CHAPTER 1

INTRODUCTION

1.1 Definition

The exponential growth of waste materials due to rapid urbanization has put immense pressure on our environment. Improper handling and disposal of waste materials has polluted our ground water and land resources. Therefore, it is imperative that we examine the process of waste collection, segregation and automation for better management of the waste materials. This project provides a solution that can detect, identify and segregate waste items into dry and wet waste categories without any human assistance.[1] This work is an integration of machine learning concept, Image processing and embedded application using Raspberry Pi. Machine Learning is used to identify the category of the waste item. The proposed system does not use any sensors and is totally based on training hardware using artificial intelligence. The waste item is then dropped into its respective bin that are attached at the sides of the Robotic Arm. The system continues to travel in its path until the end of the area is reached. The designed segregation of bio-degradable and non-biodegradable items is carried out with 75% accuracy in short time. In today's world, garbage disposal has become a cause of major concern. An astounding amount of 0.1 million tons of waste is generated each day in our country. Unfortunately, only 5% of this colossal amount of waste is recycled. The huge amount of waste that is generated gets disposed by means which have an adverse effect on the environment due to improper waste management. Several advancements in technology has made it possible to convert waste items into useful sources of energy. But, to enable the waste items to be used as sources of energy, they need to be carefully processed and any non-biodegradable waste item needs to be removed.

The number of ways have been proposed to solve this challenge; in a new concept uses inductive proximity sensor and capacitive sensing module that can sort wastes at the initial stage of segregation. Segregating module-DC geared motors sorts these wastes into three different categories, namely metal, dry and the wet waste. The waste segregation is carried out largely with the help of manual workers. The efficiency of manual segregation is low. The chances of a waste material being incorrectly classified are high due to human error. Along with that, the workers are subjected to the risk of infection and diseases which are very common in such working conditions [2]

Over 377 million urban people live in 7,935 towns and cities and generate 62 million tonnes of municipal solid waste per annum. Only 43 million tonnes (MT) of the waste is collected, 11.9 MT is treated and 31 MT is dumped in landfill sites. Solid Waste Management (SWM) is one among the basic essential services provided by municipal authorities in the country to keep urban centers clean. However, almost all municipal authorities deposit solid waste at a dump yard within or outside the city haphazardly. Experts believe that India is following a flawed system of waste disposal and management.

The key to efficient waste management is to ensure proper segregation of waste at source and to ensure that the waste goes through different streams of recycling and resource recovery. Then reduced final residue is then deposited scientifically in sanitary landfills. Sanitary landfills are the ultimate means of disposal for unutilised municipal solid waste from waste processing facilities and other types of inorganic waste that cannot be reused or recycled. Major limitation of this method is the costly transportation of MSW to far away landfill sites.

Waste segregation using deep learning is proposed for faster and cleaner working. It involves acquiring images from camera with detection, object recognition, prediction and classification into categories as wet and dry waste.

1.2 Challenges associated with waste management in India

India faces major environmental challenges associated with waste generation and inadequate waste collection, transport, treatment and disposal. Current systems in India cannot cope with the volumes of waste generated by an increasing urban population and this impacts on the environment and public health.[3]

Figure 1.1: Clean & Green volunteers in Bangalore

1.2.1 Waste Generation in India

According to the Press Information Bureau, India generates 62 million tonnes of waste (mixed waste containing both recyclable and non-recyclable waste) every year, with an average annual growth rate of 4% (PIB 2016). The generated waste can be divided into three major categories: Organic (all kinds of biodegradable waste), dry (or recyclable waste) and biomedical (or sanitary and hazardous waste).

As shown in Figure 1.2, nearly 50% of the total waste is organic with the volumes of recyclables and biomedical/hazardous waste growing each year as India becomes more urbanized (McKinsey Global Institute 2010).

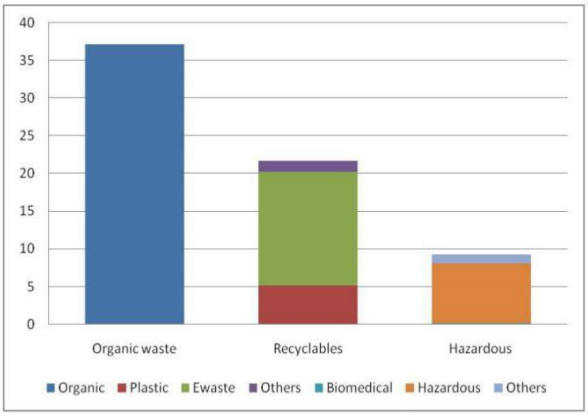

Figure 1.2: Waste Composition of India, in Million Metric Tonnes per annum.

1.2.2 Statistics on waste generation and waste characterization data

India is experiencing rapid urbanization while remaining a country with physical, climatic, geographical, ecological, social, cultural and linguistic diversity. The population of India was 1252 million in 2013, compared with 1028 million in 2001. Population growth is a major contributor to increasing MSW in India . Waste generation rate depends on factors such as population density, economic status, level of commercial activity, culture and city/region. Figure 1 provides data on MSW generation in different states, indicating high waste generation in Maharashtra (115 364–19 204 tonnes per day), Uttar Pradesh,Tamil Nadu, West Bengal (11 523–15 363 tonnes per day), Andhra Pradesh, Kerala (7683–11 522 tonnes per day) and Madhya Pradesh, Rajasthan, Gujarat, Karnataka and Mizoram (3842–7662 tonnes per day).[3]

Lower waste generation occurs in Jammu and Kashmir, Bihar, Jharkhand, Chhattisgarh, Orissa, Goa, Assam, Arunachal Pradesh, Meghalaya, Tripura, Nagaland and Manipur (less than 3841 tonnes per day).[3]

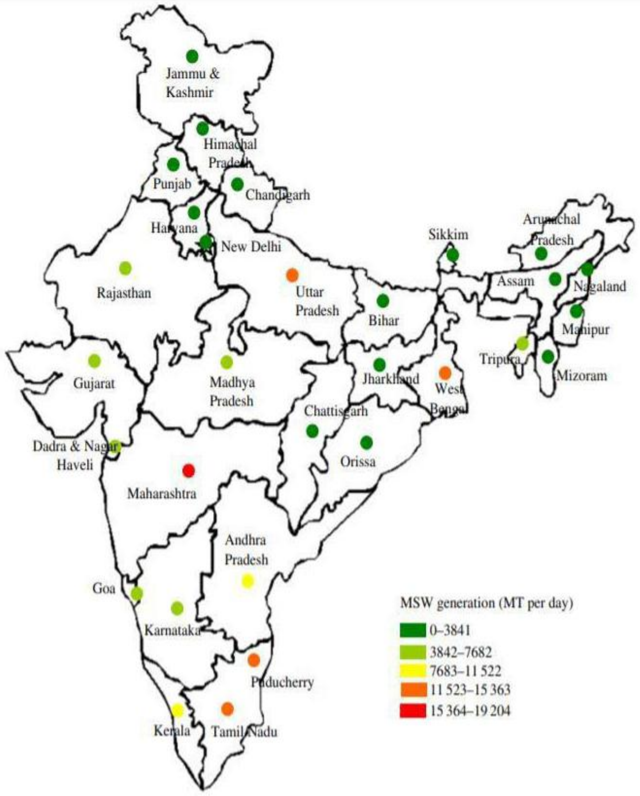

Figure 1.3: State-level statistics of MSW generation in India (2009–2012)

1.3 Problem Definition

Segregation is the most important step for the waste treatment. Diverse waste materials require different ways of treatment; mixed waste cannot be treated. As waste is segregated, it can be treated accordingly. Biodegradable waste can be deposited in vacant land for composting or can be sent to dumping ground. Non-biodegradable waste can be further recycled or can be treated separately. Segregation makes the recycling of the waste easier.

The table below shows us easy ways of recognizing the different categories of household garbage into ‘wet waste’ consisting of organic & biodegradable waste and ‘dry waste’ inorganic and recyclable waste. Dry waste can be further divided into hazardous waste and e-waste before recycling.

Wet waste	Dry waste
Kitchen waste	Plastic bags, polythene covers, wrappers
Rotten fruits and vegetables	Metal items, tin cans, foils, sheets, scraps, etc
Paper bags & Newspapers	Tetra pack
Cotton clothes and rags	Glass bottles, bulbs, window panes, etc.
Thin sheets or pieces of wood	Synthetic cloth fabric
Cardboard	E-waste such as batteries, CDs, toys, etc

Figure 1.4: List of household waste segregation

Figure 1.5: Waste Segregation bins labels

1.4 Problem Statement

1) To develop a robotic arm that will pick up garbage. This part of the system will let people not to touch garbage by their hand.

2) The system will be capable to sort different types of wastes to different baskets based on their type.

4) The system will be able to move around to pick up the waste. Thus,covering a larger ground area.

3) A mechanism will be used to differentiate among different types of waste materials namely paper,dry leaves and fruit waste.

CHAPTER 2

LITERATURE SURVEY

2.1 Existing systems

In the existing system a solution is provided that can detect, identify and segregate waste items into dry and wet waste categories without any human assistance. This work is an integration of machine learning concept, Image processing and embedded application using Raspberry Pi.

Machine Learning is used to identify the category of the waste item. The proposed system is totally based on training hardware using artificial intelligence. The waste item is then dropped into its respective bin that are attached at the sides of the Robotic Arm. The system continues to travel in its path until the end of the area is reached.

2.1.1-AGDC: Automatic Garbage Detection and Collection

Siddhant Bansal, Seema Patel ,Ishita Shah , Prof. Alpesh Patel , Prof. Jagruti Makwana , Dr. Rajesh Thakker

Waste management is one of the significant problems throughout the world. Contemporaneous methods find it difficult to manage the volume of solid waste generated by the growing urban population. In this paper, we propose a system which is very hygienic and cheap that uses Artificial Intelligence algorithms for detection of the garbage.

Once the garbage is detected the system calculates the position of the garbage by the use of the camera only. The proposed system is capable of distinguishing between valuables and garbage with more than 95% confidence in real time. Finally, a robotic arm controlled by the microcontroller is used to pick up the garbage and places it in the bin.

Concluding, the paper explains a system that is capable of working as a human in terms of inspecting and collecting the garbage. The system is able to achieve 3-4 frames per second on the Raspberry Pi, capable of detecting the garbage in real time with 90%+ confidence.

Outcomes of the paper

AGDC is the robotic system, in which machine learning algorithms are used for the detection of the garbage lying on the ground. After detection of the garbage, the position of the garbage is calculated. This position is shared serially with a microcontroller controlling the robotic arm. A robotic arm collects the detected garbage and puts it into a container which is attached to a robot. Hence, this system can be used as a substitute for humans for finding and collecting the garbage.

The progression of this paper is as follows, in the 1st portion of the methodology, Machine Learning approach for the detection of the garbage is explained. Which includes the description of the object detection and CNN models for the computer vision. In the 2nd portion of the methodology, algorithms for finding the position of the garbage with respect to the camera are described.

This location is sent to the microcontroller using serial communication which is explained in the section-3. Now as explained in the section-4 of the methodology, the microcontroller uses that location to control the robotic arm which is used to pick the garbage and place it in the dustbin.

2.1.2 - Waste Segregation Using Machine Learning

Yesha Desai , Asmita Dalvi , Pruthviraj Jadhav , Abhilasha Baphna

The present Indian government has started different projects for advancing sanitation and neatness. Mega cities in India, for example, Ahmedabad, Hyderabad, Bangalore, Chennai, Kolkata, Delhi and more noteworthy Mumbai have dynamic monetary development and high wastage per capita. Scratch issues and difficulties such as absence of gathering and isolation at source, shortage of land, dumping of e-Waste, and so on.

The present waste accumulation framework assembles a wide range of waste in an unsorted way by utilizing physical work. The isolation of this waste is exceptionally repetitive, tedious and wasteful undertaking, which is numerous a period dangerous to the soundness of the specialists. Subsequently, there is requirement for a framework, which robotizes the procedure of waste isolation, with the goal that the junk transfer can be executed effectively and productively.

The proposed framework utilizes machine learning strategies such as, CNN to accurately characterize the loss into degradable and non-degradable. The grouped waste can be isolated into different classifications utilizing a flap. The computerized order subsequently helps during the time spent for sanitation. The ordered waste can be additionally arranged and concurring handled by the businesses

This model can be scaled up to a modern level with the goal that it can be utilized as a part of semi- urban and urban territories. Keywords: Waste, Waste Segregation, Machine Learning, Convolutional Neural Network (CNN), degradable, non-degradable, Raspberry Pi.

Outcomes of the paper

By studying relevant self-assembly technologies of the swarm robot and considering current situations of self-assembly control, this paper comes up with a distributed control method for self-assembly according to distance priority. This solution measures distance through simple local communication and lowers traditional blindness of random control by providing optimum local navigation, so as to improve efficiency of local self-assembly. In addition, this paper has successfully verified effectiveness of this method by studying self-assembly efficiency in a simulation experiment. For further research of distributed control over the swarm robot, algorithms should be applied to real simulation robots. To improve time efficiency of self-assembly, synchronous coordination during navigation and assembly process shall be a major focus. In addition, robots shall be set to form up different adaptive topological morphology according to interactions with application conditions, so as to provide effective control for practical application of self-assembly of the swarm robot.

2.1.3 - Challenges and opportunities associated with waste management in India

Kumar S, Smith S.R, Fowler G, Velis C, Kumar SJ, Arya S.R, Kumar R, Cheeseman C

India faces major environmental challenges associated with waste generation and inadequate waste collection, transport, treatment and disposal. Current systems in India cannot cope with the volumes of waste generated by an increasing urban population, and this impacts on the environment and public health. The challenges and barriers are significant, but so are the opportunities. This paper reports on an international seminar on ‘Sustainable solid waste management for cities: opportunities in South Asian Association for Regional Cooperation (SAARC) countries’ organized by the Council of Scientific and Industrial Research-National Environmental Engineering Research Institute and the Royal Society. A priority is to move from reliance on waste dumps that offer no environmental protection, to waste management systems that retain useful resources within the economy. Waste segregation at source and use of specialized waste processing facilities to separate recyclable materials has a key role. Disposal of residual waste after extraction of material resources needs engineered landfill sites and/or investment in waste-to-energy facilities. The potential for energy generation from landfill via methane extraction or thermal treatment is a major opportunity, but a key barrier is the shortage of qualified engineers and environmental professionals with the experience to deliver improved waste management systems in India.

Outcomes of the paper

Population growth and particularly the development of mega cities is making SWM in India a major problem. The current situation is that India relies on inadequate waste infrastructure, the informal sector and waste dumping. There are major issues associated with public participation in waste management and there is generally a lack of responsibility towards waste in the community. There is a need to cultivate community awareness and change the attitude of people towards waste, as this is fundamental to developing proper and sustainable waste management systems. Sustainable and economically viable waste management must ensure maximum resource extraction from waste, combined with safe disposal of residual waste through the development of engineered landfill and waste-to-energy facilities. India faces challenges related to waste policy, waste technology selection and the availability of appropriately trained people in the waste management sector. Until these fundamental requirements are met, India will continue to suffer from poor waste management and the associated impacts on public health and the environment.

2.1.4 Waste Segregation in India: A wake up call

Abhinav Tyagi

All of us are familiar with the dustbin and household waste management. However, have we ever given a thought, what happens to the household waste that is thrown out of our houses every day? If we think of garbage disposal, we will realize it gets loaded on municipal trucks and is dumped on landfills in city outskirts regularly. Beyond this, most of us would rarely bother about it, like what is going to happen to it after the dumping? Is it going to be treated? What would be the condition of villages in such dump zones? Does it have any effect on the people living nearby?

Today, solid waste segregation is the biggest challenge faced by urban areas and metropolitan cities across the world. Especially, in a country like India which has weak environmental regulations, the situation is becoming worse. Satyamev Jayate, the popular TV talk show hosted by Aamir Khan highlighted the seriousness of this issue recently. According to a report from Delhi Development Authority, the city of Delhi alone produces 25,000 tons of waste every day. This waste is dumped in the various locations around the city like Ghazipur, Okhla and Balsawa.

2.1.5- Waste Segregation Using Smart Robotic Arm

V.V.Joshi, Rohan Ghugikar, Bhagavat Bhise, Pradip Bhawar, Shivam Kakade

Waste segregation is a simple method of reducing the amount of waste dumped into our landfills. People who not aware of waste segregation for these guidelines are implemented by the government with regards to waste segregation but these efforts have yet to touch the mindset of the people.

Large amount of recyclable waste that are not maximized and which is different in proper waste segregation. A solution to this is Automated Waste Sorter (AWS) and Mobile Robot Waste Deliver System are intended to automate the sorting process of paper, glass and metal. Along with this we integrate a robot system to deliver the process of collecting the waste that is to be sorted by the AWS, to minimize the human interference. For each material to control we approach the sensor array, along with a robotic arm as the Automated Waste Sorter. The Mobile Robot Delivery System is composed of a robot that is able to mechanically pick up the waste and put it in appointed trash bin

Outcomes of the paper

The robotic arm will able to sort out the three different materials like paper, glass and metals. When the sensors are triggered the motor-powered arm is actuated and the materials are dispensed onto its proper bins.

2.1.6- Advanced Robot for Automatic Waste Segregation and Status Alert

Sneha M P, Varshitha C K , Vandhana H S, Varshini H K , Dr. M B Anandaraju

One of the main concerns with our environment has been solid waste management which in addition to disturbing the balance of environment also has adverse effect on health of the society. Effective waste management is one of the major problems of the present era.

The segregation, handling, transportation and disposal of waste are to be properly managed so as to minimize the risk to the environment. The economical value of waste is best realized when it segregated. The traditional way of manually segregating the waste utilizes more human effort, time and cost.

This work proposes an economic automated waste segregator which is cheap and easy to use solution for a segregation system at households, so that it can be sent directly for processing. It is designed to sort the refuse into metallic waste, wet waste, dry waste, and plastic waste.

Outcomes of the paper

The proposed system “advanced robot for automatic waste segregation and status alert” sorts wastes into three different categories, namely metal, dry and the wet (organic) waste. Separating our waste is essential as the amount of waste being generated today causes immense problem.

Whenever any kind of waste is placed on the robotic hand the sensors will sense the type of material and container moves in such a way that the particular partition will be exactly below the robotic hand so that robotic hand flips the waste into that particular partition.

2.1.7-Automated Waste Collection And Segregation Robot

Nishaanth Kumar Alwar.R, Praveen.R, Sanjeev Kumar.K.V, Viswaeswaran.M, P.Sathish Kumar Solid waste management is a worldwide phenomenon. Improper management of solid waste (SW) cause hazards to inhabitants. It is a big challenge all over the world for human beings. The problem requires sustained group work and indefatigability on the part of the workers.

This problem can be solved by automation and swarm intelligence. This project is mainly about upgrading the waste collection robot to the next level by adding the segregation process. To control the robot coding is used, which performs inverse kinematic calculations and communicates the proper angles serially to a microcontroller Atmel 89S52 that drives the DC motors and servo motors automatically with the capability of modifying position, speed and acceleration.

The collection of waste material is performed by using robotic hand with the help of servo motor and the waste materials are segregated by using blower, electromagnet in the conveyor system. The implementation of our project in the domestic and industrial environment will enable us to bring contribution to the society.

Outcomes of the paper

In this Paper, development of a waste collection and segregation robot that make collection and segregation of waste much more easier. The design is done so that the knowledge of designing, mechanism and forces

Objective

i) To develop the Waste collection and segregation robot.

ii) To fabricate Waste collection and segregation robot of low cost and time consuming.

iii) To implement an incentive Reward system that works automatically to avoid working stress and to avoid waste overflow.

2.1.8` - Cost-Effective Autonomous Garbage Collecting Robot System Using Iot And Sensor Fusion.

A. Sengupta, V. Varma, M. Sai Kiran, A. Johari, Marimuthu R.

Waste collection and management is a subject undergoing extensive study, and solutions are being proposed meticulously. Thanks to an exponential rise in population, there is an increased production of waste, and also a significant amount of litter consisting of plastic, paper, and other such products carelessly thrown about and scattered in public.

Thus, the need for a more robust waste management strategy is essential. Presently, waste management techniques either lack efficiency, or incur high costs. Several Governmental as well as Non-Governmental Organizations have made efforts to clean public spaces. Collection of the unorganized and scattered garbage is the preliminary and most vital step of waste management, following proper segregation and disposal. This paper proposes, explains, and implements an original concept of making a modular, scalable and cost effective system for garbage collection. Making an efficient use of Internet of Things to maintain a constant connection between a central server and a network of garbage processing and collecting, independent, autonomous robots, we rely upon such a system to produce accurate results, as well as considerably reduce the cost, hence providing a feasible solution to minimize human effort and costs during waste collection.

It provides a gateway towards implementing garbage collecting robots in smart cities. Rather than describing the design of a single robot, we propose an entire system of robots interconnected in a network, to optimize time, energy and overall speed.

There is always a trade-off between accuracy, efficiency and cost of garbage collection, especially when robots get into the picture. Our purpose is to find the perfect balance between these factors.

Outcomes of the paper

The novelty of this paper lies in the concept of a cost-effective system that uses IoT to optimize the working of a network of garbage collectors. Furthermore, the adoption and optimization of the best features from existing technologies, into a single integrated system makes it very efficient.

The deployment of OpenCV in a real-time environment for image processing and classification, makes the module dynamic in contrast to MATLAB based classifiers which is widely used, and lacks real-time processing capabilities.

The third novelty of this paper is that the processing is done on a central server, which can handle several tasks at a time, and thus a swarm of garbage collecting robots can be deployed simultaneously. Thus, while optimizing cost, there is also no compromise in the quality and functionality of the robot, hence rendering it an optimal prototype for garbage collecting applications. This approach can be used to simultaneously deploy multiple robots in different areas. The system is cost-effective and time optimal.

2.2 Proposed System

The system provides a solution that can detect, identify and segregate waste items waste into categories like Fruit waste, Leaf and Paper without any human assistance. The arm is mounted on a movable bot to cover majority of the ground area. This work is an integration of machine learning concept, Image processing and embedded application using Raspberry Pi.

A total of 1500 images is taken as a data set of waste of 3 different categories i.e, leaf, paper and fruit waste.All the images are labeled using LableImg. It is then split into test and train data set. A TensorFlow model called SSD_Mobilenet_v2 is the model we have chosen to perform the detection.The entire model is trained for our particular data set.The model is then exported and used.

2.2.1 Single shot object detection algorithm

1. The first step is to load a pre-trained object detection network with the OpenCV's dnn (deep neural network) module.
2. This will allow us to pass input images through the network.
3. We then obtain the output bounding box (x, y)-coordinates of each object in the image.
4. Now we write the code to print the name of the detected object.
5. Their confidence scores are also printed.
6. At last, we look at the output of MobileNet Single Shot Detector for our input images.

2.2.2 Initial Approach of the proposed system

- A smaller robotic arm with servo controllers :

  Ayasa robotic arm was a pre-built system which was controlled by four 9g servo motors.[10] Speed of the arm was not controllable.
- Moving bot :

  A bot with DC motors and metal shield was used
- Image capture using SCP protocol :

  Images were transferred using SCP protocol using SSH connection where the end system would access the Pi and the Pi would transfer the image.[11]
- Dataset with 200 images of one class label :

  200 images with the same background and no variation of only paper waste was used.
- Canny's edge detection :

  Initial approach to detect the waste was done using edge detection.
- CNN algorithm for classification :

  To classify the waste into different categories.[12]
- Faster-rcnn model for object detection :

  Initial object detection TensorFlow mode that was used
- Live data detection using webcam :

  The detection was performed on live data and not on a particular image
- All individual systems with no automation :

  All the systems were made to run individually without any use of MQTT protocol

CHAPTER 3

SYSTEM REQUIREMENTS SPECIFICATION

3.1 Purpose

The main purpose of the project is to develop a robotic arm that will detect,classify and pick up garbage and drop the garbage into the buckets attached to it’s either side. This part of the system will let people not to touch garbage by their hand. The system will be capable to sort different types of wastes to different baskets based on their type.

3.2 Background

Self-autonomous bots are mainly designed to move around freely on the ground and to automatically detect waste if any and to sort them into it’s respective bins.

3.3 Hardware Requirements

- Raspberry Pi3 ModelB.
- Raspberry Pi Camera Module
- Micro SD Card.
- Power Bank
- Servo motors
- Johnson motors
- Arduino Uno
- Arduino Nano
- Lead Acid Battery
- Regular wheels

3.3.1 Raspberry Pi 3 Model B

The Raspberry Pi 3 Model B is the earliest model of the third-generation Raspberry Pi. It replaced the Raspberry Pi 2 Model B. A tiny Raspberry Pi that's affordable enough for any project. This powerful credit-card sized single board computer can be used for many applications and supersedes the original Raspberry Pi Model B+ and Raspberry Pi 2 Model B. Whilst maintaining the popular board format the Raspberry Pi 3 Model B brings you a more powerful processor, 10x faster than the first generation Raspberry Pi.

Figure 3.1: Raspberry Pi 3 Model B

The specification of Raspberry Pi Zero are as follows,

- 1.2GHz quad-core64bit CPU
- 1GB RAM
- Full size HDMI port
- Micro USB OTG port
- 4 USB2 ports
- HAT-compatible 40-Pin header
- Composite video and reset headers
- CSI camera port (v1.3only)

3.3.2 Raspberry Pi Camera Module

Figure 3.2: Raspberry Pi Camera Module

From its first launch the Raspberry Pi has had a connector on it to attach a camera to the GPU (the Video Core 4 Graphics Processing Unit on the Raspberry Pi) . This connection uses the CSI -2 electrical protocol and is a standard used in most mobile phones. It is an extremely fast connection, which on the Raspberry Pi is capable of sending 1080p sized images (1920x1080 x10bpp) at 30 frames per second, or lower resolution at even higher frame rates.

3.3.3 Micro SD card

Figure 3.3: Micro SD card

The micro SD card is a key part of the Raspberry Pi, provides the initial storage for the Operating System and files. Storage can be extended through many types of USB connected peripherals. 16 GB SD card is used for our Project.

3.3.4 Power bank

Figure 3.4: Power bank

Raspberry Pi zero can work without the main connection by using power bank that can be connected to Raspberry Pi zero using an USB cable.

3.3.5 Servo motors

- **Micro Servo 9g**

Figure 3.5: Servo motor

A **servo motor** is an electrical device which can push or rotate an object with great precision. If you want to rotate and object at some specific angles or distance, then you use servo motor. It is just made up of simple motor which run through **servo mechanism**. If motor is used is DC powered then it is called DC servo motor, and if it is AC powered motor then it is called AC servo motor. We can get a very high torque servo motor in a small and light weight packages. Doe to these features they are being used in many applications like toy car, RC helicopters and planes, Robotics, Machine etc.

Servo motors are rated in kg/cm (kilogram per centimeter) most hobby servo motors are rated at 3kg/cm or 6kg/cm or 12kg/cm. This kg/cm tells you how much weight your servo motor can lift at a particular distance. For example: A 6kg/cm Servo motor should be able to lift 6kg if the load is suspended 1cm away from the motors shaft, the greater the distance the lesser the weight carrying capacity.

Servo Mechanism

It consists of three parts:

- Controlled device
- Output sensor
- Feedback system

Servo Working

A servo consists of a Motor (DC or AC), a potentiometer, gear assembly and a controlling circuit. First of all we use gear assembly to reduce RPM and to increase torque of motor. Say at initial position of servo motor shaft, the position of the potentiometer knob is such that there is no electrical signal generated at the output port of the potentiometer. Now an electrical signal is given to another input terminal of the error detector amplifier. Now difference between these two signals, one comes from potentiometer and another comes from other source, will be processed in feedback mechanism and output will be provided in term of error signal. This error signal acts as the input for motor and motor starts rotating. Now motor shaft is connected with potentiometer and as motor rotates so the potentiometer and it will generate a signal. So as the potentiometer's angular position changes, its output feedback signal changes. After sometime the position of potentiometer reaches at a position that the output of potentiometer is same as external signal provided. At this condition, there will be no output signal from the amplifier to the motor input as there is no difference between external applied signal and the signal generated at potentiometer, and in this situation motor stopsrotating.

Controlling Servo Motor:

All motors have three wires coming out of them. Out of which two will be used for Supply (positive and negative) and one will be used for the signal that is to be sent from the MCU.

Servo motor is controlled by PWM (Pulse with Modulation) which is provided by the control wires. There is a minimum pulse, a maximum pulse and a repetition rate. Servo motor can turn 90 degree from either direction form its neutral position. The servo motor expects to see a pulse every 20 milliseconds (ms) and the length of the pulse will determine how far the motor turns. For example, a 1.5ms pulse will make the motor turn to the 90° position, such as if pulse is shorter than 1.5ms shaft moves to 0° and if it is longer than 1.5ms than it will turn the servo to 180°.

- **Mg 996r**

Figure 3.6: Mg996r servo motor

The **MG996R** is a **metal gear servo motor** with a maximum stall torque of 11 kg/cm. Like other RC servos the motor rotates from 0 to 180 degree based on the duty cycle of the PWM wave supplied to its signal pin.

There are lots of **servo motors** available in the market and each one has its own specialty and applications. The following two paragraphs will help you identify the right type of servo motor for your project/system.

Most of the hobby Servo motors operates from 4.8V to 6.5V, the higher the voltage higher the torque we can achieve, but most commonly they are operated at +5V. Almost all hobby servo motors can rotate only from 0° to 180° due to their gear arrangement so make sure your project can live with the half circle if no, you can prefer for a 0° to 360° motor or modify the motor to make a full circle. The gears in the motors are easily subjected to wear and tear, so if your application requires stronger and long running motors you can go with metal gears or just stick with normal plastic gear.

Next comes the most important parameter, which is the torque at which the motor operates. Again there are many choices here but let us assume the one with 2.5kg/cm torque which comes with the **MG996R Motor**. This 2.5kg/cm torque means that the motor can pull a weight of 2.5kg when it is suspended at a distance of 1cm. So if you suspend the load at 0.5cm then the motor can pull a load of 5kg similarly if you suspend the load at 2cm then can pull only 1.25. Based on the load which you use in the project you can select the motor with proper torque.

Characteristics of the Servo Motor -

- Operating Voltage is +5V typically
- Current: 2.5A (6V)
- Stall Torque: 9.4 kg/cm (at 4.8V)
- Maximum Stall Torque: 11 kg/cm (6V)
- Operating speed is 0.17 s/60°
- Gear Type: Metal
- Rotation : 0°-180°
- Weight of motor : 55gm
- Package includes gear horns and screws

3.3.6 Johnson Motor

Figure 3.7: Johnson Motor

300RPM 12V Johnson high torque DC geared motors for robotics applications. It gives a massive torque of 9Kgcm. The motor comes with metal gearbox and off-centered shaft.

Features

- 300RPM 12V DC motors with Metal Gearbox and Metal Gears
- 18000 RPM base motor
- 6mm Dia shaft with M3 thread hole
- Gearbox diameter 37 mm.
- Motor Diameter 28.5 mm
- Length 63 mm without shaft
- Shaft length 30mm
- 180gm weight
- 9.06kgcm Holding Torque

3.3.7 Arduino Uno

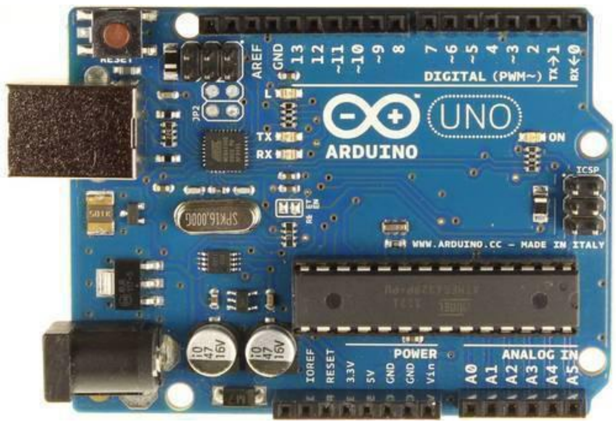

Figure 3.8: Arduino Uno

The Arduino UNO is the best board to get started with electronics and coding. If this is your first experience tinkering with the platform, the UNO is the most robust board you can start playing with. The UNO is the most used and documented board of the whole Arduino family.

Features of the Arduino UNO:

- Microcontroller: ATmega328
- Operating Voltage: 5V
- Input Voltage (recommended): 7-12V
- Input Voltage (limits): 6-20V
- Digital I/O Pins: 14 (of which 6 provide PWM output)
- Analog Input Pins: 6
- DC Current per I/O Pin: 40 mA
- DC Current for 3.3V Pin: 50 mA
- Flash Memory: 32 KB of which 0.5 KB used by boot-loader
- SRAM: 2 KB (ATmega328)
- EEPROM: 1 KB (ATmega328)
- Clock Speed: 16 MHz

3.3.8 Arduino Nano

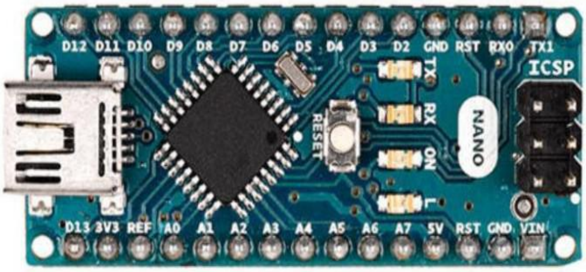

Figure 3.9: Arduino Nano

The Arduino board is designed in such a way that it is very easy for beginners to get started with microcontrollers. This board especially is breadboard friendly is very easy to handle the connections. Let's start with powering the Board.

Powering you Arduino Nano:

There are totally three ways by which you can power your Nano.

USB Jack: Connect the mini USB jack to a phone charger or computer through a cable and it will draw power required for the board to function

Vin Pin: The Vin pin can be supplied with a unregulated 6-12V to power the board. The on-board voltage regulator regulates it to +5V

+5V Pin: If you have a regulated +5V supply then you can directly provide this o the +5V pin of the Arduino.

Features of Arduino Nano

- Microcontroller - ATmega328P – 8 bit AVR family microcontroller
- Operating Voltage - 5V
- Analog Input pins - 6 (A0 – A5)
- Digital I/O pins - 14 (Out of which 6 provide PWM output)
- DC current on I/O pins - 40 mA
- DC current on 3.5V pin - 50 mA
- Flash Memory - 32 KB (2 KB is used for Bootloader)
- SRAM - 2 KB
- EEPROM - 1KB
- Frequency(Clock speed) - 16Mhz

3.3.9 Lead Acid Battery

Figure 3.10: Lead Acid Battery

Despite having a small energy-to-volume ratio and a very low energy-to-weight ratio, its ability to supply high surge contents reveals that the cells have a relatively large power-to-weight ratio.

Lead-acid batteries can be classified as secondary batteries. The chemical reactions that occur in secondary cells are reversible. The reactants that generate an electric current in these batteries (via chemical reactions) can be regenerated by passing current through the battery (recharging).

The chemical process of extracting current from a secondary battery (forward reaction) is called discharging. The method of regenerating active material is called charging.

3.3.10 Regular wheels

Figure 3.11: Regular wheel

A circular object that revolves on an axle and is fixed below a vehicle or other object to enable it to move easily over the ground.

3.2 Software Requirements

- Raspbian OS
- MQTT
- Tensor Flow
- Open CV
- SSD (Single Shot Detector)
- Arduino Uno Language(C/C++)
- Python

3.4.1 Raspbian OS

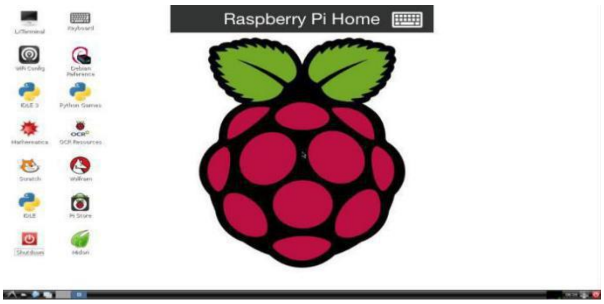

Figure 3.12 : The Raspbian Desktop

Although the Raspberry Pi's operating system is closer to the Mac than Windows, it's the latter that the desktop most closely resembles

It might seem a little alien at first glance but using Raspbian is hardly any different to using Windows (barring Windows 8 of course). There's a menu bar, a web browser, a file manager and no shortage of desktop shortcuts of pre-installed applications.

Raspbian is an unofficial port of Debian Wheezy arm with compilation settings adjusted to produce optimized "hard float" code that will run on the Raspberry Pi. This provides significantly faster performance for applications that make heavy use of floating point arithmetic operations. All other applications will also gain some performance through the use of advanced instructions of the ARMv6 CPU in Raspberry Pi.

Although Raspbian is primarily the efforts of Mike Thompson (MP Thompson) and Peter Green (plug wash), it has also benefited greatly from the enthusiastic support of Raspberry Pi community members who wish to get the maximum performance from their device.

3.4.2 MQTT

Figure 3.13: MQTT

MQTT stands for MQ Telemetry Transport. It is a publish/subscribe, extremely simple and lightweight messaging protocol, designed for constrained devices and low-bandwidth, high- latency or unreliable networks. The design principles are to minimize network bandwidth and device resource requirements whilst also attempting to ensure reliability and some degree of assurance of delivery. These principles also turn out to make the protocol ideal of the emerging ―machine-to-machine‖ (M2M) or ―Internet of Things world of connected devices, and for mobile applications where bandwidth and battery power are at a premium.[13]

3.4.3 Tensor Flow

Figure 3.14: Tensor Flow and content

Currently, the most famous deep learning library in the world is Google's TensorFlow. Google product uses machine learning in all of its products to improve the search engine, translation, image captioning or recommendations.

What is object detection?

Given an image or a video stream, an object detection model can identify which of a known set of objects might be present and provide information about their positions within the image.

An object detection model is trained to detect the presence and location of multiple classes of objects. For example, a model might be trained with images that contain various pieces of waste, along with a *label* that specifies the class of waste they represent (e.g. paper, fruit, or leaf), and data specifying where each object appears in the image.

When we subsequently provide an image to the model, it will output a list of the objects it detects, the location of a bounding box that contains each object, and a score that indicates the confidence that detection was correct.

To give a concrete example, Google users can experience a faster and more refined the search with AI. If the user types a keyword a the search bar, Google provides a recommendation about what could be the next word.

Google does not just have any data; they have the world's most massive computer, so Tensor Flow was built to scale. TensorFlow is a library developed by the Google Brain Team to accelerate machine learning and deep neural network research.

It was built to run on multiple CPUs or GPUs and even mobile operating systems, and it has several wrappers in several languages like Python, C++ or Java

3.4.4 OPENCV

Figure 3.15: OpenCV

OPENCV (Open Source Computer Vision Library) is an open source computer vision and machine learning software library ˙OPENCV was built to provide a common infrastructure for computer vision applications and to accelerate the use of machine perception in the commercial products. Being a BSD-licensed product, OPENCV makes it easy for businesses to utilize and modify the code. The library has more than 2500 optimized algorithms, which includes a comprehensive set of both classic and state-of-the-art computer vision and machine learning algorithms.

These algorithms can be used to detect and recognize faces, identify objects, classify human actions in videos, track camera movements, track moving objects, extract 3D models of objects, produce 3D point clouds from stereo cameras, stitch images together to produce a high resolution image of an entire scene, find similar images from an image database, remove red eyes from images taken using flash, follow eye movements, recognize scenery and establish markers to overlay it with augmented reality, etc.

OPENCV Structure and Content

OPENCV can be broadly structured into five primary components, four of which are shown in the figure 3.16. The CV component contains mainly the basic image processing and higher-level computer vision algorithms; MLL the machine learning library includes many statistical classifiers as well as clustering tools. High GUI component contains I/O routines with functions for storing, loading video & images, while CX Core contains all the basic data structures and content.

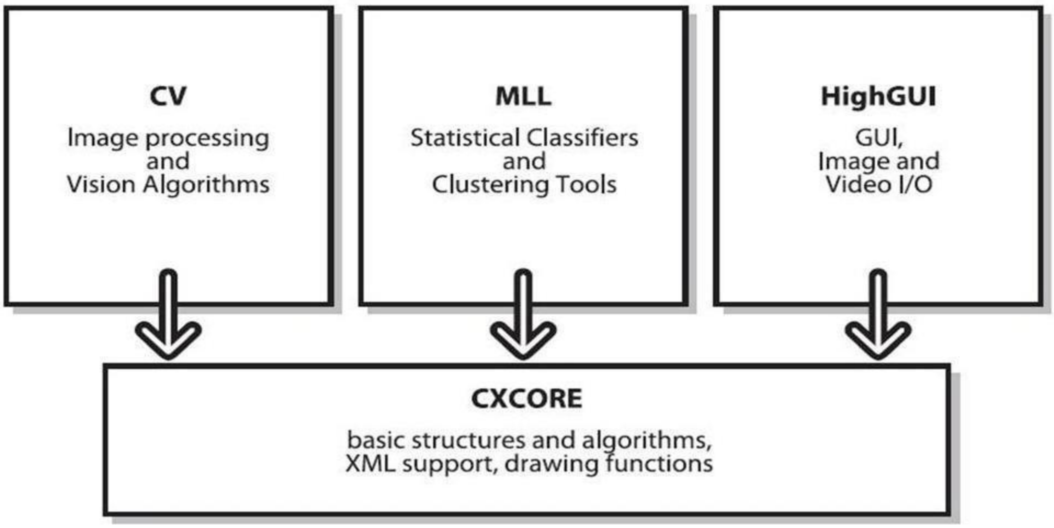

Figure 3.16: Structure of OPENCV and content

Why OPENCV?

1. Specific

OPENCV was designed for image processing. Every function and data structure has been designed with an Image Processing application in mind. Meanwhile, MATLAB, is quite generic. You can get almost everything in the world by means of toolboxes. It may be financial toolboxes or specialized DNA toolboxes.

2. Speedy

MATLAB is just way too slow. MATLAB itself was built upon Java. Also Java was built upon C. So when we run a MATLAB program, our computer gets busy trying to interpret and compile all that complicated MATLAB code. Then it is turned into Java, and finally executes the code.

If we use C/C++, we don't waste all that time. We directly provide machine language code to the computer, and it gets executed. So ultimately we get more image processing, and not more interpreting.

After doing some real time image processing with both MATLAB and OPENCV, we usually.got very low speeds, a maximum of about 4-5 frames being processed per second with MATLAB. With OPENCV however, we get actual real time processing at around 30 frames being processed per second.

Sure we pay the price for speed – a more cryptic language to deal with, but it's definitely worth it. We can do a lot more, like perform some really complex mathematics on images using C and still get away with good enough speeds for your application.

3.Efficient

MATLAB uses just way too much system resources. With OPENCV, we can get away with as little as 10mb RAM for a real-time application. Although with today's computers, the RAM factor isn't a big thing to be worried about. Thus we can see how OPENCV is a better choice than MATLAB for a real-time system.

3.4.5 SSD(Single Short Detector)

Figure 3.17: Single Shot Detector

Single Shot object detection or SSD takes one single shot to detect multiple objects within the image. As you can see in the above image we are detecting coffee, iPhone, notebook, laptop and glasses at the same time.

It composes of two parts

- Extract feature maps, and
- Apply convolution filter to detect objects

SSD is developed by Google researcher teams to main the balance between the two object detection methods which are YOLO and RCNN.

There are specifically two models of SSD are available

1. SSD300: In this model the input size is fixed to 300×300. It is used in lower resolution images, faster processing speed and it is less accurate than SSD512
2. SSD512: In this model the input size is fixed to 500×500. It is used in higher resolution images and it is more accurate than other models.

SSD is faster than R-CNN because in R-CNN we need two shots one for generating region proposals and one for detecting objects whereas in SSD It can be done in a single shot.

The MobileNet SSD method was first trained on the COCO dataset and was then fine-tuned on PASCAL VOC reaching 72.7% mAP (mean average precision).

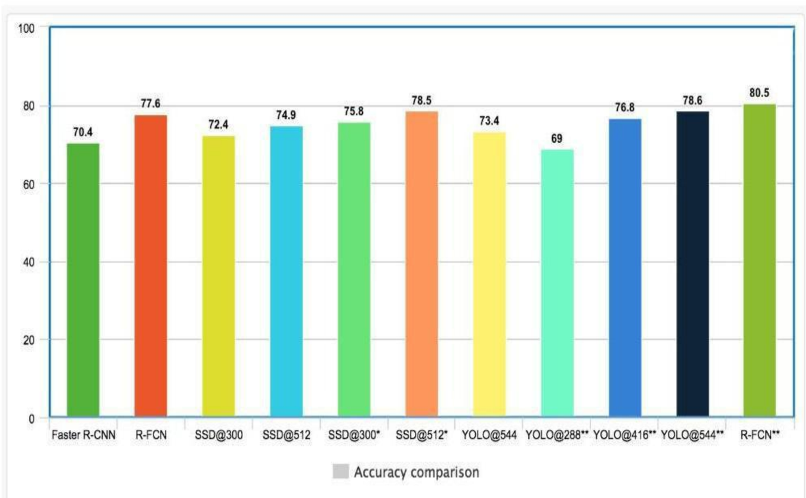

Figure 3.18: We can observe that R-FCN outperforms the accuracy

3.4.5 Arduino Programming Languages

Figure 3.19: Arduino Programming Languages

Arduino, natively, supports a language that we call the Arduino Programming Language, or Arduino Language.This language is based upon the Wiring development platform, which in turn is based upon Processing, which if you are not familiar with, is what p5.js is based upon. It's a long history of projects building upon other projects, in a very Open Source way.

3.4.6 Python

Figure 3.20: Python

Python is an interpreted high-level programming language for general-purpose programming. Created by Guido van Rossum and first released in 1991, Python has a design philosophy that emphasizes code readability, notably using significant whitespace. It provides constructs that enable clear programming on both small and large scales.

Python features a dynamic type system and automatic memory management. It supports multiple programming paradigms, including object oriented, imperative, functional and procedural and has a large and comprehensive standard library. Python interpreters are available for many operating systems.

3.5 Functional Requirements

- The system should correctly classify the various labels of the waste.
- The prediction algorithm used by the system must be accurate.
- The arm must pick up the correct classified waste object.
- The arm must correctly place the waste object in its respective bin.
- The arm and the bot should come back to the initial position of where it started.

3.6 Use Cases

- It is important to maintain cleanliness and hygiene of our country. The collected waste should be segregated during the initial stages. Thus, making it faster and easier to recycle.
- The Bot being remotely controlled by a human, helps in identification of the waste lying on the ground. The segregated waste will be placed into its respective baskets.

3.6.1 Acceptance Criteria

- Object is detected based on the images given to the trained model.
- Detected object will be present within a bounding box.

3.6.2 Dependencies

- Number of images provided for training the model.
- The robotic arm can lift the weight upto 240 grams
- The robotic arm does not cover a large area. It can lift objects placed in a certain position only.

3.6.1 Risk/Suggestions

- During the design and programming stages,mechanical part failure is not always taken intoaccount
- Power sources that have communication to the robotic arm can be disrupted and lead to undesired actions.

3.7 Non - Functional Requirements

Accuracy

The Robotic Arm should be able to segregate the waste correctly. The rate of accuracy must be high.

Look and Feel

The look and feel of the Robotic Arm should be simple and portable. All the components must be assembled neatly.

Safety

Workplace robotics safety is an aspect of occupational safety and health when robots are used in the workplace. This includes traditional industrial robots as well as emerging technologies such as drone aircraft and wearable robotic exoskeletons. Types of accidents include collisions, crushing, and injuries from mechanical part.

3.8 User Characteristics

- There is always a single user who controls the movement of the bot .
- The bot is made to stop when waste is detected .

CHAPTER 4

SYSTEM DESIGN

4.1 Architecture

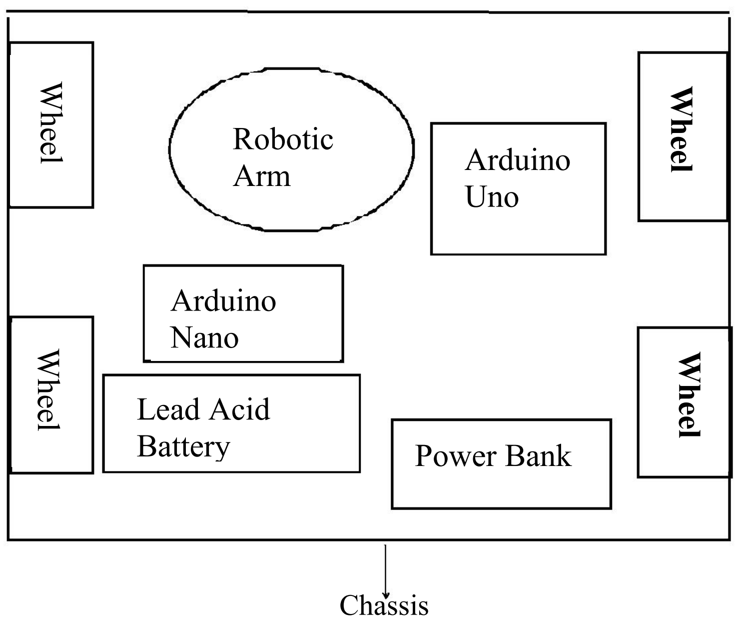

Figure 4.1: Architecture of proposed system

- The above figure represents the overall assembly of the system.
- The system consists of Raspberry Pi 3 Model B, Arduino Uno, Arduino Nano, Robotic arm,Servo motors, Power Bank,wheel and a Lead acid battery.
- The bot is controlled by a human via Bluetooth. The bot is made to stop in front of the waste that is lying on the ground.

4.2 Architecture of the Robotic Arm

Figure 4.2: The architecture of the 3D printed Robotic Arm

- A ready made .sdh file was downloaded which had designs of every part of the robotic arm
- These designs was 3D printed and then were assembled.
- The gripper used here can lift weight up to 240 grams
- The robotic arm will be mounted on a moving bot.
- The movements of the robotic arm is controlled by an Arduino.
- The robotic arm is controlled by 6 servo motors

4.3 Design of the Proposed System

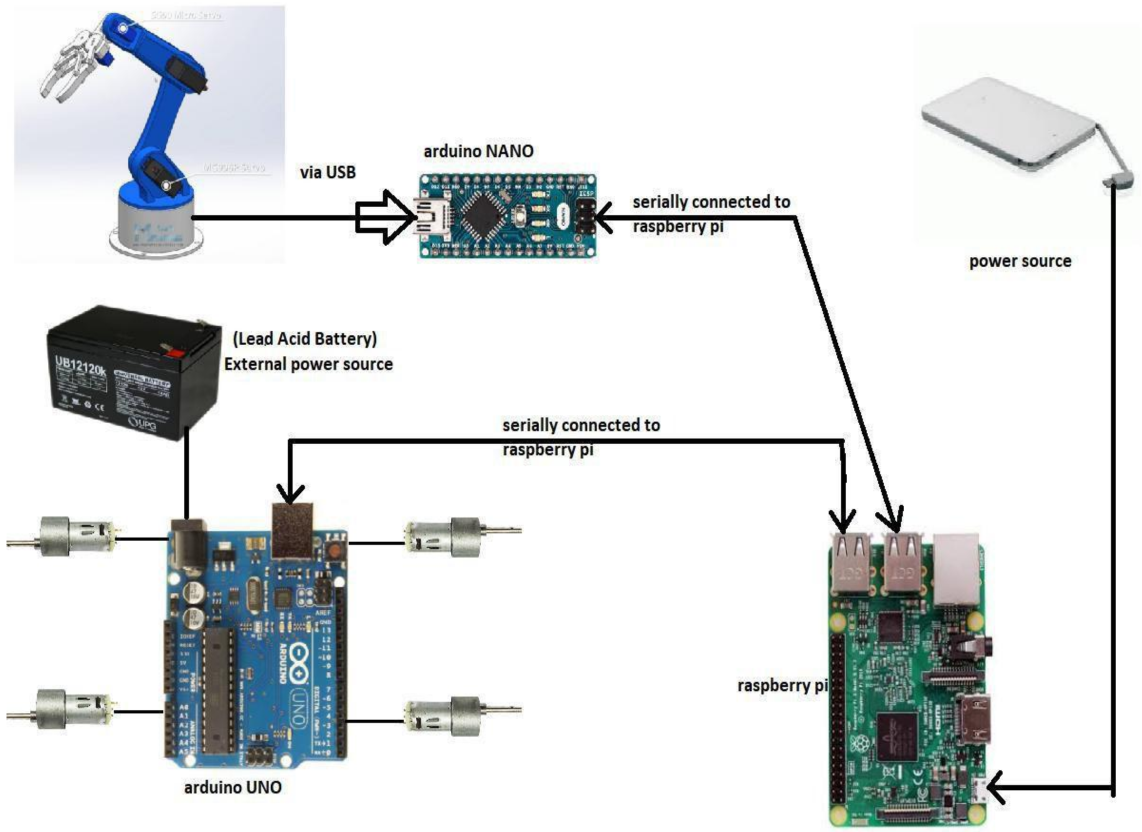

Figure 4.3: The above figure shows the entire setup of the robotic arm mounted on a moving bot.

- Wired connection is made between the robotic arm and Arduino Nano. Arduino Nano controls the movements of the robotic arm.
- Arduino Nano and Arduino Uno are connected to the Raspberry Pi serially.
- Lead Acid Battery acts as an external power source to Arduino Uno. It has a voltage capacity of 12V.
- Power bank supplies continuous power supply to the Raspberry Pi.
- Arduino Uno controls the movements of the Bot that carries the robotic arm.

4.4 Use Case Diagram

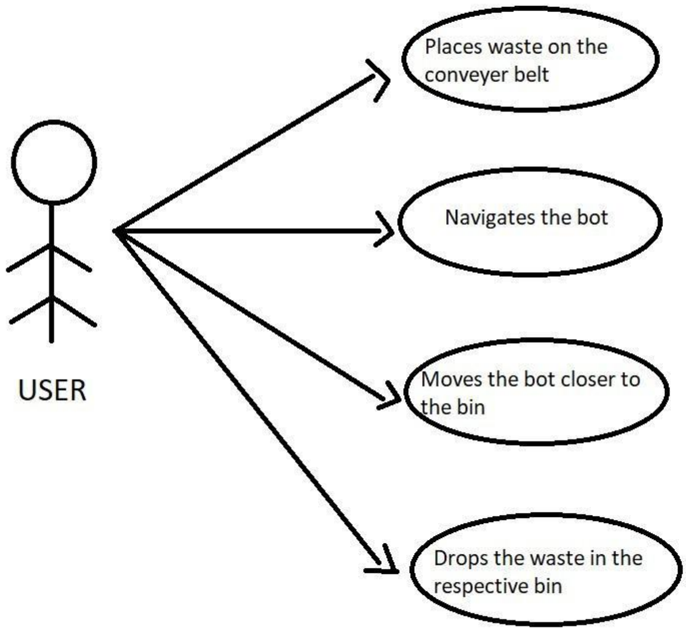

Figure 4.4: The use case diagram of the user and bots

The user performs the following tasks :

1. The user places the waste on a conveyor belt
2. The user navigates the bot towards the waste to pick up.
3. The user moves the bot closer to the bin for the disposal of the collected waste. The bot is controlled via Bluetooth.
4. The Robotic arm is then instructed to place the waste into it's respective bin.

4.5 Sequence Diagram

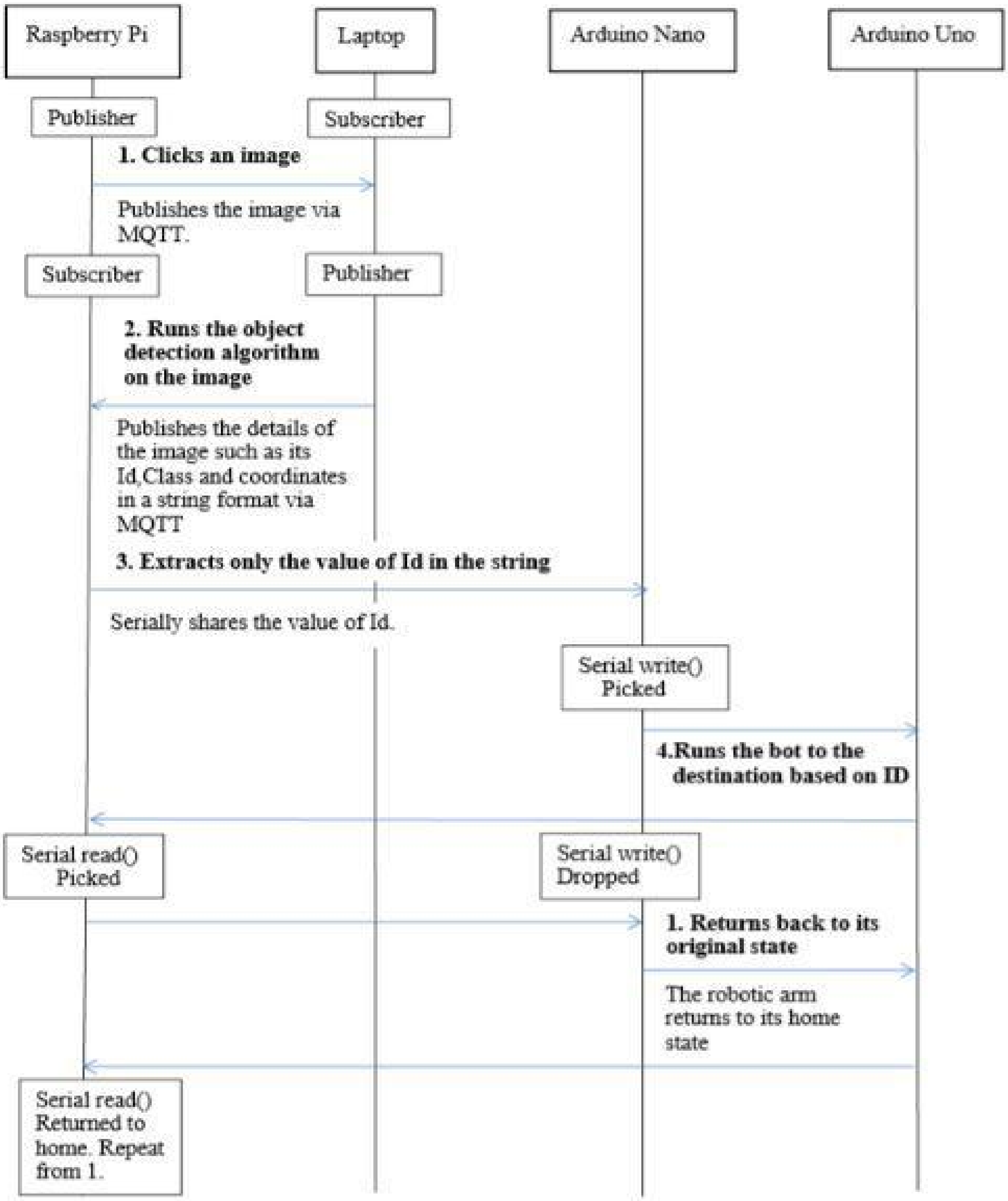

Figure 4.5: Sequence diagram

CHAPTER 5

IMPLEMENTATION

5.1 Module 1 -Devices

5.1.1 Raspberry Pi

- The one part of the device is made up of raspberry pi3 model B.
- The raspberry pi is connected with a camera module which is to capture image orvideo.The following are the tasks done by raspberry pi:

1) The raspberry pi camera is used to click an image of the detected waste.
2) The image clicked will be sent to the system via MQTT.
3) Will receive the details of the image such as its Id,class and coordinates.
4) Extracts only the Id and its value.
5) Sends the Id to Arduino Nano via serial wired connection.
6) Instructs the Arduino to move to the coordinates.

5.1.2 Arduino Uno

- This part of the device is used to control the moving bot.
- It runs the motors of the bot using a motor shield .
- Uses an external power source i.e. Lead Acid Battery , to supply the required voltage to the motors.

5.1.3 Arduino Nano

- This part of the device is used to control Robotic arm.
- Receives image Id from the Raspberry Pi.
- Based on the id received , the program calls the respective functions to pick and drop thewaste detected.

5.2 Module 2 – Bots

5.2.1 Robotic Arm

- The robotic arm is mounted on the moving bot.
- It has a raspberry pi camera installed on it which captures the image .
- The arm is run via Arduino Nano.

5.2.2 Moving Bot

- The moving bot is controlled via Bluetooth.
- It is made to stop in front of the waste that is lying on the ground.
- Once the arm picks it up, the bot moves to the destination .
- Once the waste is dropped , the bot moves back to the initial position i.e. home state.

5.3 Challenges Faced

- Small battery for the construction of the bots .
- Finding a efficient motor for driving a system
- Identifying edge points in a given set of co-ordinates.
- Motor co-ordination.
- Managing to supply power continuously.
- Finding a efficient camera module for better quality.
- Using efficient object detection module for accurate detection.
- Transferring files over a network from Raspberry Pi to the system and vice verse

5.4 Working

The device consists of Raspberry pi3, Arduino Uno, Arduino Nano, Robotic arm, Servo motors, Ball wheel and a Lead acid battery. The bot is controlled by a human via Bluetooth. The bot is made to stop in front of the waste that is lying on the ground. The robotic arm will be mounted on a moving bot.

The movements of the robotic arm is controlled by an Arduino. The arm is mainly used to pick up the waste and segregate it according to its type.There is always a single user who controls the movement of the bot.The bot is made to stop when waste is detected .The Bot being remotely controlled by a human, helps in identification of the waste lying on the ground. The segregated waste will be placed into its respective baskets.

Image Processing using Object detection API -

A TensorFlow object detection API is used to classify the waste. This is how it is done:

- A total of 1500 images is taken as a data set of waste of 3 different categories.
- All the images are labeled using LableImg
- It is then split into test and train data set
- A TensorFlow model called SSD_Mobilenet_v2 is the model we have chosen to perform the detection.
- The entire model is trained for our particular data set.
- The model is then exported and used.[14]

The process starts off by the pi camera clicking the picture of the waste. The image is then sent to the system via MQTT. Here, the system acts as a subscriber and the Pi acts as a publisher. Object detection algorithm will be made to run on the captured image. The object detection algorithm is trained to classify images of three classes namely :

- Fruit waste
- Paper
- Leaf

The Id, class and coordinates of the captured image will be printed as an output and a string of variables will be created. This string of variables is shared to the Raspberry Pi via MQTT. Here, the system acts as a publisher and the Pi acts as a subscriber. Now, the Pi reads the string and extracts only Id and its respective value. This Id is serially shared to Arduino Uno. Arduino Uno controls the movements of the Robotic Arm.[21]

CHAPTER 6

SOFTWARE TESTING

6.1 Unit Testing

Unit testing is a software development process in which the smallest testable parts of an application, called units, are individually and independently scrutinized for proper operation. The unit testing for our proposed system are as follows:

- The Pi camera is mounted under the gripper and it should be able to click pictures.
- The system should be subscribed to a topic to which the clicked image will be published by the Raspberry Pi via MQTT.
- On receiving the image, the system will run the object detection algorithm
- The algorithm generates the Id, class and coordinates of the image.
- The Raspberry Pi should be subscribed to a topic to which the string of variables will be published by the system via MQTT
- The Pi reads the string and extracts only Id and its respective value.
- The Id is shared to Arduino Nano through a serial connection.
- Arduino Nano controls the movements of the Robotic Arm.
- Arduino Uno with the help of a bluetooth module controls the moving bot.

6.2 Integration Testing

Integration testing (sometimes called integration and testing, abbreviated I&T) is the phase in software testing in which individual software modules are combined and tested as a group. Therefore the Waste segregating system is divided by it subsystems called robotic arm and a moving bot These sub systems when combined together works efficiently and with accuracy and is being tested well.

6.3 Test Cases

TEST CASE NO: 01	**TEST CASE NAME:** Classification of waste objects
INPUT: Image to be tested	
OUTPUT: Image correctly classified into it's respective class label.	
RESULT: PASS	

TEST CASE NO: 02	**TEST CASE NAME:** Prediction Algorithm
INPUT: The image received from the Pi camera	
OUTPUT: A string of variables containing ID, Class and coordinates are generated for the respective image	
RESULT: PASS	

TEST CASE NO: 03	**TEST CASE NAME:** Pick up of the waste
INPUT: Waste placed in the fixed position	
OUTPUT: Correct pickup of the waste object	
RESULT: PASS	

TEST CASE NO: 04	**TEST CASE NAME:** Placement of the waste in the bin
INPUT: Picked up waste object	
OUTPUT: Placement of the object into it's respective bin	
RESULT: PASS	

TEST CASE NO: 05	**TEST CASE NAME:** Back to home state
INPUT: Placement of the waste in the bin	
OUTPUT: Arm and bot moves back to it's initial position	
RESULT: PASS	

6.4 Unit Test Cases

TEST CASE NO: 01	**TEST CASE NAME:** Working of the Pi camera
INPUT: ➢ Mount the Pi camera under the gripper ➢ Click an image using the Pi camera	
OUTPUT: The Pi camera should be able to click an image and store it in a desired location	
RESULT: PASS	

TEST CASE NO: 02	**TEST CASE NAME:** Pi to System communication via MQTT
INPUT: The system is subscribed to a topic to which the clicked image is published by the Raspberry Pi via MQTT.	
OUTPUT: Image received by the system	
RESULT: PASS	

TEST CASE NO: 03	**TEST CASE NAME:** Object detection algorithm on an image
INPUT: Object detection algorithm is made to run on the image	
OUTPUT: The algorithm generates the Id, class and coordinates of the image	
RESULT: PASS	

TEST CASE NO: 04	**TEST CASE NAME:** System to Pi communication via MQTT
INPUT: The Raspberry Pi is subscribed to a topic to which the string of variables is published by the system via MQTT.	
OUTPUT: The Raspberry Pi receives the string of variables	
RESULT: PASS	

TEST CASE NO: 05	**TEST CASE NAME:** Pi extracts the Id of the image
INPUT: The Raspberry Pi reads the string	
OUTPUT: Only Id and it's respective value is extracted	
RESULT: PASS	

<table>
<tr><td>TEST CASE NO: 06</td><td>TEST CASE NAME:
Pi to Arduino Nano connection</td></tr>
<tr><td colspan="2">INPUT:
➢ Serial connection is made between the Pi and Arduino Nano
➢ Id is shared to Arduino Nano</td></tr>
<tr><td colspan="2">OUTPUT:
Arduino Nano receives the Id of the image.</td></tr>
<tr><td colspan="2">RESULT: PASS</td></tr>
</table>

<table>
<tr><td>TEST CASE NO: 07</td><td>TEST CASE NAME:
Robotic Arm movements</td></tr>
<tr><td colspan="2">INPUT:
Arduino Nano controls the movements of the Robotic Arm based on the Id received.</td></tr>
<tr><td colspan="2">OUTPUT:
The robotic arm should be able to move in the desired motion and speed without any disturbance.</td></tr>
<tr><td colspan="2">RESULT: PASS</td></tr>
</table>

TEST CASE NO: 08	**TEST CASE NAME:** Moving bot
INPUT: Arduino Uno is connected to the Johnson motors and a bluetooth module.	
OUTPUT: Arduino Uno is able to control the movements of the bot	
RESULT: PASS	

CHAPTER 7

SNAPSHOTS AND RESULTS

The GitHub link for the project source code is :

https://github.com/UWSRA/urban_waste_segregrating_robotic_arm_using_machine_learning

Figure 7.1: Ayasa Robotic Arm

The above Robotic arm was initially considered to perform all the tasks. The arm was later discarded from the project because of the following reasons -

- The overall size of the robotic arm was small and it had no ability to lift objects of heavyweight as it was designed for sg90 servo motors.
- The gripper of the arm was small and light.
- There was a Jitter during the movements of the arm.
- A separate library called adafruit had to be installed and used in which there were no options to make the arm to move on it's own.

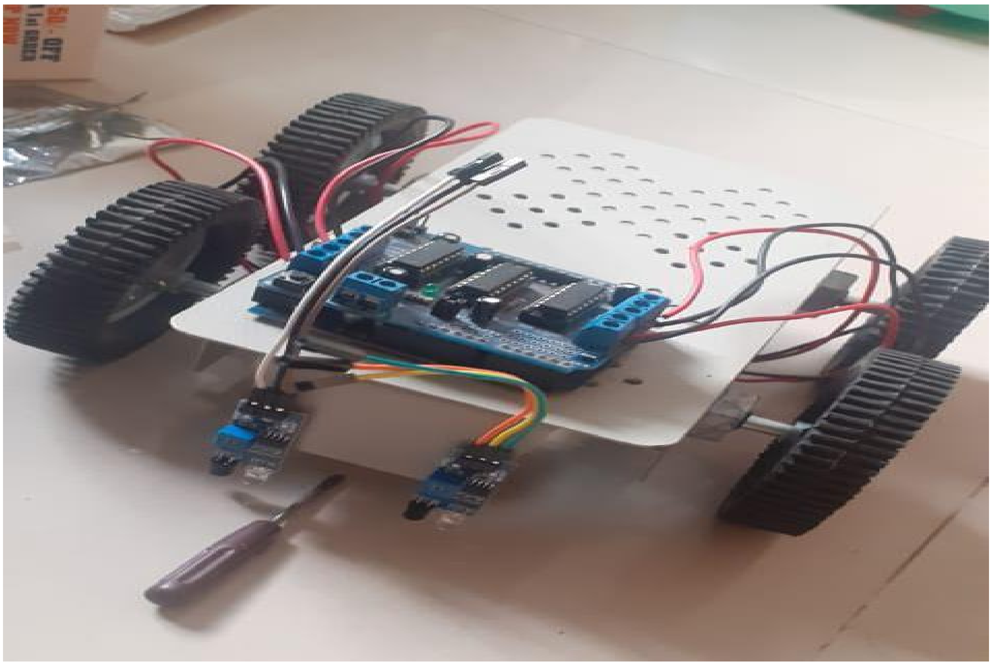

Figure 7.2: The initial metal base moving bot.

The above picture shows the initial bot that was used for carrying the older model of the robotic arm.This metal base bot was later replaced by a wooden base bot that could carry more weight.

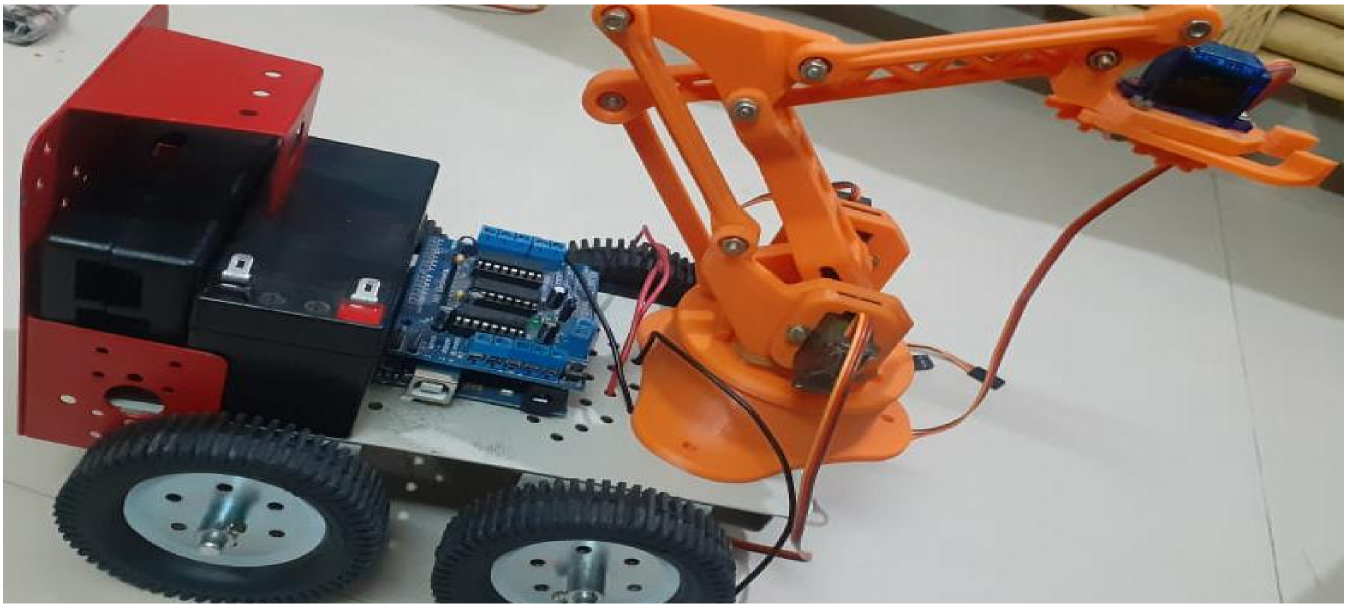

Figure 7.3: The overall prototype of the initial system

The above image shows us the prototype that was initially used to carry out the process. This could lift the total weight of about 40 grams only. The prototype was later upgraded for the betterment of the project.

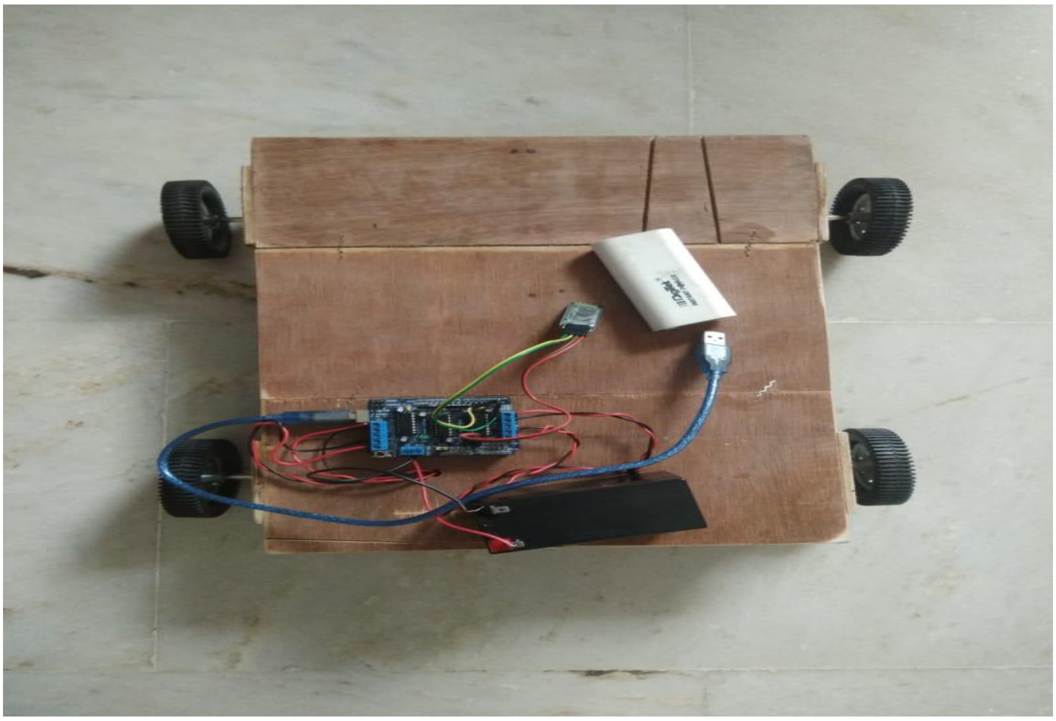

Figure 7.4: Wooden base moving bot

The above image shows us the final look of the moving bot that is used to carry the 3D printed robotic arm. Wooden base was chosen for the moving bot so that it could lift more weight and had a larger base area.

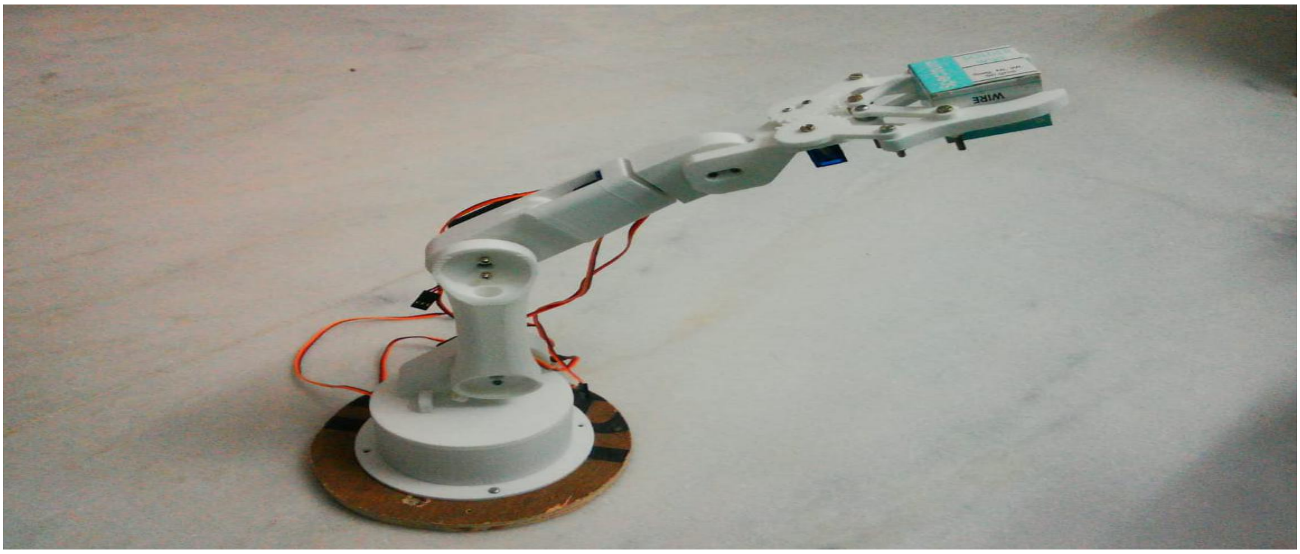

Figure 7.5: 3D printed robotic arm

The above image shows us the 3D printed robotic arm that is used to pick up the waste. This arm can lift weights upto 240 grams firmly. Each and every part of this arm was 3D printed individually and was later assembled.

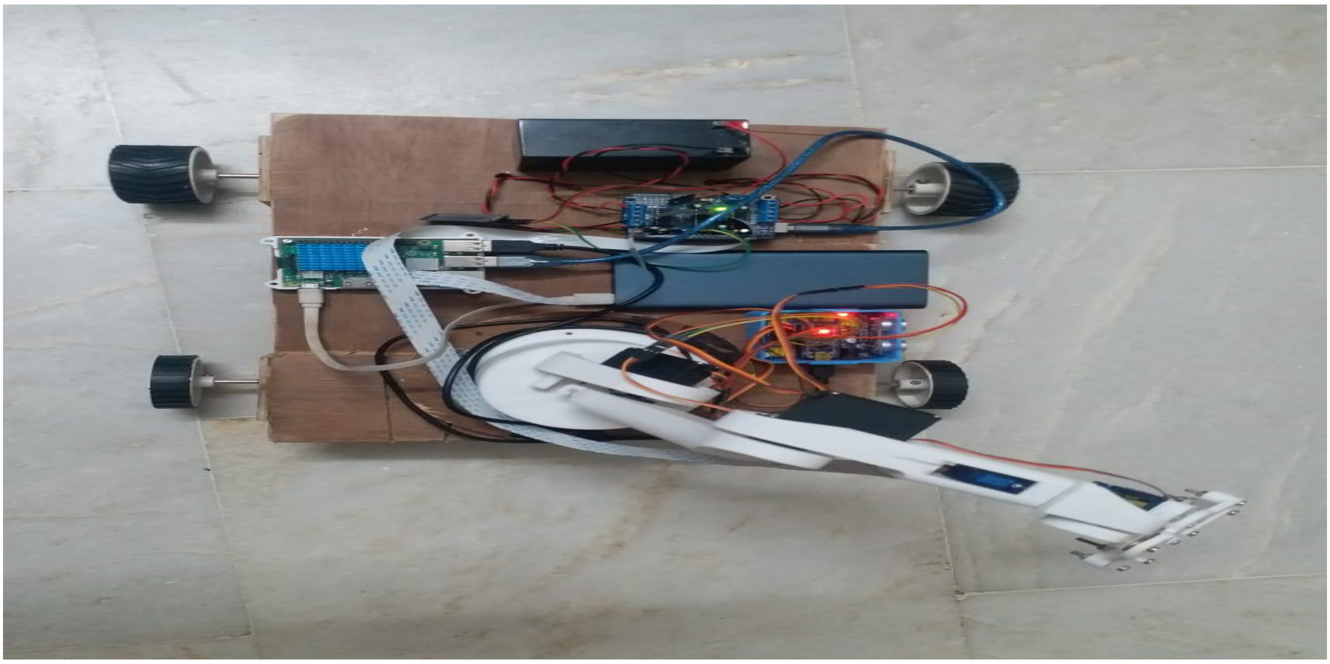

Figure 7.6: Overall set up the of system

The above image shows us the over all set up of the system that is used to carry out the entire process. The robotic arm is carefully placed on the wooden base moving bot and their respective connections are made for it to function.

Figure 7.7: 3D printed robotic arm picking up the detected waste

The above image shows us the robotic arm picking up paper after detecting its class. When there is waste on the ground, the raspberry pi clicks the image of the waste and sends it to the system via MQTT. The system runs the detection algorithm on the waste to detect its class. The Id, class and coordinates of the captured image will be printed as an output and a string of variables will be created. This string of variables is shared to the Raspberry Pi via MQTT. The Pi reads the string and extracts only Id and its respective value. This Id is serially shared to Arduino Uno. Arduino Uno signals the robotic arm to pick up the waste.

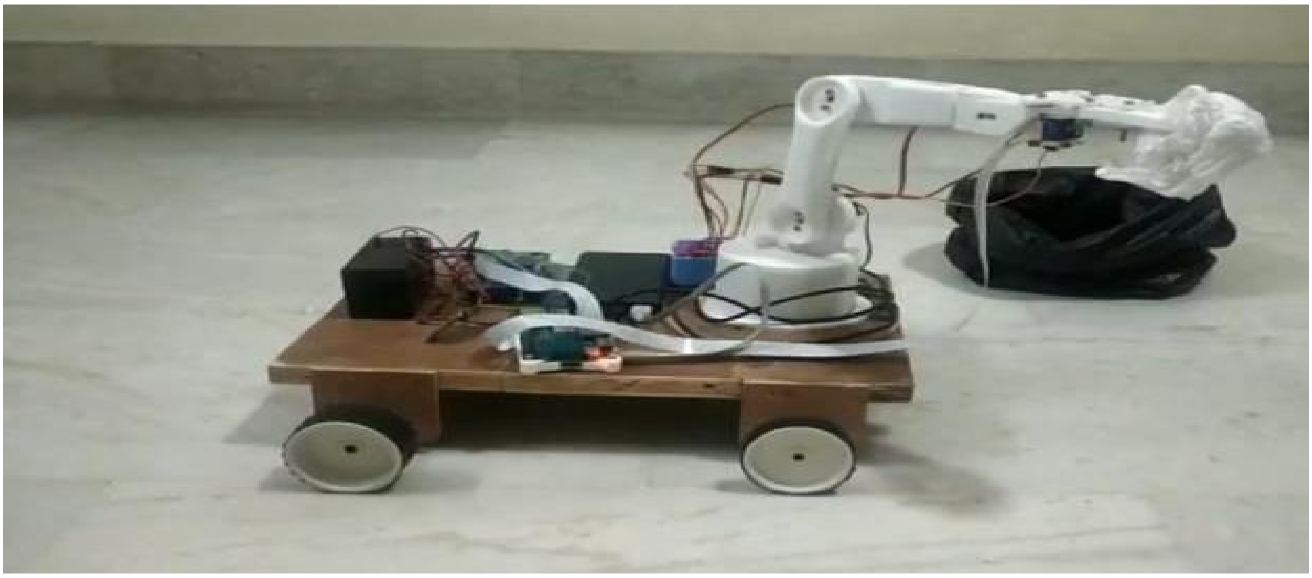

Figure 7.8: The system moving towards the bin to drop the waste

The above image shows us the bot moving towards the waste bin to drop the picked up waste. The movement of the bot is controlled via Bluetooth. The Id of paper waste is 3.

Figure 7.9: The system dropping the waste into its bin

The above image shows us the robotic arm turning in the direction of the bin and dropping the waste into it.

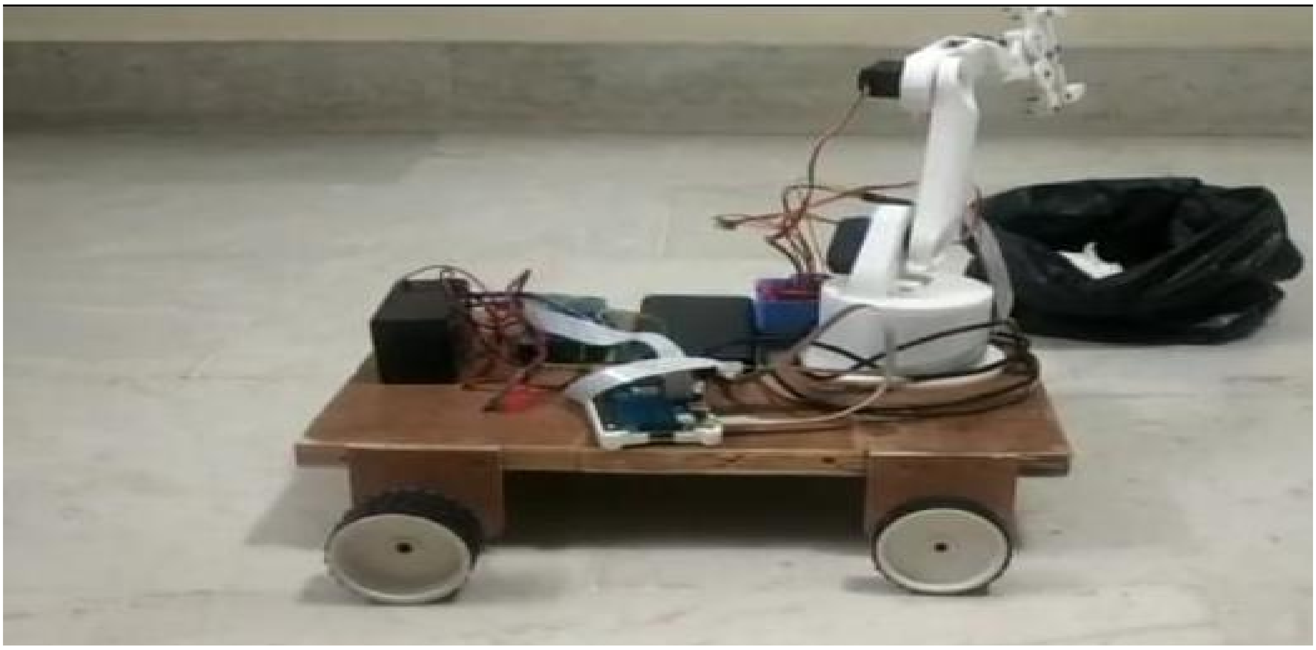

Figure 7.10: The robotic arm after dropping the waste

The above image shows us the robot arm coming back to its position after dropping paper waste into its respective bin.

Figure 7.11: Home state of the robotic arm

The above image shows us the robotic arm coming back to its home state after completing the process of detecting paper waste,and dropping it into its respective bin.

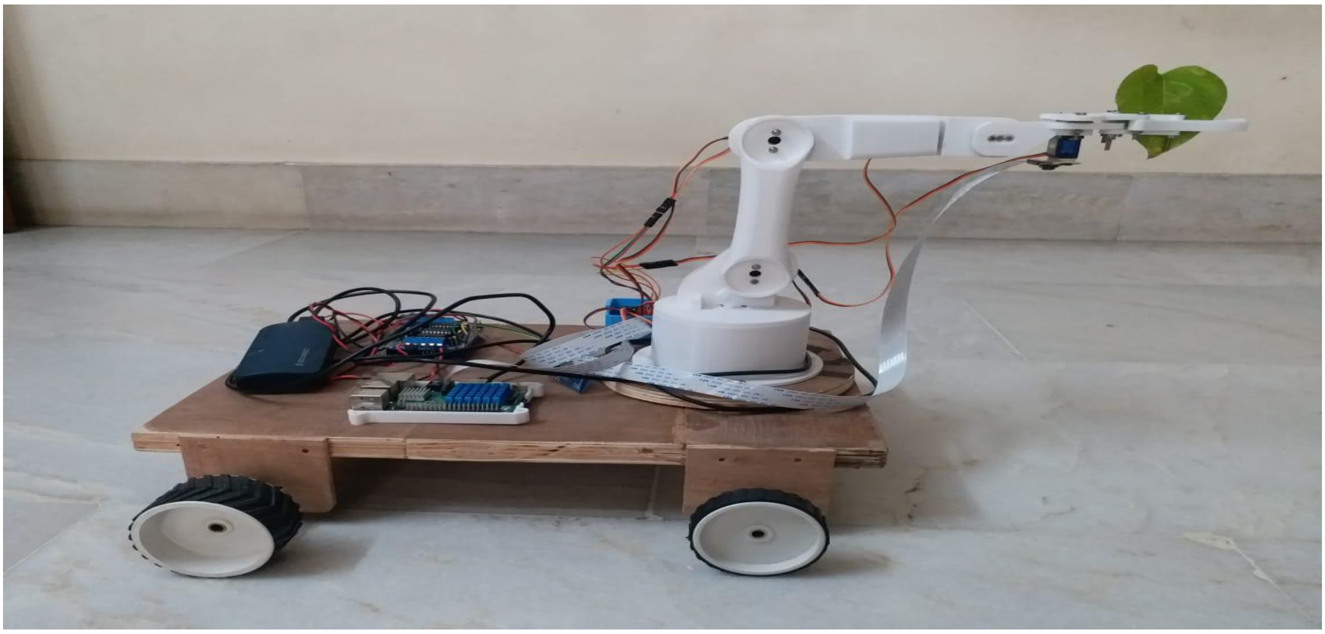

Figure 7.12: Robotic arm picking up leaf

The above image shows us the robotic arm picking up waste after detecting it as leaf. The Id of leaf is 2.

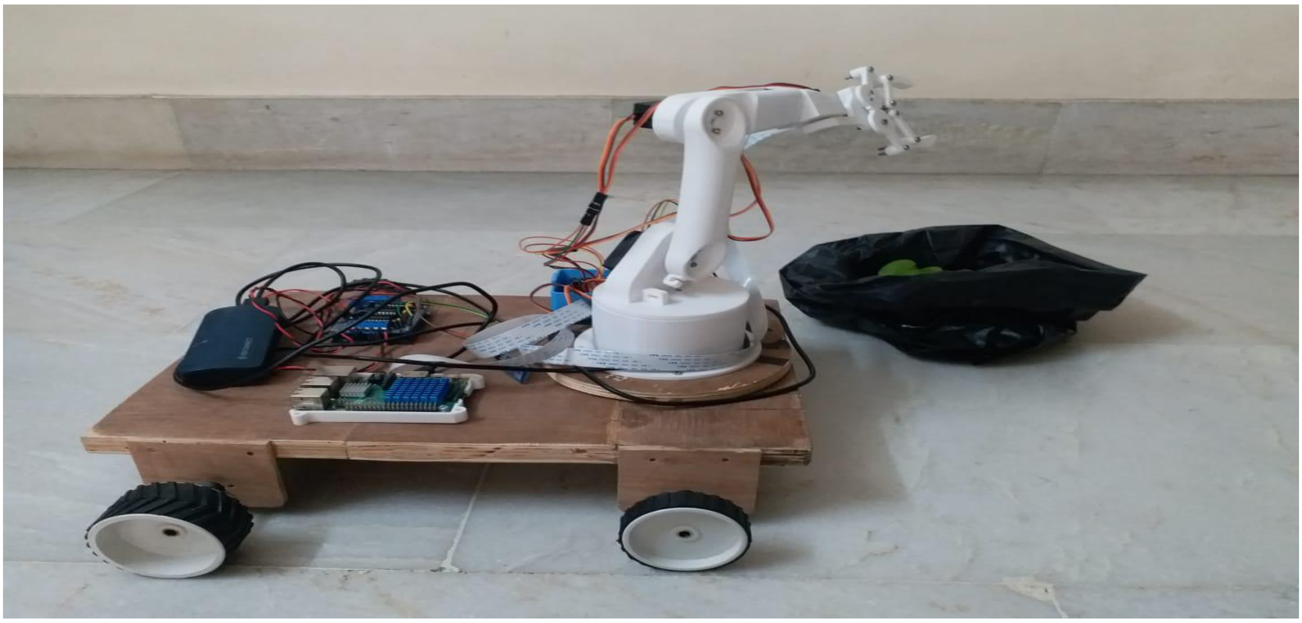

Figure 7.13: Robotic arm dropping leaf waste

The above image shows us the robotic arm dropping the leaf waste into its respective bin and coming back to its position

Figure 7.14: Robotic arm dropping fruit waste

The robotic arm picked up the fruit waste whose id is 1. Once the fruit waste was picked up, it moved towards the bin. The movements was controlled via Bluetooth. Once the system reached the bin, it turned towards the bin to drop the waste

Figure 7.15: Fruit waste dropped into its bin

The above image shows us the robotic arm has dropped the fruit waste into its respective bin and is coming back to its original position.

Figure 7.16: Multiple waste lying on the ground

The above image shows us that there are multiple waste lying on the ground i.e, leaf and paper waste. This image is clicked using the Pi camera and sent to the system via MQTT and image detection is done on these two waste categories to detect its respective Id, class and coordinates.

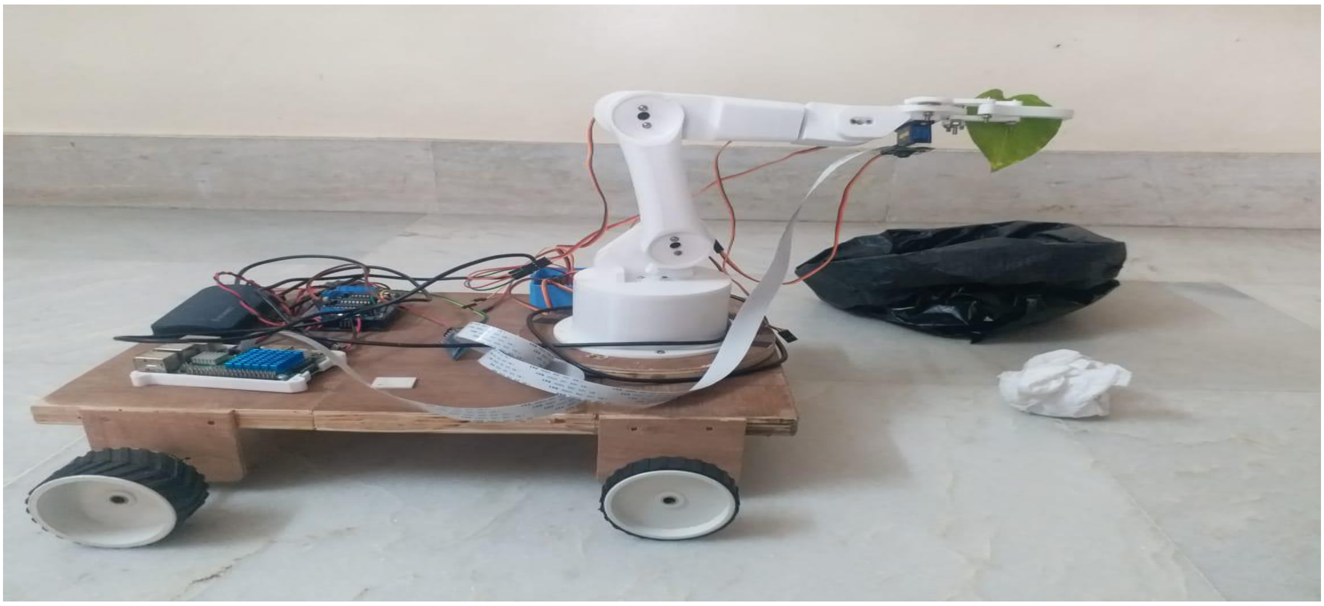

Figure 7.16: Leaf waste getting picked up by the robotic arm

The above image shows us the robotic arm picking up leaf waste which is placed next to paper waste after detecting its type in order to place it in the bin. The Id of leaf is 2.

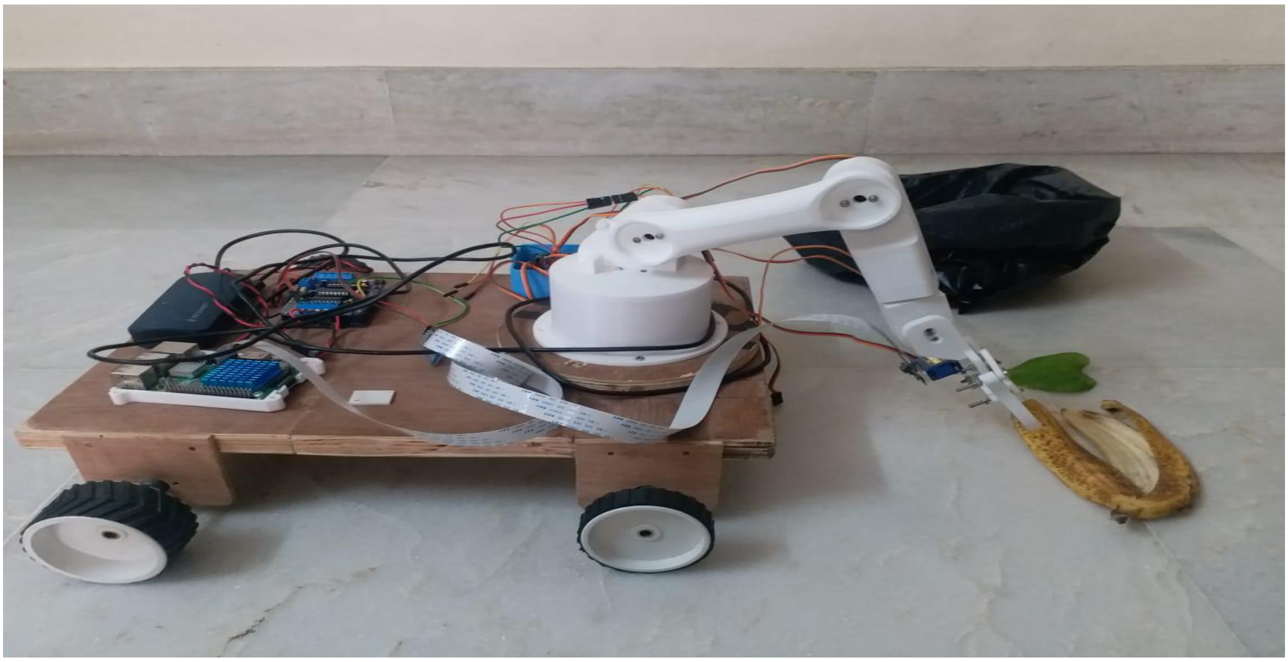

Figure 7.17: Multiple waste lying on the ground

The above image shows us that there are multiple waste lying on the ground i.e, fruit and leaf waste. This image is clicked using the Pi camera and sent to the system via MQTT and image detection is done on these two waste categories to detect its respective Id, class and coordinates.

Figure 7.18: Fruit waste getting picked up by the robotic arm

The above image shows us the robotic arm picking up fruit waste which is placed next to leaf waste after detecting its type in order to place it in the bin.

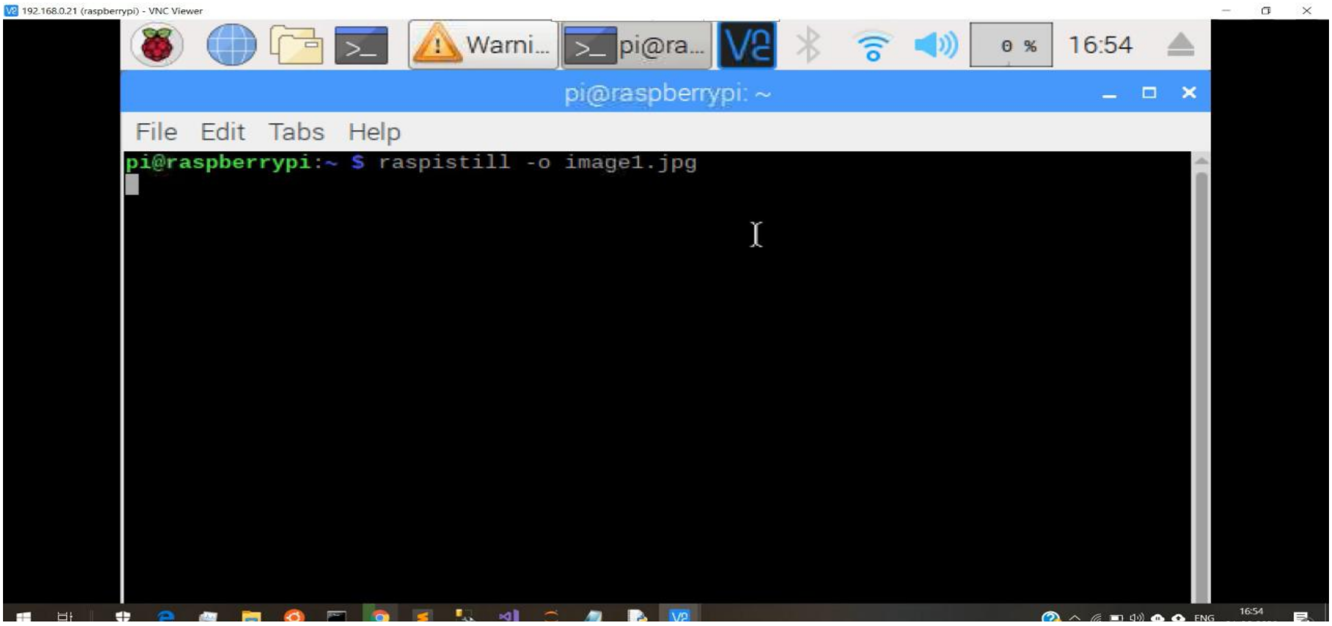

Figure 7.19: Command to click an image

The above image shows us the command which is used to click images using Raspberry pi camera. All the commands are written into a shell script which gets executed automatically when the Pi starts.

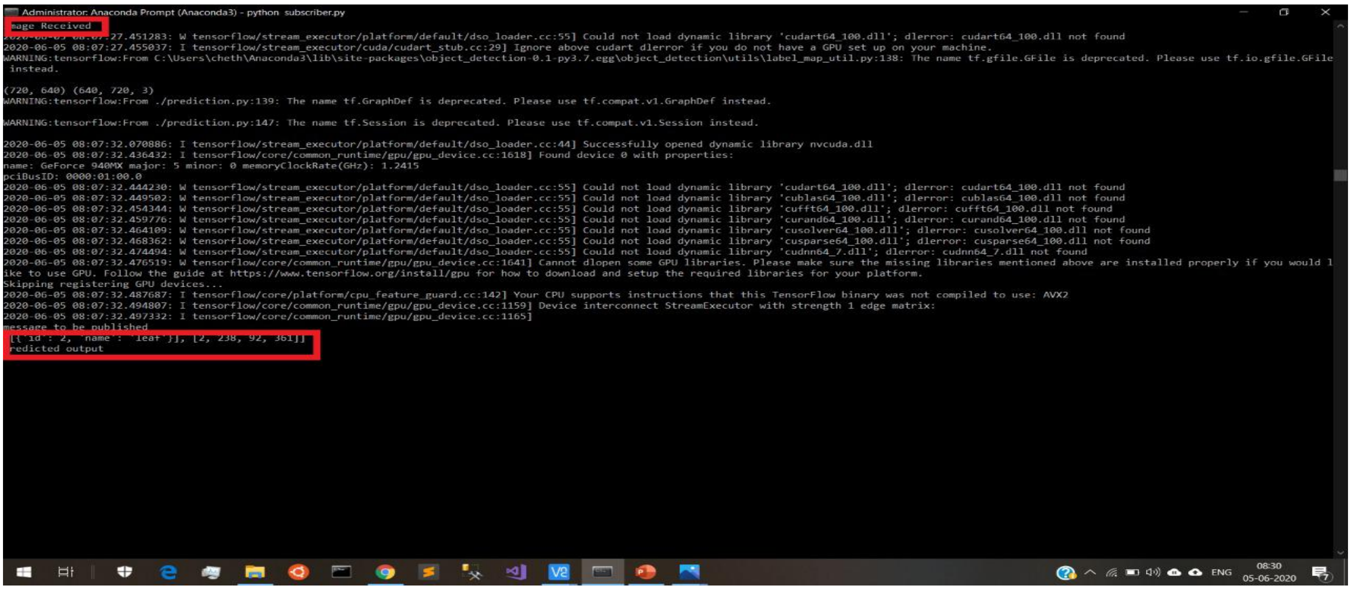

Figure 7.20: Image received and predicted

The above image shows us the image being received by the system via MQTT. "Image Received" is the message that gets displayed in the terminal once the image is transferred by the Raspberry Pi to the system. Once the image is received, the algorithm to predict the waste type is run. The final output displayed is the string of variables containing id,class and coordinates of the image.

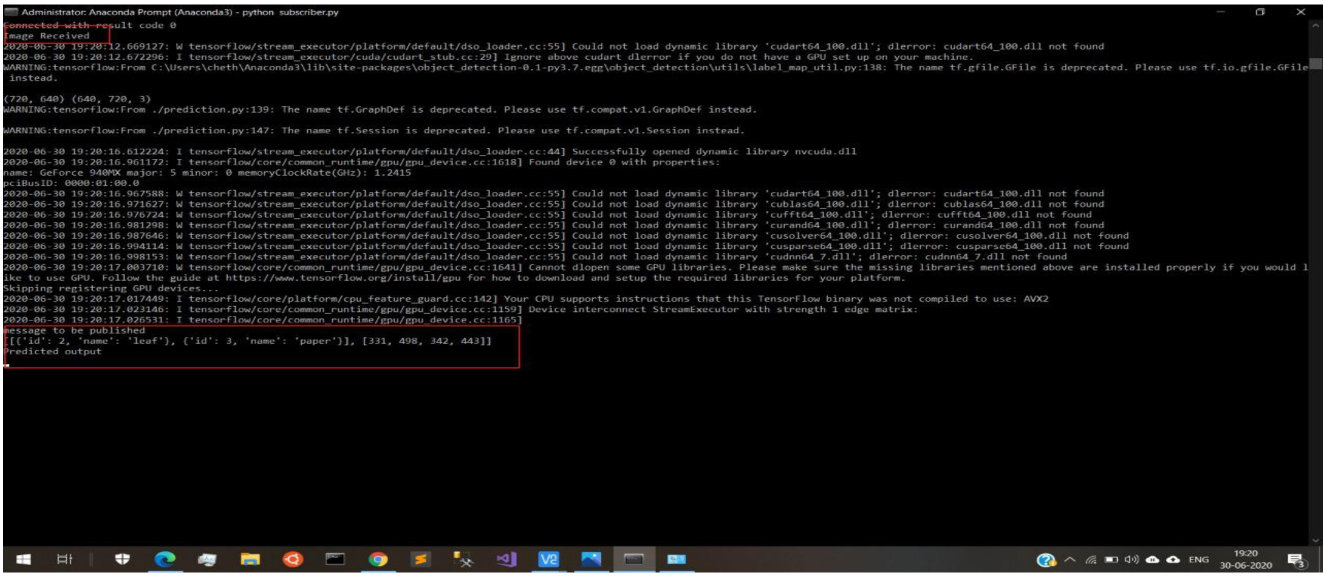

Figure 7.21: Multiple object detection for leaf and paper waste

The above image shows us the image being received by the system via MQTT. "Image Received" is the message that gets displayed in the terminal once the image is transferred by the Raspberry Pi to the system. The algorithm detects multiple waste i.e, leaf and paper waste lying on the ground. The object detection algorithm is made to run and string of variables containing Id,class and coordinates are generated respectively.

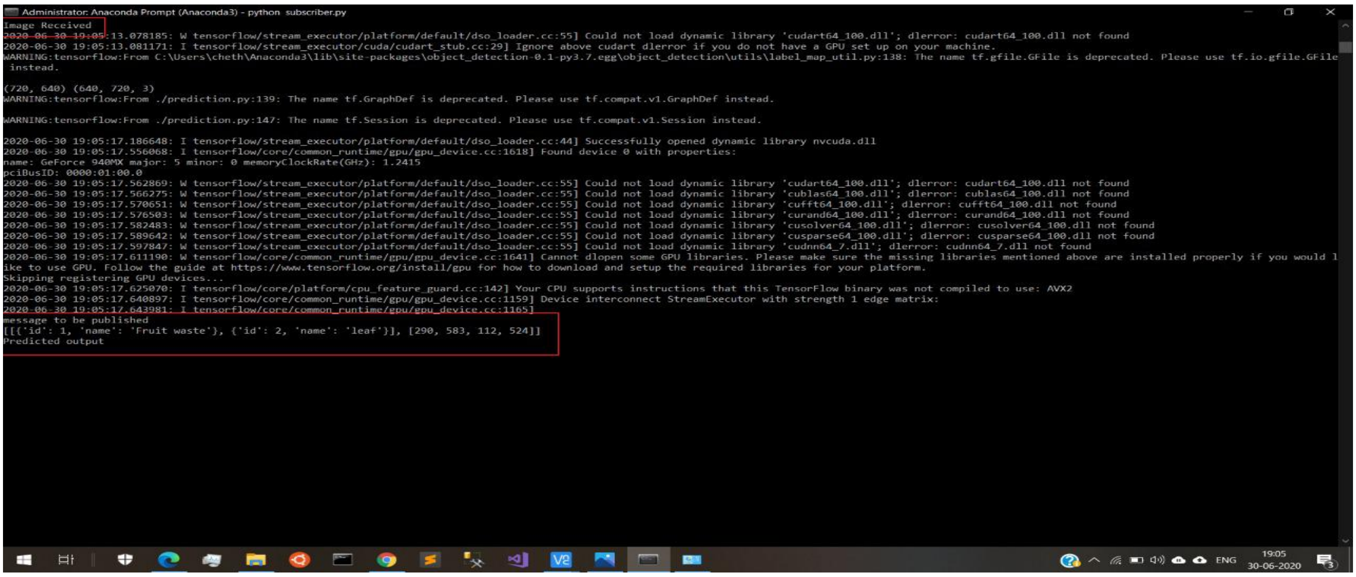

Figure 7.22: Multiple object detection for fruit and leaf waste

The above image shows us the image being received by the system via MQTT. "Image Received" is the message that gets displayed in the terminal once the image is transferred by the Raspberry Pi to the system. The algorithm detects multiple waste i.e, fruit and leaf waste lying on the ground. The object detection algorithm is made to run and string of variables containing Id,class and coordinates are generated respectively.

CONCLUSION

This paper introduced a fully user controlled system which detects and collects the waste. We used different concepts for different application to make the whole system. In which pre-trained Convolutional Neural Network is used for detecting the waste. This system is robust and adequately efficient. This system is capable of segregating the collected waste into its respective groups.

The novelty of this paper lies in the concept of a cost-effective system that uses IoT to optimize the working of a network of garbage collectors. Furthermore, the adoption and optimization of the best features from existing technologies, into a single integrated system makes it very efficient.The deployment of OpenCV in a real-time environment for image processing and classification, makes the module dynamic in contrast to MATLAB based classifiers which is widely used, and lacks real-time processing capabilities. Also, to optimize time, speed and memory, the images are sent to a central server for processing, rather than using the on-board processor, since the on-board processor has limited processing speed and capabilities. The third novelty of this paper is that the processing is done on a central server, which can handle several tasks at a time, and thus a swarm of garbage collecting robots can be deployed simultaneously. Thus, while optimizing cost, there is also no compromise in the quality and functionality of the robot, hence rendering it an optimal prototype for garbage collecting applications.

Overall this robot pushes the state-of-the-art in the waste management in our country with full automation.

FUTURE ENHANCEMENTS

1. Create an User interface to get a regular feedback .
2. Automate the movements of the Robotic arm completely.
3. Interface sensors to detect any kind of obstacles.
4. Upgrade the Gripper to lift larger and heavier object

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