AN ECO FRIENDLY WASTE MANAGEMENT SYSTEM IN SMART CITIES USING EMBEDDED SYSTEM AND IOT

Project report submitted
in partial fulfilment of the requirement for the degree of

Bachelor of Technology

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CERTIFICATE

This is to certify that the thesis entitled "An Eco Friendly Waste Management System In Smart Cities Using Embedded System And IOT" submitted by Jimli Nath(200611026019) Pranami Priyam Bharati (200610026039) Mrinmoy Deka(200610026032) and Rajashree Borah(210650026004) in the partial fulfillment of the requirements for the award of Bachelor of Technology degree in Electronics & Telecommunication at Assam Engineering College, Jalukbari, Guwahati is an authentic work carried out by them under my supervision and guidance.

To the best of my knowledge, the matter embodied in the thesis has not been submitted to any other University/Institute for the award of any Degree or Diploma.

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DECLARATION

We, Jimli Nath (200611026019) Pranami Priyam Bharati (200610026039) Mrinmoy Deka (200610026032) and Rajashree Borah (210650026004) declare that this written submission represents our ideas in our own words and where other ideas or words have been included, we have adequately cited and referenced the original sources. We also declare that we have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/source in my submission. We understand that any violation of the above will be cause for disciplinary action by the Institute and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been taken when needed.

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ABSTRACT

In the era of rapid urbanization, managing solid waste has become critical issue for smart cities. Traditional waste management systems are often inefficient and can lead to environmental problems. Incorporating embedded systems into waste management methods offers a revolutionary way to approach the task. It can be used to create smart waste management systems that are more efficient, effective, and environmentally friendly. It brings real-time monitoring, automation and reducing resource consumption.

This project proposes a solid waste management system based on embedded system and IOT for proper, efficient and effective management of the waste produce by the residents of smart city. The system consists of microcontroller (Node MCU), different types of sensors, and a web server for monitoring all the data. The sensors capable of real-time monitoring of waste bin fill levels. The sensors are strategically placed across different locations to capture accurate data about the waste accumulation status. The embedded system is integrated with a centralized database. This enables the seamless transmission of data from the sensors to a server, where the information is stored, processed, and analysed.

To design this project we have to follow a proper methodology. The first step is to design the circuit for the solid waste management system using a microcontroller. Once the circuit is designed and assembled, the next step is to program the microcontroller. The sensors need to be calibrated to ensure accurate readings. The next step is testing of the project. Once the system is tested and verified, it can be deployed in garbage bins of smart city.

The project aims to enhance waste management in smart cities through embedded systems, expecting improved efficiency, reduced costs, and minimized environmental impact. With real time monitoring, data-driven optimization, and automated collection, the project anticipates a cleaner urban environment, demonstrating technology's role in creating sustainable and efficient smart cities.

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CHAPTER 1
INTRODUCTION

1.1 Introduction

Waste management is the systematic process of handling waste from its inception to its final disposal. This includes collection, transport, treatment, and disposal of waste, as well as monitoring and regulation. The main goal is to minimize the adverse effects of waste on human health and the environment. Effective waste management strategies encompass reducing waste generation, reusing materials, recycling, composting, and safe disposal methods such as landfilling and incineration. Successful waste management requires collaboration between individuals, communities, industries, and governments to ensure a cleaner and sustainable environment

1.2 Introduction to the area of work

In day today life lots of waste are generated and the challenging part is to manage them. Smart dustbins are an innovative solution to the problem of waste management. They are designed to be more efficient and effective than traditional waste bins. Smart dustbins are equipped with sensors that can detect when they are full and need to be emptied. They can also segregate the waste into dry and wet, bio-degradable and non-biodegradable, metallic and non-metallic categories which makes it easier to dispose of the waste in an eco-friendly manner.

1.3 Present day scenario

In the present day, smart dustbins have evolved to address modern waste management challenges. Equipped with sensors and connectivity, these bins offer real-time monitoring of fill levels, facilitating efficient waste collection. Advanced models incorporate sorting mechanisms to promote recycling, contributing to sustainability goals. Integration with IoT technology enables remote monitoring and control, enhancing overall waste management efficiency. These innovations demonstrate a commitment to smart and eco-friendly solutions in urban environments, making smart dustbins an integral part of contemporary waste management systems.

1.4 Motivation to do the project

The motive behind the smart waste management project is to address the growing environmental and logistical challenges associated with waste disposal specially in urban areas.

Traditional waste management systems often suffer from inefficiencies, such as inconsistent collection schedules and overflowing bins, leading to increased pollution and health hazards. The eco-friendly dustbin is designed to segregate waste into dry and wet categories, making it easier to dispose of waste in an environmentally friendly manner in efficient way. Smart dustbins are an innovative solution to the problem of waste management. They are designed to store a large amount of garbage and are particularly useful in big cities. The primary motivation behind the development of smart dustbins is to reduce the workload of municipalities and improve the hygiene of the environment. Smart dustbins are equipped with sensors that measure the waste capacity and provide alerts to waste managers when the bin is ready to be emptied. This step-by-step waste removal innovation machine allows workers to maintain the cleanliness of the environment. Smart dustbins are cost-effective and eco-friendly solutions that allow you to collect and reduce waste effectively. This helps to enhance cleanliness and hygiene. Bad smell and hazardous gas can also be emitted form dustbin which can cause hamper to the environment so smart dustbin can help to reduce them also it will help to reduce the manual activity to some extend.

1.5 Objective of the work

i) Segregation of dry and wet waste
ii) Resisting the plate movement when bin is full
iii) Detection of hazardous gas
iv) Automatic spray dispenser for reducing odour
v) Making a web server to measure the height of waste in the dustbin, detection of presence of gas and detection of gas concentration level in ppm.

1.6 Target specification

Sensitivity: The system should be capable of detecting the moisture content of waste to segregate them and to measure the height of waste in the bin.

Power Efficiency: The system should be designed to operate efficiently, consuming minimal power to ensure long-lasting battery life or low energy consumption.

Size and Portability: The system should be compact and portable, allowing for easy installation and placement in various environments, such as home, school, public place etc.

Scalability: The system should be scaled up or down based on changing needs.

Real time monitoring: The system should be able to track waste status in terms of heights and gas detection.

Environmental Impact Monitoring: The system should be able to detect hazardous gas if any and spraying some compound automatically to reduce odour. This will help to keep the surrounding environment clean and hygiene.

1.7 Project work schedule

- Block diagram: First of all a functional block diagram has been designed. In this the probable connections and components are used.
- Selection of components: After making the block diagram we have come to know the components we require like ESP32 board, soil moisture sensor, ultrasonic sensor, IR sensor, servo motor, gas sensor, a sprayer, connecting wires, etc.
- Selection of software: Further for designing purpose software like Arduino IDE and Proteus 8 are selected.
- Circuit diagram: The circuit diagram is designed in Proteus 8 software. Components like ESP32, Infrared sensor, ultrasonic sensor, servo motor, soil moisture sensor etc. were taken from the library and then they were connected as required.
- Programming: Programming part is done in Arduino IDE software.
- Hardware connection: After software circuit is tested hardware part was proceeded. ESP32, soil moisture sensor, ultrasonic sensor, IR sensor, servo motors, gas sensor, were connected with the help of jumper wires.
- Assemble and test: After the hardware connection the code that is developed in the Arduino IDE is uploaded in the ESP32 and then it is tested and the circuit gave the output as required.

1.8 Organization of the project report (chapter wise)

The project is organized in different chapter according to the needs such as introduction, literature review, system design, implementation methodology, experimental results, discussion, conclusion, and recommendations for future work. This organizational structure will provide a comprehensive overview of the project, its findings, and potential avenues for further exploration and improvement.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

A literature review is an essential component of academic research that involves a systematic examination and evaluation of existing literature, scholarly articles, books, and other sources relevant to a particular research topic or question. A literature review provides a comprehensive summary and analysis of existing research on a specific topic. It involves identifying key theories, methodologies, findings, and gaps in the literature. This synthesis of previous studies helps to establish the context and significance of the current research. A well-conducted literature review not only demonstrates familiarity with the field but also highlights how the new research will contribute to and expand existing knowledge. It critically evaluates the strengths and limitations of past studies, ensuring that the current research is informed by and builds upon prior work. It serves multiple purposes within a research project, such as,

- Contextualizing the research
- Identifying gaps and research questions:
- Supporting theoretical frameworks
- Evaluating methodologies
- Synthesizing findings

2.2 Introduction to the project title

In an era of rapid technological advancement, even traditional aspects of our daily lives are being transformed by electronic innovations. One such area is the smart waste management, where waste can be segregated based on their different characteristics also some features like waste height measurement, automatic spray dispenser communicating with users etc. can be implemented. Here in this project we have implemented the feature of segregating dry and wet waste and also determining the height of waste using ultrasonic sensor, presence of gas detection in ppm and monitoring real time data communication through web server. The conventional waste management system has evolved into a sophisticated electronic device that offers enhanced security, convenience, and efficiency. This introduction aims to provide an overview of smart waste management system, exploring their features, benefits, and impact on environment.

2.3 Literature review

2.3.1 Present state or recent developments in the work area

Smart waste management systems are rapidly evolving, integrating advanced technologies to optimize waste collection, processing, and recycling processes. This project provides an overview of the present state and recent developments in the field of smart waste management, highlighting the innovative technologies, emerging trends, and their impact on hygiene public health and environment. Smart dustbin is a device that can automatically collect and dispose of waste in a smart and hygienic way. It uses sensors, wireless communication, and local web server to monitor the level of garbage, send alerts to the user, and open and close its lid when needed. Smart dustbin is an example of how the internet of things (IoT) can be applied to improve the environment, health, and hygiene of urban area. these advancements are leading to more sustainable and eco-friendly waste management practices, benefiting both the environment and society. Some of the present state or recent developments in the work area of smart dustbin are:

- A study by Malla et al[10.1007/978-981-19-1146-0_6] proposed a model of smart dustbin that can be used to create a smart environment. They explained how the smart dustbin model can be applied efficiently to achieve smart environmental goals, such as reducing public health risks, enhancing public safety, and saving resources. They also discussed the challenges and future scope of their work.
- A research by D Yadav, A Pandey, D Mishra, T Bagchi, A Mahapatra, P Chandrasekhar, A Kumar, et al developed an IoT-enabled smart dustbin with a messaging alert system that alerts the municipal members for instant clearing of garbage based on the remaining capacity to take in more waste. The work also added an automatic lid opening and closing feature using a passive infrared (PIR) sensor that prevents contact with hazardous surfaces.
- A project report by Chaitanya Kumar, U. Nagaraju, Ritu Mishra and Rajkumar of VIT et al presented a design and development of smart dustbin using ultrasonic sensors for garbage level detection and sending message to the user updating the status of the bin using GSM module. The project also included a user interface for monitoring and controlling the smart dustbin remotely.

- A tutorial by 1000 Projects explained how to design and develop a smart dustbin project using Arduino Uno board, ultrasonic sensor HC-SR04, GSM module SIM900A, servo motor 12V DC 1A, buzzer 8 ohms 220V AC 50Hz 1W, breadboard, jumper wires, LED indicator 220 ohms 12V DC 1A etc. The tutorial also provided the circuit diagram, code explanation, working principle, advantage and disadvantages of smart dustbin project.

These are some of the examples of how smart waste management system is being used or developed in different domains. Smart dustbin is a promising technology that can help in creating a better world for everyone.

2.3.2 Brief background theory

- Smart waste management system using NodeMCU(ESP32 board), soil moisture sensor, infrared sensor, ultrasonic sensor, servo motor are based on fundamental principles and concepts in moisture sensing by moisture sensor, height measurement by ultrasonic sensor, object detection by infrared sensor and movement of object keeping plate by servo motor and microcontroller programming, and display technologies.
- The NodeMCU plays a crucial role in processing the sensor's output signals, performing calculations, and controlling the system's operation. It receives analog signals from the sensor and converts them into digital values for further analysis and decision-making.
- Resistive soil moisture sensor is a type of sensor that measures the water content of the soil by using electrical resistance. The sensor consists of two probes that are inserted into the soil and connected to a circuit. The circuit generates an output voltage that depends on the resistance of the soil between the probes. The resistance of the soil varies with its water content, as water is a good conductor of electricity and reduces the electrical resistance. Therefore, the output voltage is proportional to the water content of the soil. Using the same principle in the smart waste management system resistive soil moisture sensor is used to detect the moisture content in the waste so that they can be segregated into dry and wet waste.
- An infrared sensor is a device that can detect and measure infrared radiation, which is a type of electromagnetic wave that has a wavelength longer than visible light but shorter than microwaves. Infrared sensors can be used for various purposes, such as sensing temperature, motion, distance, and presence of objects or people. The working principle of an infrared sensor is based on the fact that all objects with a temperature

above absolute zero (0 Kelvin) emit infrared radiation. The amount and wavelength of the radiation depend on the temperature and material of the object. The sensor consists of an infrared source (such as an LED or a laser), a transmission medium (such as air or fibre), and an infrared receiver (such as a photodiode or a phototransistor). The infrared source emits infrared radiation of a specific wavelength and power. The transmission medium carries the radiation from the source to the receiver. The receiver converts the radiation into an electrical signal that can be processed by a circuit. Here in this project IR sensor is used to detect if there is any waste in the plate.

- An ultrasonic sensor is a device that can measure the distance to an object by emitting and receiving ultrasonic waves. Ultrasonic waves are sound waves that have a frequency higher than the human hearing range, which is about 20 kHz. Ultrasonic sensors can be used for various purposes, such as obstacle detection, level measurement, distance measurement, etc. The working principle of an ultrasonic sensor is based on the fact that when an ultrasonic wave hits an object, some of it is reflected back to the sensor. The time it takes for the wave to travel from the sensor to the object and back is proportional to the distance between them. For the smart waste management system we have used ultrasonic sensors in both the dry and wet chambers to measure the height of waste continuously so that waste can be collected before the dustbin getting filled.
- A servo motor works by continuously comparing the desired position or speed with the actual state, making instantaneous adjustments through a feedback loop. This inherent ability to maintain precise control and make rapid corrections is what makes the servo motor a fundamental tool in the world of automation and robotics. IN this project servo motor is used to rotate the plate towards either dry chamber or wet chamber based on their moisture content.

2.3.3 Literature Survey

A literature survey in smart waste management reveals a growing body of research focused on enhancing efficiency, sustainability, and cost-effectiveness in waste collection and recycling processes. Studies often highlight the integration of IoT sensors and real-time monitoring systems to optimize waste collection routes and schedules. A comprehensive literature survey was conducted to explore the existing research studies, technical papers, and articles related to gas leakage monitoring systems utilizing a soil moisture sensor, IR sensor, ultrasonic sensor, servo motor, NodeMCU microcontroller, and web server. The survey aimed to gain insights into the methodologies, technologies, and approaches employed in previous works, as well as to critically analyse their effectiveness, limitations, and potential areas for improvement. Research emphasizes the importance of stakeholder engagement and policy frameworks to support the adoption of smart waste management technologies. Through searching for different research paper, studying them we have taken different inputs and insights. Some of them with their works and features and future scope have been discussed below in a tabular form,

Paper Name	Year of Publication	Salient Features	Future Scopes
Energy Efficient Technology for Solid Waste Management in IoT-Enabled Smart City (10.35940/ijrte.2277-3878)	2019	i)Waste gathering preparation and implementation ii)Transport of waste to specific location iii)Recycling and preparation for Re-use.	i)Compelling IoT-empowered model for solid waste collection and get updates in web page ii)Adding direction link in the web page to sent message to nearest truck driver
Smart bins for garbage monitoring in smart cities using IoT system (10.1088/1757-899X/1055/1/012078)	2021	Send alert message to municipal authorities whenever the height of garbage in the bin is greater than threshold value.	Stores the data in cloud for future
A Sensor-based Garbage Gas Detection System (10.1109/CCWC51732.2021.9376147)	2021	i)Indicate the garbage level and a gas sensor (MQ2) to detect bad smell. ii)Alert the garbage collector to send a garbage vehicle if either the bin is full or it has bad smell.	i)This system will be developed into more complete system. ii)To solve the problem of smelly garbage.
IoT assisted MQTT for Segregation and Monitoring of Waste for Smart Cities (10.1109/ICACCS48705.2020.9074399)	2020	To design and develop a segregation system which sort wastes automatically into wet and dry.	To classify the recyclable materials from garbage and wastes into different categories would make the recycling process better and easier.

Paper Name	Year of Publication	Salient Features	Future Scopes
Early detection and evaluation of waste through sensorized containers for a collection monitoring application (10.1016/j.wasman.2009.08.016)	2009	The detection of potentially hazardous materials for incineration plants (like concretes), and the awareness of local conditions at collection points to be used in optimizing truck routing and other procedures.	Waste classification using sensor fusion techniques will be undertaken.

Table 2.1: Literature survey

2.4 Summarized outcome of the literature review

The literature review revealed extensive research on smart waste management systems using soil moisture sensor, infrared sensor, ultrasonic sensor, servo motor, NodeMCU microcontroller, gas sensor and web server. Key findings include the effectiveness of the sensors and versatile capabilities of the microcontrollers. Opportunities for improvement include calibration techniques, advanced signal processing, wireless communication, and energy efficiency. This review informs the current study, guiding the development of an enhanced smart waste management system.

2.5 Theoretical discussions

The following limitations associated with smart waste management system using soil moisture sensor, infrared sensor, ultrasonic sensor, servo motor, NodeMCU microcontroller, gas sensor and web server:

- Sensor accuracy and calibration: Achieving precise and reliable moisture, height detection and precisely object detection may be challenging due to the need for accurate calibration of soil moisture ultrasonic and infrared sensor respectively which requires technical expertise and periodic maintenance.
- Response time: The system's response time can be a critical factor in ensuring timely detection of moisture and height. There might be limitations in achieving rapid response times, potentially leading to delayed notifications or warnings.
- Integration in public place: While integrating the smart waste management system in public place can offer added convenience, it may require additional technical complexity and compatibility considerations.

- Power consumption: While the power consumption of the system may not be excessively high, optimizing it further can help prolong the system's battery life and enhance overall efficiency.

Addressing these limitations through ongoing research and development efforts can lead to improved sensor accuracy, faster response times, seamless integration with smart home automation, and better power optimization, thereby enhancing the overall performance and usability of gas leakage monitoring systems.

2.6 Conclusion

In conclusion, the literature review underscores the significant progress and potential of smart waste management systems leveraging embedded systems and IoT technologies. It has provided valuable insights into the current state and recent developments in electronic smart waste management system. It has highlighted the benefits, challenges, and future directions of this technology. The findings underscore the potential of smart waste management to revolutionize the segregation and communication making it more secure, convenient, and environmentally sustainable. Future research in this area can explore the implementation challenges, user acceptance, and long-term implications of smart dustbin to further enhance their effectiveness and impact. Further research is needed to address the challenges and realize the full potential of smart waste management systems in creating cleaner and more sustainable cities.

CHAPTER 3

METHODOLOGY

3.1 Introduction

Methodology defines the processes, methods, and tools that the project team uses to initiate, plan, and execute the project. It refers to the systematic, theoretical analysis of the methods applied to a field of stud. A project methodology also reflects the strategy and rationale of the research project, based on the methods and theories used in the field. It is a framework for managing projects that provides a roadmap for the planning and day-to-day management of a project. A well-defined methodology helps ensure the reliability and validity of research findings by providing a structured approach to inquiry. The methodology begins with project initiation, where the objectives, scope etc. are defined. This is followed by project planning, where a detailed plan is created, including tasks, timelines, and resource allocation. Then it includes the execution part and the progress is monitored. It typically includes the selection of research methods (such as qualitative or quantitative), data collection techniques (like surveys or experiments), and analysis strategies (including statistical or thematic analysis). Ultimately, methodology serves as a blueprint guiding the research process from hypothesis formulation to conclusion. Through a methodology, we are achieving the knowledge about planning, design, and implementation and testing. In this chapter we are going to discuss how we have proceeded throughout the project the brief description of the components.

3.2 Methodology

3.2.1 Detailed methodology

The project includes some procedures which have been shown in the form of diagram below

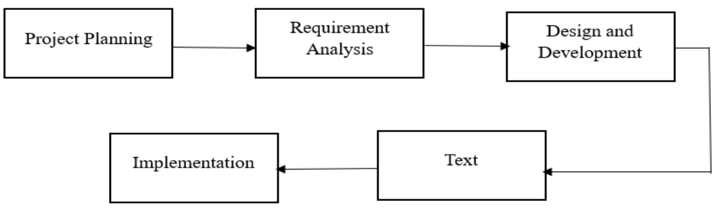

Fig 3.1: Workflow for the project

i)Requirement Analysis: In this step the components both in hardware and software are selected on the basis of analysis. Selected components are listed below, Hardware components:

ESP32

Soil moisture sensor

Ultrasonic sensor

Infrared sensor

Gas sensor

Servo motor

MG 5 servo motor

Power supply

Breadboard

Connecting Wires

Software components:

• Arduino IDE

• Proteus 8

ii) Design and Development: The system is designed the proteus 8 software and the programming part in Arduino IDE. After the code worked in proteus it was implemented in the ESP32 board.

iii)Testing and Implementation: Testing of the system is conducted to ensure proper functionality, accuracy, and reliability. After testing phase, the project is implemented.

3.2.2 Block Diagram

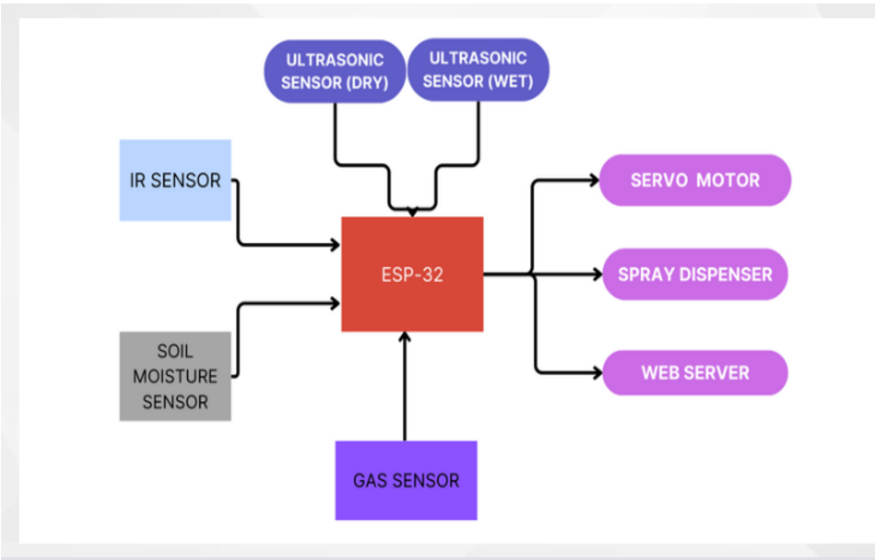

Fig 3.2: Block Diagram

3.2.3 Circuit Diagram

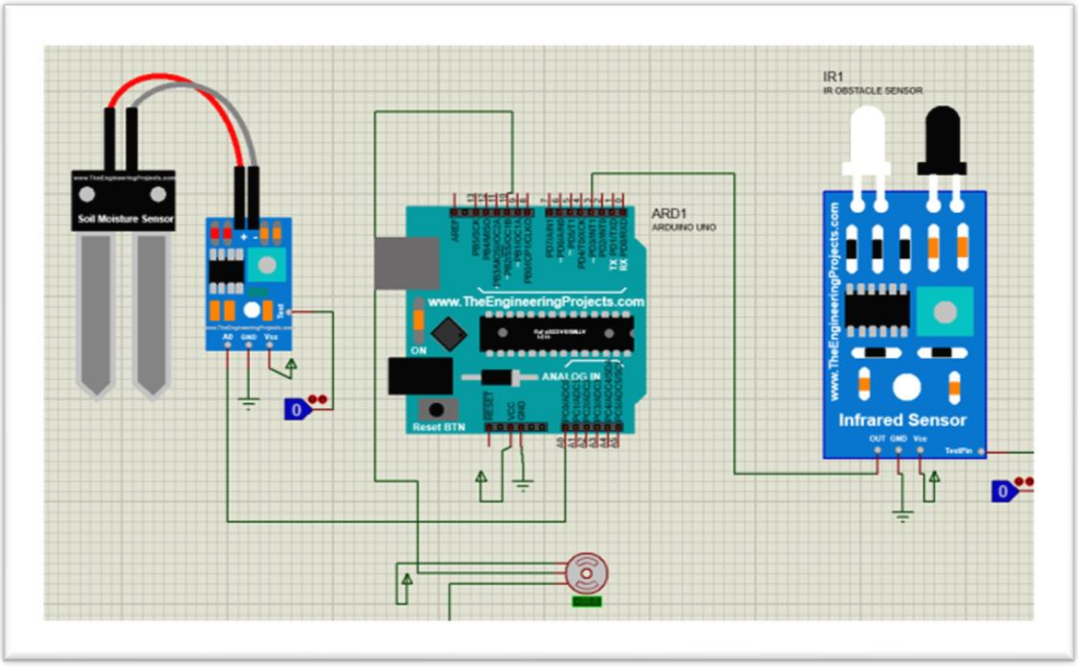

Fig 3.3: Circuit diagram

3.3 Tools used (component used)

3.3.1 Hardware component

i. ESP32 Board:

The ESP32 is a feature-rich microcontroller unit (MCU) developed by Espressif Systems. It's known for its integrated Wi-Fi and Bluetooth connectivity, making it suitable for a wide range of applications, including mobile devices, wearable electronics, and Internet of Things (IoT) applications. ESP32 is a series of low-cost, low-power system on a chip microcontroller with integrated Wi-Fi. In this project we have used ESP Wroom 32 NodeMCU board. ESP Wroom 32 microcontroller has 30 pins with 15 pins on one side and 15 pins on the other side. It employs a Tensilica Xtensa LX6 microprocessor, available in both dual-core and single-core variations. It has 320 KiB SRAM. It supports Wi-Fi (802.11 b/g/n) and Bluetooth (v4.2 BR/EDR and BLE). It includes 12-bit SAR ADC up to 18 channels, and more. It's engineered for ultra-low power consumption, making it ideal for mobile and wearable electronics. It's worth noting that the ESP32 is a successor to the ESP8266 microcontroller. It's designed to function reliably in industrial environments, with an operating temperature ranging from -40°C to +125°C[1]. It also offers a high level of integration, reducing the Printed Circuit Board (PCB) requirements.

Fig 3.4: ESP32 board

ii. SG 90 Servo Motor:

A servo motor is an electro-mechanical device used for precise control of angular position, velocity, and acceleration. Servo motors are known for their high precision and ability to maintain a specific position. It converts electrical signals into precise mechanical movement. It comprises a DC motor, a feedback mechanism (commonly a potentiometer), and a control circuit. The control circuit continuously compares the desired position with the actual position obtained from the feedback, making real-time adjustments to the motor's operation. This closed-loop system allows servo motors to achieve and maintain accurate positions, making them essential components in applications demanding precision, such as robotics, automation, and control systems. The controller uses a closed-loop feedback system to regulate the motor’s movement and ensure that it matches the desired setpoint within a certain tolerance. The controller can also implement various control algorithms, such as proportional-integral-derivative (PID) control, fuzzy logic control, adaptive control, etc., to optimize the performance of the servo motor. Servo motors are widely used in industrial applications such as robotics, CNC machinery, and automated manufacturing, where high accuracy, fast response, and smooth motion are required.

Fig 3.5: SG 90 Servo motor

iii. Soil moisture sensor:

A soil moisture sensor is a device used to measure the water content in soil. Soil moisture sensors typically work by measuring the electrical conductivity or resistance of the soil, which changes with varying moisture levels. There are two main types: capacitance sensors and resistance (or resistive) sensors.

Capacitance Sensors: These sensors estimate soil moisture by measuring the dielectric constant of the soil, which is influenced by its water content. Higher dielectric constant corresponds to higher moisture levels. They are generally more accurate but can be affected by soil salinity.

Resistance Sensors: These sensors rely on the principle that the electrical resistance of the soil changes with moisture content. As soil moisture increases, the resistance decreases, and vice versa. They are simpler and more cost-effective but might be less accurate than capacitance sensors.

In this project we have used resistance soil moisture sensor.

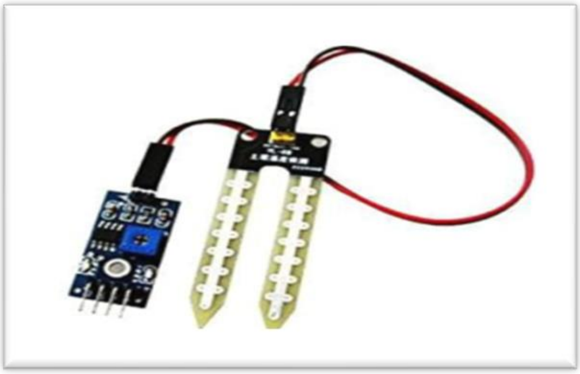

Fig 3.6: Soil moisture sensor

iv. Infrared (IR) sensor

Infrared (IR) sensors are electronic devices that can detect and measure infrared radiation, which is a form of electromagnetic radiation with wavelengths longer than those of visible light. IR sensors work based on the principle of detecting infrared radiation, which is emitted by all objects with a temperature above absolute zero. They typically use a combination of an emitter to send out infrared light and a receiver to detect the reflected or emitted light.

Types of IR Sensors:

Passive Infrared (PIR) sensors detect changes in infrared radiation, commonly used in motion detection applications like security systems.

Infrared Temperature Sensors measure the thermal radiation emitted by an object, useful for non-contact temperature measurements.

Infrared Proximity Sensors sense the presence or absence of an object within a certain range without physical contact.

Applications:

Widely used in home automation for motion-activated lights, security alarms, and smart appliances.

In industrial settings, IR sensors are employed for temperature monitoring, object detection, and quality control processes.

Fig 3.7: IR sensor

v. **Ultrasonic Sensor**

An ultrasonic sensor is an electronic device that calculates the distance to a target by emitting ultrasonic sound waves and converting those waves into electrical signals. The speed of the emitted ultrasonic waves is faster than audible sound. The sensor consists of two main elements: a transmitter and a receiver. The transmitter generates sound using piezoelectric crystals, which travels to the target and gets reflected back to the receiver. The sensor calculates the time required for the sound to travel from the transmitter to the receiver to determine the distance to the target. The working principle of an ultrasonic sensor is similar to sonar or radar, which evaluates attributes of a target by interpreting the received echoes from sound/radio waves.

Here are some specifications of an ultrasonic sensor:

- Sensing range: 40 cm to 300 cm
- Response time: 50 milliseconds to 200 milliseconds
- Beam angle: around 50 degrees
- Operating voltage range: 20 VDC to 30 VDC
- Precision: ±5%
- Frequency of the ultrasound wave: 120 kHz
- Resolution: 1mm
- Output voltage: 0 VDC – 10 VDC
- Weight: nearly 150 grams
- Ambient temperature: -25 degrees Celsius to +70 degrees Celsius
- Target dimensions to measure maximum distance: 5 cm × 5 cm

Ultrasonic sensors find applications in various domains such as drones, EV vehicles, obstacle avoidance systems in robotics, autonomous vehicles, parking technology, anti-collision safety systems, and manufacturing engineering. They are also used to detect, monitor, and control liquid levels in closed vessels, such as chemical plant drums.

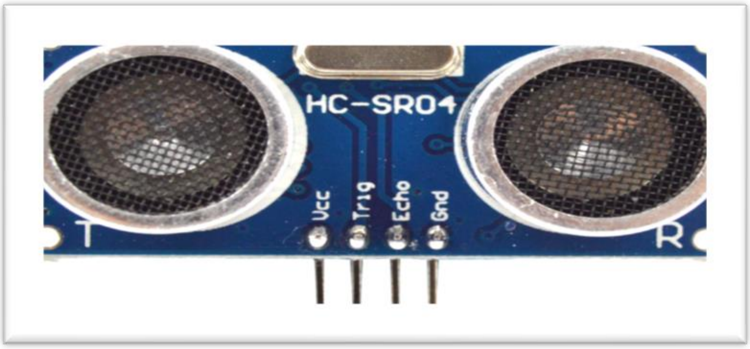

Fig 3.8: Ultrasonic sensor

i. LPG gas sensor:

An LPG gas sensor is a device designed to detect the presence of liquefied petroleum gas (LPG) in an environment. It is a one kind of device which is used to sense the presence of a hazardous LPG gas leak in service station, cars, storage tanks and homes. These sensors are crucial for ensuring safety in both residential and industrial settings, where LPG is commonly used for heating, cooking, and other applications. This sensor is attached to an alarm circuit to give an alert to the operators through a buzzer sound in the area where the gas leak is occurring. The LPG gas sensor is also used to detect cigarette smoke, toxic gases, combustible, propane, iso-butane and LNG. Typically, LPG gas sensors use technologies such as semiconductors, electrochemical cells, or infrared sensors to identify the gas's presence. When LPG is detected, the sensor triggers an alarm or initiates other safety measures to prevent potential hazards like explosions or fires. These sensors are essential for early detection and prompt response to gas leaks, thus protecting lives and property.

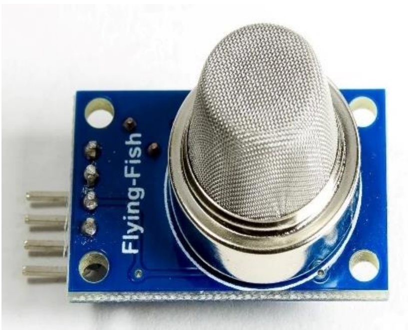

Fig 3.9: LPG gas sensor

ii. MG 5 Servo motor:

The MG 5 servo motor also known as MG 995 servo motor stands out for its exceptional precision, making it a preferred choice in applications requiring high accuracy and reliability. It is a versatile and reliable component commonly used in robotics, RC (radio-controlled) models, and various automation systems. This precision is achieved through advanced control algorithms and high-quality components that ensure minimal backlash and smooth operation. Known for its high torque and precision, the MG 5 servo motor features metal gears that ensure durability and longevity, making it suitable for demanding applications. It operates on a standard PWM (pulse-width modulation) control signal, allowing for easy integration with microcontrollers and other control systems. The motor's encoder provides accurate feedback, allowing for fine-tuned adjustments and consistent performance. Additionally, its robust construction and superior torque capabilities enable it to maintain accuracy even under varying load conditions, making the MG 5 servo motor an excellent choice for industries such as robotics, CNC machinery, and automation systems where precision is paramount. With a compact design and efficient performance, the MG 5 servo motor is ideal for projects requiring precise motion control and robust mechanical performance.

Fig 3.10: MG 5 servo motor

3.3.2 Software component

i. Arduino IDE

Arduino IDE is a software application that allows us to write code and upload it to Arduino boards. It is an integrated development environment (IDE) that contains a text editor, a message area, a text console, a toolbar, and a series of menus. It also connects to the Arduino hardware to communicate with it. There are two versions of Arduino IDE available: Arduino IDE 2.1.0 and Arduino IDE 1.8.19. The Arduino IDE 2.1.0 is the new major release that is faster and more powerful than the previous version. It features autocompletion, code navigation, and a live debugger. The Arduino IDE 1.8.19 is the legacy version that is still supported and updated.

Fig 3.11: Arduino IDE logo

ii. Proteus 8

Proteus 8 is a software suite for designing and simulating printed circuit boards (PCBs) and embedded systems. It has various tools for schematic capture, PCB layout, circuit simulation, IoT builder and more. It is one of the most popular and widely used PCB design software in the world. You can download Proteus 8 from the official website[1] or from other sources[24]. The latest version of Proteus 8 is 8.16, which has some new features such as push and shove routing, design rule aware route editing and support for SAMD21 microcontrollers.

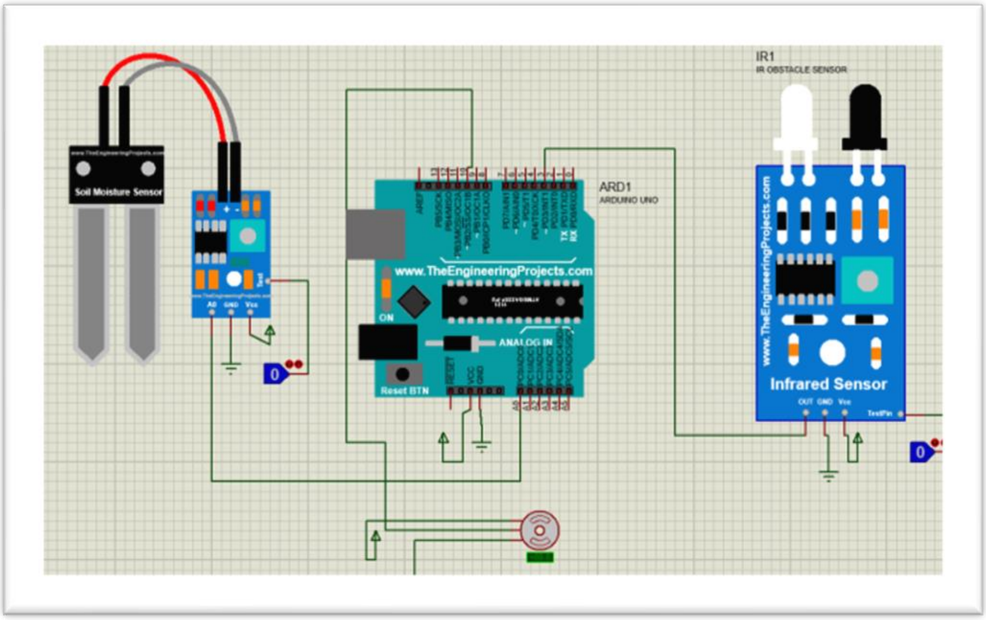

Fig 3.12: Partial circuit in Proteus 8

The methodology employed in this project provided framework for research, planning, implementation, and evaluation. The systematic approach facilitated the achievement of project objectives and generated valuable insights and outcomes. The methodology can serve as a foundation for future projects in the field and can be adapted and refined based on specific requirements and learnings from this project.

CHAPTER 4

RESULT ANALYSIS

4.1 Introduction

In this chapter we are going to discuss the result we have got after completing the project. The output is shown in a tabular format. The output is also shown in circuit format. In this chapter an explanation of the results, the significance of the obtained results, any deviations from the expected results, and their justifications, as well as concluding remarks are also included.

4.2 Result Analysis

The project titled "An Eco-Friendly Waste Management System in Smart Cities Using Embedded System and IOT" is a smart dustbin system. It is enabled to segregate waste in the basis of dry and wet. The system has an automatic spray dispenser. The circuit consist of an ESP32 board, soil moisture sensor, infrared sensor, ultrasonic sensor, servo motor, LPG gas sensor. Waste that are generated will be placed on the plate and soil moisture sensor will be there. Soil moisture sensor will sense the contest of moisture in the waste. If the waste doesn't contain any moisture then the servo motor will incline the plate towards the dry waste chamber and if the waste contain moisture then servo motor will incline the plate towards wet waste chamber. After dropping the waste plate will come to resting position. If there is no waste on the plate then the plate will be in resting position. The system is programmed such that when the bin is full the waste keeping plate can not be moved that means when the bin is already filled to the threshold limit and after that some waste is put on the plate then it won't response. It is done to resist the overflow of waste in the bins. In the dustbin there can be different kind of waste, from them some hazardous gas and bad smell can be generated. There is a gas sensor in the system which can detect the presence of hazardous gas and the gas concentration in ppm also there is an automatic spray dispenser which is able to spray certain chemical in a time interval to reduce bad smell.

Two ultrasonic sensors are connected in dry and wet chamber each to detect the height of waste continuously. A web server is designed to get the real time data.

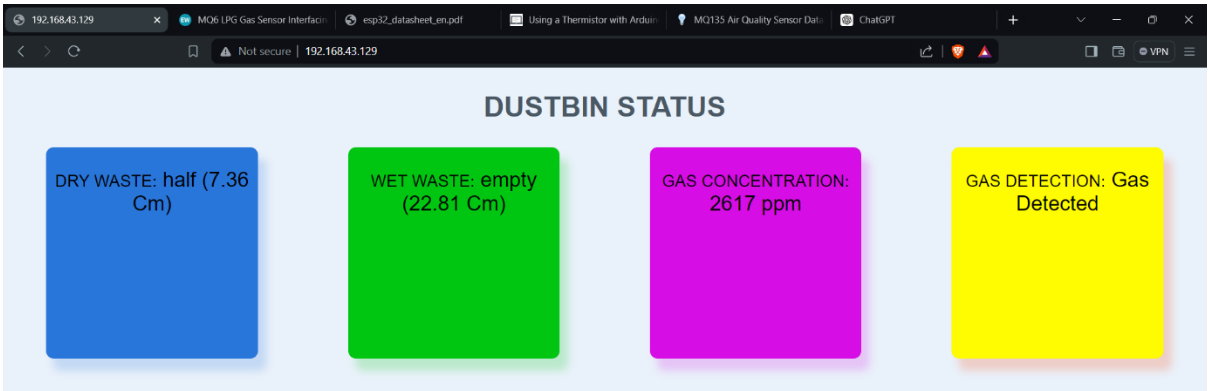

Fig: 4.1: Real time data in web server

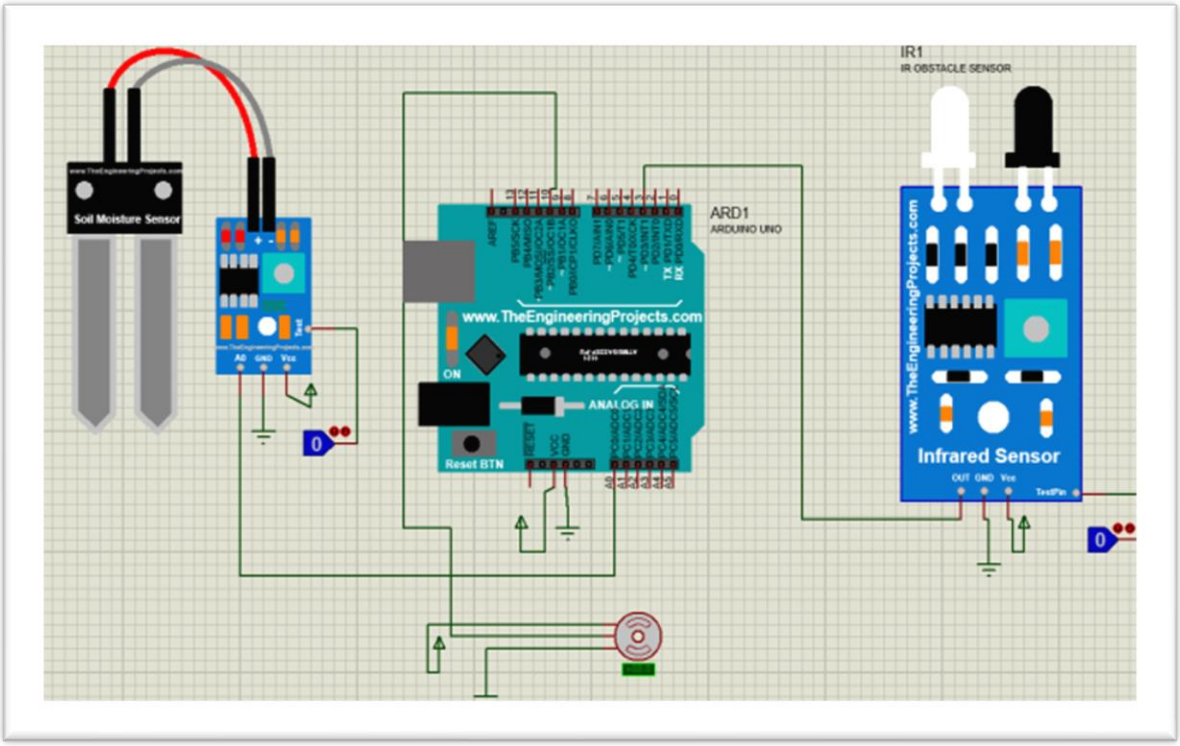

Fig: 4.2 Partial circuit simulation in proteus

4.3 Significance of the result obtained

The significance of the results obtained for a smart dustbin lies in its potential to revolutionize waste management and contribute to a cleaner environment. Here are some key points:

i. **Efficient Waste Management**: Smart dustbins use sensors to monitor the level of waste inside them. When the bin fills to a certain level, the sensors trigger a message to the waste management system. This means garbage collection only happens when needed, resulting in more effective use of resources and significantly reducing operational costs.

ii. **Real-time notifications**: The ultrasonic sensor enables the smart dustbin to send real-time notifications to the server about the height of the waste in the dustbin. This allows the user to stay informed if the bin if filled without having to check it manually.

iii. **Smart Technology**: The smart dustbin is an amalgamation of software with the latest internet of things sensor which helps to set aside the bio or non-biodegradable separately. The smart technology of these bins provides an alert to waste managers in case of overflowing.

iv. **Public Health**: The application of smart dustbins can be adopted by cities and communities to maximize public health and hygiene objectives in smarter ways, and to curb negative impacts of public health crises situations.

In summary, the results obtained for smart dustbins highlight their potential to transform waste management practices, contribute to public health and hygiene, and promote environmental sustainability.

4.4 Deviations from the expected results & its justification

During the result analysis, it is crucial to identify any deviations from the expected results. Deviations can occur due to factors such as sensor calibration, environmental conditions etc. If any deviation is observed, it is essential to investigate the possible causes and justify them based on the limitations of the sensor or the experimental setup. Any discrepancies should be taken into account when interpreting the results and making conclusions.

4.5 Conclusion

The methodology of this project consists of four main steps: designing the circuit, programming the microcontroller, testing the system, and analysing the results. The circuit design involves connecting the soil moisture sensor, ultrasonic sensor, IR sensor, servo motor, with ESP32 board using appropriate pins and wires. The programming of the microcontroller involves writing the code in Arduino IDE software to communicate, and using EEPROM to store the delivery data. The testing of the system involves inserting waste in the dustbin and checking whether the system is able to segregate the waste or not and also checking the height of waste in both the chambers through web server. The gas sensor will sense the gas content in waste and then will show its concentration in ppm in the web server and the automatic spray dispenser will spray certain chemical in a interval of time. The analysis of the results involves evaluating the performance, accuracy, reliability, and efficiency of the system, as well as identifying the limitations, challenges, and possible improvements. The methodology of this project demonstrates the feasibility and usefulness of using NodeMCU(ESP32 module) microcontroller and different types of sensors to design an eco-friendly waste management system in smart cities for ensuring hygiene public health.

CHAPTER 5
CONCLUSION AND FUTURE SCOPE OF WORK

5.1 Brief summary of the work

5.1.1 Problem statement and objective:

The project titled "An Eco Friendly Waste Management System In Smart Cities Using Embedded System And Iot" is a smart waste management system, where a NodeMCU(ESP32 module)microcontroller, soil moisture sensor, ultrasonic sensor, IR sensor, servo motor, LPG gas sensor are used to serve the purpose.

The main objective of the project is to

i) Segregation of dry and wet waste

ii) Resisting the plate movement when bin is full

iii) Detection of hazardous gas

iv) Automatic spray dispenser for reducing odour

v) Making a web server to measure the height of waste in the dustbin, detection of presence of gas and detection of gas concentration level in ppm.

5.1.2 Work methodology

A proper methodology has been followed throughout the project. Methodology includes selection of components like NodeMCU(ESP32 module, soil moisture sensor, ultrasonic sensor, IR sensor, servo motor . After that software tools like Arduino IDE, Proteus 8 are selected and programming and circuit have been developed in the software respectively. Further hardware components are assembled and testing is performed. Successful testing has led the project to fulfil the objectives.

5.2 Conclusions

As the project aimed, it has fulfilled its goal to segregate the waste into dry and wet as well as the real time data collection form height of waste in both the chambers of bin is also achieved through web server also it has fulfilled the goal of gas detection in the bin and resisting the movement of the waste keeping plate after bins get filled to a certain distance.

The user is able to monitor real time data through the web server the information from the web server making the system efficient.

Keeping our environment clean and eco friendly so that our next generation lives a disease free life is a priority. This waste management system is a step forward to the existing waste management to make the manual segregation of wastes easier by segregating dry and wet waste.

In conclusion, eco friendly smart waste management system is designed using ESP32 and different types of sensors provide an innovative solution for efficient and productive waste management system. Making the web server enables notifying users about the height of the waste in the bin continuously using local server. The ESP32 acts as the central processing unit, controlling various functionalities of the system. It monitors the movement of servo motor to move the plate for its resting and inclination position when waste is placed on the plate, detects the presence of waste on the plate by IR sensor, detection of presence of moisture by soil moisture sensor, measuring height of waste by ultrasonic sensor. The key advantages of this smart waste management system are hygiene, public health, convenience, security, and real-time communication. Waste can be separately placed in different chambers of dry and wet eliminating the need for constant manual checking. Additionally, the use of web server ensures height measurement of waste, even when the recipient is not physically present near the dustbin. The system can detect gas concentration in the wet chamber and also automatic spray dispenser is there to spray certain chemical to reduce bad smell. This enhances hygiene and efficient management of waste. Furthermore, the ESP32 module platform offers flexibility and customization options. Users can modify and expand the functionality of the system by adding additional sensors or integrating it with other smart home devices and for public use also. This adaptability allows for future enhancements and integration into larger home automation systems.

5.3 Future scope of work

In this module, we explore the future scope of the smart waste management system using ESP32 module, focusing on potential avenues for further development and expansion. We examine exciting possibilities advanced data analytics, and integration with building management systems. By envisioning these future directions, we aim to inspire ongoing innovation smart waste management technology, ultimately enhancing safety measures and improving efficiency in monitoring and mitigating gas leaks. Future scope for the system includes,

- This system will be developed into a more complete system with actuators to solve the problem of smelly garbage. Some sensors that can sense the bad smell can be connected to the existing circuit to improve the functionality.
- Implementation of GPS system for tracking bin location so that the local municipal board can get the update of filling of bin or emission of bad smell or hazardous gas.
- Segregation of waste based on metallic waste. As the way we have segregated dry and wet waste we can also segregate bio degradable and non-bio degradable, metallic and non-metallic waste. We can also enhance the system by implementing decomposition of segregated bio degradable and wet degradable waste.
- In future using different kind of higher technologies we can extend the segregation process of dry and wet waste from mixed waste. In the present system waste are separated only when they are present individually but using further technologies we can segregate a mixture of waste also.

In summary, the smart waste management system using NOdeMCU(ESP32 module) and different sensors such as soil moisture, infrared, ultrasonic and servo motor provides an hygienic, efficient, secure, and convenient method of waste management. Its ability to measure height of waste in both the chambers ensures timely and reliable and hygiene management, making it a valuable tool for modernizing and improving traditional waste management system. Smart waste management represents a pivotal advancement in our efforts to create sustainable and efficient urban environments. By leveraging cutting-edge technologies such as IoT, data analytics, and AI, municipalities can optimize waste collection, reduce operational costs, and minimize environmental impact. This integrated approach not only enhances resource management but also fosters a cleaner and healthier community. As cities continue to grow, the adoption of smart waste management solutions will be essential in addressing the challenges of urbanization and ensuring a sustainable future for generations to come.

APPENDIX

```
#include <ESP32Servo.h>

#include <ESPmDNS.h>

#include "WiFi.h"

#include "ESPAsyncWebServer.h"

#include <Adafruit_Sensor.h>


const int moistureSensorPin = 33;

const int servoPin = 5;

const int disinfectantServoPin = 4;

const int irsensor=14;

const int moistureThreshold = 3000;

const int trigPin1 = 25; // First sensor's trigger pin

const int echoPin1 = 26; // First sensor's echo pin


const int trigPin2 = 27; // Second sensor's trigger pin

const int echoPin2 = 32; // Second sensor's echo pin

const int gasSensorPin = 34;

const int gasThreshold = 350;

float Referance_V = 3300.0; /* ESP32 Referance Voltage in mV */

float RL = 1.0;             /* In Module RL value is 1k Ohm */

float Ro = 10.0;            /* The Ro value is 10k Ohm */

float mVolt = 0.0;

const float Ro_clean_air_factor = 10.0;

float RsRo_ratio;
```

```
float ppm;

Servo wasteServo;
Servo disinfectantServo;
bool isDryCabinFull = false;
bool isWetCabinFull = false;
#define SOUND_SPEED 0.034
long duration1, duration2;
float distanceCm1, distanceCm2;

const char* ssid = "ttvv";
const char* password = "mriku2001";

AsyncWebServer server(80);

String readDistance1() {
  digitalWrite(trigPin1, HIGH);
  delayMicroseconds(10);
  digitalWrite(trigPin1, LOW);

  duration1 = pulseIn(echoPin1, HIGH);
  distanceCm1 = duration1 * SOUND_SPEED / 2;
  Serial.println("Distance:");
  Serial.println(distanceCm1);
   return String(distanceCm1);
}
```

```
String readDistance2() {
  digitalWrite(trigPin2, HIGH);
  delayMicroseconds(10);
  digitalWrite(trigPin2, LOW);

  duration2 = pulseIn(echoPin2, HIGH);
  distanceCm2 = duration2 * SOUND_SPEED / 2;
   Serial.println("Distance:");
  Serial.println(distanceCm2);
   return String(distanceCm2);
}
String readGas() {

  if(LPG_PPM(RsRo_ratio)> gasThreshold) {
    return "Detected";
  } else {
    return "Not Detected";
  }
}
String readGasConcentration() {
  int gasConcentration =ppm;
  return String(gasConcentration);
}
```

```
const char index_html[] PROGMEM = R"rawliteral(
<!DOCTYPE HTML>
<html>

<head>
    <meta name="viewport" content="width=device-width, initial-scale=1">
    <style>
        html {
            font-family: Arial;
            display: inline-block;
            margin: 0px auto;
            text-align: center;
            background-color: #E9F1FA;
        }

        h2 {
            font-size: 3.0rem;
             color: #4a5764;
        }

        p {
            font-size: 2.2rem;


        }
```

```
        .units {
            font-size: 1.2rem;
        }
        .container {
            display: flex;
            flex-wrap: wrap;
            gap: 20px;
            justify-content: space-around;
        }
        .box1 {

            width: 270px;
            height: 270px;
            box-sizing: border-box;
            background-color:rgb(41, 118, 218);
            border-radius: 10px;
            transition: background-color 0.5s , color 0.5s , height
0.5s , width 0.5s;
            box-shadow: 10px 15px 10px rgba(41, 118, 218, 0.2)

        }
        .box2 {
            width: 270px;
            height: 270px;
            box-sizing: border-box;
            background-color:rgb(1, 198, 17);
```

```
            border-radius: 10px;

            transition:background-color  0.5s  ,  color  0.5s  ,height
0.5s , width 0.5s;

            box-shadow: 10px 15px 10px rgba(1, 198, 17, 0.2)

        }

        .box3 {

            width: 270px;

            height: 270px;

            box-sizing: border-box;

            background-color:rgb(214, 13, 229);

            border-radius: 10px;

            transition:background-color  0.5s  ,  color  0.5s  ,height
0.5s , width 0.5s;

            box-shadow: 10px 15px 10px rgba(214, 13, 229, 0.2)

        }

        .box4 {

            width: 270px;

            height: 270px;

            box-sizing: border-box;

            background-color:rgb(253, 0, 0);

            border-radius: 10px;

            transition:background-color  0.5s  ,  color  0.5s,  height
0.5s , width 0.5s ;

            box-shadow: 10px 15px 10px rgba(255, 64, 0, 0.2)

        }

        .box1:hover{

            background-color: rgb(0, 0, 255);
```

```
    color: white;

    height:280px;

    width: 280px;

}

.box2:hover{

    background-color: rgb(0, 255, 0);

    color: white;

    height:280px;

    width: 280px;

}

.box3:hover{

    background-color: rgb(183, 4, 196);

    color: white;

    height:280px;

    width: 280px;

}

.box4:hover{

    background-color: rgb(217, 5, 5);

    color: white;

    height:280px;

    width: 280px;

}

.dht-labels1 {

    font-size: 0.8em;

    color: black;

    vertical-align: middle;
```

```
            padding-bottom: 15px;
        }
        .dht-labels2 {
            font-size: 0.8em;
            color:black;
            vertical-align: middle;
            padding-bottom: 15px;
        }
        .dht-labels3 {
            font-size: 0.8em;
            color:black;
            vertical-align: middle;
            padding-bottom: 15px;
        }
         .dht-labels4 {
            font-size: 0.8em;
            color: black;
            vertical-align: middle;
            padding-bottom: 15px;
        }
    </style>
</head>

<body>
    <h2>DUSTBIN STATUS</h2>
```

```
<div class="container">

    <div class="box1">

        <p>

            <span class="dht-labels1">DRY WASTE:</span>

            <span id="Distance1">%DISTANCE1%</span>

        </p>

    </div>

    <div class="box2">

        <p>

            <span class="dht-labels2">WET WASTE:</span>

            <span id="Distance2">%DISTANCE2%</span>

        </p>

    </div>

    <div class="box3">

        <p>

            <span class="dht-labels3">GAS CONCENTRATION:</span>

            <span id="GasConcentration">0 ppm</span>

        </p>

    </div>

    <div class="box4">

        <p>

            <span class="dht-labels4">GAS DETECTION:</span>

            <span id="GasStatus">%GASSTATUS%</span>

        </p>

    </div>

</div>
```

```
    <script>
        function updateDistanceDisplay(distance, spanId) {
            var spanElement = document.getElementById(spanId);

            // Convert distance to a number for comparison
            var distanceValue = parseFloat(distance);

            // Determine the textual representation
            var textRepresentation = "";
            if (distanceValue <7) {
                textRepresentation = "full";
            } else if (distanceValue >= 7 && distanceValue <= 12) {
                textRepresentation = "half";
            } else {
                textRepresentation = "empty";
            }

            // Update the span text with both the representation and
the actual distance value
            spanElement.innerHTML = textRepresentation + " (" +
distance + " Cm)";
        }
           function updateGasStatus(status) {
            var spanElement = document.getElementById("GasStatus");
            spanElement.innerHTML = status;
        }
          function updateGasConcentration(concentration) {
```

```
            var                    spanElement                    =
document.getElementById("GasConcentration");
            spanElement.innerHTML = concentration + " ppm";
        }



        setInterval(function () {
            var xhttp1 = new XMLHttpRequest();
            xhttp1.onreadystatechange = function () {
                if (this.readyState == 4 && this.status == 200) {
                    updateDistanceDisplay(this.responseText,
"Distance1");
                }
            };
            xhttp1.open("GET", "/distanceCm1", true);
            xhttp1.send();

            var xhttp2 = new XMLHttpRequest();
            xhttp2.onreadystatechange = function () {
                if (this.readyState == 4 && this.status == 200) {
                    updateDistanceDisplay(this.responseText,
"Distance2");
                }
            };
            xhttp2.open("GET", "/distanceCm2", true);
            xhttp2.send();
```

```
            var xhttp3 = new XMLHttpRequest();

            xhttp3.onreadystatechange = function () {

                if (this.readyState == 4 && this.status == 200) {

                    var    gasStatus    =    (this.responseText    ===
"Detected") ? "Gas Detected"  : "No Gas Detected";

                    updateGasStatus(gasStatus);

                }

            };

            xhttp3.open("GET", "/gasStatus", true);

            xhttp3.send();


             var xhttp4 = new XMLHttpRequest();

             xhttp4.onreadystatechange = function () {

                if (this.readyState == 4 && this.status == 200) {

                updateGasConcentration(this.responseText,
"GasConcentration");

        }

    };

    xhttp4.open("GET", "/gasConcentration", true);

    xhttp4.send();


        }, 1000);

    </script>


</body>


</html>
```

```
)rawliteral";

String processor(const String& var){
  if(var == "DISTANCE1") {
    return readDistance1();
  } else if (var == "DISTANCE2") {
    return readDistance2();
  } else if (var == "GASSTATUS") {
    return readGas();
  }
    else if (var == "GASCONCENTRATION") {
    return readGasConcentration() ;
  }
  return String();
}


void setup(){
  Serial.begin(115200);
  pinMode (moistureSensorPin,INPUT);
  pinMode(gasSensorPin, INPUT);
  pinMode (servoPin,OUTPUT);
  pinMode(disinfectantServoPin, OUTPUT);
  pinMode (irsensor,INPUT);
  pinMode(trigPin1, OUTPUT);
  pinMode(echoPin1, INPUT);
```

```
pinMode(trigPin2, OUTPUT);
pinMode(echoPin2, INPUT);
wasteServo.attach(servoPin);
disinfectantServo.attach(disinfectantServoPin);

WiFi.begin(ssid, password);
while (WiFi.status() != WL_CONNECTED) {
  delay(1000);
  Serial.println("Connecting to WiFi..");
}

Serial.println("Connected to WiFi");

if(!MDNS.begin("esp32")) {
  Serial.println("Error starting mDNS");
  return;
}

Serial.println(WiFi.localIP());

server.on("/", HTTP_GET, [](AsyncWebServerRequest *request){
  readDistance1();
  readDistance2();
  request->send_P(200, "text/html", index_html, processor);
});
```

```
  server.on("/distanceCm1",    HTTP_GET,    [](AsyncWebServerRequest
*request){
    request->send_P(200, "text/plain", readDistance1().c_str());
  });
  server.on("/distanceCm2",    HTTP_GET,    [](AsyncWebServerRequest
*request){
    request->send_P(200, "text/plain", readDistance2().c_str());
  });
  server.on("/gasStatus",     HTTP_GET,     [](AsyncWebServerRequest
*request){
    request->send_P(200, "text/plain", readGas().c_str());
   });
    server.on("/gasConcentration",                          HTTP_GET,
[](AsyncWebServerRequest *request){
    request->send_P(200,                                 "text/plain",
readGasConcentration().c_str());
  });
  server.begin();
}

void loop(){
  int moistureLevel = analogRead(moistureSensorPin);
  int ir= digitalRead(irsensor);
  Serial.println(moistureLevel);
  delay(100);
  { for(int i=0; i<500; i++){
    mVolt += Get_mVolt(gasSensorPin);
  }
```

```
  mVolt = mVolt/500.0;      /* Get the volatage in mV for 500 Samples
*/
  Serial.print("Voltage at A0 Pin = ");
  Serial.print(mVolt);      /* Print the mV in Serial Monitor */
  Serial.println(" mV");

  float Rs = Calculate_Rs(mVolt);
  Serial.print("Rs = ");
  Serial.println(Rs);        /* Print the Rs value in Serial Monitor
*/
  float Ratio_RsRo = Rs/Ro;
  Serial.print("RsRo = ");
  Serial.println(Ratio_RsRo);

  Serial.print("LPG ppm = ");
  unsigned int LPG_ppm = LPG_PPM(Ratio_RsRo);
  Serial.println(LPG_ppm);    /* Print the Gas PPM value in Serial
Monitor */

  Serial.println("");
  mVolt = 0.0;              /* Set the mVolt variable to 0 */
}




  if (distanceCm1 < 7) {
```

```
    isDryCabinFull = true;
  } else {
    isDryCabinFull = false;
  }

  if (distanceCm2 < 7) {
    isWetCabinFull = true;
  } else {
    isWetCabinFull = false;
  }

  if (isWetCabinFull) {
        while (distanceCm2 < 7) {
            disinfectantServo.write(90);
            delay(1000);
            disinfectantServo.write(0);
            delay(1000);
        }
  }
  if (( ir == LOW && moistureLevel > moistureThreshold)&& !isDryCabinFull && !isWetCabinFull) {
    // Dry
    wasteServo.write(0);
    delay(1000);

  }
```

```
  else  if  ((  ir  ==  LOW  &&  moistureLevel  <  moistureThreshold)&&
!isDryCabinFull && !isWetCabinFull)
  {
    // Wet
     wasteServo.write(180);
     delay(1000);

  }
   else{
     wasteServo.write(90);
     delay(1000);
  }
}
float Calculate_Rs(float Vo) {
  float Rs = (Referance_V - Vo) * (RL / Vo);
  return Rs;
}



unsigned int LPG_PPM(float RsRo_ratio) {
  float ppm;
  ppm = pow((RsRo_ratio/18.446), (1/-0.421));
  return (unsigned int) ppm;
}

float Get_mVolt(const int gasSensorPin) {
```

```
  int gasValue = analogRead(gasSensorPin);
  delay(1);
  float mVolt = gasValue * (Referance_V / 4096.0);
  return mVolt;
}
```

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