RESEARCH ARTICLE OPEN ACCESS

Smartphone-Controlled Floor Cleaning Robot: An Arduino-Based IoT Solution

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ABSTRACT –
This paper presents the development of a smartphone-controlled floor cleaning robot designed to streamline household floor cleaning processes. Utilizing advanced technology such as an Arduino board, motor shield, and Bluetooth module, the robot offers customizable water usage and intuitive controls for efficient operation. Key features include a rotating mop and water storage attachment for thorough cleaning. The robot's standout feature is its remotecontrol capability via an Android app, enabling users to start, stop, and adjust cleaning parameters. The paper outlines the theory behind the robot's operation, including smartphone interface, initialization, Bluetooth communication, motor control, and sustainable component reuse. The utility of the robot lies in its versatility, user-friendliness, and eco-friendly design. Through strategic component reuse and energy-efficient operation, the robot embodies a commitment to sustainability. Future enhancements could include autonomous features to broaden its utility. Overall, this paper presents a practical and innovative solution for household floor maintenance, demonstrating the integration of advanced technology with environmental consciousness.
Keywords - Arduino Uno, Bluetooth module, HC-05, DC motor, motor driver, floor cleaning robot, robotics, smart home, home automation

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Date of Submission: 12-08-2024 Date of acceptance: 27-08-2024

I. INTRODUCTION

Household floor cleaning is a common chore that often requires significant time and effort. In response to this need, we present a novel solution: a smartphone-controlled floor cleaning robot. This robot represents a sophisticated approach to floor cleaning, incorporating advanced technology such as Arduino-based control, Bluetooth communication, and customizable cleaning parameters. With its intuitive controls and efficient design, the robot aims to streamline floor cleaning processes while minimizing user intervention. The integration of sustainable practices, including component reuse and energy-efficient operation, underscores our commitment to environmental responsibility. In this paper, we detail the development and functionality of the robot, highlighting its key features, theoretical underpinnings, utility, and environmental impact. Through this research, we aim to revolutionize household floor cleaning by providing a user-friendly, technologically advanced, and eco-conscious solution.

This floor cleaner represents a sophisticated solution designed to streamline floor cleaning processes while minimizing human effort. Equipped with advanced features and engineered for efficiency, it boasts customizable water usage and intuitive controls for seamless operation. Incorporating cutting-edge technology, including an Arduino board as the central processing unit, a motor shield for precise movement control, and a HC-05 Bluetooth module for remote accessibility, this device ensures thorough cleaning with minimal intervention. Featuring a rotating mop and a water reservoir attachment, it offers an innovative approach to floor maintenance, promising optimal results with every use. This project aims to revolutionize floor cleaning by providing a reliable, user-friendly solution, with potential for further enhancements in the future. Household floor cleaning, a routine yet essential task, often demands considerable time and effort, particularly in large homes, offices, or industrial spaces. Traditional cleaning methods, such as sweeping and mopping, are labor-intensive and may lead to physical strain over time, including issues like back pain, respiratory problems from dust, and even skin conditions due to exposure to cleaning chemicals. With the advent of technology, especially in the field of robotics and automation, there is a growing interest in developing tools that can alleviate these burdens, making floor cleaning more efficient, less timeconsuming, and less physically demanding. In today's fastpaced world, where time is a precious commodity, automating household chores has become increasingly appealing. The advent of cleaning robots has shown great promise in addressing these challenges. However, the high cost and limited functionalities of many commercially available cleaning robots restrict their adoption, particularly in regions like India, where affordability is a key factor in consumer decision-making. In such contexts, most cleaning robots available in the market are not only expensive but also offer limited functionalities—often restricted to either dry or wet cleaning. This gap in the market presents an opportunity to develop a more affordable, multifunctional cleaning robot that caters to the specific needs of the average household. This project addresses this need by introducing a smartphonecontrolled floor cleaning robot that is both cost-effective and versatile. This robot is designed with advanced features that cater to both dry and wet cleaning needs, making it a comprehensive solution for floor maintenance. The core of this project lies in the integration of an Arduino-based control system, which serves as the robot's brain. The Arduino platform is chosen for its flexibility, ease of use, and extensive community support, making it an ideal choice for a project aimed at affordability and widespread adoption. Central to the robot's functionality is its ability to be controlled remotely via a smartphone. This is achieved through the incorporation of an HC-05 Bluetooth module, which allows for seamless communication between the robot and the user's smartphone. The use of a smartphone interface not only enhances user convenience but also aligns with the growing trend of Internet of Things (IoT) devices, where everyday objects are connected and controlled through mobile applications. This robot is equipped with a motor shield that ensures precise control of the DC motors, responsible for the movement of the robot and the rotation of the cleaning mop. The mop itself is designed to be detachable and easy to clean, ensuring that the robot remains hygienic and effective over long-term use. One of the standout features of this robot is its customizable water usage. Unlike many existing cleaning robots that have fixed water usage settings, this design allows users to adjust the amount of water dispensed during cleaning. This feature is particularly beneficial in regions with water scarcity, where conservation is crucial. The water is stored in a detachable bottle that can be easily refilled and cleaned, making the robot both userfriendly and environmentally conscious. The emphasis on sustainability is a key aspect of this project. The robot is designed with energy efficiency in mind, minimizing power consumption without compromising on performance. Additionally, the use of readily available and recyclable materials for the robot's construction underscores our commitment to environmental responsibility. By reusing components and employing energy-efficient practices, the robot not only reduces the ecological footprint of household cleaning but also offers a cost-effective solution that is accessible to a broader audience. In developing this robot, we draw on a rich theoretical foundation that includes the principles of robotics, automation, and Bluetooth communication. The robot's operation begins with the initialization process, where the Arduino board is set up to communicate with the HC-05 module and the motor shield. Once initialized, the robot can be controlled through a userfriendly Android app, which we have developed specifically for this project. The app interface allows users to start and stop the cleaning process, adjust water usage, and monitor the robot's status in real-time. The practical implications of this project are significant. In regions where labor-intensive cleaning methods are still prevalent, this robot has the potential to revolutionize household floor maintenance. By reducing the physical demands of cleaning, it can contribute to improved health and well-being for users. Moreover, the robot's affordability makes it an attractive option for a wide range of consumers, from individual households to small businesses and even larger facilities that require regular cleaning. Looking ahead, there are numerous possibilities for enhancing the functionality of this robot. Future iterations could incorporate autonomous navigation features, enabling the robot to clean entire rooms or buildings without human intervention. This would involve integrating sensors and algorithms that allow the robot to map its environment, avoid obstacles, and plan optimal cleaning paths. Additionally, the robot could be equipped with internet connectivity, allowing it to be controlled remotely from anywhere in the world, further expanding its utility as a smart home device. Another potential enhancement is the inclusion of advanced cleaning features, such as UV sterilization or the ability to dispense cleaning agents automatically based on the type of floor being cleaned. These features would not only improve the robot's cleaning efficiency but also address concerns related to hygiene and sanitation, particularly in the wake of global health challenges. In conclusion, the development of this smartphone-controlled floor cleaning robot represents a significant step forward in the field of household automation. By combining affordability, versatility, and sustainability, this project offers a practical solution to the everyday chore of floor cleaning. This robot has the potential to improve the quality of life for users by making floor cleaning less burdensome and more efficient. As technology continues to evolve, we are confident that the principles and innovations demonstrated in this project will pave the way for future advancements in home automation and smart living.

1. COMPONENTS USED IN FLOOR CLEANING ROBOT

- List of components used: -
  - 1.1 Arduino (Micro-Controller)
  - 1.2 Motor Driver (L293D-Driver)
  - 1.3 DC Motors
  - 1.4 Bluetooth-Module (HC-05)
  - 1.5 Buck-Converter (Step-Down)
  - 1.6 DC-Water-Pump
  - 1.7 Battery (12v-1.2A)
  - 1.8 Switch
  - 1.9 Water Storage Tank
  - 1.10 Drone Propellers (2)
  - 1.11 Wooden Chassis
  - 1.12 Jumper-Wires
  - 1.13 Scrub
  - 1.14 Wheels (4)

1.1 Arduino (Micro-Controller)

The Arduino Uno board, a cornerstone of modern electronics prototyping, is the microcontroller chosen for this smartphone-controlled floor cleaning robot. As the central processing unit (CPU) of this project, the Arduino Uno orchestrates the various components of the robot, ensuring they work harmoniously to achieve the desired functionality. Its widespread popularity among hobbyists, educators, and professionals alike can be attributed to its versatility, ease of use, and robust open-source ecosystem, making it an ideal choice for this paper and development efforts.

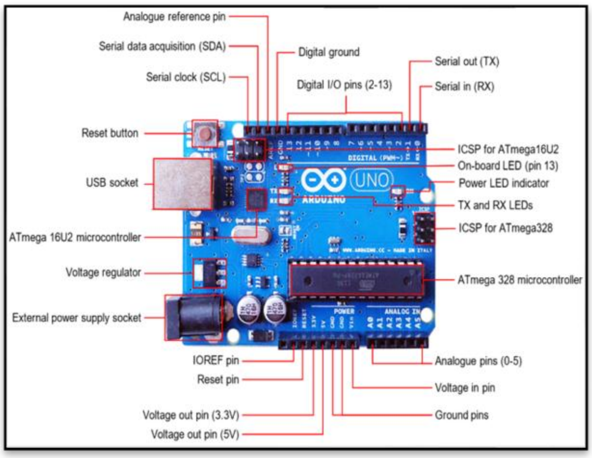

Figure 1: - ATMega32 Arduino UNO 5V Micro-Controller [1] 1.1.1 Overview of Arduino-Uno (Micro-Controller)

The Arduino Uno is a microcontroller board based on the ATmega328P microcontroller, a versatile and powerful 8-bit AVR processor from Microchip. It operates at a clock speed of 16 MHz and comes with 32 KB of flash memory for storing programs, 2 KB of SRAM for runtime data, and 1 KB of EEPROM for non-volatile storage. These specifications, while modest compared to modern processors, are more than sufficient for the vast majority of embedded applications, including this floor cleaning robot. The board itself features a compact design, with dimensions of 68.6 mm by 53.4 mm, making it suitable for integration into small and spaceconstrained projects. Despite its small size, the Arduino Uno offers a wide range of input/output (I/O) capabilities, with 14 digital I/O pins (6 of which can be used as PWM outputs) and 6 analog input pins. These pins can interface with a wide variety of sensors, actuators, and other electronic components, allowing for the creation of complex, interactive systems.[18]

1.1.2 Ease of use and Programming

One of the defining characteristics of the Arduino Uno is its user-friendly programming environment, the Arduino Integrated Development Environment (IDE). The Arduino IDE, which is available for Windows, macOS, and Linux, provides a simple and intuitive interface for writing, editing, and uploading code to the microcontroller. It uses a language that is a simplified version of C++, making it accessible to beginners while still powerful enough for advanced users. The simplicity of the Arduino programming model is further enhanced by the vast library of pre-written code available to users. The Arduino community has developed an extensive collection of libraries that cover a wide range of functionalities, from basic input/output operations to advanced communication protocols and sensor interfaces. These libraries allow developers to quickly implement complex features without having to write code from scratch, significantly speeding up the development process. In this floor cleaning robot, we leverage several of these libraries to manage tasks such as motor control, Bluetooth communication, and sensor data processing. For example, the "Servo" library simplifies the control of the robot's motors, while the "Software-Serial" library enables communication with the HC-05 Bluetooth module. By utilizing these libraries, we can focus on higher-level design and integration tasks, knowing that the underlying code is reliable and well-tested.

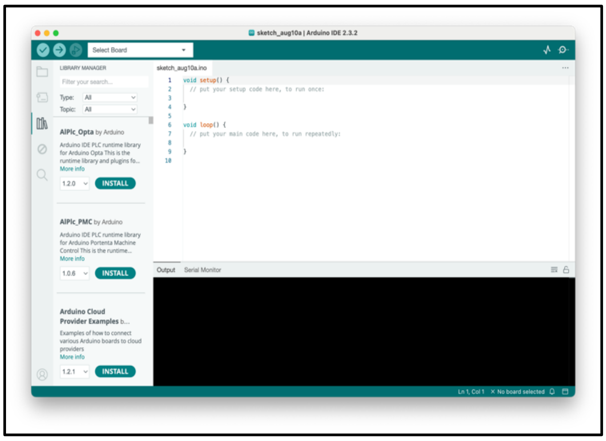

Figure 2: - Arduino Integrated Development Environment (IDE) 1.1.3 Interfacing with Sensors and Actuators

The Arduino Uno's extensive I/O capabilities make it an excellent platform for interfacing with a variety of sensors and actuators. In this floor cleaning robot, these components play a crucial role in enabling the robot to perform its cleaning tasks effectively. For motor control, the Arduino Uno interfaces with a motor shield or motor driver, which is responsible for driving the DC motors that move the robot and rotate the cleaning mop. The PWM (Pulse Width Modulation) capability of the digital I/O pins is particularly useful in this context, as it allows for precise control of motor speed and direction. By adjusting the duty cycle of the PWM signals, we can control the speed of the motors, enabling smooth and efficient movement of the robot. Sensors, such as ultrasonic or infrared sensors, can also be connected to the Arduino Uno to provide feedback on the robot's environment. These sensors can be used to detect obstacles, measure distances, or monitor the robot's cleaning progress. The analog input pins on the Arduino Uno are capable of reading sensor data with 10-bit resolution, providing accurate and reliable measurements that can be processed in real-time to adjust the robot's behavior. In addition to controlling motors and reading sensors, the Arduino Uno also manages the robot's communication with the user's smartphone. The HC-05 Bluetooth module, which allows for wireless communication, is connected to the Arduino Uno via the digital I/O pins. Through this module, the Arduino receives commands from the smartphone, such as starting or stopping the cleaning Process, adjusting the amount of water used, or changing the robot's speed. The ability to integrate wireless communication so seamlessly into the system is a testament to the flexibility and power of the Arduino platform.

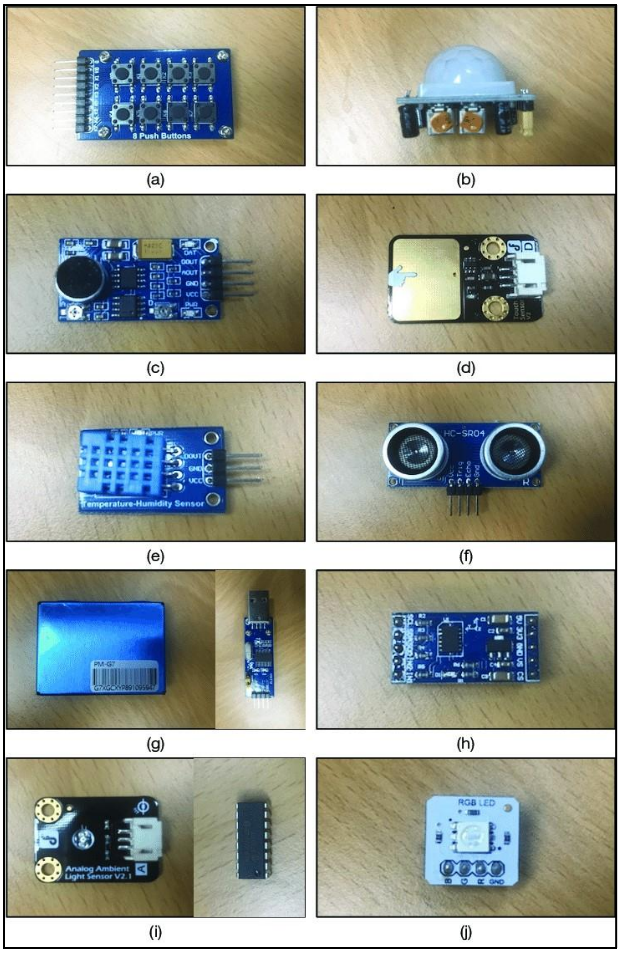

Figure 3: - Sample Sensors and Actuators [2]

1.1.4 Power Consumption and Efficiency

Power consumption is critical consideration in the design of any embedded system, particularly for mobile and battery-operated devices like this floor cleaning robot. The Arduino Uno is designed with energy efficiency in mind, consuming minimal power while still delivering robust performance. The board operates at 5V, with an operating current of around 50 mA, though this can vary depending on the peripherals. In battery-powered applications, such as this robot, it is essential to minimize power usage to extend battery life. The Arduino Uno supports several power-saving modes, including sleep modes that reduce power consumption when the microcontroller is idle. By carefully managing the robot's power consumption, it can be ensured that it operates efficiently, maximizing the time between battery charges.

1.1.5 Community and Support

The Arduino platform is backed by a vibrant and active global community of developers, educators, and enthusiasts. This community-driven support is one of the key factors that make Arduino such a powerful tool for prototyping and development. Whether it's finding solutions to technical challenges, accessing tutorials and guides, or collaborating on open-source projects, the Arduino community provides an invaluable resource for anyone working with the platform. For this paper, the community support has been instrumental in overcoming various challenges and accelerating the development process. The availability of extensive documentation, forums, and project examples has allowed us to quickly find answers to technical questions and implement new features with confidence. In summary, the Arduino Uno board is the linchpin of this smartphone-controlled floor cleaning robot, providing a reliable and versatile platform for the integration and coordination of the robot's various components. Its ease of use, coupled with its extensive I/O capabilities and low power consumption, makes it an ideal choice for this application. The robust support provided by the Arduino community further enhances the development process, enabling us to implement advanced features and functionalities with relative ease. As we continue to refine and expand the capabilities of the floor cleaning robot, the Arduino Uno will remain at the heart of the efforts, driving innovation and ensuring reliable operation.

1.7 Motor Driver (L293D-Driver)

The L293D motor driver is a popular integrated circuit (IC) used for controlling the direction and speed of DC motors in various electronic and robotic applications. Known for its versatility, efficiency, and ease of use, the L293D is a critical component in projects where precise motor control is required, such as in robotics, automation systems, and even in small household devices like the smartphone-controlled floor cleaning robot. The L293D is an H-bridge motor driver IC, which is designed to control two DC motors simultaneously, allowing them to rotate in both forward and reverse directions. The "H-bridge" concept refers to the configuration of transistors within the IC that allows for the control of the polarity of the voltage applied to the motor, which in turn controls the direction of the motor's rotation. This IC is highly valued in embedded systems and robotics for its ability to provide bi-directional drive currents and manage the speed of motors using Pulse Width Modulation (PWM) signals.

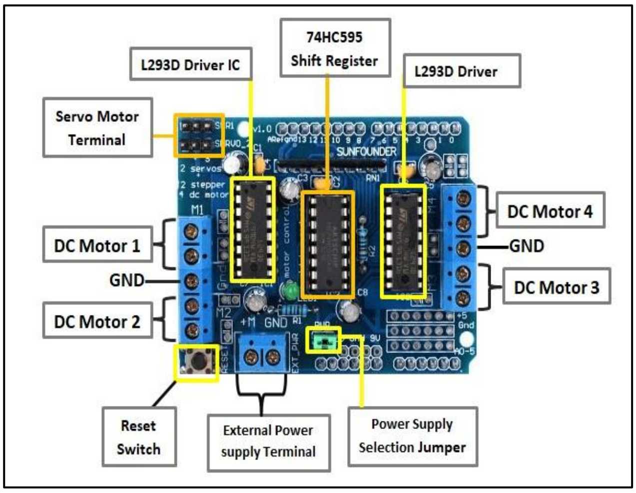

Figure 4: - Motor Driver (L293D-Driver) [3]

1.2.1 Technical Specifications

The L293D motor driver has several key technical specifications that make it suitable for a wide range of applications:

a) Operating Voltage: The L293D can operate with supply voltages ranging from 4.5V to 36V, making it compatible with both low and high voltage motors.
b) Output Current: The IC can deliver a continuous output current of up to 600mA per channel, with a peak current of 1.2A per channel. This allows it to drive small to medium-sized motors effectively.
c) Internal Diodes: The L293D has built-in diodes that protect the IC from back EMF (Electromotive Force), which occurs when the motor suddenly stops or changes direction.

This feature is crucial for protecting the IC and the entire circuit from potential damage.

d) Thermal Shutdown: The IC includes thermal shutdown protection, which prevents it from overheating and becoming damaged under heavy loads or prolonged operation.
e) Enable Pins: The L293D features two enable pins, one for each motor. These pins can be used to control the activation of the motors independently, allowing for greater flexibility in motor control.

1.2.2 Pin configuration and Functionality

The L293D IC comes in a 16-pin Dual In-line Package (DIP), with each pin serving a specific function related to motor control. The pins are arranged as follows:

a) Pin 1 (Enable 1,2): This pin controls the enable/disable function of the first motor driver channel. When this pin is high (logic 1), the first motor is enabled and can be controlled via the input pins. When low (logic 0), the motor is disabled.
b) Pin 2, 7 (Input 1, 2): These pins are connected to the microcontroller or other control logic. The signals sent to these pins determine the direction of the motor connected to the first channel.
c) Pin 3, 6 (Output 1, 2): These pins are connected to the terminals of the first motor. The voltage and direction of current applied to these pins determine the motor’s rotation.
d) Pin 4, 5 (Ground): These pins are connected to the ground (0V) of the circuit.
e) Pin 8 (Vcc2): This pin supplies the power to the motors. The voltage applied here determines the operating voltage of the motors, typically ranging from 4.5V to 36V.
f) Pin 9 (Enable 3,4): This pin controls the enable/disable function of the second motor driver channel, similar to Pin 1.
g) Pin 10, 15 (Input 3, 4): These pins control the second motor, functioning similarly to Pins 2 and 7.
h) Pin 11, 14 (Output 3, 4): These pins are connected to the terminals of the second motor.
i) Pin 12, 13 (Ground): Additional ground pins, ensuring proper grounding of the IC.
j) Pin 16 (Vcc1): This pin supplies the logic voltage for the IC, typically 5V.

1.2.3 Working Principle of L293D Motor Driver

The L293D motor driver works on the principle of an H-bridge, which is a circuit that allows the voltage to be applied across a load (in this case, a motor) in either direction. By controlling the input signals to the L293D, the direction of the motor can be changed, allowing for forward and reverse rotation. When both inputs for a channel (Input 1 and Input 2, for example) are given the same logic level (either both high or both low), the motor does not rotate because there is no potential difference across the motor terminals. However, when one input is high and the other is low, the motor rotates in one direction. Reversing these inputs will cause the motor to rotate in the opposite direction. This ability to control the direction of rotation is what makes the L293D so versatile in applications that require bidirectional motor control.

1.2.4 Applications

The L293D motor driver is widely used in various applications, particularly in projects where precise control of DC motors is required. Some of the most common applications include:

a) Robotics: The L293D is frequently used in robotics to control the movement of wheeled robots, robotic arms, and other motor-driven mechanisms. Its ability to control two motors independently makes it ideal for driving differential drive robots, where one motor controls the left wheels and the other controls the right wheels.
b) Automation Systems: In automation projects, the L293D is used to control conveyor belts, mechanical actuators, and other motorized systems. Its robust performance and ease of integration with microcontrollers make it a reliable choice for industrial and home automation.
c) Smart Devices: The L293D can be found in smart devices that require motor control, such as automated blinds, fans, and floor cleaning robots. In these applications, the L293D’s ability to operate at different voltages and control motor speed is highly advantageous.
d) Educational Projects: Due to its simplicity and effectiveness, the L293D is a popular choice in educational kits and projects, where students learn the basics of motor control, electronics, and programming. Its straightforward operation and clear documentation make it an excellent teaching tool.[18]

1.2.5 Integration with Micro-Controllers

The L293D motor driver is designed to work seamlessly with microcontrollers, such as Arduino, Raspberry Pi, and other embedded platforms. The microcontroller provides the control signals to the input pins of the L293D, determining the motor's speed and direction. In this floor cleaning robot project, the Arduino Uno sends PWM signals to the L293D to control the speed of the motors, while the direction of rotation is controlled by the digital output pins. The L293D's enable pins can also be used to implement additional features such as braking or enabling/disabling motors under certain conditions. For example, in a robotic arm, the enable pins can be used to selectively activate different motors based on the robot's current task, conserving power and reducing wear on the motors.

1.2.6 Advantages and Limitations

The L293D motor driver offers several advantages, making it a popular choice for motor control in various projects:

a) Simplicity: The L293D is easy to use, with straightforward connections and clear functionality.
b) Cost-Effective: It is an affordable solution for motor control, making it accessible for hobbyists and professionals alike.
c) Protection Features: Built-in diodes and thermal shutdown protection enhance the reliability and safety of the IC.

However, the L293D also has some limitations:

a) Current Limitation: The L293D can only handle a continuous current of 600mA per channel, which
may not be sufficient for larger motors or heavyduty applications.
b) Power Dissipation: The IC can generate significant heat during operation, particularly at higher currents, necessitating proper heat management.

The L293D motor driver is a versatile and reliable IC that plays a critical role in the control of DC motors in various applications. Its ability to control motor direction and speed, combined with its ease of integration with microcontrollers, makes it an indispensable component in robotics, automation, and smart devices. While it has certain limitations in terms of current handling, its advantages in terms of simplicity, affordability, and protection features ensure that it remains a popular choice for both beginners and experienced engineers. Whether used in educational projects or complex industrial systems, the L293D continues to be a foundational tool in the world of motor control.

1.3 Dc-Motors

The integration of DC motors in floor cleaning robots is pivotal for achieving the desired mobility, control, and functionality required for efficient cleaning operations. DC motors are valued for their simplicity, ease of control, and reliability, making them the preferred choice for many robotic applications, including floor cleaning robots. In this review, we will explore the application of four 5V, 100 RPM DC motors used for maneuvering the robot (turning, moving forward, and backward) and one high-speed 12V, 12000 RPM DC motor employed for drying purposes in a floor cleaning robot. DC motors are electrical machines that convert direct current electrical energy into mechanical energy. They are widely used in robotics due to their straightforward mechanism and controllability. The core components of a DC motor include the stator, rotor (armature), brushes, and commutator. The stator provides a magnetic field, the rotor rotates within the stator, and the brushes and commutator facilitate the flow of current to the rotating coil, producing torque.

Figure 5: - 12V DC Motor [4]

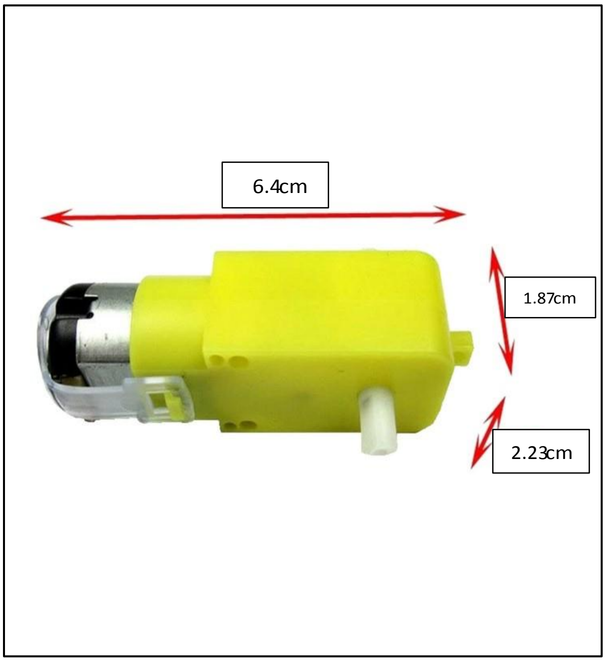

Figure 6: - DC-Motor Dimensions [5]

1.3.1 Mobility and Maneuverability: 5V, 100 RPM DC Motors

For a floor cleaning robot, mobility and maneuverability are essential to navigate through various surfaces and obstacles while performing cleaning tasks. The four 5V, 100 RPM DC motors are critical components that ensure the robot can move forward, backward, and execute turning maneuvers with precision.

Figure 7: - Disassembled View of DC-Motor [6]

i. Motor Specifications and Operation

The 5V, 100 RPM DC motors selected for this application offer a balance between torque and speed, making them ideal for driving the wheels of the robot. The 100 RPM rating indicates that the motor completes 100 revolutions per minute, which provides a suitable speed for navigating typical household floors. The 5V power requirement aligns well with common battery systems used in mobile robots, offering adequate power while maintaining energy efficiency. These motors typically have a torque output sufficient to propel the robot across different floor types, including hardwood, tile, and carpet. The torque is crucial for overcoming friction and ensuring that the robot can carry the weight of additional components, such as water tanks and cleaning mechanisms, without stalling or losing traction. ii. Control and Integration

Each of the four DC motors is individually controlled to manage the movement of the robot. By varying the voltage supplied to these motors, the speed of the robot can be adjusted. Additionally, the direction of rotation is controlled through an H-bridge motor driver, such as the L293D, which allows the robot to move forward, backward, and turn left or right by reversing the polarity of the current supplied to the motors. For turning maneuvers, the robot's control system will typically activate the motors on one side while deactivating or reversing the motors on the opposite side, allowing the robot to pivot in place. This method of differential steering is commonly used in mobile robots and is particularly effective for floor cleaning robots, as it enables them to navigate tight spaces and corners with precision. iii. Power and Efficiency Considerations

The use of 5V DC motors ensures compatibility with common battery systems, such as lead-acid or lithium-ion batteries, which are often used in robotic applications for their reliability and energy density. The power consumption of these motors is relatively low, contributing to the overall energy efficiency of the robot. This is important for extending the operational time of the robot between charges, especially in scenarios where the robot needs to clean large areas or operate over extended periods.

1.3.2 High-Speed Drying: 12V, 12000 RPM DC Motor

In addition to mobility, the floor cleaning robot incorporates a drying mechanism to ensure that floors are left clean and dry after the wet cleaning process. A high-speed 12V, 12000 RPM DC motor is employed to drive a drying mechanism, typically in the form of a fan or air blower, to achieve this.

i. Motor Specifications and Functionality

The 12000 RPM rating of this motor indicates that it operates at a significantly higher speed compared to the motors used for movement. This high speed is essential for generating the necessary airflow to effectively dry wet surfaces in a short amount of time. The 12V operating voltage ensures that this motor can be powered by the same battery system used for the movement motors, simplifying the overall power management of the robot. The high-speed motor's ability to rapidly rotate the fan blades or blower components results in the creation of a strong airflow, which is directed onto the floor surface to evaporate any residual moisture. This drying function is critical for ensuring that floors are not only clean but also safe to walk on, as wet floors can pose a slip hazard.

ii. Integration and Control

The high-speed motor is typically activated after the wet cleaning process has been completed. The robot's control system manages the timing and duration of the drying process to ensure optimal performance. In some designs, the drying motor may operate continuously as the robot moves, while in others, it may be triggered only when the robot detects that it has completed a specific cleaning cycle. Given the high speed at which this motor operates, considerations for noise reduction and motor cooling are important. High-speed motors can generate significant noise, which may be undesirable in household applications. Additionally, the rapid rotation can lead to increased heat generation, necessitating adequate ventilation or cooling mechanisms to prevent overheating.

1.3.3 Pros of Using DC Motors in Floor Cleaning Robots

The selection of DC motors for both mobility and drying functions in floor cleaning robots offers several advantages:

i. Precision Control: DC motors provide precise control over speed and direction, which is essential for navigating complex environments and ensuring thorough cleaning coverage.
ii. Simplicity: The control mechanisms for DC motors are relatively simple and well-understood, making them easy to integrate with microcontrollers and other electronic control systems.
iii. Cost-Effectiveness: DC motors are generally affordable and widely available, contributing to the cost-effectiveness of the overall robotic system.
iv. Reliability: DC motors are robust and reliable, with a long operational life when properly maintained, making them ideal for continuous use in cleaning robots.

1.3.4 Challenges and Considerations

While DC motors offer many benefits, there are also challenges that must be addressed in their application:

i. Power Management: The use of multiple DC motors requires careful power management to ensure that the battery can supply sufficient current without rapidly depleting. This involves selecting the right battery capacity and ensuring efficient motor operation.
ii. Noise and Vibration: High-speed DC motors, particularly those used for drying, can generate noise and vibration. Mitigating these effects requires careful design and possibly the use of damping materials or noise-reduction strategies.
iii. Wear and Tear: Continuous operation, especially at high speeds, can lead to wear and tear on motor components. Regular maintenance and, if necessary, replacement of worn parts is essential for maintaining long-term performance.

DC motors play a fundamental role in the operation of floor cleaning robots, providing the necessary mobility and drying capabilities required for effective cleaning. The combination of four 12V, 100 RPM motors for movement and a highspeed 12V, 12000 RPM motor for drying ensures that the robot can navigate various surfaces and leave them clean and dry. The advantages of DC motors, including their precision, simplicity, and reliability, make them an excellent choice for this application, although challenges such as power management and noise control must be carefully managed. As floor cleaning robots continue to evolve, the use of DC motors will remain a critical factor in their design and functionality.

1.4 Bluetooth-Module (HC-05)

The integration of Bluetooth technology into modern robotics has revolutionized the way we control and interact with machines. The HC-05 Bluetooth module is a widely used component in wireless communication for embedded systems and robotics, known for its ease of use, affordability, and reliable performance. In the context of a floor cleaning robot, the HC-05 module serves as the primary communication interface between the robot and the user's smartphone, enabling remote control of various functions such as movement, water pumping, drying, and mopping. This essay explores the functionality of the HC-05 Bluetooth module in a floor cleaning robot, detailing how it controls the robot's movement, operates different cleaning mechanisms, and processes commands using ASCII format. The HC-05 Bluetooth module is a serial Bluetooth module designed for wireless communication between microcontrollers and Bluetooth-enabled devices, such as smartphones, tablets, or computers. It operates using the Serial Port Profile (SPP), which emulates a serial port connection over Bluetooth, allowing it to be used as a replacement for wired serial communication.

The module operates within the frequency range of 2.4GHz, providing a wireless communication range of up to 10 meters in open space, though the effective range can vary based on environmental factors. The HC-05 is known for its versatility, as it can function as both a master and a slave device, although it is often used in slave mode when interfaced with microcontrollers like Arduino.

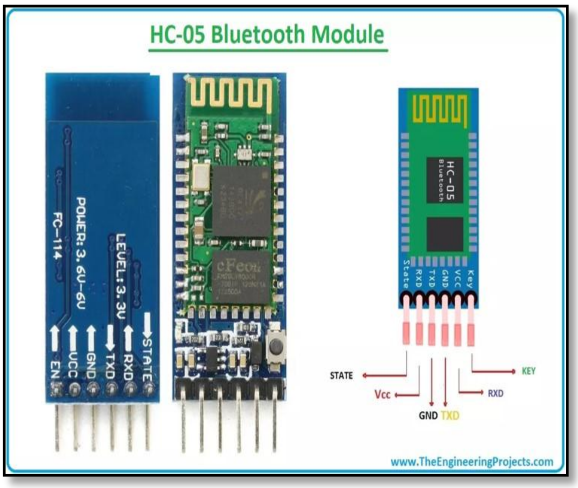

Figure 8: - HC-05 Bluetooth-Module [7]

In a floor cleaning robot, the HC-05 module is the key component that enables wireless control over the robot's various functions. The module is connected to a microcontroller, typically an Arduino, which acts as the central processing unit (CPU) for the robot. The microcontroller receives commands from the smartphone via the HC-05 module, processes them, and then activates the corresponding motors and mechanisms within the robot.

1.4.1 Controlling Movement: Forward, Backward, Left, Right

The HC-05 module plays a critical role in controlling the robot's movement. The robot is equipped with four DC motors, each responsible for driving one of the wheels. The HC-05 receives movement commands from the user's smartphone and relays them to the microcontroller. These commands typically include instructions to move the robot forward, backward, left, or right. For example, when the user sends a command to move forward, the microcontroller interprets the command and sends signals to the motor driver IC (such as the L293D or L298N). The motor driver then controls the voltage and current supplied to the DC motors, causing them to rotate in the desired direction. Similarly, when the user commands the robot to turn left or right, the microcontroller adjusts the speed and direction of the motors on either side of the robot, allowing it to pivot or change direction. The HC-05 module ensures that these commands are transmitted quickly and accurately, allowing for real-time control of the robot's movement. This is crucial for navigating the robot through different environments and ensuring that it can avoid obstacles while performing cleaning tasks.

1.4.2 Water Pump Control

The floor cleaning robot is equipped with a water pump that is used to dispense water or cleaning solution onto the floor before mopping. The HC-05 module enables the user to control this function remotely, turning the pump on or off as needed.

When the user sends a command to activate the water pump, the microcontroller receives the command via the HC-05 module and triggers the water pump motor. This is usually done by energizing a relay or using a motor driver circuit that controls the water pump. The ability to control the water pump remotely allows the user to manage the amount of water dispensed based on the cleaning requirements, ensuring that the robot uses water efficiently and avoids over-wetting the floor.

1.4.3 Drying Fan Operation

In addition to mopping, the floor cleaning robot often includes a drying mechanism, such as a high-speed fan, to dry the floor after cleaning. The HC-05 module facilitates remote control of the drying fan, allowing the user to turn it on or off as required. Similar to the water pump control, the drying fan is activated by a command sent from the smartphone. The HC-05 module transmits this command to the microcontroller, which then powers the fan motor through a relay or motor driver circuit. The ability to control the drying fan remotely is particularly useful in ensuring that the floor is left dry and safe after cleaning, preventing slip hazards.

1.4.4 Mop On/Off Control

The mopping mechanism of the robot, which typically consists of a rotating or vibrating mop, is another function that can be controlled via the HC-05 module. The user can remotely activate or deactivate the mop, depending on the cleaning task at hand. When the user sends a command to start or stop the mopping function, the HC-05 module relays this command to the microcontroller, which controls the motor responsible for the mop's operation. This allows for precise control over the mopping process, ensuring that the robot only mops areas that require cleaning and avoids unnecessary wear on the mop.

1.4.5 Use of ASCII for Command Processing

A crucial aspect of the HC-05 module's operation in the floor cleaning robot is the use of ASCII (American Standard Code for Information Interchange) to process commands. ASCII is a character encoding standard used to represent text in computers and communication devices. Each command sent from the smartphone is converted into an ASCII string, which the HC-05 module transmits to the microcontroller. For instance, when the user sends a command to move the robot forward, the smartphone app might send the ASCII string "FWD" to the HC-05 module. The module then transmits this string to the microcontroller over a serial connection. The microcontroller is programmed to recognize the "FWD" string and respond by activating the motors to move the robot forward. Similarly, other commands such as "BWD" (backward), "LFT" (left), "RGT" (right), "PUMP ON", "PUMP OFF", "FAN ON", "FAN OFF", "MOP ON", and "MOP OFF" are all processed using ASCII encoding. The use of ASCII simplifies the communication process, as the microcontroller can easily interpret the incoming strings and execute the corresponding actions.

1.4.6 Features of Using the HC-05 Module

The HC-05 Bluetooth module offers several advantages in the context of the floor cleaning robot:

i. **Wireless Control**: The HC-05 module allows for wireless control of the robot, eliminating the need for physical connections and enabling the user to operate the robot from a distance.
ii. **Real-Time Operation**: The module supports realtime communication, ensuring that the robot responds immediately to user commands, which is critical for tasks requiring precise timing and coordination.
iii. **Ease of Integration**: The HC-05 is easy to integrate with microcontrollers, thanks to its simple serial communication interface. This makes it a popular choice for DIY projects and commercial robotics applications.
iv. **Low Power Consumption**: The module operates with low power consumption, which is important for battery-powered devices like floor cleaning robots. This helps extend the robot's operational time between charges.
v. **Cost-Effective**: The HC-05 is an affordable solution for adding Bluetooth functionality to a robot, making it accessible for both hobbyists and professional developers.

1.4.7 Challenges and Considerations

While the HC-05 module offers numerous benefits, there are also challenges that must be addressed:

i. **Limited Range**: The effective range of the HC-05 module is limited to around 10 meters, which can be a constraint in larger spaces or environments with significant obstacles.
ii. **Interference**: Bluetooth operates in the 2.4GHz frequency range, which is shared with other devices such as Wi-Fi routers and microwaves. This can lead to interference and potential communication issues. iii. **Security**: Bluetooth communication can be vulnerable to unauthorized access if not properly secured. Implementing security measures such as pairing codes or encryption is essential to protect the robot from unauthorized control.

The HC-05 Bluetooth module is a versatile and effective tool for controlling a floor cleaning robot. Its ability to facilitate wireless communication between the user's smartphone and the robot enables remote control of movement, water pumping, drying, and mopping functions. By using ASCII encoding to process commands, the HC-05 ensures that the robot can interpret and execute user instructions with precision. Despite some challenges, such as limited range and potential interference, the HC-05 remains a popular choice for robotics applications, offering a cost-effective, easy-tointegrate solution for wireless control. As technology advances, the use of Bluetooth modules like the HC-05 will continue to play a significant role in the development of intelligent, connected robots for a variety of applications.

1.5 Buck Converter (Step-Down)

A buck converter, also known as a step-down converter, is an essential component in power management systems, particularly when it is necessary to reduce a higher voltage to a lower, more usable level. In the context of powering an Arduino, which typically operates at 9V or 5V, a buck converter can be used to step down a 12V input (commonly supplied by batteries or power adapters) to 9V. This efficient conversion process ensures that the Arduino receives the correct voltage without wasting energy, thereby extending battery life and improving overall system efficiency.

1.5.1 Working Principle of the Buck Converter

A buck converter operates using a switching regulator to reduce the input voltage to a lower output

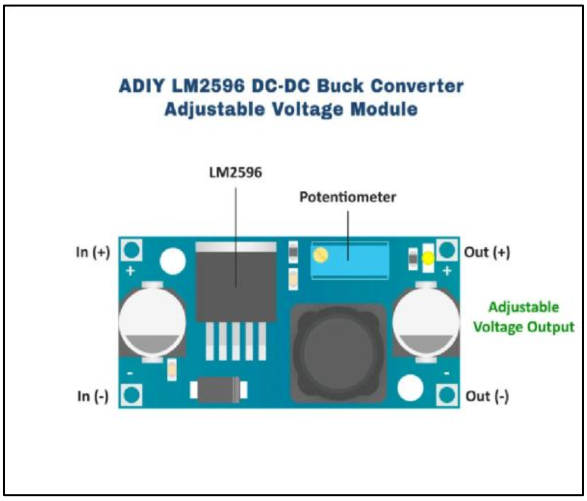

Figure 9: - Labelled Diagram of Buck Converter [8]

voltage. The core components of a buck converter include an inductor, a diode, a capacitor, and a switch (usually a transistor). The switch alternates between on and off states at high frequency, controlling the flow of current through the inductor. When the switch is on, energy is stored in the inductor's magnetic field. When the switch turns off, the inductor releases the stored energy, which is then smoothed out by the capacitor to provide a stable output voltage. The key advantage of a buck converter is its high efficiency, often exceeding 90%, because it minimizes energy loss compared to linear regulators. This efficiency is particularly important in battery-powered systems, such as those using an Arduino, where conserving power is critical.

1.5.2 Application in Arduino Power Supply

In a floor cleaning robot or similar embedded system, a 12V power supply might be used to drive motors and other high-power components. However, the Arduino microcontroller typically requires a lower voltage for safe operation. A buck converter steps down the 12V supply to 9V, providing a stable and efficient power source for the Arduino, ensuring reliable performance without overheating or voltage-related damage. This setup also allows the use of a single power supply for both high-power components and the Arduino, simplifying the overall power management system.

1.6 DC-Water-Pump

The 5V DC water pump is a compact, efficient, and versatile component widely used in small-scale applications such as floor cleaning robots. In the context of a floor cleaning robot, this pump plays a crucial role in dispensing water or cleaning solution onto the floor surface, preparing it for the mopping mechanism to effectively clean and remove dirt. The use of a 5V DC water pump is ideal for this purpose due to its low power consumption, ease of integration with microcontrollers, and sufficient flow rate to cover the cleaning area without excessive water use.

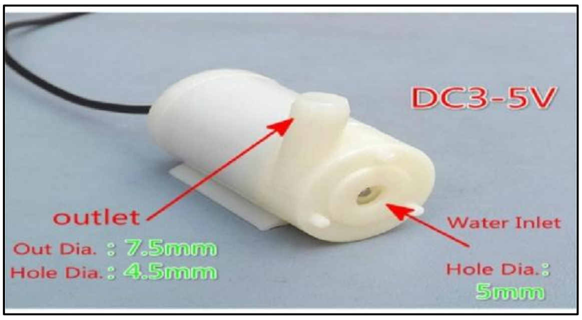

Figure10: - DC Water Pump[9]

1.6.1 Functionality and Operation

The 5V DC water pump operates on a simple yet effective principle. When powered, the motor inside the pump drives an impeller, which creates suction at the inlet and forces water out through the outlet. The pump is typically submersible, meaning it can be placed directly in the water tank of the robot, allowing it to draw water as needed. The compact size of the 5V DC pump makes it easy to integrate into the limited space available within a small robot, while the low voltage requirement ensures that it can be powered directly by the robot's onboard power supply, typically managed by a microcontroller like the Arduino. In a floor cleaning robot, the 5V DC pump is usually controlled by the microcontroller via a relay or transistor switch. The user can activate or deactivate the pump through a remote interface, such as a smartphone app, allowing precise control over when and how much water is dispensed. This control is crucial for ensuring that the robot does not over-wet the floor, which could lead to slipping hazards or ineffective cleaning.

1.6.2 Outcomes in Floor Cleaning Applications

One of the main advantages of using a 5V DC water pump in floor cleaning robots is its efficiency. The pump can deliver a sufficient flow rate to wet the floor adequately without draining the battery quickly, making it suitable for prolonged cleaning sessions. Additionally, the pump's ability to be controlled digitally allows for automation in water dispensing, contributing to the robot's overall effectiveness and user convenience. Moreover, the low operating voltage and current draw of the 5V DC pump make it compatible with various microcontroller platforms, reducing the need for additional power management components. This compatibility simplifies the design and construction of the robot, making it easier to develop and maintain. In summary, the 5V DC water pump is an essential component in the design of a floor cleaning robot, providing a reliable and efficient means of water delivery for effective cleaning. Its integration with the robot's control system allows for precise and automated water management, ensuring that the robot can clean floors effectively and efficiently while maintaining power efficiency.

1.7 Battery (12v-1.2A)

A 12V 1.2A battery is a critical component in powering a floor cleaning robot, providing the necessary energy to operate all the electronics, motors, and the water pump. This battery serves as the central power source, ensuring that the robot can perform its tasks effectively and for an extended period without frequent recharging.

1.7.1 Capacity and Power Supply

The 12V rating indicates the voltage supplied by the battery, which is suitable for driving the 12V DC motors responsible for the robot's movement and turning. The 1.2A (ampere-hour) capacity denotes the amount of current the battery can supply over time, which is a crucial factor in determining the robot's operational duration. For example, a 1.2A capacity means the battery can deliver 1.2 amperes of current continuously for an hour, or lower currents for longer periods, depending on the power demands of the system. In the floor cleaning robot, the battery powers not only the motors but also the microcontroller, sensors, and other peripherals. To ensure stable operation, a buck converter is often used to step down the 12V supply to lower voltages required by components like the Arduino microcontroller. The battery's ability to supply consistent voltage and current is essential for maintaining the robot's performance, especially when multiple motors and the water pump are operating simultaneously.

Figure 11: - 12V Battery [10]

A well-chosen 12V 1.2A battery provides a balance between power and efficiency, allowing the robot to operate for a reasonable duration while maintaining sufficient power for all its functions. The battery's longevity and rechargeability also contribute to the robot's overall sustainability, reducing downtime and operational costs. In summary, the 12V 1.2A battery is a vital element in the floor cleaning robot, offering a reliable and efficient power source that ensures the seamless operation of all its components.

1.8 Switch

The switch used to turn the floor cleaning robot on and off is a crucial component that controls the entire power supply. Positioned conveniently on the robot, it allows users to easily start or shut down all systems with a single action. This switch directly connects to the main battery circuit, enabling or disabling the flow of power to the microcontroller, motors, and other electronics. It's simple yet essential function ensures that the robot can be safely powered on for operation and turned off to conserve energy and protect components when not in use.

1.9 Water Storage Tank(500ml)

In designing the floor cleaning robot, we prioritized sustainability and cost-effectiveness by repurposing a recyclable juice bottle as the water storage tank. This approach not only promotes reusability but also aligns with the principles of eco-friendly design. By using a previously discarded juice bottle, we effectively reduce waste and minimize the environmental impact associated with manufacturing new components. The juice bottle serves as an ideal water storage tank due to its durability, light weight, and ample capacity to hold enough water for a complete cleaning session. Its transparency also allows for easy monitoring of the water level, ensuring that the user knows when a refill is needed. The bottle's original cap was modified to include a secure fitting for the 5V DC water pump, enabling efficient water dispensing during the robot's operation. This choice of material not only saved costs but also demonstrated how everyday items can be repurposed for innovative technological applications. By integrating a recycled juice bottle into this robot, we highlight the importance of sustainability in engineering design, proving that high functionality can be achieved without compromising environmental responsibility or incurring unnecessary expenses.

1.10 Drone Propellers (2)

In the design of the floor cleaning robot, we employed a drone propeller attached to a high-speed 12V DC motor for the drying function. This innovative use of a drone propeller leverages its lightweight yet durable construction, allowing it to spin at high speeds and create a powerful airflow. The 12,000 RPM motor, paired with the propeller, efficiently directs this airflow across the wet surface, accelerating the drying process and ensuring that the cleaned area is left spotless and moisture-free. Drone propellers are designed for high rotational speeds and efficient air movement, making them ideal for this application. The propeller's aerodynamic shape maximizes air displacement with minimal energy consumption, aligning with the goal of maintaining the robot's overall power efficiency. Additionally, using a readily available drone propeller reduces costs and simplifies the integration process, as it easily mounts onto the motor shaft. This setup not only enhances the robot's drying capability but also reflects a thoughtful repurposing of components typically found in other technology domains. By utilizing a drone propeller, we achieve a highly effective drying mechanism that contributes to the robot's overall performance in maintaining clean, dry floors.

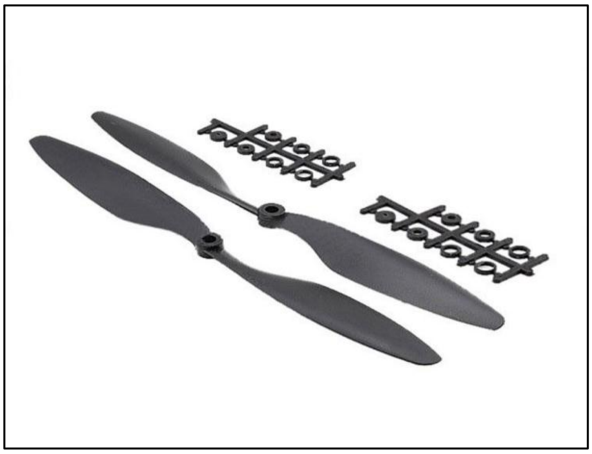

Figure 14: - Drone Propellers for drying [13]

1.11 Wooden Chassis

The floor cleaning robot is built on a robust wooden chassis, designed to provide a strong and stable foundation for all its components. This chassis serves as the central framework, supporting the four 12V 100 RPM DC motors with wheels that enable the robot's movement and turning capabilities. The choice of wood for the chassis was driven by its durability, ease of machining, and ability to absorb vibrations, which is crucial for maintaining stability during operation. The wooden chassis not only holds the motors securely in place but also provides a sturdy platform for mounting other key components, including the water storage tank and the high-speed motor with its drone propeller for drying. The strategic arrangement of these components on the chassis ensures balanced weight distribution, which enhances the robot's maneuverability and overall performance. Wood's inherent strength allows the chassis to withstand the stresses of daily operation, including the load from the water tank and the forces generated by the spinning propeller. Additionally, using wood aligns with the project's focus on cost-effectiveness and sustainability, as it is a readily available and recyclable material. Overall, the wooden chassis is a critical element that contributes to the durability, functionality, and efficiency of the floor cleaning robot.

1.12 Jumper Wires

Jumper wires play a crucial role in the assembly of the floor cleaning robot, serving as the primary means of establishing electrical connections between various components. These wires, typically made of insulated copper, are essential for creating flexible and reliable connections in prototyping and final designs alike. In the floor cleaning robot, jumper wires are used to link the Arduino microcontroller with other key components, including the 12V DC motors, the 5V water pump, the HC-05 Bluetooth module, and the buck converter. Each connection is carefully made to ensure that signals and power are transmitted correctly across the system. For instance, jumper wires connect the digital and analog pins of the Arduino to the motor driver, enabling precise control of the motors responsible for the robot's movement and turning. Similarly, they connect the power outputs of the buck converter to the Arduino, ensuring the microcontroller receives the stable 9V it needs to function properly. The use of jumper wires also simplifies the integration of the Bluetooth module, which controls the robot's various functions via smartphone commands. By connecting the module to the appropriate pins on the Arduino, the robot can receive and execute commands such as moving forward, backward, or turning, as well as activating the water pump or the drying fan. One of the key advantages of jumper wires is their ease of use, allowing for quick modifications and troubleshooting during the design and testing phases. They come in various lengths and colors, which aids in organizing the wiring and avoiding confusion during assembly. The flexibility of these wires also helps in neatly routing connections, reducing the risk of short circuits or loose connections. Overall, jumper wires are indispensable in the construction of the floor cleaning robot, providing the necessary connectivity to ensure all circuits and components work together seamlessly. Their versatility and reliability contribute significantly to the robot's functionality and ease of assembly.

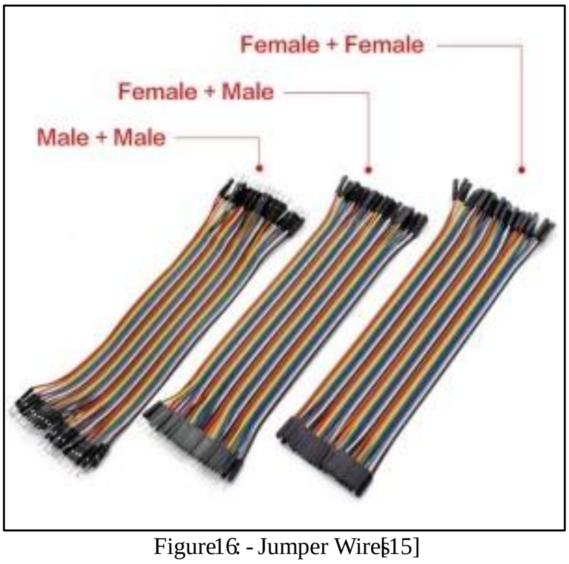

Figure16: - Jumper Wires[15]

1.13 Scrub for scrubbing the stains

The floor cleaning robot utilizes a rotating scrubber to effectively remove stains and dirt from surfaces. Attached to the robot's chassis, the scrubber features a brush or pad that rotates rapidly, leveraging friction to dislodge and lift grime from the floor. This rotating motion ensures thorough cleaning by covering a larger area more efficiently than static brushes. The scrubber's design allows it to apply consistent pressure and adapt to various floor textures, enhancing its ability to tackle stubborn stains. This mechanism, combined with the robot's automated movement, ensures a comprehensive and efficient cleaning process.

The below scrub is used in this Floor cleaning robot by attaching the scrub to 12v 100rpm motor mounted in the front of the robot, the mechanism is in such manner that the scrub moves in a rotational manner in order to cover maximum area for cleaning at a decent spinning rate. The scrub is also a costeffective way as this scrub can be purchased from any supplies store around the market. Such two scrubs have been used in the floor cleaning robot to provide more greater cleaning area. The two scrubs are glued together in a rectangular manner and attached to the 12v DC 100rpm motor.

1.14 Wheels

The wheels used in the floor cleaning robot are integral to its movement and overall functionality, providing the necessary traction and stability to navigate various floor surfaces. These wheels are typically chosen for their durability, maneuverability, and ability to handle the weight of the robot and its components. For the floor cleaning robot, we selected durable rubber wheels, which offer excellent grip on different types of flooring, from tiles and hardwood to carpets. Rubber wheels are favored for their traction, which prevents slipping and ensures smooth, controlled movement across surfaces. This is crucial for maintaining consistent contact with the floor, ensuring that the cleaning mechanisms, such as the scrubber and drying fan, operate effectively. The wheels are mounted on 5V DC motors, which drive them forward, backward, and allow for turning. The motors' 100 RPM speed provides a balance between sufficient movement speed and the precision required for navigating tight spaces. The wheels are connected to the robot's chassis through a robust mounting system that secures them firmly in place, minimizing vibrations and ensuring stability during operation. Additionally, the choice of wheels affects the robot's ability to perform tasks like turning and maneuvering around obstacles. Larger wheels with a substantial tread pattern can handle uneven surfaces and small obstacles, enhancing the robot's versatility and effectiveness in cleaning. For improved maneuverability, some designs incorporate omni-wheels or swivel casters, allowing the robot to change direction easily without requiring complex turning maneuvers. In summary, the wheels in the floor cleaning robot are selected for their durability, traction, and compatibility with the motor system, ensuring reliable movement and efficient operation. Their design and functionality are crucial for the robot's overall performance, contributing to its ability to clean various floor types effectively.

Figure 18: - Wheels for controlling the robot in all direction [17]

1.15 Table consisting component details

Table 1.1: - Components, Details, Specifications

Component	Details	Rating/Specifications
Arduino Uno	Microcontroller board	ATmega328P, 16 MHz clock
12V DC Motors (4)	For movement and turning	12V, 100 RPM
High-Speed DC Motor	For drying	12V, 12,000 RPM
Buck Converter	Steps down 12V to 9V for Arduino	Input: 12V, Output: 9V, Adjustable
5V DC Water Pump	For dispensing water	5V, flow rate: ~120L/hr
HC-05 Bluetooth Module	For wireless communication with smartphone	Bluetooth 2.0, Range: ~10m
Jumper Wires	Flexible wiring for connections	Various lengths and colors
Drone Propeller	Attached to highspeed motor for drying	Standard drone propeller size
Wooden Chassis	Frame for mounting components	Custom size, durable wood
Water Storage Tank	Recycled juice bottle for water storage	500ml capacity (approx.)
Scrubber Brush	Rotating brush for cleaning stains	Custom design, rotating
Wheels (4)	Rubber wheels for movement	2.5" diameter (approx.), rubber tread
Switch	On/Off switch for controlling the robot	Rated for 12V, standard toggle switch

II. METHODOLOGY

i. System Design and Component Selection

The methodology of developing a smartphonecontrolled floor cleaning robot begins with a thorough design phase. In this phase, the system's architecture is conceptualized, focusing on both the hardware and software requirements necessary to achieve the project's objectives. The selection of components is driven by the need for efficiency, cost-effectiveness, and ease of integration. The **Arduino Uno board** was chosen as the central processing unit due to its open-source nature, ease of programming, and ability to handle multiple inputs and outputs. The board's versatility allows it to control various peripherals, including motors, sensors, and communication modules. For motor control, the **L293D motor driver board** was selected. This driver is capable of controlling the direction and speed of the DC motors used for the robot's movement and the mop's rotation. Its ability to handle high current loads and control multiple motors simultaneously makes it ideal for this application. To enable wireless communication between the robot and the user's smartphone, the **HC-05 Bluetooth module** was selected. This module is well-suited for establishing a serial communication link between the Arduino and the smartphone, allowing for remote control of the robot. The robot's mobility is powered by **12V DC motors** rated at 100 RPM. These motors are used for driving the wheels and provide sufficient torque and speed for the robot to move across various floor surfaces. Additionally, a **high-speed 12V DC motor** rated at 12,000 RPM is used to drive the drying fan, ensuring effective water evaporation from the floor. A **step-down buck converter** is employed to reduce the 12V power supply from the battery to 9V, which is necessary for powering the Arduino Uno. This component is crucial in managing power distribution across the system, ensuring that each component operates within its specified voltage range. The **5V DC water pump** was selected for its ability to efficiently dispense water onto the floor during cleaning. The pump's low power consumption and sufficient flow rate make it an ideal choice for this application. Lastly, a variety of **peripherals** such as the wooden chassis, wheels, jumper wires, and a recycled water storage tank are chosen to support the core components, providing a stable and functional structure for the robot.

ii. Hardware Assembly

With the components selected, the next phase is hardware assembly. This involves the physical integration of the components onto a custom-designed chassis. The wooden chassis is carefully measured and cut to provide a stable platform for mounting the motors, water tank, Arduino, and other components.

The **DC motors** are mounted onto the chassis using secure brackets, ensuring they are aligned for optimal movement. Wheels are attached to the motor shafts, providing the robot with the ability to move forward, backward, and turn. The high-speed motor is positioned to drive the drying fan, which is also securely attached to the chassis. The **Arduino Uno**, motor driver, and Bluetooth module are mounted in positions that facilitate easy wiring and access. The wiring process involves connecting the motors to the motor driver board and linking the driver to the Arduino's digital output pins. The water pump is connected to the motor driver as well, allowing for precise control of its operation. A **buck converter** is wired to step down the 12V power from the battery to 9V, which is then fed to the Arduino. This ensures the Arduino and other sensitive components receive the correct voltage, preventing damage or malfunction. Jumper wires are used to establish connections between the various components, with attention to proper insulation and routing to avoid short circuits. The **water storage tank**, made from a recyclable juice bottle, is installed onto the chassis. The tank is connected to the water pump via tubing, allowing for controlled water dispensing during operation. Finally, the overall assembly is checked for structural integrity and proper alignment of all components.

iii. Software Development

In parallel with hardware assembly, software development is initiated to define the robot's behavior and control mechanisms. The **Arduino Integrated Development Environment (IDE)** is used to program the Arduino Uno, utilizing the C/C++ programming language. The software is divided into modules, each responsible for controlling a specific aspect of the robot's operation. The motor control module manages the speed and direction of the DC motors, allowing the robot to move forward, backward, and turn based on commands received from the Bluetooth module. The water pump and mop motor are controlled through additional modules, enabling precise control over their operation. Bluetooth communication is handled through a dedicated software routine that interprets commands sent from the smartphone app. ASCII codes are used to translate user inputs into actions, such as starting or stopping the motors, activating the water pump, or turning on the drying fan. This approach simplifies the communication process and ensures reliable execution of commands. Debugging and iterative testing are conducted throughout the development process to ensure the firmware operates correctly under various conditions. The software is refined to optimize performance and responsiveness, ensuring the robot performs its cleaning tasks efficiently.

iv. Integration and Testing

Once the hardware and software are complete, the system undergoes integration. This phase involves connecting all components and verifying that they work together as intended. The robot is powered on, and initial tests are conducted to check basic functionality, such as movement, Bluetooth connectivity, and water dispensing. **System-level testing** is performed to evaluate the robot's ability to navigate a typical floor space. The robot's response to commands from the smartphone app is tested to ensure accurate movement and operation of the mop and drying fan. Any issues identified during testing are addressed through hardware adjustments or software updates. Special attention is given to **battery management** and power consumption, ensuring that the robot can operate for a reasonable duration without needing frequent recharges. The integration process also involves fine-tuning the motor speeds and adjusting the mop's rotation to achieve optimal cleaning performance.

v. Smartphone Application Development

Simultaneously with the robot's development, a smartphone application is created to provide users with an intuitive interface for controlling the robot. The app is designed to connect to the HC-05 Bluetooth module, allowing users to send commands to the robot from their smartphones. The app's user interface is designed with simplicity in mind, featuring buttons for controlling movement, starting and stopping the mop, and activating the water pump and drying fan. The app also includes real-time feedback, displaying the robot's current status and any errors that may occur. The app is tested extensively to ensure reliable Bluetooth connectivity and accurate transmission of commands. User experience is a key focus, with the goal of making the app easy to use, even for individuals with little technical expertise.

vi. Evaluation and Optimization

The final phase of the methodology involves evaluating the robot's performance and making any necessary optimizations. **User feedback** is collected to gauge satisfaction with the robot's cleaning efficiency, ease of use, and overall functionality. Based on this feedback, iterative improvements are made to both hardware and software. This may include adjusting the motor speeds, refining the app's user interface, or improving the robot's ability to navigate complex floor layouts. The robot is also tested under different conditions, such as varying floor types and levels of dirt, to ensure it performs consistently across different scenarios. The goal of this phase is to enhance the robot's reliability, efficiency, and user experience, ultimately delivering a highquality floor cleaning solution.

III. CODE

The coding for the smartphone-controlled floor cleaning robot is a critical part of the project that ensures the proper functioning of the various components. The Arduino sketch provided here leverages the AFMotor library to control four DC motors, a water pump, and a mop motor. The code is structured to interpret commands received via Bluetooth, and execute corresponding actions, making the robot responsive to user input through a smartphone interface.

i. Code Breakdown-Library Inclusion and motor initialization

```
#include <AFMotor.h>  // Include the AFMotor library

AF_DCMotor motor1(1);  // Left first and second wheel
AF_DCMotor motor2(2);  // Water pump
AF_DCMotor motor3(3);  // Mop
AF_DCMotor motor4(4);  // Right first and second wheel
```

Figure20:- LibraryInclusion

The code begins by including the AFMotor library, which simplifies the control of DC motors using the Adafruit Motor Shield. Four DC motors are initialized, each assigned to a different port on the motor shield. motor1 and motor4 are connected to the left and right wheels respectively, enabling the robot to move forward, backward, and turn. motor2 controls the water pump, while motor3 operates the mop.

ii. Serial communication setup

```
int readString1;  // Variable to store incoming serial data
char state;

void setup() {
  Serial.begin(9600);  // Start serial communication at 9600 baud rate

  motor1.setSpeed(219);  // Motor speed for left two wheels
  motor2.setSpeed(190);  // Motor speed for the pump
  motor3.setSpeed(255);  // Motor speed for the mop
  motor4.setSpeed(219);  // Motor speed for right two wheels
}
```

Figure 21: - Setting up the serial communication between phone and robot

The setup () function is used to initialize serial communication with a baud rate of 9600, which is standard for communicating with the HC-05 Bluetooth module. The speeds of the motors are set using the setSpeed() function, which determines how fast each motor will run. The values chosen for each motor reflect the desired operational speeds: the wheels are set to 219 for balanced movement, the pump to 190 for moderate water flow, and the mop to 255 for maximum scrubbing efficiency.

iii. Command reception and execution

```
void loop() {
  if (Serial.available() > 0) {
    readString1 = Serial.read();
    Serial.println(readString1);
  }
```

Figure 22: - Reading the incoming values form the smartphone

The loop() function continuously checks if any data has been received via serial communication (from the Bluetooth module). If a command is received, it is stored in readString1 and printed for debugging purposes. This ensures that each command is acknowledged and can be traced back if needed.

iv. Motor Control Based on Commands

```
if (readString1 == 'F') {
  motor1.run(FORWARD);
  motor4.run(FORWARD);
}

if (readString1 == 'f') {
  motor1.run(RELEASE);
  motor4.run(RELEASE);
}
// Other similar commands follow
```

Figure 23: - Initialization of motors

v. Mop and Water Pump Control

```
  if (readString1 == 'I') {
    motor3.run(FORWARD);  // Mop on
  }

  if (readString1 == 'P') {
    motor3.run(RELEASE);  // Mop off
  }

  if (readString1 == 'T') {
    motor2.run(FORWARD);  // Water pump on
  }

  if (readString1 == 't') {
    motor2.run(RELEASE);  // Water pump off
  }

  Serial.println(readString1);  // Print the received command for debugging
}
```

Figure 24: - Initializing Mop and Water pump

Similar to movement commands, the mop and water pump are controlled using specific commands. For instance, sending 'I' turns on the mop by running motor3 forward, while 'P' stops it. The water pump is controlled in a similar fashion with 'T' and 't'. This allows the user to activate or deactivate these functions as needed during the cleaning process, giving them full control over the robot's operations.

vi. Analysis

The coding aspect of the smartphone-controlled floor cleaning robot plays a crucial role in orchestrating the operations of various hardware components. Using the Arduino Integrated Development Environment (IDE), the code is structured to control the movement of the robot, the operation of the water pump, and the mop motor, all through commands sent from a smartphone via Bluetooth.

The **AFMotor library** is employed to simplify the control of DC motors connected to the Adafruit Motor Shield, making it easier to manage the robot's wheels, mop, and water pump. The robot's responsiveness to user inputs is achieved through serial communication with the **HC-05 Bluetooth module**. Commands received from the smartphone are interpreted by the Arduino and mapped to specific actions, such as moving forward, backward, turning, or activating the mop and water pump. Each command corresponds to a specific motor operation, ensuring precise control over the robot's functions. The code's efficiency and clarity make it easy to modify or extend the robot's capabilities in future iterations. By handling all critical operations programmatically, the code serves as the brain of the robot, enabling it to perform complex tasks with minimal user intervention.

IV. RESULTS AND DISCUSSION

The development and testing of the smartphonecontrolled floor cleaning robot yielded promising results, demonstrating that the integration of various components and the corresponding code implementation were successful in achieving the project's primary objectives. The robot was designed to efficiently clean floors using a combination of mechanical and electronic systems, including DC motors, a water pump, a mop, a Bluetooth module, a drone propeller for drying, and a robust chassis. The results were evaluated based on the robot's ability to perform the cleaning tasks effectively, its responsiveness to user commands via Bluetooth, and the overall ease of operation.

i. System Performance and Task Completion

The robot was tested in various environments, including different types of flooring such as tiles, hardwood, and laminate. During these tests, the robot successfully moved forward, backward, and turned left and right, as expected, when commanded via the smartphone interface. The four 12V, 100 RPM DC motors driving the wheels provided adequate torque and speed, allowing the robot to navigate the floor smoothly and avoid obstacles. The motor control coding, implemented through the AFMotor library, proved effective in managing these movements, ensuring that the robot responded promptly to user inputs. The water pump, powered by a 5V DC motor, was tested for its ability to dispense water evenly across the floor surface. The pump performed well, delivering a consistent flow of water as required for effective mopping. The robot's mop, attached to a 12V, 100 RPM motor, rotated efficiently, covering a wide area and scrubbing the floor with sufficient force to remove dirt and stains. The mop motor's speed and rotation were well-calibrated, allowing for thorough cleaning without causing any damage to the flooring. The drying mechanism, which utilized a 12V, 12000 RPM high-speed motor coupled with a drone propeller, effectively dried the floor after mopping. The high-speed rotation of the propeller generated a strong airflow, significantly reducing the drying time. This feature was particularly useful on non-porous surfaces like tiles, where water tends to accumulate.

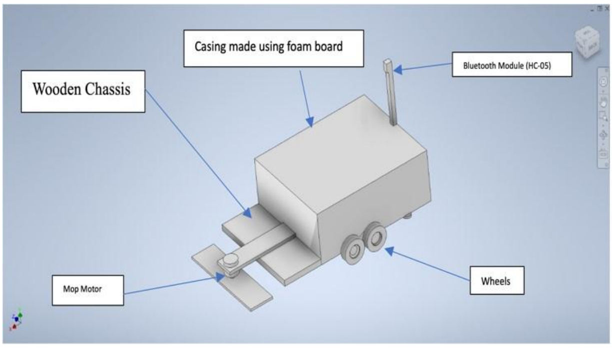

Figure26: - 3D-View of Floor cleaning robot

The robot's wooden chassis provided a stable and durable platform for mounting all components, including the motors, water tank, and drying fan. The chassis' design ensured that all components were securely attached and that the robot maintained its balance during operation. The recyclable juice bottle used as the water storage tank was both cost-effective and eco-friendly, aligning with the project’s goal of promoting sustainability.

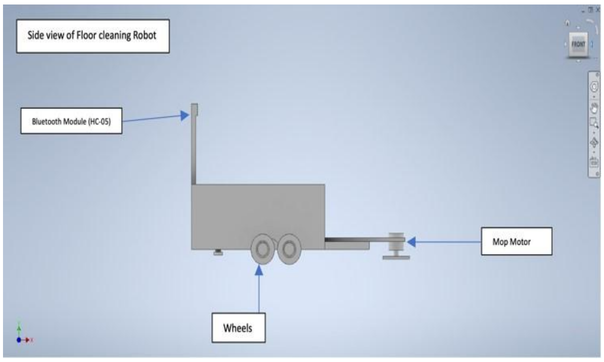

Figure27: - Side view of Floor cleaning robot ii. Bluetooth Communication and User Interface

The HC-05 Bluetooth module played a crucial role in the robot's operation, enabling wireless communication between the smartphone and the robot. The module was integrated with the Arduino Uno, allowing it to receive ASCII commands from the smartphone and convert them into motor actions. The Bluetooth connection remained stable throughout the testing, with no significant delays or interruptions in communication. The user interface, developed as a smartphone application, was intuitive and easy to use. Users were able to send commands to the robot, such as moving forward, backward, turning, activating the mop, and operating the water pump and drying fan, all with a few taps on their smartphones. The application provided realtime feedback on the robot's status, ensuring that users were always aware of its current operation. The coding implemented for the robot, particularly in managing motor control and Bluetooth communication, was robust and reliable. The use of simple, easily recognizable commands (e.g., 'F' for forward, 'B' for backward) allowed for smooth operation and minimized the risk of errors. The system's ability to handle multiple commands in sequence further enhanced the robot's functionality, making it a versatile tool for floor cleaning.

iii. Hardware Integration and Stability

The integration of hardware components was critical to the robot's overall performance. The buck converter, which stepped down the 12V battery supply to 9V to power the Arduino, performed efficiently, ensuring that the Arduino operated within its safe voltage range. This allowed the microcontroller to function reliably, without overheating or voltage drops, even when multiple components were operating simultaneously.

Figure 29: - Actual Side view of Floor cleaning robot

The use of jumper wires for connections between the various electronic components, such as the motors, buck converter, Bluetooth module, and Arduino, provided flexibility and ease of assembly. The connections were secure, with no issues of loose or faulty wiring observed during testing. This reliability in wiring ensured consistent performance and reduced the likelihood of electrical failures.

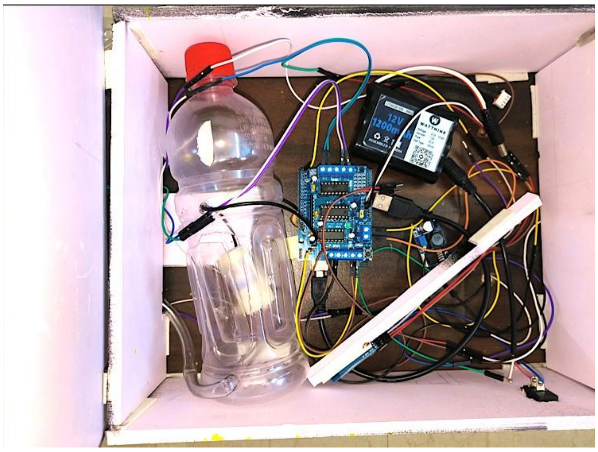

Figure 30: - Inside view of Floor cleaning robot(connections)

iv. Evaluation and Future Development

Overall, the robot performed its intended tasks with a high degree of accuracy and efficiency. It was able to clean a variety of floor surfaces, respond to user commands promptly, and operate without significant issues. The design and implementation of the robot proved to be effective in achieving the project's objectives, demonstrating the viability of using an Arduino-based system for floor cleaning automation. However, the results also indicated areas where future improvements could be made. For instance, while the robot was able to navigate floors and clean effectively, its ability to detect and avoid obstacles was limited. Incorporating additional sensors, such as ultrasonic or infrared sensors, could enhance the robot's autonomy and allow it to better navigate complex environments without manual intervention. The water dispensing system, while functional, could also benefit from optimization. The amount of water dispensed was adequate for most surfaces, but finer control over water flow could be implemented to better suit different flooring types. This could be achieved by integrating a more sophisticated control system for the water pump, possibly using pulse-width modulation (PWM) to adjust the flow rate dynamically. The drying mechanism, although effective, could be made more energy-efficient. The high-speed motor used for the drying fan consumed a significant amount of power, which could be reduced by exploring alternative drying methods or optimizing the airflow design. Another area for potential development is the user interface. While the current smartphone application provided basic control functions, adding features such as scheduling, automatic room mapping, and cleaning pattern optimization could greatly enhance the robot's usability and appeal. Additionally, integrating the robot with smart home systems, such as Amazon Alexa or Google Home, would allow for voice-activated control, further increasing its convenience.

V. UTILITY

The smartphone-controlled floor cleaning robot offers significant utility in multiple aspects. By incorporating various components like a rotating mop, high-speed dryer, water pump, and a reservoir, it effectively meets the practical demands of floor cleaning. The robot simplifies a typically labor-intensive household chore, offering an automated solution that is both efficient and user-friendly. The Bluetooth connectivity and smartphone control features allow users to easily initiate and customize the cleaning process, adapting it to the specific needs of their living space.

This remote-control capability not only enhances convenience but also optimizes the use of resources, making it easier to achieve a thorough clean with minimal effort. The design of the robot also takes into account the growing trend of compact living spaces, such as apartments and smaller homes. Its ability to maneuver in confined spaces ensures that areas which may be difficult to reach with traditional cleaning methods are cleaned effectively. This adaptability makes the robot particularly well-suited for modern living environments where space is at a premium. Beyond its immediate practical application, the robot also serves as a valuable educational tool. It demonstrates the potential of integrating repurposed components into new technological solutions, which can inspire future innovations. The robot's design highlights the importance of sustainability, showing that with thoughtful design, it's possible to create functional, automated solutions that also promote environmental consciousness. As smart home technologies continue to advance, the robot stands out as a practical addition to the automated home ecosystem. It not only addresses the immediate need for efficient floor cleaning but also contributes to a more connected and automated living environment. This makes it an essential part of any smart home setup, offering a blend of innovation, convenience, and sustainability.

VI. ENVIRONMENTAL BENEFITS AND USEFULNESS

The environmental and practical benefits of the smartphone-controlled floor cleaning robot are significant, reflecting a thoughtful integration of technology and sustainability. As households increasingly seek ways to reduce their environmental footprint, this robot exemplifies a move toward more eco-friendly living. The use of repurposed components, such as a recyclable juice bottle as a water reservoir, demonstrates a commitment to reducing waste and promoting reusability. By incorporating such elements, the robot not only minimizes the environmental impact associated with the production of new materials but also encourages users to think creatively about resource conservation in their everyday lives. The energy efficiency of the robot is another key aspect of its environmental value. The selection of components, such as the 12V DC motors and the buck converter, is geared toward optimizing power consumption. The motors provide sufficient torque and speed for effective cleaning while consuming minimal energy, and the buck converter ensures that the Arduino board and other electronics receive the appropriate voltage without unnecessary power loss. This careful management of energy resources means that the robot can perform its tasks without placing undue strain on the household's energy consumption, contributing to a reduction in overall energy use. In terms of practical usefulness, the robot's design is well-suited to the needs of modern living. The integration of a rotating mop and water pump allows it to effectively clean a variety of floor surfaces, from hardwood to tile, making it a versatile tool for households with different flooring types. The high-speed drying fan, powered by a drone propeller, ensures that floors are left dry and free of water marks, further enhancing the cleaning process. This combination of features means that the robot can tackle a range of cleaning tasks with ease, from removing dust and dirt to handling spills and stains. The robot's compact design is particularly advantageous for use in small living spaces, such as apartments and homes with limited floor areas. Traditional cleaning methods can be cumbersome in such environments, often requiring significant time and effort to maneuver around furniture and other obstacles. In contrast, the robot's ability to navigate tight spaces and clean under low-lying furniture makes it an ideal solution for those with limited space. Its user-friendly interface, enabled by Bluetooth connectivity and smartphone control, further adds to its practicality, allowing users to easily initiate and monitor the cleaning process without having to manually operate the device. Moreover, the robot serves as a practical example of how smart home technologies can be integrated into everyday life. As more households adopt smart home devices, there is a growing demand for products that not only enhance convenience but also align with environmental and sustainability goals. The robot's combination of automated cleaning and resource efficiency positions it as a valuable addition to any smart home setup. It not only addresses the need for effective cleaning but also contributes to a more sustainable and connected living environment. In summary, the smartphonecontrolled floor cleaning robot offers both environmental and practical benefits. Its design reflects a commitment to sustainability through the use of repurposed materials and energy-efficient components, while its functionality meets the demands of modern living. As households continue to seek out smart home solutions that align with their environmental values, this robot stands out as an innovative and useful tool that contributes to a cleaner, more sustainable home.

VII. CONCLUSION

At the core of this project is the Arduino Uno board, which serves as the brain of the robot. Its ease of use, versatility, and open-source nature made it an ideal choice for controlling the various components of the robot, including the DC motors, water pump, and Bluetooth communication module. The Arduino’s role in managing the robot’s operations, from movement to water dispensing, highlights the power of microcontroller-based systems in creating smart devices that respond to user commands with precision and reliability. The robot’s user-friendly interface, enabled by Bluetooth connectivity and smartphone control, adds a layer of convenience that enhances the overall user experience. By allowing users to initiate, monitor, and customize the cleaning process from their smartphone, the robot eliminates the need for manual operation and frees up time for other activities. This ease of use, combined with the robot’s ability to perform its tasks with minimal intervention, makes it an attractive solution for busy households looking to simplify their cleaning routine. While the robot performed well in testing and met its design goals, there is still plenty of room for future development. One potential area for improvement is the addition of autonomous features, such as obstacle detection and avoidance, which would allow the robot to navigate its environment more intelligently and with greater independence. Enhancing the robot’s sensor capabilities could also improve its ability to adapt to different floor types and cleaning conditions, further increasing its versatility and effectiveness. Another potential area for development is the optimization of the robot’s energy consumption. Although the current design is energy-efficient, there may be opportunities to further reduce power consumption through the use of more advanced components or by refining the robot’s control algorithms. This could extend the robot’s operating time and make it even more suitable for larger cleaning tasks or for use in homes with limited access to power outlets. The integration of additional smart features, such as voice control or integration with other smart home systems, could also enhance the robot’s appeal to tech-savvy consumers. As voice-activated assistants and smart home. In conclusion, the smartphone-controlled floor cleaning robot represents a successful integration of modern technology, practical utility, and environmental sustainability. Its ability to perform a wide range of cleaning tasks with minimal intervention makes it a valuable addition to any household, particularly those with compact living spaces. The robot’s design reflects a thoughtful approach to resource conservation and energy efficiency, while its userfriendly interface and smartphone control add a layer of convenience that enhances the overall user experience. As the project demonstrates, there is significant potential for further development and optimization. By incorporating autonomous features, optimizing energy consumption, and integrating additional smart capabilities, the robot could become an even more powerful and versatile tool for modern households. As smart home technologies continue to evolve, the floor cleaning robot stands out as an innovative solution that combines practicality with sustainability, making it a valuable contribution to the growing field of home automation.

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