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Internet of things-based floor cleaning robot

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ABSTRACT

Internet of things (IoT) based floor cleaning robot (FC-Rob) is a floor cleaning robot that uses a smartphone to assist users, primarily housewives and mothers, in completing their chores. The NodeMCU ESP8266 serves as the robot's "brain" and is controlled by a smartphone application for the purpose of this research. In accordance with current trends, an iOS and Android application using Blynk has also been developed for users to control the robot's movements, making it the ideal solution for time-crunched individuals. FC-Rob is propelled by two direct current (DC) motors to ensure comprehensive floor cleaning. The results of this research are strengthened by tests conducted on battery life and two types of fabric, as well as a comparison with two types of commercially available robots. The positive findings of these tests on this robot demonstrate its effectiveness and efficiency in cleaning houses, as well as its reasonable cost and educational value for children.

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1. INTRODUCTION

In today's rapidly advancing world, scientific and technological progress, particularly in electronic technology, has brought about significant changes in people's lives. These advancements have simplified and elevated our way of life, with the development of robots serving as notable examples of this progress. Robots are designed to aid humans in their daily tasks, aiming to make work more efficient and manageable, given the growing need for effective task completion. One such task is floor cleaning, a mundane chore that often gets postponed due to its tedious and tiring nature.

Several cleaning robots, including those designed for solar panel, floor, medical, window, stair, drain, paving, and pool cleaning, have been proposed [1]–[9]. The challenge lies in the substantial floor areas existing in buildings, which make floor cleaning a significant work. To address this, the concept of a floor-cleaning robot has emerged, offering a potentially innovative solution. Robotic cleaners have gathered significant attention in robotics research, mainly due to their ability to reform floor cleaning across diverse environments like residences, hotels, apartments, and commercial spaces. Traditional cleaning methods, involving brooms and mops, have proven time-consuming, often leading to discomfort and fatigue for users. Moreover, these methods unintentionally disperse dust, which can contribute to respiratory and flu-related issues. To counter these challenges, the development of advanced floor-cleaning robots has become paramount. The primary objective of this research is to cater to the needs of lower and middle-class users by creating an affordable cleaning robot. While addressing economic constraints is a key goal, the essence of the research remains centered on devising a more efficient means of eliminating dust from floors. By doing so, the research aims to lessen the burden of cleaning tasks, ensuring a more user-friendly experience. In addition to practicality, the research seeks to engage and educate children by allowing them to control the floor dryer robot through their smartphones. This interactive experience not only adopts technological understanding but also actively involves them in household responsibilities. Through this research, a way of learning through experiences is embraced, and a positive impact on daily living is anticipated. Notably, floor cleaning robot (FC-Rob) compared to other robots in the same category available on the market, is an inexpensive option.

In the world of science and technology that's always changing, people always want to make life better. Robots are used especially for cleaning floors, because they can make things easier and faster. This research is a combination of new ideas, making things accessible, and education. By creating a robot that can clean well and doesn't cost too much, the research helps more people. At the same time, it shows that knowing about technology is important for kids and encourages them to help with chores. Through these efforts, the research doesn't just make cleaning better; it also teaches young people a lot about technology.

Over the past decade, there has been a considerable amount of research focusing on the development and enhancement of cleaning robots. This surge in research activity signifies the growing interest and importance of these robots in various applications. One notable example is the creation of a specialized floor cleaning robot, as discussed in [10]. In this particular study, the author places a strong emphasis on strategies aimed at disinfection to eliminate harmful pathogens. This highlights the pivotal role cleaning robots can play in maintaining hygienic environments. Furthermore, the literature cited in [11], [12] explore into a different aspect of robot design which is reconfigurable mechanisms. These mechanisms allow robots to change their physical shape or behaviour, adapting to different environments. By incorporating adaptable forms, these robots can optimize their coverage of different spaces, thereby enhancing their effectiveness. Liu *et al.* [13] addresses another key aspect of cleaning robot functionality which is the path planning process. By utilizing sensor-based techniques, they focus on enabling robots to autonomously navigate and cover entire areas. This can lead to more efficient and thorough cleaning operations. Importantly, these advancements in cleaning robots hold practical benefits for various workplaces.

Notably, Ramalingam *et al.* [14] introduce a method for these robots to detect areas that require cleaning through vision-based technology. By targeting specific dirty spots, these robots can work more intelligently, saving time and resources. Moreover, Funek *et al.* [15] propose a strategy for dirt detection based on unsupervised learning methods. This approach equips cleaning robots with the ability to identify dirt without prior human guidance, which can greatly enhance their autonomy and efficiency.

The research described in [16] employs neural networks, a form of artificial intelligence, to enable robots to identify dirt. This is a significant step towards autonomous cleaning, as it reduces the need for constant human supervision. Additionally, some of these research studies have introduced practical features to enhance cleaning capabilities. For example, the inclusion of a water spray mechanism serves the purpose of mopping, adding an extra layer of cleaning functionality to these robots. A robot's ability to navigate a room on its own was detailed in [17]. This was achieved by using ultrasonic sensors linked to an Arduino Mega, which served as obstacle detectors. Furthermore, manual control of the robot was facilitated through an HC-05 Bluetooth module, and an application was created to govern the robot's movements. This allowed for both sweeping and mopping actions to be executed in a single motion. Liu *et al.* [13], Miao *et al.* [18] introduced a method called sensor-based complete coverage path planning (CCPP) for a cleaning robot that works in a dynamic environment. They also presented a technique for dividing large maps into smaller segments to make them more manageable. To explore extensive, unfamiliar areas, they employed a circular route.

While reconfigurable robots, as observed Prabakaran *et al.* [19], Tan *et al.* [20], can also be adapted for floor cleaning, they are typically designed for exploration and search-and-rescue missions [21]–[24]. These robots possess the unique advantage of altering their physical form based on obstacles and tight spaces, enabling them to effectively cover a wider area compared to robots with fixed shapes.

2. METHOD

This research involves several stages, including simulation, fabrication, and testing processes. Each stage holds significance in ensuring the success of the research. Firstly, the research commenced with simulation using proteus design suite software. This process is an essential step to verify the proper functionality of all components.

Subsequently, the research progressed with the fabrication process. In this stage, all the components listed in Table 1 were interconnected. The electronic components are comprised of three main parts which are input, controller, and output as illustrated in Figure 1. The input elements encompass a power supply (lithium ion battery), a switch, and the Blynk application, available for download from the Google Play Store and the Apple App Store.

Following this, a NodeMCU ESP8266, functioning as the controller, was linked to both the input components and the motor driver's input. This module boasts integrated Wi-Fi and Bluetooth capabilities. Its compact size, in addition to its processing power, serves to optimize space utilization [25]. The subsequent step involves connecting the direct current (DC) motors, employed as outputs, to the motor driver's output. For circuit control, the power source is linked in series with a switch. Incorporating the charging module into the power supply facilitates the robot's recharging process.

Table 1. Components of the research

No	Component	Function
1	Module charger	A constant current/constant voltage linear charger. Ideal for portable applications. The TP4056 is suitable for USB power and adapter power supplies.
2	Lithium ion battery (power supply)	Power supply for the whole system.
3	Switch	To cut off or connect the power supply current to the whole system.
4	NodeMCU ESP8266	Receive input signal from smartphone to control the movement of DC motor.
5	Motor driver (L298N)	Control the DC motor Rpm and direction of the motor rotation.
6	DC gear motor+wheel kit	To move the robot smoothly.

Technically, all the components were interlinked through the controller, as illustrated in Figure 2. The FC-Rob prototype materialized through the integration of three key components: the chassis, the water-absorbent sponge, and all other physical components. In addition, Figure 3 presents the tangible prototype, with Figures 3(a)-(c) showcasing its front, bottom, and side views, respectively.

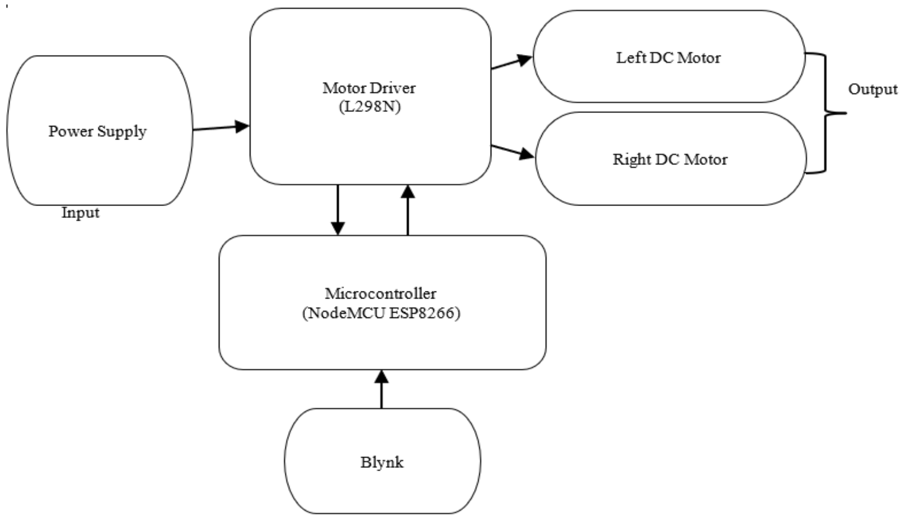

Figure 1. Block diagram of the FC-Rob system

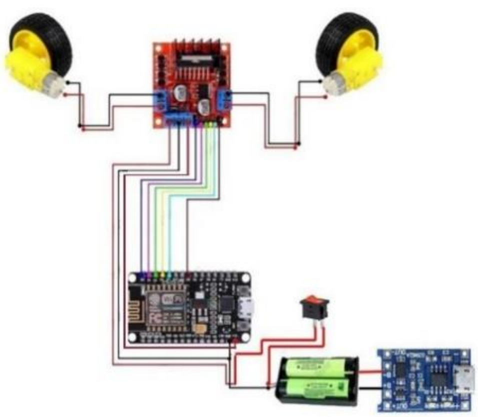

Figure 2. Circuit connection of the FC-Rob

(a) (b) (c)

Figure 3. Actual prototype of the FC-Rob; (a) front view, (b) bottom view, and (c) side view

Next, the research moved forward to the testing and analysis steps. These parts are really important because they help us understand the crucial outcomes of this study. At the outset, the longevity of the power supply (lithium ion battery) underwent rigorous testing. Throughout this experimental phase, the prototype operated under controlled conditions, moving freely without engaging in water absorption.

Subsequently, a comprehensive examination of the water absorbent material was conducted. This testing phase entailed a comparative analysis of two distinct materials: the microfiber chenille sponge and the microfiber cotton pad. Both absorbents were of dimensions 300 mm×100 mm. In the course of these tests, a predefined quantity of water was carefully introduced to the absorbent material at a consistent height. The process was repeated until the absorbent reached its saturation point, unable to contain any more water. Every step of these testing procedures was meticulously recorded and subsequently discussed in this manuscript, facilitating a thorough exploration and interpretation of the results obtained.

2.1. Operation of the research

Figure 4 is a flowchart depicting the operation of the FC-Rob system. Initially, the robot will be turned on and will await input from a smartphone running the Blynk app. If no input is received, the robot will enter standby mode and wait for input. If any input is present, the NodeMCU ESP8266 will read and examine the input. When the input is assigned to the “forward” command, the DC motor is activated, and the robot moves forward. If the input is assigned to the “backward” command, the DC motor will run, and the robot will move in a reverse direction. If the input is assigned to the “right” command, the DC motor will be activated, and the robot will move to the right direction. If the input is assigned to the “left” command, the DC motor will be activated, and the robot will move in that direction. All the processes will keep responding until the switch is turned off. Table 2 displays the behaviour of this DC motor operating system.

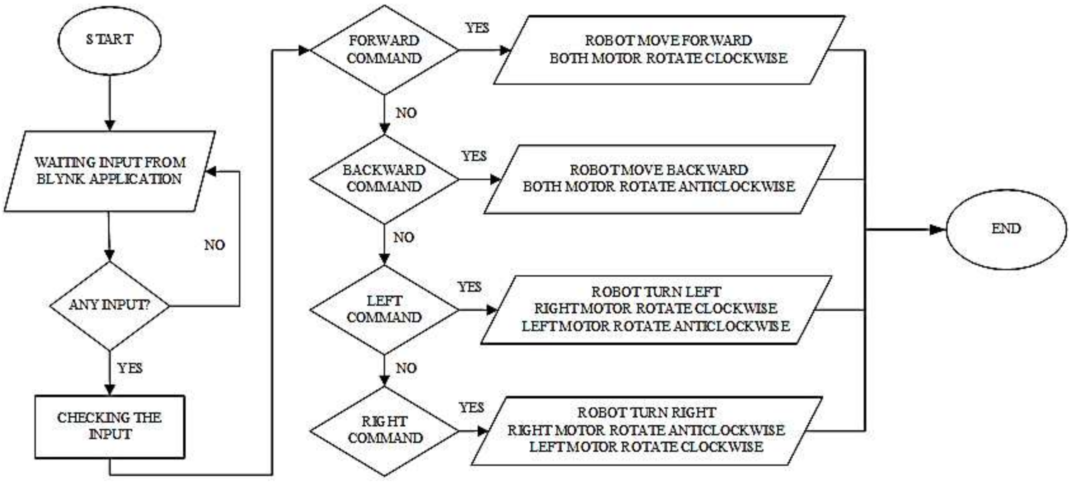

Figure 4. Flowchart of the FC-Rob system

Table 2. Behaviours of motor for different input conditions

Direction	Right motor	Left motor
Forward	Rotate clockwise	Rotate clockwise
Backward	Rotate anticlockwise	Rotate anticlockwise
Left	Rotate clockwise	Rotate anticlockwise
Right	Rotate anticlockwise	Rotate clockwise

3. RESULT AND DISCUSSION

3.1. Battery life test

Two rechargeable lithium-ion batteries with a capacity of 1,700 mAh were utilised for this research. This sort of battery was chosen for this research because of its high energy density and long lifespan, making it an ideal choice. A set of tests were done that accounted for the battery's endurance to assess the battery system's lifespan for this research. The outcomes of these meticulously crafted simulations of real-world circumstances are recorded. These test findings provide vital information regarding the durability of batteries, allowing for intelligent battery selection and management. The battery life test results are presented in Table 3. It depicts the battery life in terms of how long it takes for the battery to die and provides a clear picture of how the battery operates in various circumstances. This will ensure optimal system performance and lifetime.

Table 3. Battery life span test result

No.	Duration (minutes)	Robot movement
1	30	Yes
2	60	Yes
3	90	Yes
4	120	Yes
5	150	No

3.2. Water absorbent test

It is essential to assess the effectiveness of the fabric in terms of its ability to absorb water. To achieve this, tests were conducted with two types of fabric, microfiber chenille sponge and microfiber cotton pad. Both materials have varying capacities for water absorption. After conducting tests, it was determined that one of the fabrics had a greater water-absorption capacity than the other. Figure 5 displays the test results, making it simple to compare and evaluate the performance of each material. The data gathered from these testing is crucial for identifying the appropriate fabric for the research. Based on Figure 5, the microfiber chenille sponge was selected over the microfiber cotton pad due to its higher ability to absorb extra water. Microfiber chenille sponge can absorb up to 250 ml of water, whilst microfiber cotton pad can only absorb 200 ml.

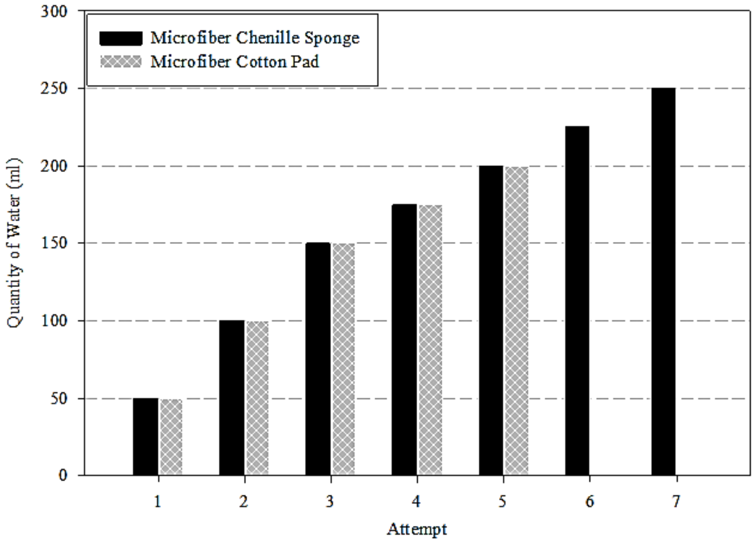

Figure 5. Water absorbent test result

3.3. Comparison with previous patented devices

A robotic vacuum cleaner is a self-sufficient electronic device that is intelligently programmed to clean a designated area using a vacuum cleaning assembly. In Table 4, two existing market robots, XiaoMi XiaoWa and Samsung Electronics Jetbot Robotic, are compared to FC-Rob. The objective of this research is to create a floor-cleaning robot and demonstrate its usability to the public. FC-Rob has the same speed and a longer battery life than the competition. Tests on the robot indicate that it can operate for up to two hours. FC-Rob is only accessible manually and is controlled by the Blynk application. It is created in manual mode to conserve the robot's energy and to clean certain areas according to the user's preferences. A user-friendly interface is given so the robot may be operated without trouble. The price of this robot may be maintained low in comparison to other robots on the market because it lacks an autonomous mode. Evaluations indicate that our products are dependable and economical. It requires less energy to operate.

Table 4. Product's comparison

Features	XiaoMi XiaoWa vacuum cleaner	Samsung jetbot mop with dual spinning technology	FC-Rob
Description	Vacuum cleaner robot	Mopping robot	Wiping robot
Remote control	Yes	No	Yes
Sensor	Yes	Yes	No
Operating hour	2 hours	1.5 hours	2 hours
Return to base	No	No	No
Battery type	Li-ion	Li-ion	Li-ion
Battery capacity	2,600 mAh	Not stated	3,600 mAh
Price	RM 1099.00	RM 1717.00	Not in market yet

4. CONCLUSION

The study illustrates a more effective and concise technique for detailing the design of a floor cleaning control robot using readily available, low-cost components. FC-Rob has all the tools required for performing manual floor cleaning. Manufacturers of floor cleaning robots like FC-Rob have several competitors who charge more for the same thing. Vacuuming and mapping tasks can be added to this robot to increase its capabilities. Given that its scheduling functionality can only be accessed via computer, Android and Windows applications can be created to make it more user-friendly. The lower and middle classes make up the product's target market. Children today are used to using smartphones, which is one advantage of FC-Rob, which may teach kids to prioritize cleanliness by using Blynk on cellphones. So, it has been shown that FC-Rob, which is less expensive than other options, can still clean the floor and teach kids something at the same time.

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