IOT-BASED VACUUM CLEANING SYSTEM USING ARDUINO

DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

Name of the Project guide

Mrs. G . SUBAYAMMA, M .Tech, (Ph. D)

Assistant Professor

H. O. D of the Department

Mr. T . JAGADEESH, M. Tech, M. S, (Ph. D)

Associate Professor

PROJECT MEMBERS:

P. LAKSHMI TRIVENI	21NE1A04E9
P. LEELA RAMYA	21NE1A04D3
P. KARUNAKAR	21NE1A04D4
Y. SREEMANNARAYANA REDDY	21NE1A04I9

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ABSTRACT

This project involves the design and development of a manually controlled Internet of Things (IoT)-based Cleaning System using Arduino intended for household and small-area cleaning tasks. The robot is operated using a smartphone via Bluetooth communication (HC-05 module), with an Arduino microcontroller interpreting user commands to control movement in real-time. It utilizes four DC motors, managed by an L298N motor driver, to navigate forward, backward, and in different directions. An ultrasonic sensor mounted on a servo motor scans for obstacles, assisting the user in manual navigation. Additionally, a mini vacuum cleaner mounted on the chassis collects dust and debris during operation. The robot's compact and efficient design makes it suitable for cleaning under furniture and in tight spaces. Built with cost-effective and easily available components, the system serves as a functional prototype for integrating embedded systems and mobile control in home automation applications.

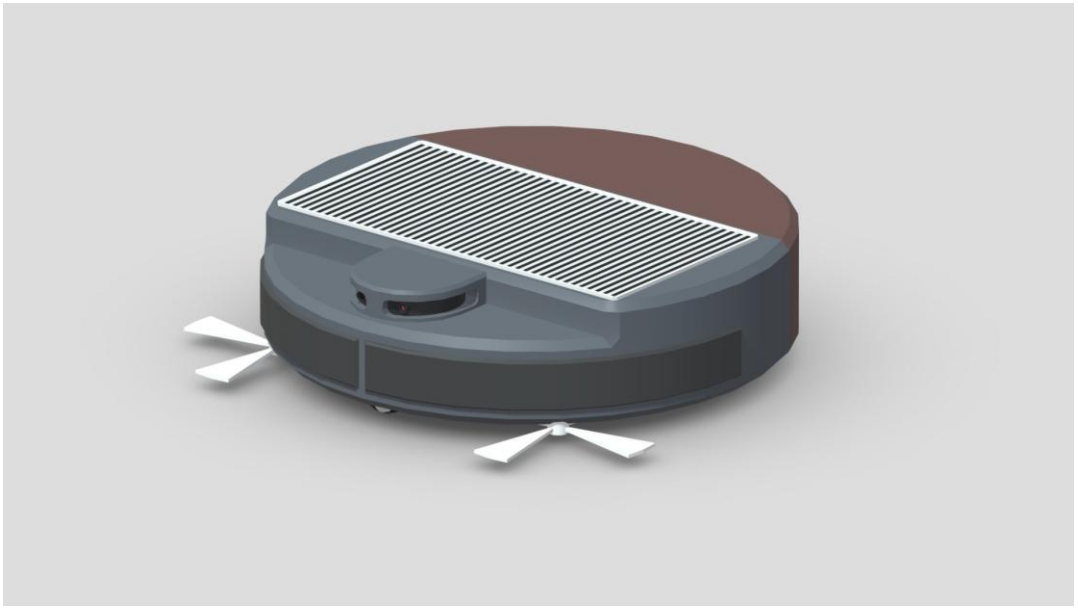
INTRODUCTION

The advent of IoT and automation has transformed daily life, particularly in smart homes. Cleaning robots like Roomba have automated household cleaning, but their high cost and complexity limit accessibility. This project focuses on developing a budget-friendly, manually controlled IoT cleaning robot that offers cleaning support with user-directed control. It utilizes an Arduino board, DC motors, and an L298N motor driver, operated via Bluetooth using a smartphone.

The robot features obstacle detection using an ultrasonic sensor on a servo and a mini vacuum that collects dust and debris in real-time. This project serves as a hands-on learning platform, covering Arduino programming, Bluetooth communication, motor and sensor interfacing, power management, and system integration.

INTRODUCTION (Contd...)

By working on this project, we can gain comprehensive knowledge in embedded systems, IoT, and robotics. It has practical applications, particularly for students and individuals with limited space, and also benefits the elderly and physically challenged users. This project showcases innovation with minimal resources, promotes sustainable and cost-effective engineering solutions, and is open for future upgrades such as mobile app interface, voice control, and internet connectivity.



LITERATURE REVIEW

Ref.no	Author	Title	Journal/Conference	Year of Publication	Methodology
1.	Choudhari & Aditya	A Smart Autonomous and Bluetooth Controlled Floor Cleaner	Journal of Communication Engineering and VLSI Design	2024	Bluetooth-based robot with semi-autonomous cleaning and IR sensors
2.	Mritunjay Kumar, Nikhil, Urmila Maurya	Arduino Based Smart Vacuum Cleaner Robot	IJNRD	2023	Arduino-enabled robot using Wi-Fi and sensors for remote cleaning
3.	Rahayu, E. S., Mardiono,	Design and Implementation of Floor Cleaning Robot Using IoT	IJRCT	2022	Bluetooth-controlled Arduino robot with basic vacuum
4.	Manasa	Smart Robot Cleaning System	Global Transitions Proceedings	2021	Manual control using HC-05 and motor drivers

LITERATURE REVIEW (Contd...)

Sl.no	Author	Title	Journal/Conference	Year of Publication	Methodology
5.	Mothe, Rajesh	An IoT Based Obstacle Avoidance Robot Using Ultrasonic Sensor and Arduino	IJETT	2020	Fully autonomous robot using ultrasonic sensors for navigation
6.	B. Sonia, P. Ganesh	Floor Cleaning Robot with Reconfigurable Mechanism	IJRET	2022	Adjustable hardware platform for variable floor types
7.	Tripathi, S	Cost-Efficient Bluetooth-Controlled Robot Car for Material Handling.	ICCDC	2019	Low-cost robot with Bluetooth control, no cleaning features
8.	Gorade, U.	Design of Bluetooth-Controlled Floor Cleaning Robot	ICRAM	2022	Bluetooth and Arduino-based system with environmental sensors

MOTIVATION

- ✓ The motivation behind developing a manually controlled IoT-based Smart Cleaning Robot stems from both personal and societal observations, combined with academic curiosity and a desire to explore innovative engineering solutions to real-world problems.

- ✓ Cleaning, though a simple and routine task, remains one of the most time-consuming and physically demanding household activities, especially in smaller living spaces or among individuals with limited mobility.

- ✓ This project aims to offer a practical, affordable, and student-friendly alternative to existing solutions, while also serving as a learning platform for key engineering concepts.

ALGORITHM USED

1. Bluetooth Command Interpretation: Receives data via HC-05 and maps to actions (F, B, L, R, S, V, U).

2. Motor Control (PWM): Controls direction & speed of DC motors using L298N and PWM signals.

3. Vacuum Toggle Algorithm: Turns the vacuum motor ON/OFF based on user command (‘V’).

4. Obstacle Scanning (Servo + Ultrasonic): Rotates servo 0°–180°, measures distance at each step using HC-SR04.

5. Distance Measurement: Uses ultrasonic sensor timing to calculate object distance in cm.

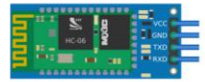
6. Debounce & Delay Handling: Adds delays to avoid repeated/unstable commands from Bluetooth.

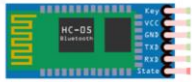
7. Auto Stop on Inactivity: Stops all actions if no command is received for a set time (e.g., 10 sec).

HARDWARE COMPONENTS

- **Arduino UNO R3 (Microcontroller):** Central controller; processes commands, controls all modules. Interfaces: Digital I/O, PWM, Analog, UART

- **HC-05 Bluetooth Module:** Wireless communication with smartphone (manual control). Interface: UART (TX/RX), 9600 baud





- **L298N Motor Driver:** Drives 4 DC motors with directional and speed control. Interface: Digital + PWM from Arduino

- **DC Motors (x4):** Provide movement; arranged in differential drive layout. Powered via motor driver

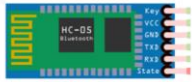
- **Ultrasonic Sensor (HC-SR04):** Measures distance to detect obstacles. Interface: Trigger + Echo pins

HARDWARE COMPONENTS

- **Servo Motor (SG90):** Rotates ultrasonic sensor for scanning. Interface: PWM from Arduino
- **Mini Vacuum Cleaner Module:** Performs cleaning by sucking dust/debris. Controlled via digital pin or relay
- **Power Supply (12V Battery Pack):** Powers all motors and electronics. Includes voltage regulators for 5V components
- **Chassis and Frame:** Holds all components; ensures structural stability
- **Wiring & Breadboard:** Ensures proper interconnections; enables easy debugging








SOFTWARE USED

- **Arduino IDE:** Used for writing, compiling, and uploading code to the Arduino Uno. Supports **C/C++** based syntax for programming microcontrollers. Allows integration of libraries for sensor handling, motor control, and serial communication. Real-time debugging and serial monitoring features help during testing and development.

- **Bluetooth Controller App (Android):** A smartphone application that sends control commands to the HC-05 Bluetooth module. Typically includes directional buttons (Forward, Backward, Left, Right, Stop). Easily available on the Play Store (e.g., “Bluetooth Terminal,” “Bluetooth RC Controller”). User-friendly interface; requires no coding experience from the user.

- **Proteus:** Used for simulating circuits before physical implementation. Helps visualize how components (Arduino, motors, sensors) will behave. Prevents hardware damage by allowing virtual testing of circuits and code.

SOFTWARE USED

- **Fritzing (For Circuit Design):** Used to create breadboard layouts and schematics for documentation and planning. Useful for visually representing how components are connected on a prototype board. Helps in project presentation and sharing circuit diagrams with peers/instructors.

- **Arduino Libraries**
  - Utilized to simplify coding tasks such as:
    - **Servo.h** – for controlling the servo motor with angle precision.
    - **NewPing.h / Ultrasonic.h** – for working with the ultrasonic distance sensor.
    - **SoftwareSerial.h** – for managing serial communication with the Bluetooth module (if needed).
  - Libraries streamline communication and improve code readability.

PROBLEM STATEMENT

- ✓ High costs and complex setup procedures limit the accessibility of autonomous robotic vacuum cleaners.
- ✓ Traditional cleaning methods can be physically demanding or impossible for individuals with disabilities or age-related limitations.
- ✓ A semi-automated or manually controlled robot can fill this gap by providing mechanical benefits without complex navigation algorithms.
- ✓ A low-cost, smartphone-controlled robot with manual navigation can be an effective solution for small-scale environments.
- ✓ The inclusion of an ultrasonic sensor can enhance user awareness and prevent accidental collisions.
- ✓ This design can make cleaning easier and more accessible for a wider audience.

PROPOSED SYSTEM

- **Requirement Analysis:** Identified the need for a low-cost, user-controlled cleaning robot. Focused on affordability, ease of use, modularity, and offline accessibility.
- **System Design:** Created a block diagram outlining all hardware and software components. Defined control flow, data exchange paths, and component interactions.
- **Component Selection**
  - **Arduino Uno**: Chosen for its ease of programming, reliability, and community support.
  - **HC-05 Bluetooth Module**: Enabled stable short-range wireless control via smartphone.
  - **DC Gear Motors + L298N Motor Driver**: Provided controlled mobility with speed regulation.
  - **Ultrasonic Sensor + Servo Motor**: Enabled obstacle detection through rotational scanning.
  - **Mini Vacuum Cleaner Module**: Delivered basic dust collection functionality.
  - **Li-ion Batteries**: Offered compact, rechargeable power supply with sufficient output.
- **Circuit Integration:** Connected all components on a breadboard and later on a custom PCB. Implemented power regulation to ensure stable operation under varying loads.
- **Programming Logic Development:** Used **Arduino IDE (C/C++)** for coding control logic and sensor handling. Implemented Bluetooth command parsing, motor direction logic, PWM for speed, and servo rotation. Included safety measures like delay handling and input debouncing.

PROPOSED SYSTEM (Contd...)

- **Mobile App Interface:** Used ready-made Bluetooth controller apps (e.g., “Bluetooth Electronics”) or a custom app. Mapped smartphone button inputs to robot movements (forward, backward, left, right, stop).
- **Testing and Calibration:** Conducted component-wise testing (motors, vacuum, Bluetooth, sensor). Calibrated ultrasonic sensor rotation and verified real-time distance readings. Ensured responsive behaviour through Bluetooth and accurate motion control.
- **Chassis and Mechanical Setup:** Designed a lightweight, portable frame ensuring vacuum nozzle proximity to the floor. Ensured stability using caster wheels and proper motor alignment.
- **Power Supply Planning:** Used Li-ion batteries with appropriate voltage regulation circuits. Designed to avoid power drops during simultaneous motor and vacuum usage.
- **Modular Design Approach:** Allowed individual modules (motors, sensors, vacuum) to be tested or upgraded independently. Facilitated future feature additions like autonomous navigation or battery monitoring.
- **Scalability and Upgradability**
- Planned for enhancements such as:
  - Voice control, App-based obstacle visualization, Dust sensing, IoT connectivity in future versions
- **Final Integration and Refinement:** Integrated all systems into a single working prototype. Performed multiple real-world tests in different environments (e.g., cluttered rooms). Optimized performance and user experience based on testing results.

PROPOSED SYSTEM (Contd...)

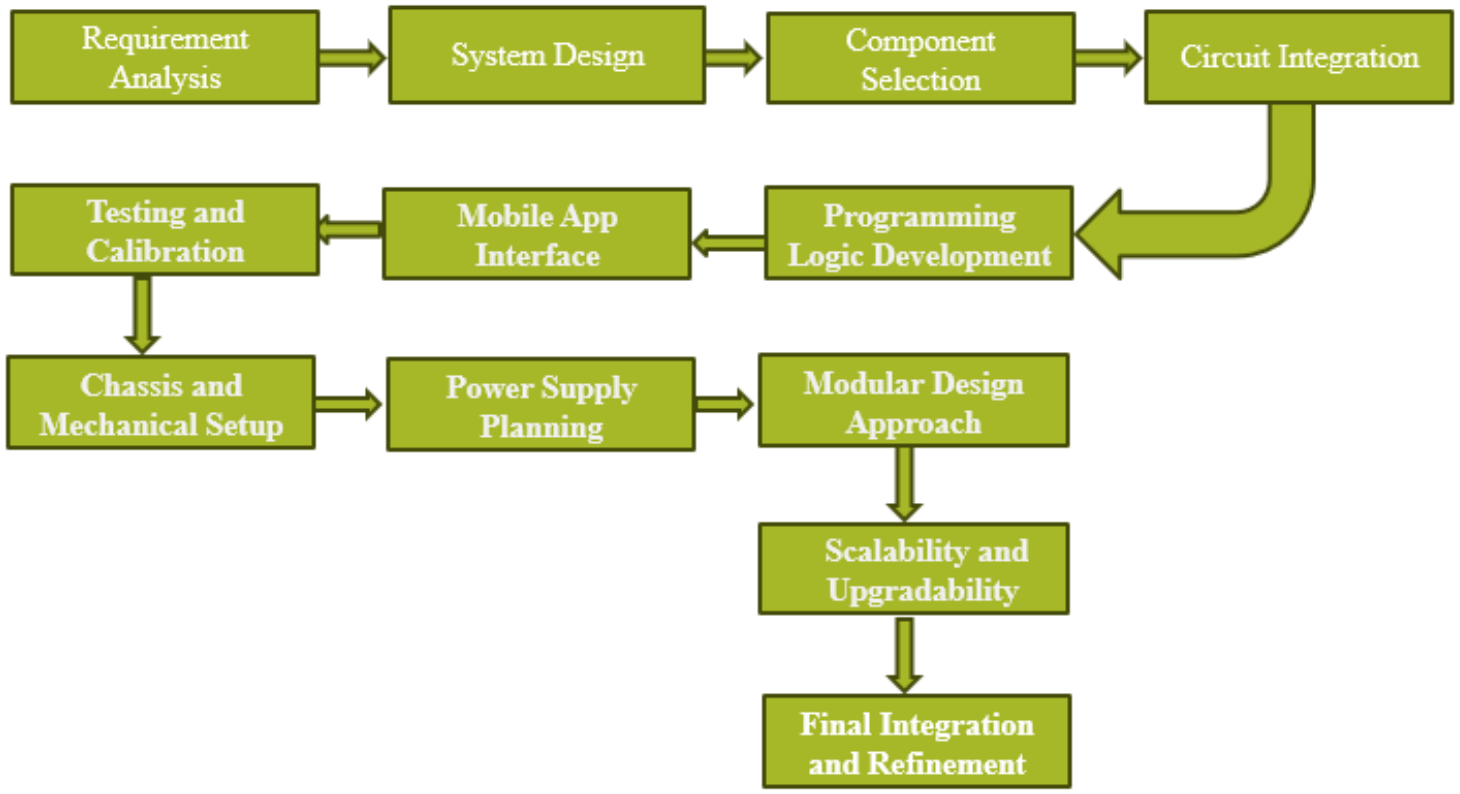


Fig : Proposed System for Smart Vacuum Cleaner

DESIGN AND IMPLEMENTATION

1. Modular System Design: Hierarchical blocks for control, sensing, actuation, and power.

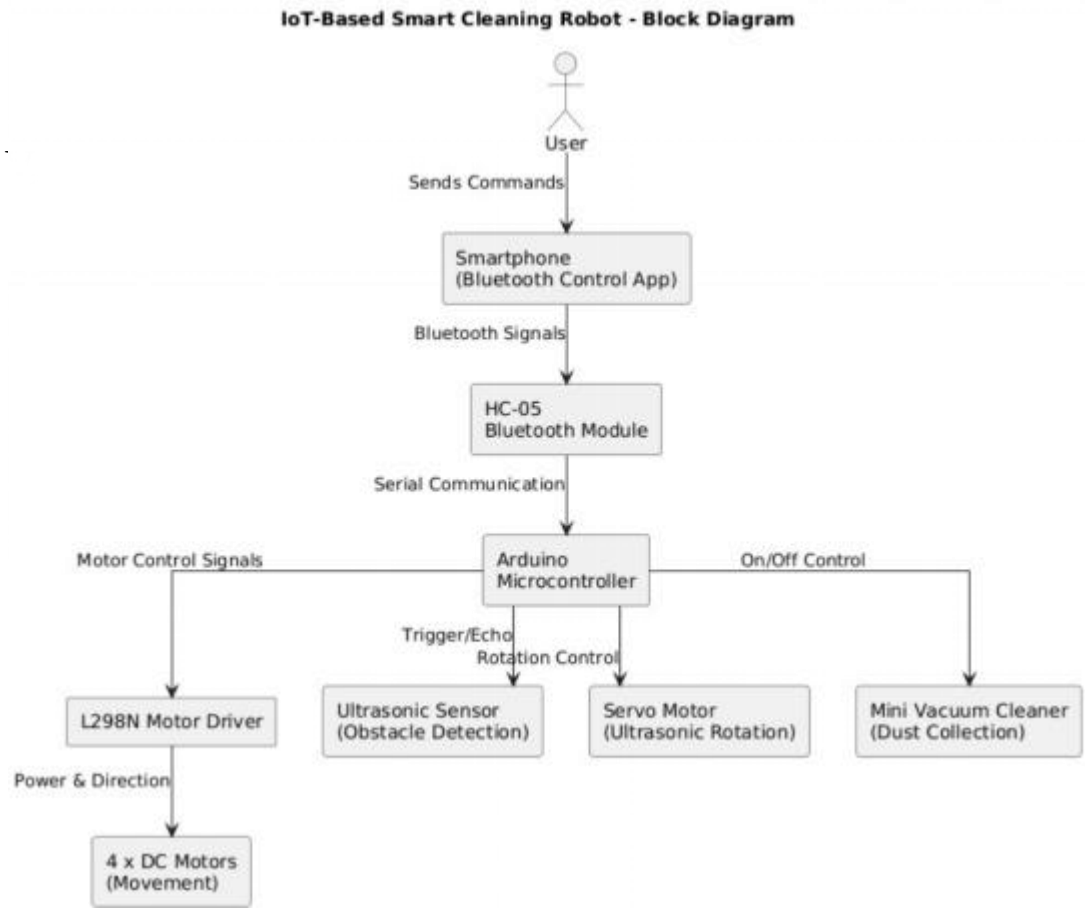
2. Smartphone Control Interface: User sends commands (F, B, L, R, S, U) via a Bluetooth app.

3. Bluetooth Communication (HC-05): Serial UART at 9600 baud; enables wireless control without internet.

4. Central Control (Arduino Uno): Decodes commands → controls motors, servo, vacuum, and sensors.

5. Motion Control (L298N + DC Motors): 4-wheel drive with PWM-based direction & speed control.

6. Obstacle Detection (Ultrasonic + Servo): Scans environment from 0° to 180° and measures distances.



DESIGN AND IMPLEMENTATION (Contd...)

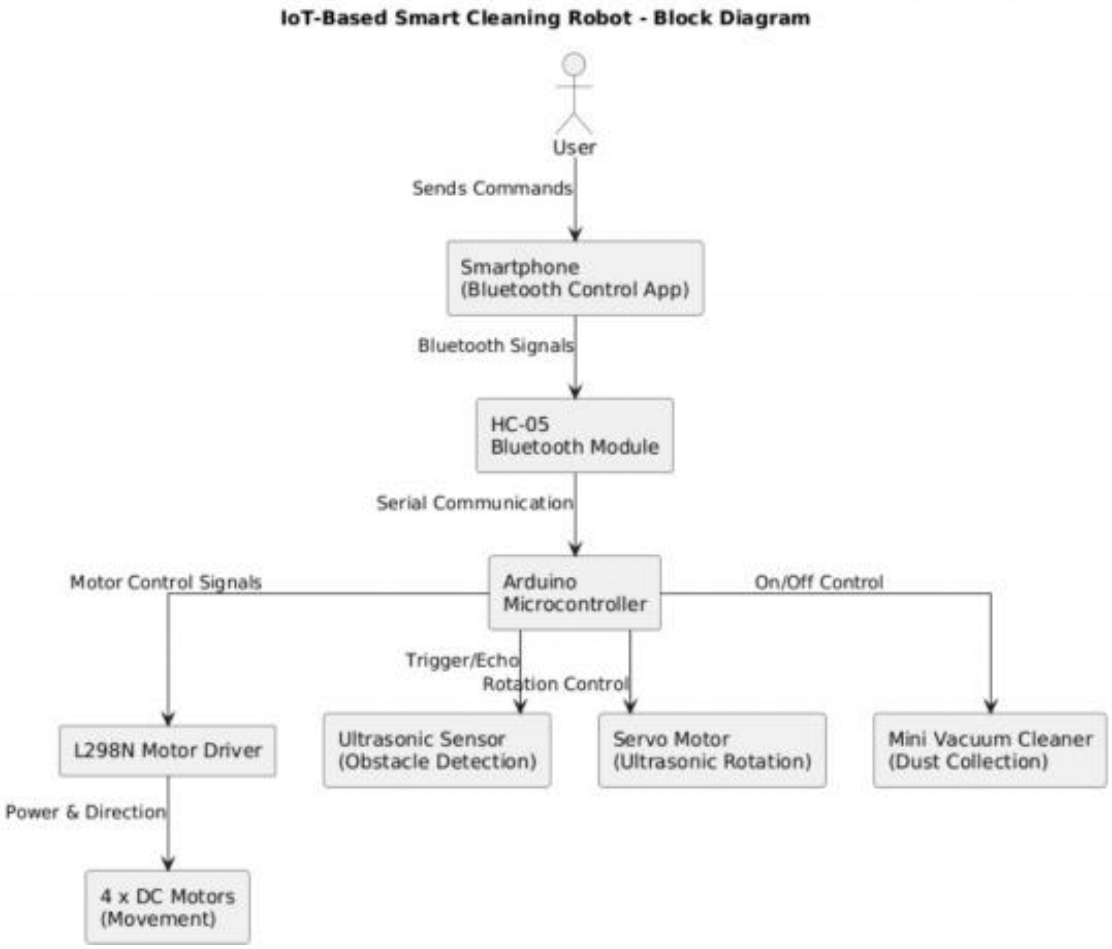
7. Cleaning Module: Mini vacuum toggled ON/OFF via Arduino for dust collection.

8. Power Management: Li-ion battery + voltage regulators → stable multi-voltage supply.

9. Real-Time Control Flow: User → Bluetooth → Arduino → Motion/Sensing/Cleaning modules.

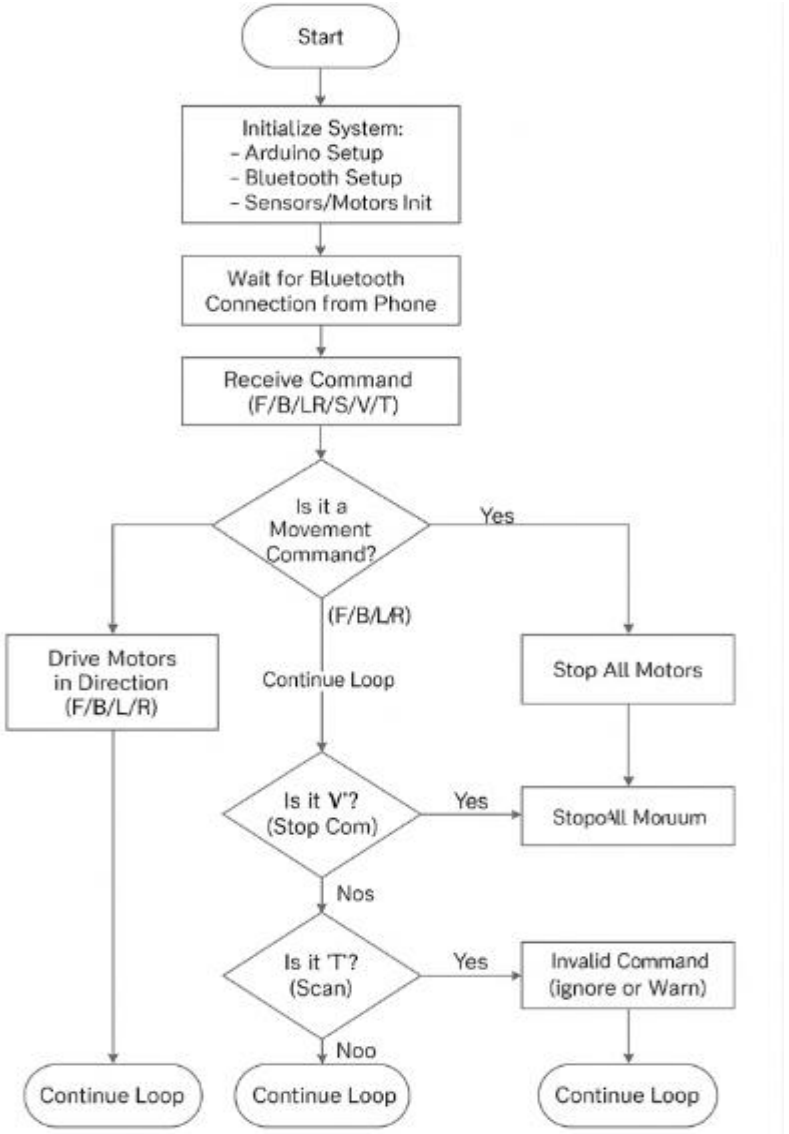
10. Architecture Benefits:

- Manual precision
- Offline operability
- Modular upgrades
- Low cost & scalable



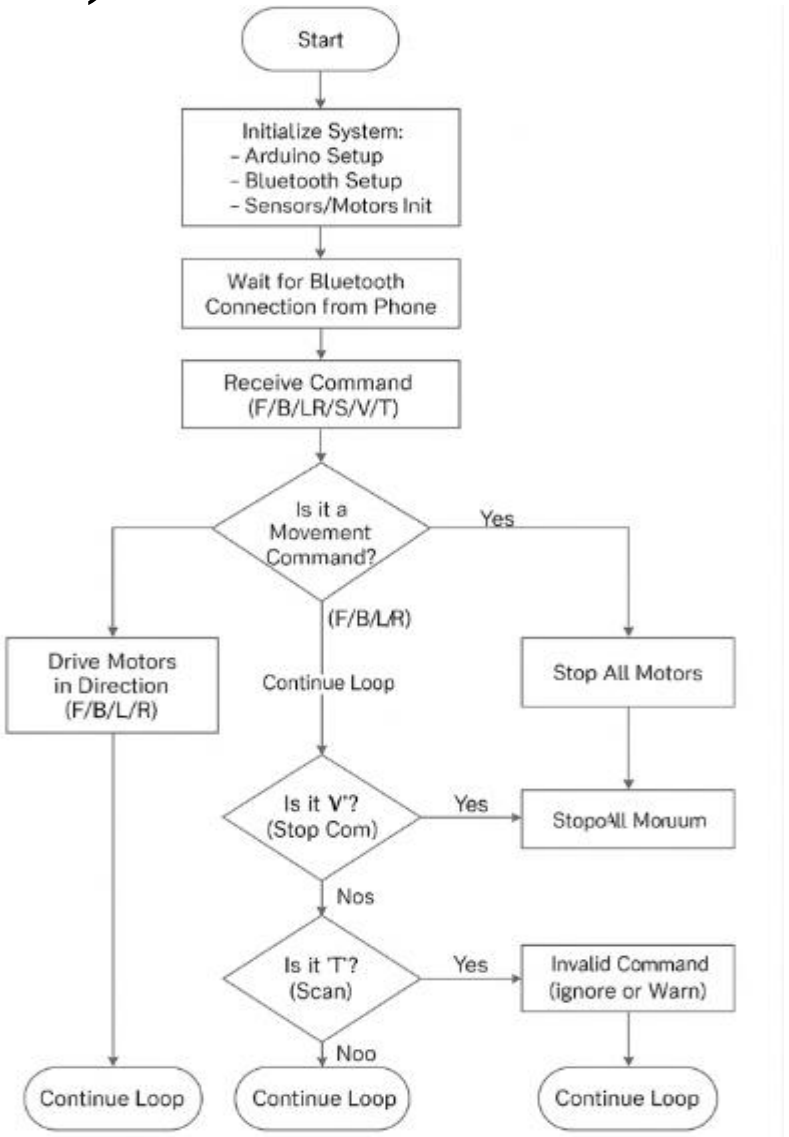
FLOW CHART

- The operation of the IoT-based Smart Cleaning Robot follows a structured real-time control loop that begins with system initialization upon powering on or resetting the device. During initialization, the Arduino sets up all I/O pins, loads necessary libraries (such as for the servo and serial communication), and prepares the motors, sensors, and Bluetooth module for operation. The system then enters a standby mode, continuously waiting for a Bluetooth connection and a valid command from the user's smartphone via a controller app.
- Once a command is received—typically a single character like 'F' for forward, 'B' for backward, or 'V' to toggle the vacuum—the Arduino interprets it and performs the corresponding action. Movement commands drive the DC motors via the L298N motor driver, enabling directional movement with optional speed control. A stop command ('S') halts all motor activity, ensuring immediate braking.



FLOW CHART (Contd...)

- When the vacuum toggle command is issued, the cleaning motor is switched on or off via a digital output pin. For environmental scanning, the 'T' command triggers the servo-mounted ultrasonic sensor to sweep between predefined angles, capturing obstacle distances and optionally outputting the data to the serial monitor.
- Invalid or unrecognized commands are ignored to maintain system stability, and optional debugging responses can be integrated for development purposes. After executing any command, the system returns to listening mode, creating a continuous, responsive loop that allows for seamless, real-time manual control via Bluetooth.



ADVANTAGES

- **Low-Cost and Affordable Design:** Uses inexpensive, easily available components, making it budget-friendly and accessible for students and hobbyists.
- **Real-Time Manual Control via Smartphone:** Offers precise control through Bluetooth-based smartphone operation, ideal for navigating cluttered or dynamic environments.
- **Modular and Easily Extendable Architecture:** Supports easy upgrades and expansions, allowing future enhancements like camera modules or Wi-Fi without major redesign.
- **Obstacle Detection for Safe Navigation:** Ultrasonic sensor with servo motor enables effective obstacle detection, improving safety and navigation accuracy.

ADVANTAGES

- **Functional Cleaning Mechanism:** Built-in mini vacuum allows real-time dust and debris collection, turning it into a practical cleaning device.
- **User-Friendly Interface:** Simple smartphone app interface makes it easy to control, even for users with no technical background.
- **Educational Value:** Hands-on project that teaches core concepts in IoT, electronics, and robotics, perfect for student learning.
- **Environmentally Adaptable:** Manual control allows flexible use in various environments, including tight or cluttered spaces where automation may fail.

APPLICATIONS

- ✓ **Domestic Cleaning:** Used for everyday household cleaning in bedrooms, kitchens, and living rooms. Its compact size and manual control allow it to clean under furniture and around objects effectively.
- ✓ **Educational Tool for Learning IoT and Robotics:** Ideal for students and beginners to learn core concepts like Arduino programming, sensor integration, and Bluetooth control in a hands-on, modular project.
- ✓ **Cleaning in Hard-to-Reach or Hazardous Areas:** Can be guided into tight or dusty spaces (like behind appliances) to clean without human exposure, reducing physical strain and contact with allergens.

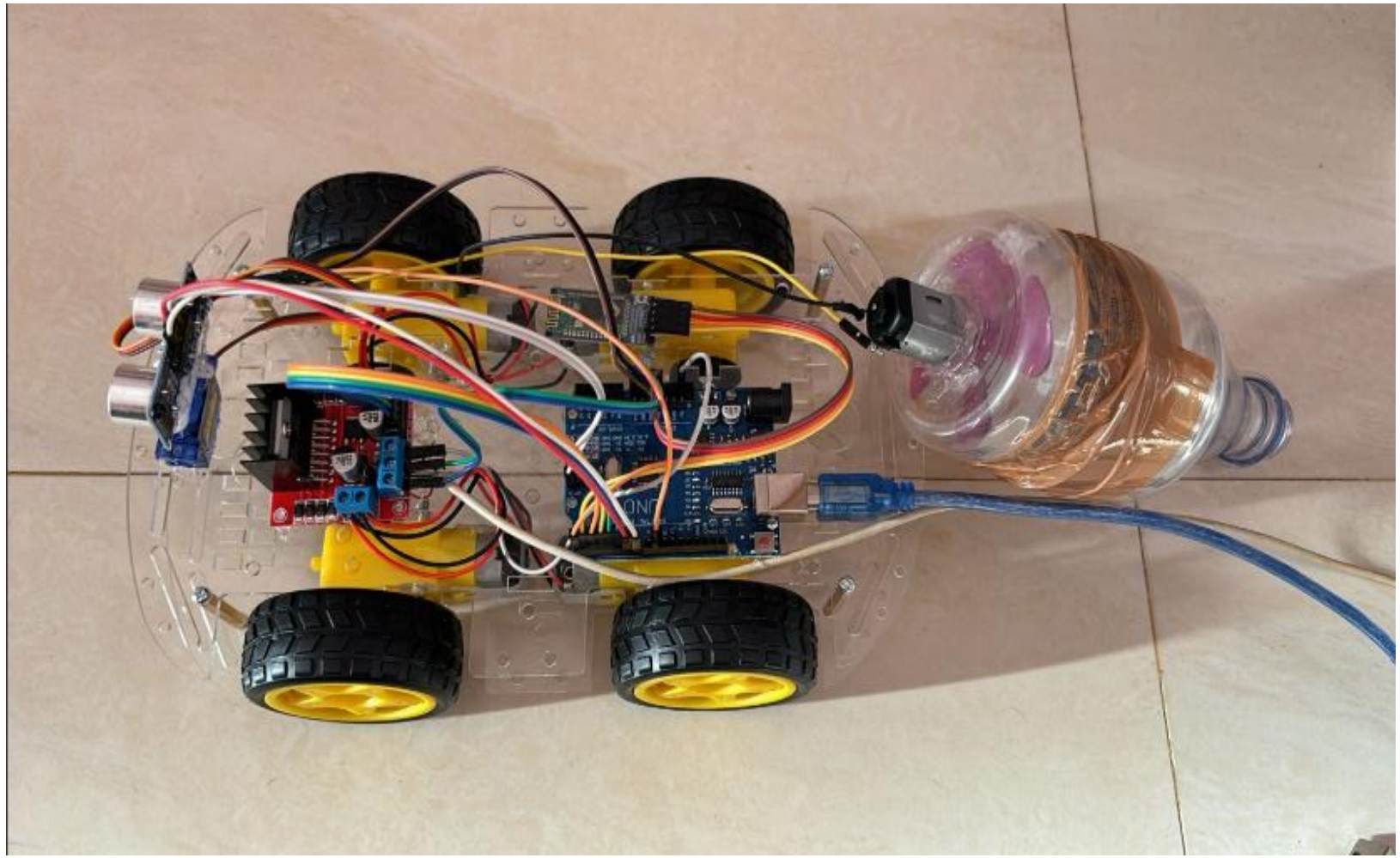
APPLICATIONS

- ✓ **Demonstration of Smart Home Integration:** Serves as a low-cost prototype to demonstrate how IoT devices can be part of a smart home system, and can be upgraded for Wi-Fi or cloud-based control.
- ✓ **Office and Small Workspace Maintenance:** Useful for routine cleaning in small offices or studios, especially when full-time cleaning services are impractical or unnecessary.
- ✓ **Use in Elderly or Mobility-Restricted Homes:** Enables individuals with limited mobility to clean their homes with ease using smartphone controls, offering convenience and independence.

SIMULATION RESULTS

The below figure shows the IoT-based smart cleaning robot in its working form. The robot is built on a transparent acrylic chassis with four DC motors and wheels for movement. At the center, the Arduino Uno microcontroller is visible, connected to various modules including the HC-05 Bluetooth module, L298N motor driver, ultrasonic sensor for obstacle detection, and servo motor for rotating the sensor. On the right side, a mini vacuum cleaner made from a plastic bottle is attached, demonstrating the dust collection mechanism. Wires connect all components, showing a fully assembled and functional model of the cleaning robot ready for operation. The setup is powered via a USB connection, indicating it's currently being tested or programmed through a connected system like a laptop or power bank.

SIMULATION RESULTS



CONCLUSION

The development of the manually controlled IoT-based Smart Cleaning Robot demonstrates the practical application of embedded systems and mobile communication technologies in solving real-world problems. This project successfully integrates an Arduino microcontroller, Bluetooth module, motor drivers, ultrasonic sensor, and a mini vacuum cleaner into a single system that performs efficient and controlled cleaning operations. It offers a low-cost, user-friendly alternative to commercially available smart cleaning robots by allowing users to remotely guide the robot through their smartphones. The obstacle detection system adds a layer of safety and precision, while the cleaning mechanism makes the robot functional for basic dust and debris collection. As a student project, it has achieved its intended objectives by showcasing a working prototype that embodies key concepts in IoT, robotics, and automation.

FUTURE SCOPE

While the current implementation provides an effective and interactive cleaning system, there is ample scope for enhancement and expansion. Future iterations can focus on introducing semi or fully autonomous navigation using advanced path-planning algorithms and simultaneous localization and mapping (SLAM) techniques. Replacing Bluetooth with Wi-Fi or GSM modules would allow for remote internet-based control and integration with smart home platforms like Google Home or Amazon Alexa. Additional features such as real-time camera feedback, voice commands, dustbin full alerts, and scheduled cleaning routines can further increase the system's utility and user experience. Moreover, improvements in hardware like stronger suction mechanisms, better battery capacity, and all-terrain mobility can make the robot more robust and applicable to a broader range of environments, including commercial and industrial settings.

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thank you