SAVITRIBAI PHULE PUNE UNIVERSITY

A PROJECT REPORT ON

"An IoT Based Automatic Waste Segregation and Monitoring System"

SUBMITTED IN THE PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE AWARD OF THE DEGREE
OF

BACHELOR OF COMPUTER ENGINEERING

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2024-2025



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"An IoT Based Automatic Waste Segregation and Monitoring System"

Is verified for its originality in documentation, problem statement, proposed work and implementation successfully completed by

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Abstract

The Proposed System represents a pioneering solution to address the growing challenges of waste management and environmental sustainability. Leveraging the Internet of Things (IoT) technology, this system offers an automated, efficient, and environmentally responsible approach to waste segregation and monitoring. In this innovative system, IoT sensors are strategically integrated into waste collection bins and containers, enabling real-time monitoring of waste composition and fill levels. These sensors, equipped with various sensors such as ultrasonic sensors, accurately classify waste into dry and wet categories. The data collected from these sensors is transmitted wirelessly to a central data processing unit.

Users, including waste management authorities and environmental agencies, gain access to a comprehensive dashboard that provides real-time insights into waste composition, fill levels, and collection status. Data analytics tools process this information, offering actionable insights for optimizing waste collection routes and schedules, reducing operational costs, and minimizing environmental impact.

The system's automation extends to waste collection trucks, which receive optimized route plans based on real-time data. Furthermore, the system enhances public engagement in sustainable waste management practices. Mobile applications allow residents to receive notifications for waste collection schedules, access educational resources on proper waste disposal, and track their own waste contributions.

The proposed system is a transformative solution that promotes waste reduction, recycling, and sustainability. By leveraging IoT technology, automation, and data analytics, it enables efficient waste segregation, optimized collection processes, and improved environmental stewardship. This project represents a significant step toward smarter, more sustainable waste management practices for a cleaner and greener future.

Keywords: Internet of Things (IoT), Modern/Smart Cities, Waste Segregation and Monitoring, Ultrasonic Sensors, Cloud-Based Platform, etc.

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CHAPTER 1

SYNOPSIS

1.1 PROJECT TITLE

"An IoT Based Automatic Waste Segregation and Monitoring System."

1.2 PROJECT OPTION:-

Internal Project

1.3 INTERNAL GUIDE:-

Prof. P. B. Palve

1.4 TECHNICAL KEYWORDS(AS PER ACM KEYWORDS):-

1. H.5 INFORMATION INTERFACES AND PRESENTATION
   (a) H.5.1 Information Systems
      i. Machine Learning
      ii. Image Processing
      iii. IOT Algorithm
      iv. Evaluation/Methodology
      v. Garbage Detection
      vi. Waste Classification or Segregation

1.5 PROBLEM STATEMENT:-

- Dustbins are containers for temporarily storing waste. Due to urbanization, there is an increase in production of waste. Managing waste is a crucial task at public places. When the massive amount of waste material is collected, it is difficult to separate and unhygienic. The Proposed work aims to address these challenges by introducing an automated, data-driven, and sustainable approach to waste management. It seeks to revolutionize waste segregation, monitoring, and collection processes while engaging the public in responsible waste disposal practices.

1.6 ABSTRACT:-

In this innovative system, IoT sensors are strategically integrated into waste collection bins and containers, enabling real-time monitoring of waste composition and fill levels. These sensors, equipped with various sensors such as ultrasonic sensors, accurately classify waste into dry and wet categories. The data collected from these sensors is transmitted wirelessly to a central data processing unit.

Users, including waste management authorities and environmental agencies, gain access to a comprehensive dashboard that provides real-time insights into waste composition, fill levels, and collection status. Data analytics tools process this information, offering actionable insights for optimizing waste collection routes and schedules, reducing operational costs, and minimizing environmental impact.

The system's automation extends to waste collection trucks, which receive optimized route plans based on real-time data. Furthermore, the system enhances public engagement in sustainable waste management practices. Mobile applications allow residents to receive notifications for waste collection schedules, access educational resources on proper waste disposal, and track their own waste contributions.

The proposed system is a transformative solution that promotes waste reduction, recycling, and sustainability. By leveraging IoT technology, automation, and data analytics, it enables efficient waste segregation, optimized collection processes, and improved environmental stewardship. This project represents a significant step toward smarter, more sustainable waste management practices for a cleaner and greener future.

1.7 GOALS AND OBJECTIVES

TThe primary objectives of the Proposed System are as follows:

- Efficient Waste Segregation: Implement IoT technology to automate the segregation of waste into dry and wet categories within collection bins, ensuring consistent and accurate sorting.
- This system not only saves the manual segregator of the numerous health issues, but also proves to be economical to the nation.
- Design a unit of automatic sensing system with dedicated apparatus.

- In this project dry waste and wet waste can be separated efficiently and the levels of dumpsters/dustbin.

1.8 RELEVANT MATHEMATICS ASSOCIATED WITH THE PROJECT:-

- **System Description:**

  A System has represented by a 5-different phases, each phase works with own dependency System S = (Q, Σ, δ, q0, F) where :

  - Q is a finite set of states.
  - Σ is a finite set of symbols called the alphabet.
  - Δ is the transition function where δ : Q x Σ → Q
  - q0 is the initial state from where any input is processed (q0 ε Q).
  - F is a set of final state/states of Q (F ⊆ Q).

2. Analysis:-

All t(n) policies will return 1 then from training patterns and it generate the similarity weight of fitness function of specific rules.

Q = {VaiSet[i=0.....n]} set of generated attribute of various images as initial set.

Σ = {data conversion, saveinDB}

Δ = {_CorrecltyclassifiedInstnaces*100 / SumF(x)}

q0 = {First event generated by sensor function Σ i=0 }

F = {Generated report according to class [a,b,c.....n]}

3. Intersection of two sets:-

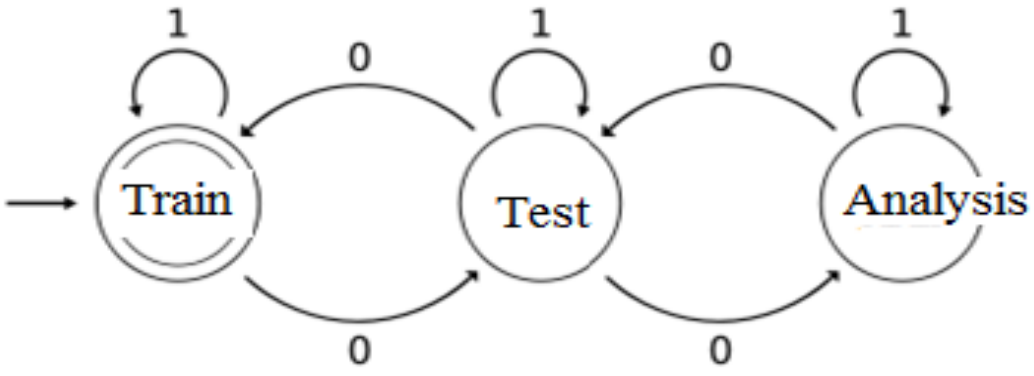


Figure 1.1: Mathematical Model

4. Success Conditions:

Give proper input to the system it will generate proper output.

5. Failure Condition:

If IoT does not working hardware or system properly this will be a case of failure.

1.9 NAMES OF CONFERENCES / JOURNALS WHERE PAPERS CAN BE PUBLISHED:-

1. International Journal of Research and Analytical Reviews (IJRAR).
2. International Journal of Scientific Research in Science and Technology (IJSRST)
3. Journal of Emerging Technologies and Innovative Research (JETIR)

1.10 REVIEW OF CONFERENCE / JOURNAL PAPERS SUPPORTING PROJECT IDEA:-

1. Chun-Yen Chung, I-Ting Peng, Jong-Chao Yeh, "Environmental Monitoring and Smart Garbage Sorting System Based on IoT and Wireless Transmission Technology.

   Since the industrial revolution, scientific and technological advancements have made life more convenient and have facilitated the rapid growth of the global population. However, the amount of waste produced has also increased. Governments have invested a considerable amount of resources in solving this problem on waste source reduction and recycling. Accordingly, this study with a smart city concept developed a recyclable garbage sorting system that could be used in various locations to help eliminate littering in the city (from inconsistent waste disposal), diminish labor costs, and achieve the goals of increased recycling and reduced waste. This study integrated LoRaWAN communication networks (networks developed using the Internet of Things) with garbage sorting equipment to create a system that offers automated garbage can operation, environmental monitoring, and graphical interface monitoring. The system uses electrostatic capacitance-type proximity sensors to determine the types of garbage deposited in garbage cans. Furthermore, it contains an embedded motor and smart devices that can perform functions such as automatically opening and closing insertion points, sorting waste materials, initiating automated garbage compression, monitoring water levels, and issuing warnings when the water level exceeds the specified limit. This system employs a C# graphical monitoring

interface to remind users to remove the garbage.

1.11 PLAN OF PROJECT EXECUTION:-

This section explains how our project will developed into different phases and how much time each phase will require.

1.11.1 Project Phase Analysis

Table 1.1: Project Phase Analysis

NO	TASK	START DATE
1	Group Formation	25/05
2	Decide Area Of Interest	30/05
3	Search Topic	03/06
4	Topic Selection	15/07
5	Sanction Topic	20/07
6	Search Related Infomation	03/08
7	Understanding Concept	10/08
8	Search Essential Document(IEEE & White Paper, Software)	18/08
9	Problem Definition	22/08
10	Literature Survey	02/09
11	Project Planning	23/09

CHAPTER 2

TECHNICAL KEYWORDS

2.1 TECHNICAL KEYWORDS

1) Categories and Subject Descriptors:

K.4.4 [Electronic Commerce]: Waste Segregation IOT System.

K.6.5 [Security and Protection]: Internet of Things (IoT), Waste Segregation and Monitoring, Ultrasonic Sensors, etc.

2) General Terms:

Design, Human factors, IOT.

3) Keywords:

- Machine Learning
- Machine Learning
- Image Processing
- IOT Algorithm
- Evaluation/Methodology
- Garbage Detection
- Waste Classification or Segregation

CHAPTER 3

INTRODUCTION

3.1 PROJECT IDEA

The Proposed System represents a groundbreaking advancement in waste management and environmental conservation. As the world grapples with escalating waste generation and its adverse ecological impact, this innovative project harnesses the power of the Internet of Things (IoT) to introduce automation, efficiency, and sustainability into waste handling processes.

Traditional waste management practices often struggle to cope with the increasing volume and complexity of waste streams. Proper segregation of dry and wet waste, critical for recycling and minimizing landfill usage, frequently relies on manual labor and inconsistent practices. Moreover, monitoring waste bin fill levels and optimizing collection routes can be resource-intensive and environmentally inefficient.

In response to these challenges, the Proposed System offers a holistic solution. It deploys IoT sensors within waste collection bins, empowering them to autonomously classify waste into dry and wet categories. These sensors, equipped with cutting-edge technology like ultrasonic and image recognition, ensure precise and consistent segregation.

Real-time data from these sensors is transmitted to a central data processing unit, providing stakeholders with dynamic insights into waste composition, bin fill levels, and collection status. This data-driven approach allows for optimized waste collection routes, reducing fuel consumption, minimizing emissions, and significantly lowering operational costs.

Beyond operational efficiency, the system engages the community in responsible waste management practices. Residents receive notifications for waste collection schedules and access educational resources on proper waste disposal, fostering a culture of sustainability.

The Proposed System is not merely a technological advancement; it embodies a commitment to environmental preservation and resource optimization. By automating waste segregation, monitoring, and collection processes, this project paves the way for smarter and more sustainable waste management, contributing to a cleaner, greener future.

3.2 MOTIVATION

- The motivation behind the project stems from the pressing need to address the challenges associated with traditional waste management practices. Conventional waste management methods often lead to inefficient segregation, improper disposal, and environmental pollution. By leveraging IoT technology, this project aims to revolutionize waste management by automating the segregation process and providing real-time monitoring capabili-

ties. This system not only enhances the efficiency of waste segregation but also promotes environmental sustainability by encouraging recycling and reducing landfill waste. Additionally, the project aligns with global initiatives aimed at promoting smart cities and sustainable development, contributing to a cleaner and healthier environment for future generations.

3.3 LITERATURE SURVEY

- Padmakshi Venkateshwara Rao, Pathan Mahammed Abdul Azeez, 2020[1] introduces the IoT based Waste Management for Smart Cities to overcome the challenges in the environment such as inadequate waste collection, treatment, disposal. Due to flooding of the dustbin causes unhygienic conditions are created, the dustbin is placed in the entire city; it is delivered with minimum cost embedded method to assist in tracking of the garbage, therefore the Blynk app is used to get the immediate SMS as early as garbage bin reaches its peak level. Therefore, instant action will be taken by the alarmed authorities once the status of a bin is notified through the internet. Ultrasonic sensor, node MCU, blynk app, a servo motor is used to develop the proposed system.

- Nikolaos Baras, Dimitris Ziouzios, 2020[2] introduces A cloud-based smart recycling bin for in-house waste classification urban waste increases as long as modern lifestyle increases. Recycling is the best way to create a sustainable environment and also it needs the segregation of waste materials which is a tedious time-consuming task. It is the minimal cost and effective smart recycling bin that uses the power of the cloud in order with waste classification in personal in-house usage. A centralized Information System collects measurements in smart dustbins, the waste in each bin can be classified using Artificial Intelligence and also neural networks. And it is capable of classifying different types of waste with an accuracy of 93.4%.

- Shashank Shetty, Sanket Salvi, 2020[3] This introduces the SAF-Sutra: A Prototype of Remote Smart waste segregation and garbage level monitoring system, which can remotely monitor and is built at a very minimal cost. The design of the presented system considers the portability and ease of assembly of components as the essential factors during implementations. The demonstration shows the implemented system; its interaction with the user using the mobile along with the web application.

- Clude-Noel Tamakloe, Dr. Elena v. Rosca, Introduces the Smart System and the Internet of Things (IoT) for waste management to provide an efficient and effective manner for waste disposal, improving the citys waste management. The proposed system is drawn and makeup a prototype of a solar powered, compact smart garbage bin whose monitoring is done with server side applications. The smart garbage bin is capable of monitoring internal garbage levels, compact them, and also free 25% of the space with each compactness. The bin detects and monitors the total weight and is capable of sending all the information to a secure server side application.

- Rania Rizki Arinta, Dominikus Boli Watomakin, 2020[5] introduces the Improves smart waste management to preserve tourists attractions Yogyakarta in IoT environment, the main agenda is to make waste recycled, if it is not recycled, it will make the decomposition process more tedious. Therefore, the dustbin is integrated with the smartphone to find out information about the capacity of the garbage by using the ultrasonic sensor. The wi-fi module combined with the dustbin allows the sensor to send the data through the wi-fi module via smartphone.

- Chethan Kaushal, Anshu Singha, 2020[6] introduce the Architecture for garbage monitoring systems using integrated technology, proposed the novel architecture of waste management that utilizes the concept of IoT and digital image processing, the architecture acts as a surveillance system to monitor the over the flow of the garbage and delivers the message to the concerned authorities to take the necessary and instant action.

CHAPTER 4

PROBLEM DEFINITION AND SCOPE

4.1 PROBLEM STATEMENT

- Dustbins are containers for temporarily storing waste. Due to urbanization, there is an increase in production of waste. Managing waste is a crucial task at public places. When the massive amount of waste material is collected, it is difficult to separate and unhygienic. The Proposed work aims to address these challenges by introducing an automated, data-driven, and sustainable approach to waste management. It seeks to revolutionize waste segregation, monitoring, and collection processes while engaging the public in responsible waste disposal practices.

4.1.1 Goal and Objectives

The primary objectives of the Proposed System are as follows:

- Efficient Waste Segregation: Implement IoT technology to automate the segregation of waste into dry and wet categories within collection bins, ensuring consistent and accurate sorting.
- This system not only saves the manual segregators of the numerous health issues, but also proves to be economical to the nation.
- Design a unit of automatic sensing system with dedicated apparatus.
- In this project dry waste and wet waste can be separated efficiently and the levels of dumpsters/dustbin.

4.1.2 Statement of Scope

The statement of scope for the project encompasses various aspects related to the design, development, and implementation of the system. It includes defining the objectives, functionalities, and features of the system, such as automatic waste segregation based on predefined categories, real-time monitoring of waste levels, and integration with IoT devices for data collection and analysis. The scope also outlines the target environment for deployment, which may include residential areas, commercial complexes, or industrial facilities. Furthermore, it identifies the key stakeholders involved, including waste management authorities, municipal corporations, residents, and IoT technology providers. Overall, the statement of scope provides a compre-

hensive overview of the project's boundaries and objectives, guiding its successful execution.

4.2 METHODOLOGIES OF PROBLEM SOLVING

1. **Requirement gathering and analysis:** In this step of waterfall we identify what are various requirements are need for our project such are software and hardware required, database, and interfaces.

2. **System Design:** In this system design phase we design the system which is easily understood for end user i.e. user friendly. We design some UML diagrams and data flow diagram to understand the system flow and system module and sequence of execution.

3. **Implementation:** In implementation phase of our project we have implemented various module required of successfully getting expected outcome at the different module levels. With inputs from system design, the system is first developed in small programs called units, which are integrated in the next phase. Each unit is developed and tested for its functionality which is referred to as Unit Testing.

4. **Testing:** The different test cases are performed to test whether the project module are giving expected outcome in assumed time. All the units developed in the implementation phase are integrated into a system after testing of each unit. Post integration the entire system is tested for any faults and failures.

5. **Deployment of System:** Once the functional and non-functional testing is done, the product is deployed in the customer environment or released into the market.

6. **Maintenance:** There are some issues which come up in the client environment. To fix those issues patches are released. Also to enhance the product some better versions are released. Maintenance is done to deliver these changes in the customer environment. All these phases are cascaded to each other in which progress is seen as flowing steadily downwards like a waterfall through the phases. The next phase is started only after the defined set of goals are achieved for previous phase and it is signed off, so the name "Waterfall Model". In this model phases do not overlap.

4.3 MAJOR CONSTRAINTS

- **Environmental Constraints:**
  - **Power Failure:** The system cannot function if there is a power failure.
- **Functional Constraints:**
  - **Network Failure:** System will not function if there is a network failure while connecting with the database, while sending alerts, or generating reports.
  - **Connectivity Failure:** Data may get lost if there are connectivity issues.

4.4 OUTCOME

The outcome of the project is a comprehensive and efficient waste management solution that leverages Internet of Things (IoT) technology to streamline waste collection, segregation, and monitoring processes. By integrating smart sensors into waste bins, the system enables real-time data collection on waste levels, types, and disposal patterns. This data is transmitted to a centralized cloud platform, where it is analyzed using machine learning algorithms to classify waste items into recyclable, non-recyclable, and organic categories automatically.

The key outcome of the system is improved waste management efficiency and effectiveness. By automating waste segregation processes, the system reduces the manual effort required for sorting and processing waste, thereby minimizing human error and increasing operational efficiency. Additionally, the real-time monitoring capabilities provided by the system enable proactive waste management strategies, such as timely waste collection scheduling, optimized bin placement, and proactive maintenance of waste collection infrastructure.

Furthermore, the system's data analytics capabilities facilitate data-driven decision-making by providing insights into waste generation trends, recycling rates, and overall waste management performance. This enables stakeholders, including waste management authorities, municipal agencies, and environmental organizations, to make informed decisions and implement targeted interventions to improve waste management practices and reduce environmental impact.

Overall, the outcome of the project is a more sustainable, cost-effective, and environmentally friendly approach to waste management that addresses the challenges of traditional waste management methods and contributes to building smarter and greener cities.

4.5 APPLICATIONS

The has several real-time applications in various sectors. Here are some of the practical applications:

1. Municipal Waste Management: Municipalities and waste management authorities can use the system to optimize waste collection routes, reduce operational costs, and enhance the efficiency of waste disposal.

2. Residential Communities: Residential complexes and communities can implement the system to encourage residents to segregate waste, monitor collection schedules, and reduce the environmental impact of waste disposal.

3. Commercial and Industrial Facilities: Large commercial and industrial sites can utilize the system for effective waste management and reporting, ensuring compliance with environmental regulations.

4. Smart Cities: The system can be integrated into the infrastructure of smart cities to enhance overall waste management efficiency and environmental sustainability.

5. Educational Institutions: Schools, colleges, and universities can use the system to educate students about responsible waste disposal practices and track waste generation on campus.

6. Healthcare Facilities: Hospitals and healthcare facilities can benefit from the system to manage hazardous waste disposal, monitor fill levels of medical waste bins, and ensure compliance with safety standards.

7. Tourist Destinations: Popular tourist destinations can implement the system to efficiently manage waste generated by visitors and maintain clean, attractive environments.

8. Remote and Rural Areas: Even in remote or rural areas, the system can help improve waste management practices, reduce littering, and promote recycling.

9. Public Events: Organizers of public events, such as festivals and concerts, can use the system to manage the temporary surge in waste generation during events.

10. Environmental Conservation Projects: Environmental organizations can deploy the system to monitor waste and litter in natural habitats, aiding in conservation efforts.

4.6 SOFTWARE RESOURCES REQUIRED

Platform :

1. Programming Languages: Embedded C
2. Compilers : Keil 4.0uv
3. Dumping Software: Using Micro controller flash magic/ preload Software we are dumping our HEX Code into Micro Controller.

4.7 HARDWARE RESOURCES REQUIRED

- System: AMD Ryzen 3 or more / Intel i3 or more
- Hard Disk: 240 GB.
- RAM: 2 GB.
- I/O Devices: Keyboard, Mouse, Monitor, etc.
- ATMega328 Microcontroller
- Dry & Wet Sensor
- Gas Sensor
- L293D
- Dc Motor
- LCD
- Power Supply
- Buzzer

CHAPTER 5

PROJECT PLAN

5.1 PROJECT ESTIMATE

5.1.1 Cost Estimates

Cost of project

C=N*Cp

C=3*8000

C=24,000

The Cost of the project is approximately up to 24000.

5.1.1.1 Time Estimates

Line of Code (LoC): Estimating LOC for this project is difficult at estimation stages this project is of innovative type project. Average estimation of this project is 10000 to 12000 line of code.

LOC based Estimation:

Efforts in Person in months

$E = 3.2 * (KLOC)^{1}.05$

$E = 3.2 * 9.0^{1}.05 to 11.0 * 4.2^{1}.05$

5.1.1.2 Man Month Utilization:

Estimation of the man month is divide into following sub activities:

1-Technical training of the team member: This will take nearly 1 months. This will include Advance python, serialization etc.

2-Research: Being an innovative project research for the project is an important part currently it seems to have 1 to 1.5 months.

Table 5.1: LOC Based Estimation

Function	**Estimated KLOC**
GUI design	1.1-1.3
Logical code	1.5-2.0
Location Based code	1.1-1.3
Directory matching code	1.0-1.3
Business logic	2.2-2.5
Testing	1.1-1.2
Re-correct Code	1.0-1.2
Total	9.0-10.11

5.1.2 Project Resources

- **Hardware Resources Required:**

  1. Processor: Intel i3
  2. Hard Disk: Minimum 100GB
  3. RAM: 4GB

- **Software Resources Required:**

  1. Programming Languages: Embedded C
  2. Compilers : Keil 4.0uv
  3. Dumping Software: Using Micro controller flash magic/ preload Software we are dumping our HEX Code into Micro Controller.

5.2 RISK MANAGEMENT W.R.T. NP HARD ANALYSIS

- In appropriate dataset -To overcome this risk we are trying to use well organized and complete dataset.
- Security- To overcome and improving security we use multilevel security like access permissions of user.

When solving problems we have to decide the difficulty level of our problem. There are three types of classes provided for that. These are as follows:

- P class
- NP-Hard Class
- NP Complete Class

P Class:-

In computational complexity theory, P, also known as PTIME or DTIME (nO(1)), is a fundamental complexity class. It contains all decision problems that can be solved by a deterministic Turing machine using a polynomial amount of computation time, or polynomial time.P class problems are deterministic problems i.e. P class problems can be solve by deterministic Turing Machine.

Np Class:-

In computational complexity theory Equivalently, the formal definition of NP is the set of decision problems solvable in polynomial time by a theoretical non-deterministic Turing machine. This second definition is the basis for the abbreviation NP, which stands for ”nondeterministic, polynomial time.” However, the verifier-based definition tends to be more intuitive and practical in common applications compared to the formal machine definition. The two definitions are equivalent because the algorithm for the machine definition consists of two phases, the first of which consists of a guess about the solution, which is generated in a non-deterministic way, while the second phase consists of a deterministic algorithm that verifies or rejects the guess as a valid solution to the problem.

3. NP Hard Class:-

- NP-hardness stands for Non-deterministic polynomial-time hard.
- Informally, ”at least as hard as the hardest problems in NP” are called as NP hard class problem.

5.2.1 Risk Identification

For risks identification, review of scope document, requirements specifications and schedule is done.

1. Have top software and customer managers formally committed to support the project?
   Ans: All the required software’s are freely available and hence development will be possible.

2. Are end-users enthusiastically committed to the project and the system/product to be built?
   ans: The end user will be developers itself.

3. Are requirements fully understood by the software engineering team and its customers?
   Ans: Yes. All the requirements are fully understood by our team.

4. Have customers been involved fully in the definition of requirements?
   Ans: This is academic level project. So that whatever requirement be specify it should be by our team members and our guide.

5. Do end-users have realistic expectations?
   Ans: Yes.

6. Does the software engineering team have the right mix of skills?
   Ans: Yes, we have.

7. Are project requirements stable?
   Ans: All the basic requirements for this project are stable, from though some being variable but can be fulfilled.

8. Is the number of people on the project team adequate to do the job?
   Ans: Yes.

9. Do all customer/user constituencies agree on the importance of the project and on the requirements for the system/product to be built?
   Ans: Yes.

5.2.2 Risk Analysis

The risks for the Project can be analyzed within the constraints of time and quality.

5.2.3 Overview of Risk Mitigation, Monitoring, Management

Following are the details for each risk.

Table 5.2: Risk Table

ID	Risk Description	Probability	Impact		
			Schedule	Quality	Overall
1	Deadline Risk	medium	Low	High	High
2	Technical skill Risk	medium	Low	High	High
3	Hardware Failure Risk	high	high	medium	high
4	Accuracy Risk	medium	medium	low	high

Table 5.3: Risk Probability Definitions

Probability	Value	Description
High	Probability of occurrence is	$> 75\%$
Medium	Probability of occurrence is	$26 - 75\%$
Low	Probability of occurrence is	$< 25\%$

Table 5.4: Risk Impact Definitions

Impact	Value	Description
Very high	$> 10\%$	Schedule impact or Unacceptable quality
High	$5 - 10\%$	Schedule impact or Some parts of the project have low quality
Medium	$< 5\%$	Schedule impact or Barely noticeable degradation in quality Low Impact on schedule or Quality can be incorporated

Table 5.5: Risk Impact Definitions

Risk ID	1
Risk Description	Development Deadline Risk
Category	Development Environment.
Source	Software requirement Specification document.
Probability	Low
Impact	High
Response	Mitigate
Strategy	Team Work distribution and Task plan.
Risk Status	Occurred

Risk ID	2
Risk Description	Technical skill risk
Category	Requirements
Source	Software Design Specification documentation review.
Probability	Low
Impact	High
Response	Mitigate
Strategy	Self study and Internet will be best source for technology knowledge
Risk Status	Identified

Risk ID	3
Risk Description	Hardware Failure
Category	Requirements
Source	Software Design Specification documentation review.
Probability	Low
Impact	High
Response	Mitigate
Strategy	Check whether Hardware is accurately fit or not according to knowledge
Risk Status	Identified

5.3 PROJECT SCHEDULE

5.3.1 Project task set

Major Tasks in the Project stages are:

- Task 1.1: Checking Feasibility of product
- Task 1.2: Scope of Product
- Task 1.3: Product Planing
- Task 1.4: Technical Risk
- Task 1.5: Proof of product

- Task 1.6: Implementation
- Task 1.7: Costumer Feedback

5.3.2 Task network

Project tasks and their dependencies are noted in this diagrammatic form.

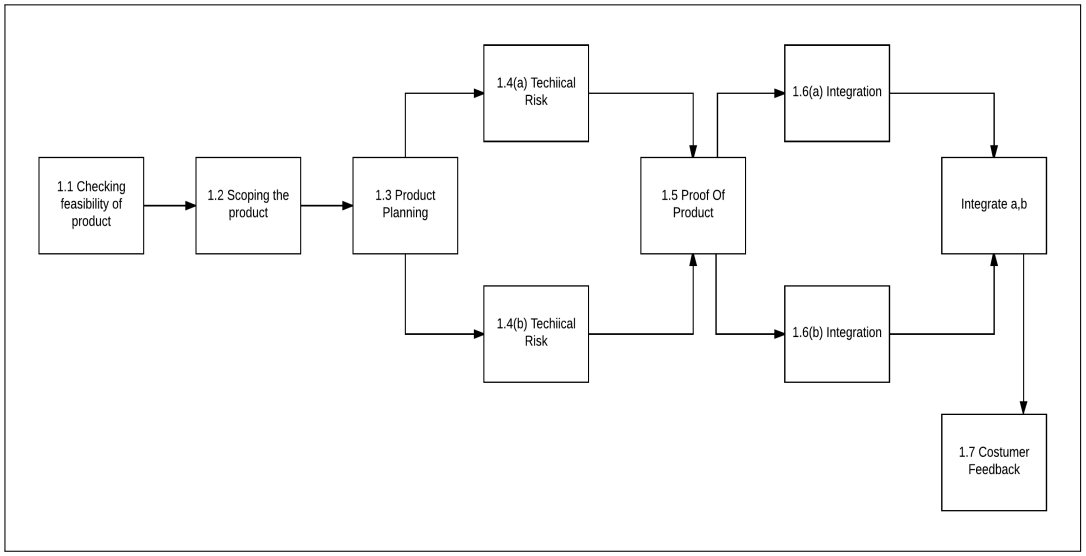


Figure 5.1: Task Network

5.3.3 Timeline Chart

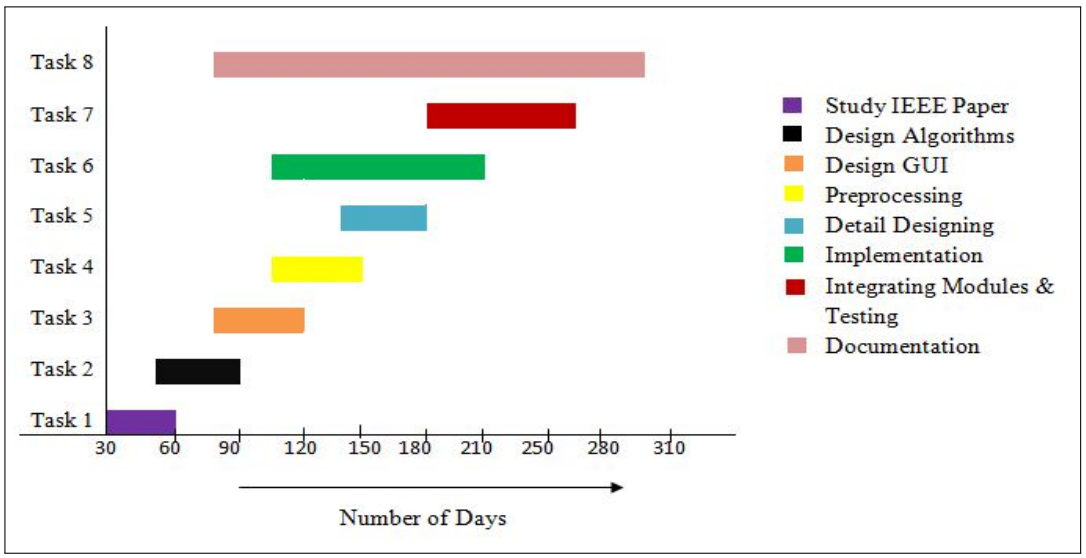


Figure 5.2: Time line Chart

5.4 TEAM ORGANIZATION

Team Member Details:-

1. Riyaj Multani
2. Akash Sonawane
3. Ganesh Shegokar
4. Gaurav Sangale

5.4.1 Team structure

The team structure for the project is identified. Roles are defined. Our team have three members. We select this topic after discussing with each other. All the members performing all the task whatever tasks are assign to the members.

Table 5.6: Team Work Distribution

Name	**Role**
Member 1	Schedule all plan of project. Manage the team. Divide the work in team. The deadline are assign. Consider the all requirements and as per requirement gathering develop the module.
Member 2	Arrange the developing tool i.e platform, language, software, hardware and make the system architecture. Write the code of every module and apply the appropriate use case to test the plan.
Member 3 & 4	Test the each module if result is correct then combine all module and again test. After deployment manages the feedback report and correct some corrections.

5.4.2 Management Reporting and Communication

Table 5.7: Team Work Distribution Plan

Sr.No.	Reporting Date	Project Activity
1	25/05/2024	Decide project group member
2	15/07/2024	Submitted 3 Project Topic with IEEE Paper
3	20/07/2024	Discuss 5 point analysis of selected IEEE Paper
4	18/08/2024	3 Topics are presented and 1 topic selected
5	26/08/2024	Created and Submitted synopsis of a selected project
6	02/09/2024	Literature Survey and info gathering of a selected project
7	20/09/2024	30 percent project completion and presentation
8	14/10/2024	Draw UML diagram of a project
9	23/11/2024	50 percent project completion and presentation
10	23/05/2025	100 percent project completion and presentation
11	30/05/2025	Show the paper published
12	05/06/2025	Show the final report
13	05/06/2025	Show the final PPT
14	05 June 2025	Final Project overview

CHAPTER 6

SOFTWARE REQUIREMENTS SPECIFICATIONS

6.1 ASSUMPTIONS AND DEPENDENCIES

- End User application will be developed in Windows OS.
- Database will be in MySQL (if required).
- All HTML code shall conform to the HTML 5.0 standard.
- All scripts shall be written in JavaScript.
- Application design pattern shall be Singleton.

6.2 FUNCTIONAL REQUIREMENTS

- The application is user friendly.
- It provides an easy interface to user.
- The accessibility or response time of the application should be fast.
- Performance of the system is appropriate.

6.3 EXTERNAL INTERFACE REQUIREMENTS

6.3.1 User Interface

All kind of users: Proposed System is a powerful, yet easy application to use so, all users with some basic experience with electronic devices are able to use it efficiently.
Open source software developers and contributors:

- Software Developers: People with very good knowledge of programming language project, in order to understand and be able to extend project's source code.
- End User: People of all age groups with very good knowledge of a language not included in the current translation list.
- Anyone who wants to help Social community: The whole project is based on the conception of Free and Open Source Software, so all people are welcome to contribute any way they can/like.

6.3.2 Hardware Interface

The hardware should have following specifications:

- Ability to read gallery
- Ability to exchange data over network
- Touch screen for convenience
- Keypad (in case touch pad not available)
- Continuous power supply
- Ability to connect to network
- Ability to take input from user
- Ability to validate user

6.3.3 Software Interface

The computer this software going to be install need to have System equal or above, Windows 7. On that Windows platform C#, Keil 4.0uv Compilers will be installed and that will be the platform the particular software will be run.

6.3.4 Communication Interface

- Our Project belongs to web based, so connecting user at online with request and response form. For that HTTP protocol we are going to use. That is provided by tomcat server 7/8.
- HTTP protocol: The Hypertext Transfer protocol is an application protocol for distributed, collaborative, and hypermedia information systems. HTTP is the foundation of data communication for the World Wide Web. Hypertext is structured text that uses logical links (hyperlinks) between nodes containing text.

6.4 NON-FUNCTIONAL REQUIREMENTS

6.4.1 Performance Requirement

- System can produce results faster on 4GB of RAM.

- It may take more time for peak loads at main node.
- The system will be available 100% of the time. Once there is a fatal error, the system will provide understandable feed back to the user.

6.4.2 Safety Requirements

- Only administrators have access to the database of each individual user.
- All data will be backed-up every day automatically and also the system administrator can back-up the data as a function for him.
- This makes it easier to install and updates new functionality if required.
- For the safety purpose backup of the database must be required.

6.4.3 Security Requirements

- Our System is being developed in C#. C# is an object oriented programming language and shall be easy to maintain. The system is designed in modules where errors can be detected and fixed easily.
- For the security purposes and to avoid illegal use of the system, while using this application user must do following things:
  - At the time of deploying this software user have to register to system.
  - To use software user have to login and logout each time.

6.4.4 Software Quality Attributes

The system considers following non-functional requirements to provide better functionalities and usage of system.

- **Availability :** The system shall be available during 24 hours of a day.
- **Usability :** The system is designed keeping in mind the usability issues considering the end-users who are developers/programmers. It provides detailed help which would lead to better and faster learning. Navigation of system is easy.
- **Consistency :** Uniformity in layout, screens, Menus, colours scheme, format.

- **Performance :** The performance of the system should be fast and as per user requirement. From this system we will get expected outcome in less time and less space since efficiency is higher. Speed is totally depending on the response of the database and connection type.
- **Extendibility :** Prevention in the system should be done in the system by which we make changes in the system later on.
- **Reusability :** Files of any type can be used by the system for any number of times during transformation.
- **Reliability :** Protection of data from malicious attack or unauthorized access.
- **Security :** The system provides security to the randomly generated private key by performing encryption to it for encrypting patient data and thus protects from other nodes in the network. The network is free from malicious node and misbehaving node attacks.
- **Reliability :** Our system can provide user an efficient search each time. So the user can reliable on the system. Because system can guarantees user to provide his/her interested data every time in least amount of time.

6.5 SYSTEM REQUIREMENTS

6.5.1 Database Requirements

- No

6.5.2 Software Requirements

1. Programming Languages: Embedded C
2. Compilers : Keil 4.0uv
3. Dumping Software: Using Micro controller flash magic/ preload Software we are dumping our HEX Code into Micro Controller.

6.6 HARDWARE REQUIREMENTS

- System : Intel IV 2.4 GHz.

- Hard Disk : 100 GB(Min).
- Monitor : 15 VGA Colour.
- IO Devices : Keyboard and Mouse.
- Ram : 4 GB(Min).
- ATMega328 Microcontroller
- Dry & Wet Sensor
- Gas Sensor
- L293D
- Dc Motor
- LCD
- Power Supply
- Buzzer

6.7 ANALYSIS MODEL

We are using waterfall model for our project:

- **Requirement gathering and analysis:**
  In this step of waterfall we identify what are various requirements are need for our project such are software and hardware required, database, and interfaces.
- **System Design:**
  In this system design phase we design the system which is easily understood for end user i.e. user friendly. We design some UML diagrams and data flow diagram to understand the system flow and system module and sequence of execution.

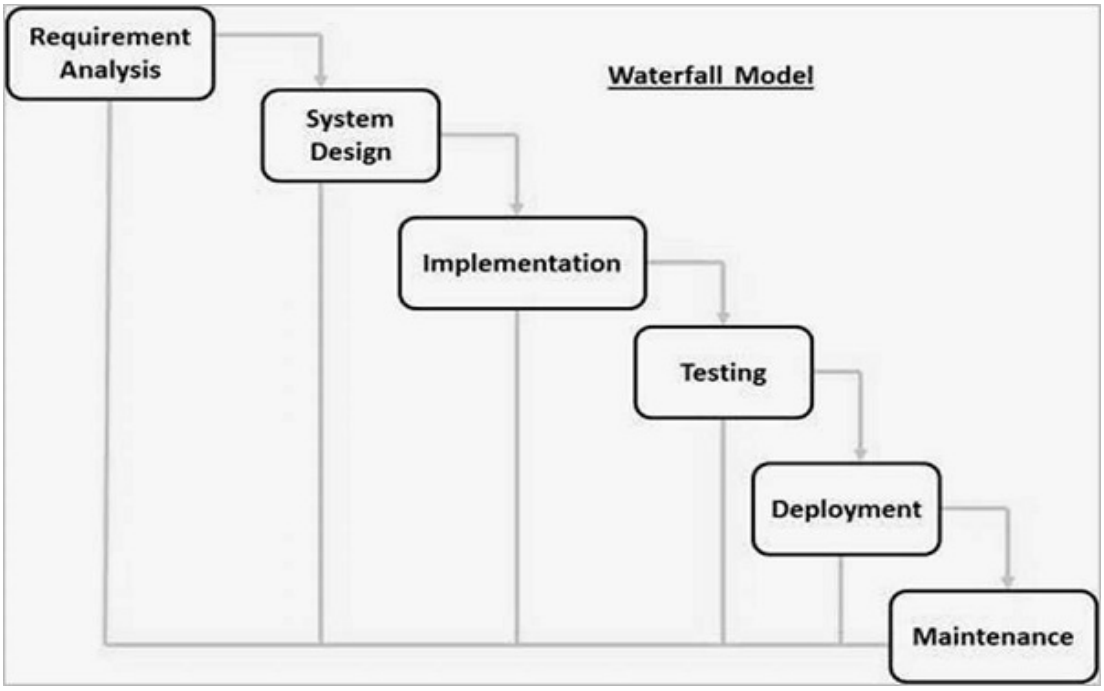


Figure 6.1: Waterfall Model

- **Implementation:**

  In implementation phase of our project we have implemented various module required of successfully getting expected outcome at the different module levels.

  With inputs from system design, the system is first developed in small programs called units, which are integrated in the next phase. Each unit is developed and tested for its functionality which is referred to as Unit Testing.

- **Testing:**

  The different test cases are performed to test whether the project module are giving expected outcome in assumed time. All the units developed in the implementation phase are integrated into a system after testing of each unit. Post integration the entire system is tested for any faults and failures.

- **Deployments of System:**

  Once the functional and non-functional testing is done, the product is deployed in the customer environment or released into the market.

- **Maintenance:**

  There are some issues which come up in the client environment. To fix those issues patches are released. Also to enhance the product some better versions are released. Maintenance is done to deliver these changes in the customer environment. All these

phases are cascaded to each other in which progress is seen as flowing steadily downwards like a waterfall through the phases. The next phase is started only after the defined set of goals are achieved for previous phase and it is signed off, so the name ”Waterfall Model”. In this model phases do not overlap.

6.8 SYSTEM IMPLEMENTATION PLAN

- **Plan of execution**

NO	TASK	START DATE
1	Group Formation	25/05
2	Decide Area Of Interest	30/05
3	Search Topic	03/06
4	Topic Selection	15/07
5	Sanction Topic	20/07
6	Search Related Infomation	03/08
7	Understanding Concept	10/08
8	Search Essential Document(IEEE & White Paper, Software)	18/08
9	Problem Definition	22/08
10	Literature Survey	02/09
11	Project Planning	23/09

Table 6.1: Plan of Execution

- **PERT Chart/ Gantt chart:**

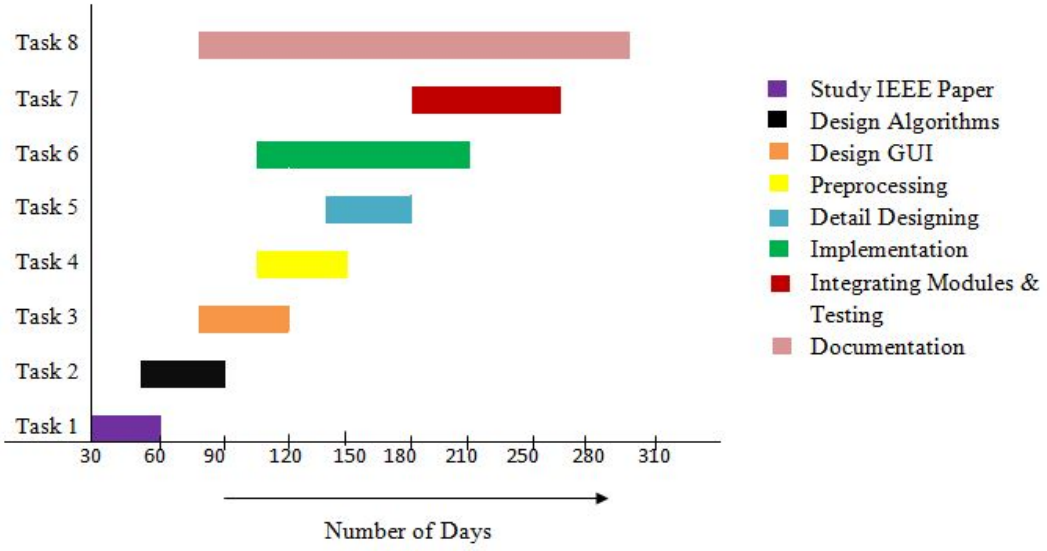


Figure 6.2: PERT Chart/ Gantt chart

CHAPTER 7

DETAIL DESIGN DOCUMENTS USING APPENDIX A AND B

7.1 ARCHITECTURE DESIGN

The methodology and system design involve a systematic approach to address the challenges associated with waste management. The first step encompasses a comprehensive requirement analysis phase, where stakeholder needs, objectives, and constraints are carefully examined. Based on these requirements, suitable sensors are selected and integrated into the system architecture. These sensors, including ultrasonic, infrared, and weight sensors, are crucial for collecting data on waste levels, types, and weights.

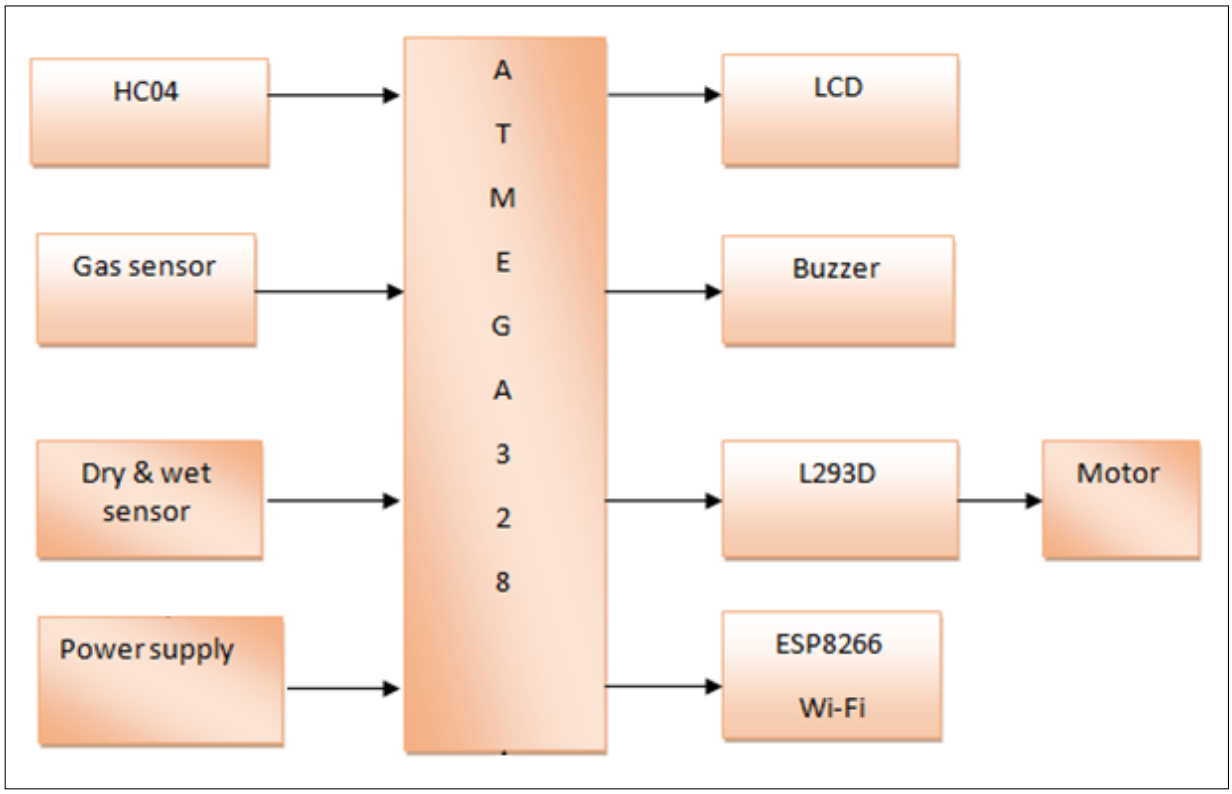


Figure 7.1: Proposed System Block Diagram

Following sensor integration, IoT devices such as microcontrollers or single-board computers are configured to interact with the sensors and establish connectivity with the internet. Cloud platforms are then employed to receive, store, and process the sensor data, leveraging services like AWS IoT or Google Cloud IoT. Once the data is collected, it undergoes processing and analysis to extract meaningful insights using machine learning algorithms for intelligent waste segregation and anomaly detection.

The development of a user-friendly interface is pivotal, allowing stakeholders to visualize real-time waste data and exercise control options. This interface may take the form of web-based dashboards, mobile applications, or desktop applications. Additionally, an alerting mechanism is implemented to notify waste management authorities or users of critical events or system failures.

Security and privacy considerations are paramount throughout the system design process, with measures such as encryption, authentication, and access control implemented to safeguard sensitive data. Rigorous testing and validation procedures ensure the functionality, reliability, and performance of the system before deployment in real-world environments. Continuous maintenance and monitoring activities are then conducted to ensure optimal system operation and address any emerging issues. Overall, this methodology aims to develop a robust and efficient waste management solution that contributes to environmental sustainability and improved waste management practices.

7.2 DATA DESIGN (USING APPENDICES A AND B)

7.2.1 Internal Software Data Structure

- Waste Object Class: Represents individual waste items, including attributes like type (biodegradable, recyclable, etc.), weight, and timestamp.
- Sensor Data Structure: Stores real-time data from IoT sensors, such as temperature, humidity, and weight measurements for waste bins.
- Queue for Data Processing: A FIFO (First In, First Out) queue to handle sensor data as it is collected, ensuring real-time processing.
- Database for Storage: A relational database structure to store processed waste data, including waste type, segregation results, bin status, and historical monitoring data.
- Event-Driven Architecture: An event handler for triggering actions like waste bin alerts or automatic sorting based on real-time sensor input.

7.2.2 Global Data Structure

- Global Waste Data: A centralized data structure that aggregates waste status from all bins, including type, weight, and segregation status.

- Device Status List: Maintains the real-time status of IoT devices (sensors, actuators) across the system, including connectivity and operational health.
- Waste Bin Network: A linked list or tree structure representing all waste bins, with attributes for location, fill levels, and segregation status.
- Historical Logs: A time-series structure storing historical sensor data for waste tracking and analytics.
- Alerts Queue: A priority queue for managing system alerts related to full bins, malfunctioning devices, or abnormal conditions.

7.2.3 Temporary Data Structure

- Buffer for Sensor Data: A temporary storage (array or list) to hold raw data from IoT sensors (e.g., weight, temperature) before processing.
- Segregation Decision Queue: A temporary queue to hold waste items pending classification based on real-time sensor inputs and machine learning algorithms.
- Bin Status Flags: Flags or temporary variables to indicate the current state of bins (e.g., full, overflow, or requires servicing).
- Processing Buffer: A short-term data structure to store intermediate results of waste segregation decisions before updating global data.
- Event Stack: A stack for managing recent actions or events, such as sorting or alert triggers, for undo/redo operations or rollback.

7.2.4 Database Description

No database

7.3 COMPONENT DESIGN

7.3.1 Class Diagram

Class diagram is a static diagram. It represents the static view of an application. Class diagram is not only used for visualizing, describing, and documenting different aspects of a system but also for constructing executable code of the software application.

Class diagram describes the attributes and operations of a class and also the constraints imposed on the system. The class diagrams are widely used in the modeling of object oriented systems because they are the only UML diagrams, which can be mapped directly with object-oriented languages.

Class diagram shows a collection of classes, interfaces, associations, collaborations, and constraints. It is also known as a structural diagram.

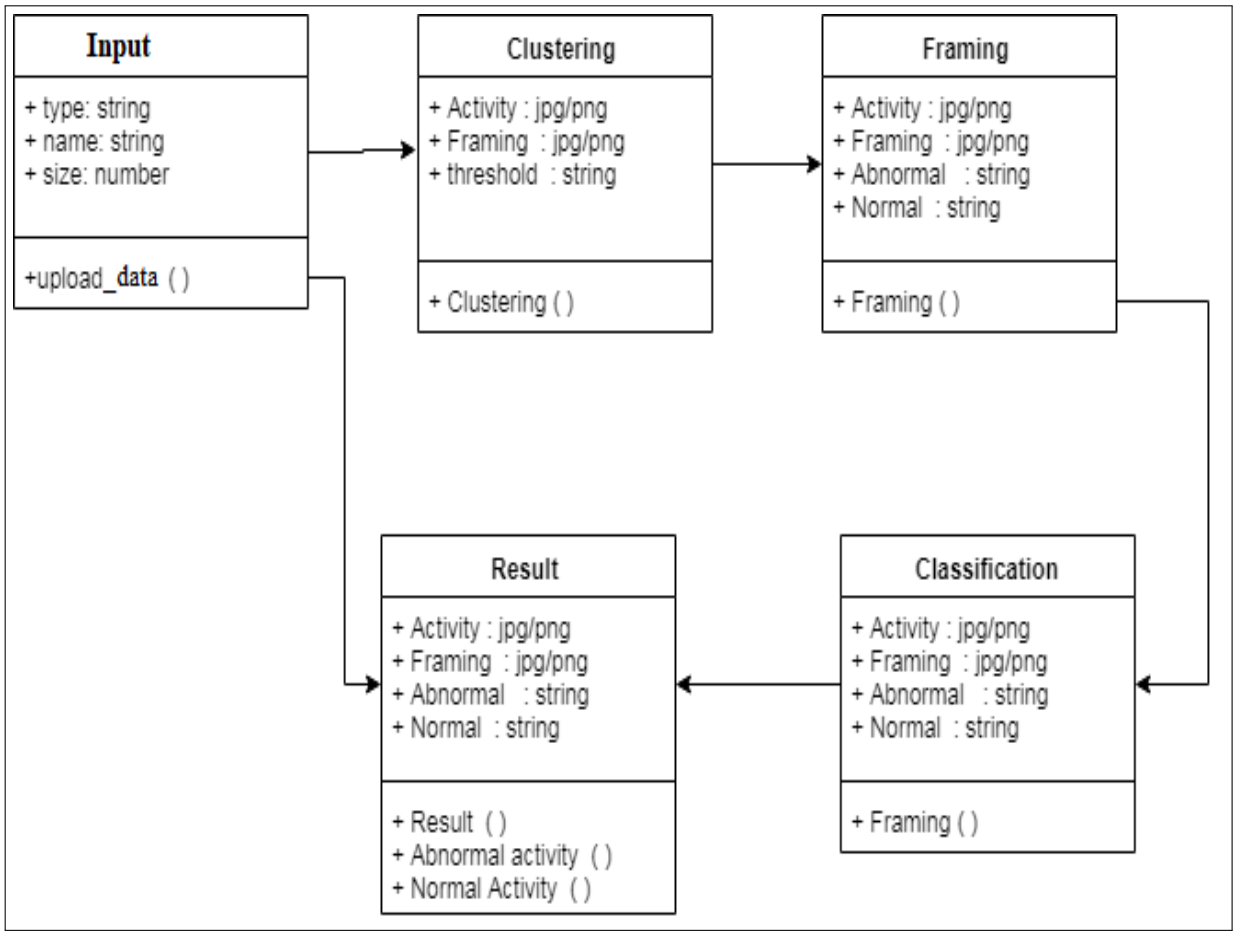


Figure 7.2: Class Diagram

CHAPTER 8

PROJECT IMPLEMENTATIONS

8.1 INTRODUCTION

The implementation of the "Enhancing Automatic Waste Segregation and Monitoring System using IoT Platform" marks a significant step toward revolutionizing waste management through automation and smart monitoring. This project is designed to address the growing challenges of improper waste segregation, delayed waste collection, and inefficient resource utilization in urban and semi-urban environments. The system combines hardware and software elements in a cohesive manner to detect, classify, and segregate waste into categories such as biodegradable, non-biodegradable, and metallic waste. The core of the implementation involves deploying sensors such as moisture sensors, inductive proximity sensors, and capacitive sensors integrated with a microcontroller like Arduino or Raspberry Pi. These sensors help in identifying the type of waste based on physical and chemical characteristics.

Once the waste is detected and categorized, servo motors or actuators are employed to mechanically direct the waste into appropriate bins. Simultaneously, the status of each bin — including its fill level and type of waste — is monitored in real time using ultrasonic sensors and is updated on an IoT dashboard. This data is transmitted via Wi-Fi or GSM modules to a centralized cloud platform, where authorities or municipal teams can access it through a web or mobile interface. This enables real-time alerts when bins are full or when anomalies are detected (e.g., presence of hazardous materials). The implementation process also includes the design of a user-friendly dashboard that provides visual analytics, historical data, and waste collection schedules. The entire setup is housed within a compact, modular framework that is scalable and suitable for smart city integration.

This phase of implementation also focuses on ensuring low power consumption by using energy-efficient components and, where applicable, renewable energy sources like solar panels. The prototype is tested in controlled environments to fine-tune the sensor thresholds and mechanical movement of the segregating components. Feedback loops from the sensors to the control logic ensure the system self-corrects any misclassification by re-processing the item. Ultimately, this implementation strategy ensures that waste management becomes more intelligent, less labor-intensive, and environmentally sustainable — laying the groundwork for a cleaner and more organized society.

8.2 TOOLS AND TECHNOLOGIES USED

The implementation of the automatic waste segregation and monitoring system involves a well-coordinated integration of both hardware and software components. The technologies employed were carefully chosen to ensure accurate waste detection, real-time monitoring, and seamless IoT-based communication. Below is a detailed overview of the tools and technologies used in the project:

8.2.1 Hardware Components

- **NodeMCU ESP8266:** A low-cost microcontroller unit based on the ESP8266 chip. It serves as the central processing unit of the system, responsible for receiving data from sensors and transmitting it to the IoT platform for monitoring and analysis.
- **Gas Sensor (MQ-135):** Used for detecting the presence of hazardous gases, which helps in identifying non-biodegradable or harmful waste. It is especially useful in distinguishing between general and chemical waste.
- **Dry and Wet Waste Sensor:** A custom sensor module designed to differentiate between dry and wet waste based on conductivity and moisture content. It plays a crucial role in the initial segregation process.
- **Ultrasonic Sensor (HC-SR04):** Utilized for monitoring the fill level of the waste bin. It emits ultrasonic waves and measures the time taken for the echo to return, thus calculating the distance to the waste material.
- **LCD Display with I2C Module:** A 16x2 Liquid Crystal Display paired with an I2C module to reduce the number of GPIO pins used. It displays real-time system status such as waste type detected, bin level, and connectivity updates.
- **DC Motor and L293D Motor Driver:** The DC motor is responsible for controlling the mechanical movement of the waste flap or conveyor, which directs waste into the correct bin. The L293D motor driver acts as an interface between the motor and microcontroller, allowing for bidirectional motor control.
- **Dust Bin Model:** A physical container system consisting of separate compartments for dry, wet, and metallic waste. It is the endpoint for sorted waste, and is integrated with mechanical components for automatic segregation.

8.2.2 Software Technologies

- **Arduino IDE:** Used for writing and uploading the embedded C/C++ code to the NodeMCU microcontroller. It supports the necessary libraries for sensor integration and IoT communication.
- **Blynk IoT Platform:** A cloud-based IoT dashboard used for real-time monitoring of waste levels, gas detection alerts, and system status. It allows remote access via mobile app or web interface.
- **ThingSpeak (Optional):** An alternative IoT analytics platform used for storing, visualizing, and analyzing sensor data. It can be integrated for enhanced data logging and predictive analysis.
- **Wi-Fi Communication (ESP8266):** Enables seamless data transmission from the NodeMCU to the cloud using the built-in Wi-Fi capabilities of the ESP8266 chip.

The combined use of these tools and technologies has enabled the development of a robust, smart, and scalable waste segregation system, contributing significantly to smart city infrastructure and environmental sustainability.

8.3 METHODOLOGIES/ALGORITHM DETAILS

The methodology for implementing the enhanced automatic waste segregation and monitoring system is centered around sensor-based detection, microcontroller-based decision-making, mechanical segregation, and IoT-based real-time monitoring. The process is broken down into sequential stages and controlled using an algorithm that ensures efficient waste classification and responsive bin monitoring. The major components involved include the NodeMCU ESP8266, various sensors, actuators, and an IoT platform.

8.3.1 System Workflow

The system functions as follows:

1. Waste is placed into the input section of the dustbin where initial sensing begins.
2. The **Gas Sensor (MQ-135)** first checks for the presence of toxic gases to identify whether the waste is potentially hazardous or non-biodegradable.

3. If the waste is not toxic, it proceeds to the **Dry and Wet Sensor**, which differentiates between dry and wet waste based on moisture detection.

4. Based on sensor readings, the **NodeMCU ESP8266** processes the data and determines the type of waste using a decision-making algorithm.

5. The **DC Motor** (controlled via **L293D Motor Driver**) actuates the mechanical arm or rotating flap to direct the waste into the appropriate bin compartment.

6. The **Ultrasonic Sensor** monitors the fill level of each bin and sends this data to the cloud through the NodeMCU.

7. The **LCD Display with I2C module** shows the real-time waste category and bin status.

8. Simultaneously, data such as bin fill level, detected gas values, and waste type are sent to the **IoT platform (Blynk)** for remote monitoring and alerts.

8.3.2 Decision-Making Algorithm

The logic of the system is implemented as a rule-based algorithm embedded in the NodeMCU, as described below:

Algorithm 1: Waste Classification and Bin Assignment

[1] **Input:** Sensor data from Gas Sensor, Dry/Wet Sensor, Ultrasonic Sensor

Output: Waste categorized and directed to correct bin Initialize all sensors and motor driver **while** *System is ON* **do**

Read value from Gas Sensor **if** *Gas level ¿ threshold* **then**

Classify as Non-Biodegradable waste Rotate motor to Bin 3 **else**

Read value from Dry/Wet Sensor **if** *Moisture level ¿ threshold* **then**

Classify as Wet Waste Rotate motor to Bin 1 **else**

Classify as Dry Waste Rotate motor to Bin 2 Measure bin level using Ultrasonic Sensor Display status on LCD Send data to IoT dashboard via Wi-Fi

8.3.3 IoT Integration Methodology

- The **NodeMCU ESP8266** uses its built-in Wi-Fi module to connect to the internet and transmit data to the Blynk server.

- The sensor values and bin statuses are continuously updated in real-time on the mobile app dashboard.
- Alerts are triggered when the bin is full or if gas levels exceed a safe threshold.
- Optional integration with **ThingSpeak** allows for historical data logging and visual analytics.

This methodology ensures that waste is classified accurately and efficiently, bins are monitored in real-time, and waste management becomes data-driven and smart. The modular approach allows for future upgrades, such as AI-based waste classification or solar-powered operation.

8.4 VERIFICATION AND VALIDATION FOR ACCEPTANCE

To ensure the reliability and correctness of the implemented system, both verification and validation processes were conducted during various stages of the project.

8.4.1 Verification

Verification was carried out to confirm that all hardware components and software modules were functioning as intended:

- Sensor readings (Gas, Dry/Wet, and Ultrasonic) were cross-checked using calibrated testing samples.
- The NodeMCU ESP8266 was verified for stable Wi-Fi communication and accurate data transmission to the IoT dashboard.
- The LCD with I2C interface displayed appropriate status messages for waste type and bin level during all operational tests.
- The motor and L293D driver were tested under multiple scenarios to verify correct directional rotation and actuation for bin segregation.

8.4.2 Validation

Validation ensured that the system met the project objectives and performed correctly under real-use conditions:

- Waste samples of known categories were used to validate classification accuracy.
- Bin levels were validated using physical measurements compared against ultrasonic sensor readings.
- IoT monitoring was tested through the Blynk platform for real-time updates, alerts, and user accessibility.
- System performance was observed over multiple cycles to confirm consistent segregation, data reporting, and mechanical operation.

The successful completion of these verification and validation steps confirmed that the system met its functional requirements and was ready for deployment in a real-world smart waste management environment.

CHAPTER 9

SOFTWARE TESTING

9.1 TYPE OF TESTING

Types of Testing:

Along with the type of testing also mention the approach to be followed for the testing, that is, Manual Testing or Automated Testing. Use Automated Testing Plan for planning automation activities in details. The different types of testing that may be carried out in the project are as follows:

- **Unit Testing:**

  Individual components are tested independently to ensure their quality. The focus is to uncover errors in design and implementation, including.

  - Data structure in component
  - Program logic and program structure in a component
  - Component interface
  - Functions and operations of a component

- **Integration Testing :**

  A group of dependent components are tested together to ensure their quality of their integration unit. This approach is to do incremental integration to avoid “bigbang” problem. That is when the entire program is put together from all units and tested as a whole. The big-bang approach usually results in chaos which incremental integration avoids. Incremental integration testing can be done in two different way top down and bottom up. Then there is also the possibility of regression integration.

  The top down integration is when modules are integrated by moving downwards through the control hierarchy, beginning with the main control module. Modules subordinate to the main control module are incorporated into main structure n either depth-first or breadth-first manner. The top down integration verifies major controls or decision points early in the test process. If major control problems do exist, early recognition is essential. Bottom-up integration testing begins construction and testing with the lowest levels in the program structure. Because modules are integrated from the bottom-up,processing required for modules subordinate to a given level is always available and the need for test stubs is eliminated.

  The focus is to uncover errors in:

- Design and construction of software architecture
- Integrated functions or operations at sub-system level
- Interfaces and interaction and/or environment integration

- **System Testing :**

  The system software is tested as a whole. It verifies all elements mesh properly to make sure that all system functions and performance are achieved in the target environment. The focus areas are:

  - System functions and performance
  - System reliability and recoverability (recovery test)
  - System behavior in the special conditions (stress and load test)
  - System user operations (acceptance test/alpha test)
  - Hardware and software integration collaboration
  - Integration of external software and the system.

- **Validation Testing:**

  Validation can be defined in many ways, but a simple definition is that succeeds when software functions in a manner that can be reasonably expected by the customer. Software validation is achieved through a series of black-box tests that demonstrate conformity with requirements. A test plan outlines the classes of tests to be conducted and a test procedure defines specific test cases that will be used to demonstrate conformity with requirements. Both the plan and procedure are designed to ensure that all functional requirements are satisfied, all behavioral characteristics are achieved, all performance requirements are attained, documentation is correct, and human engineered and other requirements are met.

- **White Box Testing:**

  White-box test design allows one to peek inside the “box”, and it focuses specifically on using internal knowledge of the software to guide the selection of test data. Synonyms for white-box include: structural, glass-box and clear-box.

White box testing is much more expensive than black box testing. It requires the source code to be produced before the tests can be planned and is much more laborious in the determination of suitable input data and the determination if the software is or is not correct. This testing is concerned only with testing the software product; it cannot guarantee that the complete specification has been implemented.

- **Black Box Testing:**

  Black-box test design treats the system as a "black-box", so it doesn't explicitly use knowledge of the internal structure. Black-box test design is usually described as focusing on testing functional requirements. Synonyms for black box include: behavioral, functional, opaque-box, and closed-box. Black box testing is concerned only with testing the specification; it cannot guarantee that all parts of the implementation have been tested. Thus black box testing is testing against the specification and will discover faults of omission, indicating that part of the specification has not been fulfilled.

9.2 TEST CASES AND TEST RESULTS

Comprehensive testing was carried out on the software and integrated hardware modules to ensure system accuracy, reliability, and robustness. The test cases were designed to validate each functional unit of the system, such as sensor readings, data transmission, actuator response, and IoT monitoring. Below is a summary of key test cases and their results:

9.2.1 Test Case Table

Test Case Description	Input	Expected Output	Result	Status
Dry Waste Detection	Dry paper/plastic	Classified as Dry Waste, directed to Bin 2	Bin 2 rotated	Pass
Wet Waste Detection	Moist food waste	Classified as Wet Waste, directed to Bin 1	Bin 1 rotated	Pass
Non-Biodegradable/Gas Waste Detection	Waste with gas emission (e.g., battery)	Detected by Gas Sensor, directed to Bin 3	Bin 3 rotated	Pass
LCD Display Status Update	Waste inserted	Correct status message on LCD: "Dry/Wet/Non-Biodegradable Detected"	Message displayed	Pass
Motor Rotation for Bin Selection	Waste identified as Dry/Wet/Non-Biodegradable	Motor rotates to correct bin via L293D	Correct bin selected	Pass
Ultrasonic Sensor Bin Level Test	Bin filled up to 80%	Fill level warning sent to IoT dashboard	Warning visible	Pass
IoT Dashboard Data Transmission	Sensor data from NodeMCU	Live updates on Blynk app (Waste Type, Bin Level)	Data synced	Pass
Wi-Fi Disconnection Handling	Wi-Fi turned off	Retry logic attempts reconnection, status message shown	Reconnected/Alert	Pass

Table 9.1: Test Cases and Results for Waste Segregation System

9.2.2 Observations

- All major test scenarios were passed successfully, including edge cases for unclear or borderline waste materials.
- Response time between sensor detection and actuator movement was under 2 seconds, indicating good real-time performance.
- IoT dashboard updates were reliably synced within 1–2 seconds over standard Wi-Fi.
- Error handling for Wi-Fi loss and invalid sensor readings ensured continued system operation without crashes.

The test cases confirm that the system meets functional and performance requirements. The integration between software, hardware, and IoT services works as intended, ensuring automated, intelligent, and remote waste monitoring with high reliability. The results validate the system's readiness for deployment in smart waste management environments.

CHAPTER 10

RESULTS

10.1 SCREENSHOT

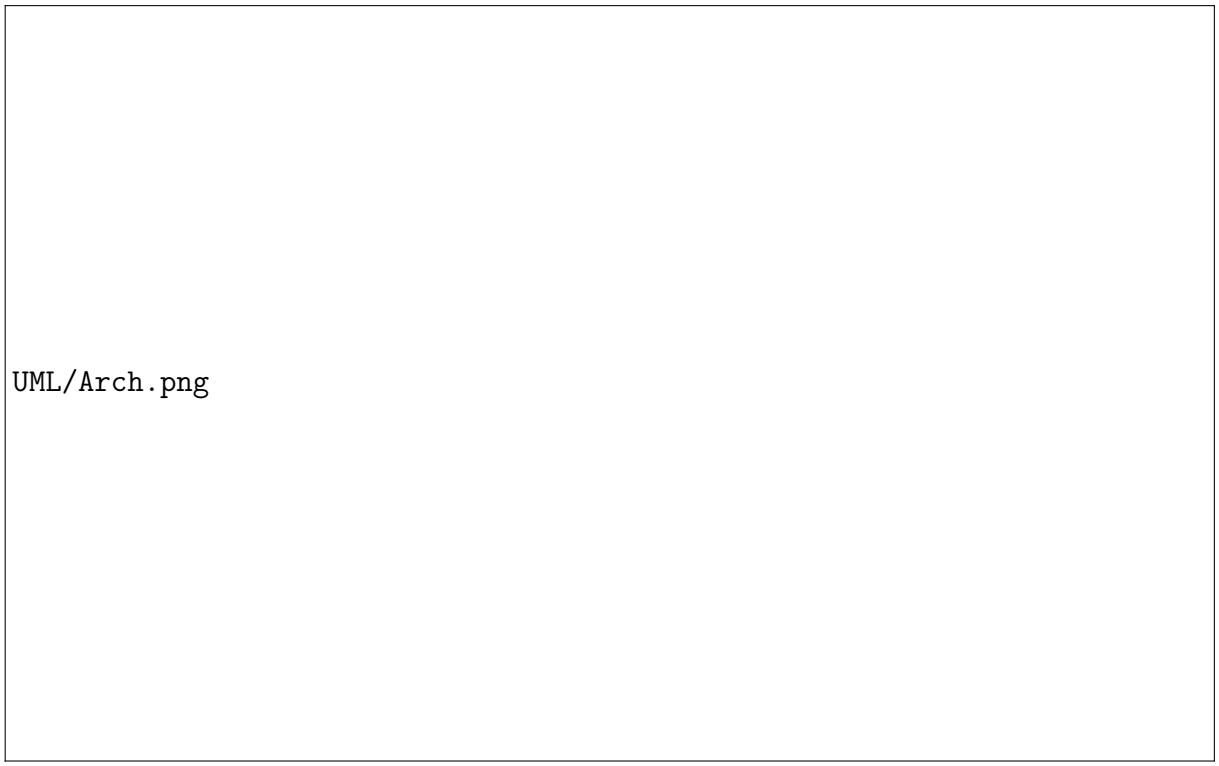


Figure 10.1: Project Snap

10.2 OUTPUTS

The outcome of the project is a comprehensive and efficient waste management solution that leverages Internet of Things (IoT) technology to streamline waste collection, segregation, and monitoring processes. By integrating smart sensors into waste bins, the system enables real-time data collection on waste levels, types, and disposal patterns. This data is transmitted to a centralized cloud platform, where it is analyzed using machine learning algorithms to classify waste items into recyclable, non-recyclable, and organic categories automatically.

The key outcome of the system is improved waste management efficiency and effectiveness. By automating waste segregation processes, the system reduces the manual effort required for sorting and processing waste, thereby minimizing human error and increasing operational efficiency. Additionally, the real-time monitoring capabilities provided by the system enable proactive waste management strategies, such as timely waste collection scheduling, optimized bin placement, and proactive maintenance of waste collection infrastructure.

Furthermore, the system's data analytics capabilities facilitate data-driven decision-making

by providing insights into waste generation trends, recycling rates, and overall waste management performance. This enables stakeholders, including waste management authorities, municipal agencies, and environmental organizations, to make informed decisions and implement targeted interventions to improve waste management practices and reduce environmental impact.

Overall, the outcome of the project is a more sustainable, cost-effective, and environmentally friendly approach to waste management that addresses the challenges of traditional waste management methods and contributes to building smarter and greener cities.

CHAPTER 11

DEPLOYMENT AND MAINTENANCE

11.1 INSTALLATION AND UN-INSTALLATION

The installation process for the system involves assembling hardware components, uploading firmware, and configuring the IoT dashboard:

- Mount and wire all sensors (Gas Sensor, Dry/Wet Sensor, Ultrasonic Sensor) and connect them to the NodeMCU ESP8266 and L293D Motor Driver.
- Attach the LCD with I2C module and position the motor-controlled segregation flap linked to the designated bins.
- Upload the embedded code to the NodeMCU using the Arduino IDE.
- Configure the Wi-Fi credentials and Blynk authentication token in the code for IoT communication.
- Power the system using a 5V adapter or portable power supply.
- Test all modules individually and then as an integrated system for proper operation.

11.1.1 Un-installation

Un-installation involves safely dismantling the system components for relocation or maintenance:

- Power off the system and disconnect from the power supply.
- Unplug and carefully remove all sensor connections from the NodeMCU.
- Detach the LCD, motor, and other peripheral devices.
- Remove the code from the NodeMCU or reset it to factory settings if required.
- Disassemble the bin and mechanical framework, storing components properly for future use.

The system is designed for modular setup, enabling quick installation, maintenance, or upgrades as needed for long-term deployment.

11.2 USER HELP

To ensure smooth operation and maintenance of the system, a user support guide is provided for interacting with both the hardware and IoT interface.

- **System Start-Up:** Ensure all components are connected properly. Power the system using a 5V adapter and wait for the LCD display to show the system status.
- **Waste Disposal:** Users can dispose of waste by placing it in the input section. The system will automatically detect and segregate it without any manual intervention.
- **Monitoring Waste Status:** Users can view bin levels and segregation updates on the Blynk mobile app in real-time. Alerts will be sent if any bin is full or if gas levels exceed safety limits.
- **Troubleshooting:**
  - If the LCD does not display text, check I2C connections and power supply.
  - In case of no IoT updates, verify Wi-Fi credentials and internet connection.
  - If motor is not rotating, inspect L293D driver wiring and motor power.
- **Maintenance Tips:** Regularly clean the sensors and bins to prevent false readings. Restart the NodeMCU after firmware updates or sensor recalibration.

This user help guide aims to empower users with minimal technical knowledge to effectively operate and maintain the smart waste segregation system with ease.

CHAPTER 12

CONCLUSION AND FUTURE SCOPE

12.1 CONCLUSION

In conclusion, the project represents a significant advancement in waste management technology. By harnessing the power of Internet of Things (IoT) devices, machine learning algorithms, and cloud computing, the system offers a scalable and efficient solution for managing waste in urban environments.

Through automated waste segregation, real-time monitoring, and data analytics, the system enables municipalities, waste management authorities, and environmental organizations to optimize waste collection processes, reduce operational costs, and minimize environmental impact.

The system's ability to classify waste items into recyclable, non-recyclable, and organic categories allows for more effective recycling initiatives and resource allocation. Additionally, the real-time monitoring capabilities ensure timely waste collection and maintenance, enhancing overall efficiency and service quality.

Overall, the project has the potential to revolutionize waste management practices, leading to cleaner, healthier, and more sustainable urban environments. With continued refinement and implementation, this technology can play a crucial role in building smarter, greener cities for the future.

12.2 FUTURE SCOPE

The future scope of the project includes the integration of artificial intelligence for more accurate waste classification using image processing techniques, enabling the system to identify complex materials beyond sensor limitations. Solar-powered modules can be added for energy efficiency and off-grid deployment. The system can be expanded to support real-time municipal data sharing for smart city integration, enabling route optimization for waste collection based on bin status. Additionally, voice assistance and multilingual LCD interfaces can enhance accessibility for diverse users, making the system more inclusive and adaptable for large-scale deployment.

CHAPTER 13

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ANNEXURE A

LABORATORY ASSIGNMENTS ON PROJECT ANALYSIS OF ALGORITHMIC DESIGN

- To develop the problem under consideration and justify feasibilty using concepts of knowledge canvas and IDEA Matrix.

  Refer [2] for IDEA Matrix and Knowledge canvas model. Case studies are given in this book. IDEA Matrix is represented in the following form. Knowledge canvas represents about identification of opportunity for product.

  Feasibility is represented w.r.t. business perspective.

I	D	E	A
Increase	Drive	Educate	Accelerate
Improve	Deliver	Evaluate	Associate
Ignore	Decrease	Eliminate	Avoid

Figure A.1: IDEA Matrix

- Project problem statement feasibility assessment using NP-Hard, NP-Complete or satisfy ability issues using modern algebra and/or relevant mathematical models.
- input x, output y, y=f(x)

IDEA Matrix

The IDEA Matrix—Identify, Design, Execute, and Assess—serves as a structured innovation framework applied throughout the development of this project.

- **Identify:** The core problem addressed is the inefficiency in manual waste segregation and the lack of real-time monitoring in public waste management systems.
- **Design:** A smart, sensor-driven solution was conceptualized using NodeMCU ESP8266, Gas Sensor, Dry & Wet Sensor, Ultrasonic Sensor, LCD with I2C, and motorized bins, aiming to automate and digitize the waste handling process.
- **Execute:** The system was implemented by integrating hardware components with embedded software logic and IoT connectivity via the Blynk platform for real-time data access and control.

- **Assess:** The project was tested for accuracy, reliability, and scalability. Results showed successful segregation, timely alerts, and consistent cloud communication, validating the system's functionality in smart environments.

This matrix-driven approach helped structure the innovation lifecycle of the project, ensuring clarity, feasibility, and impact at each phase of development.

ANNEXURE B

LABORATORY ASSIGNMENTS ON PROJECT QUALITY AND RELIABILITY TESTING OF PROJECT DESIGN

It should include assignments such as

- Use of divide and conquer strategies to exploit distributed/parallel/concurrent processing of the above to identify object, morphisms, overloading in functions (if any), and functional relations and any other dependencies (as per requirements). It can include Venn diagram, state diagram, function relations, i/o relations; use this to derive objects, morphism, overloading
- Use of above to draw functional dependency graphs and relevant Software modeling methods, techniques including UML diagrams or other necessities using appropriate tools.
- Testing of project problem statement using generated test data (using mathematical models, GUI, Function testing principles, if any) selection and appropriate use of testing tools, testing of UML diagram's reliability. Write also test cases [Black box testing] for each identified functions. You can use Mathematica or equivalent open source tool for generating test data.
- Additional assignments by the guide. If project type as Entreprenaur, Refer [3],[4],[5], [6].

To ensure high quality and reliability, the system design underwent rigorous testing under various operational conditions. The waste detection modules (Gas Sensor, Dry & Wet Sensor, Ultrasonic Sensor) were calibrated with multiple waste samples to verify classification accuracy. The NodeMCU ESP8266 was stress-tested for continuous data transmission over Wi-Fi, ensuring stable communication with the Blynk IoT platform. The motor and L293D driver circuits were tested repeatedly for mechanical endurance and accurate bin selection. LCD with I2C was validated for real-time status updates without display lag. Additionally, environmental tests such as temperature variation and power fluctuation scenarios were simulated to confirm system resilience. The consistent performance of all modules in these conditions confirmed that the design meets essential quality standards and exhibits strong operational reliability for long-term smart waste management use.

ANNEXURE C

PROJECT PLANNER

Using planner or alike project management tool.

Table C.1: Project Planner

NO	TASK	START DATE
1	Group Formation	25/05
2	Decide Area Of Interest	30/05
3	Search Topic	03/06
4	Topic Selection	15/07
5	Sanction Topic	20/07
6	Search Related Infomation	03/08
7	Understanding Concept	10/08
8	Search Essential Document(IEEE & White Paper, Software)	18/08
9	Problem Definition	22/08
10	Literature Survey	02/09
11	Project Planning	23/09

ANNEXURE D

REVIEWERS COMMENTS OF PAPER SUBMITTED

1. Paper Title:

2. Name of the Conference/Journal where paper submitted :

3. Paper accepted/rejected :

4. Review comments by reviewer :

5. Corrective actions if any :

ANNEXURE E

PLAGIARISM REPORT

Plagiarism Scan Report

Report Generated on: **April 09, 2025**



Plagiarised



Unique

Total Words:	257
Total Characters:	2032
Plagiarized Sentences:	0
Unique Sentences:	13 (100%)

Content Checked for Plagiarism

The Proposed Framework speaks to a spearheading arrangement to address the developing challenges of squander administration and natural supportability. Leveraging the Web of Things (IoT) innovation, this framework offers an computerized, effective, and naturally capable approach to squander isolation and observing. In this inventive framework, IoT sensors are deliberately coordinates into squander collection containers and holders, empowering real-time observing of squander composition and fill levels. These sensors, prepared with different sensors such as ultrasonic sensors, precisely classify squander into dry and damp categories.

The information collected from these sensors is transmitted wirelessly to a central information handling unit. Clients, counting squander administration specialists and natural offices, pick up get to to a comprehensive dashboard that gives real-time experiences into squander composition, fill levels, and collection status. Information analytics apparatuses prepare this data, advertising noteworthy experiences for optimizing squander collection courses and plans, diminishing operational costs, and minimizing natural impact.

The system's mechanization amplifies to squander collection trucks, which get optimized course plans based on real-time information. Besides, the framework improves open engagement in economical squander administration hones. Versatile applications permit inhabitants to get notices for squander collection plans, get to instructive assets on legitimate squander transfer, and track their possess squander contributions.

The proposed framework is a transformative arrangement that advances squander decrease, reusing, and maintainability. By leveraging IoT innovation, robotization, and information analytics, it empowers proficient squander isolation, optimized collection forms, and progressed natural stewardship. This venture speaks to a noteworthy step toward more astute, more economical squander administration hones for a cleaner and greener future.