Mobile Controlled Smart Robot

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ABSTRACT

This project presents the comprehensive design and development of a Mobile Controlled Smart Robot, specifically engineered to assist users in navigating and acquiring information within large, complex, and dynamic environments such as educational campuses, museums, hospitals, exhibitions, corporate buildings, and other public spaces. The robot is envisioned as a multi-functional assistant that not only helps in orientation and movement through these spaces but also disseminates location-specific information in an interactive and user-friendly manner.At the core of this intelligent system lies the integration of RFID (Radio Frequency Identification) technology, which enables the robot to recognize and interact with strategically placed RFID tags positioned at key locations throughout the environment. These tags are placed at significant points of interest such as departmental laboratories in academic institutions, gallery sections in museums, specialized wards in hospitals, stalls in exhibitions, and service points in corporate buildings. When the robot approaches any of these RFID tags, the RFID reader embedded within the robot scans the unique identifier associated with that tag. This triggers a dual-response system: a pre-programmed informational message is displayed on the robot's onboard screen, and a corresponding voice message is played through an audio output system. This dual-modality ensures that users receive clear and accessible information, catering to both visual and auditory preferences.

The robot's hardware architecture is built around a robust microcontroller platform (Arduino Uno), integrated with essential modules such as the RFID reader, Bluetooth module for wireless control, digital display for real-time information output, and a speaker system for audio guidance. To ensure stable and efficient operation, the robot is also equipped with a buck converter for regulated power supply, a ventilation fan for thermal management, and a high-capacity rechargeable battery for extended field use. The system is designed to be compact, mobile, and durable, making it suitable for various indoor terrains.Control and interaction with the robot are facilitated through a custom-designed mobile application, which provides an intuitive interface for real-time directional control. Users can navigate the robot effortlessly using this application, allowing for manual exploration and engagement with the environment. This design gives users full autonomy over the robot's path, enhancing interactivity and engagement, while ensuring that each location visited provides meaningful, context-specific information.

INTRODUCTION

In today's rapidly evolving world, the demand for intelligent, interactive, and user-friendly robotic systems is steadily increasing across a wide range of domains. With significant strides in embedded systems, wireless communication, sensor integration, and microcontroller-based development, robots are no longer confined to traditional industrial or academic research settings. Instead, they are becoming increasingly prevalent in public environments such as educational campuses, museums, hospitals, exhibitions, corporate premises, and other large-scale infrastructures. These intelligent systems play a crucial role in enhancing user experience, offering real-time guidance, and improving accessibility for visitors, especially in unfamiliar or complex locations.

The Mobile Controlled Smart Robot developed in this project is a tangible and practical solution tailored to address the prevalent challenges of navigation, information dissemination, and user engagement in such environments. It offers an innovative blend of manual control and automated feedback, making it uniquely capable of interacting with its surroundings in a meaningful way. Unlike fully autonomous robots that rely on complicated pre-programmed paths, GPS, or advanced AI algorithms for movement and decision-making, this robot adopts a more user-centric approach—operated entirely through a Bluetooth-enabled smartphone application. This allows users to manually control the robot's movement, making it both intuitive and flexible for real-time exploration.

One of the most distinctive features of this robotic system is the seamless integration of RFID (Radio Frequency Identification) technology. This technology enables the robot to detect and interpret RFID tags strategically placed at various important checkpoints or locations within the environment. These tags are mapped to specific IDs, and when an RFID tag is scanned by the robot's RFID reader, it automatically triggers a response—displaying relevant text-based information on an onboard screen and playing a personalized, pre-recorded voice message. Notably, the audio output has been crafted using the real voices of the development team members, which adds a layer of personalization and warmth to the overall user experience. This dual-modality feedback—visual and auditory—not only makes the system inclusive but also enhances its effectiveness in engaging a diverse audience, including individuals with visual or hearing impairments.

The robot has a wide scope of application, making it a versatile tool in various scenarios. For instance, in universities and colleges, the robot can guide new students and visitors during orientation programs or open-house events. In museums, it can provide dynamic, audio-visual content about historical artifacts and artworks. In hospitals, it can assist in navigating patients or visitors to specific departments or service counters. In corporate settings, the robot can serve as an interactive assistant during events, exhibitions, or guided tours.

To ensure feasibility and cost-effectiveness, the robot has been developed using easily available and affordable hardware components, including the Arduino Uno microcontroller, RFID reader module, Bluetooth module (HC-05), display unit (LCD or OLED screen), audio output system (speakers or buzzer), buck converter for voltage regulation, ventilation fan for cooling, and a reliable battery backup system for uninterrupted operation. The modular architecture of the system ensures ease of assembly, maintenance, and replication, making it suitable for educational projects, proof-of-concept demonstrations, and community deployments.

Furthermore, the mobile-controlled navigation removes the dependence on complex and resource-heavy autonomous pathfinding algorithms, thereby reducing system complexity and increasing ease of use. This makes the robot accessible to non-technical users as well, empowering a broader group of stakeholders—including students, educators, and event organizers—to interact with and benefit from the system.

Looking ahead, the project offers tremendous potential for scalability and future enhancement. Some of the proposed upgrades include:

- Integration of voice recognition to enable hands-free operation using simple voice commands.
- AI-powered navigation suggestions, which could recommend optimized paths based on user preferences, crowd analysis, or real-time data.
- IoT connectivity, allowing remote access, monitoring, diagnostics, and dynamic updates to the robot’s informational content.
- Multi-language support, which would further increase inclusivity and make the robot accessible to users from different linguistic backgrounds.
- Gesture-based control systems or touchless interaction modules, especially useful in healthcare or sterile environments.

Therefore, the Mobile Controlled Smart Robot exemplifies a highly adaptable, engaging, and practical implementation of modern robotics in public environments. By combining manual navigation, RFID-triggered content delivery, and multi-sensory output, it not only addresses real-world navigation and information challenges but also demonstrates the power of affordable, modular, and user-friendly robotic systems in enhancing public interaction and user satisfaction. This project serves as a foundational prototype for future smart robotic assistants that can be deployed in diverse real-life scenarios, paving the way for more inclusive, responsive, and intelligent public service technologies.

LITERATURE REVIEW

Number of studies and researches have been accomplished related to robot controlling through speech and recognition and smart devices. The following presents some of these researches. Yokoma et al. (2003) developed a humanoid robot named "HRP-2P" that demonstrated capability of working hand-to-hand with human operators in construction work. While the robotic arm developed by Haloda and Pelc (2008) is based on formal research, this research involved a voice-controlled dialogue system, speech recognition and vocabulary design, and speech synthesis feedback for user command confirmation.

Together with a scene manager and a digital image processing module, it formed the core of the control system. Winter (2013) has developed a low-cost and open-source philosophy Android-controlled mobile robot. Horlodo & Pelc (2008), together, has proposed a robotic system attached with a wireless camera for the purpose of surveillance via. Bluetooth technology. Guardi (2014) has proposed a design of Bluetooth technology. Android applications for microcontrollers drive on robots. The main objective of this research is to show that a single Android application is capable of working with different electronic devices, typically used within the hobby and amateur robotic field.

A significant amount of research has been dedicated to improving the design, functionality, and control systems of robots. Various studies emphasize the integration of sensor networks for real-time environmental interaction, such as the work by M. Mataric (2002), which highlighted the role of sensors in enhancing autonomous robot navigation and interaction with dynamic surroundings. In recent years, mobile-based control systems have gained prominence. S. Jain et al. (2016) discussed how mobile applications, such as Blynk and NodeMCU, enable remote control of robotic systems, offering users greater flexibility and real-time control from handheld devices.

Finally, the role of integrated sensors in robotics, as highlighted by J. McClain and A. Chen (2017), is crucial for enhancing the robot's ability to perceive and respond to its environment.

METHODOLOGY

The following figure 1 illustrates the circuit diagram of Mobile Controlled Robot. The circuit diagram showcases the complete hardware architecture of the Mobile Controlled Smart Robot, integrating two microcontrollers, output devices, and power regulation modules. The design facilitates wireless, mobile-based manual control of the robot, along with RFID-based location identification and informative user feedback.

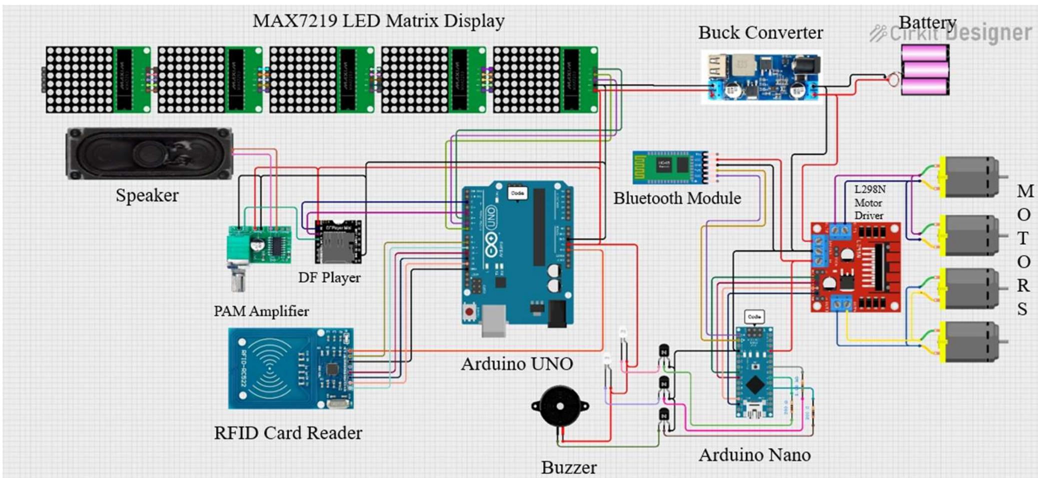


Fig 1:- Circuit Diagram of Mobile Controlled Smart Robot

Power Supply Unit:

The system draws power from a rechargeable battery pack, connected via a buck converter. This converter regulates the input voltage to a stable level suitable for all modules, ensuring safe and reliable operation across the circuit.

Microcontroller Units:

- The Arduino UNO serves as the central processing unit for the display, RFID reader, audio output, and user interface components.
- The Arduino Nano manages robot mobility, receiving commands via a Bluetooth module and translating them into directional motor actions.

Motion Control Section:

The robot's movement is controlled by the L298N Motor Driver Module, which is connected to four DC gear motors. These motors enable forward, backward, and turning movements. The driver receives PWM signals from the Arduino Nano, which interprets control inputs received wirelessly from a smartphone through a connected Bluetooth Module. This setup enables smooth, real-time remote navigation of the robot.

RFID Location Detection:

An RFID Card Reader (RC522**)** is interfaced with the Arduino UNO. As the robot is manually driven around a facility, it scans nearby RFID tags. Each tag corresponds to a specific location, such as a lab, room, or section within a campus, museum, or hospital. Upon successful scanning, the UNO processes the unique tag ID.

LED Matrix Display System:

To visually communicate the detected location, the system incorporates a MAX7219-based LED Matrix Display. Controlled by the UNO, the display shows the name or code of the detected location, providing immediate feedback to the user or bystanders.

Audio Feedback Mechanism:

The project features a DF Player Mini connected to a PAM Amplifier and speaker setup. When an RFID tag is identified, a corresponding pre-recorded voice message is played. This feature adds an auditory layer of interaction, making the robot suitable for public guidance tasks or educational purposes.

HARDWARE COMPONENTS

It includes Arduino UNO, Arduino Nano, Bluetooth Module (HC-05), L298N Motor Driver, DC Motors, MAX7219 LED Matrix Display, RFID Reader (RC522), DF Player Mini, PAM8403 Audio Amplifier, Speaker, Buzzer, Buck Converter, Rechargeable Battery, Connecting Wires.

3.2.1 Arduino Uno:

The Arduino UNO is a popular open-source microcontroller board based on the ATmega328P microcontroller. It operates at a clock speed of 16 MHz, features 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a USB interface, a power jack, an ICSP header, and a reset button. It can be powered either via USB or an external power supply ranging from 7V to 12V, making it highly flexible for embedded applications.

In this project, the Arduino UNO functions as the brain of the system that handles all RFID-based operations. It reads input from the RFID Card Reader (RC522), which detects the presence of RFID tags. Once a tag is scanned, the UNO processes the unique ID and identifies the corresponding lab or destination. Based on this data, it sends output to the MAX7219 LED Matrix Display, visually guiding users with the lab name or directional cues.

Simultaneously, the Arduino UNO controls the DF Player to play pre-recorded audio using a PAM amplifier and speaker, giving users clear audio feedback in the form of navigation instructions or welcome messages. The code stored in the UNO's 32 KB flash memory ensures that all these interactions are smooth, timely, and synchronized.

By coordinating visual, audio, and alert-based responses, the Arduino UNO plays a crucial role in managing user interaction, accessibility, and efficient lab navigation, making it an essential component of this smart robotic system.Arduino UNO serves as the primary microcontroller in our project, managing RFID-based identification, audio output, and display systems.

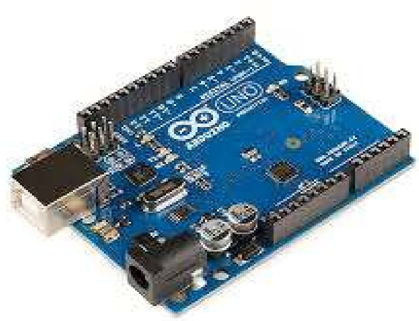


Fig 2: Arduino Uno

3.2.2: Arduino Nano

The Arduino Nano is a compact, breadboard-friendly microcontroller based on the ATmega328P, ideal for space-constrained embedded systems. Operating at 5V with a 16 MHz clock speed, it offers 14 digital I/O pins, 8 analog inputs, PWM support, and 32 KB Flash memory.In this project, it handles robot movement control. Paired with a Bluetooth module, it receives commands from a smartphone and sends signals to the L298N motor driver for motion.

Fig 3:- Arduino Nano

3.2.3 DC Motor:

The 12V High Torque DC Motor is a crucial component in the Device-Controlled Smart Robot, providing the necessary power and performance for efficient movement and operation. Designed to deliver high torque at relatively low speeds, this motor enables the robot to navigate various terrains and handle demanding tasks with ease. The 12V power supply ensures that the motor operates efficiently while maintaining optimal performance levels, making it suitable for applications requiring strong and reliable motion.

Fig 4:- DC Motor

3.2.4 Wheels:

Wheels used in Mobile Controlled Smart Robot are typically designed for traction, stability, and smooth movement. They come in various sizes and materials, such as rubber or plastic, depending on the terrain and application. The wheels are attached to motors, allowing the robot to move forward, backward, and turn. Additionally, some wheels may feature built-in encoders for precise control and navigation.

Fig 5:- Wheels

3.2.5 L298N Motor Driver :

The L298N Motor Driver is a dual H-Bridge motor driver IC commonly used to control the direction and speed of DC motors and stepper motors. It can drive two motors simultaneously, making it ideal for robotic applications where precise control of movement is needed.In this project, the L298N is connected to the Arduino Nano, receiving directional signals based on Bluetooth commands from a smartphone. It then drives the two high-torque motors used in the mobile robot, enabling forward, backward, left, and right motion. The module also allows for PWM speed control, giving smooth and adjustable movement.

Fig 6:- L298N Motor Driver

3.2.6 Bluetooth Module:

The Bluetooth module in the Device-Controlled Smart Robot plays a critical role in enabling wireless communication between the robot and external devices, such as smartphones or tablets. This module allows users to remotely control the robot through mobile applications, providing real-time feedback and interaction. By using a Bluetooth module, such as the HC-05 or HC-06, the system offers a convenient and cost-effective method for wireless control, without requiring complex network setups. The module operates within a range of approximately 10 meters, ensuring reliable connectivity for tasks in both domestic and industrial environments.

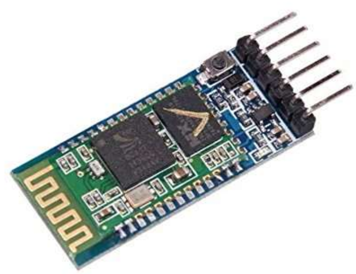


Fig 7:- Bluetooth Module

3.2.7 MAX7219 LED Matrix Display :

The MAX7219 LED Matrix Display is an efficient and compact solution for controlling an 8x8 LED matrix using just a few microcontroller pins through a serial communication protocol. It simplifies the process of displaying characters, numbers, and basic graphics by handling all the multiplexing, decoding, and LED driving internally.In this project, the MAX7219 is interfaced with the Arduino UNO and is used to display useful information such as lab names and room numbers. This helps observers or users easily understand the robot’s current location or action visually.

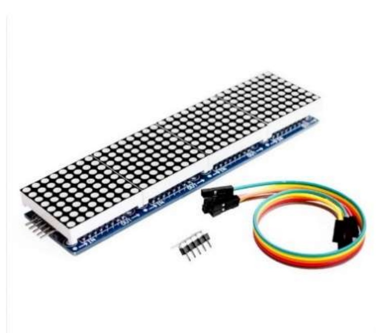


Fig 8:- MAX7219 LED Matrix Display

3.2.8 RFID :

The RFID (Radio Frequency Identification) system in the Device-Controlled Smart Robot enhances its capabilities by enabling wireless identification and tracking of objects or users within its environment. Utilizing RFID tags and a reader module, this technology allows the robot to read unique identifiers, facilitating tasks such as automated inventory management, access control, or object recognition. Integrated with the Arduino Uno, the RFID reader processes data from the tags, enabling the robot to perform specific actions based on the scanned information, such as navigating to predefined locations or executing related tasks.

Fig 9 :- RFID

3.2.9 DF Player Mini:

The DFPlayer Mini is a compact and low-cost MP3 audio player module capable of playing audio files stored on a microSD card. It supports popular audio formats such as MP3 and WAV and features an onboard amplifier, making it suitable for standalone audio playback or integration with microcontroller-based systems.In this project, the DFPlayer Mini is connected to the Arduino UNO and is used to deliver audio-based lab announcements or guidance as the robot navigates through different locations. It helps make the robot more interactive and accessible, especially in environments like large campuses, museums, or hospitals where clear voice instructions are helpful.

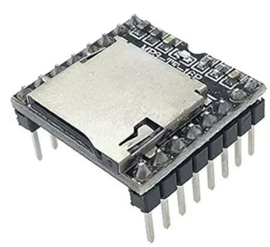


Fig 10:- DF Player Mini

3.2.10 SD CARD:

The 64 GB microSD Card is a high-capacity, non-volatile memory storage device used for storing large volumes of digital data. In this project, it is inserted into the DFPlayer Mini module and holds various pre-recorded audio files, such as lab names, directional instructions, and welcome messages.Its ample storage space allows the system to store hundreds of MP3 or WAV files, enabling the robot to support multiple zones or departments within a large area like a campus or hospital. The card is formatted typically in FAT32 or exFAT file systems and provides fast read access, ensuring smooth and instant playback without delay.

Fig 11:- SD Card

3.2.11 PAM8403 Audio Amplifier:

The PAM8403 is a compact, low-power, and highly efficient class-D audio amplifier module capable of delivering up to 3W output per channel (2×3W) to stereo speakers. It operates on a low voltage range (2.5V to 5.5V) and offers excellent audio quality with minimal distortion, making it ideal for portable and embedded audio applications.In this project, the PAM8403 amplifier is used in conjunction with the DFPlayer Mini to boost audio output and drive a small speaker mounted on the robot. This ensures that voice announcements such as lab names, navigation guidance, or alerts are clearly audible in public spaces like campuses, hospitals, or museums.

Fig 12:- PAM8403 Audio Amplifier

3.2.12 LM2596 DC-DC Buck Converter:

The LM2596 DC-DC Buck Converter is a high-efficiency step-down voltage regulator module used to convert higher DC input voltages to lower, stable output voltages. It is based on the LM2596 switching regulator IC, which supports input voltages from 4V to 40V and delivers an adjustable output in the range of 1.25V to 35V at up to 2A of continuous current.In this project, the LM2596 module plays a critical role in power management, ensuring that different components such as the Arduino Nano, DFPlayer Mini, PAM8403 amplifier, and Bluetooth module receive the correct operating voltage (typically 5V or 3.3V), even when powered from a higher-capacity main battery (like 12V or 15V).

Fig 13:- LM2596 DC-DC Buck Converter

3.2.13 Speaker:

The speaker in this project serves as the audio output device for delivering voice announcements and guidance instructions to users. It is connected to the DFPlayer Mini through the PAM8403 audio amplifier, which boosts the signal strength to produce clear and audible sound.This speaker typically operates at 4Ω impedance and 3W power rating, making it suitable for small embedded systems like mobile-controlled robots. It plays pre-recorded MP3 or WAV files stored on the SD card, such as lab names, directions, or welcome messages.

Fig 13:- Speaker

BLUETOOTH RC CONTROLLER - Mobile Application:

The Bluetooth RC Controller interface shown above is used to wirelessly control the robot via a Bluetooth module (HC-05/HC-06) connected to the Arduino Nano. This Android-based application allows the user to send directional and functional commands to the robot in real time using a simple and intuitive graphical interface.

Key Features:

- Directional Control Pad (Center):
  The eight-arrow control panel in the center allows the user to command the robot to move forward, backward, left, right, and in diagonal directions.
- Speed Control (Top Right):
  A slider bar at the top-right corner enables dynamic adjustment of the robot's speed for precise movement.
- Functional Buttons (Top Row):
  Buttons for various actions like:
  - Start/Stop
  - Light or Indicator toggling
  - Sound (Buzzer/Speaker) activation
  - Settings and Mode selection
- Dual Joystick Control (Right Bottom):
  The large left/right buttons on the right bottom may be used for individual wheel control or advanced movement features like rotation or differential drive.

Application Role in Project:

This app acts as the user interface to control the Arduino Nano, which interprets the received Bluetooth commands and directs the L298N motor driver accordingly.

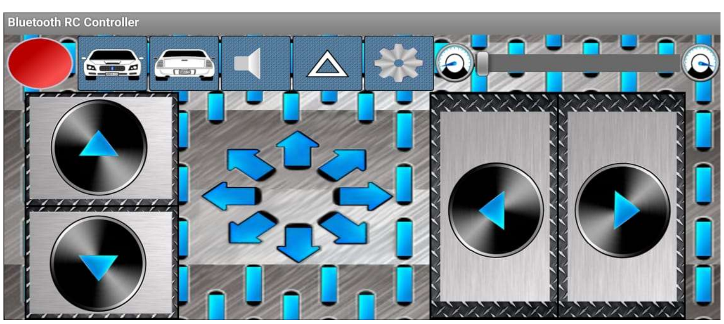


Fig 14:- Bluetooth RC Controller - Mobile Application

FLOW DIAGRAM:

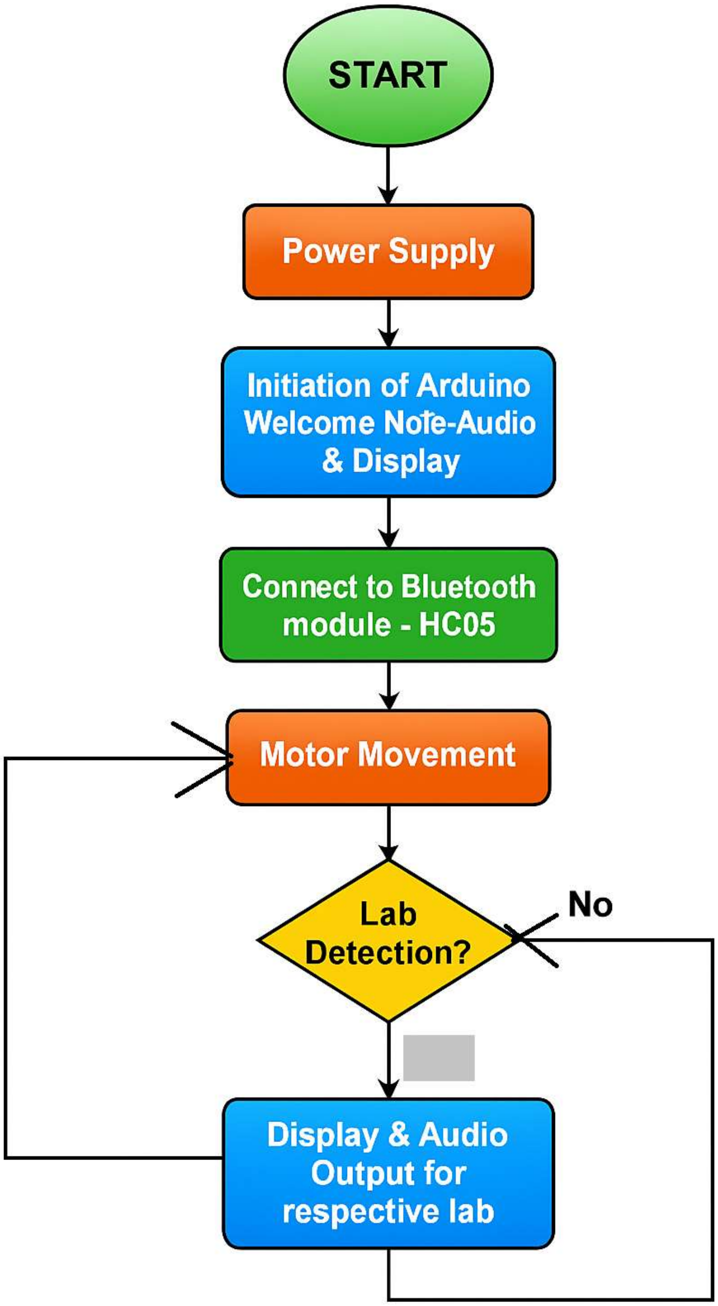
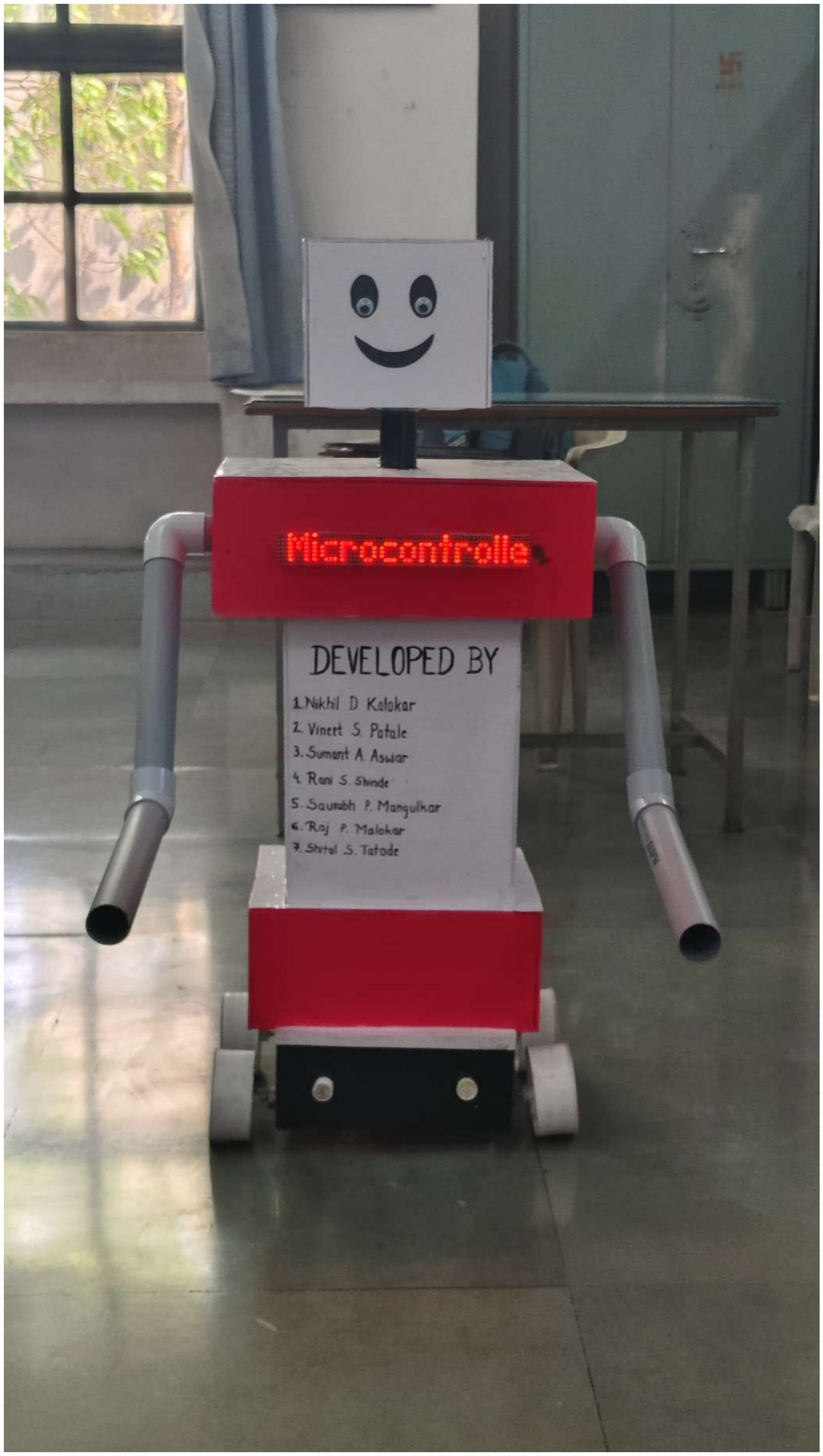


Fig 15: Flow diagram

RESULT:


Microcontrolle
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CONCLUSION

The development of the Bluetooth-controlled smart navigation robot integrated with RFID technology, audio assistance, and LED matrix display marks a significant step toward creating an efficient, interactive, and intelligent indoor navigation system. This project successfully demonstrates how the fusion of manual and autonomous control mechanisms can enhance user experience, particularly in structured environments like educational institutions.The robot's design leverages two microcontrollers—Arduino Uno and Arduino Nano—to manage different operations independently. While the Nano handles precise motor control and Bluetooth communication for manual navigation, the Uno is responsible for logic processing, RFID data handling, audio output, and visual display. This distributed architecture improves system reliability, responsiveness, and modularity.

By recognizing RFID tags placed outside various labs, the robot can automatically identify its current location, play personalized audio messages using pre-recorded team member voices, and simultaneously display the lab name on an LED matrix. This dual-sensory feedback ensures clarity and accessibility, even in noisy or visually restricted environments.

The Bluetooth module offers an additional layer of flexibility, allowing users to manually control the robot via a smartphone app, which is particularly useful during demonstrations or controlled experiments.The power management system, consisting of a Li-ion battery pack and a buck converter, provides a reliable and regulated power supply to all modules. The compact design, along with the use of cost-effective and easily available components, makes this project highly suitable for academic institutions and practical exhibitions.

From an educational perspective, the robot encapsulates multiple core concepts such as embedded systems, wireless communication, automation, real-time processing, and human-machine interaction. It promotes hands-on learning and collaboration while demonstrating real-world applications of classroom theories.

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