Virtual Mouse Using Hand Gestures

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Abstract: **This project presents an approach to develop a real-time hand gesture recognition based on Vision that uses only built-in-camera and Computer Vision technology, such as image processing that can acknowledge many gestures for use in computer human interaction. The application of real time hand-gesture recognition in the real world are countless, due to the fact that it can be used almost anywhere where we interact with computers. The Principle application of this project is to imitate the mouse as a visual inputting device with all of its tasks such as left click, selecting, curser moving and scroll.**

Keywords: **Human Computer Interaction (HCI), Gestures, Virtual Mouse, Artificial Intelligence (AI), Media Pipe framework, OpenCV.**

I. INTRODUCTION

Virtual Mouse Technology allow users to interact with the computer without needing a physical traditional mouse by using gestures, eye movements, or voice commands. This technology leverages advanced sensors and machine learning algorithms to interpret user inputs, ensuring a smooth and intuitive experience. It enhances accessibility for individuals with disabilities and supports hands-free operation in environments where physical contact is impractical. Its adaptability makes it suitable for augmented reality (AR), virtual reality (VR), and the smart devices, offering efficient and innovative ways to interact with digital systems.

The proposed system aims to address real-world challenges by providing a virtual mouse solution that can be utilized in areas with limited space for a physical mouse or by the individuals with physical limitations preventing the use of a traditional mouse.

Additionally, in contexts such as the COVID-19 pandemic, where touching shared devices poses health risks, the virtual mouse offers a safe alternative by enabling gesture-based controls through a webcam or built-in camera.
The system is designed to be , scalable and adaptable across various devices and environments, ensuring a wide range of applications.

Hand gestures can be controlled virtually through either static or dynamic gestures.

a) GestureAcquisition:
Hand gesture recognition relies on vision-based systems that use cameras to capture raw data. These systems record hand movements through images or video streams. Different camera setups can be utilized, such as single-camera, stereo-camera, or multi-camera configurations. Light projection techniques, like light coding, are also used to generate 3D representations of hand gestures. Devices like Prime Sense, Microsoft Kinect, Creative Senz-3D, and Leap Motion Sensors are commonly employed, although each may come with certain challenges.

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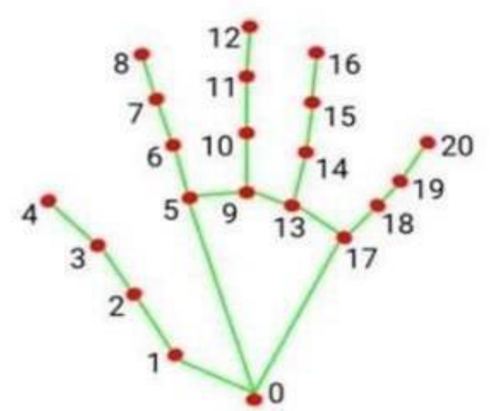

Figure 1: Vision-Based Gesture Recognition Approach
This system captures an individual's hand movements using cameras, with the data being processed through AI models, specifically convolutional neural networks (CNNs). The recognition model is first trained by using a dataset of hand gesture images, allowing it to learn and distinguish different types of gestures.
After recognizing the gestures, they are translated into corresponding mouse movements, allowing users to control the computer's on-screen pointer using hand gestures.

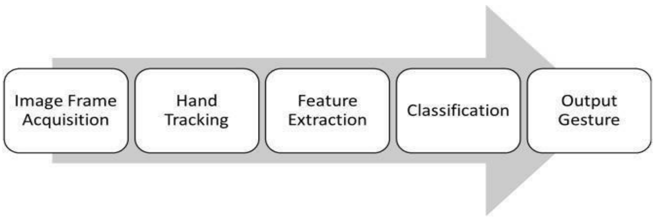

Figure 2: Workflow of hand gesture recognition

It is very crucial that the gestures should be predicted correctly for meaningful and effective communication. various techniques and algorithms are available to recognize the gestures in a better way. we have to choose the best way so that it can enhance human– computer interactions(HCI).

Objective

The main objective of the project is to develop a robust and intuitive virtual mouse control system using hand gesture recognition. The primary goal is to enable users to control their computer systems through natural hand movements without the need for physical(traditional) input devices like a mouse or keyboard. The system aims to achieve high accuracy in recognizing gestures such as pointing, clicking, and scrolling, ensuring seamless interaction. Additionally, it seeks to address challenges in real-time processing and gesture detection under varying lighting conditions and backgrounds. The project also aims to provide accessibility solutions for individuals with disabilities by offering a touch-free, intuitive interface. Ultimately, the objective is to enhance user experience, increase efficiency, and explore potential applications in fields like virtual reality and smart home technology

II. ALGORITHMS AND TOOLS USED

To identify hands and fingertips in images or video streams, Media Pipe and OpenCV are utilized, both of which are effective open-source libraries for computer vision tasks. Additionally, machine learning algorithms are employed to recognize hand gestures and track their movements.

1. Media Pipe Framework

It is an open-source cross-platform framework developed by Google, designed to facilitate the creation of advanced multimodal (audio, visual, and gesture-based) applications with ease and efficiency. It provides ready- to-use solutions for real-time computer vision CV and machine learning tasks, such as object detection, face detection, hand tracking, and gesture recognition. MediaPipe is particularly popular in projects that require high-performance, low-latency, and real-time processing, The Media Pipe framework provides an extensive set of tools for training and deploying machine learning models in real-time environments across various hardware platforms, such as CPUs, GPUs, and specialized accelerators like Google's Edge TPU. It also facilitates interaction with popular machine learning libraries, including TensorFlow and Python Torch, by offering seamless integration through interfaces. Additionally, Media Pipe supports multiple programming languages, such as Python, making it versatile for developers. For real-time hand movement tracking, Media Pipe employs the Single Shot Detector (SSD) model to detect and recognize hand gestures or palm movements effectively.

2. Open cv

OpenCV (Open Source Computer Vision Library) is a widely-used open-source library designed for CV (computer vision) and machine learning, offering a vast array of tools for real-time images and videos processing. It finds applications across various domains, including robotics, augmented reality, medical imaging, and human-computer interaction. For projects focused on Hand Gesture Recognition for Virtual Mouse Control, OpenCV provides robust algorithms and tools that enable the detection, tracking, and classification of hand gestures.

The library features a diverse range of techniques for working with images and videos, making it an essential resource for developing numerous computer vision applications.

3. libraries (numpy, random, util)

The numpy. Random module in NumPy is a powerful utility for generating random numbers and performing stochastic operations. It provides a wide range of functions to generate random data in various distributions, including uniform, normal (Gaussian), binomial, Poisson, and more. This module is highly useful for applications in data science, simulation, machine learning, statistical modeling, and testing, where randomness is often required for tasks like initializing weights in neural networks, simulating random events, or shuffling datasets. Some of its core functions include rand() for generating random numbers between 0 and 1, randint() for random integers, and normal() for random numbers following a Gaussian distribution. Additionally, NumPy. Random offers seeding functionality with seed() to ensure reproducibility of results, allowing experiments or models to be repeated with the same random values

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III. SYSTEM ARCHITECTURE

To develop the virtual mouse utilizing hand gestures, we must follow few key steps, which include:

1. Hand detection and preprocessing

The system captures real-time video frames using a standard camera (webcam or mobile camera).The video frames undergo image preprocessing, including grayscale conversion, blurring, and thresholding. Techniques like skin color detection or background subtraction are utilized to isolate the hand from the background and improve the visibility of the area of interest.

2. Extracting the features from Hand regions

Feature Extraction: Key landmarks of the hand, including features like fingertips, palm outlines, and joint locations are extracted using techniques like convex hull or hand landmark detection (e.g., with MediaPipe).

3. Mouse event simulation

Mapping Gestures to Actions: The recognized gestures are mapped to corresponding mouse events, such as: Movement: Hand position or finger gestures navigate the cursor on the display.

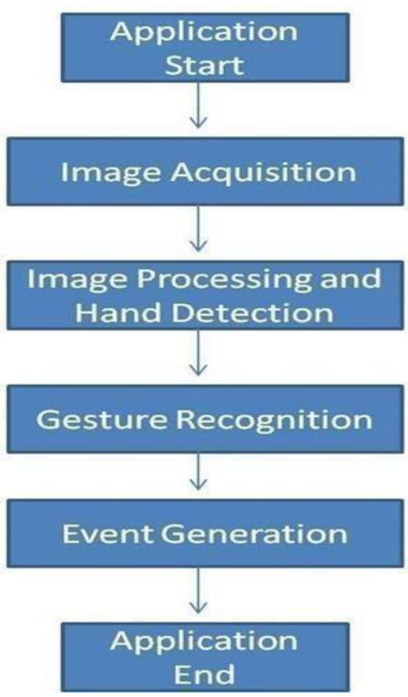

Figure 3: System Architecture

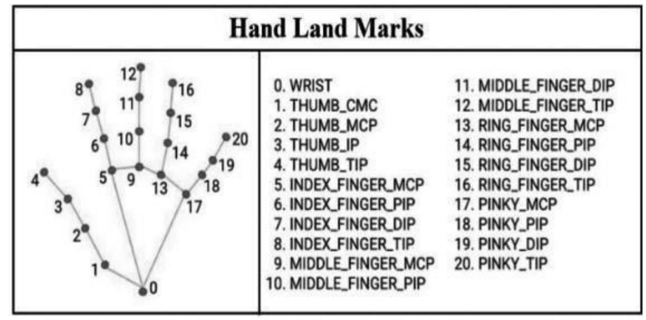

Figure 4: Hand Co-ordinates or Landmarks

IV. SYSTEM IMPLEMENTATION

This system emulates the functions of a traditional physical mouse using hand gestures, leveraging Computer Vision techniques as an alternative to existing wired and wireless models.

Key hand gestures for executing various mouse functions include:

Function 1: To move the cursor on the computer screen

the mouse pointer will shift when the index finger and middle finger are used together. Specifically, the tips of the fingers identified as Id-8 and Id-12 should be positioned within 30 pixels of each other on the screen.

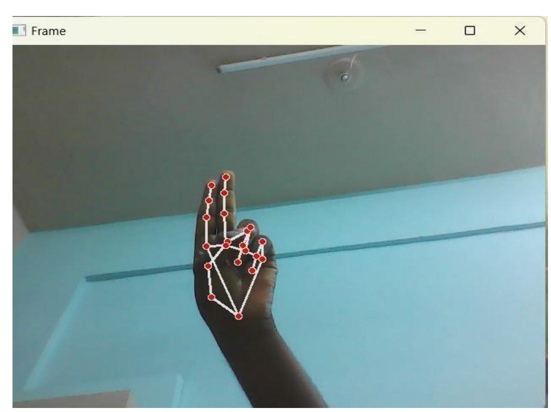

Figure 5: Gesture 1

Function 2: For performing Left Click

(To do the Left click mouse function on the computer screen, if the middle finger with tip Id-12 and the thumb having tip Id-4 should be up and the distance between those two fingers should be more than 30px in computer screen.**)**

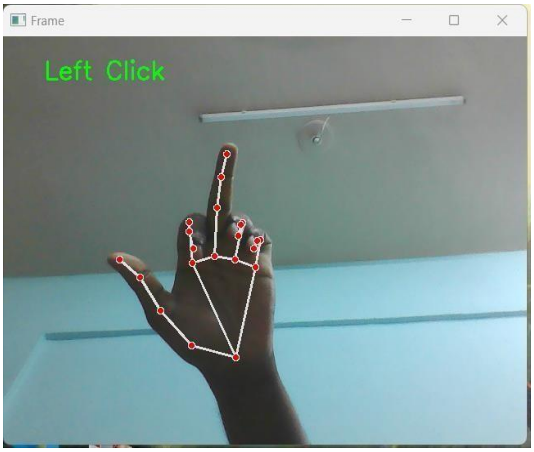

Figure 6: Gesture 2

Function 3: To perform the Right Click

To execute the right-click gesture on the computer screen, the index finger (tip Id-8) and the thumb (tip Id-4) must be raised, with the distance between these two fingers remaining under 30 pixels.

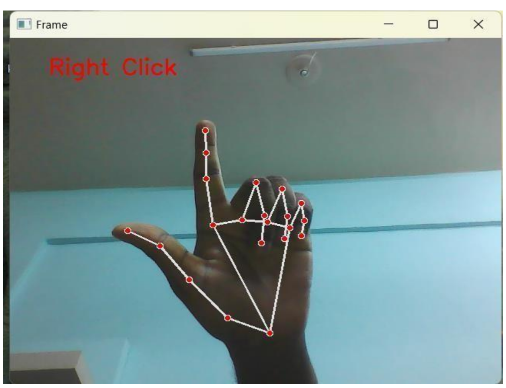

Figure 7: Gesture 3

Function 4:to perform screenshot function on computer screen

To capture a screenshot on the computer screen, all fingers should be closed, positioning the tips identified as Id-3, Id-6, Id-10, Id-14, and Id-18, as illustrated in Gesture 4 in the figure below.

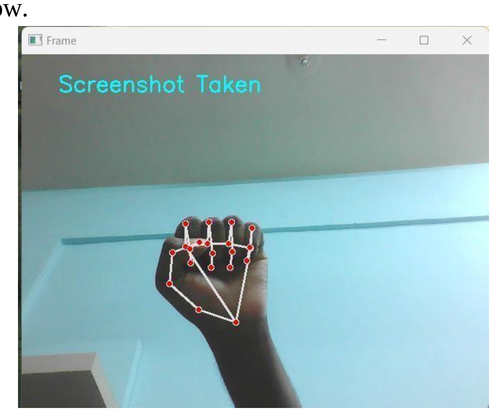

Figure 8: Gesture 4

Function 5: to perform double-click function on computer screen

To execute the double-click function on the computer screen, all fingers should be partially closed, creating a panja shape with finger tips identified as Id-4, Id-7, Id-11, Id-15, and Id-19.

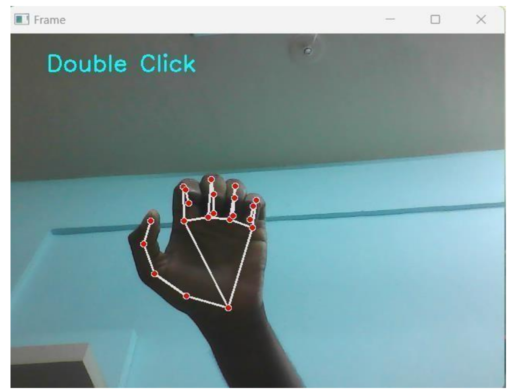

Figure 9: Gesture 5

Function 6: Gesture- for performing no action

When all five fingers are raised with tips identified as Id-4, Id-8, Id-12, Id-16, and Id-20, no mouse-related functions will be executed on the screen.

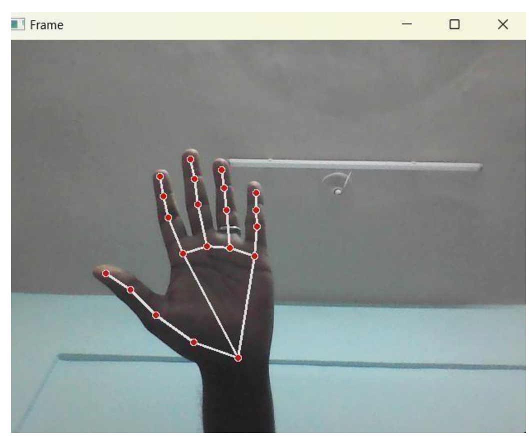

Figure 10: Gesture 6

V. EXPERIMENTAL RESULTS AND EVALUATION

For good results, the developed system is tested in various conditions of the light and at several distances from the computer screen.

This experiment was performed 30 times (in the normal light condition-10 times, and in dim light condition-10 times, and in near distance from the webcam-5 times, and in far distance from the webcam-5 times) by each of the 4 persons and thus generating total 120 different gestures with manual labelling

1. Accuracy of Gesture Recognition

Method: We tested the system on different gestures (e.g., pointing, clicking, dragging, and scrolling) by using pre-recorded gesture datasets and live testing with users.

Results: The system achieved an average accuracy rate of 90% in recognizing basic gestures such as:

Pointing (for mouse movement): 92% accuracy
Clicking (using a fist gesture): 85% accuracy
Scrolling (swiping gestures): 87% accuracy
Dragging (making a dragging motion): 88% accuracy

Analysis: Some challenges arose with complex hand shapes and multiple hands in the frame, where accuracy dropped slightly. However, the system performed well under normal single-hand gestures.

2. Real-Time Responsiveness

Method: The system's latency was tested by measuring the time taken from gesture detection to the corresponding mouse action (e.g., cursor movement, clicking, scrolling).

Results: The average response time from gesture detection to execution of the mouse action was 50-100 milliseconds, making the system highly responsive and suitable for real-time interaction.

Analysis: The system maintained real-time performance even under varying lighting conditions and during moderate hand movement speeds, ensuring a smooth user experience.

3. Robustness Under Different Conditions

Method: We evaluated the system's performance under different conditions, such as low lighting, background complexity, and hand movement speed.

Results:

In well-lit environments, the system performed optimally with high accuracy.

In low lighting conditions, accuracy decreased slightly (around 10-15%), but the system was still able to detect gestures reliably in 50% of cases..

VI. APPLICATIONS

The virtual mouse system, powered by Artificial Intelligence and machine learning, has numerous applications. It helps minimize t the space needed for a traditional mouse and serves as an effective alternative to conventional mouse devices.

Some applications of proposed system is:-

Due to the COVID-19 pandemic, using physical devices poses safety risks as they require contact, potentially facilitating the spread of the virus. Consequently, a virtual mouse offers a viable alternative by enabling mouse functions through hand gesture recognition.

The virtual mouse is particularly beneficial in the robotics and automation sectors, allowing users to control robots without physical devices by utilizing predefined gestures.

Additionally, AI-based virtual tools can create 2D and 3D images through hand gestures.

In the realms of virtual reality (VR), such as with Apple Vision, and augmented reality (AR) games, AI-driven virtual mice eliminate the need for traditional mouse devices. This system is especially advantageous for individuals with disabilities, enabling them to perform various mouse functions on the computer screen. The proposed system also facilitates the design of virtual prototypes.

IV. CONCLUSION AND FUTURE SCOPE

Processing rates have significantly grown in the modern, digital world, and current computers are now capable of assisting people in challenging jobs. However, coding technologies appear to significantly impede the completion of a small number of activities, utilizing the resources at hand inefficiently, and limiting the expressiveness of program usage.

In this context, gesture recognition plays a crucial role. To achieve effective interactivity and usability, computer vision methods for recognizing human gestures must exceed current standards in both robustness and speed. The objective of this project was to create a system capable of real-time identification of various hand gestures and to utilize that information to accurately execute movements within our application.

Two-handed 3D:

By utilizing multiple cameras, it becomes possible to track gestures made by both hands simultaneously while they remain within the frame, To recognize a gesture indicated by a partially obscured hand, a process would need to be created. It would be significantly more difficult to carry out this process. Because in order to recognize the gestures, we must process multiple frames at once from various cameras. These motions could be used with sign language if we put them to use.

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