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

UE17CS490B – Capstone Project Phase - 2

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January - May 2021

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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 eighth semester Capstone Project Phase - 2 (UE17CS490B) in the Program of Study - Bachelor of Technology in Computer Science and Engineering under rules and regulations of PES University, Bengaluru during the period Jan. 2021 – May. 2021. 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 8th semester academic requirements in respect of project work.

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DECLARATION

We hereby declare that the Capstone Project Phase - 2 entitled **"Smart Waste Segregation"** has been carried out by us under the guidance of Prof. Charanraj B R , Assistant Professor 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 January – May 2021. 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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ACKNOWLEDGEMENT

I would like to express my gratitude to Prof. Charanraj B R, Department of Computer Science and Engineering, PES University, for her continuous guidance, assistance, and encouragement throughout the development of this UE17CS490B - Capstone Project Phase – 2.

I am grateful to the project coordinators, Prof. Silviya Nancy J and Prof. Sunitha R, for organizing, managing, and helping with the entire process.

I take this opportunity to thank Dr. Shylaja S S, Chairperson, Department of Computer Science and Engineering, PES University, for all the knowledge and support I have received from the department. I would like to thank Dr. B.K. Keshavan, Dean of Faculty, PES University for his help.

I am deeply grateful to Dr. M. R. Doreswamy, Chancellor, PES University, Prof. Jawahar Doreswamy, Pro-Chancellor – PES University, Dr. Suryaprasad J, Vice-Chancellor, PES University for providing to me various opportunities and enlightenment every step of the way. Finally, this project could not have been completed without the continual support and encouragement I have received from my family and friends.

ABSTRACT

Rapid growth in population, urbanization, and economic development has a huge impact on the increasing amount of waste that is being generated. According to an estimate, the amount of solid waste produced in a year is about 2.01 billion tonnes. By 2050, the predicted 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 important step involved in recycling waste is its proper segregation. This is better utilized if the segregation is at the source itself. In the present scenario, there is no cost-effective 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 itself. Most of the solid waste such as glass and plastics are recyclable, therefore we aim to segregate the wastes into the aforementioned 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 the demand for food and other essential items. This in turn leads to the production of a huge amount of waste. The waste when not disposed of correctly leads to many health and environmental hazards. The common practices of disposal adopted include, the collection of waste by city municipal corporations and dumping them into wastelands, which are later converted to landfills. These landfills are open, exposed to nature such as sunlight, wind, and rain that results in the emission of toxic gases and production of harmful liquids, which have adverse effects on the ecosystem. This way of dumping the waste also affects workers who manually sort them, leading to deteriorating effects on the health of the workers.

One of the major ways to stop generating waste is by following the principles of the three R's which are Reduce, Recycle, and Reuse. The major component of the waste generated today is plastic. Colored plastics may contain many heavy metals in their pigment which impacts the health of the people and animals around them. Since these are not biodegradable, one of the ways to get rid of them is by stopping their use. Another way includes recycling and reusing them. Metallic waste from electronic items is also another major contributor to the waste. This can also be recycled and reused. Glass wastes are also a threat to the environment. Therefore, recycling glass waste reduces pollution and space in landfills. Studies have proven that producing glass from raw materials is expensive and more pollutive than producing from recycling. Hence, materials that can be recycled are better if they are recycled.

As can be seen from the above pieces of evidence, most of the waste can be recycled and 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 manually, which has hazardous effects on them. Therefore, we propose a solution that automates the process of segregation of waste, which has numerous advantages like, reducing the number of workers needed for the entire process of waste management. It also results in good quality of materials that can be recycled, since segregation of waste is done at the source of its generation itself.

CHAPTER-2

PROBLEM STATEMENT

Design a system that is capable of automating the process of segregation of waste. The system should be able to categorize waste into different categories such as wet, metallic, plastic, and glass. The system should be designed in such a way that it works in low power consumption mode. The only action required by the user should be placing the waste on the system and the rest of the process of segregation should be automatic. The system should be affordable in terms of labor and usage.

The entire system should work as expected when the waste is placed one by one on the belt rather than placing mixed waste. The developed system can find its applications in domestic and industrial sectors.

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 that the segregation of waste helps in realizing the importance and value of the waste. This paper proposes a system that 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 a major 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 if there is any waste in the bins. If found, the waste falls onto 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, 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.

3.1.2 Working of the metal detection system

The metallic waste detection module 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 system

A capacitive sensor is used for this purpose. The dielectric constant of wet objects is greater than that of 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.

3.1.4 Results 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 banana peel, lemon, and wet cloth. Materials that were detected as metallic waste include keys and an Aluminum sheet.

3.1.5 Future scope of improvement suggested in the system

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. The data collected from the IoT system can be used to train a model capable of predicting trends in the amount of waste.

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

The paper elucidates the fact that one of the major concerns today is disposing of the waste collected. It also reports that 2.02 billion tonnes of waste are generated worldwide. This paper tells that, for proper management of waste it has to be segregated and transported efficiently. It also quotes that the 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 suggests that it is better if the waste is segregated at the source, rather than first sending the waste to a segregation plant and later to a 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 tends to reduce the hazards caused to manual waste segregator. It emphasizes that metal, glass, and plastic form the major part of waste materials.

3.2.2 Working 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 the 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.

3.2.3 Results and conclusions

For testing the metal detection module, a metal tin was used, plastic and glass bottles were used to test the plastic and glass detection modules respectively. The true acceptance rate for metallic, glass, and plastic wastes was found to be 90,93 and 98 percent respectively.

3.2.4 Future work

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. The paper suggests that once the waste is segregated, advanced processing can be adopted for further enhancement.

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

Jeberson Retna Raj et. Al

3.3.1 Introduction

The 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, the solution suggested here, aims to build an autonomous system that can separate waste into metallic, non-biodegradable, and biodegradable (dry and wet).

The system proposed here is built using:

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

3.3.2 Working of the system

The garbage is dumped into a funnel, which is then 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 moves along the conveyor. Later, the metallic waste falls into a bin equipped with a metal detection sensor.

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 that leads into a bin equipped with an IR sensor to detect the non-biodegradable waste. Further, the leftover waste that is of higher weight than the plastics and papers fall over the second conveyor belt which leads into 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.

3.3.4 Conclusions

The data collected during segregation is stored in the cloud which is made available to the municipal corporation for taking further actions and decisions.

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. The belt 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 electromagnet is powered on 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 metallic bin. The belt then

starts to move, to dump the remaining waste (wet waste) into the bin which is placed at the end of the belt.

3.4.3 Results

The wastes that are segregated as wet include banana peel and teabags. Materials segregated as dry waste include dry leaves and thermocol. Nails and nuts and safety pins are segregated as metallic wastes.

3.4.4 Conclusions and Future Scope

The system proposed here is cost-effective, compact, and convenient for the users. It suggests improving the proposed system to handle the mixed waste.

3.5 Automated Waste Segregation [5]

Amrutha Chandramohan et. Al

3.5.1 Introduction

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 sent directly to the recycling plant for reuse. The number of workers needed will also be reduced.

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 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 Results

Materials that are tested for metal waste detection include foil, staple pins, and paper clips. Onion peel and carrot peel were tested for wet waste detection. Ceramic plate, wood, and polythene bags were tested for dry waste detection.

3.5.5 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. It is suggested to improve the efficiency and accuracy of the system by reducing the noise in the sensing modules.

3.6 Automatic Waste Segregator and Monitoring System [6]

K. Balakrishnan et. Al

3.6.1 Introduction

This paper elucidates the fact that proper management of waste needs to be adopted to avoid hazardous effects on the ecosystem. It tells that about 60 million tonnes of waste is generated in India each year and about 50 percent of people face issues regarding waste disposal. Hence, this paper attempts to build a cost-effective automatic waste segregator that is capable of segregating waste into three categories such as metallic, organic, and plastic. This paper further throws light on existing methodologies used for segregation like x-ray technology and induction sorting.

3.6.2 Working of the system

The system consists of a conveyor belt, ultrasonic sensors, inductive proximity sensors, blower, GSM module, and robotic arm equipped with electromagnet. Once the waste is placed on the open-close mechanism, the inductive proximity sensor checks if the waste is metallic. If the waste is found to be metallic, the robotic arm with electromagnets picks up the waste and rotates 180 degrees, and demagnetizes so that the metallic waste falls in its bin. If it is non-metallic, the waste falls on the conveyor belt which starts moving. It stops once the waste enters the blower section. The blower is turned on for a specified time to enable the dry waste to be blown off which is collected in a separate bin. The unblown waste is collected at the bin placed at the end of the belt. Each bin is equipped with ultrasonic sensors to monitor the fill level of the bins. When the bins are full, the GSM module sends SMS to the monitoring system.

3.6.3 Results

The system proposed here is efficient since the bins are emptied as and when they are full using the monitoring system. The system proposed here takes some time for segregation. It also assumes that the waste should fit in the funnel used in the open-close mechanism. Some materials that were classified as metallic waste include paper clips and batteries. Some materials that were classified as organic waste include vegetable peels and rotten fruits. Papers and milk covers were among the few that were classified as dry waste.

3.6.4 Conclusions and future work

The continuous operation of any particular module is avoided by using the Arduino. The future enhancements possible in this system include the incorporation of a crusher in the inlet so that large waste can also be segregated using the system. It also suggests using solar energy for powering the system instead of using electricity.

3.7 Development of Automatic Waste Sorter Machine [7]

Md. Mahmudul Hasan Russel et. Al

3.7.1 Introduction

The paper enlightens various advantages of managing waste effectively that help our surroundings to be healthier and recycling the waste efficiently. The system proposed here aims to segregate the waste into metal, glass, paper, and plastic categories. It adopts an electromechanical system integrated with a microcontroller to achieve its purpose. The system makes use of conventional sensors to segregate some kind of wastes, whereas LASER and LDR are incorporated for the separation of other kinds. This whole process is automated which makes the system smart and easy to use.

3.7.2 Working of the system

The system consists of a tray, IR sensor, weight sensor, metal sensor, glass sensor, LASER, and LDR. Initially, the waste is placed in a detection zone that is equipped with a system tray and an IR sensor. On detection of the waste, the weight sensor is activated to calculate the weight of the waste which is later used to analyze the amount of waste generated for each type of waste. A metal sensor is incorporated to detect the metallic waste. Omran, the glass sensor is incorporated to detect glass waste. On successful detection, the servo motor is rotated in a specific direction to dump the waste into its respective bin. If the above sensors fail to detect the type of waste, the LASER/LDR module is activated. Transparent materials allow LASER to pass through, this property can be used to differentiate between plastic and paper wastes that are later put into their respective bins using a servo motor.

3.7.3 Conclusions and future work

It suggests the fact that incorporating more sensors into the system helps in the segregation of the waste into more categories such as conductors, semiconductors, thin and thick papers, transparent and non-transparent plastics, etc. It tells that large-scale production of such automatic waste segregator helps in reducing the overall cost required to manufacture existing segregation system.

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 of mixed 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.

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

Limitations: The system is capable of segregating only one waste at a time. This system works efficiently when one waste at a time is given to it rather than dumping the mixed waste all at once.

4.3 Product Perspective

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

4.3.1 Product Features

The proposed system consists of a conveyor belt mechanism and a combination of various types of sensors along with image classification to achieve the aforementioned objective. The main purpose of using the conveyor belt mechanism 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 incoming waste into wet and metal categories. Image classification is incorporated to differentiate between glass and plastics.

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 IDE is used for writing the programs to control its operation and the programs are written in supported languages such as C and C++. Python program is written in google collaboratory to incorporate image classification model. IP webcam app is installed to capture the image of the waste placed on the conveyor belt.

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 placed on 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 they should be discarded into the wet bin.
- After the wet waste is segregated, the next type of waste detected should be metal waste. This is achieved through the usage of an inductive proximity sensor.
- Later the leftover waste should be classified into two categories namely, plastic and glass. This is achieved through image classification.

Input to our system is waste to be classified and the expected output of the system is that the waste should be classified and discarded to the correct bin.

4.5 Non-Functional Requirements

4.5.1 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.

4.5.2 Power Consumption

The system should consume only a limited amount of power. This is achieved by starting the conveyor belt only when the garbage is placed on it.

CHAPTER 5

SYSTEM DESIGN

5.1 Introduction

5.1.1 Overview

The detailed design of the system is explained thoroughly in the subsequent sections. It consists of a master class diagram spanning the entire system and also contains design details of every module along with its associated UML diagrams. This is intended to provide the logical design of the actual code that is being used in the system.

5.2 Design Description

The system mainly consists of the following modules. They are:

- Conveyor belt module
- Moisture detection module
- Metal detection module
- Glass and Plastic separation module

5.2.1 Usecase Diagram

The below diagram represents the use case diagram for the entire system.

This is further explained at the module level in subsequent sections.

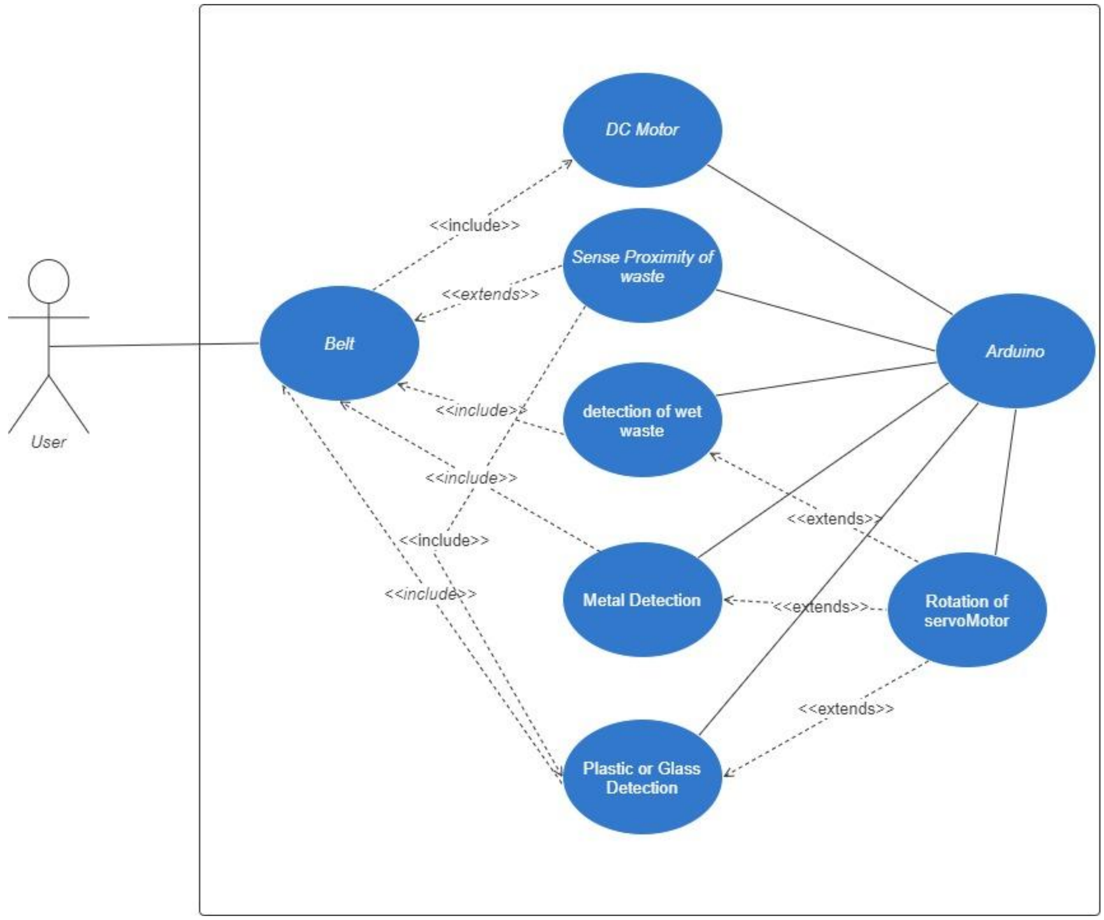

Fig1. Usecase diagram for the entire system.

5.2.2 Deployment Diagram

The below diagram shows the deployment diagram for the entire system.

This is further explained at the module level in subsequent sections.

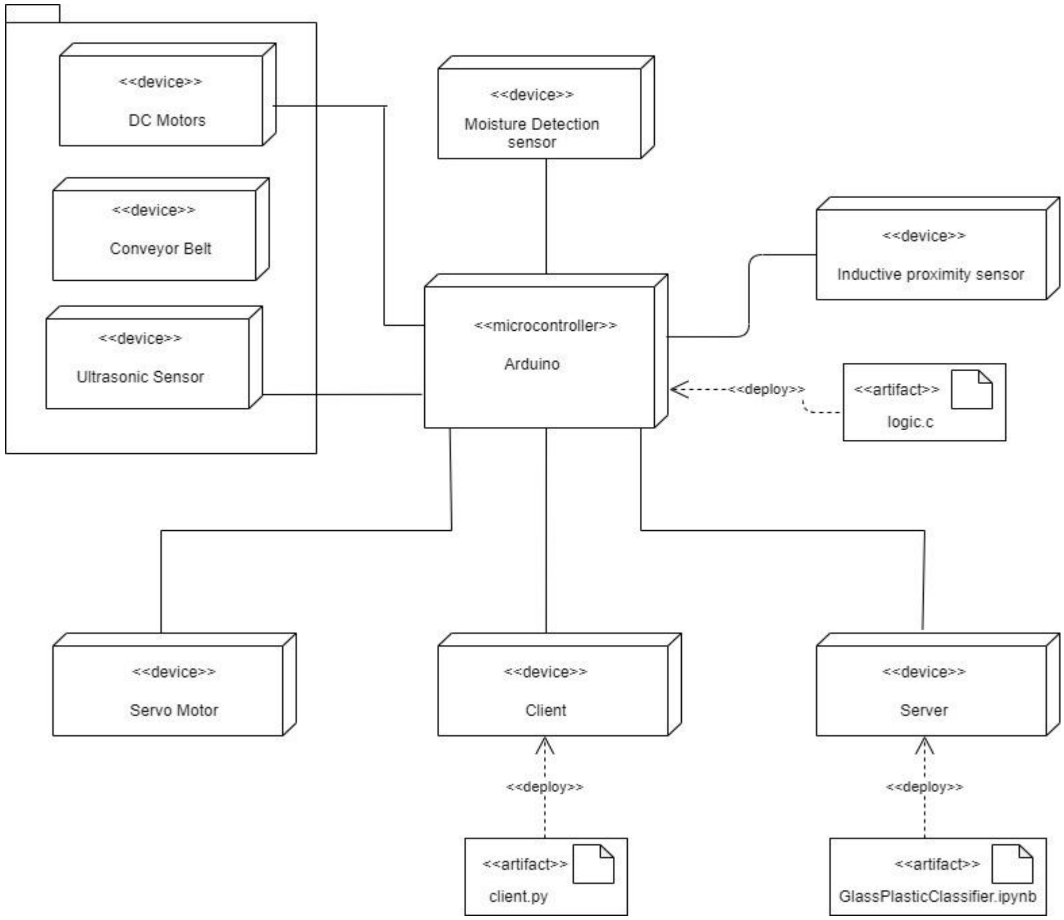

Fig2. Deployment diagram for the entire system.

5.2.3 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.

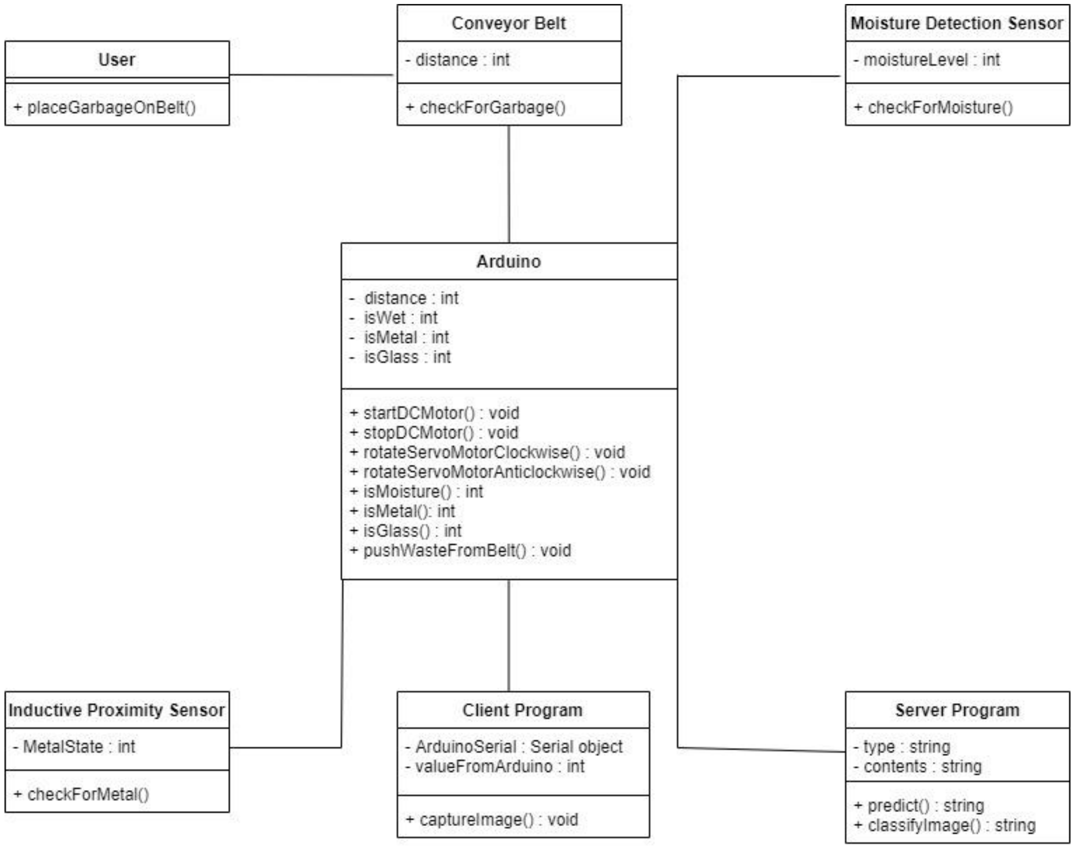

Fig3. Class diagram for the entire system.

Class Name: User

Class Description: This class represents the user, who will use the system to segregate waste automatically.

Class Method: placeGarbageOnBelt() This is a representative method, which represents the user's action of placing the waste on the belt.

Class Name: Conveyor Belt

Class Description: This class represents the belt along with the ultrasonic sensor and DC motors.

Data Member: distance: It is an integer variable that indicates the distance of the waste placed on the belt from the sensor.

Class Method: checkForGarbage(): This method checks if the waste is placed on the belt or not. This is achieved by checking if the waste is within a certain distance from the sensor.

Class Name: Moisture Detection Sensor

Class Description: This class represents the moisture detection sensor along with the servo motor.

Data Member: moistureLevel: It is a variable that indicates the moisture level of the material.

Class Method: checkForMoisture(): This function internally uses the above variable to check if the waste is wet or not using a threshold value for the variable.

Class Name: Inductive Proximity Sensor

Class Description: This class represents the inductive proximity sensor along with the servo motor.

Data Member: MetalState: It is an integer variable that indicates whether the waste is metallic or not.

Class Method: checkForMetal(): This function uses the output of the inductive proximity sensor and returns waste is metallic or not.

Class Name: Client Program

Class Description: This class represents the python program that is responsible for capturing the image and requesting the category of the image from the server.

Data Member: Arduino Serial: It is an instance of the Serial object that is used to communicate with the Arduino and write values to Arduino.

valueFromArduino : It is an integer variable used to instantiate the process of capturing images.

Class Method: captureImage(): This function is responsible for capturing the image using the IP Webcam android app and saves it in a jpeg file. This file is then sent to the server

to get the category of the captured image and writes the response to the Arduino for further actions.

Class Name: Server Program

Class Description: This class represents a python program that is responsible for classifying the image as plastic or glass from the image file sent by the client using a pre-trained classifier model.

Data Member: type: It is a string that contains the value that represents whether the image is plastic or glass.

contents: It is a string that contains the image in binary format.

Class Methods: predict(): This function takes the image as input and predicts its category using the classifier model and returns the category.

classifyImage(): This function fetches the image using REST API, saves it in a jpeg file, and then invokes the predict function.

Class Name: Arduino

Class Description: This class represents the Arduino microcontroller which is the heart of the entire system. It coordinates with all the other classes to ensure the system works as intended.

Data Member: distance: It is an integer variable that indicates the distance of the waste placed on the belt from the sensor.

isWet: It is an integer variable that contains value 0 or 1, where 0 indicates dry waste and 1 indicates wet waste.

isMetal: It is an integer variable that contains value 0 or 1, where 0 indicates metallic waste and 1 indicates non-metallic waste.

isGlass: It is an integer variable that contains value 0 or 1, where 0 indicates plastic waste and 1 indicates glass waste.

Class Methods:

startDCMotor(): This function is responsible for starting the DC motors.

stopDCMotor(): This function is responsible for stopping the DC motors.

rotateServoMotorClockwise(): This function takes a servo object, start degree, and end degree. It then rotates the servo motor between the start degree and end degree in the clockwise direction.

rotateServoMotorAnticlockwise(): This function takes a servo object, start degree, and end degree. It then rotates the servo motor between the start degree and end degree in the anticlockwise direction.

isMoisture(): This function is responsible for checking if the waste is wet or dry.
isMetal(): This function is responsible for checking if the waste is metallic or non-metallic.
isGlass(): This function is responsible for checking if the waste is glass or plastic.

pushWasteFromBelt(): This function accepts a servo object as the parameter and internally invokes startDCMotor(), stopDCMotor(), rotateServoMotorClockwise() and rotateServoMotorAnticlockwise() to push the waste off the belt.

5.2.4 Conveyor belt module

5.2.4.1 Description

The conveyor belt module is responsible for moving the waste placed on the belt to the different sensing modules. This module is driven by two DC motors which are powered by a microcontroller and a 12V DC power supply. It also contains an ultrasonic sensor. This module initiates the movement of the conveyor belt only if the ultrasonic sensor detects the waste on the belt or else it continues to stay in a stationary state. This is done to achieve a less power-consuming design.

5.2.4.2 Use case diagram

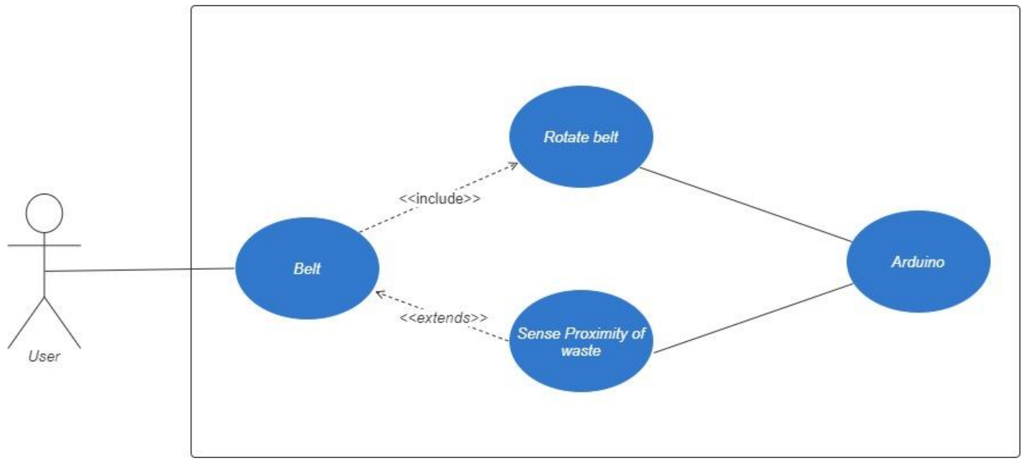

Fig4. Usecase diagram for the conveyor belt module.

Use Case Item	Description
Belt	It includes the conveyor belt made of rexine material used to move the waste from the source to respective bins.
Rotate Belt	It includes two 12V DC motors used to drive the conveyor belt.
Sense Proximity of waste	This includes an ultrasonic sensor which is used to detect the proximity of the waste on the belt.
Arduino	It is the microcontroller that contains the logic for driving DC motors and checking the proximity of waste that is placed on the belt.

Table 1. Usecase description for the conveyor belt module.

5.2.4.3 Sequence diagram

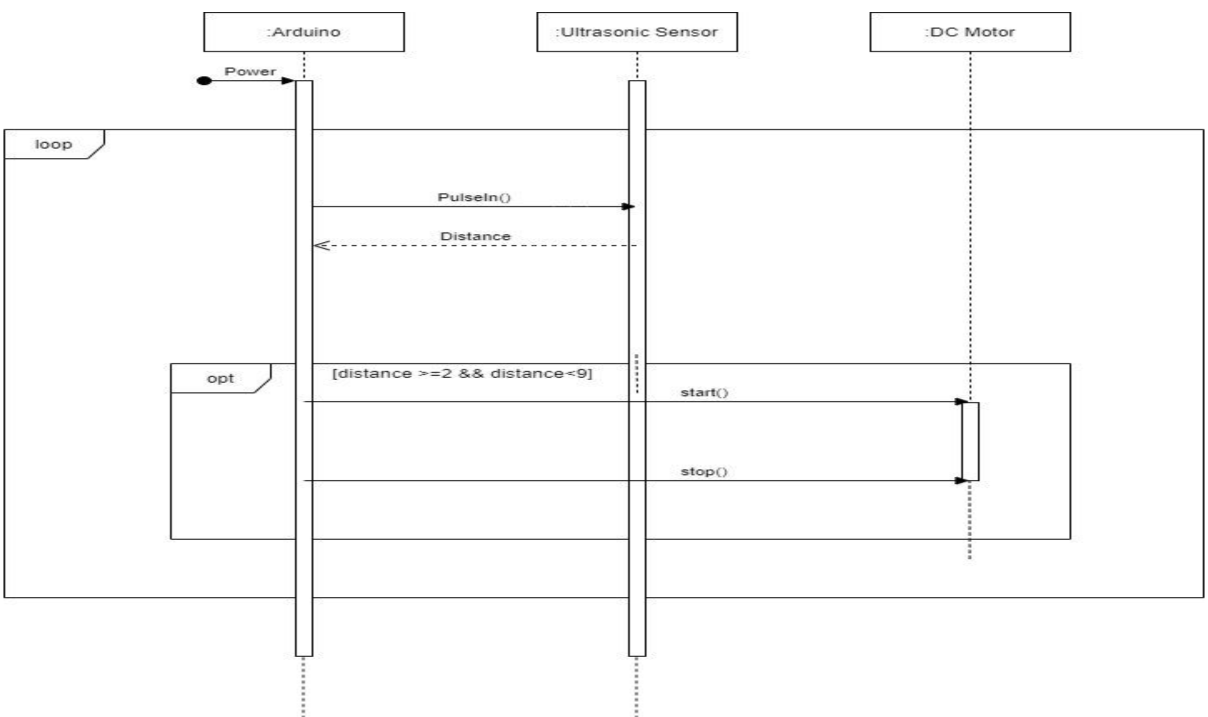

Fig5. Sequence diagram for the conveyor belt module.

5.2.5 Moisture detection module

5.2.5.1 Description

The moisture detection module consists of a moisture detection sensor along with the servo motor with flaps which is used to push the waste off the belt. When the moisture detection sensor detects the waste to be wet, the waste is pushed off the belt using the flap-like mechanism else, the waste is moved further on the belt to the next module for further segregation.

5.2.5.2 Use case diagram

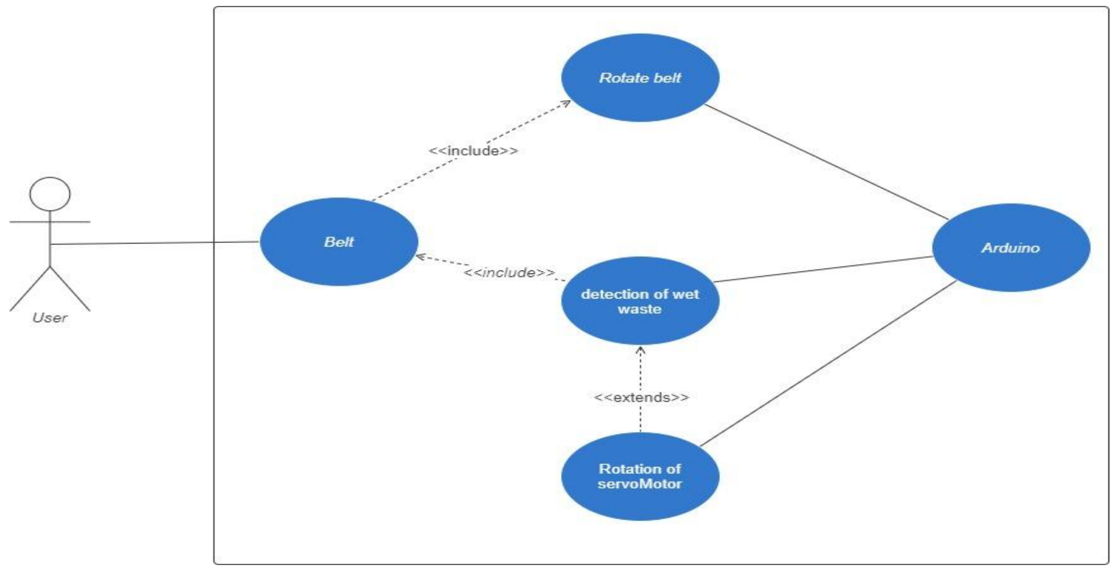

Fig6. Usecase diagram for the moisture detection module.

Use Case Item	Description
Belt	It includes the conveyor belt made of rexine material used to move the waste from the source to respective bins.
Rotate belt	It includes two 12V DC motors used to drive the conveyor belt.
Detection of Wet Waste	It includes a moisture detection sensor which when comes in contact with the material detects it as wet or dry.

Rotation of Servo Motor	It consists of a servo motor and flap attached to it which is used to push waste off the belt when detected as wet waste.
Arduino	It is the microcontroller that contains the logic for driving DC motors and coordinates with the moisture detection sensor and respective servo motor.

Table 2. Usecase description for the moisture detection module.

5.2.5.3 Sequence diagram

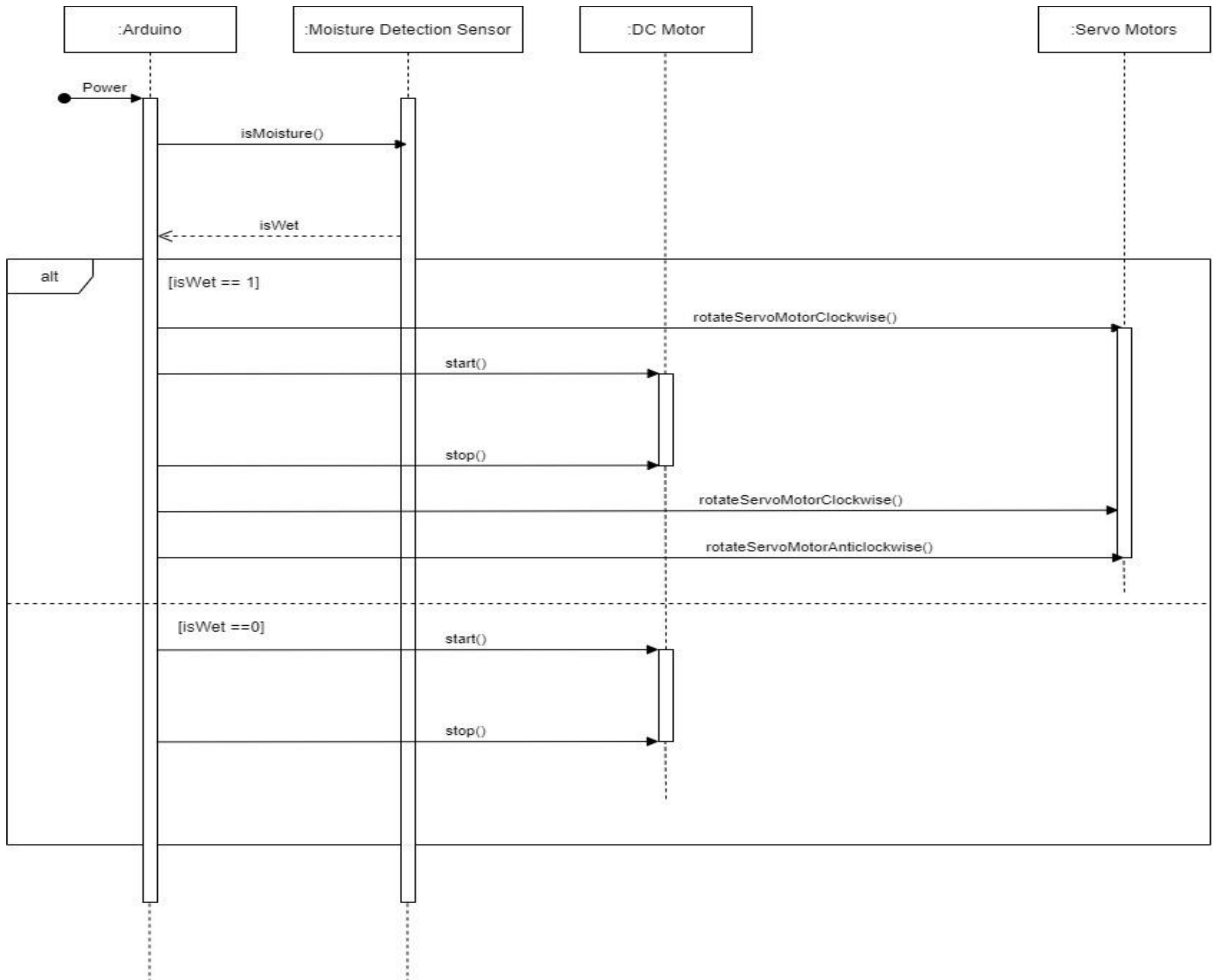

Fig7. Sequence diagram for the moisture detecton module

5.2.6 Metal detection module

5.2.6.1 Description

This module consists of an inductive proximity sensor along with a servo motor and a flap-like mechanism attached to the servo motor to push waste off the belt. The servo motor is activated once the inductive proximity sensor detects the waste to be metallic. If it is non-metallic, then the waste is moved further on the belt to classify it as glass or plastic.

5.2.6.2 Use case diagram

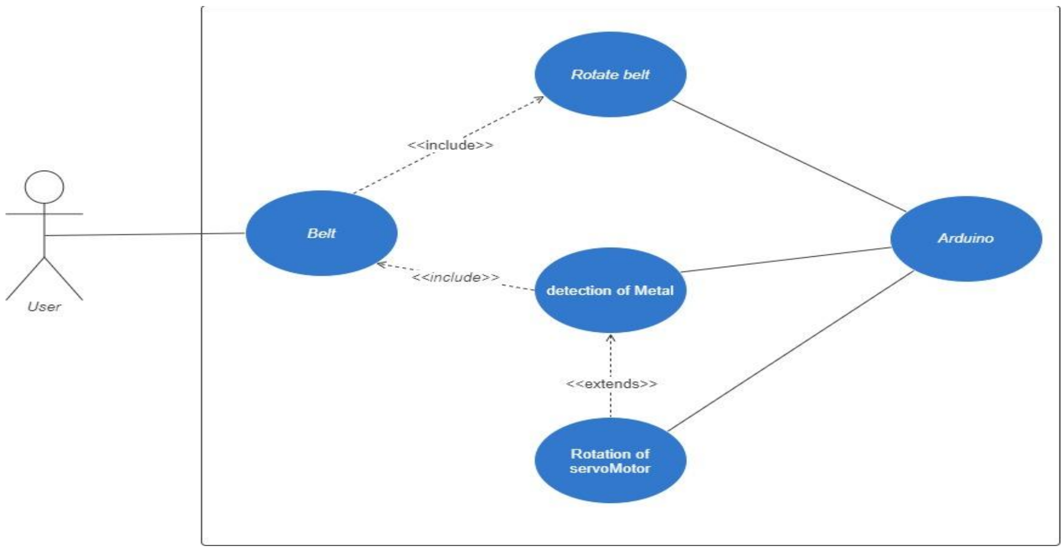

Fig8. Usecase diagram for the metal detection module.

Use Case Item	Description
Belt	It includes the conveyor belt made of rexine material used to move the waste from the source to respective bins.
Rotate belt	It includes two 12V DC motors used to drive the conveyor belt.

Detection of Metal	It includes an inductive proximity sensor that detects the material as metallic or non-metallic when the material comes in the vicinity of the sensor.
Rotation of Servo Motor	It consists of a servo motor and flap attached to it which is used to push waste off the belt when detected as metallic waste.
Arduino	It is the microcontroller that contains the logic for driving DC motors and coordinates with the inductive proximity sensor and respective servo motor.

Table 3. Usecase description for the metal detection module.

5.2.6.3 Sequence diagram

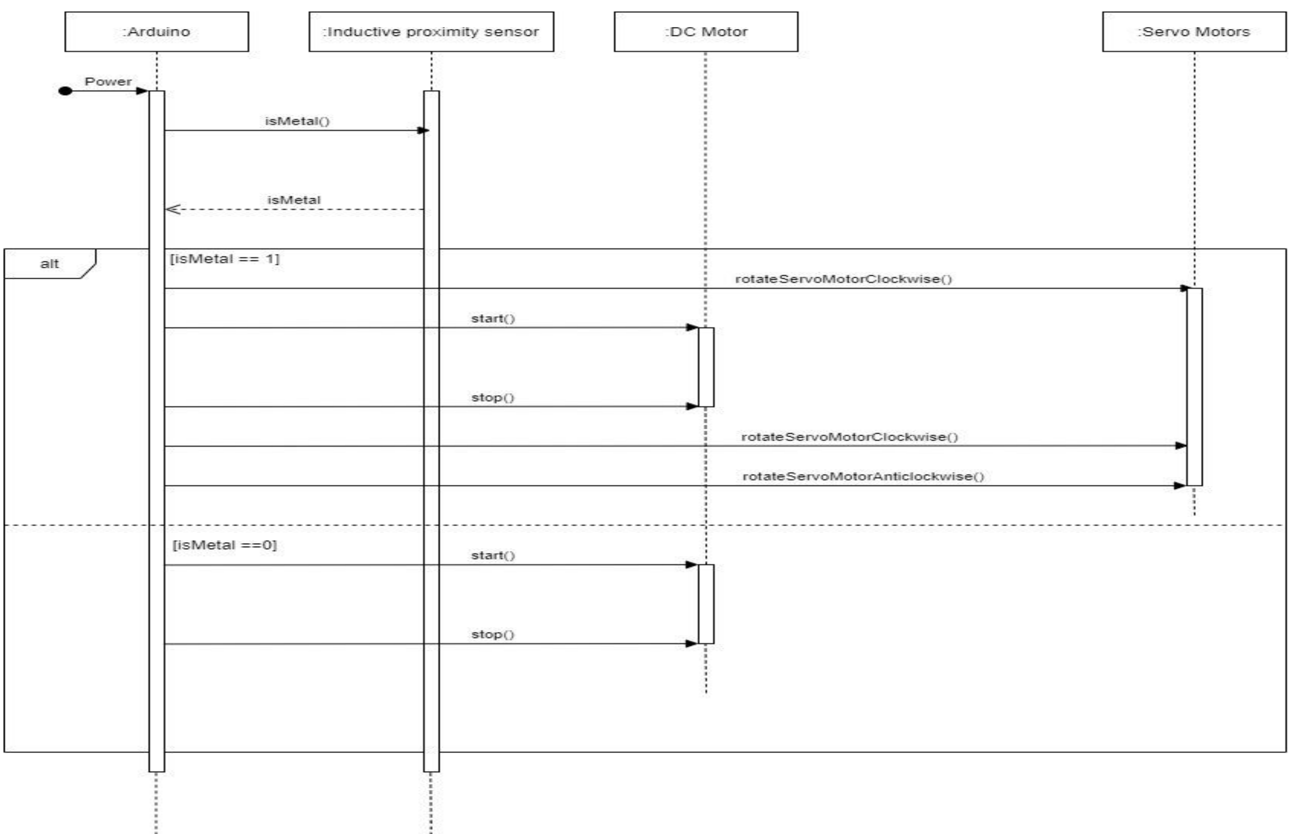

Fig9. Sequence diagram for the metal detection module.

5.2.7 Plastic and glass detection module

5.2.7.1 Description

This consists of an ultrasonic sensor, a python client program, a python server program, a servo motor along with a flap-like mechanism for pushing waste off the belt, and a mobile camera for capturing images.

The ultrasonic sensor is connected to Arduino to sense the proximity of the waste. The Arduino is in turn connected to the python client program using a serial port connection.

Whenever the ultrasonic sensor detects the waste in its proximity, it activates the python client, which in turn captures the image from the mobile camera and sends the image to a server program running on google collaborator through a REST request.

The server has a pre-trained classifier that classifies the image as either glass or plastic. The category is sent back to the python client as a response to the REST request. Based on the response from the server, the client program writes values to Arduino to push waste off the belt if the waste is plastic else, it activates the DC motors so the glass waste can fall at the end of the belt.

5.2.7.2 Use case diagram

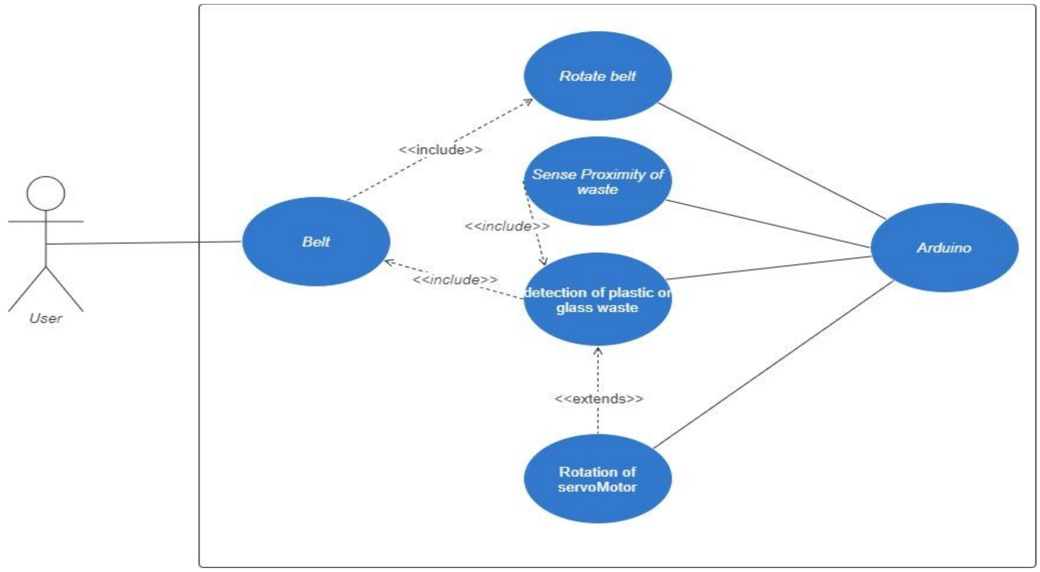

Fig10. Usecase diagram for the plastic and glass detection module.

Use Case Item	Description
Belt	It includes the conveyor belt made of rexine material used to move the waste from the source to respective bins.
Rotate belt	It includes two 12V DC motors used to drive the conveyor belt.
Sense Proximity of Waste	This includes an ultrasonic sensor which is used to detect the proximity of the waste on the belt.
Detection of Plastic or Glass Waste	It consists of a python client, a python server, and a mobile camera for capturing images. The python client is responsible for capturing images from the camera and sending them to the server for classification of material as plastic or glass. The server program has a pre-trained classification model that takes the image as input and sends the category of the waste in the image back to the client. The client coordinates with the Arduino for segregation.
Rotation of Servo Motor	It consists of a servo motor and flap attached to it which is used to push waste off the belt when detected as plastic waste.
Arduino	It is the microcontroller that contains the logic for driving DC motors and coordinates with the python client and respective servo motor.

Table 4. Usecase description for the plastic and glass detection module.

5.2.7.3 Sequence diagram

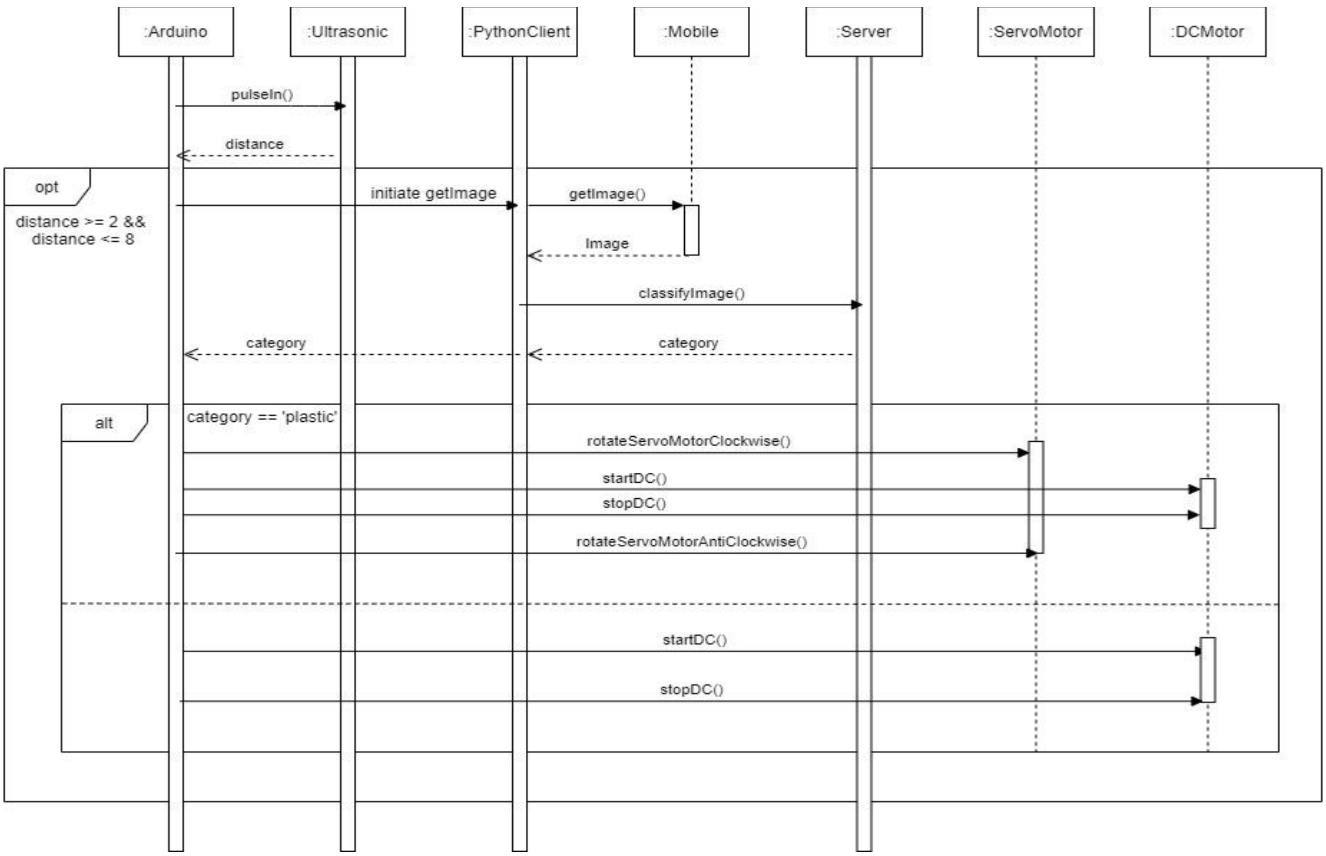

Fig11. Sequence diagram for the plastic and glass detection module.

CHAPTER 6

PROPOSED METHODOLOGY

The proposed system consists of a conveyor belt, ultrasonic sensor, moisture detection sensor, inductive proximity sensor, mobile camera, and Arduino. The system is designed to work in a low power consumption mode, this is achieved through the use of an ultrasonic sensor. The system will remain in an idle state until the waste is placed on the belt. Once the waste is placed, the belt starts moving and stops at the moisture detection module. At this point, the moisture detection sensor comes in contact with the material to check if it is wet waste. If the waste is wet, then the servo motor activates and pushes the waste into the wet waste bin. If the waste is dry, it is further moved on the conveyor belt to the metal detection module. Here, the inductive proximity sensor checks if the waste is metallic or non-metallic. If the waste is metallic, then the servo motor activates and pushes the waste into the metal waste bin. The non-metallic waste is further sent to the plastic or glass detection module. The entrance of waste to this module is identified using an ultrasonic sensor. Once the ultrasonic sensor senses the presence of waste, an image of waste is captured using a mobile camera in the client program. The client program further forwards it to a server that is responsible for the classification of an image as glass or plastic. If the image is identified as plastic, the waste is pushed off the belt into the plastic bin using servo motors. If it is glass, the conveyor belt starts moving and the glass waste falls into the glass bin placed at the end of the conveyor belt.

The flowchart below depicts the working of the system as explained above.

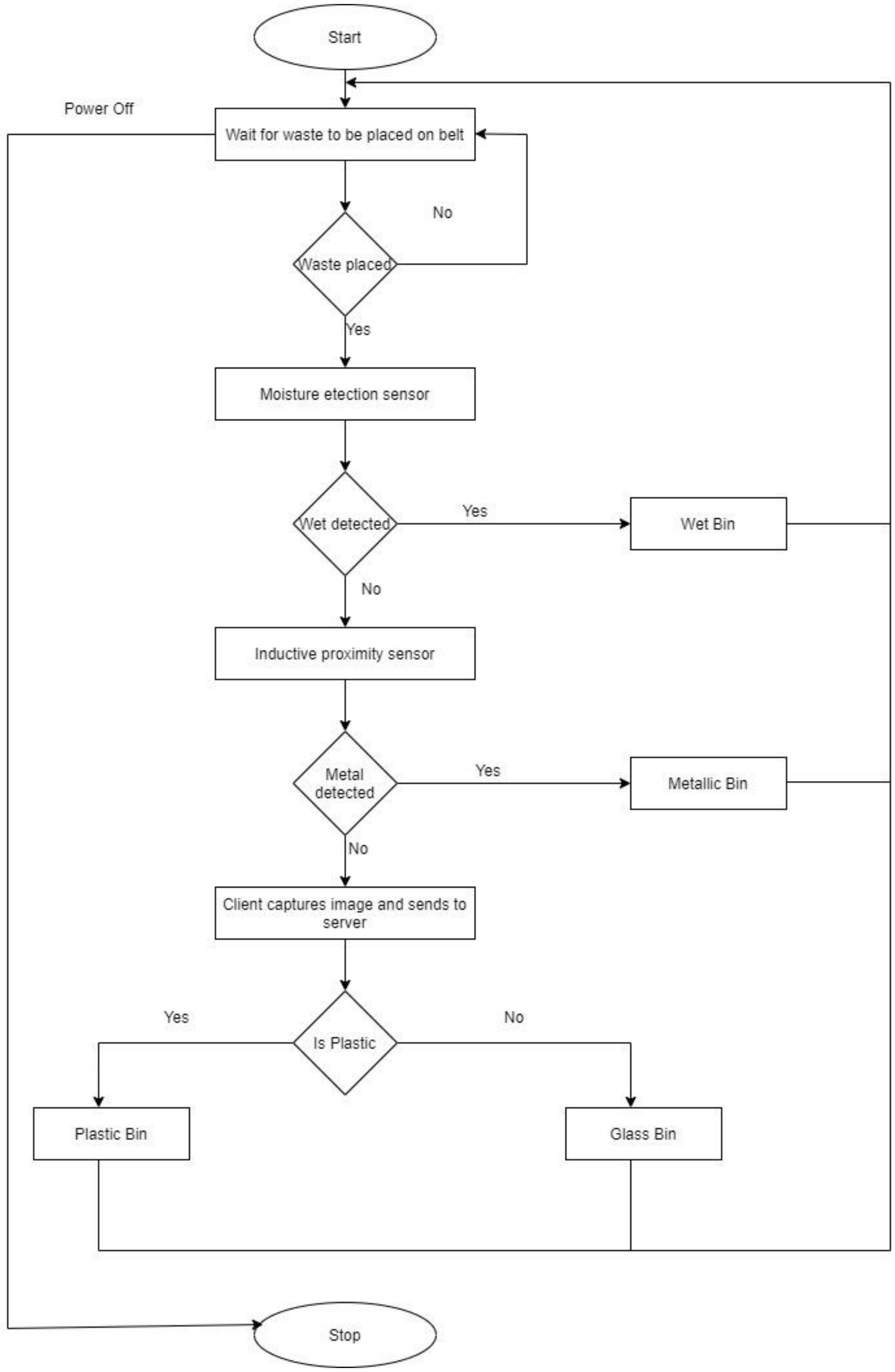

Fig. 12. A flowchart representing the algorithm of the Smart Waste Segregation System.

CHAPTER 7

IMPLEMENTATION

7.1 Conveyor belt module

Conveyor belt: The conveyor belt is used as a medium to carry waste from source to destination bins. It also helps to move the waste from one sensing module to another. The system requires a frame, rollers over which the belt can rotate. The frame is constructed using wooden planks, capable of holding two 12V DC motors that act as drivers for the belt. The rexine material stitched at both ends acts as a belt that rolls over the roller. PVC pipes are used as rollers. These pipes are connected to motors on one end and have a ball bearing on the other end. The ball bearings are used to facilitate the easy rotation of the roller. This roller along with the belt is responsible for converting the rotary motion of the DC motors to translatory motion for carrying the waste. The two DC motors are connected to an L298N motor driver that is powered using a normal power supply. These DC motors are controlled by two functions namely, start() and stop().

The start() function controls both the speed and direction of rotation of the motors. The motor is rotated at its full speed by setting the enable pins of the motor driver to maximum value i.e., 255. The motors are turned on when one of the pins is low and the other is high. If both pins are in the same state, the motor will be off. This state also determines the direction of rotation of the motor.

The stop() function is responsible for turning off the motors by setting the states of both the pins to either high or low.

```
#define setPinState( pin, state ) digitalWrite(pin,state);
int enablePinA = 6;
int enablePinB = 10;
int inputPin1 = 8;
int inputPin2 = 7;
int inputPin3 = 11;
int inputPin4 = 12;

void start()
{
   analogWrite(enablePinA, 255);
   analogWrite(enablePinB, 255);

   setPinState(inputPin1, HIGH);
   setPinState(inputPin2, LOW);

   setPinState(inputPin3, LOW);
   setPinState(inputPin4, HIGH);
}

void stop() {
   setPinState(inputPin1, LOW);
   setPinState(inputPin2, LOW);
   setPinState(inputPin3, LOW);
   setPinState(inputPin4, LOW);
}
```

Fig 13. The complete view of the conveyor belt.

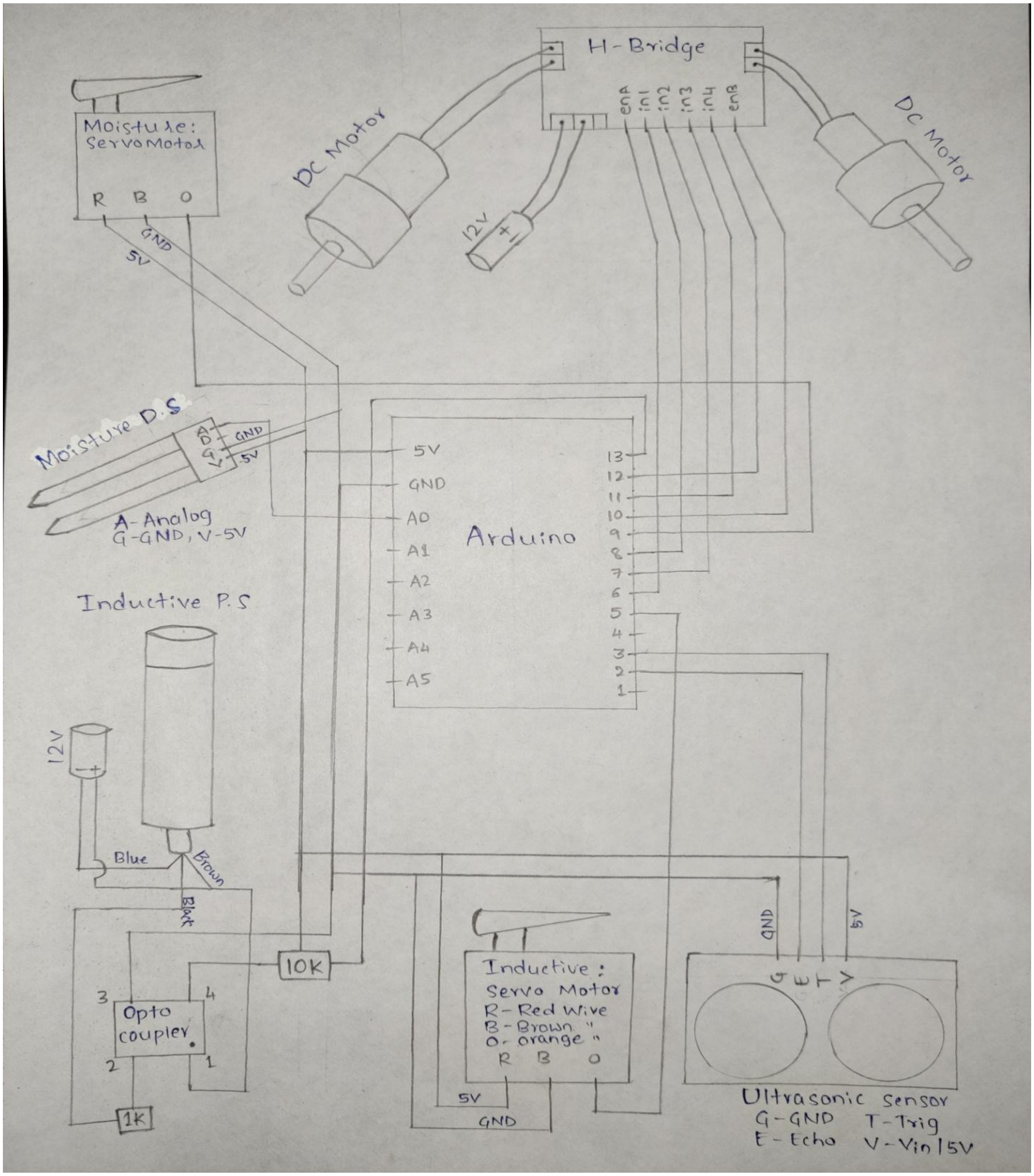

Fig 14.a. Circuit diagram of the system.

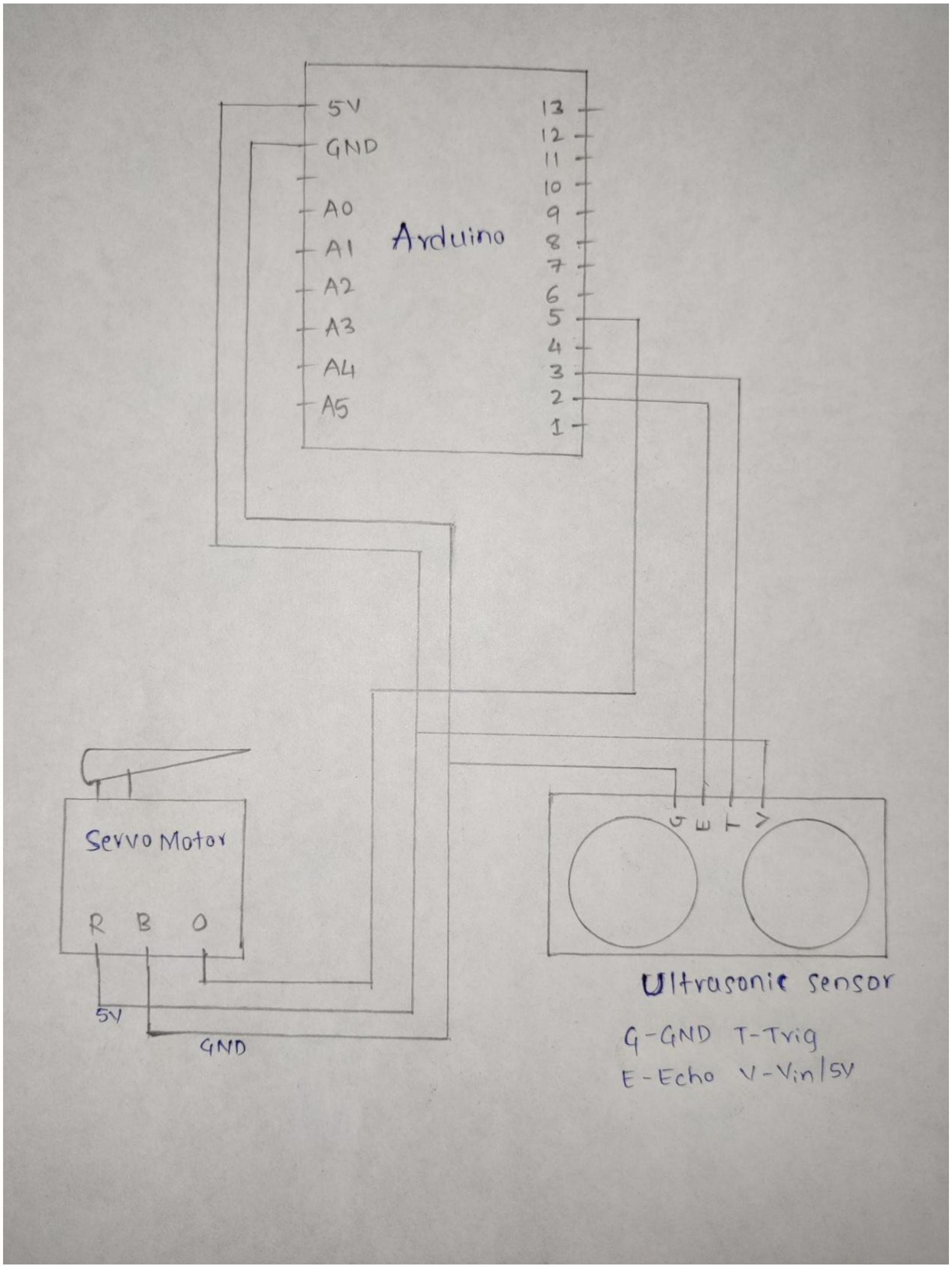

Fig 14.b. Circuit diagram of the system.

7.2 Conveyor belt power consumption mode

This functionality of the system is achieved using an ultrasonic sensor. The ultrasonic sensor used here is HC-SR04. It is used to measure the distance of any obstacle placed in front of it. It can convert electric signals to sound waves. The waves produced here are ultrasonic sound waves. This particular sensor produces waves at 40kHz. Once the microcontroller triggers the sensor, it emits ultrasonic waves. If there are any obstacles, the waves are reflected to the sensor. The time required for the waves to reach back to the sensor after it is emitted is used for calculating the distance of the obstacles.

The aforementioned principle matches our requirements. So, we have used an HC-SR04 sensor to detect if there is any waste placed on the belt. This is done by checking if the waste is in the range of 2cm to 8cm from the sensor. If found so, the belt is rotated and the process of segregation begins. If there is no waste placed on the belt, the belt remains in the stationary state thereby saving the power needed to rotate the conveyor belt.

7.3 Servo motor module

This module is used to push waste off the belt. A flap-like mechanism is attached to the servo motors that facilitate the purpose. This module is activated from the Arduino by invoking the pushWasteFromBelt utility function. This function is written in a generic way for it to work with different servo motors. This is achieved by passing the servo object as a parameter to the function.

This function internally calls various functions as listed below:

- **rotateServoMotorClockwise():** This function takes three parameters, servo motor object, start degree, and end degree. It rotates the servo motor arms that contain the flap in the clockwise direction starting from start degree to end degree.
- **rotateServoMotorAnticlockwise():** This function takes three parameters, servo motor object, start degree, and end degree. It rotates the servo motor arms that contain the flap in the anticlockwise direction starting from start degree to end degree.
- **start() and stop():** functions to control DC motors that rotate the belt.

The pushWasteFromBelt() function invokes the rotateServoMotorClockwise() with start and end degree as 135 and 85 respectively. Then it rotates the belt for 2.2 seconds to carry the waste from the sensing module to a point where it can be segregated. Then an extra push is given to the material so that it falls off the belt into the bin by rotating the servo arm clockwise by another 20 degrees. After this, the servo motor arm is rotated back to its original position using the rotateServoMotorAnticlockwise() function

```
void rotateServoMotorClockwise( Servo mServo, int startDegree, int endDegree )
{
   int angle;
   for( angle = startDegree; angle >= endDegree; angle -= 10 ) {
      mServo.write( angle );
      delay( 5 );
   }
}

void rotateServoMotorAnticlockwise( Servo mServo, int startDegree, int endDegree )
{
   int angle;
   for( angle = startDegree; angle <= endDegree; angle += 10 ) {
     mServo.write( angle );
     delay( 5 );
   }
}

void pushWasteFromBelt( Servo mServo )
{
   rotateServoMotorClockwise( mServo, 135, 85 );
   start();
   delay( 2200 );
   stop();

   rotateServoMotorClockwise( mServo, 85, 55 );
   delay( 200 );
   rotateServoMotorAnticlockwise( mServo, 55, 135 );
}
```

7.4 Moisture detection module

This module consists of a soil moisture detection sensor (FC-28), servo motor along with a flap-like mechanism attached to it. The soil moisture detection sensor is used to detect the presence of moisture in the waste material. The type of sensor used here is resistive i.e., the resistance is used as a measure to calculate the water content. This sensor has two probes in it through which electricity is passed. When the sensor comes in contact with wet materials, the resistance decreases since water is a good conductor of electricity. This reduction in resistance indicates the presence of water. The increase in conductance level is directly proportional to the amount of water contained in the material.

We have used the aforementioned sensor in the analog mode so that the output will be in the range of 550 - 0 which is then converted to percentage to set a threshold level. If the output is above the fixed threshold value, we classify it as wet waste and is separated accordingly.

Once the waste is detected as wet, it is pushed off the belt using a servo motor and pushWasteFromBelt utility function as described earlier. If the waste is not detected as wet, the belt is rotated for 1.1 seconds so that the waste will reach the next module i.e metal detection module. The time for which the belt is rotated is fixed based on experimentation results. In this way, this module meets its functional requirement of segregating wet waste from dry, which is processed further.

```
int moistureSensorPin = A0;
int moistureSensorOutput ;

int isMoisture()
{
   moistureSensorOutput= analogRead( moistureSensorPin );
   moistureSensorOutput = map( moistureSensorOutput, 550, 0, 0, 100 );
   Serial.print( "Mositure : " );
   Serial.print( moistureSensorOutput );
   Serial.println( "%" );
   if ( moistureSensorOutput > -75 ) {
      Serial.println( "wet waste" );
      return 1;
   }
   Serial.println( "dry waste" );
   return 0;
}
```

7.5 Metal detection module

This module consists of an NPN-type inductive proximity sensor, servo motor along with a flap-like mechanism attached to it. The inductive proximity sensor is used to detect the presence of metallic waste. The inductive proximity sensors are available in two types namely, NPN and PNP. Both of these can be used to detect the presence of metals and the only way in which they vary is in their output type. The NPN sensor outputs a value of 0 indicating the presence of metal whereas the PNP type gives some positive voltage as output. The NPN type is most suitable for our application hence we decided to use the same.

The inductive proximity sensor works on the principle of eddy currents. There is a coil inside the sensor that produces a magnetic field around it and when any metal is in the proximity of the sensor, eddy currents are introduced on the metal surfaces which reduces the amplitude of the magnetic field indicating it is metal.

To check if the waste is metallic or not, the isMetal() function is invoked. It returns 0 or 1 indicating non-metal or metal respectively. This functionality is achieved by reading the output of the sensor. Since it is NPN type, if the sensor output is 1, we return 0 indicating non-metal and if the sensor output is 0 then we return 1 from the function indicating the presence of metal.

Once the waste is detected as metal, it is pushed off the belt using a servo motor and pushWasteFromBelt utility function as described earlier.

If the waste is not detected as metal, the belt is rotated for one second so that the waste will reach the next module i.e., glass and plastic detection module.

The time for which the belt is rotated is fixed based on experimentation results.

In this way, this module meets its functional requirement of segregating metallic waste from other types, which is processed further.

```
int IPS_TO_ARDUINO = 13;
int STATE = LOW;

int isMetal()
{
   int mSensorOutput = digitalRead( IPS_TO_ARDUINO );

   if( mSensorOutput != STATE )
   {
     STATE = mSensorOutput;
     if( STATE == 0 )
       return 1;
     else
       return 0;
   }
}
```

7.6 Glass and plastic detection module

7.6.1 Overview

This module consists of an Arduino, an ultrasonic sensor, a mobile camera, a python client, a python server, and a servo motor along with a flap-like mechanism attached to it. This module uses an image classification model trained using fastai built on PyTorch. The image classification model is capable of detecting glass and plastics. It also requires the IP webcam application to be installed on the mobile to facilitate the capturing of images. The python client program is connected to the Arduino using a cable so that there is constant communication between them.

The glass or Plastic detection module is a separate subsystem and is isolated from all the other modules. This module has a separate Arduino and ultrasonic sensor attached to it. The waste that enters this system is detected using the ultrasonic sensor in similar lines as described in section 7.2. The Arduino is connected to a laptop using a cable so that both can communicate in serial mode. The python client is responsible for capturing the image of the material on the belt. It sends it to the server for classification and takes corresponding actions for segregating glass and plastics.

```
Servo mServo;

void loop() {
   char data;
   int dis = ultraSonic();
   if( dis >= 2 && dis  <= 9 )
   {
      stopDC();
      Serial.println( "1" );
      while( !Serial.available() );
      data = Serial.read();
      Serial.flush();
      if( data == '1' )
         pushWasteFromBelt( mServo );
      else
      {
         startDC();
         delay( 800 );
         stopDC();
         delay( 500 );
      }
   }
}
```

7.6.2 Python client module

The client program waits for the output of the ultrasonic sensor from Arduino that is connected in serial mode with the laptop running python client. The Arduino sends output as 1 if the material is on the belt. Once the client program receives the output as 1, it enters the image capture phase. In this phase, one of the requirements is that both the laptop and the mobile having IP webcam app must be connected to the same network. If the requirement is satisfied, it is possible to control the mobile camera from the laptop. Hence, the image from mobile is captured from the camera and is saved as a JPG file. Then this file is transmitted to the server with the help of a REST API using the content type as image/jpeg. Once the server sends the class of image as glass or plastic, the client program, connected in serial mode indicates the same to Arduino using binary values 0 or 1 where 0 indicates glass and 1 indicates plastic. If the output from the client program is 1, the pushWasteFromBelt() utility function as described in section 7.3 is invoked to push plastic waste off the belt since plastics are lighter when compared to glass. If the output is 0, then the belt moves forward for 0.8 seconds so that the glass waste falls into the bin that is placed at the end of the belt. This entire operation continues until the client program is stopped manually.

7.6.3 Python server module

This module has a machine learning module that uses CNN for image classification. The dataset used for training contains various images of glass and plastics organized in the respective folders. The image names are in a readable format that contains the type of material followed by a serial number in the type. The training of the model is a long and time-consuming process. Therefore we train the model once and then store the trained model in a pickle file for further use. This entire module is available as a REST API. The REST API is made available online using the ngrok package that gives a specific URL to the REST API. It receives an image as input in binary format, stores the received image in a file, and uses the model to predict if the object in the image is glass or plastic. This is sent as a response to the request. The figure below shows the pipeline carried out to achieve the purpose.

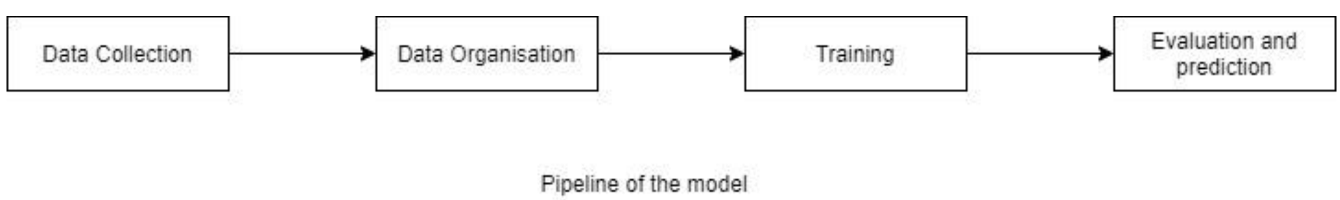

Fig 15. The pipeline of the image classification model.

7.6.3.1 Data preprocessing

This step involves extracting the zipped images. Then, the data is split into train, test, and validate sets. The ratio in which they are split is 2:1:1. The data is randomly sampled and then separated into the three aforementioned sets. The train and validate folders in turn contains the glass and plastic folders that have images of the respective categories in them. The test folder has randomly picked images of two categories in it which will be used for testing. This completes the preprocessing required for training.

7.6.3.2 Classification model

Resnet34 which is a CNN is trained for classifying the images. The Resnet34 is pre-trained on ImageNet Database. Hence, this model incorporates transfer learning i.e., it uses previously trained knowledge to classify the images. This model will therefore perform better when compared to normal CNN. This resnet34 model is then trained on the dataset that is organized as described earlier. We then save the trained model in a pickle file for future use. We use the test data to calculate the accuracy of the model by comparing the predicted classes of images to its actual class.

The function that classifies images, predict():

This function will be invoked by the REST API each time when it receives the request from the client program. This function takes an image as an input and then predicts the class of the image using the trained model. The model takes the image in tensor form only and not in any other form. Hence, this function also converts the image into a tensor, feeds it into the model, gets the predicted class from the model, and returns it to the API.

In this way, the desired functionality of segregating plastic from glass is achieved.

CHAPTER 8

RESULTS AND DISCUSSION

This section entails the results through various visuals of the system and discussion on the same.

8.1 Moisture detection module

The expectations of this module are as follows. The wet waste detected by the moisture detection sensor should be pushed off the belt using a servo motor with a flap. The dry waste should be carried forward on the belt to the next module for further segregation.

The figures below depict the system at different points in time during the segregation of the wet waste.

Fig.16. Moisture detection sensor in contact with the wet cloth.

In Fig.16., the focused region indicates that the wet cloth has entered the moisture detection module. The moisture detection sensor has come in contact with the wet cloth.

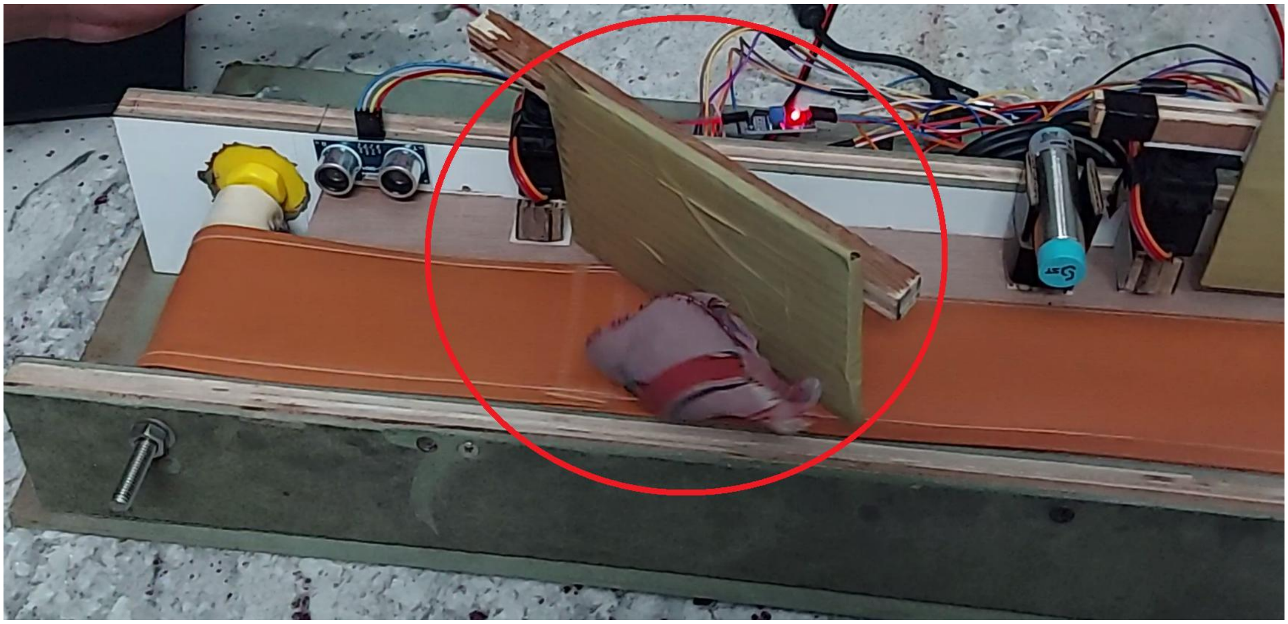

Fig.17. Servo motor of moisture detection module segregating the wet cloth.

Fig.17., shows the servo motor with the flap of this module pushing the wet waste off the belt since the moisture detection sensor has indicated the presence of moisture in the wet cloth.

Fig.18. Moisture detection sensor in contact with the metal tin.

In Fig.18., the focused region indicates that the metal tin has entered the moisture detection module. The moisture detection sensor has come in contact with the metal tin.

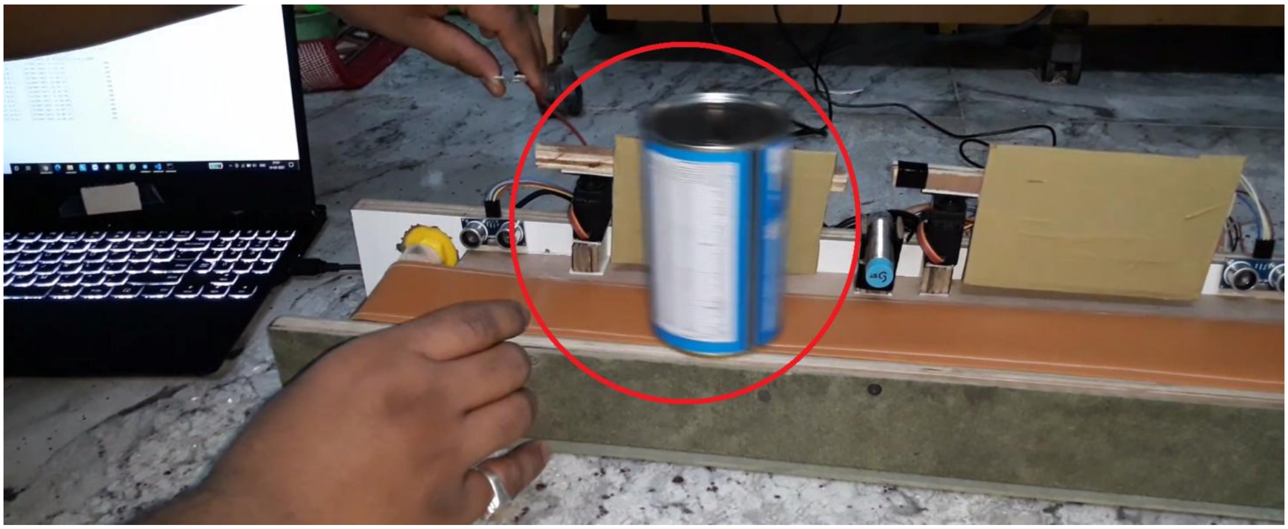

Fig.19. Metal tin moving to the next module after being identified as dry.

Fig.19., shows the metal tin moves further on the belt to the next module i.e metal detection module after being identified as dry waste by the moisture detection sensor. It can also be seen from the fig that the servo motor of the moisture detection module is in its original position without interfering with the motion of the conveyor belt.

All the figures above show that the moisture detection module is working as intended.

8.2 Metal detection module

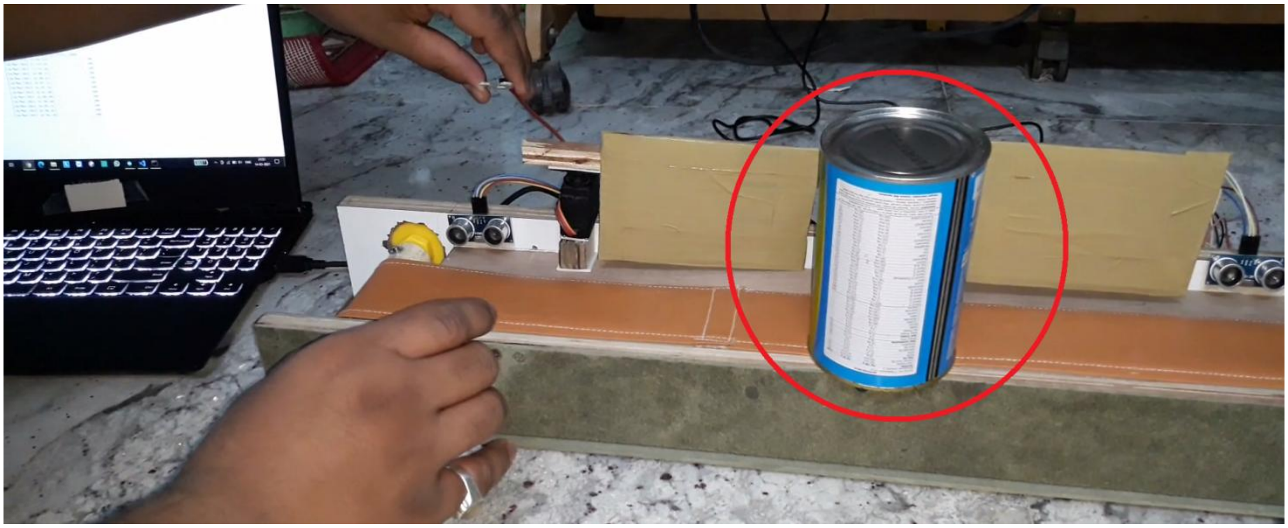

Fig.20. Inductive proximity sensor sensing the metal tin.

In Fig.20., the focused region indicates that the metal tin has arrived at the metal detection module after being sensed as dry waste by the moisture detection module. As can be seen, the inductive proximity sensor behind the tin is sensing the tin as metal or non-metal.

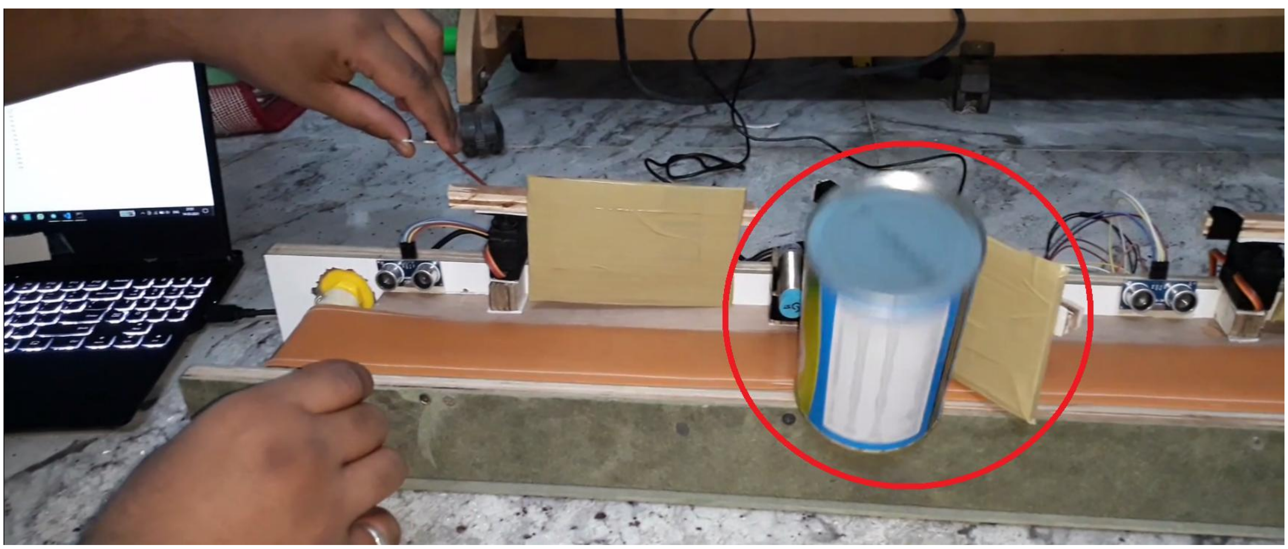

Fig.21. Servo motor of the metal detection module segregating the metal tin.

Fig.21., shows the servo motor with the flap of this module pushing the metallic waste off the belt since the inductive proximity sensor has detected it as metal.

Fig.22. Inductive proximity sensor sensing the plastic water bottle.

In Fig.22., the focused region indicates that the plastic water bottle has entered the metal detection module after being identified as dry waste from the moisture detection module. The inductive proximity sensor is sensing it as metal or non-metal.

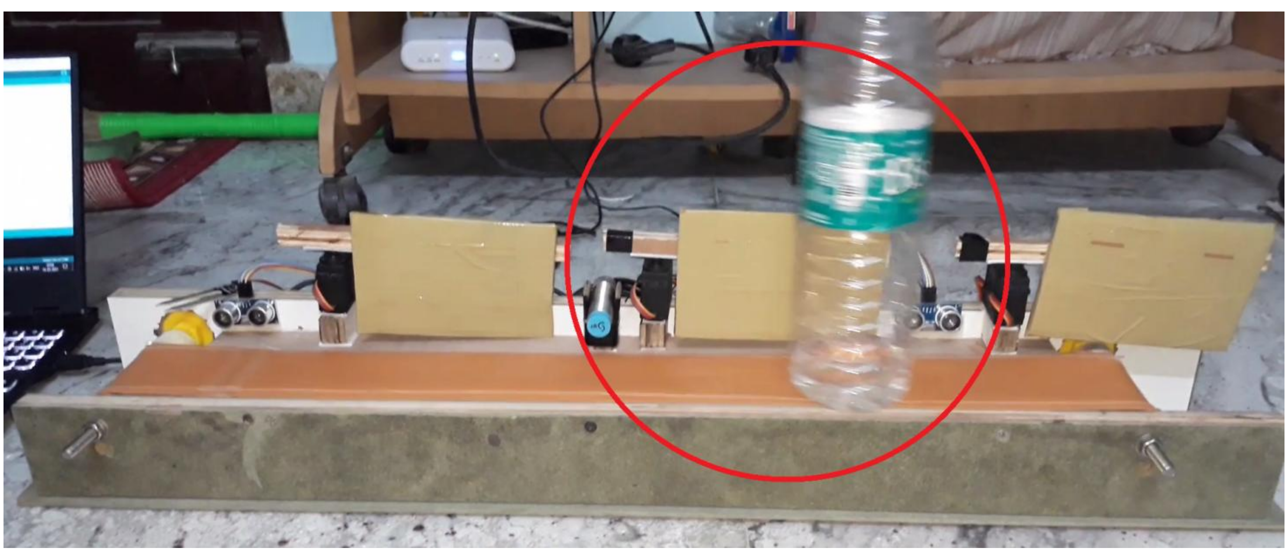

Fig.23. Plastic water bottle moving to the next module after being identified as non-metal.

Fig.23., shows the plastic water bottle moves further on the belt to the next module i.e glass or plastic detection module after being identified as non-metallic waste by the inductive proximity sensor. It can also be seen from the fig that the servo motor of the metal detection module is in its original position without interfering with the motion of the conveyor belt.

All the figures above show that the metal detection module is working as intended.

8.3 Glass or plastic detection module

Fig.24. Ultrasonic sensor sensing the entry of the plastic water bottle to the glass or plastic module.

As indicated by the red circle in Fig.24., the ultrasonic sensor is detecting the entry of the plastic water bottle into this module since it is dry and is a non-metal. The client program is activated to capture the image of the bottle through the mobile camera.

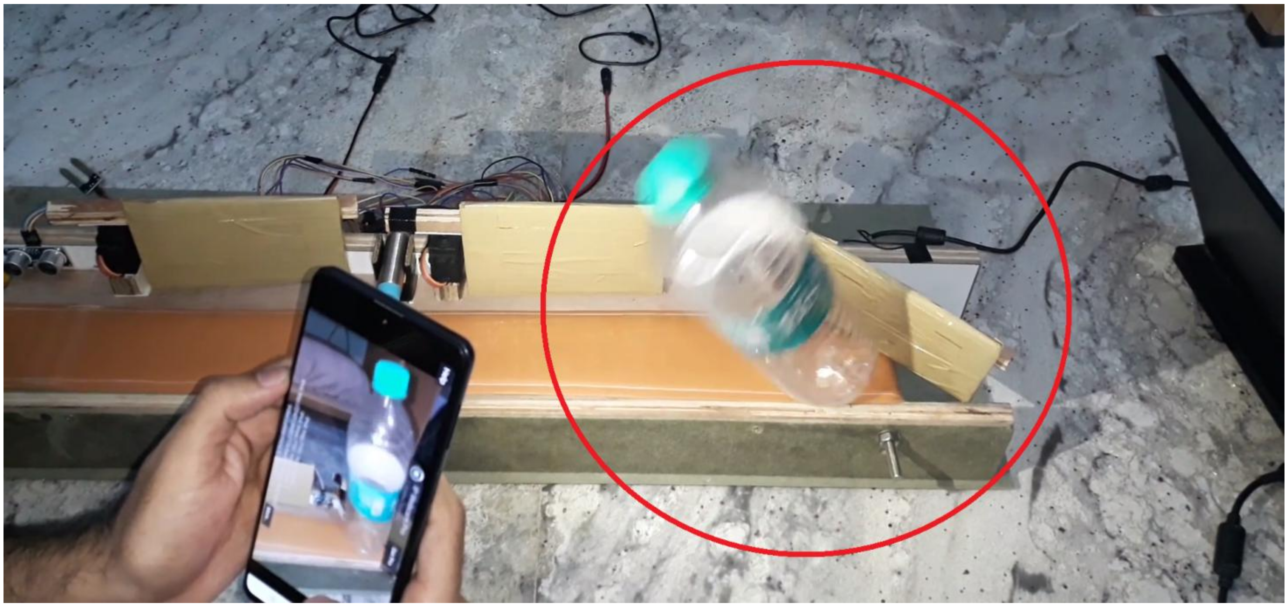

Fig.25. Servo motor of the glass or plastic detection module segregating the plastic water bottle.

Fig.25., shows the servo motor with the flap of this module pushing the plastic water bottle off the belt since it is classified as plastic by the server program.

CHAPTER 9

CONCLUSION AND FUTURE WORK

The world today is facing issues related to waste collection and disposal due to an increasing amount of waste generated and a lack of efficient methods adopted for disposal of the same. This could pose a serious threat to the ecosystem. The seriousness of the problem was taken into consideration and an attempt to design a solution for the problem was carried out. Our system is designed in a manner that combines multiple existing systems to deliver an easily usable and robust system. The proposed system is also cost-effective and easy to use and maintain.

The project was carried out in a structured way by starting off with a detailed literature survey on the problem statement and existing systems. After this phase, all the requirements and scope were finalized considering the feasibility. The design of the system was documented using the high-level and low-level design documents, which were later converted to implementation of the system. The implementation phase of the project was the most challenging one. Once the system was built, testing was carried out to ensure the intended functionality of the system.

The proposed system was intended to segregate the waste into different categories such as wet, metal, glass, and plastic. The wet and metal waste detection modules were successfully built using sensors whereas we faced difficulties during the segregation of glass and plastic wastes using capacitive proximity sensor since the output from the sensor was varying without a significant pattern. Therefore an image classifier model was built to differentiate between these categories. In this way, the entire system was implemented.

The proposed system provides the bare minimum solution to the problem. This can be enhanced by using various techniques as follows. The system can incorporate a chemical sensor to detect any harmful substances in the mixed waste and take necessary actions such as alert the municipal corporation or segregate them into a separate bin. Our system is incapable of handling mixed waste, this drawback can be fixed by segregating the dumped waste using multiple conveyor belts and screening mechanism before it reaches the main conveyor belt for segregation. IoT can be incorporated to collect the amount of waste segregated for each type and this can be used to perform analytics and visualizations. The fill level of each bin can be measured using IR/Ultrasonic sensors which can be used as an indication for emptying the bin.

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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 servo motor to push off the garbage to the wet bin if the garbage is detected as wet.

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

Glass or plastic detection module: This module consists of a mobile camera, python client, server and, image classifier model to differentiate between glass and plastics along with a servo motor to push off the garbage to the plastic bin if the garbage is detected as plastic.

JPG: It stands for Joint Photographic Experts Group. It is a standard extension used to store images with considerable loss.

app: Acronym for the word "application". Used to refer to any software application.

API: Acronym for Application Programming Interface. It defines an interface that enables two or more applications to communicate with each other.

REST: It stands for Representational State Transfer. The architecture used to build stateless APIs.

resnet: It stands for residual network. It is a deep Convolutional Neural Network.

APPENDIX B USER MANUAL

The link to datasheets for the hardware components used in the project is as follows.

https://drive.google.com/drive/folders/1LfQ24E1DXBx_o83an1xjRRTKKOu8wkXJ?usp=sharing