



AI BASED HAND GESTURE CONTROLLED ROBOT

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Abstract:

The proposed system presents an advanced AI-based hand gesture controlled telepresence robot designed for operation in hazardous and inaccessible environments. The system enables a remote operator to control a robotic rover using real-time hand gestures without the need for physical controllers or wearable devices. It integrates computer vision techniques using OpenCV and MediaPipe for accurate skeletal hand tracking and gesture recognition.

A dual-processing architecture ensures efficient handling of high-definition video streaming and gesture interpretation with minimal latency. The robot provides real-time visual feedback through wireless video transmission, enabling safe navigation and monitoring. The system ensures intuitive control, improved safety, and enhanced operational efficiency.

This solution is highly applicable in disaster management, industrial inspection, and healthcare environments where human presence is risky or limited.

Keywords: Telepresence Robot, Hand Gesture Recognition, Computer Vision, Real-Time Control, Wireless Communication, Hazardous Environment Exploration.

1. INTRODUCTION

Modern industrial, medical, and disaster-response environments often involve hazardous conditions such as toxic exposure, radiation, structural instability, and biological contamination. Direct human involvement in such environments poses significant risks, creating the need for



systems that enable safe and efficient remote operation. Telepresence robotics has emerged as a key solution by allowing operators to control robotic systems from a distance while maintaining real-time decision-making capabilities.

Conventional telepresence systems rely on physical interfaces such as joysticks and controllers, which are non-intuitive and require training. These interfaces introduce a gap between human intent and robotic action, increasing cognitive load and reducing efficiency, especially in time-critical applications like search-and-rescue operations. Therefore, there is a growing need for more natural and user-friendly human-machine interaction methods.

Hand gesture recognition offers an intuitive and contactless approach for controlling robotic systems. By leveraging computer vision and machine learning techniques, human hand movements can be detected and translated into control commands in real time. This eliminates the need for wearable devices or manual controllers, improving usability and reducing the risk of contamination in sensitive environments such as healthcare facilities.

The proposed AI-based hand gesture controlled telepresence robot integrates real-time gesture recognition with remote robotic navigation. The system utilizes OpenCV and MediaPipe for accurate skeletal hand tracking and gesture interpretation. A live video streaming module provides continuous visual feedback to the operator, enabling effective navigation and monitoring. This creates a closed-loop system that enhances control accuracy and situational awareness.

To address computational challenges, the system adopts a distributed architecture, separating gesture processing and robot control to ensure low latency and efficient performance. The robotic platform is equipped with high-torque motors and reliable motor drivers, allowing smooth and precise movement in multiple directions.

In conclusion, the proposed system provides an intuitive, efficient, and safe solution for remote operation in hazardous environments. It improves human-robot interaction by enabling gesture-based control and demonstrates the practical application of artificial intelligence and robotics in real-world scenarios.

2. LITERATURE SURVEY

Prongnuch et al. (2025) developed a real-time gesture recognition system using MediaPipe, enabling contactless interaction through skeletal tracking without wearable devices. The system achieved high accuracy but was sensitive to lighting conditions and complex backgrounds.

Yaseen (2025) proposed a gesture-controlled robotic system for navigation, mapping hand gestures to movement commands. While intuitive and effective in controlled environments, it suffered from latency on low-power embedded systems, highlighting computational limitations.

Godase (2025) introduced a deep learning-based gesture recognition model that improved accuracy and robustness. However, it increased computational complexity, making real-time deployment on embedded systems challenging.



Van den Bergh et al. (2025) addressed this issue using lightweight CNN models optimized for faster processing on edge devices. Although efficient, the approach required careful model tuning, increasing system complexity.

Chen et al. (2024) proposed the “GestureMoRo” algorithm for gesture-based teleoperation, enabling smooth robot control. However, system performance depended heavily on stable communication and proper calibration.

Michels (2025) developed a MediaPipe-based gesture-controlled robotic arm, achieving precise control but facing misclassification during dynamic gestures.

García-Gil et al. (2025) presented a vision-based interaction system that improved usability through natural gestures but was affected by environmental disturbances such as lighting and background noise.

Darmawan et al. (2025) proposed a lightweight deep learning model for real-time gesture recognition, achieving faster processing at the cost of slight accuracy reduction.

Verduyn et al. (2025) improved gesture stability using frame-invariant similarity measures, though additional preprocessing increased system complexity.

Kobzarev et al. (2025) introduced GestLLM, integrating large language models for contextual gesture understanding, but it required high computational power and was not suitable for embedded systems.

Zhang et al. (2021) proposed a real-time gesture-based mobile robot control system using CNN models and TensorFlow Lite on Raspberry Pi. The system improved recognition accuracy but required extensive dataset preparation and training, increasing complexity.

Alam and Khan (2022) developed a vision-based teleoperation system combining gesture recognition with wireless communication and real-time video feedback. While it enhanced remote navigation and situational awareness, performance degraded under unstable network conditions and varying lighting environments.

Park et al. (2023) introduced an intelligent telepresence robot integrating gesture control with obstacle detection and autonomous features. Although the system improved safety and efficiency, it increased hardware complexity and computational requirements.

Bamani et al. (2025) developed DiG-Net, a dynamic gesture recognition model designed for assistive robotics. The system achieved high accuracy in recognizing complex gesture sequences using advanced neural network architectures. However, it required hardware acceleration such as GPUs for real-time performance, increasing system cost and limiting its use in low-cost robotic platforms.



Overall, existing systems highlight challenges such as environmental sensitivity, computational load, latency, and communication dependency, which motivate the need for an optimized and efficient gesture-controlled telepresence system.

Author (Year)	Approach / Method	Key Contribution	Limitations
Prongnuch et al. (2025)	MediaPipe-based gesture recognition	Contactless interaction using skeletal tracking	Sensitive to lighting & background
Yaseen (2025)	Vision-based gesture-controlled robot	Intuitive gesture-to-motion mapping	Latency on embedded systems
Godase (2025)	Deep learning-based gesture recognition	High accuracy and robustness	High computational complexity
Van den Bergh et al. (2025)	Lightweight CNN models	Faster processing on edge devices	Complex model tuning required
Chen et al. (2024)	GestureMoRo teleoperation algorithm	Smooth gesture-based robot control	Depends on stable communication
Michels (2025)	MediaPipe-based robotic arm control	Precise gesture-to-action mapping	Errors in dynamic gestures
García-Gil et al. (2025)	Vision-based interaction system	Improved usability with natural gestures	Affected by lighting & background noise
Darmawan et al. (2025)	Lightweight deep learning model	Faster real-time processing	Slight accuracy reduction
Verduyn et al. (2025)	Frame-invariant similarity method	Improved gesture stability	Increased preprocessing complexity
Kobzarev et al. (2025)	GestLLM (LLM-based system)	Context-aware gesture understanding	High computational requirement
Zhang et al. (2021)	CNN + TensorFlow Lite (Raspberry Pi)	Improved recognition accuracy	Requires large dataset & training
Alam and Khan (2022)	Gesture + wireless teleoperation	Real-time video + remote control	Network & lighting sensitivity
Park et al. (2023)	Hybrid telepresence robot	Added obstacle detection & autonomy	High hardware complexity

Bamani et al. (2025)	DiG-Net deep learning model	High accuracy for dynamic gestures	Requires GPU, high cost
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3. METHODOLOGY

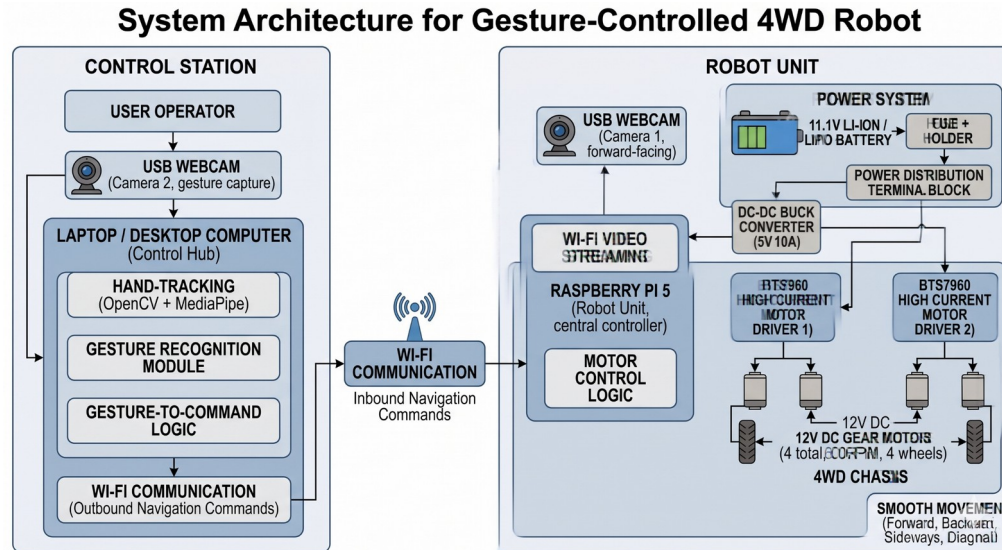


Fig. System Architecture of AI-Based Hand Gesture Controlled Telepresence Robot

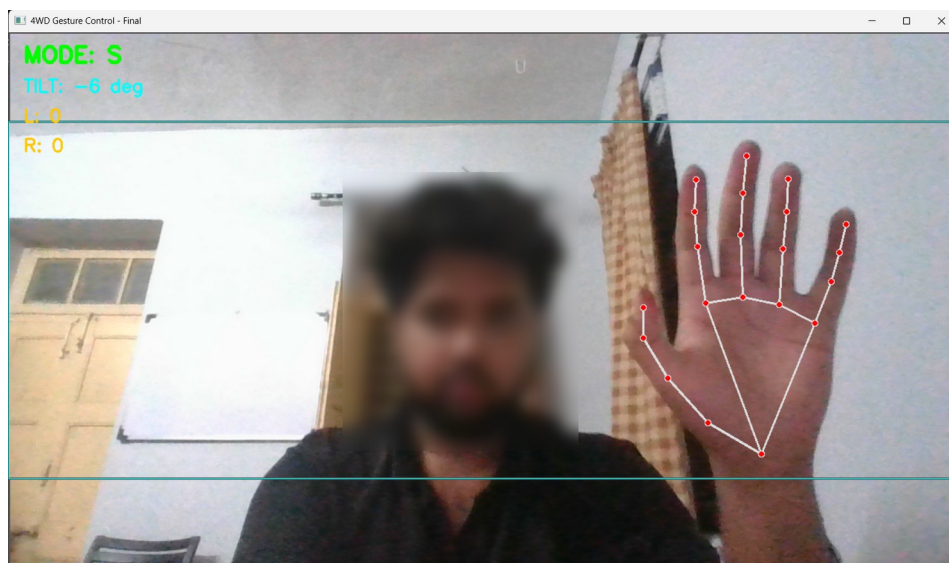
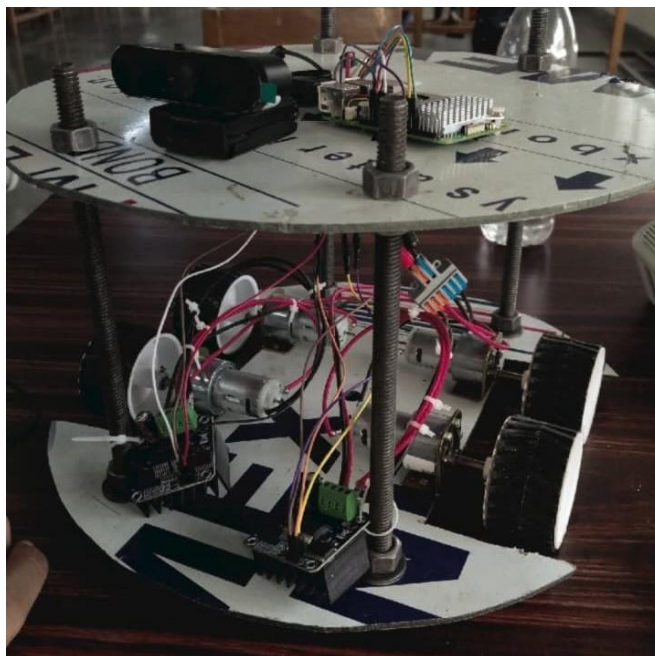
The proposed system consists of two main units: a control station for gesture recognition and a robot unit for motion control and video transmission. At the control station, a camera captures the user's hand gestures, which are processed using OpenCV and MediaPipe for real-time skeletal tracking and gesture recognition. The identified gestures are mapped to movement commands such as forward, backward, left, right, and stop.

These commands are transmitted wirelessly via Wi-Fi to the robot unit. A Raspberry Pi 5 receives the commands and generates appropriate control signals to drive the motors. The robot uses four high-torque DC motors with BTS7960 motor drivers, enabling smooth and precise movement in multiple directions using PWM-based control.

A camera mounted on the robot provides real-time video streaming to the operator, ensuring continuous monitoring and navigation. This creates a closed-loop system where gestures control the robot while visual feedback assists decision-making.

To improve performance, a distributed architecture is used to separate gesture processing and robot control, reducing latency and ensuring efficient operation. The system is tested under different conditions to evaluate accuracy, communication reliability, and movement stability.

4. RESULT



The system successfully achieved real-time gesture-based control with smooth robot movement and low latency. Gesture recognition was accurate, and live video streaming enabled effective remote navigation. Minor performance issues were observed under poor lighting and unstable network conditions.

5. DISCUSSION

The results of the proposed AI-based hand gesture controlled telepresence robot demonstrate that the system is effective in enabling intuitive and real-time robot control. The use of computer vision techniques with MediaPipe allowed accurate detection and classification of hand gestures,



resulting in smooth mapping of gestures to robot movements. The system showed reliable performance with low latency, ensuring responsive control and effective navigation. Similar to findings in prior works such as Yaseen (2025) and Chen et al. (2024), minor delays were observed when running on embedded platforms, highlighting the challenges of real-time processing in resource-constrained environments.

The integration of gesture recognition with wireless communication and live video streaming adds significant practical value to the system. The real-time video feedback enhances situational awareness, allowing the operator to make informed decisions during navigation. This aligns with recent trends in telepresence robotics, where user-friendly and contactless interfaces are prioritized for applications in healthcare, industrial inspection, and disaster management. The system successfully demonstrates how natural human gestures can replace traditional control mechanisms, reducing cognitive load and improving usability.

Future work can focus on improving robustness by incorporating advanced preprocessing techniques, optimizing models for embedded systems, and expanding gesture sets for more complex interactions. Integration of additional features such as obstacle avoidance, autonomous navigation, and edge AI optimization can further enhance system performance. Overall, the study confirms that gesture-based telepresence robotics is a practical and efficient approach, offering significant improvements over traditional control methods and contributing to the advancement of human-robot interaction.

6. CONCLUSION

The proposed AI-based hand gesture controlled telepresence robot provides an effective solution for safe and intuitive operation in hazardous and inaccessible environments. By replacing traditional control interfaces with vision-based gesture recognition, the system enables natural and contactless interaction. The integration of OpenCV and MediaPipe allows accurate real-time gesture detection, while wireless communication ensures responsive control and continuous operation.

The system successfully demonstrates smooth robot navigation along with real-time video feedback, enabling the operator to monitor and interact with remote environments efficiently. The distributed architecture improves performance by reducing latency and optimizing computational load, making the system suitable for practical deployment on embedded platforms.

Overall, the proposed approach enhances human-robot interaction by reducing complexity and improving accessibility. It has strong potential applications in healthcare, disaster management, surveillance, and industrial inspection. Future improvements can focus on enhancing robustness under varying environmental conditions and incorporating autonomous features for improved functionality.



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