

# SMART CLOTHING RACK SYSTEM

Higher National Diploma in Software Engineering

IOT  
Final Report Documentation



School of Computing  
National Institute of Business Management  
Colombo - 07

**NATIONAL INSTITUTE OF BUSINESS MANAGEMENT  
HIGHER NATIONAL DIPLOMA IN SOFTWARE ENGINEERING**

**Final Report Documentation**

**Smart Clothing Rack System**

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## DECLARATION

We, the undersigned, hereby declare that the project titled "**Smart Clothing Rack System**", carried out as part of our **IOT** project, is submitted for the partial fulfillment of the course requirements at **NIBM University** under the guidance of **Mr. Bathiya Seneviratne**. The content of this project report is based on our work, except where explicitly stated otherwise in the text. We also declare that this project has not been submitted, in whole or in part, for any degree or diploma at any other institution or university.

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## ABSTRACT

The Smart Clothing Rack System is an advanced Internet of Things (IoT) solution designed to automate and safeguard the outdoor clothes-drying process by responding intelligently to changing environmental conditions. In many households, clothes are traditionally dried outside, making them vulnerable to sudden rainfall or adverse weather, often requiring immediate human intervention. This project addresses this practical challenge by introducing a fully automated, self-navigating clothing rack capable of detecting rain, avoiding obstacles, and relocating indoors without manual assistance.

The proposed system integrates multiple sensing and actuation technologies to achieve reliable autonomous operation. An ESP8266 microcontroller programmed in C++ using the Arduino IDE serves as the system's central controller, responsible for data acquisition, decision-making, and communication with the IoT platform. A rain sensor continuously monitors rainfall, while a DHT-series sensor captures ambient temperature and humidity levels to support weather awareness. For mobility, the rack uses four geared DC motors controlled through dual L298N motor driver modules, enabling smooth and stable movement. An IR sensor array implements the line-following mechanism, ensuring accurate navigation along a predefined path from the outdoor drying area to the interior of the house. Additionally, ultrasonic sensors positioned at the front and rear enable dynamic obstacle detection and avoidance, enhancing the safety and reliability of movement.

To support sustainable operation, the entire system is powered by a rechargeable Li-ion battery pack supplemented by a solar panel and solar charge controller, ensuring continuous functionality with minimal energy consumption. All electronic components, including batteries, converters, control boards, and wiring, are securely enclosed within a concealed base compartment that forms the lower structure of the rack. Beyond physical automation, a dedicated web dashboard provides real-time monitoring of environmental data, rain status, battery level, and the rack's current location (indoor or outdoor), enabling users to stay informed from any internet-enabled device.

By integrating autonomous navigation, environmental sensing, IoT monitoring, and renewable energy, the Smart Clothing Rack System demonstrates a practical and innovative approach to resolving everyday household problems through technology. The project highlights the potential of IoT-based automation to improve convenience, enhance safety, and promote energy-efficient solutions suitable for modern living environments.

## ACKNOWLEDGMENTS

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# Chapter 1: Introduction

## 1.1 Introduction of the Project

The Smart Clothing Rack System is an innovative IoT-based solution designed to automate the process of drying clothes outdoors while ensuring protection against sudden weather changes. In many households, clothes are traditionally hung outside to make use of natural sunlight and airflow. However, this method requires constant attention, as unexpected rainfall can soak the clothes and undo the drying process. This inconvenience becomes even more significant in regions with unpredictable weather patterns, where users must frequently monitor the outdoor environment.

To address this challenge, the Smart Clothing Rack System introduces an intelligent and autonomous clothing rack capable of sensing environmental conditions and reacting accordingly. By combining multiple sensors, motorized mobility, and wireless connectivity, the system can detect rain, follow a predefined path, avoid obstacles, and automatically move indoors to protect the clothes. This not only reduces the need for human intervention but also enhances reliability and convenience in day-to-day household tasks.

The project incorporates a wide range of hardware and software technologies to achieve its core functionalities. Sensors such as a rain sensor, DHT temperature and humidity sensor, ultrasonic obstacle detectors, and a line-following IR array ensure accurate environmental awareness and safe navigation. The **NodeMCU ESP8266** microcontroller programmed in **C++** using the **Arduino IDE** serves as the brain of the system, processing sensor data and controlling the four DC motors through motor drivers. A solar-powered battery system supplies energy to the rack, promoting eco-friendly and cost-efficient operation.

A key feature of the system is its IoT dashboard, which provides users with real-time information including weather status, battery percentage, temperature, humidity, and the rack's current position. Additionally, when an obstacle is detected during movement, the system immediately displays a notification on the website, allowing users to stay informed about any obstructions or interruptions in real time. This enhances safety, improves user awareness, and ensures reliable operation.

Overall, the Smart Clothing Rack System represents a practical application of IoT, automation, and renewable energy integration. It demonstrates how everyday household tasks can be enhanced using intelligent technologies to improve comfort, efficiency, and user experience.

This report presents the complete development process of the Smart Clothing Rack System, covering the system architecture, design rationale, hardware integration, programming logic, and testing procedures. It further highlights the technical and practical challenges encountered throughout the implementation and offers recommendations for potential enhancements in future versions. Ultimately, this project aims to modernize the clothes-drying experience by providing a more reliable, time-saving, and user-friendly alternative to traditional outdoor drying methods through the integration of IoT, automation, and sustainable energy technologies.

## 1.2 Problem Statement

In many households, clothes are commonly dried outdoors to take advantage of sunlight and natural airflow. However, this practice presents several challenges, especially during unpredictable weather conditions. Sudden rainfall can cause clothes to become wet again, forcing users to rush outside to bring them indoors. This frequent need for manual monitoring is inconvenient, time-consuming, and often impractical for individuals with busy schedules, elderly users, or those away from home.

Additionally, outdoor drying areas may contain physical obstacles or limited space, making it difficult to move traditional clothing racks safely and efficiently. Existing racks lack the capability to sense environmental changes, avoid obstacles, or relocate autonomously. Furthermore, most traditional solutions do not incorporate any form of real-time monitoring or notification system, leaving users unaware of weather changes or the drying status of their clothes.

There is a clear need for an intelligent, automated solution that can independently detect rain, navigate to a safe indoor location, and provide real-time updates on environmental conditions. The absence of such a system leads to user inconvenience, inefficient drying processes, and potential damage to clothes. The Smart Clothing Rack System aims to address these issues by integrating IoT technologies, autonomous movement, and environmental sensing to create a more reliable and user-friendly clothes-drying experience.

## 1.3 Objectives

The primary objective of the Smart Clothing Rack System is to develop an intelligent, autonomous, and IoT-enabled solution that enhances the traditional clothes-drying process by improving convenience, safety, and user awareness. To achieve this, the project focuses on the following specific objectives:

### 1. Main Objective:

- To design and implement an automated clothing rack system capable of detecting rain, avoiding obstacles, and autonomously moving indoors using a line-following mechanism.

### 2. Specific Objectives:

- **To detect sudden weather changes** using a rain sensor and environmental monitoring sensors such as temperature and humidity modules.
- **To implement autonomous navigation** through a predefined path using an IR line-following sensor array.
- **To ensure safe movement** by integrating ultrasonic sensors for real-time obstacle detection and avoidance.

- **To provide immediate obstacle alerts** by displaying real-time notifications on the IoT dashboard whenever an obstruction is detected.
- **To integrate IoT monitoring**, allowing users to view weather status, rack position, battery level, and sensor data through a web-based interface.
- **To develop reliable motor control** using DC geared motors and motor drivers for smooth and stable movement.
- **To implement sustainable power management** using a solar panel, charge controller, and Li-ion battery system for continuous operation.
- **To write embedded control code in C++** using the Arduino IDE for sensor reading, motor control, decision-making, and IoT communication.
- **To create a secure and concealed hardware enclosure** that houses the electronics and battery system to ensure durability, aesthetics, and safety.
- **To test and evaluate system performance** under various weather and environmental conditions to ensure reliability and responsiveness.

## 1.4 Scope of the Project

The scope of the Smart Clothing Rack System defines the boundaries, features, and functional capabilities covered within the development of this project. It outlines what the system is designed to achieve and the specific areas it will address during implementation.

### Functional Scope

- **Automated Rain Detection:**  
The system will detect rainfall using a rain sensor and initiate automatic movement to protect the clothes.
- **Autonomous Path Navigation:**  
The rack will follow a predefined path using an IR line-following sensor array, allowing it to move between outdoor and indoor locations without human guidance.
- **Obstacle Detection and Alerts:**  
Ultrasonic sensors will identify obstacles in the rack's path, stopping movement and sending immediate notifications to the IoT dashboard.
- **Motorized Movement:**  
The system will move using four DC geared motors controlled through motor driver modules, ensuring smooth and stable operation.

- **IoT-Based Monitoring:**  
A web dashboard will allow users to monitor key parameters such as rain status, temperature, humidity, battery level, system alerts, and rack location in real time.

## Technical Scope

- **Microcontroller Programming:**  
All system logic, sensor integration, and motor control will be implemented using C++ in the Arduino IDE on an ESP8266 microcontroller.
- **Power Management:**  
The project includes a Li-ion battery system, supported by a solar panel and solar charge controller for sustainable, continuous operation.
- **Hardware Integration:**  
The project covers the connection, mounting, and integration of sensors, motor drivers, power components, and wiring within a concealed compartment at the bottom of the rack.
- **Web Application Development:**  
A simple and user-friendly web interface will be created for real-time system monitoring and alert notifications.

## Design & Construction Scope

- **Physical Structure Design:**  
The system will be integrated into a clothing rack with a concealed lower storage compartment to house electronics and maintain an aesthetically pleasing external appearance.
- **Prototype Development:**  
A fully functional prototype will be built and tested under normal outdoor conditions to validate system performance.

## Limitations (Within Scope)

- The system moves only along the predefined path created using a line-following track.
- It does not support remote manual control for movement (only automated movement is included).
- The solar charging capacity is designed for low-power IoT and motor operation; excessive cloudy conditions may reduce charging speed.

## 1.5 Tools and Technologies

The Smart Clothing Rack System is developed using a combination of hardware technologies, software tools, and design platforms that work together to enable autonomous movement, environmental sensing, and IoT monitoring. The system is built around an **ESP8266 microcontroller**, which acts as the central unit responsible for processing sensor data, controlling motor functions, and managing wireless communication.

The hardware technologies used include various sensors for weather and obstacle detection, motor drivers to control the rack's movement, and a rechargeable power system supported by solar charging. These components provide the essential functionality required for navigation, environmental awareness, and user safety.

For software development, the **Arduino IDE** is used to write and upload C++ code to ESP8266, handling tasks such as sensor integration, decision-making, and IoT communication. Web technologies are also utilized to create the IoT dashboard, allowing real-time monitoring of system data through any internet-connected device.

On the design side, 3D modeling and prototyping tools may be used to develop the lower enclosure that houses the electronic components and ensures a clean, concealed structure. Basic fabrication tools and prototyping materials support the assembly and testing of the prototype.

By combining these tools and technologies, the project successfully delivers a functional and intelligent prototype that demonstrates the practical capabilities of IoT-based automation.

## 1.6 Chapter Summary

This chapter introduced the Smart Clothing Rack System and provided a comprehensive overview of the motivations, goals, and technological foundations of the project. It began by explaining the limitations of traditional outdoor clothes drying, particularly the inconvenience caused by sudden weather changes and the need for continuous monitoring. The proposed solution an autonomous, IoT-enabled clothing rack was then described, emphasizing its ability to detect rain, avoid obstacles, and automatically move indoors to protect clothing.

The chapter outlined the problem statement, identifying the key challenges the system addresses. The objectives of the project were presented to clarify the intended outcomes, followed by the scope, which defined the system's operational boundaries and primary functionalities. A high-level overview of the tools and technologies used throughout the development process was also provided to indicate the resources involved in constructing the prototype.

Overall, Chapter 1 defines the purpose and background of the Smart Clothing Rack System by presenting the problem, objectives, scope, and the technologies incorporated into its development. These elements form the structural basis of the project and guide the detailed explanations and implementation processes discussed in the subsequent chapters.

## Chapter 2: System Overview

### 2.1 How the System Works

The Smart Clothing Rack System operates as a fully automated and intelligent mechanism designed to protect clothes from sudden rainfall while providing continuous environmental monitoring and safe mobility. The functioning of the system is based on coordinated interaction between sensors, actuators, the ESP8266 microcontroller, and the IoT dashboard.

The system continuously collects environmental data. The rain sensor plays a critical role by detecting water droplets or moisture on its surface. When no rain is present, the rack remains in its outdoor position, allowing clothes to dry naturally. Simultaneously, the DHT11/DHT22 sensor measures temperature and humidity, with the data being sent to the IoT dashboard for real-time monitoring.

Once the rain sensor detects rainfall, the ESP8266 shifts the system into its “Return Indoors” mode. The microcontroller activates the DC geared motors through the L298N motor driver modules and begins navigating along the predefined path. The IR line-following sensor array tracks the black line on the ground and directs the motors to keep the rack centered and aligned. This ensures reliable movement from the outdoor location to the designated indoor area.

As the rack moves, ultrasonic sensors continuously scan the surroundings for obstacles. If an object is detected, the system halts to prevent collisions and sends an alert to the IoT dashboard. This safety mechanism prevents damage or injury and informs the user about any obstruction in the path.

Power is supplied by a rechargeable Li-ion battery pack housed within a concealed bottom compartment. The battery is supported by a solar panel and solar charge controller, allowing extended operation without manual charging. A buck converter provides stable voltage to the ESP8266, sensors, and motor controllers.

All decision-making including movement, obstacle handling, and line following is managed by the ESP8266 microcontroller programmed in C++ using the Arduino IDE. The microcontroller also handles Wi-Fi communication, sending updates to the IoT dashboard. Users can view live data such as weather conditions, battery level, system status, rack location, and obstacle alerts through the web interface.

Through these combined mechanisms environmental sensing, autonomous navigation, obstacle detection, power management, and IoT monitoring The Smart Clothing Rack System operates as a reliable and intelligent solution that enhances convenience and ensures the protection of clothes in dynamic weather conditions.

## 2.2 Main Components

The Smart Clothing Rack System consists of a set of essential electronic, mechanical, and IoT components that work together to automate movement, detect weather conditions, avoid obstacles, and send real-time updates to the user. The key components used in the system are listed below:

- **NodeMCU ESP8266 Microcontroller** - Serves as the central controller of the system. It processes sensor data, executes navigation logic, controls the motors, and handles IoT communication through built-in Wi-Fi functionality.
- **Rain Sensor Module** - Detects rainfall or moisture levels. When rain is detected, it triggers the rack to automatically move indoors to protect the clothes.
- **DHT11/DHT22 Temperature & Humidity Sensor** - Measures the environmental temperature and humidity and sends the data to the IoT dashboard for real-time monitoring.
- **Ultrasonic Sensors (HC-SR04)** - Placed at the front and/or rear of the rack to detect obstacles in the path. If an object is detected, the rack stops immediately and sends an alert to the website.
- **IR Line-Following Sensor Array** - Detects the predefined black line path on the floor. It guides the rack accurately from the outdoor drying area to the indoor location.
- **DC Geared Motors (4 Units)** - Provide the torque required to move the rack smoothly in the desired direction. Each motor is attached to one wheel for stable mobility.
- **L298N Motor Driver Modules** - Control the speed and direction of the DC motors based on signals received from the ESP8266. Two modules are used to manage all four motors.
- **Li-ion Battery Pack (with BMS)** - Acts as the primary power source for the system. The Battery Management System ensures safe charging, discharging, and cell balancing.
- **Solar Panel** - Provides renewable energy to charge the battery through the solar charge controller, allowing the system to operate efficiently even outdoors.
- **Solar Charge Controller** - Regulates the power from the solar panel and ensures safe charging of the Li-ion battery pack.
- **Buck Converter** - Used to regulate voltage levels and supply stable power to the ESP8266, sensors, and motor drivers.
- **Buzzer** - Provides audio alerts when necessary, such as during rain detection or system warnings.

- **LEDs (Indicator Lights)** - Used for basic status indication such as power on, system active, or charging status.
- **Enclosure / Bottom Compartment** - A concealed housing structure located at the bottom of the rack, used to neatly store the electronics, batteries, converters, and wiring.
- **Wheels (4 Units)** - Attached to the bottom of the rack to support smooth mobility during automated or manual movement.
- **Jumper Wires & Connectors** - Used for electrical connections between sensors, controllers, and other electronic modules.
- **Breadboard** - Used during development to test and connect electronic components without soldering.

Together, these components form a complete system capable of autonomous navigation, environmental sensing, obstacle detection, and IoT-based monitoring, allowing the Smart Clothing Rack to operate efficiently and reliably.

## 2.3 Features of the System

The Smart Clothing Rack System includes a range of intelligent and automated features designed to enhance convenience, ensure safety, and provide reliable protection for clothes during unpredictable weather conditions. The key features of the system are as follows:

- **Automatic Rain Detection**

The rack uses a rain sensor to continuously monitor rainfall. When rain is detected, the system automatically initiates the movement from the outdoor drying area to the indoor location.

- **Autonomous Navigation**

A built-in line-following sensor array allows the rack to follow a predefined black line path. This ensures accurate and consistent movement between outdoor and indoor positions without human intervention.

- **Obstacle Detection and Safety Stop**

Ultrasonic sensors detect obstacles in the rack's path. If an obstruction is identified, the system stops immediately to prevent collisions and damage.

- **Real-Time Obstacle Notifications**

When an obstacle is detected, the system sends an instant alert to the IoT dashboard, informing the user of the issue and indicating that manual clearance is required.

- **IoT Monitoring Dashboard**

The system is connected to a web-based dashboard that displays real-time information, including weather status, battery level, temperature, humidity, system alerts, and rack location.

- **Sustainable Solar-Powered Operation**

A solar panel and charge controller work together to recharge the battery, ensuring that the system can operate efficiently with minimal external power requirements.

- **Concealed Bottom Compartment**

All electronics such as the ESP8266, motor drivers, battery, converters, and wiring are stored inside a hidden compartment at the bottom of the rack, creating a clean and organized appearance.

- **Battery-Powered Mobility**

The system uses a rechargeable Li-ion battery pack to power motors and sensors, allowing smooth and uninterrupted movement regardless of outdoor conditions.

- **Automatic Movement Control**

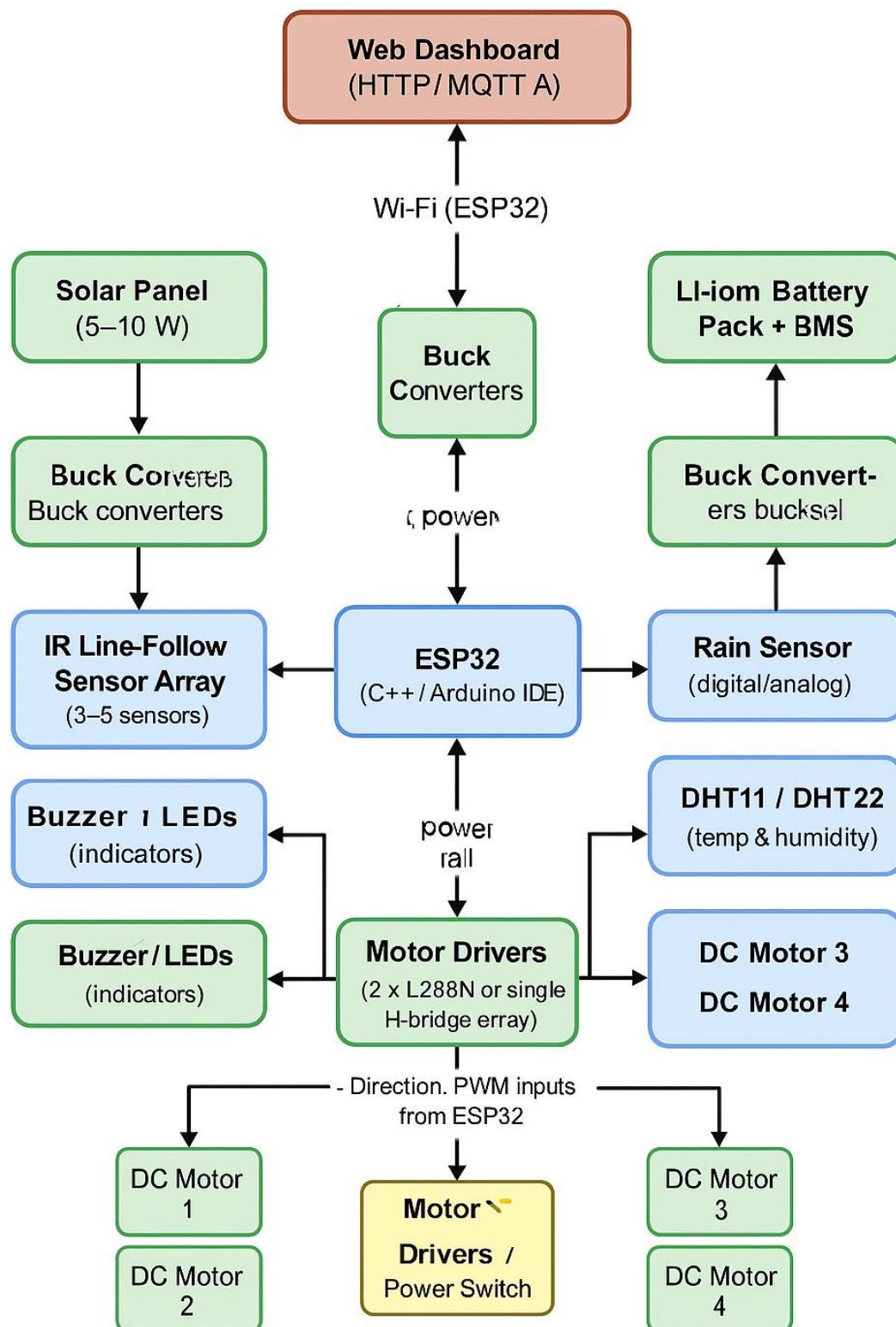
Four DC geared motors controlled by L298N motor drivers ensure stable and balanced movement during navigation.

- **Real-Time Temperature and Humidity Monitoring**

The DHT sensor continually measures environmental conditions and updates the dashboard, allowing the user to monitor the drying environment.

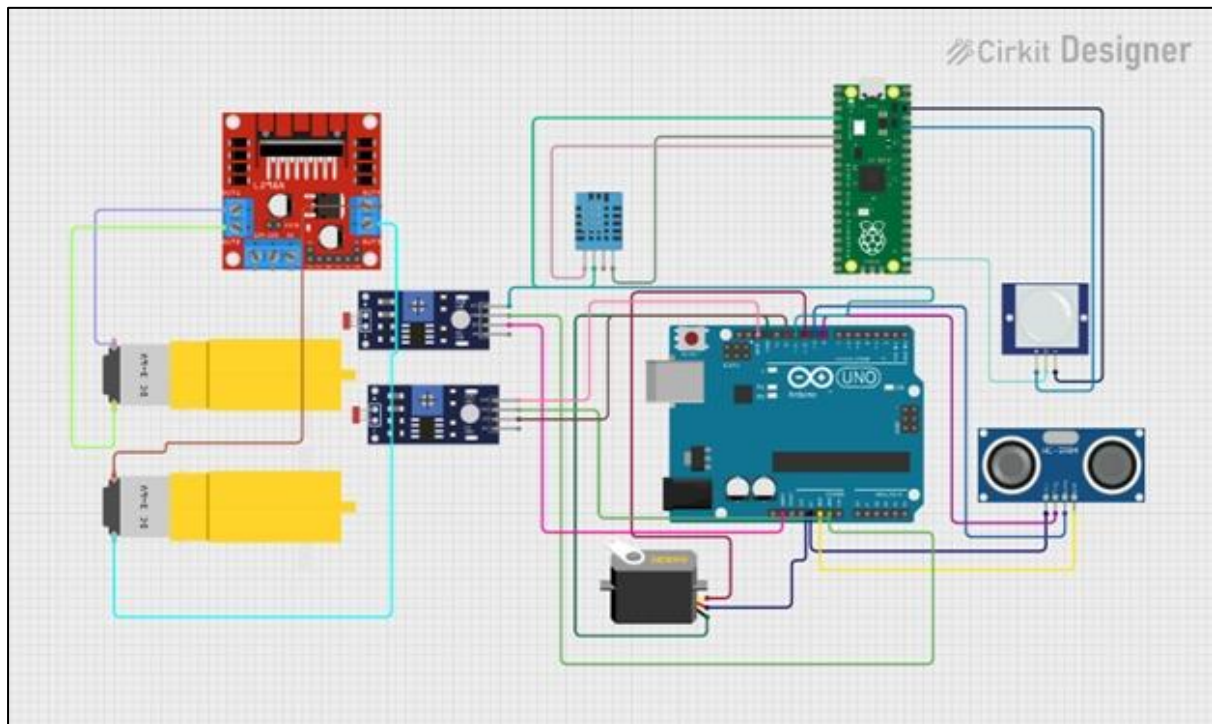
These features work together to create a reliable and efficient smart drying solution that reduces manual effort and ensures consistent protection of clothes during unexpected weather conditions. The system is designed to be easy to operate, highly responsive to environmental changes, and suitable for use in households where convenience, automation, and safety are important. By integrating IoT connectivity, autonomous movement, and renewable energy, the Smart Clothing Rack System offers a modern and practical improvement over traditional drying methods.

## 2.4 System Diagram (Block Diagram)



**Enclosure:** All electronics – battery, ESP32, drivers, buck converters – are housed inside a concealed bottom compartment

## 2.5 Circuit Design



## 2.6 Chapter Summary

Chapter 2 presented a comprehensive overview of the Smart Clothing Rack System by explaining its operational workflow, major components, and functional capabilities. The chapter described how the system detects weather conditions, follows a predefined path using line-tracking sensors, and avoids obstacles through ultrasonic sensing. It also outlined the hardware modules involved, such as the ESP8266 controller, motor drivers, sensors, and power system, highlighting the role each component plays within the overall design.

In addition to the functional explanation, this chapter also included the system's Block Diagram and Circuit design, which illustrate the internal relationships between the hardware components and the logical sequence of operations carried out during autonomous movement and environmental monitoring. These diagrams support a clearer understanding of the system's architecture and decision-making process.

Overall, Chapter 2 provides a structured description of the system's design logic, functionality, and operational interactions, forming the foundation for the hardware integration and software implementation discussed in the next chapter.

## Chapter 3: Hardware and Software

### 3.1 List of Components

The Smart Clothing Rack System integrates a set of hardware and software components that enable autonomous movement, environmental monitoring, obstacle detection, and IoT connectivity. Each component was selected based on functionality, reliability, and compatibility with the NodeMCU ESP8266 microcontroller.

#### ❖ Hardware Components

Component Name	Quantity	Description
NodeMCU ESP8266	1	Serves as the main microcontroller responsible for reading sensor inputs, controlling motors, managing Wi-Fi communication, and sending data to the IoT dashboard.
IR Sensor	2	Detects the black path line on the ground and enable the rack to navigate correctly along the predefined route.
Ultrasonic Sensors	2	Used for obstacle detection by measuring distance to objects; stops the system when an obstacle is detected.
Rain Sensor Module	1	Identifies rainfall and signals the system to return indoors when rain is detected.
DHT11 / DHT22 Sensor	1	Measures temperature and humidity to monitor outdoor drying conditions.
L298N Motor Driver Modules	2	Controls the four DC geared motors by regulating voltage and direction.
DC Geared Motors	4	Enable movement of the rack by driving the wheels.
Rechargeable Li-ion Battery Pack	1	Provides power to the motors, sensors, and microcontroller.
TP4056 Charging Module	1	Safely charges the Li-ion battery pack and prevents overcharging/over-discharging.
Solar Panel	1	Recharges the battery using solar energy for continuous operation.
Buck Converters	2	Step down voltage to safe operating levels for the ESP8266 and other modules.
Buzzer / LED Indicators	Optional	Provide status alerts such as system movement, low battery, or warnings.
Wheels (Castor/Directional)	4	Allow the rack to move smoothly along the ground.

Breadboard	1	Used to connect components during prototyping.
Chassis / Bottom Compartment	1	Houses all electronics including battery, drivers, and wiring inside a concealed lower unit.
Jumper Wires	Various	Used to connect sensors, drivers, and modules to the NodeMCU board.
Switches / Power Controls	Few	Used for system power control and emergency stop functions.
Resistors	1 Pack	For pull-ups/pull-downs, LED current-limiting, sensor circuits and general circuit protection.
Capacitors	1 Pack	For power smoothing, decoupling, and transient suppression (especially near motor drivers and supply inputs).
Mounting Hardware & Fasteners	1 Set	Screws, standoffs, zip-ties, brackets, and adhesive for assembly and mounting.

#### ❖ Software

Software/Tool	Purpose
Arduino IDE	Write, compile, and upload C++ firmware to the NodeMCU ESP8266; use serial monitor for debugging.
Web Dashboard (HTML/CSS/JavaScript, Firebase)	Real-time monitoring UI for rain status, temperature/humidity, battery level, rack position, and alerts.
Google Gemini (3D Design)	Used to generate, visualize, or refine 3D design concepts for the rack structure and bottom compartment.
Proteus	Basic circuit simulation or prototyping before physical assembly.

## 3.2 Hardware Integration and Layout

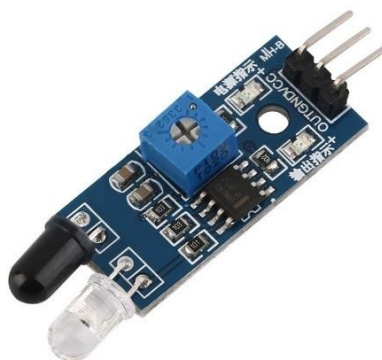
This section explains how each major hardware component is physically integrated into the Smart Clothing Rack System. It focuses on the placement, wiring, and functional role of each part in enabling autonomous navigation, rain detection, obstacle avoidance, and IoT monitoring.

- **NodeMCU ESP8266**



The NodeMCU ESP8266 is placed securely inside the bottom compartment, serving as the central controller for all sensors and motors. Its position ensures short wiring paths, good airflow, and protection from outdoor moisture. All signal, power, and communication lines are routed to this controller for efficient system management.

- **IR Sensor**



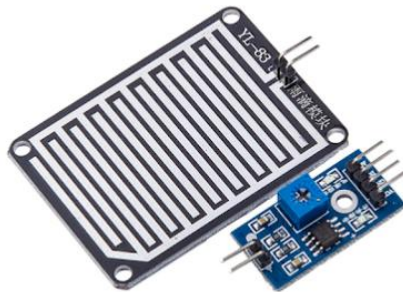
The IR line-following sensor array is mounted beneath the front of the rack, close to the floor surface. This position allows the sensor to clearly detect the black line used for navigation. Proper height alignment ensures accurate tracking even on slightly uneven surfaces.

- **Ultrasonic Sensor**



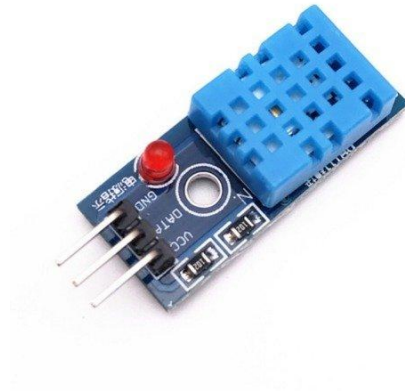
Two ultrasonic sensors are mounted on the front and rear sides of the rack using small angled brackets. Their placement allows unobstructed distance measurement, ensuring that the system can detect obstacles and stop immediately. This enhances safety during autonomous movement.

- **Rain Sensor Module**



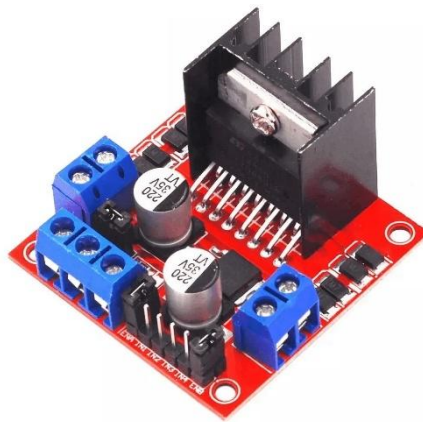
The rain sensor is positioned on the top bar of the clothing rack, fully exposed to open air. This placement ensures early detection of rainfall. A protected cable route runs from the sensor down to the NodeMCU, preventing moisture from entering the electronics housing.

- **DHT11 / DHT22 Sensor**



The DHT sensor is installed on the outer side of the rack where airflow is consistent. This allows accurate measurement of temperature and humidity levels. The sensor data is continuously sent to the IoT dashboard for real-time monitoring.

- **L298N Motor Driver Modules**



The motor driver modules are mounted inside the bottom compartment beside the power components. Their placement allows short, stable wiring connections to the motors while keeping them secure and protected from vibration. These modules regulate speed and direction for all four motors.

- **DC Geared Motors with Wheels**



The DC geared motors with wheels are mounted at each corner of the rack's base. Each motor is directly connected to a wheel, providing the torque and traction needed for smooth and controlled movement. This combined setup ensures stable navigation along the predefined path, even when the rack is carrying multiple clothes. The motors receive direction and speed signals from the L298N motor drivers, allowing the system to move forward, reverse, and make precise turns as required.

- **Rechargeable Li-ion Battery Pack**



The rechargeable Li-ion battery pack is housed in a dedicated section inside the bottom compartment. Its position ensures safe handling, reduced vibration, and proper weight distribution for system stability. The battery powers all electronic modules and the motors.

- **TP4056 Charging Module**



The TP4056 charging module is mounted near the battery pack to provide safe and controlled charging. Its accessible placement allows easy connection to an external charger when solar power is insufficient.

- **Solar Panel**



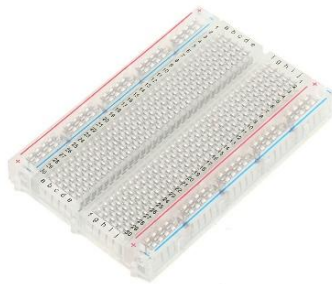
The solar panel is installed at the upper rear of the rack, facing upward to maximize sunlight exposure. The panel charges the battery through a solar charge controller, supporting efficient and renewable power usage.

- **Buck Converter**



Buck converters are placed inside the electronics compartment to provide stable 5V and 3.3V outputs for the NodeMCU and sensors. Their location ensures clean power delivery while reducing electrical noise from the motors.

- **Breadboard**



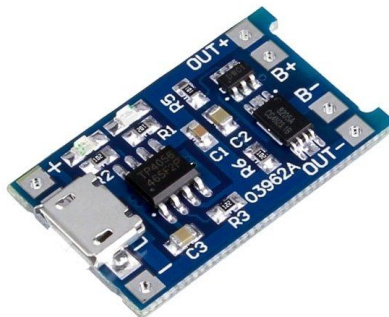
A breadboard is used during prototyping and mounted temporarily inside the compartment. It allows flexible adjustments to wiring layouts and component connections during system testing and calibration.

- **Jumper Wires**



Jumper wires are used throughout the system to interconnect modules. They are organized with cable ties and routed neatly along the sides of the compartment to prevent tangling and accidental disconnections.

- **JTP4056 5V 1A Micro USB Lithium Battery Charging Module**



The TP4056 charging module is installed next to the Li-ion battery pack inside the lower compartment. In this system, it is wired to receive regulated 5V output from the solar charge controller, allowing the solar panel to safely charge the battery. The module ensures stable charging and provides built-in protection against over-charging, over-discharging, and short circuits. Its placement offers easy access for wiring while keeping the charging circuit secure and organized.

### 3.3 NodeMCU Programming

This section explains how the NodeMCU ESP8266 was programmed to manage sensor inputs, motor control, wireless communication, and overall system logic. All programming was done using the Arduino IDE with C++ language and ESP8266 board support libraries.

- **Programming Environment**

The firmware for the Smart Clothing Rack System was developed using the Arduino IDE with the ESP8266 core installed. This provides necessary libraries for Wi-Fi features, GPIO handling, PWM motor control, and sensor communication. The code was tested using the serial monitor to verify sensor responses, motor behavior, and real-time data transmission before deployment.

- **Sensor Integration**

The NodeMCU reads inputs from multiple sensors including the rain sensor, DHT sensor, IR line-follow array, and ultrasonic sensors. Each sensor is assigned to specific GPIO pins, and corresponding libraries (such as *DHT.h* for temperature/humidity) are used to collect accurate readings. These values determine the system's behavior—for example, detecting rainfall switches the system into automatic return mode, while ultrasonic readings ensure safe navigation.

- **Motor Control Logic**

PWM signals from the NodeMCU are sent to the L298N motor driver modules to control speed and direction of the DC geared motors. The programming logic includes forward movement, stopping, turning left or right, and reversing. The IR line-following sensor continuously provides feedback, allowing the NodeMCU to make real-time adjustments to follow the black navigation path accurately.

- **Obstacle Detection and Safety Response**

Ultrasonic sensors are programmed to measure distance at regular intervals. When an obstacle is detected within a defined threshold, the NodeMCU immediately stops motor operation to prevent collisions. A signal is also sent to the IoT dashboard indicating that an obstruction has been detected, ensuring safety and letting users respond promptly.

- **Rain Detection Response**

The rain sensor output is monitored continuously. When rain is detected, the NodeMCU overrides all manual or idle states and activates the return-to-indoor routine. This includes enabling the motors, switching to line-following mode, and navigating along the predefined path until a safe indoor location is reached.

- **IoT Data Transmission**

Using the ESP8266's built-in Wi-Fi functionality, the firmware transmits real-time system data to the IoT dashboard through HTTP requests. Temperature, humidity, rain status, obstacle detection, and battery information are uploaded to a Firebase database at regular intervals. This enables continuous remote monitoring and ensures that all sensor readings and system updates are reflected accurately on the web interface.

- **System Workflow Programming**

All operations are organized into a main loop that continuously evaluates sensor readings, responds to environmental conditions, and adjusts motor behavior accordingly. Sub-functions are used to keep the program structured—such as functions for reading sensors, controlling motors, following lines, stopping on obstacles, and transmitting telemetry.

This modular programming approach ensures smooth operation, easy debugging, and the ability to add new features in future updates.

### 3.4 3D Design

The 3D model of the Smart Clothing Rack System was created using Google Gemini to visualize the complete physical layout before hardware integration. The model illustrates the external structure, wheel system, electronics compartment, and sensor placements, ensuring all components fit correctly and function as intended.

#### ➤ 3D Model Overview

The 3D design provides a full representation of the clothing rack, including the main hanging frame, support legs, and the bottom box that houses the electronics. The design maintains a simple, modern appearance while prioritizing functionality for indoor and outdoor use.



#### ➤ Bottom Compartment Design

The bottom compartment is designed as a fully enclosed box that protects the NodeMCU, motor drivers, battery pack, TP4056 module, buck converters, and wiring. This compartment keeps all electronics safely hidden while providing enough ventilation and space for secure mounting. The placement at the bottom also improves weight distribution, giving the rack more stability during movement.

### ➤ **Sensor and Module Placement**

The 3D design allocates specific mounting positions for all sensors:

- The IR line-following sensor is placed underneath the front bottom area for accurate path detection.
- Ultrasonic sensors are positioned at the front and rear for obstacle detection.
- The rain sensor is mounted at the top part of the rack for direct exposure to rainfall.
- The DHT sensor is positioned on the side, ensuring it receives proper airflow for accurate temperature and humidity readings.

These placements ensure optimal operation without interfering with the clothes hung on the rack.

### ➤ **Mobility Structure**

The model includes four wheels attached to DC geared motors mounted at each corner of the bottom box. This structure provides stable and controlled movement along the predefined path. The wheel installation is designed to support smooth motion while maintaining an unobtrusive appearance.

### ➤ **Solar Panel Integration**

The solar panel is mounted on the top surface of the bottom compartment. This location provides a stable and flat mounting area while ensuring good sunlight exposure. Power from the panel is routed directly to the charging circuitry inside the compartment, allowing continuous charging of the battery during daylight hours.

### ➤ **Role of the 3D Design**

The 3D model supports the physical build process by:

- Providing an accurate visual layout of all system components.
- Ensuring correct spacing and alignment for sensors and motors.
- Allowing early adjustments before building the prototype.
- Improving understanding of the system's mechanical structure.

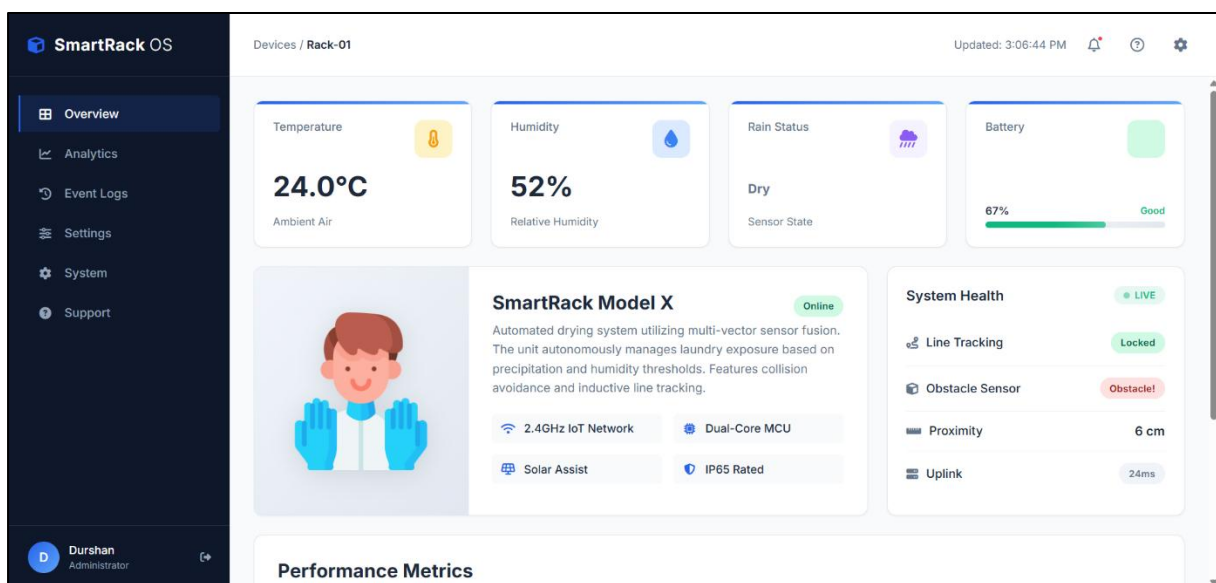
By using Google Gemini for the 3D modeling, the design was generated efficiently with precise detail, enabling smoother hardware assembly and alignment during construction.

### 3.5 Website Design

The website for the Smart Clothing Rack System is designed to provide real-time monitoring of environmental conditions, system status, and safety alerts. It acts as the primary user interface, allowing remote visibility of the rack's operation through a clean and responsive web dashboard. The interface retrieves data uploaded by the NodeMCU ESP8266 through HTTP communication and stores it in Firebase for continuous updating.

#### ❖ Dashboard Overview

The web dashboard displays essential real-time information including temperature, humidity, rain detection status, obstacle alerts, battery level, and the current position of the rack. The layout is structured to present data clearly, making the system easy to monitor at any time. The design focuses on simplicity and readability, ensuring that users can quickly assess the rack's operational state at a glance.



#### ❖ Real-Time Data Display

The dashboard retrieves sensor readings from Firebase as soon as new values are uploaded by the NodeMCU. This includes;

- **Temperature and humidity** readings from the DHT sensor
- **Rain status** from the rain sensor
- **Obstacle detection alerts** from the ultrasonic sensors
- **Battery percentage** reported through the power system
- **Rack position or movement status** determined by system logic

These values are updated automatically without requiring manual page refresh, ensuring accurate and up-to-date monitoring.

### ❖ **Firebase Integration**

Firebase Realtime Database is used to store and synchronize all sensor data. When the NodeMCU uploads new values through HTTP requests, Firebase updates instantly and the dashboard retrieves the latest readings. This architecture ensures:

- Low latency
- High reliability
- Seamless real-time data flow between hardware and web interface

Firebase also simplifies future expansion if additional features or sensors are added.

### ❖ **Responsive Layout**

The web interface is designed to be responsive, making it accessible from computer browsers, tablets, and mobile devices. This ensures that users can monitor the system conveniently, even when away from home.

### ❖ **Purpose of the Website**

The website enhances the functionality of the Smart Clothing Rack System by:

- Providing continuous remote monitoring
- Improving awareness of environmental conditions
- Offering safety alerts for obstacles or rainfall
- Displaying power and system status to avoid unexpected shutdowns
- Creating a modern IoT experience aligned with smart-home technologies

Overall, the website acts as a crucial component of the system's IoT architecture, enabling reliable user interaction through real-time data visualization.

### 3.6 Chapter Summary

Chapter 3 presented the hardware and software foundation of the Smart Clothing Rack System. The chapter outlined the major components used in the design, including the NodeMCU ESP8266, sensors, motor drivers, power modules, and supporting electronics. It also described how these components are integrated physically within the system through organized placement, secure mounting, and structured wiring inside the bottom compartment.

The chapter further explained the programming logic implemented on the NodeMCU using C++ in the Arduino IDE, covering sensor handling, motor control routines, obstacle detection, rain response, and IoT data communication via HTTP and Firebase. Additionally, the 3D model was discussed to illustrate the structural arrangement of the rack, the electronics compartment, and the placement of sensors and mobility components. The website design section detailed the real-time monitoring dashboard, data visualization, and communication architecture used to track system status and environmental conditions.

Overall, Chapter 3 provided a comprehensive view of the system's hardware layout, firmware structure, and user interface, forming the technical basis for evaluating system performance in the following chapter.

## Chapter 4: Final Analysis and Conclusion

### 4.1 System Output and Performance

The Smart Clothing Rack System delivers automated movement, environmental monitoring, and IoT-based status reporting through the coordinated operation of its hardware and software components. The system's performance was evaluated through multiple testing stages, focusing on its core functionalities and response accuracy.

The line-following mechanism performed reliably during navigation along the predefined path. The IR sensor array successfully detected the black line and enabled the rack to maintain its route with minimal deviation. Motor response was stable, and the L298N motor drivers provided consistent control over speed and direction, allowing the rack to move smoothly both indoors and outdoors.

The rain detection feature operated effectively, with the rain sensor responding immediately upon contact with moisture. Once rainfall was detected, the system accurately switched into return mode and navigated back along the line without manual intervention. This ensured timely protection of clothes under unexpected weather conditions.

Obstacle detection using ultrasonic sensors demonstrated high responsiveness. During testing, the sensors identified objects placed in the rack's path and triggered an immediate stop, preventing collisions. This safety feature functioned consistently under different lighting and environmental conditions.

Environmental monitoring using the DHT sensor delivered stable temperature and humidity readings. These values, along with rain status, obstacle alerts, and battery information, were transmitted successfully to the IoT dashboard through HTTP communication. Firebase updated all sensor values in real time, providing reliable remote visibility of the system's operation.

Power management through the Li-ion battery and solar charging setup also performed as expected. The TP4056 charging module and solar panel ensured continuous operation, extending system uptime without frequent manual charging.

Overall, the Smart Clothing Rack System demonstrated dependable performance across navigation, sensing, safety response, and IoT communication, validating its effectiveness as a practical and autonomous household solution.

## 4.2 Challenges Faced

The development of the Smart Clothing Rack System presented several technical and logistical challenges that affected different phases of the project, including hardware acquisition, assembly, software development, testing, and overall team coordination. These challenges, along with their impact on the project timeline and workflow, are summarized below:

- **Component Availability**

Obtaining the required electronic components proved difficult, especially items such as motor drivers and power management modules. Limited local availability necessitated visiting multiple electronic stores, which led to delays in both procurement and assembly stages.

- **Components Damage During Testing**

During hardware testing and wiring adjustments, certain components including sensors, jumper wires, and small modules were accidentally damaged or burned. These incidents increased project costs and extended the testing period due to the need for replacements.

- **Software–Hardware Integration**

Integrating the NodeMCU firmware with sensors, motor drivers, and power modules required multiple iterations to achieve stable operation. Issues such as inconsistent sensor readings, Wi-Fi interruptions, and motor control conflicts had to be resolved through debugging and code optimization.

- **Prototype Design Time**

The physical design and assembly of the prototype required significantly more time than the software development portion. Ensuring proper placement of all components, routing wires cleanly, and maintaining structural stability made the process longer than initially expected.

- **Team Member Availability**

Unexpected illness among team members during the project period affected the planned schedule and slowed down progress. Task assignments had to be adjusted and certain activities were postponed to accommodate reduced manpower.

- **Space and Layout Constraints**

Fitting all components including the ESP8266 board, sensors, motor drivers, battery pack, solar charging modules, and wiring into the lower compartment of the rack was challenging. Proper airflow, safety clearances, and maintenance access had to be considered, requiring several redesigns of the internal layout.

### 4.3 Project Conclusion

The Smart Clothing Rack System successfully demonstrates the integration of IoT technology, autonomous mobility, and environmental sensing to automate the process of protecting outdoor-dried clothes from sudden weather changes. Through the combined use of the NodeMCU ESP8266, rain detection, obstacle avoidance, line-following navigation, and real-time data monitoring, the system provides a practical and reliable solution for everyday household needs.

The autonomous movement of the rack, guided by IR line-following sensors and controlled through DC geared motors, performed effectively during testing. The system was able to return indoors automatically when rain was detected, eliminating the need for constant human supervision. The ultrasonic sensors ensured safe operation by accurately identifying obstacles and preventing collisions, while the rechargeable battery system with solar support allowed extended operation without frequent manual charging.

The IoT dashboard, powered by Firebase and HTTP communication, offered continuous visibility of important system parameters such as temperature, humidity, rain status, battery level, and obstacle alerts. This remote access strengthened the convenience and usability of the design, demonstrating the value of integrating cloud platforms into smart home applications.

Overall, the project achieved its intended objectives by delivering an automated, responsive, and energy-efficient solution. It highlights the potential of IoT-driven systems to improve household automation and showcases how simple sensing and mobility technologies can be combined to solve real-world problems effectively. The project also provides a strong foundation for further enhancement and future expansion.

## 4.4 Future Improvements

Although the Smart Clothing Rack System successfully meets its primary objectives, several enhancements can further improve its reliability, efficiency, and overall user experience. The following improvements are recommended for future versions of the system:

- **Enhanced Navigation System**

The current system relies on line-following sensors for path tracking. Future versions could incorporate advanced navigation techniques such as GPS modules, RFID guided routes, or computer vision based tracking to enable more flexible movement without requiring a fixed path.

- **Improved Weather Detection**

A more advanced rain detection method, such as capacitive rain sensors or real-time weather API integration, could increase accuracy and provide earlier warnings. This would enable the rack to respond faster during unexpected rainfall.

- **Mobile App Integration**

In addition to the web dashboard, a dedicated mobile application could be developed for Android and iOS. A mobile app would offer push notifications, real-time alerts, and an easier interface for monitoring the system remotely.

- **Automatic Charging Dock**

Instead of relying solely on solar charging and manual charging methods, an automatic docking station could be added. When the battery level is low, the rack could autonomously return to a charging dock, improving long-term usability.

- **Weatherproofing and Durability Enhancements**

Improving outdoor durability by adding waterproof enclosures, dust protection, and corrosion-resistant materials would increase the lifespan of the system and make it more suitable for long-term outdoor exposure.

- **Load Handling and Stability Improvements**

Additional structural enhancements such as stronger frames, improved weight distribution, and reinforced wheels could allow the rack to carry heavier loads without impacting movement or stability.

- **Energy Optimization**

Energy usage can be further optimized by integrating more efficient motor drivers, low-power sensors, or MPPT-based solar charging modules. This would extend operating time and reduce power losses.

- **Voice Assistant Integration**

Integration with virtual assistants (e.g., Google Assistant, Alexa) would allow users to check system status or trigger specific actions using voice commands, making the system more user-friendly.

- **Advanced Obstacle Detection**

Adding additional sensors such as infrared proximity sensors or LiDAR modules can provide more precise obstacle detection and allow smoother navigation around complex environments.

These improvements would enhance the system's performance, durability, and usability, making it more adaptable to real-world conditions and closer to a fully autonomous smart-home solution.

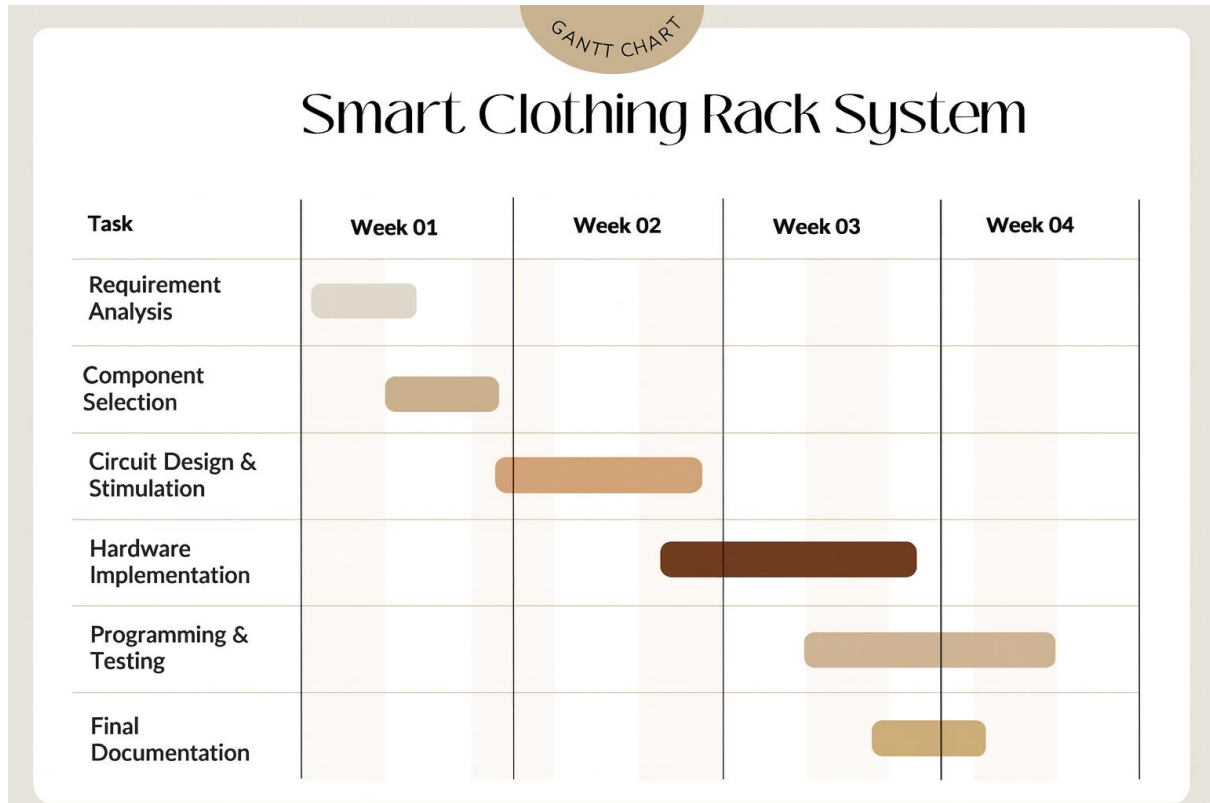
## 4.5 Chapter Summary

Chapter 4 evaluated the overall performance, outcomes, challenges, and potential enhancements of the Smart Clothing Rack System. The system demonstrated effective autonomous operation through accurate rain detection, stable line-following navigation, reliable obstacle avoidance, and consistent real-time data transmission to the IoT dashboard. These results confirmed that the system successfully addresses the problem of protecting clothes from unexpected weather conditions while reducing the need for manual intervention.

The chapter also outlined the key challenges encountered during development, including hardware availability issues, component failures, integration difficulties, prototype assembly constraints, and team-related delays. Additionally, several future improvements were proposed, focusing on enhanced navigation, improved weather detection, expanded IoT features, structural durability, and energy optimization.

Overall, Chapter 4 summarized the practical performance of the system, highlighted areas of difficulty, and provided a forward-looking perspective on how the Smart Clothing Rack System can be further developed in future iterations.

## GANTT CHART



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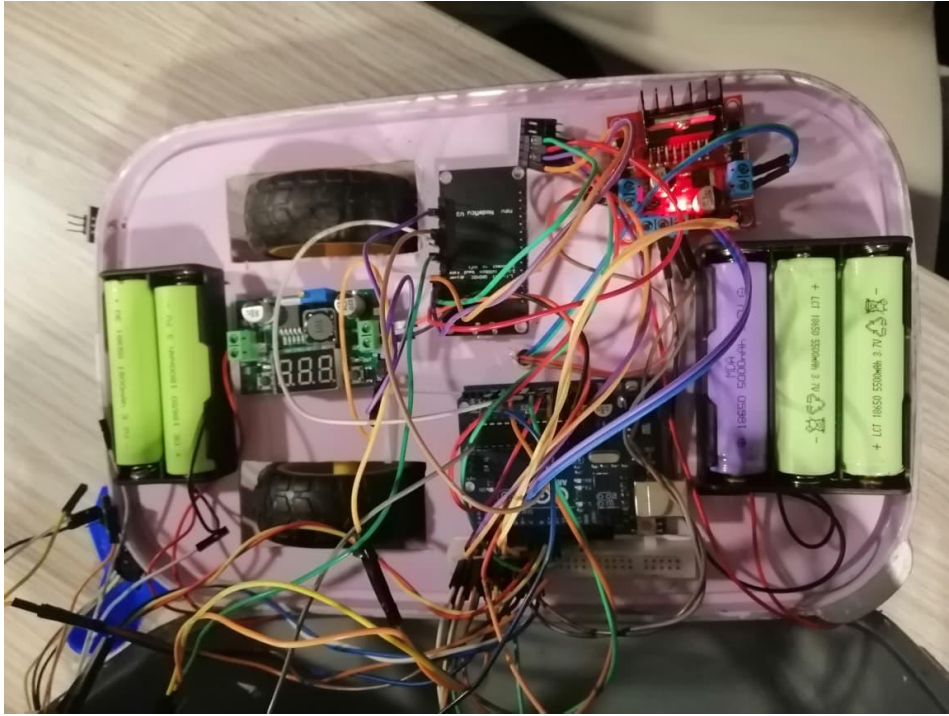
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OpenAI – available at <https://openai.com/>

## APPENDIX



- **Prototype with Team Members**



- **Code**

► [GitHub Link for Code](#)