecture was heavily restricted by the lack of portability, expensive equipment, and constrained user hand agility, establishing the clear historical need for touchless camera-based alternatives.[2] Stark in 2010 evaluated a multimodal Virtual Role Players (VRP) system combining automated speech recognition with Hidden Markov Model (HMM) hand gesture classifiers. This research demonstrated that fusing linguistic inputs with spatial body movements increases total intent tracking accuracy to 93% (up from 78% for standalone gestures), proving that multi-modality successfully compensates for low-light camera frame drop errors.[3] Bartindale et al. in 2011 explored the use of virtual multi-touch supplementation by presenting Surface Mouse, which renders a software cursor underneath a user's flat palm on a touch surface. This design successfully co-opted existing physical mouse muscle memory and desktop applications while eliminating target occlusion and point accuracy degradation caused by "fat finger" contact boundaries.[4] Osunkoya and Chern in 2012 introduced a gesture-based Human-Computer

Interaction interface using the skeletal tracking framework of the Microsoft Kinect depth sensor. Because low-resolution depth mapping prevented fine finger-tip detection, their workaround split tasks by assigning continuous cursor movement to one tracked hand while allocating secondary mouse actions to gross gestures performed by the opposite hand.[5] Rzepecki et al. in 2012 By pairing Microsoft Kinect tracking sensors with consumer-grade EEG (brainwave) headsets, researchers expanded how humans and machines interact. This setup allowed users to control computer applications simply by focusing their attention. [6] Shirley and Jayanthi in 2015 developed a portable, low-cost embedded gesture recognition interface using an open-source Python IDE hosted on a Linux-based Raspberry Pi microcomputer. By processing BGR video streams from a lens into an HSV color space, the system avoided noisy skin-pixel segmentations by successfully tracking simple finger-mounted colored markers to control real-time cursor movement, left clicks, and right clicks.[7] Champion et al. in 2016 designed a large-scale 3D telepresence platform incorporating Microsoft Kinect tracking arrays inside an 8-meter-wide curved cylindrical display. Utilizing Unity engines and the Zigfu Development Kit, this spatial architecture allowed a speaker's structural hand pointing gestures to naturally drive non-linear presentations and navigate digital avatars, removing traditional desk bounds entirely.[8] Xu in 2017 built a real-time, low-resource virtual mouse interface using a single monocular camera camera feed without tracking markers or expensive depth peripherals. The pipeline deployed a Ramer-Douglas-Peucker polygonal curve approximation to identify



fingertips via hand contour convexity defects, which were then classified using a lightweight, fast LeNet-5 CNN framework paired with a smoothing Kalman filter.[9] Shibly et al. in 2019 proposed a cost-effective Human-Computer Interaction virtual mouse framework based on standard webcam video captures processed via OpenCV. Fingertip tracking was accomplished by isolating-colored caps worn on a user's fingers using BGR-to-HSV color space segmentation; however, the framework highlighted that changing environmental light levels remained a massive bottleneck for consumer deploy ability.[10] Kher et al. in 2020 implemented a motion and gesture control architecture featuring an ordinary laptop webcam and image processing executed via MATLAB. The model isolated red, green, and blue taped targets via an image-subtraction loop, converted gray pixel patches into a binary scale, and tracked real-time cursor positioning through continuous centroid matrix calculations while matching keyboard shortcut triggers to static gesture classes.[11] Tran et al. in 2021 designed a robust fingertip-gesture-based interface utilizing Microsoft Kinect V2 depth-sensing arrays to bypass traditional RGB camera noise. The system extracted the palm center and hand regions from depth maps, mapped hand outlines via border-tracing, and isolated exact fingertip positions using a specialized K-cosine corner detection algorithm, successfully supporting multi-user target locking for up to six people.[12] Sen et al. in 2022 engineered an advanced, low-cost six-stage human-machine interface utilizing deep transfer learning architectures trained over multiple image datasets. By passing resized, binary-thresholded hand regions into six parallel convolutional networks, they established that an

Inception-V1 module provided the highest accuracy (99.30%), which was paired with a recursive Kalman filter to eliminate erratic cursor jumping across screen borders.[13] Prithvi et al. in 2023 presented a touchless, bare-hand virtual mouse system integrating voice automation features on top of a standard Windows operating system platform. Powered by Convolutional Neural Networks running directly inside the Google MediaPipe hand detection framework, the markerless architecture mapped anatomical finger joints to mouse controls, providing an intuitive, touch-free tool for users with physical limitations.[14] Rao et al. in 2025 constructed an optimized finger-tracking virtual mouse powered by Python's OpenCV modules and high-speed Artificial Intelligence object tracking. Focused strictly on device-free accessibility, the system processed sequential webcam image frames through advanced filtering matrices, lowering data-entry processing latency down to an ultra-responsive 3.81 milliseconds per frame to enhance live user engagement.

Research Methodology:

The proposed system functions as a continuous pipeline divided into four interconnected phases: Image Acquisition, Hand Landmark Detection, Gesture Mapping, and OS-Level Execution.

First, the system continuously pulls video frames from the integrated webcam using OpenCV. Each frame is converted from BGR to RGB colour space to ensure compatibility with the tracking model. The frame is also flipped horizontally to provide a natural mirroring effect for the user. Second, the processed image frame is sent to the MediaPipe Hand Landmarker model. The framework maps



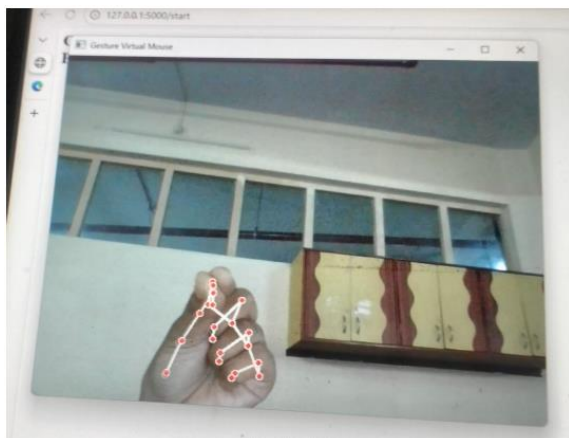
exactly 21 coordinate points onto the hand joints in a 3D coordinate space. Third, the system isolates the index finger tip coordinate (Landmark 8) and scales it to match the monitor's native screen resolution. An

exponential smoothing filter is applied to prevent shaky cursor movement. Fourth, the system measures the Euclidean distance between specific finger landmarks to trigger click actions.

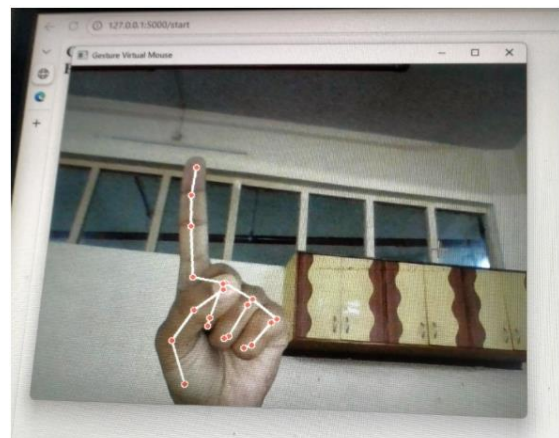
Mouse Function	Hand Gesture Type	System Response
Cursor Movement	Move your Index Finger	Move the mouse pointer smoothly across the screen
Left Click	Index and Middle Finger pinch together	perform a standard single left-click event
Right Click	Thumb and Pinky finger pinch together	Open the context using right-click event
Double Click	Index, Middle and ring fingers extended UP and brought close	Open an application, file, or select a word basically which you want to open
Scroll Up	Middle, ring and pinky fingers keep in front of camera	Scroll the active window page or document upwards
Scroll Down	Index and ring fingers bring in the front of camera	Scroll the active window page or document downwards
Brightness Control	Thumb and index finger pinch	It increases or decrease screen brightness levels
Volume Control	Thumb, index and middle fingers pinch together	It adjusts system audio levels louder or softer
Drag & Drop Click	Thumb and index finger	Hold and latch onto a file to move it across the desktop

Result & Discussion:

The implementation was extensively tested across varying environments to measure structural speed and gesture precision. In standard, well-lit rooms, the MediaPipe infrastructure extracted coordinates with an accuracy rate exceeding 95%. Processing latencies remained under 15ms per frame, ensuring responsive visual cursor feedback.



However, performance degrades substantially in low-light environments due to high image noise from standard webcams. Additionally, prolonged usage highlighted muscle fatigue ('Gorilla Arm Syndrome'), proving that while the framework functions exceptionally as a mouse replacement, user rest breaks or optimal arm positioning are required for continuous tasks. These are the outcomes:





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