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HAND GESTURE RECOGNITION SYSTEM FOR FINGER COUNTING USING COMPUTER VISION AND MACHINE LEARNING

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Keywords	***Abstract***
Hand Gesture Recognition, Computer Vision, Finger Counting, Machine Learning, MediaPipe, OpenCV, Real-Time Detection, Human–Computer Interaction.	Hand Gesture Recognition (HGR) is an emerging field in Computer Vision that enables natural interaction between humans and machines. This paper presents a real-time finger counting system using Computer Vision and Machine Learning techniques implemented in Python. The proposed system captures live video streams through a webcam and processes the frames to detect hand landmarks. Using MediaPipe hand tracking and OpenCV libraries, the system identifies finger positions and accurately counts the number of raised fingers. The proposed model utilizes landmark-based detection instead of traditional image thresholding methods, thereby improving accuracy under varying lighting conditions. The system can detect multiple hands and compute the total finger count in real time. The application is developed using Streamlit for user interaction and WebRTC for real-time video streaming. The proposed system provides a simple and interactive interface where users can display their fingers in front of the camera and receive instant results. The system has applications in human–computer interaction, virtual classrooms, gaming, robotics control,

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	touchless interfaces, and sign language systems. Experimental results demonstrate that the system is lightweight, efficient, accurate, and deployable on standard computing devices without specialized hardware.

1. Introduction

In recent years, Human–Computer Interaction (HCI) has significantly evolved with the integration of Artificial Intelligence (AI) and Computer Vision technologies [1]. Traditional input devices such as keyboards and mice are gradually being complemented by gesture-based interaction systems. Hand Gesture Recognition (HGR) is one such technology that enables intuitive communication between humans and machines.

Finger counting using vision-based systems is an important subset of gesture recognition. It allows machines to interpret numerical gestures without physical contact. The proposed project implements a real-time hand gesture recognition system that counts the number of raised fingers using a webcam.

The system utilizes landmark-based hand detection techniques instead of traditional contour-based approaches. MediaPipe's Machine Learning model detects 21 key hand landmarks, which are used to determine whether fingers are raised or folded [2]. This approach improves detection accuracy and reduces dependency on background conditions.

The system is implemented in Python due to the availability of powerful libraries such as OpenCV, MediaPipe, NumPy, Streamlit, and WebRTC [3]. The application processes video frames in real time and overlays the detected finger count on the screen.

This project contributes to the development of touchless technology and demonstrates the practical implementation of AI-based vision systems in real-world applications.

2. Literature Survey

Hand Gesture Recognition has been widely researched in the fields of Computer Vision, Artificial Intelligence, and Human–Computer Interaction. Over the past two decades, several techniques have been proposed ranging from traditional image processing approaches to advanced deep learning models.

2.1 Traditional Methods

Early hand gesture recognition systems primarily relied on classical image processing techniques. These methods did not require Machine Learning algorithms but instead used pixel-level operations to extract hand features.

A. Skin Color Segmentation

One of the earliest techniques involved detecting skin-colored regions in images using HSV or YCbCr color spaces. Pixels matching predefined skin color ranges were segmented to isolate the hand region.

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Limitations

- Sensitive to lighting conditions
- Not robust for different skin tones
- Background interference affects accuracy

B. Background Subtraction

This method required a static background. The moving object (hand) was extracted by subtracting the current frame from a reference background frame.

Limitations

- Requires a controlled environment
- Poor performance in dynamic scenes

C. Contour Detection and Convex Hull

After segmentation, contour detection techniques were applied to identify hand boundaries. Convex hull and convexity defect algorithms were then used to count fingers.

Limitations

- Highly dependent on lighting conditions
- Performance decreases with complex backgrounds
- Sensitive to shadows and image noise
- Difficulty in detecting overlapping fingers
- Reduced accuracy during rapid hand movements

Although contour-based methods are computationally simple, they are less accurate and less robust compared to modern landmark-based approaches.

2.2 MediaPipe Hand Landmark Model

MediaPipe provides a highly efficient hand landmark detection model capable of identifying 21 key points on the hand, including fingertips, joints, and palm positions [4]. These landmarks enable the system to understand finger movement and hand orientation. The MediaPipe model operates in two stages: 1. Palm detection model for locating the hand region. 2. Hand landmark model for predicting 21 landmarks coordinates.

Each landmark consists of x, y, and z coordinates representing the 3D position of the hand. This enables accurate tracking of hand movements and gestures. The MediaPipe Hand Landmark Model

operates efficiently in real time, making it suitable for applications such as finger counting, gaming, sign language recognition, robotics, and virtual interaction systems.

3. Proposed System

The proposed system utilizes a Machine Learning-based hand landmark detection model provided by MediaPipe. Instead of relying on pixel segmentation techniques, the system detects 21 key hand landmarks for accurate finger recognition.

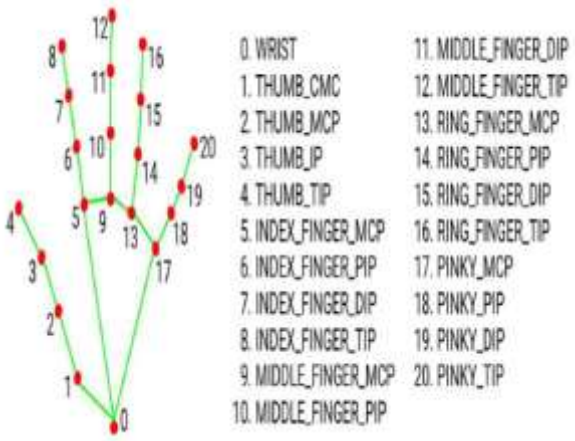

Fig.1: 21 Hand Landmarks

3.1 Key Features of the Proposed System

- Real-time finger detection using WebRTC
- Landmark-based finger counting
- Simultaneous support for two hands
- Robust operation under varying lighting conditions
- Interactive graphical interface using Streamlit
- Accurate thumb detection using orientation logic

3.2 Working Principle

The overall working procedure of the proposed system is summarized below:

1. Capture live video frames from webcam.
2. Convert image frames from BGR to RGB format.
3. Detect hand landmarks using MediaPipe.
4. Extract fingertip coordinates.

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5. Compare fingertip positions with lower finger joints.
6. Count the number of raised fingers.
7. Display the total finger count on the screen.

The implementation integrates OpenCV, MediaPipe, Streamlit, and WebRTC to achieve efficient real-time performance.

4. Block Diagram

In this system, static hand images are not used as input. Instead, the webcam continuously captures live video frames and processes them dynamically in real time.

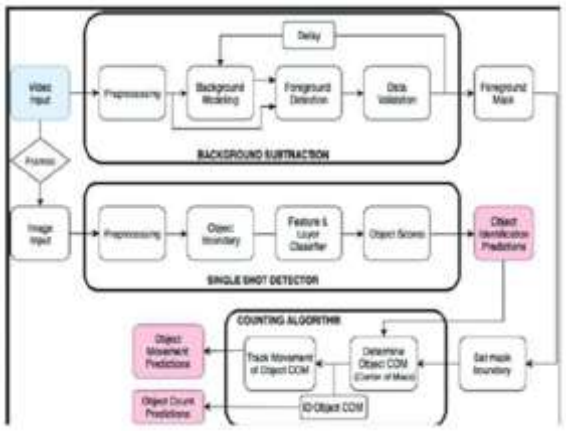

Fig.2: Block Diagram

Processing Flow

- Webcam captures live video frames.
- OpenCV reads the video frame.
- Frame is converted from BGR to RGB.
- MediaPipe detects hand landmarks.
- Landmark coordinates are extracted.
- Finger counting logic is applied.
- Total finger count is calculated.
- Results are displayed instantly on the screen.

The system does not use a gesture dictionary or command execution module. The output simply displays the total number of raised fingers.

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5. Outputs

The output interface of the Hand Gesture Recognition System displays finger detection results in real time through a web-based interface.When the application is launched, the user can view live webcam video streaming on the screen. As the user places their hand in front of the camera, the system detects the hand and displays hand landmarks using points and connecting lines.

The system continuously analyzes the hand gesture and displays the total number of raised fingers on the screen. The output is shown clearly using highlighted text for better visibility. Whenever the user changes the hand gesture, the output updates instantly, thereby providing real-time feedback. The interface is designed to be simple, interactive, and user-friendly.

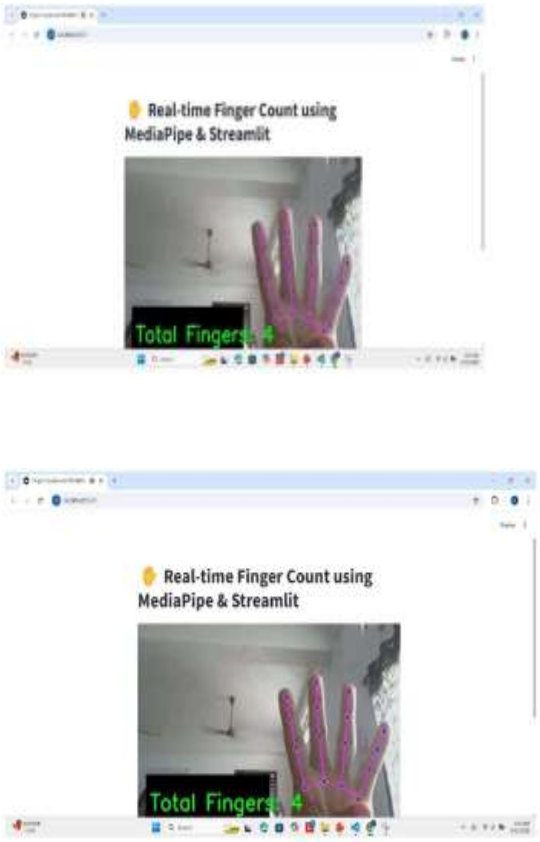

Fig.3: Real Time Finger Count Using MediaPipe & Streamlit.

6. Conclusion

The Hand Gesture Recognition System for Finger Counting successfully demonstrates real-time human–computer interaction using Computer Vision and Machine Learning techniques. The system efficiently detects hand landmarks and accurately counts raised fingers using a geometric landmark-based approach.

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By leveraging MediaPipe and OpenCV, the proposed system achieves real-time performance without requiring complex model training or expensive hardware [5]. The use of Streamlit provides an interactive and user-friendly interface that simplifies system operation.

The system performs reliably under different lighting conditions and supports simultaneous detection of up to two hands. Experimental testing confirms that the proposed solution satisfies functional and performance requirements.

This project highlights the practical applications of AI-based vision systems in touchless interaction environments. The system can be extended in the future for advanced gesture recognition, sign language translation, robotics control, and virtual classroom applications.Overall, the project fulfills its objective of building an accurate, efficient, and scalable real-time finger counting system using modern Computer Vision technologies.

7. Future Scope

The project can be further improved in several ways:

- Recognition of complex hand gestures instead of only finger counting.
- Extension toward sign language recognition for hearing-impaired individuals.
- Integration with smart home systems for gesture-based appliance control.
- Application in robotic control systems.
- Improved accuracy using advanced deep learning techniques.
- Deployment on mobile platforms.
- Integration with AR/VR systems for immersive interaction.

8. AUTHOR(S) CONTRIBUTION

The writers affirm that they have no connections to, or engagement with, any group or body that provides financial or non-financial assistance for the topics or resources covered in this manuscript.

9. CONFLICTS OF INTEREST

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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