Dissertation on

"Smart Waste Segregation"

Submitted in partial fulfilment of the requirements for the award of degree of

Bachelor of Technology
in
Computer Science & Engineering

UE17CS490A – Capstone Project Phase - 1

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CERTIFICATE

This is to certify that the dissertation entitled

‘Smart Waste Segregation’

is a bonafide work carried out by

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in partial fulfilment for the completion of seventh semester Capstone Project Phase - 1 (UE17CS490A) in the Program of Study - Bachelor of Technology in Computer Science and Engineering under rules and regulations of PES University, Bengaluru during the period Aug. 2020 – Dec. 2020. It is certified that all corrections / suggestions indicated for internal assessment have been incorporated in the report. The dissertation has been approved as it satisfies the 7th semester academic requirements in respect of project work.

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Name of the Examiners	**Signature with Date**
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DECLARATION

We hereby declare that the Capstone Project Phase - 1 entitled **"Smart waste segregation"** has been carried out by us under the guidance of Charanraj B R and submitted in partial fulfilment of the course requirements for the award of degree of **Bachelor of Technology** in **Computer Science and Engineering** of **PES University, Bengaluru** during the academic semester August – December 2020. The matter embodied in this report has not been submitted to any other university or institution for the award of any degree.

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ABSTRACT

With the rapid growth in population, urbanization, and economic development the amount of waste that is being generated is increasing. According to an estimate, the world generates 2.01 billion tonnes of solid waste annually. By 2050 the expected growth in the amount of waste generated will be increased to 3.04 billion. Many countries, today are facing lots of issues regarding the proper collection, segregation, and disposal of the solid waste generated. Improper methods adopted for the same can lead to various environmental hazards and can impact the health of the citizens of the country. The economic value of waste is realized only after its segregation. As the slogan states "Recycle today, for a better tomorrow", the step involved in recycling waste is the proper segregation of waste. This is better utilized if the segregation is at the source itself. In the present scenario, there is no such system that is capable of segregating solid waste into different categories such as glasses, plastics, metallic waste, and wet waste at the source of generation of waste. Most of the solid waste such as glass and plastics are recyclable, therefore we aim to segregate the wastes into the above-mentioned categories with the help of various sensors available and automate the process of segregation thereby reducing the manpower required for segregation which in turn reduces the occupational hazards of the manual workers.

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CHAPTER 1

INTRODUCTION

Modernization and urbanization along with population growth have lead to an increase in demand for food and other essential items, which in turn leads to the production of a huge amount of waste. This waste when not disposed of correctly causes many health hazards. The common way of disposal followed majorly is, the mixed waste is collected by municipal corporations of the city and later, they are dumped into wastelands, which is converted to a landfill at a later point in time. These landfills are exposed to nature which is sunlight, wind, and rain. Since there are many kinds of materials in the waste, they react to the conditions in which they are present and result in the emission of toxic gases and the production of harmful liquids from the waste. These could, in turn, cause many effects on the workers, who manually sort the waste in these landfills. This could lead to the spreading of infectious diseases.

The major way to stop the generation of the huge amount of waste is by following the principles of 3 R's which are Reduce, Recycle, Reuse.

One of the major components of the waste generated today is plastic. Colored plastics can contain many heavy metals in their pigment which have an impact on the health of the people and animals around them. Since these are not biodegradable, the only way to get rid of them is by stopping their use. Another way can be to recycle the plastic and use the same again.

Metallic waste from electronic items is also another major contributor to waste. This can also be recycled and used. Materials containing glass as waste is also a threat to the environment. Therefore, recycling glass reduces pollution and reduces the space in landfills. Studies have proven that producing glass from raw materials is expensive and also leads to more pollution. Hence, materials that can be recycled are better if they are recycled as they have more advantages.

As can be seen, most of the waste can be recycled and then reused. The first and foremost step in the process of recycling is the segregation of waste into different categories. This has been traditionally done by workers which cause hazards for them. Therefore, we propose a solution which automates this process of segregation of waste, which has numerous advantages like, it reduces the number of workers needed for the entire process of waste management and it also results in good quality of materials that can be recycled since segregation is done at the source.

CHAPTER 2

PROBLEM DEFINITION

We aim to build a smart waste segregator that is capable of segregating the waste into different categories. The main categories into which the waste will be segregated are wet waste that contains moisture in it, metallic waste, glass waste, and plastic waste.This is aimed to be achieved by using the intrinsic properties of different materials which they exhibit under different conditions. These properties are as follows:

The ability of a metal to be attracted to a magnet or its property of induced eddy currents can be used for the identification of metal. The system uses an inductive proximity sensor for the purpose.The property of dielectric constant, which varies across different materials can be used to distinguish between glass and plastic. This is because glass has a higher dielectric value as compared with plastic. This can be detected by the capacitive proximity sensor which is planned to be used in the system.

CHAPTER 3

LITERATURE SURVEY

In this section, we present a detailed view of the existing system which was reviewed as a part of the literature survey. These reviews helped us in finalizing the design for the project.

3.1 Automatic Waste Segregation [1]

Nimisha S Gupta et. Al

3.1.1 Introduction

This paper discusses an interesting fact thatthe segregation of waste helps in realizing the importance and value of the waste. This paper proposes a system which helps in separating metal, dry, and wet waste automatically. This helps in the reduction of the occupational hazards of the people who manually sort the waste. In this way, sorting waste automatically reduces the threat to the environment.

The system developed here consists of various small sub conveyor belts that protrude to amajor conveyor belt. The major conveyor belt is responsible for the segregation of waste. At the end of each conveyor, there is a dustbin that has IR sensors incorporated into it. This is done to detect any waste in the bins. If found, the waste falls on the small sub conveyor belt. This is achieved by rotating the bin and then, the waste is moved to the major conveyor belt. At this point, the segregation begins. A non-contact type metal sensor is used for the detection of metallic waste.

A capacitive proximity sensor is used to separate dry and wet waste. There are different bins at the end of the conveyor, that are rotated using servo motors so that the waste falls into their respective bins correctly. IoT is also incorporated to count the number of wastes of different categories that are collected and then this information is available through a mobile app.

Fig 3.1

3.1.2 Working of the metallic waste detection module

The metallic waste detectionmodule uses a non-contact type sensor which is used to detect the metallic objects that are close to it. Only metallic objects are identified and non-metallic ones are ignored. This uses the principle of eddy currents and a parallel resonance impedance system. The sensor uses an electromagnetic coil to detect conductive metals by creating a magnetic field, which in turn induces eddy currents on the metallic surface. This eddy current developed on the surface generate a magnetic field that opposes the actual magnetic field which reduces parallel impedance resonance. As the metallic object gets closer to the system, it reduces the amplitude for which a threshold is fixed, and then corresponding action is taken.

3.1.3 Working of the dry and wet waste detection module

A capacitive sensor is used for this purpose. The dielectric constant of wet objects is greater than that of the dry objects. Therefore, if the change in capacitance value is more than a fixed threshold value, the waste is classified as wet else classified as dry.

3.1.4Results and conclusions

Some materials that were detected as dry waste include paper, plastic, and dry cloth. Some materials that were classified as wet waste includes a banana peel, lemon, and wet cloth. Materials that were detected as metallic waste includes keys, and Aluminum sheet

3.1.5 Future scope

Using more sensors, the capabilities of segregation of waste into different categories can be increased. For example, waste can be categorized into biodegradable and non-biodegradable which is a useful classification.

3.2 Automation of Plastic, Metal, and Glass Waste Materials Segregation using Arduino in Scrap Industry [2]

Mohammed Rafeeq et. Al

3.2.1 Introduction / Abstract

This paper elucidates the fact that one of the major concerns today is disposing of the waste collected. It also reports that2.02 billion tonnes of wasteare generated worldwide. The paper also tells that, for proper management of waste it has to be segregated and transported efficiently. It also quotes thatthe segregation of waste helps in determining its economic value. Therefore, it aims to segregate the solid waste materials collected into three categories metals, glass, and plastic.

This paper also tells that it is better if the waste is segregated at the source, rather than first sending the waste collected to a segregation plant and later to the recycling plant. This, therefore, reduces the time for recycling. It also gives an insight into how waste is converted into energy using the syngas produced from waste.

This automated system will also reduce the hazards caused to manual waste segregator. It also tells that metal, glass, and plastic form the major part of waste materials.

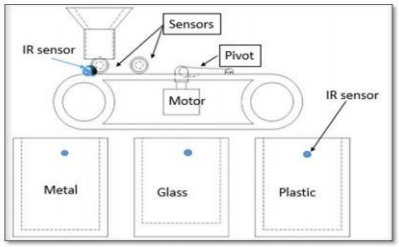


Fig 3.2

3.2.2Working of the system

This system effectively uses three types of sensors:

- IR sensor
- Inductive sensor
- Capacitive sensor

The functionality of each of these are:

- An infrared sensor is used for detection of the fill level of the bins and also to detect any object that is placed on the conveyor belt.
- The metallic waste is detected by an inductive sensor.
- The capacitive sensor is used to classify waste into glass and plastic categories.

First, the presence of an object(waste) on the conveyor is detected using an IR sensor later when the inductive senor also gives a high output, the belt moves in the clockwise direction to collect the metallic waste. If the above condition is not true, then the belt moves in the anticlockwise direction until it reaches the capacitive sensor. After this, based on the output generated by the capacitive sensor, the material is classified as glass or plastic.

If the output of the capacitive sensor is high, then the material is glass and if the output is low, the material is plastic and hence, they are collected in their respective bins.

3.2.3Conclusions and future work

This paper states that there can be several other features that can be incorporated into the system such as segregating dry and wet waste.

The Capacitive sensors available only uses digital values therefore there is a need for a sensor that can read analog values which has many uses. This can reduce the overall cost of the system.

It also states that image processing can also be incorporated for segregation.

3.3AN IoT Based Waste Segregator for Recycling Biodegradable and Non-Biodegradable Waste [3]

JebersonRetna Raj et. Al

3.3.1Introduction

This paper suggests that the segregation and disposal of garbage in cities is a key challenge. Usually, the waste is collected and dumped in a dump yard which is later either burnt or used as land to dump wastes exclusively. This will lead to the emission of harmful gases that affect the environment. Therefore, thesolution suggested here, aims to build an autonomous system which can separate waste into metallic, non-biodegradable, and biodegradable (dry and wet).

The system here is built using:

- IR sensor
- Moisture detection sensor
- Medium speed blower
- Magnet
- Two conveyor belts

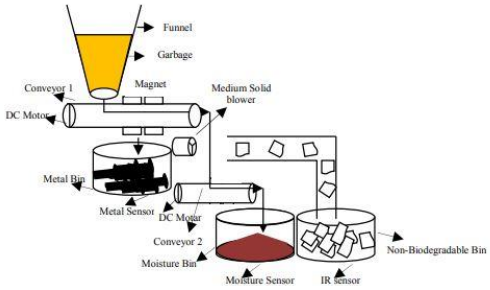


Fig 3.3

3.3.2Working of the system

All the garbage is dumped into a funnel, then the waste is taken to the first conveyor belt. It consists of a magnet, which is used to separate metallic waste. All the metallic waste is first attracted by the magnet and it moves along with the conveyor. Later, there is a bin equipped with a metal detection sensor to detect the metallic waste.

The leftover garbage after extracting metallic waste is passed through a medium speed blower, using which lightweight materials such as papers, plastics are put into a duct which leads to a bin equipped with an IR sensor to detect the waste which is non-biodegradable in a separate bin. Further, the leftover waste that is of higher weight than the plastics and papers fall over the second conveyor belt which leads to the moisture bin which has a moisture detection sensor below to sense all the wet waste coming into the bin.

IoT module is also integrated within the system to upload all the data from the sensors to a cloud which can be later used for processing and visualization.

3.3.3 Results

The metal waste accuracy is 95 percent.Paper waste was detected with an accuracy of 85 percent. The left out waste is dumped into the moisture bin, so the accuracy is 82 percent.

3.4 A unique technique for solid waste segregation [4]

Mahesh Kumar et. Al

3.4.1 Introduction

The authors started a survey of solid waste segregation.They found out that it is difficult to segregate different varieties of mixed waste in a single platform. Therefore they suggested implementation for the same. This system consists of a conveyor belt mechanism that is used for segregation. It also makes use of a blower for separating dry and wet waste. Electromagnets are used for separating metallic waste. The working of this system is explained below.

3.4.2 Working of the system

When the mixed waste is deposited on the belt for segregation, the infrared sensor detects the waste present on the conveyor belt. It signals to the microcontroller that waste has been placed on the belt, microcontroller starts the motors, which in turn powers the conveyor belt. Thebelt starts moving.

Once the waste enters the blower section, the belt stops, and the blower is switched on thereby allowing the dry waste to be blown off to the dry bin.

Once the dry waste is segregated, the conveyor belt moves towards the metallic waste segregation section. The belt again stops and the power is given to the electromagnet to attract the metallic objects from the waste. Once metallic wastes are removed from the electromagnet, it is de-magnetized. Hence, the metallic objects fall into the bin. Then the belt starts to move again, to dump the remaining waste (wet waste) into the bin which is placed at the end of the belt.

3.4.3Conclusion

The waste is segregated into three different categories, namely metal, dry and wet waste, which means a division of waste into biodegradable and non-biodegradable.

3.5Automated Waste Segregation [5]

Amrutha Chandramohan et. Al

3.5.1Introduction

The idea in this paper is that waste segregation at the source is always better than doing it in the segregation plant. The benefit of doing so is, it leaves us with higher quality materials from the waste for recycling. Also, the segregated materials are sentdirectly to the recycling plant for reuse.
The number of workers needed will also be reduced.

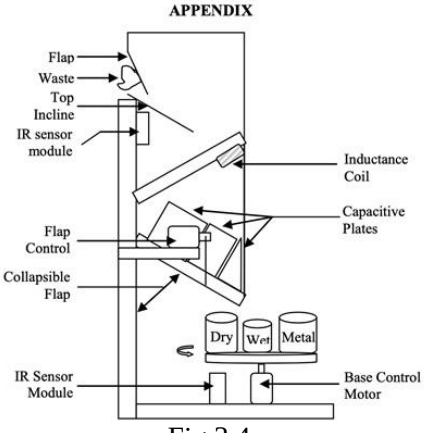


Fig 3.4

3.5.2 Working of the system

On dumping the waste into the system, the infrared proximity sensor senses the waste near it and gets activated which is responsible to bring the microcontroller to working mode(power on mode). The object slides over the inclined surface and falls on the inductance coil which is used to detect any metallic waste that is present in the waste.

The coil generates a magnetic field around it when an alternating current is passed through it. Once the metallic objects are introduced, eddy currents are induced on the surface of the metals. The newly generated magnetic fields oppose the existing field generated by the coil. This decreases the parallel resonant impedance of the circuit which can be observed as an increase in the proximity value.This shows that the object is metallic. The waste moves down towards the second inclined surface. If the garbage is non-metallic, then the capacitive sensing module starts sensing the object. The property of the relative dielectric constant is used for the classification of waste. Dry waste has a lower dielectric constant than wet waste since it has various fluids contained in it. If the output of the capacitive sensor is higher than a threshold, it is classified as wet waste else it is a dry waste.

Three bins are placed on a circular base, that can rotate and bring the correct container under the flap after the waste is identified.

Later the flap is lowered once the correct bin is under the flap so that the waste goes into the correct bin.

3.5.3 Limitations of the system

- The system is capable of segregating one type of waste at once.
- Some materials with a higher relative dielectric constant cannot be segregated into dry waste.

3.5.4 Conclusions and future work

This system has been implemented for segregating waste into metal waste, dry waste, and wet waste. Since it segregates only one type of waste at once,it can be improved to segregate mixed wastes by using buffer spaces.

CHAPTER 4

PROJECT REQUIREMENT SPECIFICATION

4.1 Introduction

This section contains the details of the project such as its scope, features, operating environment, product's perspective, constraints related to the project. It also discusses the assumptions made regarding the project and the risks that could evolve in the course of the completion of the project.
It also contains the functional and non-functional requirements of the project.

4.2 Project Scope

Purpose: One of the major problems faced today is the improper and inefficient disposal of waste produced, which has adverse effects on the environment. The segregation of waste helps in determining the economic value of the waste. The consequences of traditional practice cause health hazards, environmental pollution, and the loss of precious resources that can be recycled. Therefore, we aim to build a cost-effective and easy-to-use solution that can handle the entire segregation process automatically.
Benefits: Automating the process of waste segregation is helpful in many ways such as:

- It reduces environmental pollution caused by the improper disposal ofmixed waste.
- It reduces the amount of manpower required since the waste segregation happens automatically, which was traditionally done manually by laborers.
- It reduces the hazards on the health of workers who manually segregate the waste by automating it.
- Since the waste is segregated into different categories at the source, we can directly send the segregated waste into a recycling plant rather than first sending it to a segregation plant, which in turn reduces the overall time.

Objectives: This project is aimed at building an automatic waste segregator, capable of separating the waste into different categories such as wet waste, glass, plastic waste, and metallic waste.

Limitations: This system works efficiently when one waste at a time is given to it rather than dumping the mixed waste all at once. Another possible limitation is the fact that the system may not work as desired if the waste is mixed with different types.

4.3 Product Perspective

The automatic waste segregator aims to segregate the waste into different categories such as wet waste, glass, plastic waste, and metallic waste.

4.3.1 Product Features

The proposed system consists of a conveyor belt system and a combination of various types of sensors to achieve the aforementioned objective. The main purpose of using the conveyor belt system is to help in the movement of the waste from the source to their respective bins after being segregated. The sensors are used to detect and classify the incoming waste into different categories.

4.3.2 User Classes and Characteristics

The main user of this product could be anyone who wishes to segregate their waste automatically under the condition that one material is given at a time. Various types of users could be household users, industrial users, and city municipal corporations.

4.3.3 Operating Environment

The entire system is planned to be operational on the Arduino platform which is compatible to be configured using almost all the operating systems such as Windows, Linux, macOS, and many more.
The Arduino used Arduino IDE for writing the programs to control its operation and the programs are written in supported languages such as C and C++.

4.3.4 General Constraints, Assumptions, and Dependencies

Constraints: Garbage mixed and given for separation may not be classified into the correct category. For example, a plastic material dipped in water may not be classified as plastics due to the limitations of the hardware such as sensors used.

Assumptions: We need to place the garbage one by one for separation rather than dumping it all at once.

Dependencies: The dependency type of this system is Finish-to -Start that is the first task has to be completed before the second task can start. In our system, the separation of dry waste from wet waste needs to be completed first before further classification of dry waste into different categories. Likewise, the non-metallic waste needs to be segregated first from metallic waste before further classification of non-metals into plastic or glass.

4.3.5 Risks

This system works only when one waste at a time is given to it rather than dumping the mixed waste all at once. There could be some unforeseen failures in the hardware that could pose a problem during its final delivery.

4.4 Functional Requirements

The major functional requirements that are to be satisfied are as follows:

- The system should start working as soon as the waste material is in contact with the conveyor belt. If this is not the case then the system should be in a stationary state to reduce the system power consumption.
- The system should first detect the wet waste placed on the belt with the help of a moisture detection sensor. If any materials are detected as wet waste, then it should be discarded into the respective bin.

- After the wet waste is segregated, the next type of waste detected should be metal waste. This is achieved through the usage of a metal detection sensor.
- Later the leftover waste should be classified into two categories namely, plastic and glass. This is achieved using a capacitive sensor.

Input to our system is waste that is unclassified given one by one and the output of the system is that the waste should be classified and discarded in the correct bin.

4.5 Non-Functional Requirements

4.5.1 Performance Requirement

Our proposed system works efficiently when the waste is placed on the conveyor belt one by one rather than dumping it all together. The system may fail to segregate if the mixed waste is placed on the belt.

4.5.2 Usability

The system should be easy to use. This is achieved by automating the entire system where the user will just place the garbage and all other things are taken care of by the system itself.

4.5.3 Power Consumption

The system should consume only a limited amount of power. This is achieved by starting the major portion of the system only when the garbage is near the system.

CHAPTER 5

SYSTEM REQUIREMENTS SPECIFICATIONS

5.1 Introduction

This section contains the details of the behaviors of the system. It also contains various information that is required to meet the customer needs or for the functioning of the system as intended. This information also includes the external interface requirements of the system and the deployment diagram to show the interaction among the different modules of the system.

5.2 External Interface Requirements

5.2.1 User Interfaces

The only interface the user interacts with is the conveyor belt. The user is needed to place the garbage on the belt and then all the other interactions are abstracted from the user which is done automatically. Then after segregation, the waste bins will need to be cleared off which is a manual process.

5.2.2 Hardware Requirements

- Arduino: This is the main microcontroller that is responsible for controlling the operation of the entire system.
- DC motors: These motors act as a driver for the conveyor belt.
- Belt: This is the main component of the conveyor system on which the waste to be segregated is placed.
- Inductive proximity sensor: This sensor is used to detect any metallic objects that are present in its proximity.
- Capacitive proximity sensor: This sensor is used for classifying the waste into glass or plastic based on the concept of dielectric constant.

- Moisture detection sensor: The purpose of using this sensor is to segregate the waste into either dry or wet categories.
- Servo motors: This motor is used to push the waste into its respective bin off from the belt.

5.2.3 Software Requirements

The main software required for our project includes:

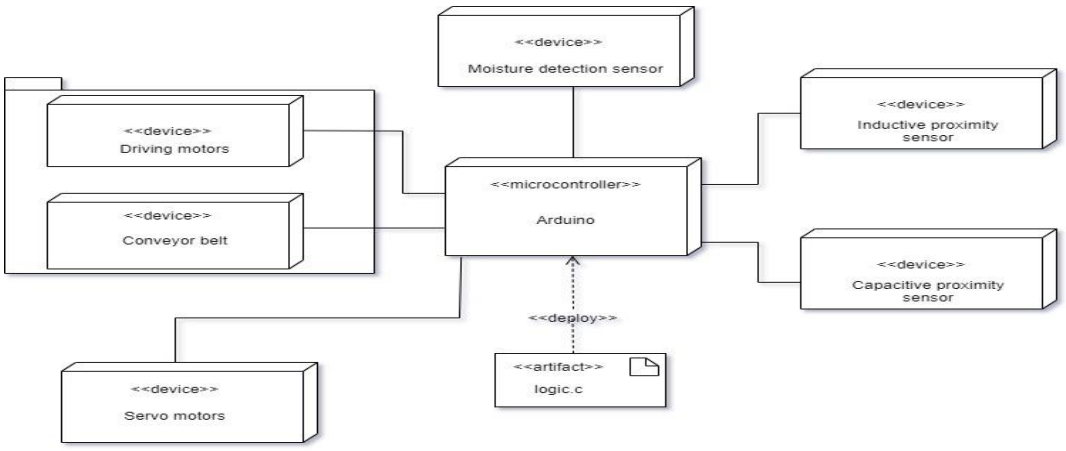
Arduino Integrated Development Environment:

- Name: Arduino IDE
- Description: This is an open-source software tool that facilitates the easy writing of the code which helps in faster development. This software tool also allows us to upload the written code into the Arduino board.
- Operating systems: This software is compatible with Windows, Mac OS X, and Linux.
- Source: The software can be downloaded from the official site which is https://www.arduino.cc/en/software

C programming language:

- Name: C language
- Description: This is a general-purpose, procedural programming knowledge that can be used for various purposes.
- Operating systems: This software is compatible with Windows, Mac OS X, and Linux.
- Source: The software can be downloaded from the official site which ishttps://www.cprogramming.com/

5.3Deployment Diagram



Deployment diagram for the proposed system

Fig 5.1

CHAPTER 6

SYSTEM DESIGN

6.1 Design Considerations

6.1.1 Design Goals

The main design goal of our system is that we should efficiently segregate the waste into different categories such as wet, metallic, glass, and plastic.Some of the existing systems classify waste into dry, wet, and metallic. Some other system classifies them into glass and plastics. Since solid waste is one of the major categories of waste generated, our system integrates both the features so that a single system has multiple features and is more robust and useful.Our system will segregate wastes that of not mixed with higher accuracy and it may not very accurately classify the waste if they are mixed such as plastic dipped in water since we are first checking for the presence of water and later checking if it is plastic or not. The system is also designed in such a way to reduce the amount of power consumed by making the conveyor belt move only when there is some waste placed on the belt.

6.1.2 Architecture Choices

The alternate choices for metal detection were the usage of electromagnets for attracting metal pieces and some systems also used the concept of eddy currents for detection of metallic waste. We planned to use the inductive proximity sensors so that the design complexity of the system remains simple and also the cost of the system remains low.

The other alternatives that were available for segregating wet and dry waste were the use of blowers. These systems used blowers to blow off the dry waste which is usually lighter when compared to wet waste. This system has the disadvantage of blowing away some of the wet waste also. Therefore, we have designed our system using a moisture detection sensor, which is more accurate than blowers.

Pros

- The system is simple and easy to use and also cost-effective.
- The entire system is automated where the user needs to place the waste material on the belt and the segregation is all automated.

- The system also uses less power by remaining in an ideal state unless the garbage is placed on it.

Cons:

- The system would not segregate waste accurately if it is mixed due to the limitations of the hardware used, which can sense only one property at a time.
- Any unforeseen hardware failures can prevent the entire system from working as intended.

6.2 System Design

The system mainly consists of 5 number of modules, which are, conveyor belt module, a moisture detection module, a metal detection module, a capacitive detection module, and a logic module which consists of the Arduino microcontroller.

The conveyor belt module is responsible for moving the waste placed on the belt to the detection sensor modules. This module is driven by DC motors which are powered by a microcontroller. This module initiates the movement of the conveyor belt only if the proximity sensor of this module detects the waste on the belt or else it continues to stay in a stationary state.

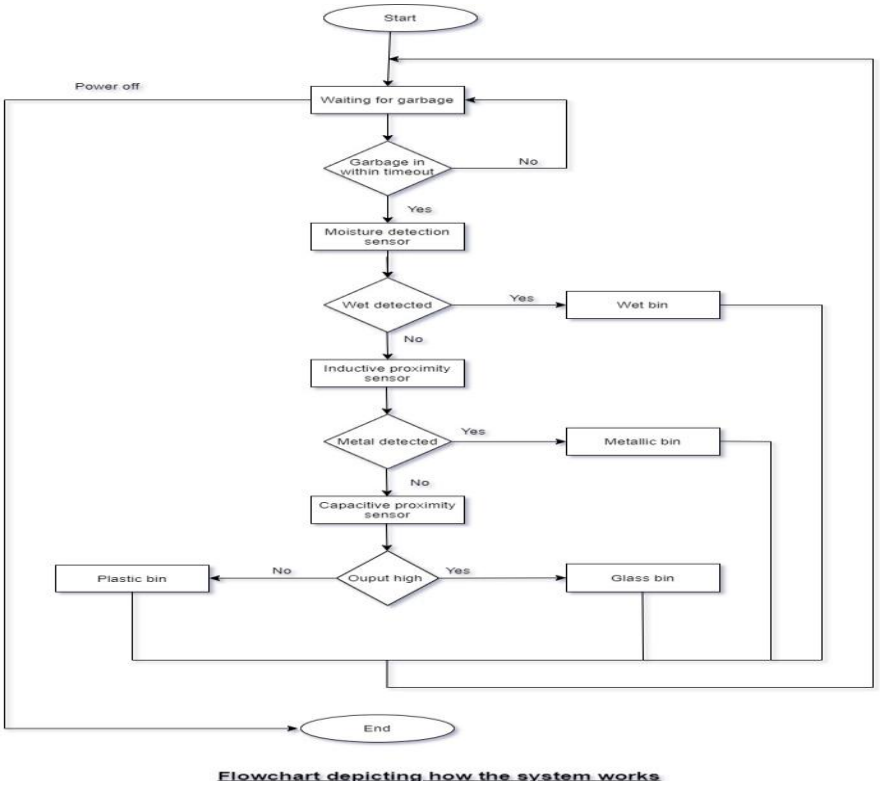
The moisture detection module which is connected to the logic module gets the waste from the conveyor belt module and is responsible for detecting the wet waste using the moisture detection sensor of this module and sweeps the waste using the servo motor of the module into the corresponding bin if the wet waste is detected.

The waste that is not detected by the moisture detection module is then checked by the metal detection module which is also connected to the logic module. This module gets the waste from the conveyor belt module, and is responsible for detecting the metallic waste using the inductive proximity sensor and sweeps the waste using the servo motor into the corresponding bin if the metallic waste is detected.

Further, the waste that is not detected by the metal detection module is then checked by a capacitive detection module which is connected to the logic module. This module gets the waste from the conveyor belt module and is responsible for detecting the plastic/glass waste using the capacitive proximity sensor. If the dielectric value read by the capacitive proximity sensor is high then the waste

is classified as glass and if the value is low then it is classified as plastic and these wastes would be swept into their respective bins by the servo motors.

The working of the conveyor belt system depends on the logic module which reacts based on the output of the proximity sensor. The segregation process is also dependent on the logic module which activates the respective servo motors for segregation depending on the output of all the other modules mentioned above. All the above modules are interconnected using physical wires, connected to various pins of the Arduino board.



Flowchart depicting how the system works

Fig 6.1

6.3Design Description

6.3.1 Master class diagram

The class diagram for the system is as follows. This shows how each module interacts with other modules to enable the working of the system as intended. This diagram also shows the dependencies between various components of the system.

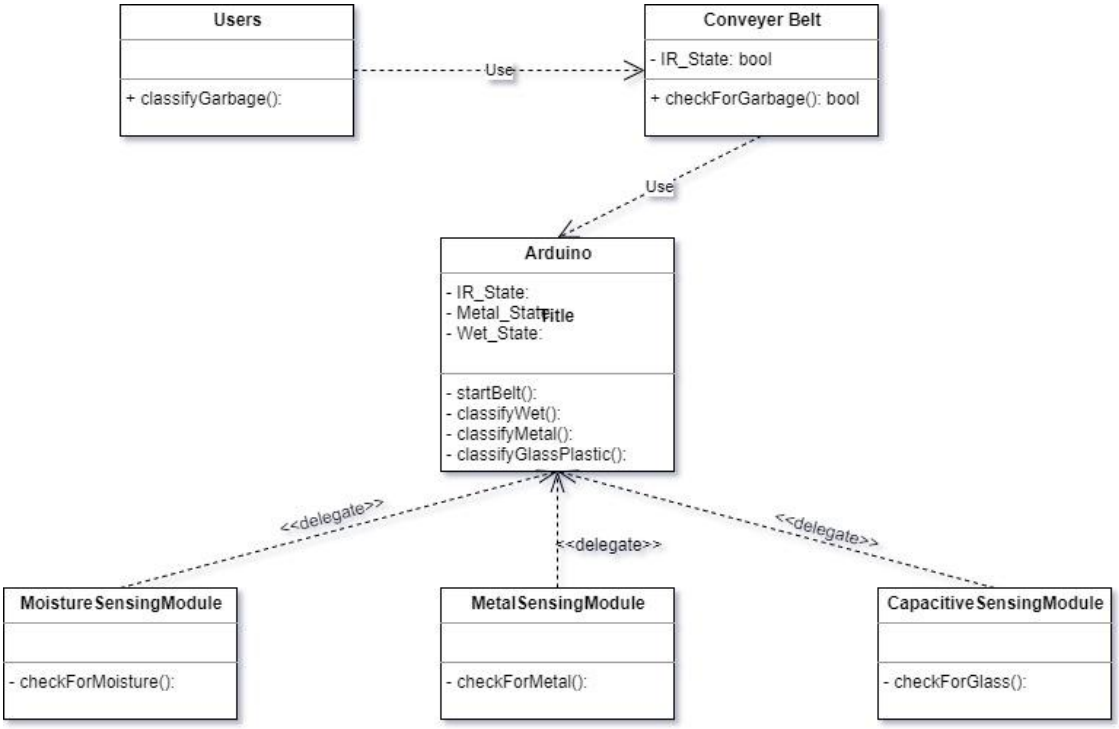


Fig 6.2

6.4 User Interface Diagrams

Our system does not contain any screen as such. It just has the conveyor belt on which the garbage is placed for segregation. This is the only interface with which the user will interact.The other part of the system with which the user interacts is the dustbins, which need to be emptied as and when the bins are full.

6.5 State Diagram

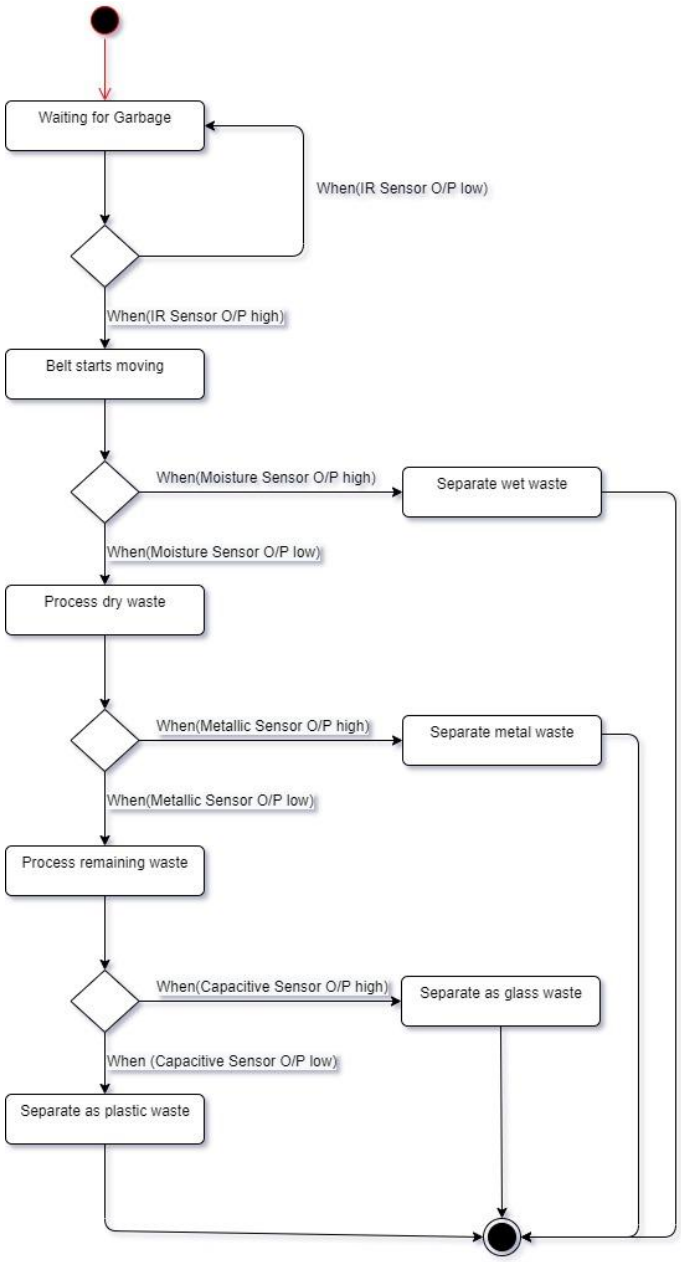


Fig 6.3

CHAPTER 7

CONCLUSION OF CAPSTONE PROJECT PHASE – 1

During the first phase of the capstone project, an attempt was made to understand the problems that are currently faced due to the improper management and disposal of garbage and the effect that these could pose on human beings. The seriousness of the problem was taken into consideration and hence, an attempt to design a solution for the problem was carried out.

As the first part of the project, a detailed literature survey was carried out, which throws light on various ways that are available to solve the problem. Our system is designed in a manner that it combines multiple existing systems to deliver an easily usable and robust system.

After the literature survey, project requirements and system requirements were noted. The main goal was to define the exact scope of the project under the assumptions made and the limitations of the implementation and the hardware available. While defining the project scope, we were also successful in identifying the functional and non-functional requirements of the system.

All the above were documented in a structured way in the project requirement specification document. The next aim was to develop a high-level design of how the system works. As the first step in this process, a flowchart was developed which indicated an overview of the working of the system and all states transited by the garbage in its lifecycle of getting classified. Next, a deployment diagram was developed which shows the interactions between various modules of the system. The class diagram and state diagram for the system were also developed considering the limitations and constraints that were defined in the phase before this one. All these diagrams along with some of the descriptions were documented in the high-level design document which was a deliverable.

All the corrections, modifications, and enhancements suggested by the guide and panel members were incorporated at each proceeding of this phase.

In conclusion, this phase gave us an idea of the project scope, background work, how an expected system is supposed to work, and how to carry out a project professionally by documenting things at each phase and also to coordinate with the team members remotely.

CHAPTER 8

PLAN OF WORK FOR CAPSTONE PHASE – 2

From the phase-I, the design of the entire system is clear. The next step is the procurement of all the essential hardware required for the system. Once all the necessary hardware is procured, we will implement each module required separately along with the testing required and finally integrate all the modules to deliver the entire system which satisfies all the requirements that are documented in the project requirement specification.

Final testing for user acceptance is performed once the entire system succeeds in unit testing, system integration testing, and regression testing. Then the final product is ready for demo. Any optimizations that are possible, which improves the performance of the system will be considered.

For ease of use and maintenance, the user guide or manual will be prepared, which has information like the circuit diagrams and the specifications of the components so that they can be replaced in case of any wear and tear.

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[5] A. Chandramohan, J. Mendonca, N. R. Shankar, N. U. Baheti, N. K. Krishnan and M. S. Suma, "Automated Waste Segregator," 2014 Texas Instruments India Educators' Conference (TIIEC), Bangalore, 2014, pp. 1-6, doi: 10.1109/TIIEC.2014.009.

For component diagram:

https://www.visual-paradigm.com/guide/uml-unified-modeling-language/what-is-component-diagram/

For deployment diagram:

https://www.visual-paradigm.com/guide/uml-unified-modeling-language/what-is-deployment-diagram/

For state diagram:

https://www.guru99.com/state-machine-transition-diagram.html

https://www.smartdraw.com/state-diagram/

Google scholar was used to view the papers.

Draw.io an online drawing tool was used to design the flowchart of the system.

https://app.diagrams.net/

APPENDIX A DEFINITIONS, ACRONYMS AND ABBREVIATIONS

Conveyor belt module: This module consists of a conveyor belt, DC motors for driving the belt, proximity sensor for switching on and off the belt.

Moisture detection module: This module consists of a moisture detection sensor along with a mechanism that uses a servo motor to push off the garbage to the respective bin if the garbage is detected as wet.

Metal detection module: This module consists of an inductive proximity sensor along with a mechanism that uses a servo motor to push off the garbage to the respective bin if the garbage is detected as metal.

Capacitive detection module: This module consists of a capacitive proximity sensor along with a mechanism that uses a servo motor to push off the garbage to the glass or plastic bins respectively based on the dielectric value read by the sensor.

Logic module: This module consists of an Arduino microcontroller which enables the working of all other modules as intended.