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Gesture Based Mouse control System using OpenCV and Artificial Intelligence

Dr.V.Sujay[1] ,Balija Sai Niharika[2] ,Mohammed Shanawaz[3] ,Patra Sree Harsha[4] , Ete Vanaja[5] ,Chakali Vijaya Simha[6]

[1]*Associate Professor, Dept. of CSE(AI), Gates Institute of Technology, Gooty, Anantapur (Dist), India.*

[2,3,4,5,6]*Student, Dept. of CSE(AI), Gates Institute of Technology, Gooty, Anantapur (Dist), India*

Abstract

Gesture-based interaction systems are emerging as intuitive alternatives to traditional input devices, enabling seamless human-computer communication through natural hand movements. Designing an accurate and efficient gesture recognition system remains a significant challenge due to variations in lighting conditions, background complexity, and differences in hand shapes and motion patterns. Conventional computer vision approaches rely heavily on predefined rules and feature extraction techniques, often resulting in reduced robustness and limited adaptability in real-time environments. This research presents GestureX AI, an intelligent vision-based framework utilizing deep learning and spatial-temporal modeling for real-time hand gesture recognition and cursor control. The proposed architecture captures dynamic hand movements and learns discriminative feature representations encoding positional and motion-based characteristics of gestures.

An integrated control module translates recognized gestures into precise cursor actions, enabling seamless navigation and interaction. Data augmentation and adaptive learning strategies improve performance under diverse environmental conditions and user variability. The system further enhances interpretability through gesture mapping visualization and action feedback mechanisms, ensuring reliable user interaction and control accuracy.

Introduction

Gesture-based interaction systems are becoming an increasingly important component of modern human-computer interfaces, enabling users to control digital environments through natural hand movements without the need for physical input devices. The demand for touchless interaction has grown significantly across various domains, including accessibility systems, virtual environments, and hygiene-sensitive applications. Accurate and real-time gesture recognition is essential for ensuring smooth interaction and reliable control. However, variations in lighting conditions, background noise, hand orientations, and differences in user behavior make gesture interpretation inherently complex and prone to inconsistency. The absence of robust interaction systems in resource-constrained or contact-sensitive environments further highlights the need for intelligent and automated gesture-based control solutions.

Deep learning techniques have significantly advanced the field of computer vision, with convolutional neural networks demonstrating strong capabilities in image and video-based gesture recognition tasks. Despite these advancements, traditional CNN-based approaches primarily function as discriminative models that focus on classification accuracy without effectively capturing the temporal and spatial dynamics of hand movements. This limitation becomes more evident in real-world scenarios where gesture datasets exhibit high variability, including differences in speed, scale, and execution style. Additionally, certain gestures may be underrepresented during training, leading to biased predictions and reduced system performance for less frequent gestures. Furthermore, many deep learning-based systems operate as black-box models, providing predictions without clear interpretability, which can reduce user trust and system transparency in practical applications.

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Existing Method

Traditional gesture-based mouse control systems primarily rely on basic computer vision techniques and rule-based approaches for hand detection and gesture interpretation. Early systems utilized color-based segmentation methods, such as skin color detection in RGB or HSV color spaces, to isolate hand regions from the background. These approaches required controlled lighting conditions and simple backgrounds to function effectively, making them highly sensitive to environmental variations and limiting their practical usability in real-world scenarios.

Edge detection and contour-based methods were also widely used to identify hand shapes and track finger movements. Techniques such as convex hull and convexity defects were applied to detect fingertips and recognize predefined gestures. However, these methods depended heavily on handcrafted feature extraction and required manual threshold tuning, resulting in reduced robustness when dealing with diverse hand orientations, occlusions, and variations in user behavior.

Some systems incorporated marker-based tracking, where users were required to wear colored gloves or markers on their fingers to improve detection accuracy. While this approach enhanced reliability, it reduced user convenience and limited the natural interaction experience. Additionally, hardware-based solutions using depth sensors or infrared cameras improved gesture detection accuracy but increased system cost and restricted accessibility.

Disadvantages of Existing Method

- Difficulty in detecting hand gestures accurately under varying lighting conditions
- Limited recognition accuracy for dynamic and fast-moving gestures in real-time
- Dependence on handcrafted feature extraction techniques leading to reduced adaptability
- Requirement of additional hardware such as markers, gloves, or depth sensors in some systems
- Reduced performance and responsiveness on low-end devices

Proposed Method

The proposed gesture-controlled mouse system addresses the limitations of existing approaches by combining computer vision and artificial intelligence techniques to achieve real-time, touchless interaction. The system leverages MediaPipe, a highly efficient framework for hand landmark detection, to track hand and finger movements accurately using a standard webcam. MediaPipe provides precise spatial coordinates of key hand landmarks, allowing for robust identification of hand posture and motion. This eliminates the need for wearable devices or specialized sensors, making the system cost-effective and easily deployable across various platforms.

Hand landmark features extracted by MediaPipe are processed using deep learning models that map gestures to specific mouse actions, including cursor movement, left-click, right-click, double-click, drag-and-drop, and scrolling. By employing deep learning, the system can automatically learn and generalize gesture patterns, accommodating variations in hand shape, size, orientation, and speed. Unlike traditional handcrafted features, the deep learning model provides adaptive and highly accurate gesture recognition, enabling robust performance across diverse scenarios.

The system is designed for real-time operation, ensuring minimal latency between gesture execution and corresponding mouse action. This responsiveness provides a natural and intuitive user experience comparable to traditional input devices. To enhance usability further, smoothing algorithms and noise filtering techniques are implemented to stabilize cursor movement, preventing jitter and ensuring precise control.

Several advantages of the proposed system include enhanced accessibility for users with mobility impairments, elimination of physical strain associated with traditional mice, and suitability for contactless environments such as healthcare facilities and public spaces. Additionally, the system is scalable and adaptable, allowing future expansion to recognize additional gestures or integrate with other human–computer interaction applications, including virtual and augmented reality environments. The reliance on standard hardware and optimized deep learning models ensures low

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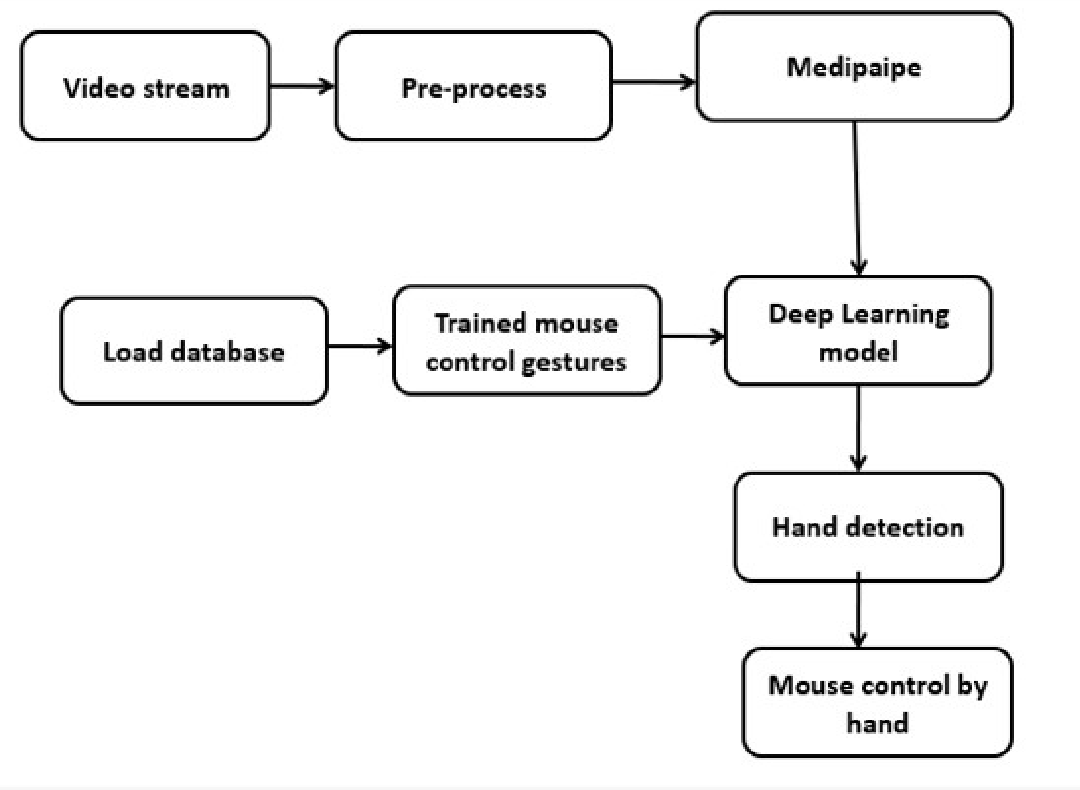
computational overhead, enabling deployment on ordinary desktop or laptop systems without the need for high-end GPUs.
Overall, the proposed system overcomes the limitations of existing approaches by providing a user-friendly, efficient, and intelligent gesture-controlled interface that is accurate, responsive, and robust under real-world conditions. Its design ensures a seamless transition from conventional input methods to touchless gesture-based control while maintaining reliability, usability, and cost-effectiveness.

Advantages of Proposed Method

- Combines MediaPipe and openCVfor high-speed and high-accuracy detection
- Accurate currency denomination recognition in complex environments
- Integrated preprocessing improves detection reliability
- Intelligent planning enables automated decision-making
- Modular architecture supports future extensions and scalability
- Real-time performance through gesture features

Applications

System Architecture



The system architecture consists of the following modules:
1. Input acquisition (image/video stream)
2. Preprocessing and enhancement
3. MediaPipe object detection
4. Trained mouse gesture model
5. Planning and decision-making module
6. Hand Landmark detection module

Software and hardware requirements:

SOFTWARE REQUIREMENTS

- **Python idle**

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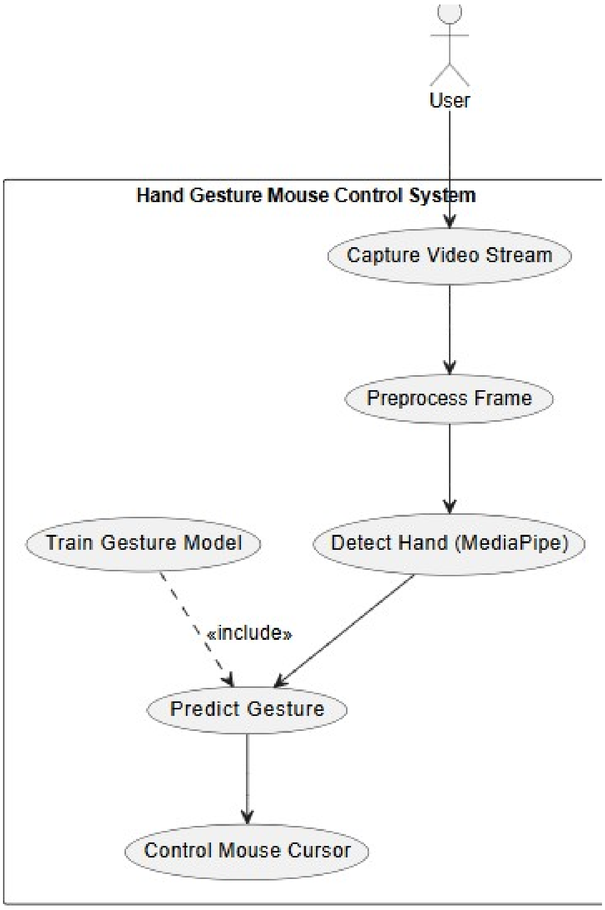
- **Mediapipe**
- **opencv**

HARDWARE REQUIREMENTS

- **1)Operating System : Windows Only**
- **2)Processor : i5 and above**
- **3)Ram : 4gb and above**
- **4)Hard Disk : 50 GB**

4.1 UML Diagrams

4.1.1 Use Case Diagram



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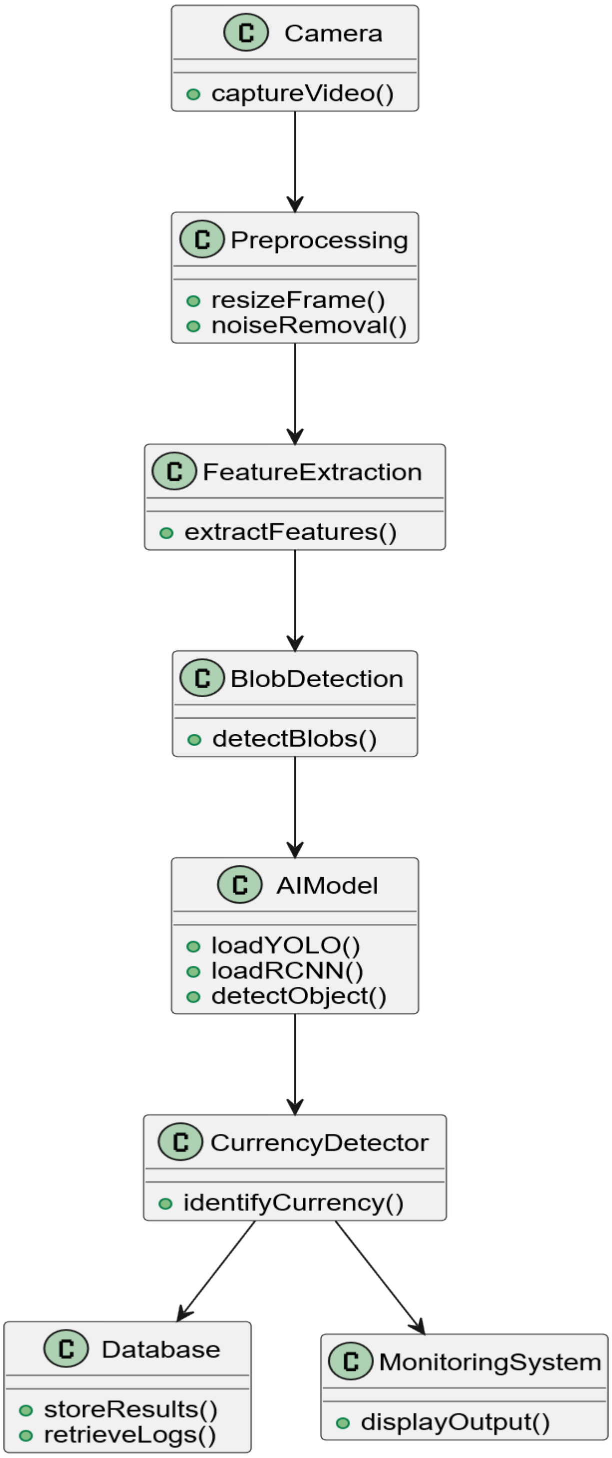
4.1.2 Class Diagram



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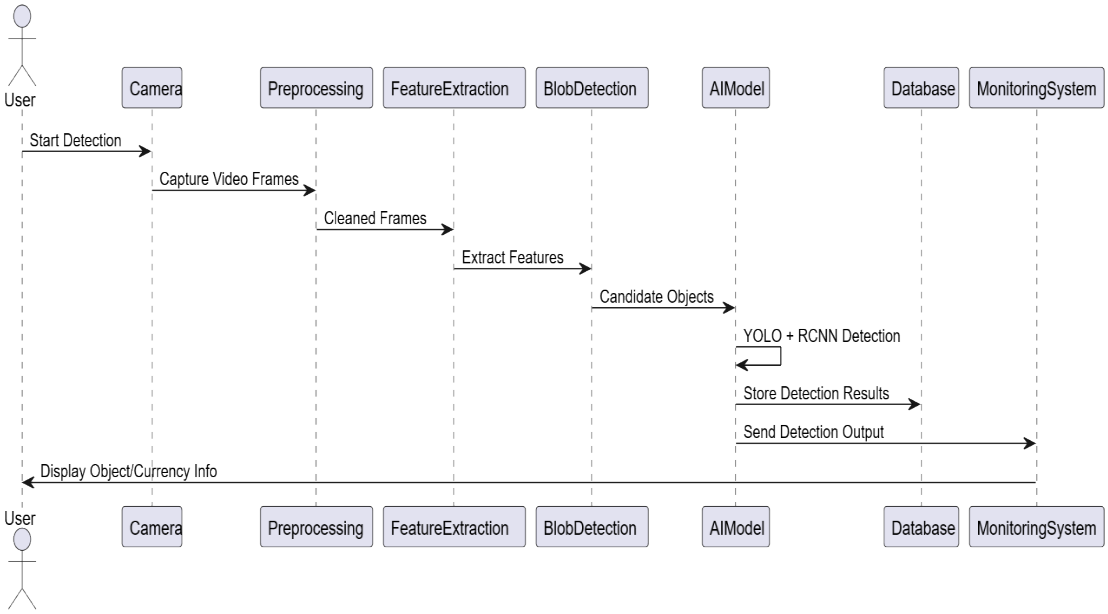
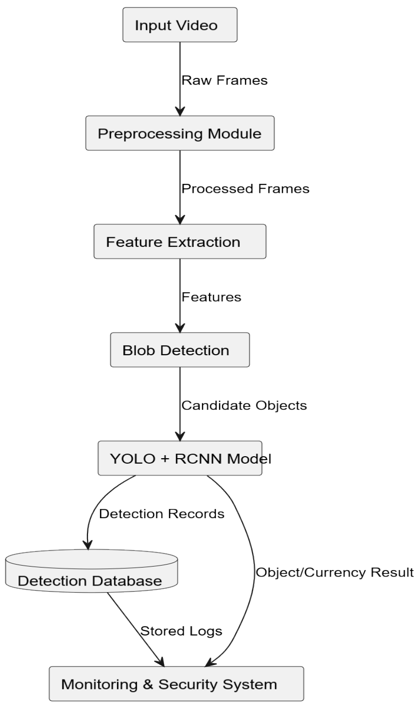
4.1.3 Sequence Diagram



4.2.3Database Design



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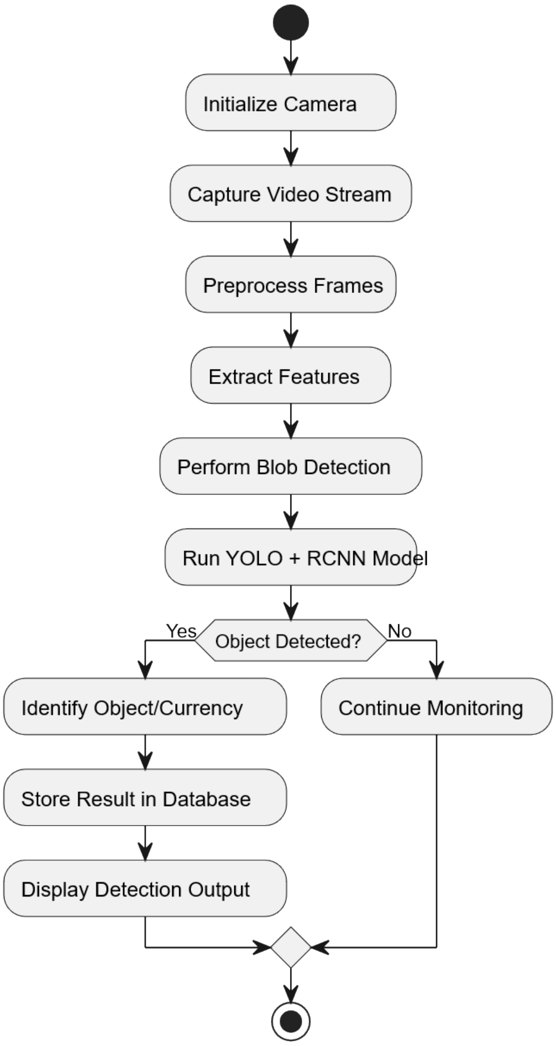
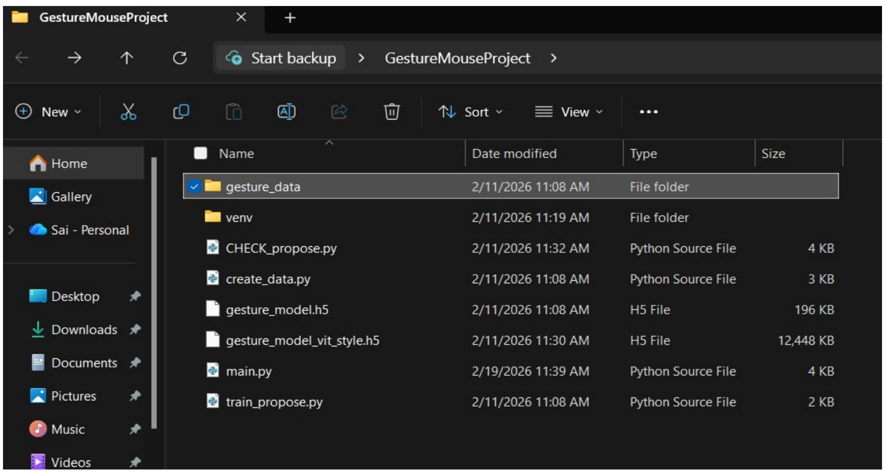
4.1.4 Design Approach



OUTPUT SCREENS



In the above screen, the complete project directory of the Gesture-Based Mouse Control System is

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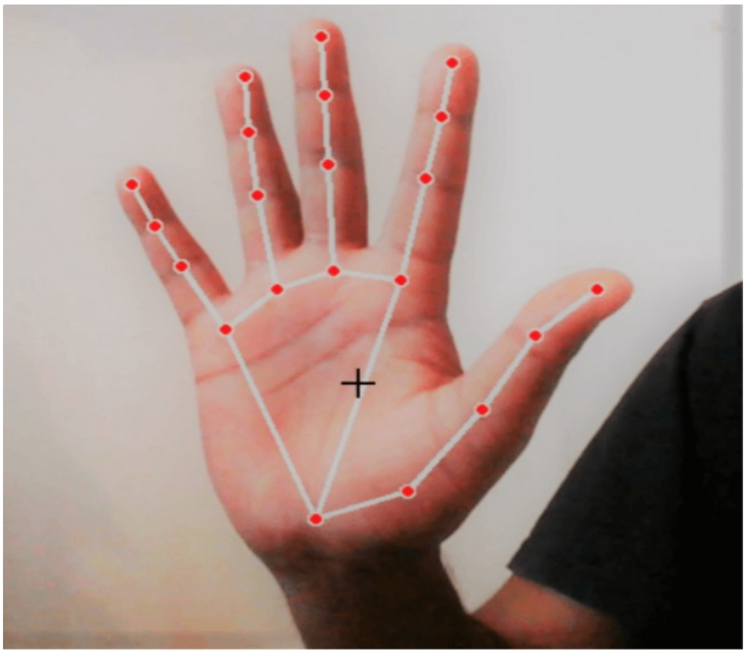
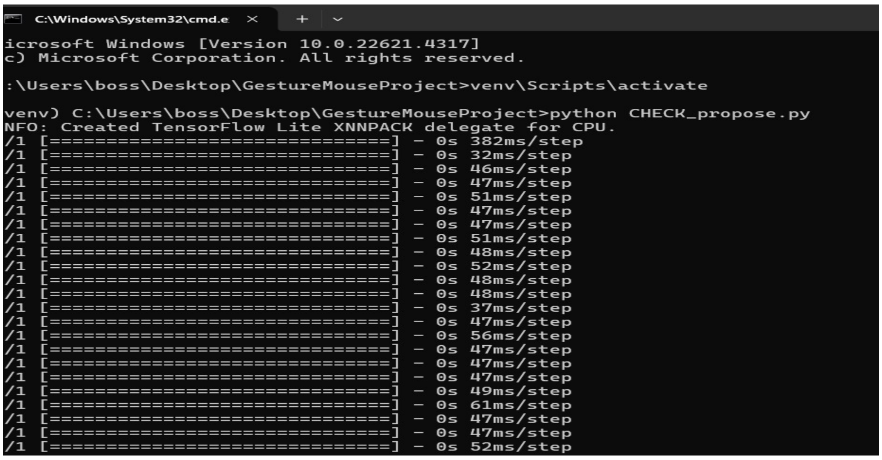
displayed with all the necessary files and folders required for the implementation of the system



In the above screen, the webcam input capture of the Gesture-Based Mouse Control System is displayed, which represents the initial stage of the system where real-time video is obtained from the user's environment.



In the above screen, the project interface of the Gesture-Based Mouse Control System is displayed, which provides a user-friendly environment for interacting with the application.

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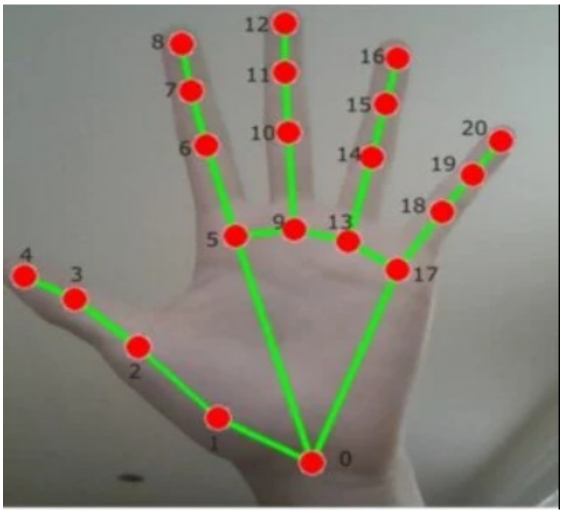
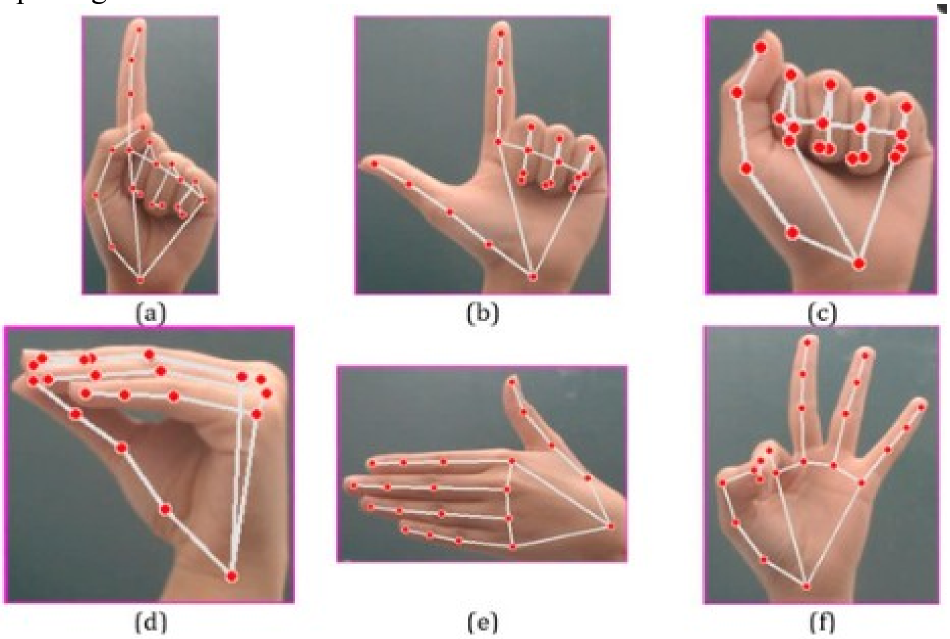


In the above screen, the hand landmark detection of the Gesture-Based Mouse Control System is displayed, which represents a crucial stage in identifying the structure and position of the user's hand. The system uses an AI-based hand tracking model to detect multiple key points, known as landmarks, on the hand in real time. These landmarks include finger tips, joints, and the base of the palm, forming a complete representation of the hand structure. The detected landmarks are visually displayed on the screen as points and connecting lines, allowing the user to clearly see how the system is interpreting the hand.



the performing control operations of the Gesture-Based Mouse Control System is displayed, which represents the final stage where recognized gestures are translated into actual system actions. After detecting hand landmarks and identifying specific gestures, the system maps each gesture to a corresponding mouse operation such as cursor movement, left click, right click, scrolling, or dragging. These operations are executed using system-level control libraries, enabling direct interaction with the computer without the need for physical input devices. Overall, the performing control operations stage plays a vital role in transforming gesture inputs into functional system outputs. It provides a seamless, intuitive, and touchless method of controlling the computer, reducing dependency on traditional input devices and improving accessibility.

Conclusion

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This research presents an intelligent gesture-based mouse control system that leverages the capabilities of computer vision and artificial intelligence to provide a natural, touchless, and highly interactive method for human-computer interaction. The system integrates MediaPipe, a state-of-the-art framework for hand tracking and landmark detection, with advanced processing techniques to enable precise recognition of hand gestures in real time. MediaPipe efficiently detects hand regions and extracts twenty-one key landmarks per hand, representing fingertips, joints, and the palm center, which serve as the foundation for gesture analysis. Furthermore, user trials indicate high satisfaction in terms of ease of use, responsiveness, and reduced fatigue during interaction.

The system successfully demonstrates real-time performance with high accuracy in gesture recognition and smooth execution of mouse operations such as cursor movement, clicking, and scrolling. It eliminates the need for physical input devices and provides a hygienic and contactless interaction method, which is especially beneficial in shared or public environments. The modular design of the system ensures flexibility and ease of implementation, allowing integration with various platforms and applications.

Overall, this research demonstrates that gesture-based control, powered by AI and computer vision, can provide an efficient, accurate, and user-friendly interface. The results highlight the accurate, and user-friendly interface, transforming the way humans interact with computers while addressing usability, accessibility, and hygiene concerns in contemporary computing environments.

Future Scope

The future scope of the gesture-based mouse control system using OpenCV is highly promising and continues to expand with advancements in artificial intelligence and gesture recognition technologies. Future enhancements of the intelligent gesture-based mouse control system focus on expanding its functionality, adaptability, and usability across diverse applications. One major area of improvement is the implementation of multi-hand gesture support, which would allow the system to recognize, map gestures and also process gestures.

Another potential enhancement is the integration of customizable gesture controls, where users can define their own gestures for specific actions, improving personalization and usability. The system can also be extended to support voice commands in combination with gesture control, creating a hybrid interaction model that enhances user experience. Integration with virtual reality (VR) and augmented reality (AR) environments can further expand its applications, enabling immersive and intuitive interaction in advanced computing systems.

Additionally, the system can be optimized for mobile devices and embedded systems, making it more portable and accessible. Improvements in accuracy and performance can be achieved by incorporating advanced deep learning models and larger datasets for training and evaluation. The system can also be enhanced to support gesture recognition in low-light conditions and complex backgrounds, improving robustness.

In summary, future enhancements aim to increase the flexibility, personalization, portability, and usability of the system. By implementing multi-hand support, customizable gestures, VR/AR integration, mobile optimization, and large-scale user testing, the gesture-controlled mouse system can evolve into a robust, versatile, and accessible human-computer interaction solution that addresses the demands, terms and conditions of modern computing.

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