GROUP NO - 1

A

PROJECT REPORT

ON

THE PROJECT ENTITLED

Multipurpose, Energy & Cost-Efficient Floor Surface Cleaning Bot.

SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE DEGREE OF

BACHELOR OF ENGINEERING

In

ELECTRONICS AND TELECOMMUNICATION ENGINEERING

By

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Submitted to

DEPARTMENT OF ELECTRONICS AND TELECOMMUNICATION ENGINEERING

STES'S SINHGAD ACADEMY OF ENGINEERING, PUNE-411048

2024-25

CERTIFICATE

This is to certify that the project report entitled

Multipurpose, Energy and Cost-Efficient Floor Surface Cleaning Bot.

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Is a bonafide work carried out by them under the supervision by Dr. K.M. Gaikwad and it is approved for the partial fulfilment of the requirement of **Savitribai Phule Pune University** for the Project in the Final Year of Electronics and Telecommunication Engineering.

This project report has not been earlier submitted to any other institute or University for the award of any degree or diploma.

Dr. K.M. Gaikwad	**Dr. R.G.Byakod**	**Dr. K. P. Patil**
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Place: Pune

Date: **Examiner**

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Abstract

Floor environments, especially in industrial and public spaces, are large, valuable, and often complex to maintain. Dust, dry waste, and debris can accumulate over time, causing hygiene issues, health hazards, and operational inefficiencies. Fine particles and dirt layers may also impact sensitive equipment and reduce indoor air quality. Clearly, solutions are required for the automated and efficient removal of such waste from floor surfaces. Hence, in this paper, a floor surface cleaning bot is designed. This cleaning bot project focuses on maintaining clean indoor environments with minimal dust and debris, reducing pollution within enclosed spaces, and minimizing manual labor and human intervention. The project incorporates a cleaning mechanism using a rotating brush and suction system. This cleaning bot initiative highlights how Science, Technology, and Community collaboration can contribute to a smarter and healthier indoor environment.

Maintaining cleanliness in large indoor environments such as industrial facilities and public spaces poses significant challenges due to dust, debris, and fine particles. These contaminants not only reduce hygiene and indoor air quality but also pose risks to health and sensitive equipment. This paper presents the design and development of an autonomous floor surface cleaning bot aimed at minimizing manual intervention. The bot integrates a rotating brush and suction system to effectively remove surface-level and embedded waste. It is built with a focus on low-cost, energy-efficient, and compact design principles. The system is controlled using microcontrollers and supports automated operation for extended cleaning tasks. Real-time data and obstacle avoidance enhance its adaptability in complex environments. The proposed solution helps in reducing indoor pollution and operational downtime. By combining science, technology, and societal needs, the project contributes to smarter, cleaner indoor spaces.

Keywords:

Indoor Hygiene, Smart Cleaning Technology, Lithium-Ion Battery, Minimizing Human Effort, Remote-controlled Bot, Floor Surface Cleaning, Dust and Waste Collection.

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CHAPTER 1

INTRODUCTION

Floors cover nearly every man-made structure, playing a vital role in maintaining hygiene and operational safety in homes, offices, industries, and public places. Since ancient times, clean floor surfaces have symbolized good health and order, and even today, they are crucial to our productivity and well-being. However, with increasing urbanization and foot traffic, the buildup of dust, waste, and other pollutants has often been overlooked, leading to potential health and maintenance issues. Daily movement spreads contaminants, including non-biodegradable micro-waste, creating risks that can degrade indoor air quality and damage sensitive equipment. It's essential to take responsibility for maintaining clean indoor environments to ensure sustainable living and working conditions. Years of manual cleaning dependence have revealed its inefficiencies. The time has come for everyone to adopt smarter solutions that support health, safety, and automation. Traditionally, floor cleaning has involved manually sweeping, mopping, and scrubbing to remove dust and debris. However, this method is labor-intensive, time-consuming, and inconsistent. This has created a need for a more efficient, eco-friendly, and autonomous solution. A floor surface cleaning bot offers such a solution by automatically navigating indoor spaces and collecting dust and waste with minimal human intervention. The bot features a rotating brush and vacuum mechanism that sweeps debris into a collection bin. It is remotely controlled through a mobile application, allowing the user to manage cleaning paths efficiently and with ease.

In modern automation and robotics, precise motor control and component selection are essential for ensuring power efficiency and meeting task-specific performance goals. This project focuses on developing a remote-controlled motorized floor-cleaning bot equipped with drive wheels and a cleaning roller, powered by DC motors, an ESP32 microcontroller, and a 22V lithium-ion battery. By calculating torque, RPM, and power requirements, the system is optimized to perform within safe and efficient ranges, offering reliable mobility and consistent floor cleaning. The ESP32 microcontroller enables wireless control, facilitating real-time direction and operation management. In addition, thoughtful load balancing and design improve system stability, making the bot suitable for prolonged, unattended operation. This project not only integrates mechanical, electrical, and control subsystems but also demonstrates the importance of intelligent motor management to enhance automation efficiency.

Indoor floor pollution, especially in public buildings, hospitals, and warehouses, has become a critical concern affecting health, safety, and equipment performance. Pollutants such as dust, hair, dry leaves, and microplastics accumulate quickly and are hard to manage manually in large spaces. Monitoring and maintaining clean floors are challenging due to surface area, constant use, and the need for regular intervention. Traditional cleaning methods incur high labor costs, are time-bound, and lack adaptability to changing conditions. This project addresses these challenges with an automated floor cleaning system capable of navigation, cleaning, and data gathering. Using DC motors and an ESP32 microcontroller, the system supports wireless operation while optimizing energy usage and reducing manual effort. The bot can monitor floor coverage and adjust cleaning paths dynamically, improving cleaning efficiency and reducing operational overhead. This approach offers a scalable and eco-friendly alternative to traditional cleaning systems in various indoor environments.

Industrial and commercial floors require consistent cleanliness for safety, hygiene, and operational efficiency. Traditional manual cleaning methods are labor-intensive and unsuitable for large spaces. This project introduces a remote-controlled floor cleaning bot using an ESP32 microcontroller, DC motors, and a 22V lithium-ion battery. The bot uses rotating brushes and suction to collect dust and debris efficiently. Controlled via a mobile app, it ensures autonomous operation with minimal human input. Designed for scalability and energy efficiency, it reduces labor costs and environmental impact. Sensor integration and smart motor control enhance performance, making it ideal for warehouses, malls, factories. Maintaining clean floors in industrial and commercial environments—such as warehouses, malls, factories, and office buildings—is essential for ensuring hygiene, safety, and operational efficiency. Traditional cleaning methods, including manual sweeping and scrubbing, are often labor-intensive, time-consuming, and impractical for large-scale operations. To address these challenges, this project introduces a smart, remote-controlled floor surface cleaning bot as a cost-effective and scalable solution.

The cleaning bot is equipped with rotating brushes and a suction mechanism that efficiently collects dust, debris, and small waste particles into an internal bin. It operates using high-torque DC motors and is controlled by an ESP32 microcontroller. The power system is supported by a lead-acid battery, selected for its reliability and cost-effectiveness in moderate-duty applications. The bot can be wirelessly controlled via Bluetooth or Wi-Fi, allowing navigation through a mobile application for convenient operation with minimal human intervention.

Proper motor selection, power optimization, and weight distribution ensure that the bot performs well across different floor surfaces. The system is designed to run for extended durations without overheating, making it suitable for industrial shifts and commercial use cases.

The bot targets common pollutants like dust, plastic scraps, and metal shavings that can accumulate in high-traffic areas and pose safety hazards or operational issues. It reduces manual labor, lowers maintenance costs, and supports eco-friendly cleaning practices. With potential future integration of sensors for obstacle detection and route mapping, the bot can be further enhanced for smarter navigation and efficient coverage.

This floor surface cleaning bot showcases the integration of mechanical, electrical, and embedded systems to provide an automated, sustainable cleaning solution. Its adaptability and minimal human involvement make it an ideal tool for modern facility management across various industrial and commercial sectors.

Floor surface cleaning bots play a vital role in maintaining the hygiene and efficiency of indoor environments. Here are some of the key roles of floor surface cleaning bots:

- Debris and dust removal: Floor bots are designed to sweep and vacuum dust, paper, hair, and other dry debris from surfaces like tiles, wood, and vinyl.
- Spill cleanup: Some models are capable of cleaning minor liquid spills, preventing slips and surface damage.
- Microbial control: Bots equipped with UV lights or sanitizing modules can help reduce germs and bacteria, especially in healthcare and food preparation zones.
- Cleaning activity tracking: Bots can be integrated with sensors or apps to track cleaning paths and coverage, offering data for maintenance audits.
- Awareness and modern living: Floor bots demonstrate the value of smart living, showing how technology contributes to cleanliness, comfort, and time efficiency.
- Improving indoor air quality: By removing dust and allergens, floor bots contribute to healthier air inside homes and workplaces.
- Promoting sustainable maintenance: These bots reduce reliance on manual cleaning staff and chemical-heavy methods, promoting eco-friendly and low-cost cleaning practices.

Overall, floor surface cleaning bots play a key role in maintaining clean, healthy, and productive indoor environments. Their integration into daily operations supports public health, technological advancement, and sustainable maintenance practices for the future.

1.1. PROBLEM STATEMENT: FLOOR SURFACE CLEANING BOT.

Statement: This project aims to design and implement a remote-controlled, motor-driven system to operate a floor surface cleaning bot that efficiently collects dust, debris, and waste from large indoor floor areas in industrial and commercial environments.

1.2. OBJECTIVE OF THE PROPOSED WORK.

- To design and implement a floor cleaning bot capable of navigating large indoor areas, ensuring stability and precision in movement to cover designated cleaning zones effectively.
- To achieve extended operation without frequent recharging or battery replacement for uninterrupted cleaning cycles.
- To enable wireless control, providing flexibility for remote operation over Wi-Fi or Bluetooth.
- To develop a cost-effective, scalable, and energy-efficient floor cleaning system that ensures robust performance across various commercial and industrial environments while minimizing human intervention and operational costs.

CHAPTER 2
LITERATURE SURVEY

2.1. INTRODUCTION:

Literature survey is the process in which a coprmplete and comprehensive review is conducted encompassing the published work from other alternative sources of information. Further, the results of this process are documented. This entire process comes in aid of the researcher to address the important and relevant aspects of the research that had not been addressed prior to the conduction of this research. Therefore, it can be understood that the conduction of literature survey is necessary for the process of gathering secondary data for the research which might prove to be extremely helpful in the research and also designing the architecture of the project.

2.2. RESEARCH PAPERS FOR FLOOR SURFACE CLEANING BOT.

In [1], This project presents a Smart Floor Cleaning Robot powered by the ESP32 microcontroller, capable of operating in both autonomous and manual modes. It uses infrared, ultrasonic, and tactile sensors for obstacle detection and efficient path navigation. The ESP32 provides wireless connectivity via Wi-Fi or Bluetooth, enabling remote control through a mobile or web-based application. DC motors are driven using motor drivers to ensure stable movement and effective cleaning. The robot includes features such as scheduled cleaning, a bagless dirt collection unit, and an automatic waste disposal mechanism. Designed for industrial and commercial use, it offers a scalable, cost-effective alternative to expensive imported robots. The system emphasizes smart automation using locally available components and IoT-based functionality.

In [2], This paper provides a comprehensive review of various floor cleaning machines developed between 2015 and 2022. It highlights the increasing need for such machines in large public and commercial spaces like hospitals, schools, railway platforms, and airports where manual cleaning is labor-intensive and inefficient. The study categorizes machines based on their operation—manual, mechanical, semi-automated, fully automated, wire-controlled, remote-controlled, and even solar or fuel-powered. It also touches on the integration of modern technologies such as wireless systems and the Internet of Things (IoT) for smart cleaning solutions. The review aims to understand the progress in design, control systems, and energy efficiency of these machines. It emphasizes the growing trend toward automation for reducing human effort while ensuring hygiene in large spaces. The literature survey section compiles and analyzes existing research and product developments. This helps identify gaps and potentials for future innovation. The paper concludes with insights that can guide future work in smart, sustainable floor cleaning systems.

In [3], This paper presents the development of an Autonomous Floor Cleaning Robot designed to address the inefficiencies and limitations of traditional cleaning methods. Unlike most market-available vacuum cleaners that only support either dry or wet cleaning, this robot integrates both functionalities in a single, cost-effective unit. Aimed at homes, schools, offices, and hospitals, it simplifies cleaning tasks while minimizing physical effort. The robot operates in two modes: manual mode controlled via a smartphone application using Bluetooth, and automatic mode, where it navigates and cleans autonomously using an ultrasonic sensor for obstacle detection. Originally built with ATmega328 and motor driver IC L293D, the design could be further improved by integrating ESP32 for enhanced wireless connectivity and control. This multifunctional, compact, and affordable cleaning bot is particularly beneficial for places with tight spaces and frequent cleaning needs, offering both accessibility and convenience for everyday users.

In [4], This paper introduces a cost-effective robotic floor cleaner aimed at reducing human effort in routine cleaning tasks, particularly for working individuals and those with limited physical capability. Designed to serve homes and office spaces, the robot integrates basic cleaning functions such as mopping, dirt pickup, and water spraying, making it suitable for both wet and dry cleaning. It operates through a mobile app via Bluetooth, allowing users to manually control the robot. The system originally built with Arduino UNO and IR sensors can be enhanced using ESP32, offering improved wireless connectivity (Wi-Fi/Bluetooth) and scalability for future automation. It features motor drivers for precise movement and cleaning actions, ensuring efficient coverage. The robot stores and drains used water after cleaning, improving hygiene. This affordable and compact design is ideal for urban users with busy schedules, aiming to automate floor cleaning without high costs or complex maintenance.

In [5], This paper presents a smart floor-cleaning robot designed to simplify and automate household cleaning tasks by reducing human involvement. It integrates both mopping and vacuuming functionalities, using a damp mop for wet cleaning and a vacuum pump for dust collection. Originally built on Arduino Mega with GSM communication, the system can be modernized using ESP32, offering Wi-Fi/Bluetooth connectivity for real-time mobile control. Users can switch between dry and wet cleaning modes, receive alerts for maintenance, and operate the bot via commands or physical switches. Obstacle detection ensures collision-free movement. Market surveys highlighted the demand for affordable, tile-compatible robots in India, where many global products remain too expensive or optimized for wooden flooring. This project addresses these issues with a cost-effective, user-friendly alternative suitable for Indian households and offices.

In [6], The author presented the design and fabrication of a remote-controlled floor surface cleaning robot aimed at reducing manual labor in daily cleaning tasks. It uses automated technology to sweep and mop dust and debris from the floor and deposit it into a built-in waste container. The system includes rotating brushes and a mopping mechanism powered by DC motors, along with sensors to detect obstacles and monitor bin capacity. This approach is designed to be efficient, cost-effective, and user-friendly compared to traditional manual cleaning, helping to maintain hygiene in homes and offices while minimizing human effort.

CHAPTER 3

THEORETICAL BACKGROUND OF FLOOR SURFACE CLEANING BOT.

3.1. BLOCK DIAGRAM OF FSCB:

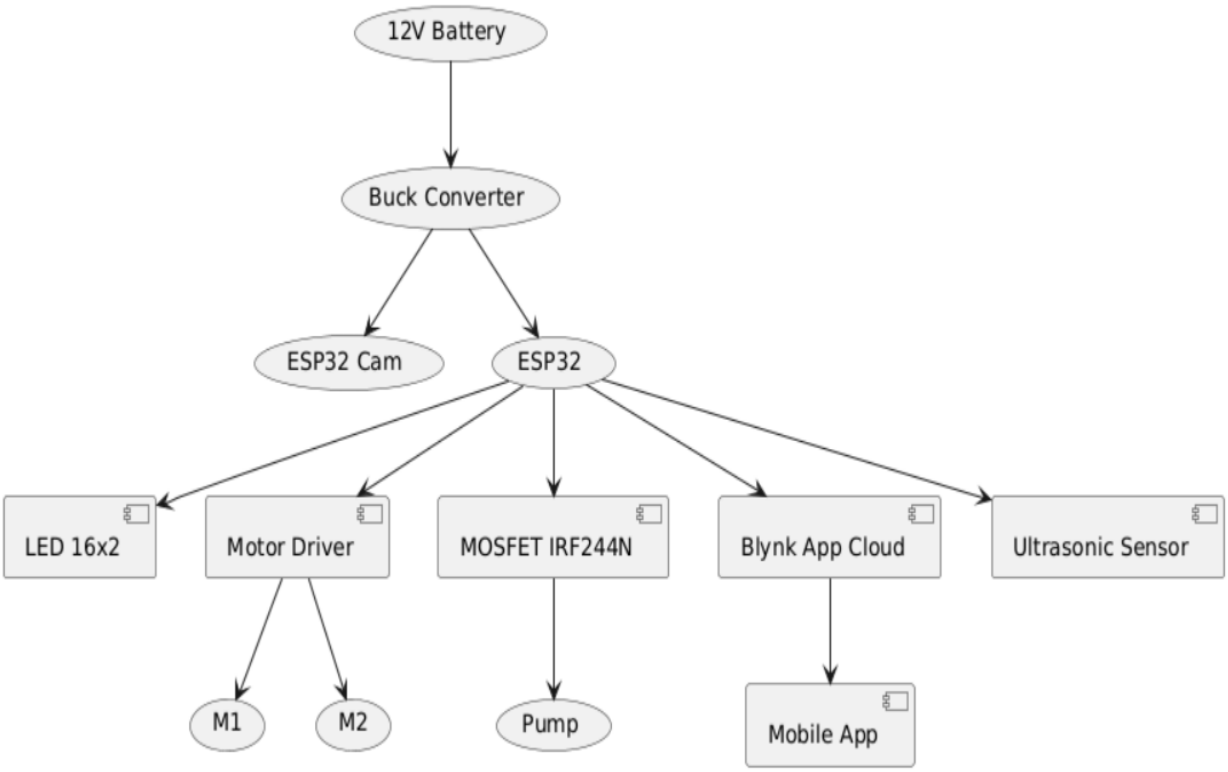

Figure 1: Block Diagram of Floor Surface Cleaning Boat

3.1.1. Block diagram description:

Figure 1 provides an overview of the components and connections in the floor surface cleaning boat project which is explained below in detail.

This block diagram shows the architecture of a floor cleaning robot powered by a 12V lead-acid battery. A buck converter regulates voltage for the ESP32 and ESP32-CAM, which control components like motor drivers (M1, M2), pump (via MOSFET IRF244N), LED display, and ultrasonic sensor. The ESP32 communicates with the Blynk cloud to allow remote control via a mobile app.

3.2. Components:

A) ESP32 Devkit V1 development board:

The central microcontroller for the system, the ESP32 manages motor control, sensor data processing, and communication. It receives inputs from the smartphone and sends signals to the motor driver. The Wi-Fi capability of the ESP32 allows it to connect to a smartphone or other devices for remote monitoring and control. In [7], the detailed specifications of the ESP32, including our ESP32 Devkit V1, are described. Fig. 2 presents the image of the ESP32 development board, while Table 1 provides its detailed specifications.

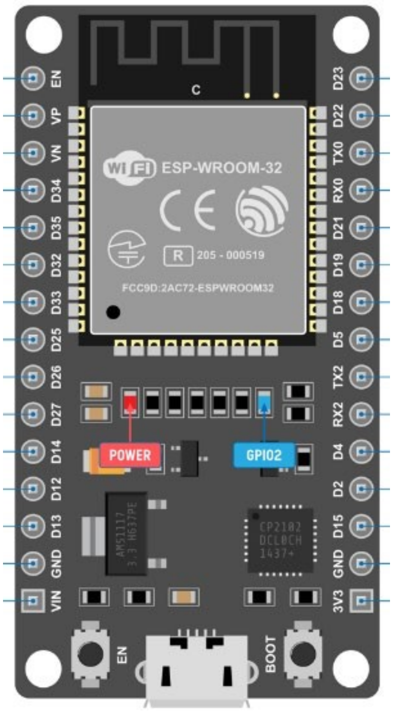

Figure 2: ESP32 devkit V1 module

Specifications:

Table 1: Specification of ESP32 Devkit V1 development board

Parameter	**Description**
Number of cores	2 (Dual core)
Wi-Fi	2.4 GHz (IEEE 802.11 b/g/n standard
Bluetooth	BLE (Bluetooth low energy) and legacy bluetooth
Architecture	32 bits
Clock frequency	Upto 240 MHz
RAM	512 KB
Pins	30, 36, or 38 (depending on the model)
Peripherals	Capacitive touch, ADC, DAC, 12C, UART, CAN 2.0, SPI, I2S, RMII, PWM and more.

B) LM298 motor driver:

This dual H-Bridge motor driver controls DC motors, which are responsible for propelling and steering the boat. Also, it is used to drive the conveyor motor which is responsible for collecting debris from the surface of the water. The L298N receives power from the battery and control signals from the ESP32. The L298N motor driver controls the speed and direction of DC motors with a current capacity of up to 2 amps. This module is responsible for the movement control of propeller motors, allowing forward and reverse motion, essential for navigating. In [8], the detailed specifications of the L298N motor driver are described. Fig. 3 displays the image of the L298N motor driver module. Table 2 provides the detailed specifications of the L298N motor driver module as per the requirements of our project. In this Project, two motor drivers are used for successful operation.

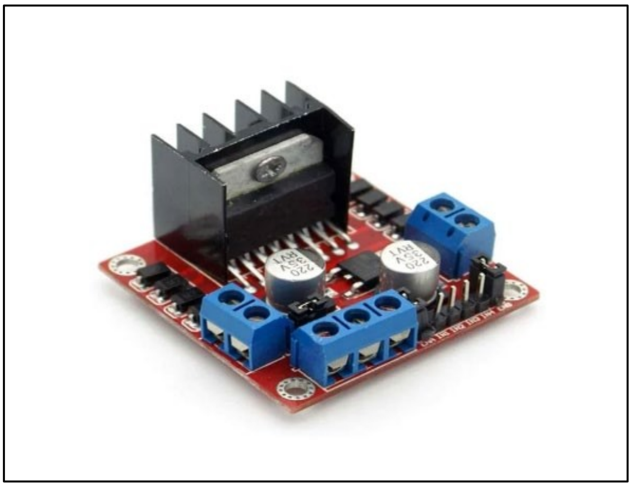

Figure 3: L298 motor driver module

Specifications:

Table 2: Specifications of L298 Motor Driver

Item type:	**L298N motor driver**
Current rating (A)	2
Voltage rating (V)	5 to 35
Driver IC	Double H-bridge L298N
Max. supply voltage (V)	46
Operating voltage (VDC)	5 ~ 35
Max. operating current (A)	2
Logical voltage (V)	5
Driver current (A)	0 – 6 mA

C) Lead Acid Battery:

The primary power source for the floor surface cleaning bot is the Accuplus++ sealed lead-acid battery, providing reliable energy to all core components including the motor drivers (e.g., L298N) and the ESP32 controller. With a 12V, 1.3Ah capacity, this maintenance-free battery delivers stable voltage suitable for powering DC motors and embedded systems. It supports a constant voltage charge range of 13.5–13.8V (standby use) and 14.4–15.0V (cycle use), making it well-suited for periodic operation in cleaning robots. Its sealed design ensures safety and durability without requiring frequent maintenance. Figure 4 displays the image of the Accuplus++ battery, while Table 3 outlines its specifications tailored to the power requirements of the floor surface cleaning bot.

Figure 4: Lead Acid Battery

Specifications:

Table 3: Specifications of Lead Acid Battery.

Nominal capacity (mAh)	3100
Nominal voltage (V)	12
Max. charging voltage (V)	14.4-15.0
Charging cut-off voltage (V)	10.5
Max. charging current	≤ 0.93 A (C/3 rate)
Nomimal charge current	~0.3 A (C/10 rate)
Max. discharge current (A)	3 – 6 A (peak)
Nominal discharge currrent	~0.3 – 1 A (continuous)
Nominal Energy (wh)	12 V × 1.3 Ah = 15.6Wh

D) DC geared motor:

These motors drive the boat forward and control its steering by differential speed control. They are connected to the L298N motor driver, which adjusts their speed and direction based on the signals from the ESP32. Another motor drives the conveyor belt mechanism, which is used to collect floating debris and waste from the water and deposit it onto the boat. This geared DC motor provides a stable 60 RPM and is used to operate the conveyor belt mechanism for collecting floating debris from the surface of the river. Two additional DC motors are used for navigation and steering of the boat. Fig. 5 displays the image of the DC geared motor, while Table 4 provides the detailed specifications of the DC motor as per the requirements of this project.

Figure 5: DC Geared Motor

Specifications:

Table 4: Specification of DC geared motor.

Item type	DC geared motor
Gear Type	Plastic
RPM	60
Working Voltage (VDC)	4-12V (12V Recommended and Maximum
Torque(kg-cm)	5 kg-cm
Load Max Current	300mA
No-load Current	60mA

E) ESP CAM Module:

The ESP32-CAM is a low-cost development board that combines the ESP32-S microcontroller with an OV2640 camera module, allowing for real-time image capture and video streaming over Wi-Fi. It features Bluetooth and Wi-Fi connectivity, making it ideal for wireless surveillance and IoT camera projects. The module can be connected to other components like sensors, motor drivers, and microSD cards via its GPIO pins. It’s commonly used in home security systems, smart doorbells, and floor cleaning bots for live monitoring. Programming is done using the Arduino IDE with an external USB-to-Serial converter. Its compact size and wireless capabilities make it versatile for embedded vision applications.

Figure 6: ESP CAM Module

Specifications:

Table 5: Specification of ESP CAM Module.

Microcontroller	ESP32 (dual-core 32-bit LX6)
Camera Sensor	OV2640 (2MP, 1600x1200 resolution)
Flash Memory	4MB
Wi-Fi	802.11 b/g/n
Bluetooth	BLE + Classic (v4.2)
Power Supply	5V via GPIO or FTDI
External Storage	MicroSD card support (up to 16GB)

F) Ultrasonic Sensor:

The ultrasonic sensor is used to detect obstacles and help the cleaning bot navigate without collisions. It emits ultrasonic waves and measures the time taken for the echo to return, calculating the distance to nearby objects. This allows the bot to avoid walls, furniture, or other barriers while cleaning. The sensor ensures smooth operation in automatic mode, enhancing efficiency and safety. It operates effectively in various indoor lighting conditions. It’s placed at the front of the bot for maximum coverage. The ESP32 reads sensor data to make real-time movement decisions.

Figure 7: Ultrasonic Sensor.

Specifications:

Table 6: Specifications of Ultrasonic Sensor

Model type	**Ultrasonic sensor**
Operating Voltage	5V DC
Interface	4-pin (VCC, Trig, Echo, GND)
Response Time	< 15 ms
Obstacle Detection Range	2 cm to 400 cm (0.02 m to 4 m)
Frequency	40 kHz
Accuracy	±3 mm

G) Diaphragm Water Pump:

The 12V diaphragm water pump is used for fluid movement in automation projects like cleaning or irrigation. It runs on 12V DC and can be controlled using an ESP32 via a relay module or transistor switch. The ESP32 sends a digital HIGH signal to activate the relay, allowing current to flow to the pump. This enables remote or sensor-based water flow control. The pump uses a motor to drive a diaphragm, creating suction to draw and expel water. It supports self-priming and can handle low-viscosity liquids. The ESP32 can also monitor water levels or pressure using sensors to automate pump operation. This setup is ideal for smart floor cleaners or river cleaning bots.

Figure 8: Diaphragm Water Pump

Specifications:

Table 7: Diaphragm Water Pump

Operating Voltage	12V DC
Current Consumption	0.5A-1.5A (depending on load)
Power Consumption	6W to 18W
Flow Rate	2-4 liters per minute
Inlet/Outlet Diameter	6nm to 8nm
Motor Type	Brushed DC Motor
Working Pressure	0.6-1.2MPa (Megapascal)

3.3. Hardware Implementation:

The Floor Surface Cleaning Bot is powered by an ESP32 microcontroller, which acts as the central control unit for managing all operations. An ESP32-CAM module enables real-time video streaming and remote monitoring via Wi-Fi. A 16x2 LCD display is used to display system status, cleaning modes, and battery information.

The bot's movement is driven by DC motors, controlled using an L298N motor driver, enabling smooth directional control. A diaphragm pump is integrated to spray water or cleaning fluid on the surface, supporting wet cleaning functionality. An ultrasonic sensor is mounted at the front to detect and avoid obstacles, enhancing safety and autonomous navigation.

Power is supplied by a 12V lead-acid battery, which supports the motor, pump, and electronic components. The ESP32 reads sensor inputs and adjusts motor and pump operations for efficient cleaning. The system is modular and scalable for future upgrades like path planning or automatic docking. This hardware setup ensures smart, semi-autonomous floor cleaning with minimal user intervention.

3.4. METHODOLOGY:

A) Overview

This project provides a comprehensive overview of the technical specifications and design considerations for the FSCB (Floor Surface Cleaning Bot). The bot is powered by a 12V, 1300mAh (1.3Ah) lead-acid battery, chosen for its consistent power supply and suitability for indoor automation. The total weight of the model is approximately 4 kg, including the bot chassis, electronics, and the onboard water tank or debris collection container. The cleaning system uses two DC motors for movement and an additional motor to operate the brush or suction mechanism. A diaphragm water pump is integrated for spraying water or disinfectant, and optional sensors like ultrasonic modules ensure obstacle detection and navigation. This report covers component selection, power consumption, battery backup calculation, sensor integration, and bot dimension planning for optimal cleaning coverage, stability, and operational.

Specifications of FSCB:

- Total Load: 4 kg (includes all the components battery and water holding tank)
- Propulsion: 2 DC motors with propellers (each with a 3.5 cm radius)
- Sensor Integration: 1 Ultrasonic Sensor for obstacle avoiding.
- ESP CAM Module: For Monitoring/ Live streaming of Bot.
- Battery: 12V, 1300mAh (1.3Ah)

Components Selection

a) Motor Overview

The 60RPM geared DC motors were selected for the FSCB to provide a balanced trade-off between speed and torque. This speed is ideal for controlled movement on indoor surfaces, allowing the bot to clean thoroughly without moving too fast or missing spots. Higher RPM motors may result in poor cleaning coverage due to rapid movement, while lower RPM motors can slow down the cleaning process unnecessarily. 60RPM motors also offer enough torque to move the bot and support additional cleaning components like brushes or a water tank. Their availability, cost-effectiveness, and compatibility with 12V lead-acid batteries make them a reliable choice. Additionally, they are easy to control using PWM through an ESP32, ensuring smooth navigation.

b) Diaphragm Water Pump Overview:

The 12V diaphragm pump is chosen for the FSCB due to its self-priming ability, compact design, and efficient water delivery for spraying cleaning solution. It provides adequate pressure (typically 0.6–1.2 MPa) to evenly distribute water on the floor surface without needing a complex plumbing system. The pump is compatible with 12V power sources, making it ideal for integration with the same lead-acid battery powering the rest of the bot. It can handle mild detergents and is resistant to clogging, ensuring long-term reliability. Its compact size allows it to fit easily into the bot’s chassis, and it can be controlled via a relay or MOSFET from the ESP32 microcontroller.

c) ESP CAM Module Integration:

The ESP32-CAM module is integrated into the floor cleaning bot project to enable real-time video monitoring through Wi-Fi. This module provides a live camera feed directly to a mobile device using the Blynk IoT platform, allowing users to remotely observe the bot’s movement and ensure effective cleaning. By visually detecting obstacles, dirty spots, or areas that need attention, the ESP32-CAM enhances the bot’s overall performance. Its compact and lightweight design makes it ideal for fitting within the limited space of the robot chassis. The module also supports SD card storage, offering optional image or video recording capabilities. The decision to use the ESP32-CAM was driven by its cost-effectiveness, ease of integration with ESP32 boards, and ability to eliminate the need for expensive vision systems. This visual feedback makes the bot semi-autonomous, enabling user supervision for critical areas while maintaining efficient operation.

d) Ultrasonic Sensor integration:

The ultrasonic sensor is integrated into the floor cleaning bot to enable obstacle detection and safe navigation. It works by emitting ultrasonic waves and measuring the time taken for the echo to return after hitting an object, allowing the bot to calculate distances accurately. This helps the bot identify and avoid obstacles such as walls, furniture, or sudden drops, ensuring it does not collide or get stuck during operation. The sensor is connected to the ESP32, which processes the distance data in real time to control the bot's direction. With a fast response time of around 15 milliseconds and an effective sensing range of 2 cm to 400 cm, it is well-suited for dynamic indoor environments. The use of ultrasonic sensing improves both efficiency and safety, enabling the bot to clean more intelligently. Its non-contact operation, affordability, and ease of integration with microcontrollers make it a practical and reliable choice for this project.

e) Battery life estimation :

Total current consumption:

Table 8 shows the total current consumption by the components of FSCB.

Table 8: Total current consumption by the components of FSCB

Components	**Current**
ESP32	0.24 A
CAM Module	0.16 A
L298N motor driver	0.18 A
Propulsion motors (2)	0.60 A
Diaphragm Pump	0.80 A
Ultrasonic Sensor	0.015 A
Total Current	**1.99 A**

Battery capacity:

- Battery rating: 12V, 1300mah = 1.3Ah.

Battery life estimation:

To calculate the battery life, use the formula:

$$\text{Battery Life (hours)} = \frac{\text{Battery Capacity (Ah)}}{\text{Total Current Consumption (A)}}$$

If diaphragm pump is used intermittently (50% duty cycle):

- Adjusted average pump current:

  $0.80 \times 0.5 = 0.40$ A

- Adjusted total current:

  $1.99 - 0.80 + 0.40 = 1.59$ A

$$\text{Battery Life} = \frac{1.3\ \text{Ah}}{1.59\text{A}} \approx 1\ \text{hours}$$

Estimated battery life: 1 hours of Continuous operation before the battery is depleted.

Charging Time:

Assuming a typical lead acid battery charger with a charging current of 1A:

- $\text{Charging Time} = \dfrac{\text{Battery Capacity}}{\text{Charging Current}}$
- Charging Time = = 1.5 hours

Summary:

- Battery Life: ~1 hours of continuous operation
- Charging Time**:** ~1.5 hours with a standard 1A charger

3.5. Programming Code:

Below programming code has been implemented to run the FSCB:

```
#define BLYNK_TEMPLATE_ID "TMPL31rK6sPRq"
#define BLYNK_TEMPLATE_NAME "floor cleaning"

#include <WiFi.h>
#include <Wire.h>
#include <LiquidCrystal_I2C.h>
#include <BlynkSimpleEsp32.h>

#define TRIG_PIN 27
#define ECHO_PIN 14
#define M1 26
#define M2 25
#define M3 33
```

```
#define M4 32
#define PUMP 23  // Pump control pin

char ssid[] = "smart";
char pass[] = "12345678";
char auth[] = "QMcO9AayLLBXWV2YVp3WSKI6nMsgUa6q";

LiquidCrystal_I2C lcd(0x27, 16, 2);
bool isMovingForward = false; // Track forward movement

int distance;

void setup() {
  Serial.begin(115200);
  lcd.init();
  lcd.backlight();
  lcd.print("Connecting WiFi");
  WiFi.begin(ssid, pass);
  while (WiFi.status() != WL_CONNECTED) delay(500);
  lcd.clear();
  lcd.print("WiFi Connected ");
  Blynk.begin(auth, ssid, pass);
  lcd.clear();
  lcd.print("Blynk Connected ");

  pinMode(TRIG_PIN, OUTPUT);
  pinMode(ECHO_PIN, INPUT);
  pinMode(M1, OUTPUT);
  pinMode(M2, OUTPUT);
  pinMode(M3, OUTPUT);
  pinMode(M4, OUTPUT);
  pinMode(PUMP, OUTPUT);
  digitalWrite(PUMP,HIGH);
  }
```

```
void loop() {
  Blynk.run();

  distance = getDistance();
  lcd.setCursor(0, 0);
  lcd.print("Dist: ");
  lcd.print(distance);
  lcd.print("cm        ");

  Blynk.virtualWrite(V5,distance);

  // If moving forward and distance goes below 50, stop
  if (isMovingForward && distance < 50) {
    stopMovement();
    lcd.setCursor(0, 1);
    lcd.print("Low Distance!   ");
    isMovingForward = false;
  }

  delay(500);
}

float getDistance() {
  digitalWrite(TRIG_PIN, LOW);
  delayMicroseconds(2);
  digitalWrite(TRIG_PIN, HIGH);
  delayMicroseconds(10);
  digitalWrite(TRIG_PIN, LOW);
  return pulseIn(ECHO_PIN, HIGH) * 0.034 / 2;
}

void stopMovement() {
  digitalWrite(M1, LOW);
```

```
    digitalWrite(M2, LOW);
    digitalWrite(M3, LOW);
    digitalWrite(M4, LOW);
    lcd.setCursor(0, 1);
    lcd.print("Stopped         ");
}

BLYNK_WRITE(V0) {  // Forward
    int value = param.asInt();
    float distance = getDistance();
    if (value == 1 && distance > 50) {
        lcd.setCursor(0, 1);
        lcd.print("Moving Forward  ");
        digitalWrite(M1, HIGH);
        digitalWrite(M2, LOW);
        digitalWrite(M3, HIGH);
        digitalWrite(M4, LOW);
        isMovingForward = true;  // Track forward movement
    } else {
        stopMovement();
        isMovingForward = false;
    }
}

BLYNK_WRITE(V1) {  // Backward
    int value = param.asInt();
    if (value == 1) {
        lcd.setCursor(0, 1);
        lcd.print("Moving Backward ");
        digitalWrite(M1, LOW);
        digitalWrite(M2, HIGH);
        digitalWrite(M3, LOW);
        digitalWrite(M4, HIGH);
    } else {
```

```
        stopMovement();
    }
}

BLYNK_WRITE(V2) {  // Left
    int value = param.asInt();
    if (value == 1) {
        lcd.setCursor(0, 1);
        lcd.print("Turning Left    ");
        digitalWrite(M1, HIGH);
        digitalWrite(M2, LOW);
        digitalWrite(M3, LOW);
        digitalWrite(M4, HIGH);
    } else {
        stopMovement();
    }
}

BLYNK_WRITE(V3) {  // Right
    int value = param.asInt();
    if (value == 1) {
        lcd.setCursor(0, 1);
        lcd.print("Turning Right   ");
        digitalWrite(M1, LOW);
        digitalWrite(M2, HIGH);
        digitalWrite(M3, HIGH);
        digitalWrite(M4, LOW);
    } else {
        stopMovement();
    }
}

BLYNK_WRITE(V4) {  // Pump Control
    int value = param.asInt();
```

```
  if (value == 1) {
    digitalWrite(PUMP, LOW);
    lcd.setCursor(0, 1);
    lcd.print("Pump ON         ");
  } else {
    digitalWrite(PUMP, HIGH);
    lcd.setCursor(0, 1);
    lcd.print("Pump OFF        ");
  }
}
```

Code Explaination:

Platform & Tools Used:

- Microcontroller: ESP32 DevKit V1
- Programming Environment: Arduino IDE v2.3.2
- IoT Platform: Blynk IoT

This embedded system is designed to automate and remotely control a floor surface cleaning boat.

This code:

- Connects your ESP32 to WiFi + Blynk.
- Controls a cleaning robot with ultrasonic sensor, LCD display, and mobile app.
- Motors move based on Blynk button presses.
- Stops automatically if something is too close when moving forward.
- Controls a cleaning pump from the app.

Overview:

1. Blynk Cloud Configuration:

The code begins by defining three key constants required to connect the ESP32 device to the Blynk IoT cloud service:

- Template ID: A unique identifier generated by the Blynk cloud when creating a new template.

- Template Name: The user-defined name for your project on Blynk.
- Auth Token: A unique key that authorizes and links your ESP32 board with the corresponding project template on your Blynk account.

These are essential for authenticating the device and managing communication between the ESP32 and the mobile app.

2. Library Inclusions:

- *#include<WiFi.h>*: Loads the WiFi library to enable the ESP32 to connect to a Wi-Fi network.
- *#include<BlynkSimpleEsp32.h>*: This Blynk library handles cloud communication and manages virtual pins on the ESP32 specifically for the ESP32 platform.

These libraries simplify the process of IoT integration.

3. Wi-Fi Credentials:

- *char ssid[] = "pixel7";*
- *char pass[] = "pppppppp";*

These variables hold the Wi-Fi SSID (network name) and password required for the ESP32 to establish internet access, which is necessary for connecting to the Blynk Cloud.

4. Motor Control Pin Setup:

These 4 pins control the two DC motors using an H-Bridge motor driver (like L298N):

- Motor A (Left Motor): Controlled using M1 and M2
- Motor B (Right Motor): Controlled using M3 and M4

1. Left Motor (M1, M2):

   Forward: M1 = HIGH, M2 = LOW

   Backward: M1 = LOW, M2 = HIGH

   Stop: M1 = LOW, M2 = LOW

2. Right Motor (M3, M4):

Forward: M3 = HIGH, M4 = LOW

Backward: M3 = LOW, M4 = HIGH

Stop: M3 = LOW, M4 = LOW

5.Water Pump Setup:

- This defines GPIO 23 as the pin connected to the cleaning pump (via relay or transistor).

Pump ON digitalWrite(PUMP, LOW); Relay activates when pin is LOW

Pump OFF digitalWrite(PUMP, HIGH); Relay deactivates when pin is HIGH

6. Sensor Timing Configuration:

• In this project, the ultrasonic sensor (for obstacle detection) is read every 500 milliseconds using delay(500) statement.
• Although lastReadTime and readInterval are not used, the fixed delay effectively limits how often the sensor is triggered.

This is a basic form of time-based polling, helping avoid excessive sensor reads and reducing power consumption.

7. *setup()* Function:

The setup() function is called once when the ESP32 starts up.

- Serial Communication Initialization:

  Serial.begin(115200); starts the serial monitor for debugging with a baud rate of 115200.

- LCD Initialization:
  lcd.init(); and lcd.backlight(); turn on and prepare the 16x2 I2C LCD display.
- WiFi & Blynk Initialization:

*WiFi.begin(ssid, pass); connects the ESP32 to WiFi. Blynk.begin(auth, ssid, pass); connects the ESP32 to the Blynk cloud using the authentication token.*Motor Pin Initialization:

- Pin Initialization:

  The following pins are configured as OUTPUT:

- Motor pins: M1, M2, M3, M4
- Ultrasonic sensor trigger: TRIG_PIN
- Pump Control: PUMP

  The ultrasonic echo pin is set as INPUT.

- Pump Default State:

  digitalWrite(PUMP, HIGH); keeps the pump OFF by default at startup.

A for loop sets all defined motor control pins as OUTPUT so the microcontroller can send signals to the motors.

8. *loop()* Function:

The loop() is the heart of the ESP32 program and runs repeatedly.

a. Blynk Communication:

- *Blynk.run();* Keeps the device connected to Blynk Cloud and processes incoming/outgoing data.

b. Ultrasonic Sensor Reading & Obstacle Detection:

- The ultrasonic sensor is triggered every 500ms using delay(500);.
- getDistance() calculates the distance to obstacles using the time it takes for ultrasonic pulses to return.
- The distance value is displayed on the LCD and sent to Blynk on Virtual Pin V5 using:

  Blynk.virtualWrite(V5, distance);

c. Automatic Safety Stop

- If the robot is moving forward and the detected distance drops below 50 cm, the bot automatically stops for safety.

9. Blynk Virtual Pin Handlers for Motor Control:

Each Blynk virtual pin (V0 to V4) corresponds to a control button in the Blynk mobile app:

Table 9: Blynk Virtual Pin Handlers for Motor Control

Virtual Pin	Button Action in Blynk App	Motor Movement
V0	Move Forward	Motors rotate to move forward if distance > 50 cm
V1	Move Backward	Motors rotate in reverse
V2	Turn Left	Left/right wheels spin in opposite directions
V3	Turn Right	Right/left wheels spin in opposite directions
V4	Pump ON/OFF	Activates or deactivates the cleaning pump motor

- Each handler reads the Blynk button state (1 = ON, 0 = OFF).
- Motor GPIO pins are updated directly using digitalWrite() based on direction logic.
- For the pump,

  digitalWrite(PUMP, LOW) turns it ON.

  digitalWrite(PUMP, HIGH) turns it OFF

In this way, the above code efficiently manages ultrasonic sensor reading, motor control, and IoT communication. The use of the Blynk IoT platform enables real-time remote monitoring of obstacle distance and intuitive control of the cleaning robot's movement and pump system via a mobile app. The ultrasonic sensor ensures safe navigation by automatically stopping the robot when an object is detected within a critical distance, enhancing both functionality and safety.

CHAPTER 4

RESULTS

4.1) OUTCOMES:

Fig. 11 shows the top view of FSCB. Fig. 12 shows the side view of FSCB. Fig. 13 shows the front view of FSCB. Fig.14 shows the control interface of FSCB.

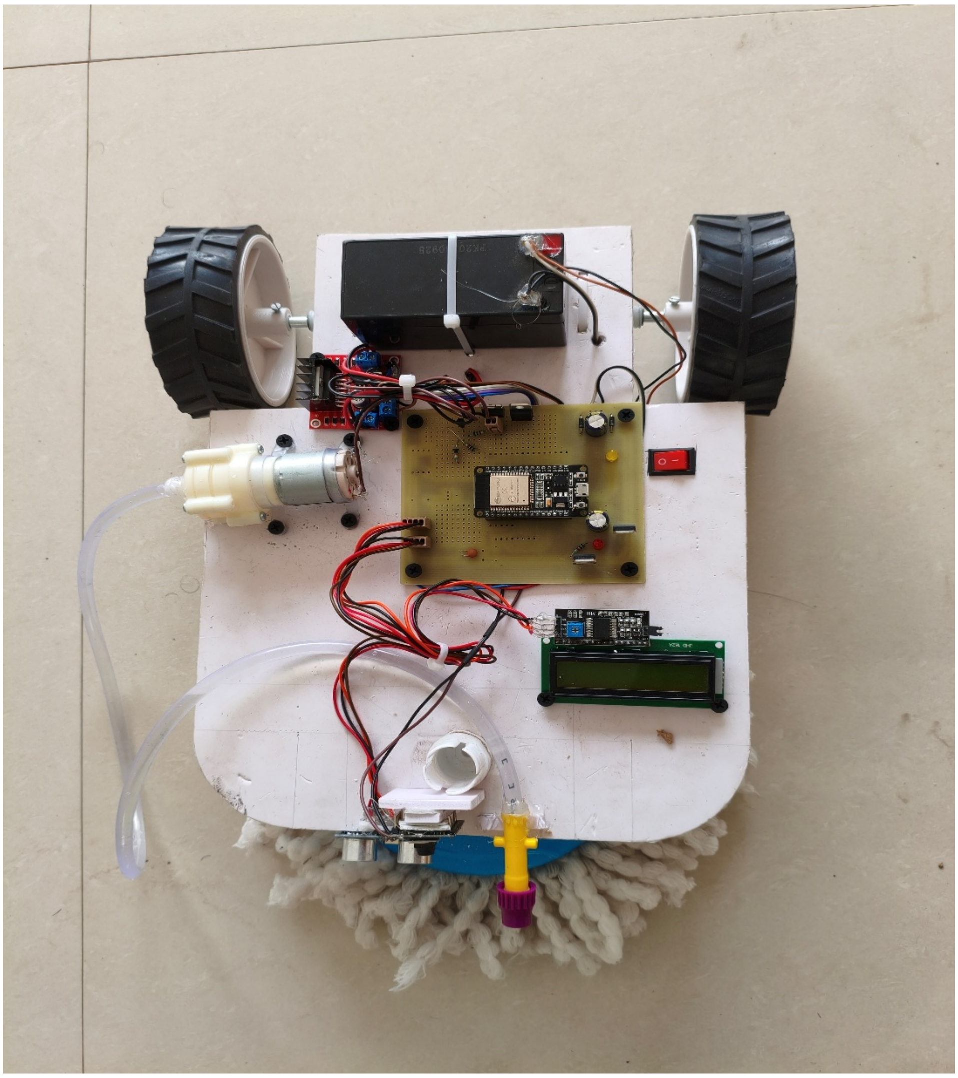

Figure 11: Top view of FSCB

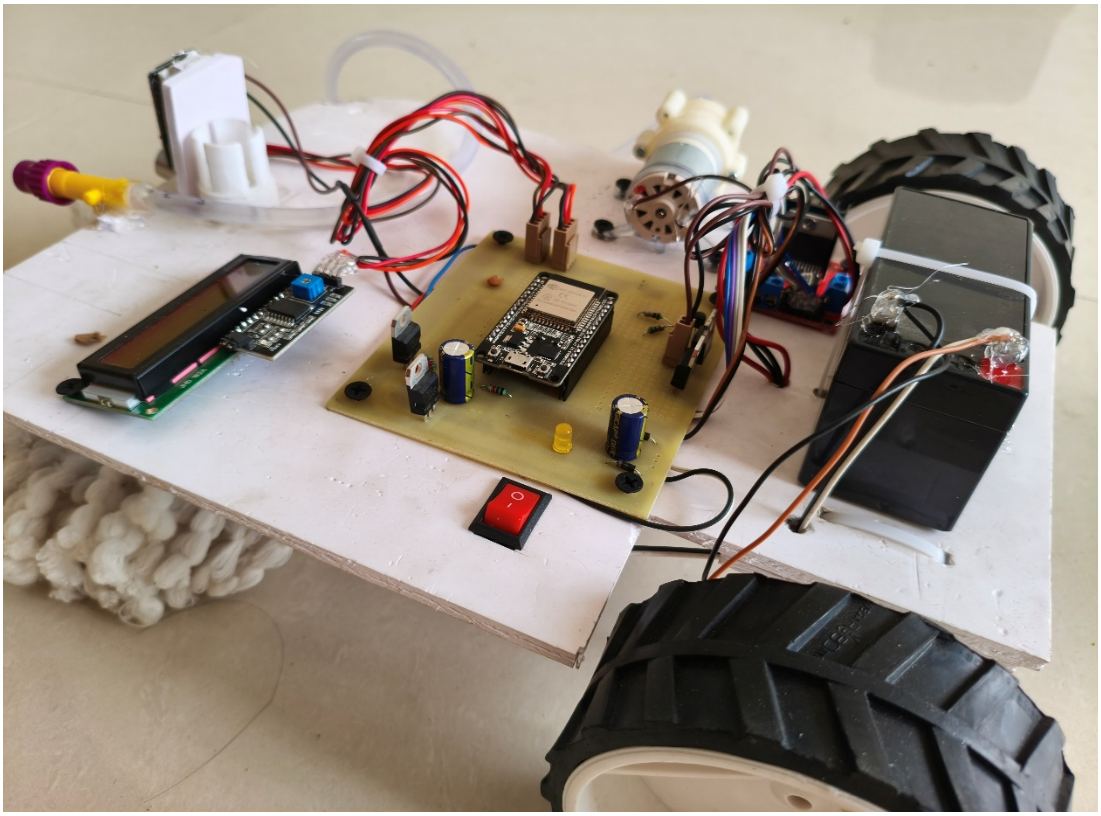

Figure 12: Side view of FSCB

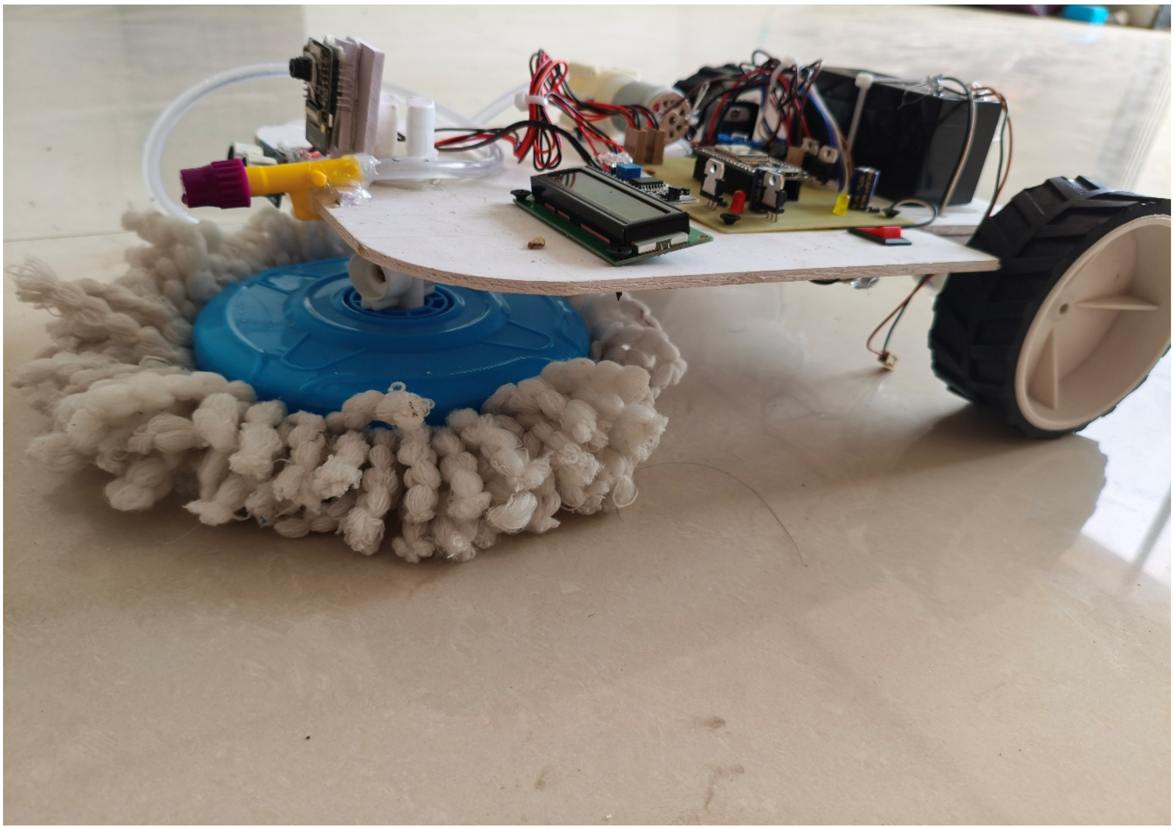

Figure 13: Front view of FSCB

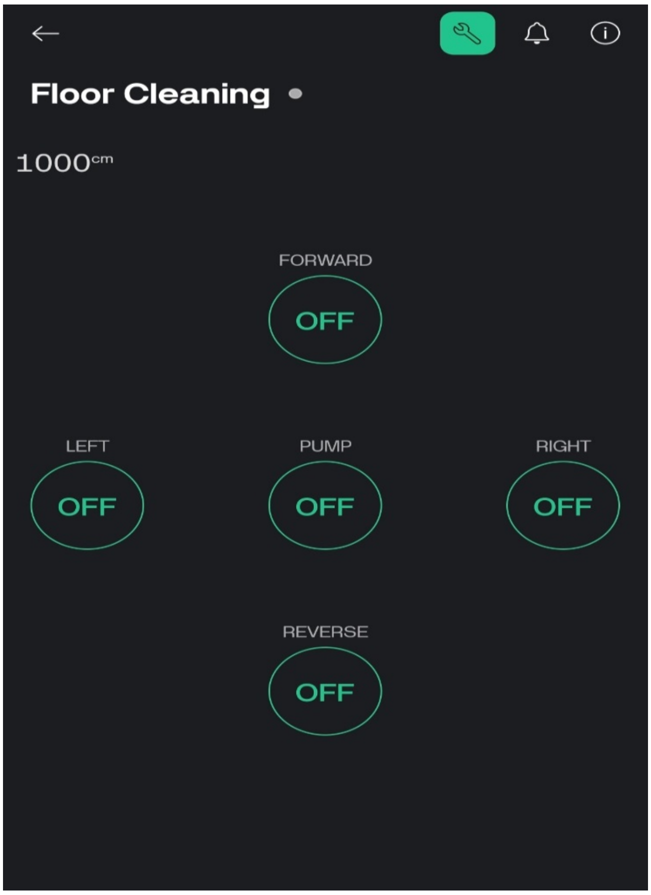

Figure 14: FSCB control interface

4.2) ADVANTAGES:

1. Cost-Effective Operation:

- Reduces the need for manual labor, cutting down recurring cleaning service costs.
- Built using affordable components like the ESP32 and ESP32-CAM, making it accessible for low-budget or DIY applications.

2. Energy Efficiency:

- Optimized power consumption through controlled motor usage and battery management.
- Can be enhanced further with low-power sleep modes and efficient charging mechanisms.

3. Automation and Autonomy:

- Capable of performing cleaning tasks with minimal human intervention.
- Easily upgradeable to support autonomous navigation, dirt detection, and intelligent cleaning cycles.

4. Wireless Control and Monitoring:

- Integrated with ESP32-CAM for live video streaming and wireless control over Wi-Fi or Bluetooth.
- Enables remote operation, supervision, and troubleshooting via smartphone or web interface.

5. Eco-Friendly and Sustainable:

- Minimizes water and chemical usage by targeting only the necessary areas.
- Potential for solar-assisted or low-carbon charging solutions to reduce environmental impact.

7. Smart Obstacle Avoidance:

- Can be equipped with sensors (ultrasonic, IR) to avoid collisions and navigate safely.
- Prevents damage to furniture or itself, making it safe for indoor use.

4.3) FUTURE SCOPE

- **Autonomous Navigation with AI and Mapping:** Integrate AI algorithms and sensors like LiDAR or ultrasonic to enable autonomous navigation, SLAM (Simultaneous Localization and Mapping), and path optimization for fully independent cleaning.
- **Automated Charging and Docking Station**: Implement a self-charging system where the bot can automatically return to a docking station when the battery is low, ensuring uninterrupted operation with minimal user input.
- **Advanced Dirt Detection and Adaptive Cleaning**: Use machine learning and image processing with the ESP32-CAM to detect high-dirt areas and adjust cleaning intensity or time based on surface conditions.
- **IoT Integration and Mobile App Control**: Connect the bot to a cloud platform and develop a mobile app for remote scheduling, monitoring, and status alerts, making it smarter and more user-friendly.

- **Solar-Assisted Charging**: Explore solar panel integration on the bot or docking station to supplement battery charging, reducing dependence on external power sources and improving energy sustainability.

4.4) CONCLUSION:

The Floor Surface Cleaning Bot (FSCB) represents a significant step toward automating and optimizing indoor cleaning operations. Traditional cleaning methods often require substantial human effort, time, and recurring costs, especially in large commercial or industrial environments. In contrast, this bot offers a practical, energy-efficient, and low-cost alternative, reducing manual labor and increasing overall cleaning productivity.

By leveraging the capabilities of ESP32 and ESP32-CAM modules, the system enables wireless control and live video monitoring, enhancing user interaction and real-time oversight. Its compact design, efficient battery usage, and autonomous features make it suitable for continuous operation in various floor conditions, including tiles, wood, and concrete surfaces.

The integration of smart sensors and microcontroller-based navigation enables the bot to detect and avoid obstacles while thoroughly cleaning the surface. This not only minimizes human intervention but also ensures precision and consistency in the cleaning process. The live video streaming further allows remote supervision, making it ideal for use in restricted or hazardous indoor zones.

In terms of sustainability, the FSCB promotes eco-friendly cleaning by optimizing energy use and minimizing the need for chemical cleaning agents. Its modular design allows for future enhancements such as automated docking, advanced dirt detection, and AI-based cleaning patterns.

In conclusion, the Floor Surface Cleaning Bot is a smart, scalable, and impactful solution for modern indoor maintenance needs. It aligns with current trends in automation and smart living, making it a valuable contribution to both home and industrial cleaning technology. Through this project, we demonstrate the potential of embedded systems and robotics in creating efficient and sustainable solutions for everyday problems.

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Multipurpose, Energy & Cost Efficient Floor Surface Cleaning Bot.

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ABSTRACT

The Floor Surface Cleaning Bot (FSCB) is a smart, semi-autonomous cleaning system designed for efficient surface maintenance in indoor environments. Powered by an ESP32-CAM module, it provides real-time video streaming for monitoring and control. An ultrasonic sensor enables obstacle detection and helps navigate the cleaning area safely, avoiding collisions and edges. The cleaning mechanism uses a diaphragm pump to spray water or cleaning solution onto the floor, ensuring effective removal of dust and dry waste. Remote control and scheduling are enabled via Bluetooth and the Blynk app, allowing users to manage operations from their smartphone. This cost-effective solution combines real-time navigation, smart control, and versatile cleaning features, offering an innovative alternative to traditional manual floor cleaning.

In addition to its core features, the FSCB uses motorized wheels controlled by the ESP32 to maneuver efficiently across various floor types. The integration of smart timing and power management ensures extended operation on a single battery charge. Its modular design allows easy maintenance and upgrades, making it suitable for both domestic and light industrial use. With live video feedback, users can monitor cleaning status in real-time and make adjustments as needed. The bot's compact structure ensures it can access tight spaces and corners that are typically hard to reach manually, enhancing overall cleanliness and coverage.

Keywords: ESP32-CAM, Ultrasonic Sensor, Diaphragm Pump, Smart Cleaning Bot, Real-Time Monitoring, Remote Control

1. INTRODUCTION

The Smart Floor Surface Cleaning Bot (FSCB) is an intelligent cleaning solution developed to automate and simplify floor maintenance in both residential and commercial settings. At its core, the system is powered by an ESP32 microcontroller, offering seamless control, connectivity, and power-efficient operation. The bot integrates an ESP32-CAM module, providing real-time video streaming and live monitoring of the cleaning process via a mobile app, enabling users to observe and manage tasks remotely.

For safe and efficient navigation, the bot utilizes an ultrasonic sensor that detects obstacles and edges in real time. This allows the FSCB to avoid collisions with objects and prevent falls from steps or platforms, ensuring smooth and safe movement throughout the environment. Instead of complex AI algorithms, the bot relies on direct sensor feedback for decision-making, ensuring reliable and consistent performance.

The cleaning mechanism is equipped with a 12V diaphragm pump, which sprays water or cleaning liquid precisely in front of the cleaning path. This is particularly effective for tackling dust, dirt, and dry waste on hard surfaces such as tiles or marble floors. Motorized wheels controlled by the ESP32 allow the bot to move systematically across the floor space.

This ESP32-based cleaning bot is a cost-effective, eco-friendly, and scalable solution, combining essential automation with smart control, aimed at enhancing hygiene with minimal manual effort.

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2. METHODOLOGY

The methodology for developing the Floor Surface Cleaning Bot (FSCB) involves several key stages tailored to its functional goals and component integration. It starts with problem analysis, identifying the need for an efficient, autonomous cleaning solution for indoor environments that reduces manual effort.

During the system design phase, essential hardware components like the ESP32 microcontroller, ESP32-CAM module for live video streaming, ultrasonic sensor for obstacle detection, and a diaphragm pump for water or cleaning fluid spraying are integrated. The obstacle avoidance functionality is implemented using the ultrasonic sensor to detect nearby objects and prevent collisions or falls, ensuring smooth and safe navigation.

Power management is handled by optimizing motor operation and using timed sensor readings to reduce energy consumption, extending battery life. The user interface is developed through the Blynk IoT platform over Wi-Fi, allowing users to control the bot remotely, schedule cleaning sessions, and monitor real-time video and status from their smartphones. This structured methodology ensures that the FSCB is smart, efficient, and easy to operate.

3.1 Problem Statement and Requirement

Problem Statement:

Maintaining indoor floor cleanliness is time-consuming and labor-intensive, especially in homes and small commercial spaces. Traditional methods lack adaptability to obstacles and varied surfaces. The FSCB offers a smart, semi-autonomous solution using ESP32, ultrasonic sensing, and automated cleaning with remote monitoring.

Requirements:

Functional Requirements:

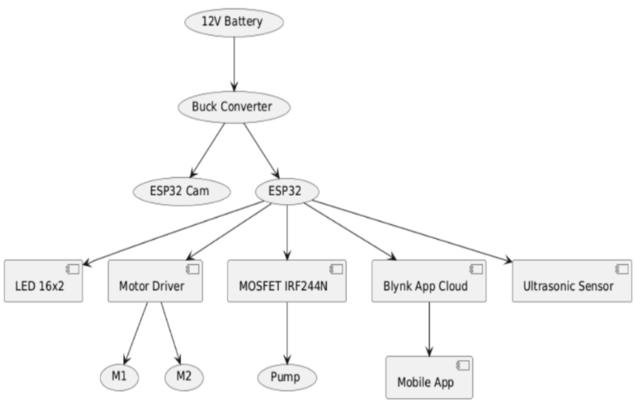
1. ESP32 Microcontroller for controlling motor functions and sensor inputs.
2. ESP32-CAM Module for live video streaming and remote surveillance.
3. Ultrasonic Sensor for real-time obstacle detection and edge avoidance.
4. Diaphragm Pump to dispense water or cleaning solution during operation.
5. Motorized Wheels for controlled movement across the floor.
6. Blynk IoT App (via Wi-Fi) for remote control, live monitoring, and scheduling.
7. Autonomous Navigation Logic based on sensor input without the need for complex AI.

Non-Functional Requirements:

1. Battery-Powered Operation optimized for 1.5–2 hours of runtime.
2. Compact and Lightweight Design for ease of movement in small spaces.
3. Modular Architecture to allow easy maintenance and component replacement.
4. Cost-Effective Materials to keep overall system affordable for end-users.
5. Low Latency Communication between bot and Blynk app for real-time control.
6. User-Friendly Interface for scheduling tasks and monitoring status.

3.2 System Design and Architecture:

Description:



The 12V Battery is the main power source for the bot. It supplies power to all components through a Buck Converter, which steps down the voltage for the ESP32 and ESP32-CAM modules.

- The ESP32 is the central controller of the system.

2. Core Functionality: The bot uses ESP32 to control

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It handles sensor data, controls movement, manages communication, and drives the cleaning mechanism.

- The ESP32-CAM module is responsible for real-time video streaming to the mobile app via the Blynk Cloud, allowing users to remotely monitor the bot's activity.
- The Ultrasonic Sensor connected to ESP32 detects obstacles and edges, enabling obstacle avoidance and safe navigation.
- The Motor Driver receives control signals from the ESP32 and drives two motors (M1 and M2) for forward, backward, and turning movement.
- The MOSFET IRF244N acts as a switch to control the Diaphragm Pump, which sprays water or cleaning solution during operation.
- A 16x2 LCD Display shows status messages or basic bot information locally.
- The Blynk App Cloud connects the ESP32 to the Mobile App via Wi-Fi, enabling users to control, schedule, and monitor the bot remotely.

This block diagram represents the architecture of the FSCB project, where the ESP32 microcontroller acts as the core, integrating sensors, actuators, and wireless connectivity. The system uses ESP32-CAM for live monitoring, ultrasonic sensing for obstacle avoidance, motor control for movement, and a MOSFET-controlled pump for cleaning action. The Blynk IoT platform provides an interface for remote operation, making the bot a smart, semi-autonomous cleaning solution.

3. PROJECT SCOPE

1. Target Environments: The FSCB is designed for efficient cleaning in residential and small commercial environments, capable of adapting to flat, hard floor types such as tiles, marble, and wood surfaces.

movement, cleaning, and communication. It autonomously navigates rooms, detects and avoids obstacles, and sprays water or cleaning solution through a diaphragm pump for effective dust and debris removal.

3. Obstacle Avoidance: Equipped with an ultrasonic sensor, the bot detects obstacles and edges in real time, ensuring collision-free and safe navigation throughout the cleaning process.
4. Power Management: The bot runs on a 12V battery, regulated via a buck converter to supply stable voltage to ESP32 and peripherals. Power usage is optimized through efficient motor control and sensor timing.
5. User Interaction: A mobile app interface built using the Blynk IoT platform over Wi-Fi enables users to monitor live video (via ESP32-CAM), start/stop the bot, and receive real-time status updates, offering convenient remote operation and scheduling.

4. COMPARISON AND ANALYSIS

The Floor Surface Cleaning Bot (FSCB), built using ESP32, ESP32-CAM, ultrasonic sensors, and a diaphragm pump, offers a smart and cost-effective alternative to traditional robotic vacuums and manual cleaning methods. Unlike high-end robotic vacuums that rely on expensive LIDAR systems or proprietary technologies, the FSCB uses low-cost ultrasonic sensors for real-time obstacle detection and edge avoidance, ensuring safe and adaptive navigation. The ESP32 microcontroller serves as the central controller, managing motor movements, pump activation, and data communication efficiently. Additionally, the ESP32-CAM module provides live video streaming, allowing users to monitor and control the bot remotely via the Blynk IoT app over Wi-Fi — a feature rarely seen in budget cleaning bots.

The diaphragm pump integrated into the FSCB enables surface cleaning through controlled water or solution spraying, replacing the traditional vacuum suction system while still delivering effective cleaning on hard surfaces like tiles or marble. Power is managed using a 12V rechargeable battery with a buck converter, making the system energy-efficient and modular. In contrast to manual cleaning, which demands physical labor and time, the FSCB operates semi-autonomously and reduces human involvement significantly.

Its modular design, open hardware, and customizable software make it easier to maintain and upgrade, unlike commercial bots that are often closed systems. Overall, the FSCB provides a practical, scalable, and low-maintenance solution that bridges the gap between affordability and automation in modern floor cleaning.

5. . DISCUSSION

1. AI/ML-Based Navigation and Dirt Detection Incorporating machine learning algorithms can allow the bot to intelligently learn room layouts, optimize cleaning paths, and detect heavily soiled areas. This would make the cleaning process more efficient and adaptive to real-world usage over time.
2. Automatic Charging (Auto-Docking) Implementing an auto-docking system would enable the bot to autonomously return to a charging station when the battery is low. This ensures continuous operation without manual intervention, improving user convenience.
3. Integration of Mapping (SLAM) Adding SLAM (Simultaneous Localization and Mapping) technology can enable the bot to create and follow accurate room maps. This allows for smart multi-room cleaning and ensures comprehensive coverage with minimal repetition.
4. Upgraded Battery System Enhancing the current battery with a higher-capacity or more efficient lithium-ion solution can extend the runtime significantly, making it suitable for larger areas and longer tasks without needing frequent recharging.
5. Voice Assistant Integration Adding compatibility with smart assistants like Alexa or Google Assistant would allow users to control and monitor the bot through voice commands, offering a hands-free, user-friendly experience that aligns with modern smart home ecosystems.

6. ADVANTAGES:

1. Low-Cost and Open-Source Hardware:
   The use of ESP32 and readily available modules like the ultrasonic sensor and diaphragm pump makes the bot affordable and ideal for student, DIY, or budget-conscious implementations.
2. Real-Time Video Monitoring:
   The integration of the ESP32-CAM allows users to view live video feeds of the cleaning area through the Blynk IoT app, improving transparency and control during operation.
3. Smart Obstacle Detection:
   The ultrasonic sensor enables the bot to detect obstacles and avoid collisions or edges in real time, improving safety and navigation accuracy in different indoor environments.
4. Semi-Autonomous Cleaning Mechanism:
   With the diaphragm pump, the bot can automatically spray water or cleaning solution on the floor, allowing for hands-free cleaning of dust and dry waste without manual input.
5. Remote Control via Wi-Fi:
   Thanks to ESP32 Wi-Fi connectivity and Blynk app integration, users can start, stop, or monitor the bot from their smartphone, making it highly accessible and user-friendly.
6. Energy-Efficient Operation:
   The system uses low-power components, optimized motor control, and a rechargeable battery, allowing for efficient energy usage suitable for extended cleaning sessions.
7. Modular and Easy to Upgrade:
   Since the bot is built using modular components, future enhancements (e.g., extra sensors, new control features) can be added easily without replacing the entire system.
8. Adaptability to Different Floor Types:
   The FSCB is designed to work on tiles, marble, wooden, or concrete floors, making it versatile for both home and small commercial settings.

7. LIMITATIONS:

1. Limited Battery Capacity:
   The current use of a basic 12V rechargeable battery restricts the bot's operational time. Without an auto-docking or fast-charging feature, the bot requires manual recharging, limiting its autonomy and suitability for larger cleaning areas.
2. No AI/ML Integration:
   The bot currently lacks machine learning capabilities, which means it follows basic movement patterns and cannot intelligently adapt to room layouts, dirt levels, or optimize cleaning paths over time — a limitation compared to high-end smart bots.
3. Absence of Surface Mapping:
   Due to the lack of SLAM or camera-based room recognition, the bot cannot create or follow floor maps. This results in inefficient or repetitive movement, especially in multi-room or irregular environments.

8. FUTURE SCOPE:

1. AI/ML-Based Navigation and Dirt Detection:
   Incorporating machine learning algorithms can allow the bot to intelligently learn room layouts, optimize cleaning paths, and detect heavily soiled areas. This would make the cleaning process more efficient and adaptive to real-world usage over time.
2. Automatic Charging (Auto-Docking):
   Implementing an auto-docking system would enable the bot to autonomously return to a charging station when the battery is low. This ensures continuous operation without manual intervention, improving user convenience.
3. Integration of Mapping (SLAM):
   Adding SLAM (Simultaneous Localization and Mapping) technology can enable the bot to create and follow accurate room maps. This allows for smart multi-room cleaning and ensures comprehensive coverage with minimal repetition.
4. Upgraded Battery System:
   Enhancing the current battery with a higher-capacity or more efficient lithium-ion solution can extend the runtime significantly, making it suitable for larger areas and longer tasks without needing frequent recharging.

9. CONCLUSION:

The Floor Surface Cleaning Bot (FSCB) project provides an affordable and semi-autonomous solution for maintaining clean indoor environments. It integrates the ESP32 and ESP32-CAM modules to enable real-time video monitoring and remote control through Wi-Fi, offering users convenience and live feedback via the Blynk app. The ultrasonic sensor allows for effective obstacle detection and edge avoidance, ensuring safe and uninterrupted navigation. The diaphragm pump-based cleaning mechanism helps in spraying water or cleaning solution, making it suitable for removing dust and debris on various floor types. The system is energy-efficient and modular, allowing easy customization and future upgrades. Although it lacks advanced AI features and relies on limited battery power, it successfully automates basic floor-cleaning tasks. The FSCB stands out as a low-cost alternative to expensive robotic vacuums, particularly for homes, offices, and small commercial spaces. This project demonstrates the potential of open-source hardware in creating practical smart cleaning systems. With future enhancements like machine learning and auto-docking, the bot can evolve into a fully autonomous and intelligent cleaning assistant.

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