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Design Of A Multi-Touch Sensing Robot For Real-Time Human Interaction

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Abstract:

Human Robot Interaction (HRI) is an emerging research area focused on enabling robots to interact naturally and intelligently with humans. Most commercially available social robots are either expensive or limited to a single interaction mode, restricting their use in educational and research environments. This paper presents the design and implementation of a multi-touch sensing robot capable of real-time human interaction through touch, motion, vision, and voice inputs.The proposed system integrates touch sensors, ultrasonic sensors, a camera module, a microphone, and a gyroscope with a Raspberry Pi–based control architecture. Multiple sensory inputs are processed using an AI-based decision module to generate expressive outputs such as emotional eye animations, sound responses, and physical movements through servo motors and a four-wheel drive system. The robot demonstrates behaviors such as touch reaction, lift detection, obstacle avoidance, and person following.The developed robot serves as a low-cost, modular, and interactive platform suitable for STEM education, classroom demonstrations, and future research in affordable social robotics.

1.Introduction

Advancements in robotics and artificial intelligence have significantly increased interest in human-robot interaction, where robots are expected to respond naturally to human actions such as touch, voice, and movement. Social robots are increasingly used in education, healthcare, and public environments; however, many existing solutions are costly and offer limited interaction capabilities.

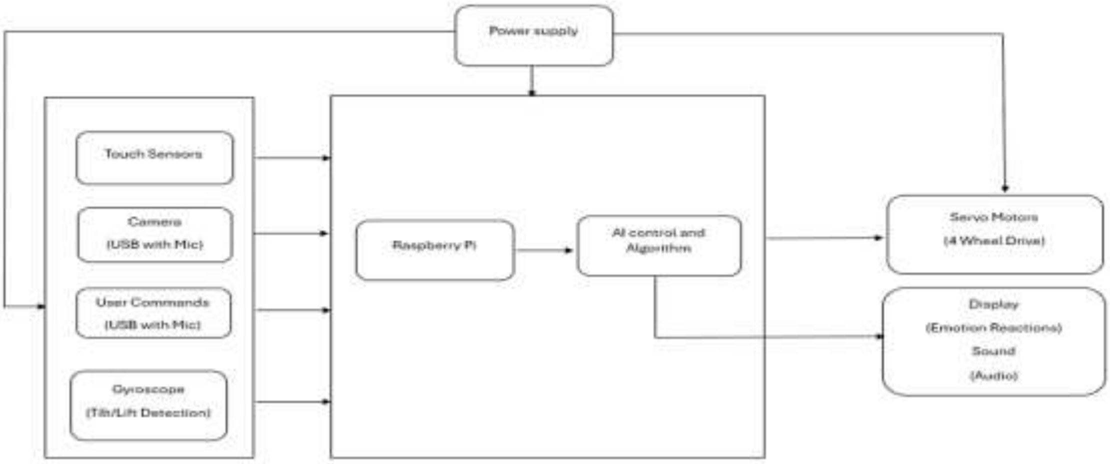
Most low-cost robots focus only on navigation or remote control, while high-end robots provide emotional expression and intelligent interaction at a significantly higher cost. This creates a gap between affordability and functionality. Addressing this challenge, the proposed work aims to design a multi-touch sensing robot that combines expressive behaviors with practical functionalities using low-cost hardware.

The robot is designed to respond to physical touch, detect lifting and orientation changes, follow nearby humans, and express emotions using visual and audio feedback. By integrating multiple sensors and an AI-based control approach, the system provides an engaging and educational platform for demonstrating real-time human-robot interaction.

2.METHODOLOGY

2.1 SYSTEM ARCHITECTURE

The system architecture consists of multiple input sensors, a central processing unit, an AI decision module, and output actuators. Touch sensors, ultrasonic sensors, a camera, microphone, and gyroscope continuously collect environmental and interaction data. A Raspberry Pi functions as the central controller, processing sensor inputs and coordinating robot behavior.



2.2 SENSOR INPUTS AND DATA ACQUISITION

Touch sensors detect direct human interaction and trigger emotional responses. Ultrasonic sensors measure distance to detect obstacles and nearby humans. The camera module captures visual data for person detection and photo capture. A microphone receives voice commands, while the gyroscope detects tilt and lift events, enabling safety and fear-based reactions.

2.3 AI BASED DECISION PROCESSING

An AI algorithm block processes sensor inputs and determines appropriate responses. The algorithm analyzes touch patterns, voice commands, orientation data, and distance measurements to generate movement and expression commands. Decision logic prioritizes safety, interaction, and responsiveness, ensuring smooth coordination between multiple interaction modes.

2.4 ACTUATION AND OUTPUT SYSTEM

The output system consists of servo motors for head and hand movement, a four-wheel drive mechanism for mobility, an OLED display for emotional eye animations, and a sound module for audio feedback. Control signals generated by the AI algorithm are sent through the microcontroller to execute physical and expressive actions.

3. PROBLEM STATEMENT

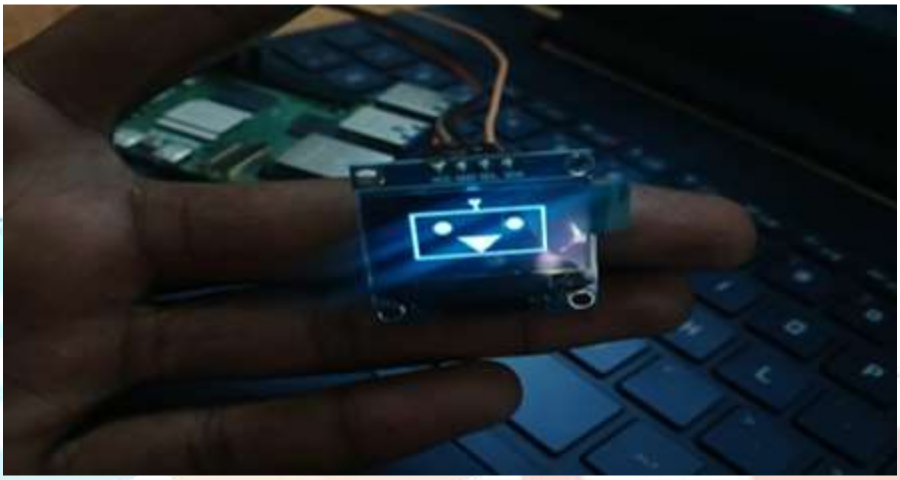
Current affordable robotic platforms lack natural and engaging interaction capabilities, while advanced social robots are financially inaccessible for educational institutions. Existing systems often rely on single-mode interaction, such as remote control or basic navigation, limiting their educational and practical value.

There is a need for a low-cost, multi-modal robotic system that can respond to touch, motion, vision, and voice in real time while providing expressive feedback. The proposed multi-touch sensing robot addresses this gap by combining multiple sensors with AI-based control to achieve realistic human-robot interaction at an affordable cost.

4. RESULTS AND DISCUSSION

The implemented robot successfully demonstrated real-time interaction through touch response, lift detection, obstacle avoidance, and person following. Touch interactions triggered immediate emotional feedback through eye animations and sound responses. Gyroscope-based lift detection enabled fear-based reactions, enhancing realism.

Obstacle avoidance using ultrasonic sensors allowed smooth navigation, while the camera module enabled basic visual interaction and photo capture. The integration of multiple sensors with AI-based decision logic resulted in coordinated and responsive behavior. The system proved reliable for classroom demonstrations and interactive learning activities.



5. CONCLUSION

This paper presented the design and implementation of a multi-touch sensing robot for real-time human interaction. By integrating touch, vision, motion, and voice sensors with a Raspberry Pi–based AI control system, the robot achieves expressive and intelligent interaction capabilities at a low cost.

The modular and affordable design makes the system suitable for educational institutions, STEM learning, and introductory research in social robotics. The project successfully bridges the gap between functionality and affordability in human-robot interaction platforms.

6. FUTURE ENHANCEMENTS

Future work may include advanced computer vision algorithms for face recognition, natural language processing for improved voice interaction, and autonomous mapping and navigation. Cloud-based AI integration and mobile application control can further enhance interaction capabilities. Expanding the emotional model and learning behaviors through reinforcement learning will improve long-term adaptability.

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