

Development of A Multi-Mode Integrated Robotic Framework (MOKO) for Hybrid Navigation

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Abstract: *Modern automation demands versatile robotic platforms capable of both independent decision-making and precise manual intervention. This paper introduces MOKO, a Multi-Mode Autonomous and Manual Control Robot designed to enhance operational flexibility in dynamic environments. The architecture integrates ultrasonic-based obstacle avoidance, Bluetooth-enabled remote operation, and an AI-driven voice command interface. By utilizing a microcontroller-based processing unit, the system manages high-frequency sensor data to ensure real-time responsiveness. Experimental results demonstrate a high success rate in collision avoidance within a 200 cm range and a stable 10-meter wireless communication link. This study concludes that an integrated multi-mode framework significantly improves the usability of low-cost robotic systems for research and domestic assistance*

Keywords: *Modern automation*

I. INTRODUCTION

Robotics has transitioned from static industrial automation to essential roles in healthcare, domestic environments, and surveillance. Modern advancements in embedded systems and sensors allow robots to operate autonomously while still maintaining high-fidelity manual control. The requirement for hybrid systems is driven by the need for robots to perform repetitive tasks independently while allowing humans to take control for complex or specific manoeuvres. The MOKO (Multi-Mode Robot) platform is engineered to address this by providing a hybrid control scheme. While fully autonomous systems are efficient, they often lack the nuance required for specific user-driven tasks. Conversely, purely manual systems require constant supervision. MOKO bridges this gap by offering three distinct operational modes: autonomous obstacle avoidance, manual smartphone control, and vocal command execution. This flexibility makes it an ideal platform for surveillance, educational training, and smart-home integration.

II. LITERATURE REVIEW

Current research in mobile robotics extensively covers the use of distance-based sensors, such as ultrasonic, for localized mapping and avoidance. These technologies are foundational in warehouse automation and consumer-grade smart devices. Simultaneously, the rise of smartphone technology has made Bluetooth based control a popular research area due to its low infrastructure requirements. Autonomous systems typically use sensor fusion to map environments, but cost remains a significant barrier for wide-scale educational deployment.

Advancements in speech recognition have also enabled more intuitive human-to-machine interactions. Recent literature suggests that multi-modal interfaces—those combining voice, touch, and autonomous logic—provide higher user satisfaction and system reliability. MOKO differentiates itself by synthesizing these modalities into a single, low-latency framework powered by affordable hardware, moving beyond isolated prototypes toward a functional, adaptable communication and navigation solution.



III. SYSTEM ARCHITECTURE

The MOKO framework is categorized into a hierarchical structure involving sensing, processing, and execution layers. Each layer is designed to handle specific data flows to ensure minimal latency during mode switching. The integration of these layers allows for a seamless transition between human-led and robot-led navigation.

1. Sensing Subsystem

The sensing layer utilizes HC-SR04 ultrasonic transceivers for spatial mapping and proximity detection. These sensors work on the time-of-flight principle, emitting high-frequency sound waves and measuring the time taken for the echo to return. This data is critical for the autonomous avoidance mode, providing a 360-degree awareness of potential collisions when multiple sensors are integrated.

2. Control Subsystem

An Arduino-based microcontroller functions as the central logic unit (CLU). It manages high-priority interrupts from the sensors and processes serial data packets from the Bluetooth module. The CLU is programmed to prioritize safety; for instance, manual commands can be overridden if the sensing layer detects an imminent collision in the autonomous safety buffer.

3. Actuation Subsystem

The actuation layer comprises a dual H-bridge motor driver (L298N) and high-torque DC motors. The L298N allows for independent control of two motors, enabling the robot to perform complex manoeuvres such as zero-radius turns. Pulse Width Modulation (PWM) is employed to control the speed of the motors, ensuring smooth acceleration and deceleration.

IV. TECHNICAL IMPLEMENTATION

1. Hardware Integration

Hardware selection was optimised for power efficiency and modularity. The robot chassis serves as the structural base, with components mounted to minimise wire length and electromagnetic interference. The power system utilises a rechargeable Lithium-Ion battery pack, stepped down via a voltage regulator to provide a stable 5V rail for the microcontroller and sensors, while providing direct power to the motor driver.

2. Software Logic and Mode Switching

The firmware is developed in Embedded C via the Arduino IDE. The main execution loop is structured to handle real-time inputs without blocking. A state-machine approach is used to manage the transition between Obstacle Avoidance, Bluetooth, and Voice modes. This ensures that the robot does not experience "lock-up" when receiving simultaneous inputs.

For the Autonomous Mode, the logic follows a simple but effective 'Scan-Analyse-Move' loop. The distance (D) is calculated using the formula: $D = (\text{Time} \times \text{Speed of Sound}) / 2$. If $D < 20\text{cm}$, the robot initiates a turn. For Manual Mode, the system listens for specific char characters ('F' for Forward, 'B' for Backward, etc.) transmitted via the HC-05 module.

Table 1: Technical Specification of Hardware Components

Component	Operational Function	Specification
Arduino Uno	Central Logic & Signal Processing	Atmega328P, 16MHz
HC-SR04	Ultrasonic Distance Sensing	2cm - 400cm Range
HC-05	Bluetooth Serial Communication	V2.0, 10m Range
L298N	Dual H-Bridge Motor Control	Up to 2A per Channel
DC Motors	Locomotion & Steering	6V-12V, Gear Driven



V. OPERATIONAL MODES

MOKO supports three primary functional states designed to cater to different user needs and environmental complexities:

1. Obstacle Avoidance Mode

This mode is designed for fully independent navigation. The robot continuously monitors its surroundings. It is particularly useful for exploring unknown terrains or moving in areas where human control is not feasible. The safety threshold is dynamic and can be adjusted based on the motor speed to ensure a safe stopping distance.

2. Bluetooth Manual Mode

This mode provides high-precision control via a smartphone application. The user interface features a directional pad that sends real-time instructions to the robot. This mode is essential for tasks requiring delicate movement, such as navigating through narrow doorways or placing objects.

3. Vocal Command Mode

Vocal Command Mode is an AI-driven interaction method that converts speech to digital signals. Using a mobile application's speech-to-text engine, commands like "GO" or "STOP" are mapped to the robot's movement instructions. This provides hands-free operation and high accessibility for users with mobility impairments.

4. Experimental Results And Analysis

The MOKO prototype underwent rigorous testing in indoor settings to validate its multi-mode stability. Several parameters, including sensor accuracy, communication latency, and battery life, were monitored.

5. Sensing and Navigation Accuracy

The ultrasonic sensors demonstrated a 95% accuracy rate in detecting solid obstacles within a 2-meter range. Testing showed that soft materials (like curtains) slightly reduced detection accuracy due to sound absorption. However, the system successfully avoided 100% of hard obstacles during a 30-minute autonomous trial run.

6. Communication Performance

Wireless signal integrity was tested in a standard laboratory environment. The HC-05 module maintained a stable connection up to 12 meters in open space. Latency was measured at approximately 50ms, which is well within the acceptable limit for real-time manual control. Voice command recognition had a slight delay of 500ms due to the speech-to-text processing on the smartphone side.

Table 2: Performance Metrics Summary

Parameter	Value/Result	Stability
Detection Range	2cm - 200cm	High
Bluetooth Range	Up to 10 Meters	Stable
Voice Recognition	92% Accuracy	Moderate (Noise Sensitive)
Response Time	< 60ms	High

VI. APPLICATIONS AND IMPACT

The developed multi-mode robot serves as a versatile platform with several real-world applications. In the educational sector, it provides a hands-on learning tool for students to explore embedded systems, C programming, and sensor fusion. In domestic assistance, the robot can be adapted for simple tasks like carrying items or patrolling rooms.



Furthermore, the surveillance capabilities can be expanded by mounting a wireless camera. The ability to switch between autonomous patrol and manual investigation makes it highly effective for security in large indoor spaces. The low cost of the components ensures that such technology is accessible to a broader demographic.

VII. CONCLUSION

The MOKO project successfully demonstrates a functional integration of autonomous and manual control schemes. By utilizing affordable components and modular programming, the platform achieves a high level of accessibility. The research proves that hybrid robotic frameworks significantly outperform single-mode systems in terms of adaptability and user interaction. The project successfully met all design objectives, including reliable sensing, low-latency control, and stable wireless communication.

VIII. FUTURE SCOPE

Future iterations of the MOKO platform will focus on enhancing intelligence and connectivity. Key areas of development include:

- Vision-Based Processing: Integrating a camera module for object recognition and facial tracking.
- IoT Connectivity: Using Wi-Fi modules (like ESP8266) to enable remote monitoring and control over the internet.
- Edge Computing: Implementing lightweight machine learning models for more complex decision-making on the edge.

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