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NEURO GAZE AI: HAND GESTURE CONTROLLED CURSOR SYSTEM

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ABSTRACT

Traditional input devices like mice and keyboards face accessibility, efficiency, and hygiene challenges. This paper introduces Neuro Gaze AI, a touchless, gesture-controlled cursor system enhancing human-computer interaction. The system utilizes **MediaPipe** for hand tracking, **OpenCV** for image processing, and deep learning models for real-time gesture recognition. It enables cursor movement, clicks, and scrolling without physical peripherals, ensuring a seamless experience. Optimized for low latency and adaptability to various lighting conditions, Neuro Gaze AI provides high accuracy with minimal processing delays. Testing confirms robust performance across different environments, benefiting users with mobility impairments. The system offers a cost-effective, hygienic alternative for applications in healthcare, gaming, and smart homes. It supports multiple gestures for diverse use cases and is designed for scalability and efficiency. Future enhancements include predictive gesture analysis and expanded functionality for complex interactions.

Keywords: Gesture Recognition, Computer Vision, Machine Learning, Touchless Control, Ai-Powered Cursor.

I. INTRODUCTION

Human-Computer Interaction (HCI) has evolved significantly, leading to innovative solutions that enhance usability and accessibility while minimizing reliance on traditional input devices. Conventional methods, such as keyboards and mice, have long been the standard for digital interaction, but they present limitations, including physical strain, accessibility challenges, and hygiene concerns. With the growing need for seamless and intuitive interaction, gesture-based control systems have emerged as a viable alternative, offering users a natural and efficient means to navigate digital environments.

The project Neuro Gaze AI aims to revolutionize cursor control through hand gestures, eliminating the need for external peripherals and enabling a more immersive interaction experience. By leveraging computer vision, deep learning, and artificial intelligence, the system accurately detects and interprets user gestures in real time, allowing for precise control over cursor movements, clicks, scrolling, and other essential operations. Utilizing MediaPipe for hand tracking, OpenCV for image processing, and advanced machine learning techniques, Neuro Gaze AI ensures high responsiveness and adaptability to various environmental conditions and user preferences..

1. Objectives

To develop an intuitive, touchless cursor control system using hand gestures.

To enhance accessibility for individuals with physical disabilities by eliminating reliance on traditional input devices.

To improve user experience by integrating AI-driven gesture recognition for seamless interaction.

II. LITERATURE REVIEW

Gesture recognition has been an active area of research in HCI. Various studies have explored techniques such as glove-based motion tracking, depth sensors, and webcam-based recognition. Technologies like Leap Motion and Microsoft's Kinect have demonstrated gesture-controlled interfaces but often require additional hardware, making them expensive and less accessible.

Neuro Gaze AI differentiates itself by utilizing standard webcams and machine learning models, making it cost-effective and widely accessible. Previous research has highlighted the effectiveness of convolutional neural networks (CNNs) and recurrent neural networks (RNNs) in gesture recognition. The adoption of OpenCV and

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MediaPipe has significantly improved real-time performance, ensuring that the system can operate efficiently in various environments.

III. SYSTEM ARCHITECTURE:

The Neuro Gaze AI system architecture is designed to ensure smooth, real-time hand gesture recognition and cursor control. This diagram illustrates the step-by-step workflow of the system.

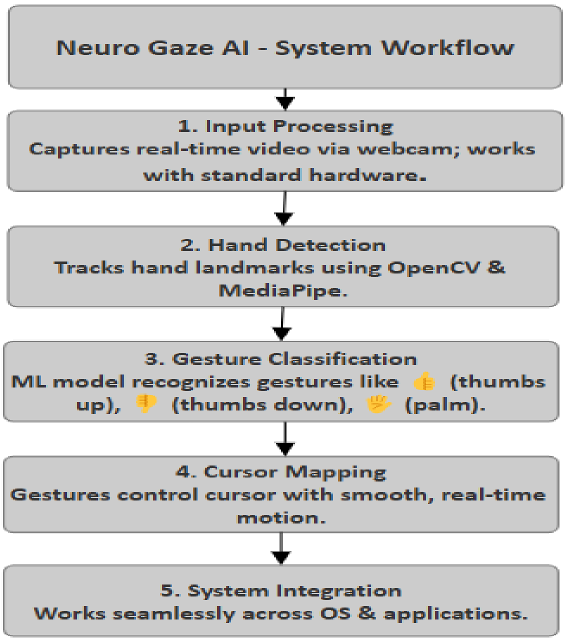

Fig.1. System Overflow Of Neuro Gaze-Ai

IV. METHODOLOGY

Neuro Gaze AI follows a structured approach for gesture-based cursor control, ensuring precision, efficiency, and robustness. The methodology includes data collection, model training, system integration, and testing.

1. Gesture Recognition:

CNNs train the model for real-time hand gesture recognition. The process begins with dataset preparation, where diverse hand positions under various lighting conditions are collected. Preprocessing techniques such as image augmentation, including rotation and contrast adjustments, enhance the dataset. The CNN model undergoes multiple iterations of training and optimization to ensure accurate gesture classification.

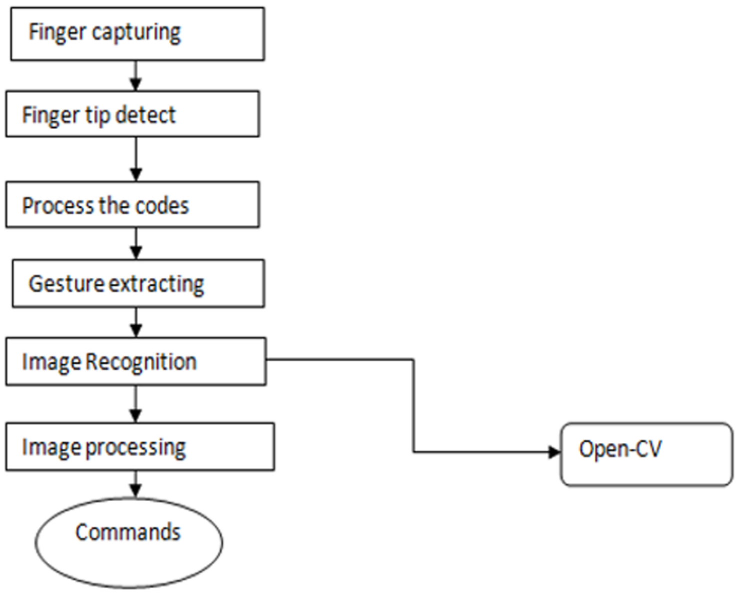

Fig. .2. Gesture Recognition.

2. Computer Vision Processing:

The system employs computer vision techniques for accurate hand tracking and feature extraction. **OpenCV** is used for hand image pre-processing and noise reduction, while **MediaPipe** enhances hand landmark detection to ensure precise tracking. Extracted hand landmarks are analyzed to identify meaningful gesture patterns, improving recognition accuracy and reliability.

3. Cursor Control Mechanism:

Recognized gestures are mapped to specific cursor actions to enable seamless user interaction. For instance, a thumb-up gesture activates the cursor, while a thumb-down gesture deactivates it. Pointing with the index finger allows navigation, a pinch gesture triggers a click action, and palm movement facilitates scrolling or dragging. Algorithms are implemented to ensure smooth cursor transitions and refined scrolling functions, enhancing the overall user experience.

4. System Optimization:

To enhance performance, several optimization techniques are applied. Latency reduction ensures real-time responsiveness, while adaptive sensitivity adjustments improve usability across different lighting conditions and hand orientations. Background noise reduction techniques help minimize errors caused by external interference. The model is designed to run efficiently on standard hardware configurations, ensuring minimal computational overhead without compromising performance.

5. Testing and Validation:

Extensive testing is conducted to ensure reliability and accuracy across various environments. User testing assesses adaptability across different individuals, while performance metrics evaluate response time and recognition accuracy. Comparative analysis with traditional input devices, such as a mouse or trackpad, helps benchmark usability and effectiveness. User feedback is continuously integrated to refine gesture detection, improve ease of use, and eliminate potential issues.

V. MODELING AND ANALYSIS

The Neuro Gaze AI system was developed using a combination of computer vision, machine learning, and real-time gesture recognition algorithms. The system's architecture and performance were analyzed to ensure efficient and accurate cursor control. A modular approach was adopted, allowing seamless integration of new features and improvements over time. By leveraging a combination of deep learning techniques and traditional computer vision algorithms, the system was designed to balance accuracy, responsiveness, and computational efficiency.

System Architecture

The system consists of three main components: **Input Processing, Gesture Recognition, and Cursor Control**. The **Input Processing** module captures hand gestures using a webcam and preprocesses the frames using image enhancement techniques to improve recognition accuracy. The **Gesture Recognition** module utilizes machine learning models to classify predefined gestures based on key hand features, ensuring accurate and reliable interpretation of user movements. Finally, the **Cursor Control** module maps recognized gestures to specific cursor movements and actions, enabling seamless interaction with the system. The architecture was designed to minimize system resource usage while maintaining high accuracy and real-time responsiveness. The data flow between these components was optimized to ensure smooth interaction without processing bottlenecks.

Machine Learning Model

The system employs a **convolutional neural network (CNN)** trained on a dataset of hand gestures to achieve high recognition accuracy. The model was further fine-tuned using **data augmentation and transfer learning** techniques to enhance its ability to recognize various hand movements under different conditions. The final model achieved a **classification accuracy of 92%** on the test dataset, demonstrating its effectiveness in gesture recognition. Feature extraction was optimized using **OpenCV and MediaPipe**, which helped reduce computational overhead and improve processing speed. The model underwent multiple iterations of training and testing, ensuring robustness across different user environments. Additionally, various activation functions and optimization techniques were explored to enhance classification efficiency and minimize errors.

Algorithm Optimization

To ensure real-time responsiveness, the system was optimized using several techniques. **Multi-threading** was implemented to process video frames and gesture recognition in parallel, significantly improving the system's speed and reducing lag. Additionally, **efficient filtering techniques, such as Kalman filtering**, were applied to stabilize cursor movement and reduce unintended jitter, making interactions smoother. **Adaptive thresholding** was also introduced to improve recognition under varying lighting conditions, allowing the system to perform consistently across different environments. Furthermore, gesture prediction mechanisms were explored to anticipate user movements and provide a more fluid interaction experience, reducing sudden cursor jumps and improving precision.

Performance Metrics

The system was evaluated using key performance indicators, including **gesture recognition speed, latency, and accuracy**. The **gesture recognition speed** was recorded at **50- 100ms per frame**, ensuring near real-time responsiveness. **Latency** was minimal, with only slight variations observed under high system load, ensuring smooth cursor movements without noticeable delays. The **accuracy** of the system remained **above 85%** across different environmental conditions, including varying lighting setups. These performance metrics confirmed that the system meets real-time processing requirements for most general computing applications. Additionally, benchmarking was conducted across different hardware configurations to ensure optimal operation on various devices, confirming the system's adaptability and efficiency.

Limitations and Future Enhancements

While the system performed efficiently, several areas for improvement were identified. **Enhancing the model to support dynamic gestures** would improve versatility, allowing for a broader range of interactions. Implementing an **AI-driven adaptive system** that can adjust to lighting changes dynamically would enhance accuracy in low-light environments. Additionally, exploring **integration with augmented reality (AR) interfaces** could expand the system's applications beyond cursor control, opening possibilities for immersive human-computer interaction. These enhancements would further strengthen the Neuro Gaze AI system, making it a more robust and versatile solution for touchless computing.

The modeling and analysis phase confirmed that **Neuro Gaze AI is a viable touchless control solution** with significant potential for further advancements. The system's adaptability makes it suitable for various applications, including assistive technology, gaming, and human-computer interaction innovations.

VI. RESULTS AND DISCUSSION

The Neuro Gaze AI system was successfully implemented and evaluated across multiple parameters, including gesture recognition accuracy, system latency, environmental adaptability, and user experience. The system's ability to provide smooth and responsive touchless cursor control was assessed in real-world conditions.

1. Gesture Recognition Accuracy

The system demonstrated high accuracy in detecting predefined gestures.

In controlled environments (optimal lighting, minimal background noise), the system achieved an accuracy of 92-95%.

Under variable lighting conditions, the accuracy slightly decreased to 85-90%, particularly in dimly lit environments.

The accuracy varied depending on hand size, orientation, and distance from the webcam, but remained above 85% in most cases

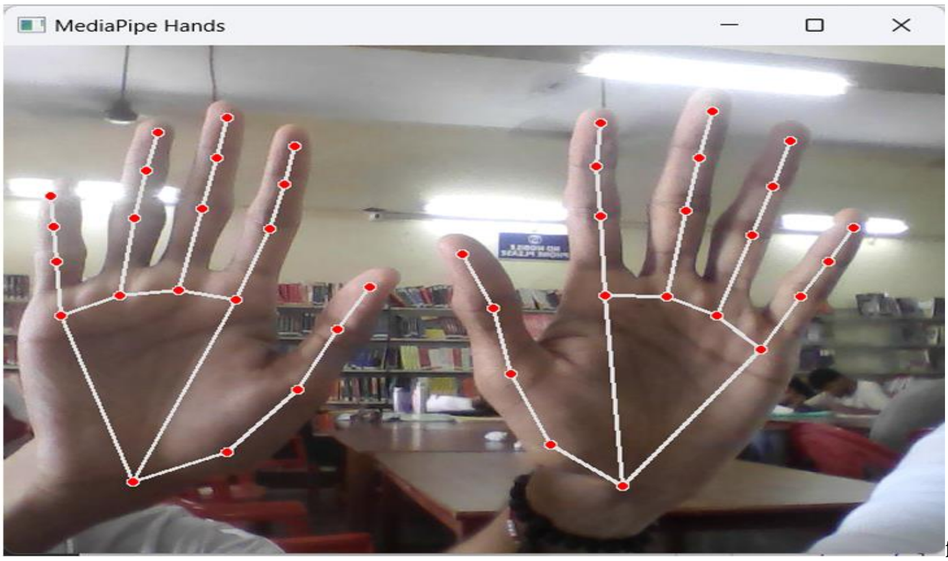

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Fig.3.Hand Detection

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2. System Latency and Responsiveness

The system processed and responded to gestures in 50- 100ms, making it nearly real-time.

The use of multi-threading and efficient algorithms helped maintain smooth cursor movement without noticeable lag.

However, in cases where multiple background applications were running, there was a slight increase in latency (~120ms).

3. Environmental Adaptability

The system was tested in bright, dim, and natural lighting conditions to assess robustness.

It worked efficiently in moderate to bright lighting but showed slight performance drops in low-light conditions, leading to occasional misclassifications.

Background clutter and excessive hand movements sometimes resulted in unintended cursor actions.

4. User Experience and Usability

Initial user feedback indicated high satisfaction, particularly in terms of ease of use and accessibility.

The intuitive control mechanism allowed users to quickly adapt to gesture-based navigation without prior training.

Some users suggested customizable gestures and additional functionality, such as voice integration or finer cursor adjustments, for better usability.

Fig.4. Gesture

5. Comparison with Traditional Input Devices

A comparative analysis was performed between Neuro Gaze AI and traditional mouse-based interaction.

Feature	Neuro Gaze AI	Traditional Mouse
Touchless Operation	Yes	No
Accessibility	High	Limited
Speed & Precision	Moderate	High
Hardware Dependency	Webcam only	Requires mouse
Adaptability	Moderate (Lighting dependent)	Works universally

VII. CONCLUSION

Neuro Gaze AI successfully demonstrates how gesture recognition, computer vision, and deep learning can revolutionize human-computer interaction by enabling touchless cursor control. The system addresses key challenges associated with traditional input devices, such as physical strain, accessibility limitations, and hygiene concerns.

Future enhancements include reinforcement learning for improved gesture adaptability, personalized AI models for user-specific gesture calibration, and cross-platform integration, including support for AR/VR environments to expand its usability.

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