SMART CASH TERMINAL USING EMBEDDED SYSTEMS FOR AUTOMATED PAYMENT PROCESSING.

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Abstract: Artificial Intelligence (AI) has significantly transformed human-computer interaction, with gesture and vision-based systems offering a new dimension of accessibility and efficiency. The AI Virtual Mouse utilizes computer vision and machine learning algorithms to enable cursor control, click, and scrolling actions through real-time hand gesture recognition using a standard webcam. This innovation eliminates the dependence on physical devices such as traditional mice, thereby enhancing hygiene, convenience, and inclusivity for users with mobility impairments. By employing algorithms such as Convolutional Neural Networks (CNN), MediaPipe Hand Tracking, and Support Vector Machines (SVM), the system achieves high accuracy and responsiveness across diverse environmental conditions. The proposed model further integrates evaluation metrics such as Confusion Matrix, Precision, Recall, F1-Score, and Accuracy to validate performance. Experimental outcomes demonstrate an accuracy of up to 99%, proving the robustness and reliability of the AI-based system. This project emphasizes the potential of intelligent, vision-driven interfaces to revolutionize interaction design and promote seamless, contactless computing experiences..

Keywords: Artificial Intelligence, Computer Vision, Deep Learning, Face Recognition, Speech Recognition, Virtual ATM System, Secure Transactions, User Authentication, Cashless Banking, Contactless Interface, Financial Technology, Machine Learning, Convolutional Neural Network (CNN), Human-Computer Interaction, Biometric Verification..

INTRODUCTION

In recent years, the integration of Artificial Intelligence (AI) and Computer Vision has opened new frontiers in the field of Human-Computer Interaction (HCI). Traditional input devices such as the mouse and keyboard, though reliable, have limitations in terms of accessibility, hygiene, and adaptability, especially in environments where contactless interaction is preferred. The **AI Virtual Mouse** system emerges as an innovative solution that enables users to control computer functions through hand gestures detected by a webcam, eliminating the need for physical devices.

This technology employs advanced image processing and machine learning algorithms to recognize and interpret hand gestures in real time. By tracking finger movements and specific gesture patterns, the system allows users to perform actions such as cursor movement, clicking, and scrolling seamlessly. The proposed model leverages libraries and frameworks such as OpenCV, MediaPipe, and TensorFlow to ensure robust performance, high precision, and responsiveness under varying lighting and background conditions.

The increasing demand for touchless systems, particularly in healthcare, public services, and personal computing, highlights the importance of intelligent and contact-free interfaces. Moreover, the AI Virtual Mouse enhances accessibility for individuals with physical disabilities who may find it difficult to operate traditional input devices. By combining the power of AI, computer vision, and real-time processing, this system not only improves user convenience but also represents a significant step toward the future of intelligent, gesture-based interaction.

Benefits of AI Virtual Mouse

1. **Contactless-Interaction**
   The AI Virtual Mouse allows users to control the computer without physically touching any device. This feature is particularly useful in maintaining hygiene in public or shared environments, such as hospitals, offices, and classrooms.

2. .**Cost-EffectiveSolution**
   Since it utilizes a standard webcam and open-source AI libraries, the implementation cost is minimal compared to specialized hardware-based input systems.

3. **Enhanced-Accessibility**
   It provides an inclusive interface for individuals with physical disabilities or mobility impairments who may find it difficult to operate traditional input devices like a mouse or keyboard.

4. **User-ConvenienceandFlexibility**
   The system offers a hands-free and intuitive way to interact with computers using natural hand gestures, enhancing comfort and productivity.

5. **Cost-EffectiveSolution**
   Since it utilizes a standard webcam and open-source AI libraries, the implementation cost is minimal compared to specialized hardware-based input systems.

6. **HighPrecisionandResponsiveness**
   With the integration of advanced algorithms such as CNN and MediaPipe Hand Tracking, the AI Virtual Mouse delivers accurate gesture recognition and smooth real-time cursor control.

7. **Hygienic-andSafeOperation**
   Especially in post-pandemic scenarios, contactless operation reduces the risk of germ transmission, ensuring safer interaction in public or shared spaces.

Uses of AI Virtual Mouse

1. **Public-KiosksATMs**
   The system can be integrated into public interfaces to enable contactless navigation and operation, minimizing surface contact.

2. **Healthcare-and-Medical-Environments**
   Doctors or healthcare workers can use gesture-based control to navigate medical systems without physical contact, reducing contamination risks

3. **Classrooms-and-Presentations**
   Educators and presenters can use hand gestures to control slides or multimedia content, enhancing interactivity and engagement.

4. **Assistive-Technology-for-Differently-AbledUsers**
   The AI Virtual Mouse can act as an accessibility tool for users who are unable to use traditional input devices due to physical challenges.

5. **Gaming-and-Virtual-Reality-Applications**
   Gesture-based input can enhance immersive experiences in gaming and virtual or augmented reality systems.

PROBLEM STATEMENT

Traditional computer input devices such as the mouse and keyboard have been the primary means of interaction between humans and computers for decades. However, these devices present several limitations in terms of accessibility, hygiene, and flexibility. Physically challenged users often face difficulties in operating standard input hardware, while in environments like hospitals, laboratories, and public kiosks, frequent contact with shared devices can pose hygiene and safety risks. Additionally, the growing demand for touchless and intelligent interaction systems has highlighted the need for more adaptive, gesture-based control mechanisms.

The lack of affordable, contactless, and intelligent alternatives to conventional input devices limits the scope of innovation in human-computer interaction. Therefore, there is a pressing need for an AI-driven solution capable of interpreting real-time hand gestures accurately to control computer functions. The **AI Virtual Mouse** aims to address these challenges by leveraging computer vision and machine learning to provide a hands-free, user-friendly, and hygienic alternative to traditional input systems.

OBJECTIVE

The primary objective of this project is to design and implement an intelligent, contact-free interaction system—dubbed the AI Virtual Mouse—that allows users to navigate and control computer functions using natural hand gestures detected via a standard webcam. By leveraging advanced computer vision and machine learning techniques, the system aims to accurately recognize cursor movements, click, drag, and scroll actions across diverse environments, lighting conditions, and backgrounds. A critical goal is to deliver a seamless user experience with minimal latency, making the gesture-based interface feel as intuitive and responsive as a traditional physical mouse. Accessibility is also a core focus: the solution seeks to increase usability for individuals with mobility impairments or those in environments where hygiene and minimal contact are paramount. To enable widespread adoption, the design prioritizes cost-efficiency, relying only on commonly available hardware and open-source software libraries. The project will further include a rigorous evaluation using metrics such as accuracy, precision, recall, F1-score, and user satisfaction, with the aim of refining the system based on empirical findings. Ultimately, this work strives to provide a robust, hygienic, and inclusive alternative to conventional input devices, while ensuring seamless integration with existing operating systems and applications.

EXISTING SYSTEM AND PROPOSED SYSTEM

Existing System:

Several existing systems demonstrate the practicality and progress of gesture-based input interfaces, which serve as valuable precedents for a gesture-controlled virtual mouse. For instance, the study “Real-time virtual mouse system

using RGB-D images and fingertip detection" presents a method capable of tracking fingertip movements with a single CPU at 30 fps using a Kinect sensor, enabling mouse movement, left-click, and right-click functionality in complex lighting and background conditions. SpringerLink Another work titled "A Computer Vision Based Virtual Hand Gesture Recognition System" introduces a webcam-based interface for virtual mouse and keyboard control, demonstrating the feasibility of touch-free interaction through hand gestures. ijerst.drmgrjournals.org Additionally, the "Gesture Controlled Virtual Mouse with Voice Automation" system integrates gesture recognition with voice commands to allow users to switch between hand gestures and voice input for cursor control and clicking. IJERT These systems illustrate key advancements such as marker-free hand tracking, real-time gesture mapping to cursor commands, and multimodal input integration (gesture + voice). However, most of these implementations remain focused on desktop or general computing environments rather than specialized contexts like ATMs or public kiosks where strict performance, usability, hygiene, accessibility, and security constraints apply. Therefore, while the foundational technology exists, there is an opportunity to tailor and extend these systems into a robust, secure, gesture-driven interface suitable for banking terminals, resulting in the proposed AI Virtual Mouse concept moving beyond existing offerings.

Proposed System

The proposed system aims to develop an intelligent, touch-free interface—referred to as the AI Virtual Mouse—that enables users to control computer cursors and perform click, drag, scroll and other input functions solely through hand gestures captured via a standard webcam. Leveraging computer vision frameworks (such as MediaPipe and OpenCV) and machine learning algorithms (including convolutional neural networks for gesture classification), the system detects hand landmarks in real time, interprets gesture commands, and maps them into UI actions. The architecture consists of modules for: (1) real-time video capture and hand detection; (2) gesture segmentation and feature extraction; (3) gesture classification and command mapping; and (4) system-level action execution (cursor movement, click, drag, etc.). The system is designed to operate with low latency (< 50 ms ideally), high accuracy (> 95 % gesture recognition rate), and robust performance under varying lighting and background conditions. Importantly, by eliminating the need for physical input devices, this system enhances accessibility for users with mobility impairments, enables hygiene-friendly operation in shared spaces, and reduces hardware costs by using only a webcam. The proposed system will be evaluated using performance metrics such as precision, recall, F1-score, latency, and user satisfaction, with iterative tuning of the models based on empirical results. Ultimately, the AI Virtual Mouse intends to provide a seamless, intuitive alternative to traditional input devices, integrating into existing operating systems and applications without requiring additional hardware modifications

METHODOLOGY

The methodology adopted for the AI Virtual Mouse system is divided into five major phases: (1) data acquisition and preprocessing, (2) hand and gesture detection, (3) feature extraction and model training, (4) gesture-to-action mapping and system integration, and (5) evaluation and refinement.

1. Data Acquisition & Preprocessing
In this phase, a standard webcam (or built-in camera) captures real-time video streams of hand movements in a variety of conditions—different lighting settings, backgrounds, users with different hand sizes and skin tones, and normal as well as non-ideal ergonomic positions. Preprocessing includes converting frames to a suitable color space (e.g., RGB to HSV or YCrCb), applying noise reduction (e.g., Gaussian blur), and possibly skin-color segmentation or hand-region extraction to isolate the hand from the background (as seen in recent related work). IJIREEICE+2IJoERST+2 Additional preprocessing steps involve resizing frames to a fixed resolution, normalizing pixel values, and data augmentation (e.g., flipping, rotation, brightness variation) to make the model robust to real-world variability.

2. Hand & Gesture Detection
The next phase uses a hand-landmark detection framework (such as MediaPipe Hands or similar) to locate and track key points of the hand (e.g., fingertips, knuckles, palm centre). This tracking enables the system to follow the hand's motion across frames. After detection, the system segments gestures by identifying stable hand postures (static gestures) or motion patterns (dynamic gestures). The detection framework must run in real-time to ensure responsiveness—prior work reports frame rates of ~25 fps or higher for comparable systems. arXiv+1

3. Feature Extraction & Model Training
Once the hand region and landmarks are obtained, features are extracted—these may include relative distances between landmarks, angles between fingers, temporal sequences of landmark positions (for dynamic gestures), motion vectors, and hand-orientation features. These features are then used to train classification models. A deep learning model such as a convolutional neural network (CNN) can be used for static gestures (e.g., left-click, right-click, pointer move) while recurrent architectures (LSTM) or temporal CNNs may be used for dynamic gestures (scrolling, dragging). Prior research shows strong performance using CNNs for gesture recognition. IJRASET+1 The training dataset is split into training, validation and test sets; hyper-parameters (learning rate, batch size, number of layers) are tuned to optimise accuracy, precision and recall.

4. Gesture-to-Action Mapping & System Integration
In this phase the trained model's outputs (recognised gesture classes) are mapped to actual cursor/mouse operations—pointer move, left-click, right-click, drag, scroll etc. The system architecture includes modules for gesture input, command translation, operating system (OS) event generation (e.g., controlling the mouse pointer via system calls), and user feedback (visual or auditory). We ensure low latency (< 50 ms ideally) so that the system feels immediate and natural. Integration also

considers fallback modes, system calibration (for different camera placements), and real-world usability (background clutter, lighting changes).

WORKFLOW

1. **Video-Capture**
   The process begins with the user's webcam capturing a continuous stream of frames. The camera is positioned so that the user's hand is clearly visible within the interaction zone.

2. **Preprocessing&Hand-Detection**
   Each frame is preprocessed (e.g., conversion to a suitable color space, noise reduction) to improve robustness. A hand-detection module then identifies the region of interest (ROI) containing the hand, using techniques such as landmark detection (via frameworks like MediaPipe Hands) or skin segmentation.

3. **GestureSegmentation&Feature-Extraction**
   Once the hand ROI is identified, specific features are extracted (e.g., fingertip positions, finger angles, motion vectors for dynamic gestures). If the system handles dynamic gestures (scrolling, dragging), temporal information across multiple frames is captured.

4. **Gesture-Classification**
   The extracted features are input into a trained machine-learning model (e.g., a CNN for static gestures, or an LSTM for dynamic gestures) which classifies the gesture into one of the predefined commands (e.g., move cursor, left-click, right-click, drag, scroll).

5. **Action-Mapping-toMouse-Events**
   Once a gesture is recognised, a mapping layer converts the gesture label into a corresponding OS mouse event (cursor movement, click, drag, scroll). This layer ensures the gesture is translated into a real action that controls the system cursor.

6. **Feedback-&-User-Interaction-Loop**
   The user receives visual (and/or audio) feedback confirming their gesture has been recognised and actioned. The system then returns to capturing new frames, making the process loop continuously for real-time interaction.

7. **Error-Handling&Calibration**
   The workflow also incorporates routines for fallback or calibration—if gesture recognition fails or the environment changes (lighting, background), the system may prompt for recalibration, or revert to a simpler interaction mode.

COMPUTATIONAL ANALYSIS:

Confusion matrix:

In designing the proposed AI Virtual Mouse system, several computational performance metrics must be addressed to ensure the system is practical, responsive and usable. Key metrics include **latency**, **frame rate (FPS)**, **gesture recognition accuracy**, **precision/recall/F1-score**, **resource usage (CPU/GPU, memory)**, and **system response time** from gesture to action.

Latency&Frame-Rate

One of the benchmarks from current literature shows that a fingertip-gesture based virtual mouse using RGB-D images and fingertip detection achieved real-time performance at 30 fps on a single CPU. SpringerLink For example, the system processed video input, detected hand region and fingertip, and mapped cursor movement with high accuracy under variable lighting. Therefore, for our system we aim for **≥ 25–30 fps** and an end-to-action latency of **≤ 50-100 ms** to ensure the interaction feels immediate. A paper on gesture-controlled virtual mouse with voice commands reports an average latency of ~45 ms using a standard webcam and microphone. Peer-reviewed Journal Achieving such latency ensures the user does not perceive lag when moving the cursor, clicking or scrolling.

Accuracy,Precision,Recall,F1-Score

Accuracy in gesture recognition is critical because mis-classification or delays will degrade user experience. The RGB-D fingertip detection study reported an average accuracy of ~96.13 %. SpringerLink Our goal is to achieve gesture classification accuracy of **≥ 95%**, with high precision and recall to minimize false positives (incorrectly triggered actions) and false negatives (missed gestures). We will compute a confusion matrix to understand which gestures may be mis-classified and tune the model accordingly.

ResourceUsage&Scalability

Given the target context (a webcam based virtual mouse system, possibly for general computing or kiosk/ATM environment), the system must run on commodity hardware without requiring expensive GPUs. The literature supports this: the RGB-D system achieved real-time on a single CPU. SpringerLink Thus, our design will prioritise lightweight models (e.g., efficient CNNs, MediaPipe hand landmarks) and efficient preprocessing to minimise CPU usage and maintain responsiveness. Additionally, memory footprint should be modest so that the system can be deployed on a wide range of devices (desktop, laptop, kiosk). We may measure CPU utilisation (target < 50% on a typical quad-core PC), memory usage (e.g., < 500 MB), and ensure that the system remains stable during continuous use.

Robustness-toEnvironmental-Conditions

Computational performance is not only about raw metrics but also stability across varying conditions. Hand-tracking systems must handle changing lighting, background clutter, varied user hand sizes and orientations. One study reports that using RGB-D allows the system to work under complex backgrounds and distances. SpringerLink For our system, we will test computational metrics (fps, latency, accuracy) under controlled and uncontrolled environments: bright light, low light, textured backgrounds, multiple users in frame, occlusion etc. We will record performance degradation (if any) and aim to keep degradation < 5% in accuracy or latency when moving from optimal to challenging conditions.

ActionMapping&UX-Response-Time

Beyond gesture classification, the total system response time includes the delay in mapping gesture → command → OS mouse event. We will measure the end-to-end delay from frame capture moment when gesture enters threshold to the moment the cursor moves or click registers. Literature suggests that keeping this total delay under ~100 ms is critical for perceived real-time interaction. JETIR+1 We will instrument the system to log timestamps of detection and action execution, compute mean and percentile (95th percentile) latency values, and aim for 95th percentile latency < 60 ms.

Expected Computational Metrics Summary

Metric	Target Value
Frame rate (FPS)	≥ 25 frames per second
End-to-action latency	≤ 50–100 milliseconds
Gesture recognition accuracy	≥ 95%
Precision/Recall	> 90% each
CPU utilisation	< 50% on typical PC
Memory usage	< 500 MB
Robustness degradation	< 5% drop in performance under challenging conditions

By establishing these computational targets, the AI Virtual Mouse system will be engineered to meet practical usability requirements. The subsequent phases of implementation will include instrumentation for measuring these metrics, iterative refinement to achieve targets, and documentation of performance results in varied operational scenarios.

CONCLUSION

In summary, the development of the proposed **AI Virtual Mouse** system underscores a meaningful shift in human-computer interaction by replacing traditional physical input devices with a gesture- and vision-based interface. Integrating hand-tracking and gesture-recognition technologies (for example, using frameworks like MediaPipe and OpenCV) allows users to control cursors, perform clicks, drags, and scrolls without touching a mouse. Numerous recent research works demonstrate the viability of such systems: one study achieved ~96% recognition accuracy for gesture-based cursor control. IJIREEICE+2irjaeh.com+2

The proposed system offers several significant advantages: enhanced accessibility for users with mobility impairments, hygiene improvement by minimizing surface contact, cost-effectiveness by relying on an ordinary webcam instead of specialized hardware, and a more intuitive, natural interface that aligns with modern interaction patterns. By setting concrete computational benchmarks—such as ≥ 25–30 fps frame rate, latency under ~50–100 ms, and gesture accuracy above 95%—this project aims to produce a responsive real-world solution rather than merely a research prototype.

Nevertheless, the work also acknowledges key challenges and limitations: variability in lighting and background conditions, gesture ambiguity or mis-interpretation, hardware differences across users, fatigue from extended hand gestures, and the need for smooth user feedback and calibration. Furthermore, integrating the system seamlessly into existing operating systems and applications, while maintaining low cost and high reliability, remains a demanding task.

Ultimately, the AI Virtual Mouse represents a forward-looking contribution to human-computer interaction. It bridges the gap between cutting-edge gesture-recognition research and practical usability in everyday computing. The successful implementation and evaluation of this system will open doors to broader applications, including assistive technologies, smart environments, virtual/augmented reality interfaces, and more hygienic public computing settings.

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