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Hand Tracking-Based Virtual Mouse System

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***Abstract:** This study presents a real-time hand gesture-based virtual mouse system leveraging computer vision technologies. The system utilizes a webcam, OpenCV, Mediapipe, PyAutoGUI, and Pynput to allow touchless cursor movement, left/right clicks, double click, and screenshot functionality. The goal is to improve human-computer interaction, especially in hygienic or accessibility-focused environments. This method replaces traditional physical mouse devices with intuitive gestures, enhancing ease of use and inclusivity.*

I. INTRODUCTION

In the digital age, touchless interaction has become vital across domains including healthcare, gaming, AR/VR, and assistive technology. Hand tracking provides a natural interface between users and machines. This project aims to build a gesture-based virtual mouse system that uses hand landmarks detected through a webcam to simulate mouse events.

II. LITERATURE REVIEW

Hand tracking techniques have evolved from color segmentation and contour analysis to deep learning models. Libraries like Mediapipe provide fast, lightweight hand landmark detection. Previous systems faced challenges such as lighting sensitivity, gesture misinterpretation, and the need for wearable devices. Our system addresses these by using a simple webcam and machine-learned landmarks.

III. METHODOLOGY

The methodology consists of the following steps:

1) Webcam captures live video.
2) OpenCV processes frames.
3) Mediapipe detects 21 hand landmarks.
4) Angles and distances between landmarks are calculated.
5) Specific gestures are mapped to mouse actions using PyAutoGUI and Pynput.

Cursor movement is enabled when the index finger is extended. Click gestures are based on calculated angles between joints, ensuring reliable detection. Screenshot functionality is triggered using a unique hand pose.

IV. IMPLEMENTATION

The system was developed in Python using the following libraries:

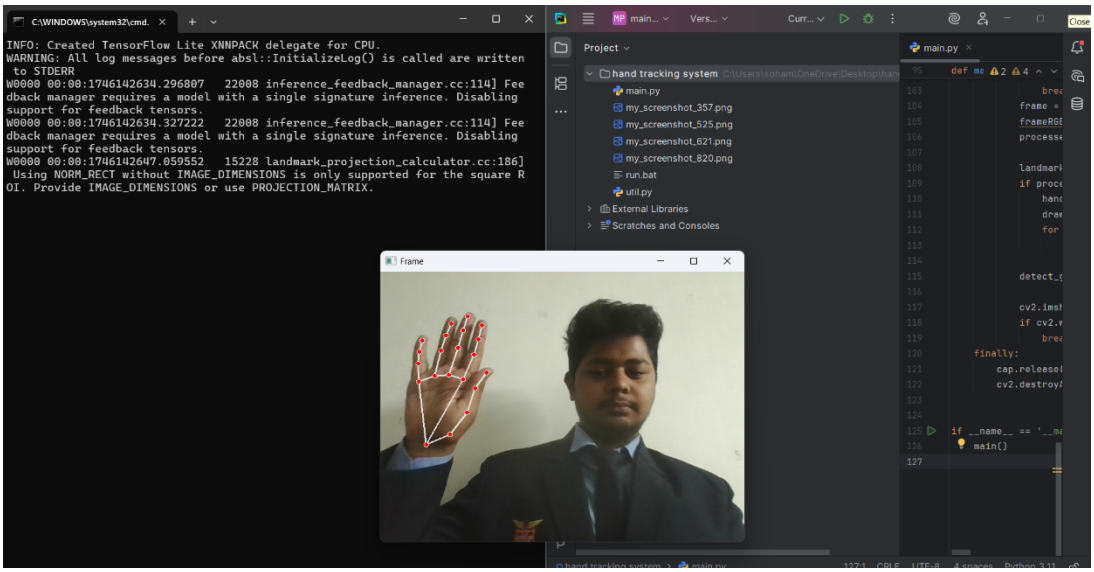
1) OpenCV: For capturing and displaying frames.
2) Mediapipe: For real-time hand landmark tracking.
3) PyAutoGUI: For executing screen actions like cursor move, click, and screenshot.
4) Pynput: For precise mouse button control.

The application tracks one hand, evaluates gestures in each frame, and simulates the corresponding mouse action. Landmark coordinates are scaled to screen resolution to ensure natural movement.

V. RESULTS & DISCUSSION

Testing was done under various lighting conditions and backgrounds. Results showed accurate cursor movement and gesture detection under proper lighting. The click and screenshot gestures worked reliably with minimal delay. Limitations include sensitivity to hand positioning and occlusions. The system performs best with a clear background and adequate lighting. Improvements could include adaptive thresholding and gesture training customization.

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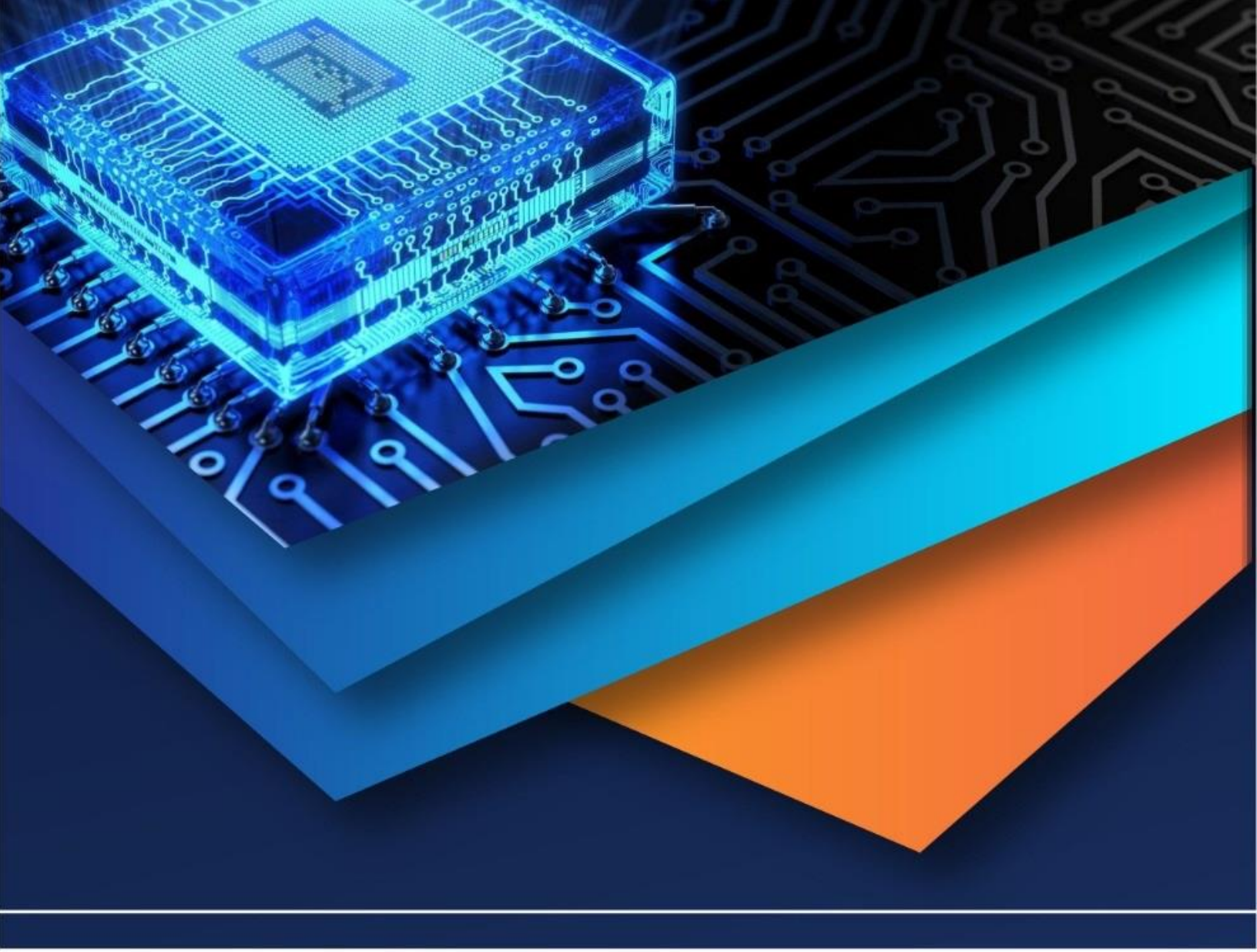
VI. CONCLUSION

This virtual mouse system showcases the practical potential of real-time hand tracking for touchless HCI. It demonstrates that standard webcams and lightweight libraries are sufficient for effective mouse control. The system can serve as an assistive tool for differently-abled users or be deployed in environments requiring hygiene. Future enhancements could involve multi-hand detection and custom gesture training for expanded control.

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