Wireless Embedded Robotic Tank for Hazardous Environments

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Abstract

The design and development of a Wireless Robotic Tank utilizing RF communication is detailed, with a focus on applications such as remote surveillance, obstacle detection, and targeting. The system is cantered around the Arduino UNO microcontroller, serving as the primary control unit. ZigBee modules are employed to establish stable and long-range wireless communication between the transmitter and receiver. For real-time obstacle detection, the tank integrates an ultrasonic sensor, with the sensed data shown on an LCD screen connected through an I2C interface for efficient monitoring. Mobility is achieved using two DC motors managed by an L298N motor driver (M1 and M2), while a servo motor mounted on the chassis facilitates the rotation of a laser pointer, useful for indicating direction or targets. The transmitter module includes an Arduino UNO, ZigBee module, push buttons, and an LCD with an I2C module, enabling remote control functionality. This robotic tank is particularly beneficial in hazardous or hard-to-reach locations, such as disaster zones, military areas, or during search and rescue missions.

Keywords: ZigBee, L298N Motor Driver, Servo Motor, Arduino UNO

1. Introduction

Embedded systems have significantly transformed the landscape of modern automation, robotics, and remote control by enabling the creation of compact, intelligent, and responsive devices. These systems combine both hardware and software to perform specific tasks within a broader application, particularly excelling in environments that require high reliability, real-time operation, and energy efficiency. The project focuses on a wireless robotic tank driven by an embedded system architecture, featuring RF communication via ZigBee modules to facilitate two-way data exchange between a handheld transmitter and a mobile robotic receiver. The architecture is built around two Arduino Uno microcontrollers, functioning as the central processing units for both control and response operations.

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The transmitter setup includes push buttons for directional input, a ZigBee module for wireless transmission, and an LCD with an I2C interface for displaying real-time feedback, all housed within a user-friendly compact control unit. On the receiving end, the robotic platform integrates several embedded components: a ZigBee receiver, an L298N motor driver to control DC motor-based mobility, a servo motor combined with an ultrasonic sensor for obstacle detection and distance sensing, and a laser module for targeting or simulation purposes. An additional LCD with an I2C interface presents continuous feedback on sensor data and movement status.

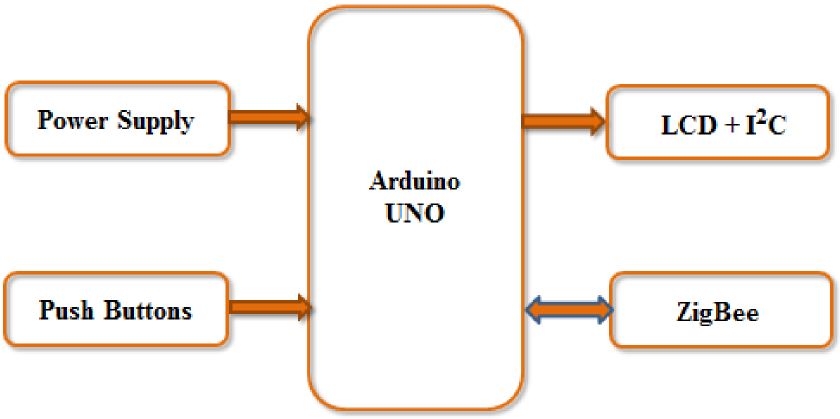

Figure 1: Block diagram of Transmitter section

Figure 2: Block diagram of Receiver section

This integrated system showcases the strength of embedded systems in robotic applications by merging sensor input, actuator output, and wireless communication into a cohesive and efficient design. The implementation of ZigBee ensures reliable, low-power communication, making the system highly applicable to fields like surveillance, military simulation, disaster response, and remote monitoring in hazardous or unreachable locations.

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Through the co-design of hardware and software, the project illustrates how embedded technologies can lead to intelligent, task-specific machines that enhance control, automation, and operational safety.

2. Embedded System

Embedded systems are essential to modern automation and intelligent device design, enabling compact, real-time, task-specific solutions. These systems combine microcontrollers, software, and peripheral interfaces to perform dedicated functions efficiently.

In the wireless robotic tank project, Arduino Uno microcontrollers serve as the core processing units for both transmitter and receiver. The transmitter setup includes push buttons for input, a ZigBee module for RF communication, and an LCD with I2C for real-time feedback, forming an intuitive control interface. On the receiver side, the embedded system interprets incoming commands via a ZigBee module and controls the tank's movement through an L298N motor driver. A servo-mounted ultrasonic sensor enables real-time obstacle detection, while a laser module can simulate targeting. A secondary LCD displays system and sensor data.

This design ensures precise, real-time control and coordination between the user and the robotic platform. With features like low power usage, modularity, and wireless capability, the system is well-suited for applications such as surveillance, remote inspection, and security operations.

3. Robotic Tank

A Wireless Robotic Tank using RF communication represents an effective integration of embedded systems and wireless technologies, designed for remote control and intelligent mobility. It brings together key components—microcontrollers, sensors, actuators, communication modules, and display interfaces—to build a responsive vehicle suited for controlled environments. Common applications include surveillance, military training, hazardous area monitoring, and educational robotics.

The system is structured into two primary units: the Transmitter (Control) Unit and the Receiver (Tank) Unit. The transmitter unit features an Arduino Uno microcontroller, push buttons for command input, a ZigBee module for RF communication, and an LCD with an

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I2C interface for displaying system status. This setup allows users to wirelessly control the tank's movement and functions such as activating a laser pointer, providing a simple and portable interface.

On the receiver side, another Arduino Uno acts as the central processor, receiving commands through a ZigBee module. The L298N motor driver controls the tank's DC motors for directional movement, while an ultrasonic sensor mounted on a servo motor scans for obstacles, enabling collision avoidance. Additional components, such as a laser module, can be triggered remotely. A second LCD with an I2C interface provides real-time feedback on sensor data and system responses.

Operating entirely offline using ZigBee for RF communication, the system offers reliable, low-latency performance without the need for internet connectivity. It highlights the capability of embedded systems to integrate sensing, control, and communication in a compact and modular form. The design supports easy upgrades or customization with new components.

Offering a cost-effective and scalable platform, the wireless robotic tank serves as a practical example of embedded system applications in areas demanding mobility, autonomy, and remote access. It reinforces essential embedded concepts such as real-time control, data processing, wireless interfacing, and system integration, making it suitable for academic, industrial, and defense-related projects.

4. Existing System

In the evolving domain of robotics and remote control systems, various solutions have been introduced to enable the wireless operation of robotic vehicles across different communication technologies. These systems find widespread use in areas such as military surveillance, disaster response, search and rescue missions, and educational applications.

Initially, robotic platforms relied on wired control methods, which, although stable in signal transmission, significantly restricted the robot's mobility and range. Such setups proved unsuitable for real-time or field operations, particularly in dangerous or unpredictable environments.

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Basic RF-controlled robots typically employ conventional RF modules like 433 MHz or 315 MHz, combined with simple encoder-decoder circuits to enable manual control through push-button remotes. However, these systems come with notable limitations:

- Short communication range (usually 10–50 meters)
- Lack of feedback (unidirectional communication)
- No sensor support (manual operation only)
- Absence of obstacle detection and autonomous navigation capabilities

5. Proposed Method

The wireless robotic tank system utilizing RF communication is designed with two primary sections: the transmitter and the receiver, each equipped with dedicated components to enable effective wireless control.

The transmitter unit features an Arduino UNO as the main controller. It includes five push buttons assigned to specific movement commands—forward, backward, left, right, and stop. When a button is pressed, the corresponding command is transmitted via a ZigBee module. An LCD with an I2C interface is connected to provide real-time visual feedback, displaying the active command to the user.

On the receiver side, a second Arduino UNO interprets the incoming signals from the ZigBee receiver. These commands are used to control the robotic tank's movement through an L298N motor driver, which operates the DC motors for directional motion. A servo motor is used to adjust the orientation of a laser module for pointing or marking. To enable obstacle detection, an ultrasonic sensor is included to measure distances and help prevent collisions. An LCD with an I2C interface on the receiver side displays sensor data and system updates.

This configuration enables reliable wireless communication between the user and the robotic tank, combining RF-based control with enhanced functionality through sensors and display modules.

6. Software Employed

In the Wireless Robotic Tank project using RF communication, the Arduino IDE is the main development environment for programming the Arduino Uno microcontrollers that

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control both the transmitter and receiver units. The software is developed using Embedded C, focusing on real-time processing, sensor data handling, motor control, and serial communication. The Arduino IDE supports writing, compiling, and uploading code to the microcontrollers, with access to essential hardware libraries and tools for serial debugging. Key programming tasks include configuring I/O pins, generating PWM signals for servo motors, and managing serial data exchange through ZigBee modules.

Several libraries enhance system functionality. *SoftwareSerial.h* enables serial communication with the ZigBee module via digital pins, freeing the main serial port for debugging. *LiquidCrystal_I2C.h* simplifies communication with a 16x2 LCD using the I2C protocol, used for displaying commands and sensor data. *Servo.h* manages the servo motor that rotates the ultrasonic sensor for dynamic obstacle detection. Libraries like *NewPing.h* or *Ultrasonic.h* are used for accurate distance measurement.

ZigBee configuration involves setting up modules (typically XBee) through tools like XCTU, where parameters such as PAN ID, source/destination addresses, baud rate, and channel are defined. One module is set as the transmitter (Coordinator) and the other as the receiver (Router or End Device), establishing a reliable wireless link for data transmission.

7. Results and Discussions

The setup of the wireless robotic tank begins with assembling key components onto a sturdy chassis. These include the Arduino Uno, L298N motor driver, RF communication module (such as ZigBee or nRF24L01), ultrasonic sensor, servo motor, and a reliable power supply. The Arduino is securely fixed, and components are interconnected using a custom PCB or breadboard for organized wiring. The motor driver connects to both the Arduino and DC motors, enabling precise movement control of the tank tracks.

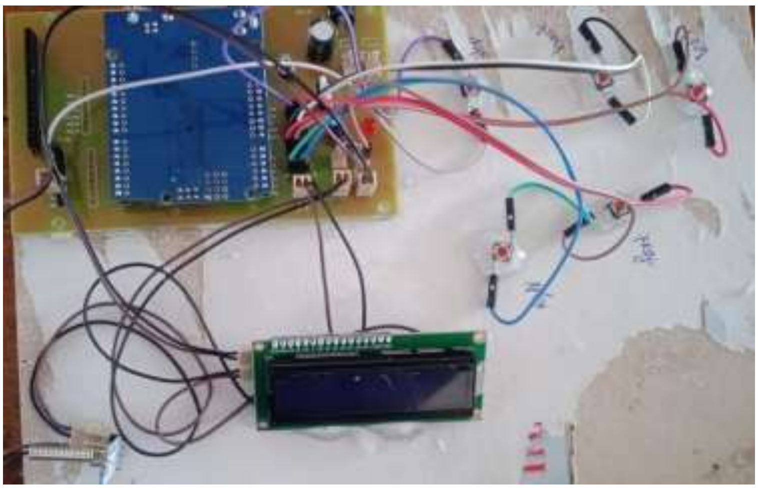

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Figure 3: Experimental Setup

The RF module is connected to specified digital pins on the Arduino. If ZigBee is used, the SoftwareSerial library facilitates communication. The ultrasonic sensor is placed on a servo motor at the front, allowing it to rotate and provide distance readings for obstacle detection. Power is supplied through a battery pack regulated to maintain stable voltage levels.

Before operation, the control code is uploaded to the Arduino using the Arduino IDE via USB. This code handles movement logic, obstacle detection, and RF data communication. A separate transmitter unit—comprising another Arduino with buttons or a joystick—sends commands wirelessly to the receiver. After completing the hardware setup and uploading the software, the system is powered on. The robotic tank receives commands wirelessly and moves accordingly—forward, backward, left, or right. Real-time distance data from the ultrasonic sensor is shown on an LCD using the LiquidCrystal_I2C library. The rotating servo motor allows the sensor to scan in multiple directions, enhancing obstacle detection and navigation.

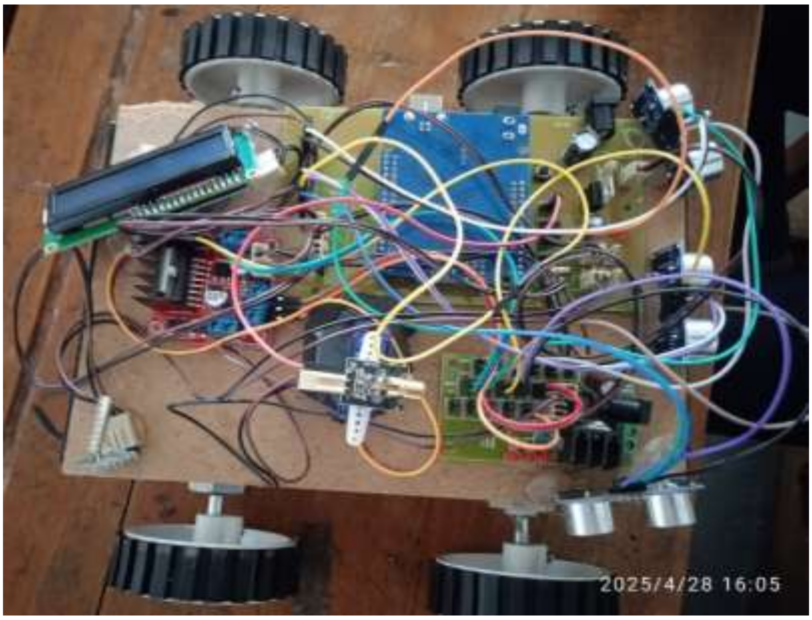

Figure 4: Experimental Setup

In the wireless robotic tank system using RF communication, directional commands—such as "forward," "backward," "left," or "right"—are input through a handheld transmitter

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unit equipped with buttons or a joystick, typically interfaced with an Arduino board. When a button is pressed, the transmitter sends a corresponding signal via the RF module (e.g., Zigbee or nRF24L01). These signals are received by the RF module on the robotic tank, which is connected to an Arduino Uno.

Upon receiving the signal, the Arduino interprets the command and triggers the motor driver to actuate the tank's motors accordingly. For example, a "forward" command powers both motors in the same direction, while a "left" or "right" command powers only one motor or runs them in opposite directions to pivot the tank. Additionally, commands for obstacle scanning can trigger the servo motor to rotate the ultrasonic sensor, enabling environmental analysis and basic path planning.

Figure 5: Giving Commands For Receiver

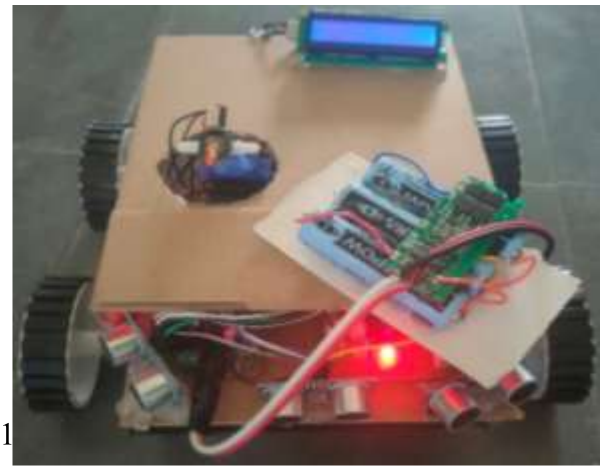

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Figure 6: Experimental Result

This setup effectively demonstrates remote control of a robotic system through wireless communication. The system allows the user to operate the robotic tank from a distance without physical contact, highlighting the potential for remote surveillance, search-and-rescue applications, or educational robotics. The reliability and responsiveness of the RF communication ensure that the robotic tank can be controlled in real time, making it an efficient and practical wireless solution.

Figure 7: Displaying the Distance

7. Conclusion

The wireless robotic tank system using RF communication effectively integrates embedded systems with wireless technology for remote-controlled robotic operations. It demonstrates how RF modules like Zigbee enable reliable communication between a handheld transmitter and a mobile platform, allowing real-time command execution and obstacle detection through an ultrasonic sensor mounted on a servo motor.

While limitations such as limited range and RF interference exist, the system performed well in testing, accurately responding to inputs and navigating with basic autonomy. The project highlights the potential of wireless control for applications like surveillance, rescue missions, and robotics education.

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Future improvements may include adding GPS for navigation, camera modules for video streaming, or AI for semi-autonomous functions. Overall, the system presents a scalable and practical approach to mobile robotic design, focusing on mobility, adaptability, and ease of implementation..

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