

Thumb Gesture Controlled Mouse Movement Recognition System

Sakshi Binawade¹, Tanvi Mahajan², Sakshi Bhosale³, Prof. S. N. Shah⁴

ME Students, Department of Computer Engineering, Sharadchandra Pawar College of Engineering and Technology,
Someshwarnagar, Baramati, Maharashtra, Savitribai Phule Pune University, Pune, India¹

Professor, Department of Computer Engineering, Sharadchandra Pawar College of Engineering and Technology,
Someshwarnagar, Baramati, Maharashtra, Savitribai Phule Pune University, Pune, India²

ABSTRACT: This project presents a thumb gesture-controlled mouse system developed in Python, designed to provide a touch-free and intuitive way to interact with a computer. By using a standard webcam, the system tracks the user's thumb through colored markers or anatomical points and converts gestures into corresponding mouse commands. Simple gestures such as swiping, tapping, or holding are interpreted as cursor movement, left-click, and right-click, respectively. The system incorporates computer vision and machine learning techniques to filter out noise, track motion accurately, and map thumb gestures to precise on-screen actions. The focus of this project is to develop a robust, user-friendly, and calibration-efficient interface that can serve as an alternative to conventional input devices. By offering a touch-free interaction method, this system not only improves ergonomics but also assists users with physical limitations. Additionally, it lays the foundation for future applications in augmented reality, virtual reality, and smart environments, exploring new possibilities for immersive and natural human-computer interaction.

KEYWORDS: Thumb Gesture Recognition, Mouse Control, Computer Vision, Machine Learning (ML), Deep Learning, Colored Markers / Anatomical Points, Gesture Mapping, Touch-Free Interaction, Human-Computer Interaction (HCI), Augmented Reality Integration, Artificial Intelligence (AI), etc.

I. INTRODUCTION

In recent years, the field of human-computer interaction has evolved significantly, with gesture-based interfaces gaining attention for their natural, intuitive, and contactless input methods. Traditional input devices like keyboards and mice often pose limitations in terms of accessibility and ergonomics. To address these challenges, this project proposes a thumb gesture-controlled mouse system, which enables users to perform standard computer operations without physically touching any device.

The system leverages a webcam to track thumb movements and employs computer vision algorithms to interpret gestures accurately. By using either colored markers or anatomical points on the thumb, the software can detect swipes for cursor movement, taps for left-clicks, and holding gestures for right-clicks. These gestures are processed through a pipeline that minimizes noise, smooths motion, and converts them into precise mouse commands on the desktop.

This project aims to provide a user-friendly and efficient interface suitable for general users as well as individuals with physical impairments. Beyond accessibility, the system also explores the potential of gesture-based control in immersive environments such as augmented reality and smart workspaces, demonstrating how natural human movements can be seamlessly translated into digital commands.

II. PROBLEM STATEMENT

Traditional input devices such as mice and keyboards often pose limitations in terms of ergonomics, accessibility, and interaction flexibility, particularly for users with physical disabilities or repetitive strain injuries. There is a need for an intuitive, touch-free method of interacting with computers that reduces physical effort while maintaining precision and responsiveness. This project addresses this problem by developing a thumb gesture-controlled mouse system that uses computer vision and machine learning to convert natural thumb movements into accurate cursor and click operations.

The system aims to enhance accessibility, improve user comfort, and provide a foundation for gesture-based interaction in emerging technologies like augmented reality and smart workspaces.

III. LITERATURE SURVEY

- **M. Ranawat et al.**, Ranawat and coauthors describe a practical virtual mouse system where hand gestures captured by a webcam are processed to control pointer actions; they combine preprocessing, hand/point detection, and rule-based gesture mapping to implement left/right clicks and cursor movement. Their work emphasizes real-time responsiveness and user-friendly mapping (for example, distinguishing tap vs hold) and discusses robustness measures such as smoothing and simple filtering to reduce jitter. The paper is relevant because it shows how to balance accuracy and latency in a deployable system, and it provides useful implementation lessons—GUI feedback, parameter tuning, and lightweight algorithms—that help when building a calibration-efficient thumb-gesture mouse.
- **Li and colleagues** present an end-to-end HCI system that integrates robust hand tracking with gesture recognition for real applications; the paper covers detection, temporal tracking, feature extraction, and classification, and it discusses usage scenarios where natural hand gestures replace traditional controls. The contribution lies in combining accurate tracking (to handle occlusions and motion blur) with classification that tolerates intra-user variability, often using spatio-temporal descriptors or lightweight learning models. This paper is valuable for thumb-gesture systems because it highlights strategies for continuous tracking and for turning transient finger motions into stable commands, and it stresses evaluation in realistic settings.
- **D. He, Y. Yang and R. Wu, et al.** propose a hybrid tracking approach that improves Kernelized Correlation Filter (KCF) performance by optimizing parameters with an enhanced Particle Swarm Optimization (PSO), aiming to increase tracking stability and reduce drift. The paper focuses on improving the tracker's adaptability to scale changes, occlusion, and fast motion—common challenges in real-time hand/thumb tracking—by tuning model hyperparameters automatically. For a thumb-based virtual mouse, their methods are important because robust, low-latency tracking is the backbone of reliable gesture control; automatic parameter optimization can reduce per-user calibration and improve operation across varied environments.
- **L. Yu and S. Fei**, investigate interaction on large displays using 3D sensors, combining clustering-based noise filtering with an Unscented Kalman Filter (UKF) to refine position estimates and smooth user motions. Their approach shows how sensor fusion and probabilistic filtering can turn noisy depth or 3D point data into stable control signals suitable for large-scale pointer mapping or gesture-based control. Although focused on 3D sensing rather than a single webcam, the ideas—clustering to remove outliers and UKF for nonlinear smoothing—are directly applicable to webcam-based thumb tracking when integrating depth or multi-sensor inputs to improve robustness and reduce jitter.
- **Agrawal, R. Raj and S. Porwal**, authors explore a multimodal vision system that combines hand and head gestures to provide richer and more reliable HCI commands, arguing that fusing multiple gesture sources improves accuracy and expressiveness. Their system highlights how complementary modalities (e.g., head orientation to disambiguate hand gestures) reduce false positives and allow more complex interactions without extra hardware. For thumb-mouse systems, this work indicates that combining simple thumb gestures with an auxiliary cue (like head pose or eye gaze) can reduce misclassification and allow context-aware commands, especially in noisy conditions.
- **W. Chen and Z. Zhang**, focus on electromyography (sEMG) signals to recognize hand gestures, using features extracted from muscle electrical activity and classifying them with Support Vector Machines. While sEMG is a wearable modality rather than vision-based, the paper demonstrates the benefit of physiological sensing for low-latency, robust gesture recognition—particularly useful where visual occlusion or lighting is an issue. The study is relevant to the gesture-mouse domain because it suggests hybrid systems: combining vision with sEMG can significantly increase reliability and offer alternatives for users or environments where webcam tracking is less effective.

- **J. Ryu, D. Im and H.-J. Yoo, et al.** review hardware solutions—AI System-on-Chips (SoCs)—designed to accelerate on-device neural inference for AR/VR user interactions, emphasizing power-efficient, low-latency processing of vision and sensor data. Their discussion underlines the importance of edge inference for real-time gesture recognition and for keeping privacy-sensitive processing local to the device. For a thumb-gesture mouse project, this paper points to hardware pathways (embedded AI chips or optimized edge accelerators) that enable smoother, always-on gesture control on portable devices or AR headsets without relying on heavy desktop GPUs.
- **X. Zhang, Y. Sun and Y. Zhang,** This paper applies system-dynamics and evolutionary game theory to model collaborative human-computer interactions in complex environments like aircraft cockpits, emphasizing how interaction strategies evolve under constraints and shared objectives. While domain-specific, the work provides a high-level view of designing HCI frameworks that balance automation, human workload, and trust—concepts relevant when deploying gesture interfaces in safety-critical or multi-agent contexts. Its lessons for thumb-gesture interfaces include designing interaction policies that are predictable, minimize cognitive load, and can adapt as user behavior changes.

IV. SYSTEM OVERVIEW

The Thumb Gesture-Controlled Mouse Movement Recognition System represents an innovative approach to human-computer interaction by replacing the need for traditional input devices such as physical mice or touchpads. The system utilizes a standard webcam to detect and interpret the user's thumb movements, translating them into meaningful cursor actions on the computer screen. By integrating computer vision and machine learning algorithms, the system can effectively recognize various gestures such as swipes for cursor movement, taps for left-clicks, and prolonged gestures for right-clicks. This touch-free control mechanism allows users to interact with their computers more naturally and hygienically, offering a convenient solution that can be operated from a distance without any physical contact.

The system's workflow involves several key stages—image acquisition, preprocessing, feature extraction, gesture recognition, and command mapping. Initially, the webcam captures continuous video frames, which are processed to detect the thumb's position and movement pattern using techniques like color thresholding, contour detection, or motion tracking. The extracted features are then analyzed through a trained machine learning model that classifies the detected gestures into predefined categories. Once a gesture is identified, it is mapped to a corresponding mouse command, which controls the cursor's behavior in real time. This modular design not only improves the system's accuracy but also ensures low latency and adaptability across different lighting conditions and environments.

V. PROPOSED SYSTEM

The proposed system aims to develop a thumb gesture-controlled mouse that enables users to interact with a computer through simple hand gestures captured by a standard webcam. Instead of relying on physical devices like a mouse or trackpad, the system interprets the movement and position of the user's thumb to control the cursor on screen. It leverages computer vision techniques such as color segmentation, contour detection, and motion tracking to identify the thumb's motion in real time. Each gesture is mapped to a specific mouse action—such as a swipe for cursor movement, a tap for a left-click, or a stationary hold for a right-click—providing an intuitive, touch-free, and accessible alternative to traditional input methods.

The system architecture integrates image processing, gesture classification, and event mapping into a unified pipeline. The webcam captures continuous video frames that are filtered to reduce background noise and lighting variations. Using algorithms like MediaPipe Hands or OpenCV contour tracking, the system extracts key thumb features such as orientation, velocity, and position. These parameters are then processed by a machine learning model or rule-based classifier to determine the intended action. Once recognized, the gesture is converted into corresponding OS-level mouse events through libraries like PyAutoGUI, enabling seamless control of the desktop environment.

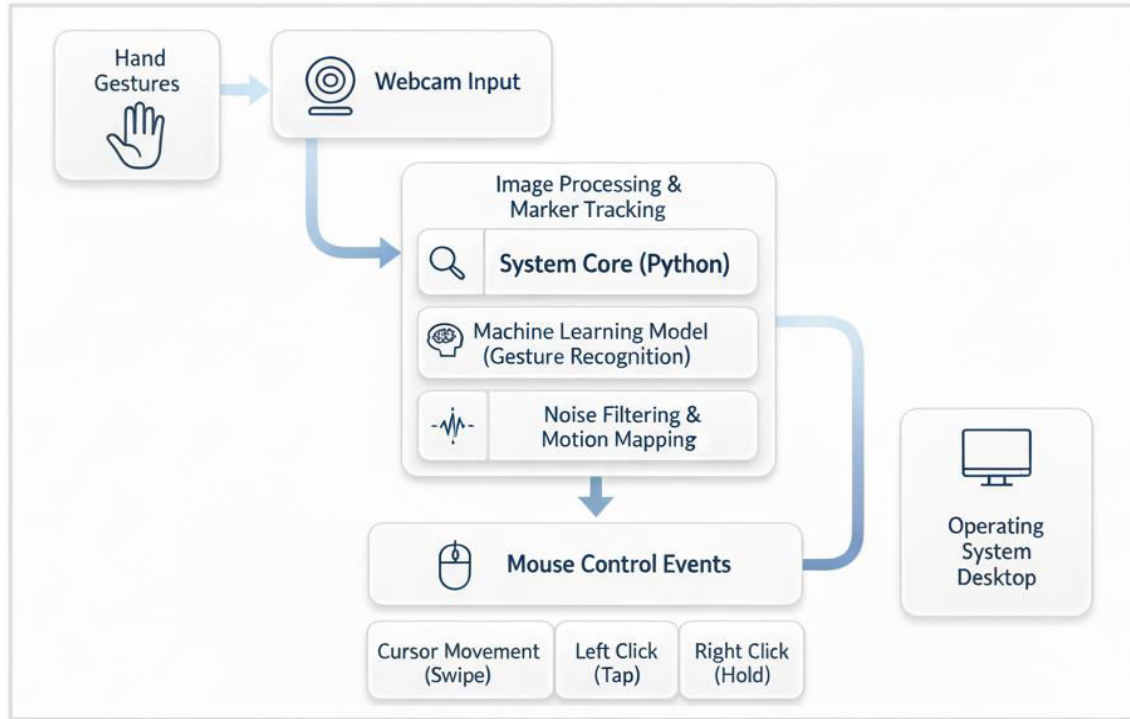


Fig.1: System Architecture Design

The proposed system provides an ergonomic, cost-effective, and versatile interaction method suitable for everyday computing, gaming, and accessibility support for users with motor disabilities. Its touchless design minimizes the need for physical contact, enhancing hygiene and convenience, especially in public or medical environments. Furthermore, its adaptability to various lighting and background conditions makes it robust for real-world applications. In the long term, the system can be extended for AR/VR interfaces, smart displays, and IoT environments, where natural gesture-based interaction will play a crucial role in creating immersive and intelligent user experiences.

VI. CONCLUSION

The Thumb Gesture-Controlled Mouse Movement Recognition System successfully demonstrates a modern, intuitive, and touch-free approach to human-computer interaction. By integrating computer vision and Python-based image processing, the system translates thumb gestures into precise cursor movements and mouse commands in real time. This innovation eliminates the need for conventional input devices like a mouse or touchpad, providing a seamless, hygienic, and highly accessible interface. The system achieves accurate gesture detection using webcam-based tracking of thumb positions and intelligently maps these gestures to actions such as movement, left-click, and right-click. Furthermore, the project emphasizes usability, accessibility, and ergonomic design, ensuring that individuals with physical disabilities or limited mobility can operate computers efficiently. The implementation also proves to be low-cost, as it relies only on a standard webcam and open-source tools like OpenCV and PyAutoGUI. By ensuring smooth execution and calibration-free performance, the system offers an adaptable and user-friendly experience that meets the needs of both general and specialized users.

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