



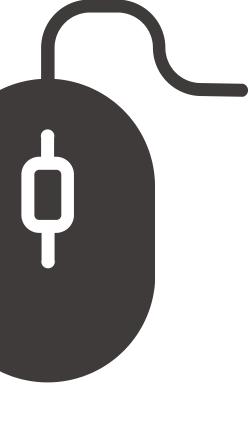
RABINDRANATH  
TAGORE UNIVERSITY

# HAND GESTURE RECOGNITION

GESTURE. CONTROL. EMPOWER

2024

# AI Virtual Mouse System



This document presents an overview of the AI Virtual Mouse System, a technology designed to replace traditional mouse devices with an intuitive, gesture-based interface.... By harnessing the power of artificial intelligence and computer vision, this system interprets hand movements to control the cursor, offering a hands-free alternative for interacting with digital devices.... The following sections will detail the system's features, benefits, & potential applications across various industries....

## About the lead

I am Priyanshu Chouhan (AU220788), a student in the Department of Computer Science and Information Technology at Rabindranath Tagore University (RNTU), Bhopal, from the 2022 batch.... As the developer of this project and the author of this paper/document, I have leveraged my academic background and technical expertise to design and implement the AI Virtual Mouse System.... My commitment to advancing technology and my enthusiasm for innovative solutions have guided this endeavor, reflecting the educational foundation and support provided by my university and department....

## Primary Contributors

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We dedicate this project to Rabindranath Tagore University, Bhopal, and the Department of Computer Science and Information Technology (CS/IT). The knowledge, guidance, and support we have received here have been instrumental in shaping our academic journey and have inspired us to push the boundaries of innovation.... This work is a reflection of the education and opportunities provided by this esteemed institution, and we are proud to contribute to its legacy of excellence....

~PRIYANSHU & TEAM

## 1 Introduction

As technology advances in augmented reality and the devices we use daily become increasingly compact, often leveraging Bluetooth or wireless technologies, there is a growing need for innovative input solutions.... This paper/document presents an AI Virtual Mouse System that utilizes hand gesture and fingertip detection to perform mouse functions through computer vision.... The primary objective of this system is to enable computer mouse cursor operations and scrolling using a web camera or built-in camera, eliminating the need for a traditional mouse.... By employing hand gesture recognition as a human-computer interface (HCI), the system allows users to control cursor movements and scrolling functions efficiently.... Unlike conventional wireless or Bluetooth mice, which require additional components such as a dongle and batteries, the proposed system relies solely on a built-in camera or webcam to detect hand gestures and manage computer operations....

### • Project Aim:

The primary objective of the proposed AI Virtual Mouse System is to provide an alternative to traditional mouse devices for controlling and executing mouse functions.... This system utilizes a web camera to capture hand gestures and fingertip movements, which are processed to perform specific mouse operations such as left-click, right-click, and scrolling.... By leveraging computer vision technology, the system aims to enhance user interaction with computers through intuitive gesture-based controls....

### • Problem Statement:

The proposed AI Virtual Mouse System addresses several challenges associated with traditional mouse devices.... It is particularly useful in environments where space is limited and a physical mouse cannot be used effectively.... Additionally, it provides a valuable solution for individuals with grip difficulties who may struggle with conventional mouse operation.... The system is also relevant in the context of health concerns, such as the COVID-19 pandemic, where reducing physical contact with devices can help minimize the risk of disease transmission.... By utilizing hand gesture and fingertip detection through a camera or webcam, this AI Virtual Mouse System offers a touchless alternative to traditional input methods, overcoming the limitations of physical mouse devices and enhancing user convenience & hygiene....

## 2 Literature Survey for Problem Identification and Need of Project

The existing literature reveals a variety of approaches to virtual mouse and trackpad control systems, including hand gesture-based control mechanisms.... While some systems attempt to utilize hand movements to interact with screens from a distance, their effectiveness is often limited by the range and precision of gesture recognition.... Current virtual mouse systems generally support basic functions such as controlling the mouse pointer, left-clicking, right-clicking, & dragging etc. However, these systems frequently rely on static hand gesture recognition, which involves interpreting predefined hand shapes and their associated actions.... This approach often results in limited functionality and user inconvenience due to the restricted range of recognized gestures

As technology advances, there is a growing need for more sophisticated and flexible input methods beyond traditional mice.... The following are some of the key techniques used in existing systems:

- **Camera-Based Systems:** Projects like the Virtual Gesture Mouse often utilize OpenCV, a Python library for computer vision, to process frames captured by a camera.... These systems rely on edge detection and image processing to interpret hand gestures and translate them into mouse functions....
- **Input Representation:** In computer vision, images are represented as arrays of pixel values, which correspond to varying degrees of brightness or color.... This data can be analyzed in multiple ways, including as raw pixel values or through more complex visual analysis techniques, to facilitate gesture recognition and interaction....
- **Hand Movement Through the Window Using Rectangular Area:** The AI Virtual Mouse System employs an algorithmic approach to convert fingertip coordinates captured by the camera into corresponding positions on the full-screen computer window.... This method enables seamless control of the mouse cursor based on hand movements....
- **Finger Tip Detection and Cursor Control:** The system utilizes advanced techniques to detect fingertips and enhance mouse cursor operations.... By leveraging MediaPipe for precise fingertip tracking, the system accurately identifies finger positions and translates them into corresponding mouse actions
- **Health and Safety Considerations:** Despite the advancements in gesture-based control systems, they have limitations and potential health risks.... Continuous use of head or eye movements to control the cursor can lead to physical strain and health issues.... Additionally, maintaining focus on a touch screen for extended periods may result in discomfort and fatigue.... Our goal is to develop a solution that addresses these concerns while enhancing user comfort and safety....

### • Need of Project:

The PC mouse is a remarkable advancement in Human-Computer Interaction (HCI) technology.... However, in the modern era, even wireless or contactless mice are not entirely free from physical devices, as they require power from batteries or external sources and occupy physical space.... Additionally, during the COVID-19 pandemic, maintaining social distancing and minimizing contact with shared objects is crucial to reduce the risk of virus transmission....

The proposed AI Virtual Mouse System addresses these challenges by leveraging advanced camera technology and computer vision to detect hand gestures and fingertip movements.... This system uses artificial intelligence (AI) and machine learning (ML) algorithms to interpret gestures, allowing users to perform mouse functions such as left-clicking, right-clicking, scrolling, and cursor movement without the need for a physical mouse.... By employing this contactless method, the project aims to enhance user convenience, promote hygiene, and contribute to a more seamless and intuitive interaction with computer systems....

## • Algorithm Used, Proposed System/Model

The proposed AI Virtual Mouse System employs the MediaPipe framework in conjunction with the OpenCV library to facilitate accurate hand gesture detection and tracking.... MediaPipe provides advanced machine learning models specifically designed for real-time hand and fingertip recognition, while OpenCV offers robust computer vision capabilities essential for processing and analyzing video input.... The algorithm integrates these technologies to monitor and interpret hand movements, leveraging machine learning concepts to effectively track and recognize various hand gestures and fingertip positions.... By utilizing this combination of MediaPipe & OpenCV, the system can reliably translate detected hand movements into corresponding mouse functions, enabling intuitive and contactless control of the computer interface....

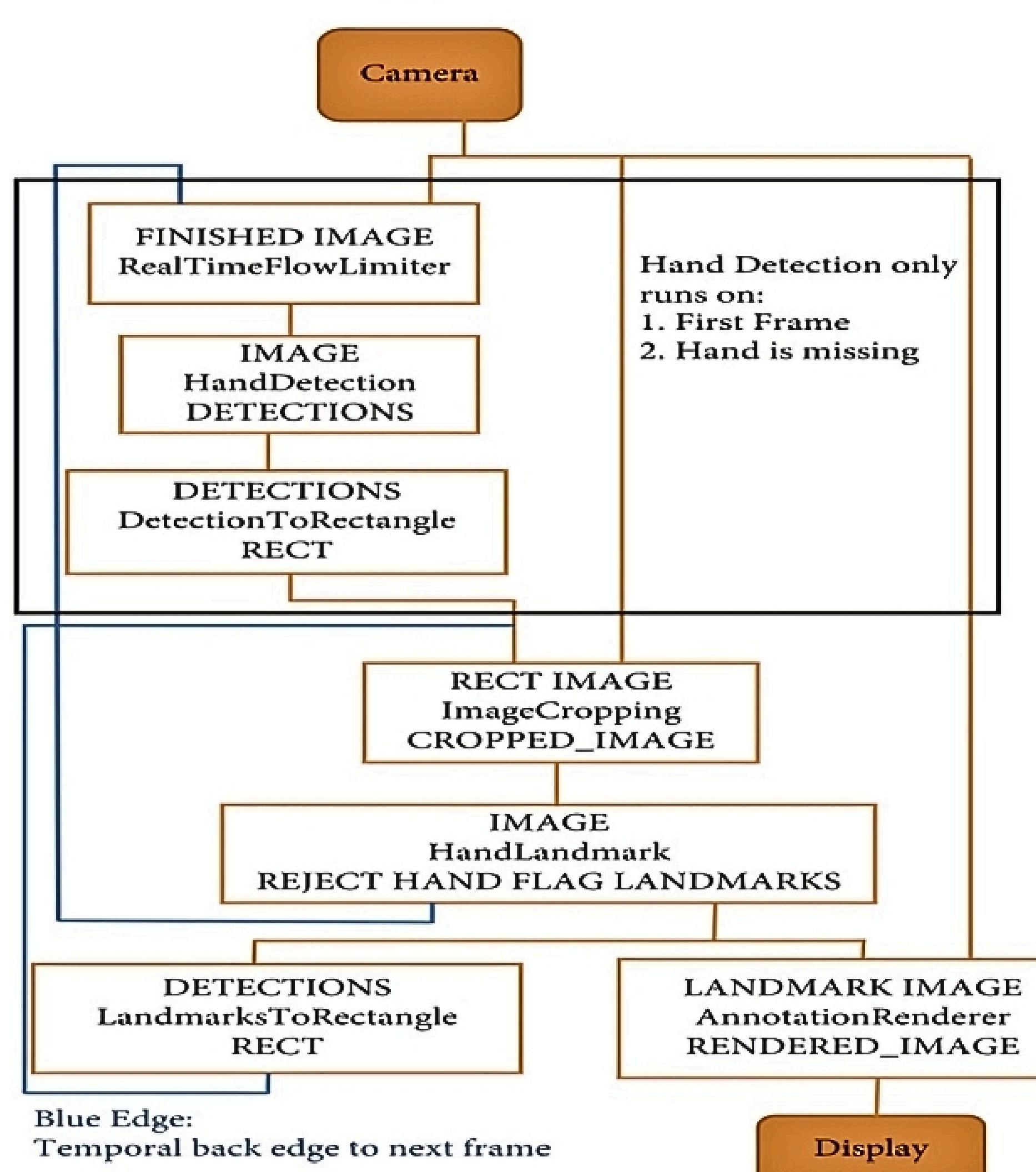
### • MediaPipe

MediaPipe is an open-source framework developed by Google, designed for building machine learning pipelines.... It is particularly useful for cross-platform development due to its ability to handle time series data.... MediaPipe supports multimodal applications, making it suitable for both audio & video processing.... The framework facilitates system development and analysis through a graph-based approach, enabling scalable deployment on various platforms, including mobile & desktop....

#### MediaPipe operates based on three fundamental components:

- **Performance Evaluation:** Ensures the efficiency and effectiveness of the pipeline
- **Sensor Data Retrieval:** Handles the acquisition of data from various sensors....
- **Calculators:** Reusable components that process data within the pipeline

The MediaPipe pipeline is structured as a graph where each node represents a calculator, and connections between nodes are defined by data streams.... This architecture allows developers to create and customize their applications by defining or replacing calculators within the graph.... The visual representation of the pipeline, as shown in **Figure 1**, illustrates how calculators are interconnected by streams, forming a data-flow diagram that facilitates complex data processing tasks....



### • OpenCV Module

Computer Vision is a field that enables the interpretation and analysis of images and videos, focusing on how they are stored, processed, & retrieved.... It serves as a foundational technology for many artificial intelligence applications.... OpenCV, which stands for Open Source Computer Vision Library, is a widely-used tool in this domain....

The initial release of OpenCV was version 1.0. The library is distributed under the BSD license, making it freely available for both academic and commercial use.... OpenCV supports multiple programming languages, including C++, C, Python, and Java, and is compatible with various operating systems such as Windows, Linux, Mac OS, iOS, and Android....

OpenCV was designed with an emphasis on real-time applications and computational efficiency, providing a robust set of tools for developing advanced computer vision solutions....

## 3 Methodology

Pre-processing, or image processing, is a crucial preliminary step in computer vision aimed at converting images into formats suitable for further analysis.... This phase includes operations such as exposure correction, color adjustment, noise reduction, and image sharpening, all of which are essential for achieving accurate and reliable results....

In this paper/document, I will present a subset of commonly used image processing techniques utilizing the well-established OpenCV library.... The methodology will involve a concise explanation of each operation, with a focus on practical implementation.... The goal is to provide a clear and hands-on understanding of these techniques, accompanied by the necessary code to facilitate active engagement with the material....

### • The Camera Used in the AI Virtual Mouse System

The proposed AI Virtual Mouse System operates by analyzing frames captured by a webcam on a laptop or computer.... Utilizing the Python computer vision library OpenCV, the system initializes a video capture object, which enables the webcam to begin capturing and processing video in real-time.... This setup allows the system to detect and interpret hand gestures and movements for controlling the mouse functions....

### • Detecting Which Finger Is Up and Performing the Corresponding Mouse Function

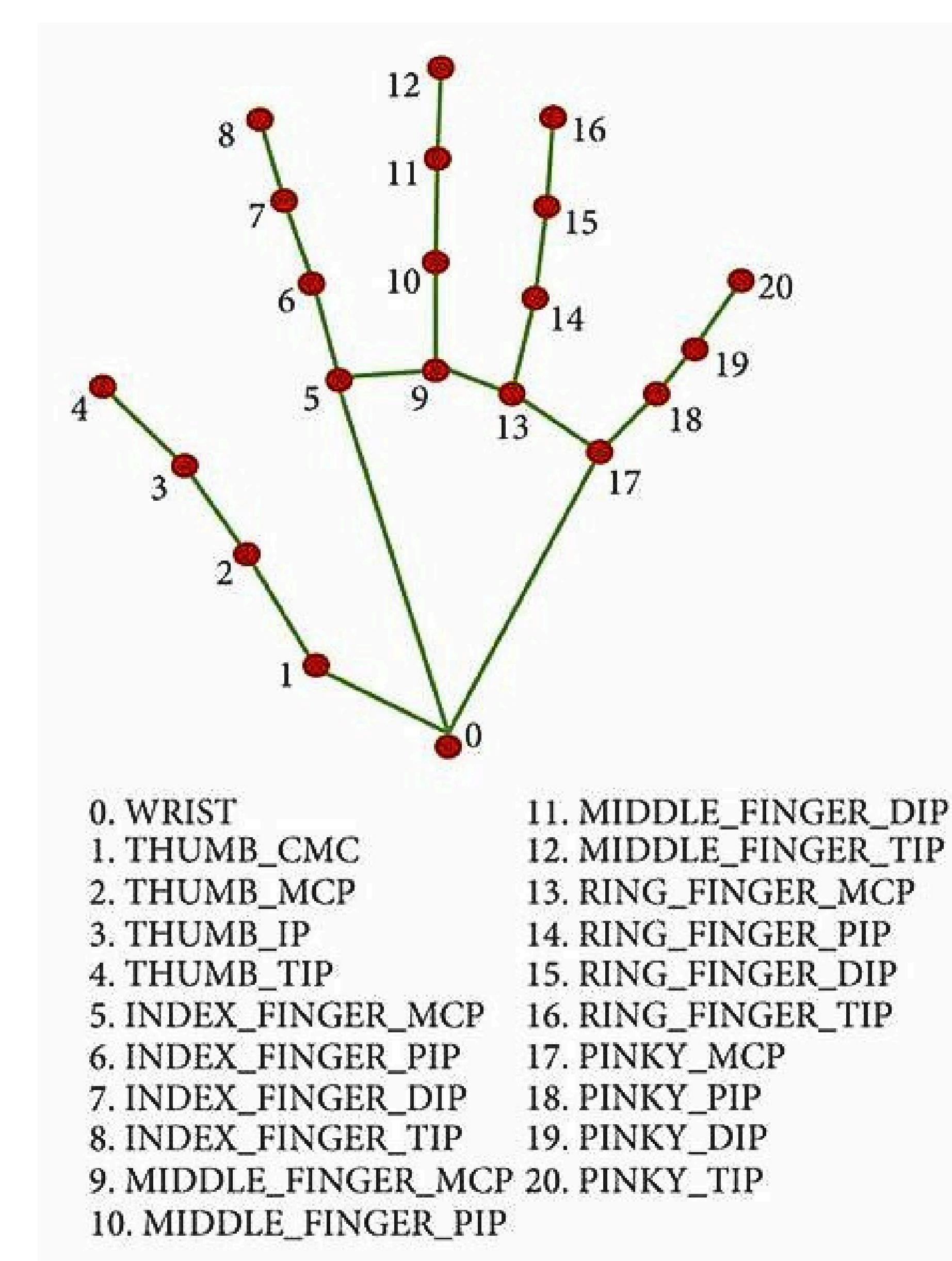
In this stage, the system identifies which finger is raised by using the fingertip IDs and their coordinates detected through MediaPipe.... Based on the specific finger that is up, the system executes the corresponding mouse function.... This involves interpreting the finger positions to perform actions such as left-click, right-click, or scrolling, allowing for intuitive & gesture-based control of the mouse functions....

### • Performing a Right Mouse Button Click

To execute a right mouse button click, the system follows these conditions:

- Both the index finger (tip ID = 1) and the middle finger (tip ID = 2) must be raised....!!
- The distance between the tips of these two fingers must be less than 40 pixels....!!

When these conditions are met, the system triggers a right mouse button click using the `pyautogui` Python package



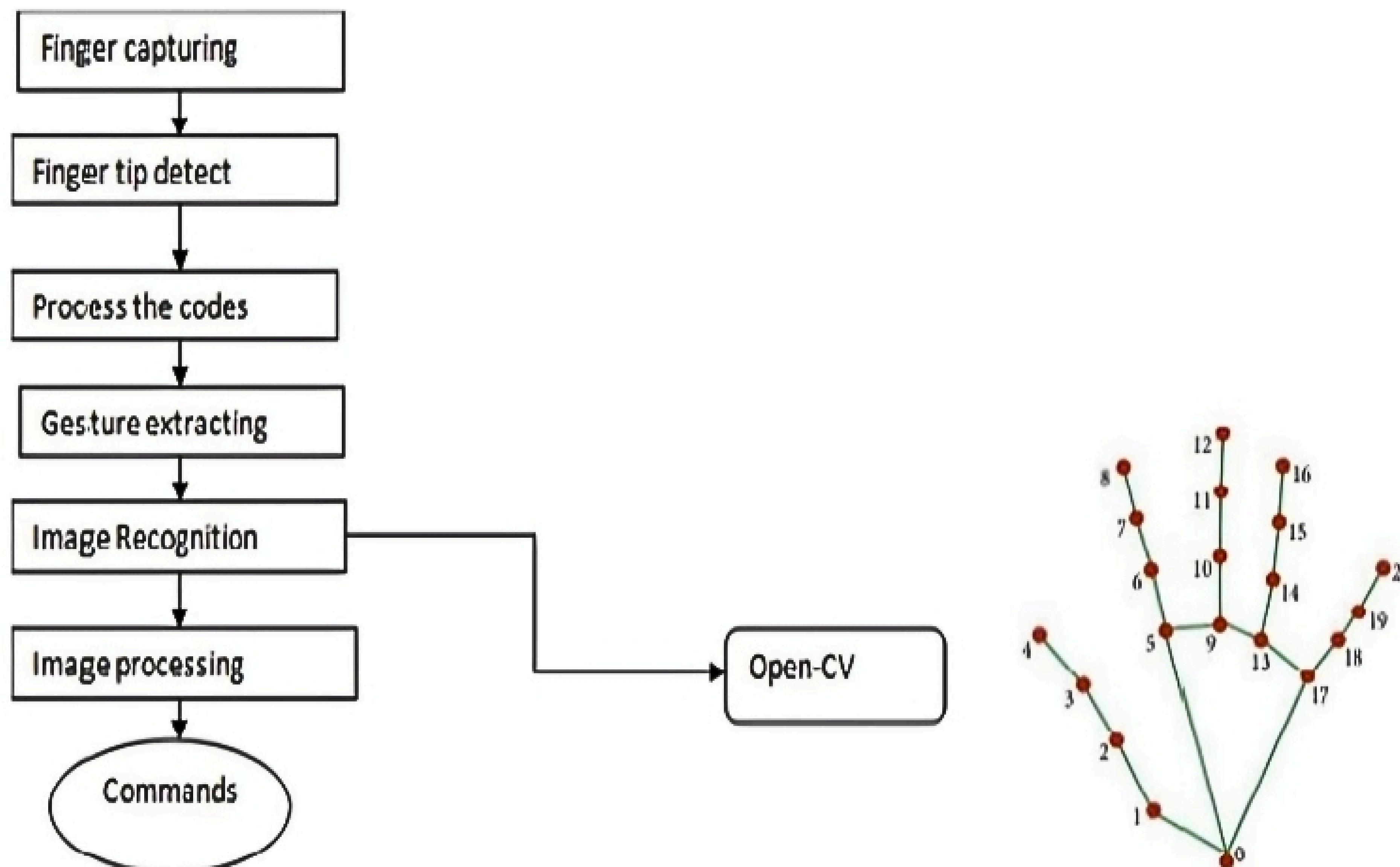
## • Proposed System/Model

The proposed AI Virtual Mouse System utilizes the MediaPipe framework for hand gesture and movement detection, while the OpenCV library provides the computer vision capabilities necessary for processing and interpreting these gestures.... MediaPipe is employed to recognize and track hand movements and fingertip positions, while OpenCV supports image processing tasks essential for effective gesture recognition....



Pre-processing, or image processing, is a critical preliminary step in computer vision, aimed at converting images into formats suitable for further analysis.... Key operations include exposure correction, color adjustment, noise reduction, and image sharpening.... These tasks are crucial for achieving accurate and reliable results....

In this paper/document, I will introduce several commonly used image processing techniques with the OpenCV library.... The focus will be on providing a clear and practical understanding of these techniques, including detailed explanations and the necessary code to facilitate hands-on experience with the material....

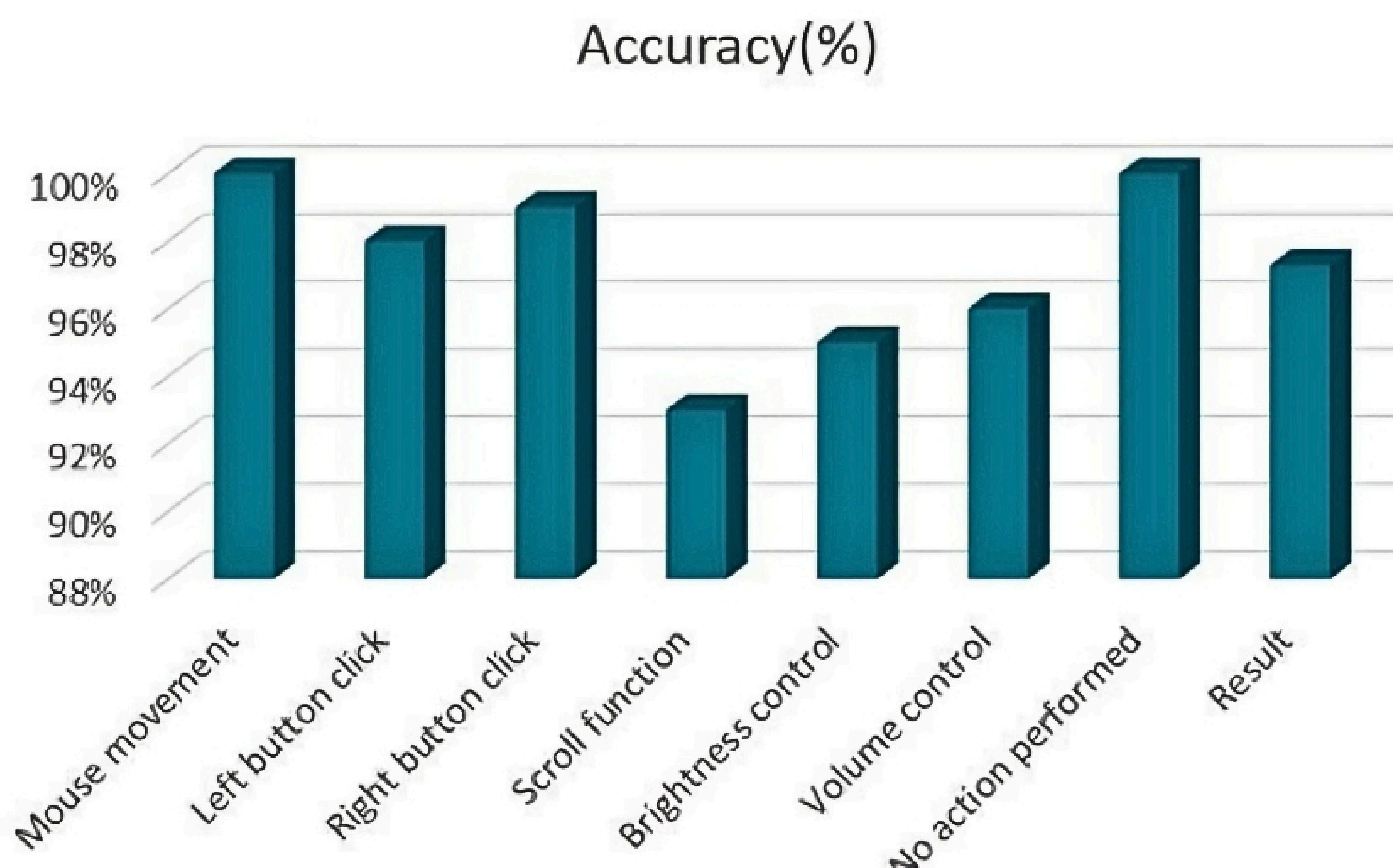


## 4 Performance Analysis

The proposed AI Virtual Mouse System aims to enhance human-computer interaction through advanced computer vision techniques.... Evaluating the performance of this system involves comparing its effectiveness under various conditions, though limited datasets pose a challenge....

To assess the system's performance, hand gesture and fingertip detection were tested under different illumination conditions and at varying distances from the webcam.... An experimental evaluation was conducted involving 25 tests performed by 4 individuals, resulting in a total of 600 manually labeled gestures.... The tests were conducted under diverse conditions: each person tested the system 10 times in normal light, 5 times in dim light, 5 times at a close distance from the webcam, & 5 times at a greater distance....

The results of these tests are summarized in Table, which provides insights into the system's accuracy & reliability across different scenarios....



## 5 Applications

The AI Virtual Mouse System offers a range of practical applications, enhancing usability and accessibility in various contexts.... It eliminates the need for physical mice & improves human-computer interaction.... Key applications include:

- (i) **High Accuracy:** The proposed model achieves a remarkable accuracy of 99%, significantly surpassing other virtual mouse models, and is applicable in numerous scenarios....
- (ii) **COVID-19 Safety:** In the context of the COVID-19 pandemic, using physical devices poses a risk of virus transmission.... The AI Virtual Mouse allows users to control PC mouse functions without physical contact, promoting hygiene and safety....
- (iii) **Robotics and Automation:** The system can be utilized to control robots and automation systems, eliminating the need for physical input devices....
- (iv) **Image Creation:** Users can create 2D and 3D images using hand gestures, enabling intuitive and hands-free drawing and design....
- (v) **Virtual and Augmented Reality:** The AI Virtual Mouse facilitates interaction with virtual and augmented reality environments, providing an alternative to traditional wired or wireless mice....
- (vi) **Accessibility:** Individuals with hand mobility issues can use the system to control mouse functions, offering a more accessible computing solution
- (vii) **Robotic Control:** In robotics, the system serves as a human-computer interface (HCI) for controlling robots, enhancing interaction and control....
- (viii) **Design and Architecture:** The system can be employed in virtual design and prototyping, allowing designers and architects to interact with their models in a hands-free manner

## 6 Conclusion

The primary goal of the AI Virtual Mouse System is to control mouse cursor functions using hand gestures rather than a physical mouse.... The system achieves this by utilizing a webcam or built-in camera to detect hand gestures and fingertip positions, processing these frames to perform the desired mouse functions....

The results demonstrate that the proposed AI Virtual Mouse System performs exceptionally well, achieving higher accuracy compared to existing models and addressing many of their limitations.... The system is particularly beneficial for real-world applications, including reducing the risk of COVID-19 transmission by enabling touchless interaction with computer systems....

However, some limitations remain, such as a slight decrease in accuracy for right-click functions and challenges with clicking and dragging to select text.... Future work will focus on enhancing the fingertip detection algorithm to improve accuracy and address these issues, ensuring more reliable and seamless user interaction....

## Acknowledgement

It is a moment of great satisfaction and pride to reflect on the journey undertaken and to express heartfelt gratitude to those who have contributed to this project.... I am deeply thankful to the many individuals who have supported me, whether from the beginning or at various stages along the way.... Their kindness, encouragement, and blessings have been instrumental in reaching this milestone.... I extend my sincere thanks to each of them for their invaluable support and inspiration....