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Waste Segregation Robot - A Swachh Bharat Initiation

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Abstract

With the increase in waste creation rate, well-built waste management has become very essential. Dumped unmanaged wastes causes severe harm to humans and also severely affects the environment. It additionally causes different climatic changes and obstructs the financial development of nation. Dynamic raise in the quantity of waste and contemptible dumping of waste has turn out to be a matter of worry, because of the threat it causes the big damage to environment. There comes the essential role of an automated waste segregate system which avoids these troubles and also reduces the complexity of recycling. The significance and the financial importance of waste is realized only when it is segregated. Currently there are no such systems for auto segregation. Our work proposes a smart waste sorting system which consists of hardware and a software system based on image processing with open CV. It aims at efficiently sorting out wastes so that it would be easy for the group to segregate them on a huge scale basis. The hardware includes core module Raspberry Pi integrated with the pi camera, dc motor, pick and place robotic arm, sensors such as IR, moisture, inductive proximity, wet sensor and also use of image classification algorithm for performing object detection based on the haar-cascade classifier with open CV. The ultimate goal of the work is to automatic segregation of wastes into categories – dry, wet, plastics, and metals. This would help in easy recovery of useful and recyclable items.

Keywords: *Sensors, Haar-Cascasde, Raspberry Pi, 3 Robotic ARM.*

1. Introduction

Currently India is facing a biggest challenge related to waste, which is poor waste collection, transport, treatment, and disposal. Current systems in India cannot manage with the big volumes of waste generated by a increasingly more in urban population, and this is impacting on the environment and public health. The challenges and barriers are significant, but so are the opportunities. Even though significant development in social, economic, and environmental areas, but the waste management systems in India have remained comparatively unaffected. Currently waste management is incompetent with waste is having a negative impact on public health, the environment, and the economy. The problems are worsening with governance complicate the situation. Waste management in developing countries and cities is a continuing challenge due to weak institutions constant under-resourcing and speedy urbanization.

Waste management generally includes all those activities required to manage waste from its collection to its disposal. It deals with all types of waste including industrial, biological, and household. Waste management is intended to reduce the adverse effects of waste on human health, the environment, or the aesthetic. Waste segregation is done at the source level it will help smoothen the recycling process. India is in a critical condition with regard to waste generation by the increasing urban population. This degrades the pollution as well as is a threat to the health of humans and animals living around. So it's crucial for Indians to bring a system to collect, transport, treat, and dispose of waste adequately. The opportunities to recover from such a situation are as significant as the current barriers being faced. Despite significant development in social, economic, and environmental areas, the waste management systems in India have remained relatively unchanged.

Current waste management is inefficient with waste having a negative impact on public health, the environment, and the economy. Most of the areas coming under the developing economies do not have proper services for waste collection thereby leading to uncontrolled and insufficiently managed dumpsites. The problems are worsening. Problems with governance complicate the situation. Waste management in developing countries and cities is an ongoing challenge due to weak institution's chronic under-resourcing and rapid urbanization. Proper waste management is necessary to have sustainable and habitable cities. Almost all growing cities and developing countries are still working to overcome this challenge. So we propose a mobile waste segregation robot system where the first input image captured by the pi-camera undergoes object detection based on haar-cascade files created and on detection the robot ARM picks and places objects in the respective bin. If not classified then the sensors are activated one after the other to classify it further. Basically, the object detection algorithm classifies waste as plastic/glass/paper. The inductive proximity sensor detects metal; moisture

sensor detects the moisture content and classifies it as wet or dry. Figure 1 shows the waste before and after auto segregation.

Fig.1.Waste after segregation

2. Literature Survey

An Automated Waste Control Management System (AWCMS) using Arduino [1], proposed by Agha Muhammad Furqan Durrani. In this work, when the bin gets completely filled the signal received by the IR sensor reduces and it sends a signal to the microcontroller which locates the position of the bin using GPS and sends alert SMS with location to a central unit that is connected to the UI software. The central unit has a GSM module connected Arduino board which receives the message from the bin. The UI has 2-3 windows and altogether serves the purpose of storing the location of all bins, SIM numbers and also shows the status of each bin. Wesley Pereira et al., [2] proposed a system based on the ATMEGA328P microcontroller which is programmed to control the IR and ultrasonic sensors, copper clads Indicator LED's, stepper motor, and Bluetooth module. The wet and dry waste is identified depending on the capacitance measured between copper plates. Once identified the respective bin aligns itself under the plates and one of the plates slides dropping the garbage. The method of spectroscopy is used to identify plastic from dry waste. The app developed is connected to the cloud and this data is used to analyze and optimize the route for the garbage disposal vehicles. S Nandhini et al., [3] proposed a system based on Arduino which will be connected to robotic ARM, which picks the waste after receiving the signal from the ultrasonic sensor and places the material on the binary classifier platform which classifies based on Convolution Neural Network (CNN) classifier. Here the waste is assessed and classified into biodegradable and non-biodegradable. In the lennet-5 architecture: the first convolution layer where the image is processed as a matrix of pixel values and extracts features like boundaries, color, etc., the second the non-linear layer added to the convolution layer extracts out the non-linear properties, the third the pooling layer performs down sampling operation, the fourth fully connected layer has an N-dimensional vector of classes from which the desired class is chosen for the image, and the final a soft max-classifier. Nimisha.S.Gupta et al., [4] implemented a system, based on the waste input into the trash bin increases, the signal received by IR sensor within the bin reduces and this is taken as the identification for the presence of waste. In turn, alerts the microcontroller which runs the sub conveyer belt connected to the respective bin and drops waste into the main conveyer belt that transports waste to the main segregator. A non-contact type electronic sensor (inductance coil) detects metal whereas a moisture sensor classifies the waste as wet or dries. Automatic waste segregator bin using robotic arm [5], another paper which uses the robotic arm and a segregator bin along with sensors such as the IR sensor, metal sensor, and ultrasonic sensor for waste management. The microcontroller in here is the LPC2148 ARM7 and the DC motors are included for the rotation of the bin as well as the entire unit's movement. The writers have proposed such a system aiming to make further treatment of wastes effortless. As and when the IR sensor senses the obstacle the ultrasonic sensor estimates the distance and the unit moves to the location. The robotic arm then picks and places the material on the platform allocated for waste type detection. At this point, the metallic sensor and moisture sensor come into action. Depending on the type (according to the coding on the microcontroller) the bin is rotated clockwise or anticlockwise and the dc motor slides the flipper to drop it into the respective partition. The ultrasonic sensor also plays the role of sending the signal to ARM7 once the bin is full and in turn, the microcontroller uses the GSM module to send SMS to a mobile number in code. Himadri Nath Saha [6] proposed "IoT based garbage monitoring and clearance alert system" here the concept of IoT is the backbone of the work. They have put forth an IoT based shrewd junk framework wherein they have better-used cloud technology to administer remote area waste and midway screening of the areas for its temperature, dampness, smoke, fire discovery,

refuse to fill the volume with remote detecting hubs set up. The main power source is the solar panel. An Arduino Uno board connected with an ultrasonic sensor, DHT-11 sensor, and GSM module is connected to the garbage bin. If the waste in the bin reaches its maximum capacity the ultrasonic sensor sends its signal to the microcontroller. Following this Arduino Uno sends alert SMS using the GSM module to the operator and live data is stored in the cloud too. Furthermore, a GPS module gives the location of the particular garbage bin which sends the alert at that time. DHT-11 senses if the waste is degrading even before the bin gets filled. Deterioration & non-deterioration wastes separation using pick & place robot [7] by K. Dhayalini et al., have put forth the use of a pick and place robot to separate waste into two categories one which deteriorates i.e., leaves, food wastes, paper, and the other which is non-deterioration/non-degradable waste i.e., glass, wood, plastics. They elaborate on the concept of robotics and how useful are the machine vision system employed in robots. The method involves the use of an android phone, Arduino Uno along with a Bluetooth module and a robotic arm. Image processing is carried out here with the help of the android application developed which has a database of images and further with the help of a mobile camera it takes input images. Manisha Jayson [8] et al., present SmartBin-automatic waste segregation, and collection. 'SmartBin', a bin, a system which aims at segregating waste at the source and sending automatic alerts to the collection center. The SmartBin is equipped with a GSM module, IR sensor, servo motors, and moisture sensor. The heart of the system is Arduino Mega 2560 which controls the process. The waste item disposed into the bin falls on a tray which rotates with the help of servo and drops the waste into the respective bin. The IR sensor detects waste which activates the moisture sensor. The moisture sensor with respect to the pre-set threshold value classifies dry and wet objects. S.Vinoth Kumar [9] et al., proposed a "Smart Garbage Monitoring and Clearance System using Internet of Things". The IoT based garbage collector is a combination of an ultrasonic sensor, force sensor, GPS, and GSM module. The level of waste in the bin is detected using the ultrasonic sensor and the weight is measured using a force sensor. An LED is connected to the bin which turns red if the bin is full else turns green. Concurrently the GSM module sends the status of the bin along with the location to the android device as well as a web server. B R Santhosh Kumar et al., [10] implemented "Eco-friendly IoT based waste segregation and management". The objective of the paper is to segregate waste collected in a bin into bio-degradable, metal, and plastic. Here STM32 is the backbone of the system which coordinates the activities of both modules the hardware and software. The paper stands out as the biodegradable segment not only collects the waste but also is equipped with microbe sensors that sense the production of methane gas. So the process here has sensors namely moisture, capacitive, inductive gas level detecting, and microbe sensors. These are the input and output controls i.e. when waste dumped into the bin, the sensors actively operate and drop them into respective bins. If any of the segments fill up, the level detecting sensor detects and compares with data saved in the cloud. Balaji Masanamuthu Chinnathurai Kumar et al., [11] implemented "Design and automation of a semi-automation waste segregation robot". The paper presents a robot "Recyclebot" to be set in public places to segregate waste as recyclable and non-recyclable. It's a mobile unit which is controlled by a wireless touch screen-based human-machine interface. Raspberry pi and a Linux machine together form the backbone for the operations. The image processing is carried out in MATLAB and a python driver controls the entire execution. They have employed the Content-Based Image Retrieval (CBIR) method which uses a bag of visual words and certain other features like color, shape. All over the air communication is implemented using the XBee module.

3. Proposed System and Block Diagram

The proposed system is a combination of hardware and software design. The specific function is that this embedded system uses image processing to segregate waste material and the use of a mechanical Robotic ARM is to replace direct human involvement in the waste management process. Figure 2 shows the hardware and software components involved in the proposed work.

The IR sensor is installed on the top of the system for detecting obstacles and sends signals to the pi board which alerts the camera. In turn, the camera is programmed to capture the image of the obstacle, and the image forms the input for image processing using open CV. Object detection uses classifiers to identify or detect if the input image is the particular object waste(such as paper, plastic etc.) or not. Local binary patterns and HAAR cascades are the two types of classifiers that can be trained in the open CV. In our design, we have used the latter for the identification and recognition of images. Thus, it involves the creation of haar cascade XML files for each type of waste. The algorithm needs a lot of positive and negative image dataset to train the classifier. The more number of positive images, the more in accurate of object detection. Then need to extract features from it and this process is called haar-like feature training.

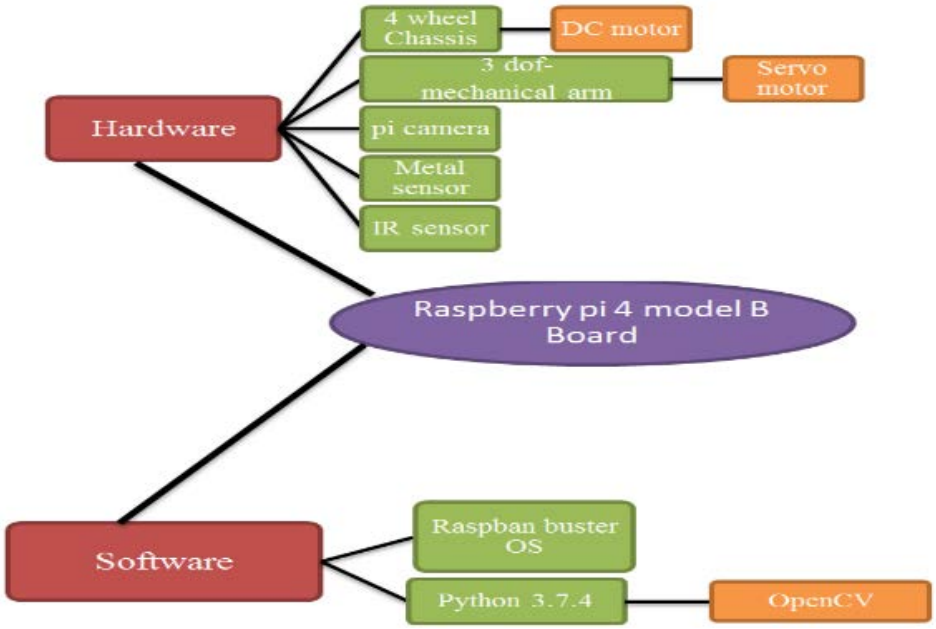

Fig.2.Basic building blocks of the System

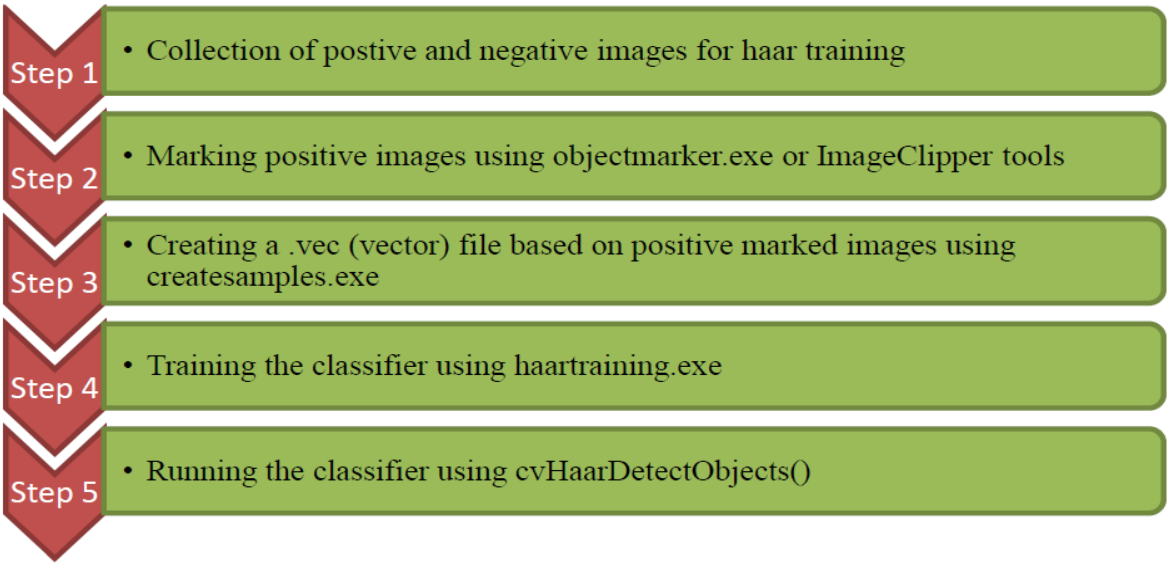

Fig.3.Training steps to create Haar-like classifier

Afterimage identification through image processing, the board is programmed to control the robotic arm movement such that the gripper picks the object to place in the compartment. Basically, the MG995 servo motors are the hardware interfaced to the Raspberry Pi to control the entire pick and place action.

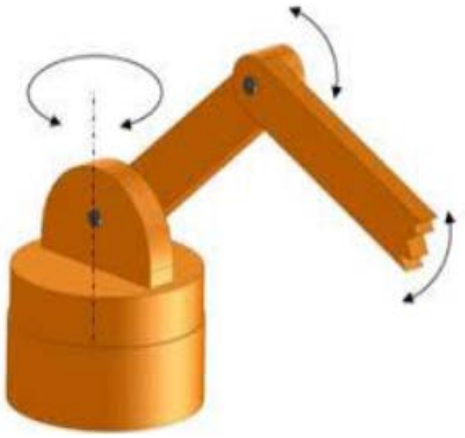

Fig.4.Robot ARM indicating the three axis of rotation to be controlled

Now, if the image is detected and the image is not present in the image database, then the metal and wet sensors are alerted by the board. If either of the sensors detects signals then the robot arm is activated to pick and place the object in the respective bin. If not then the raspberry pi is instructed to control the movement of the unit by directing the basic chassis.

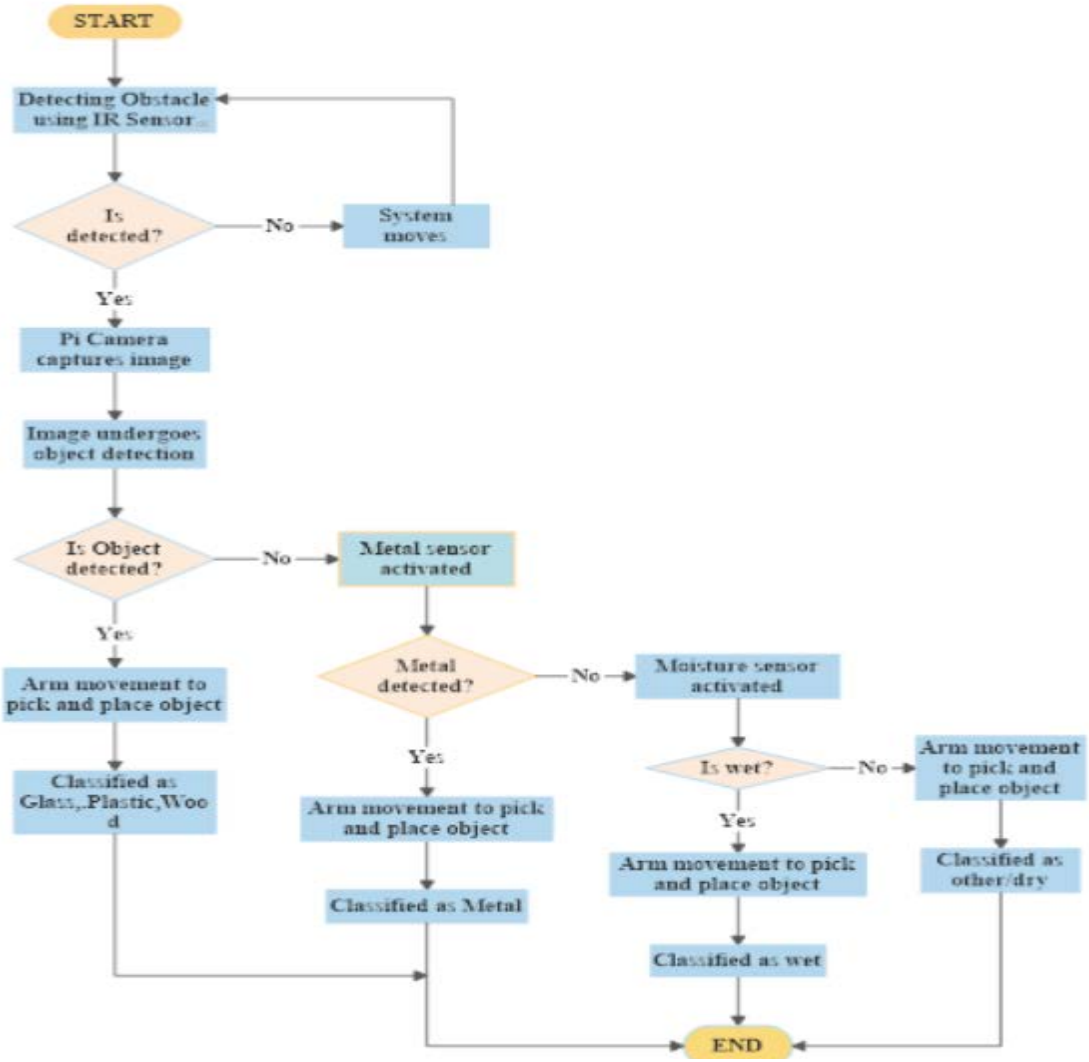

Fig.5. Flowchart

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4. Hardware and Software Implementation

A. Hardware Implementation

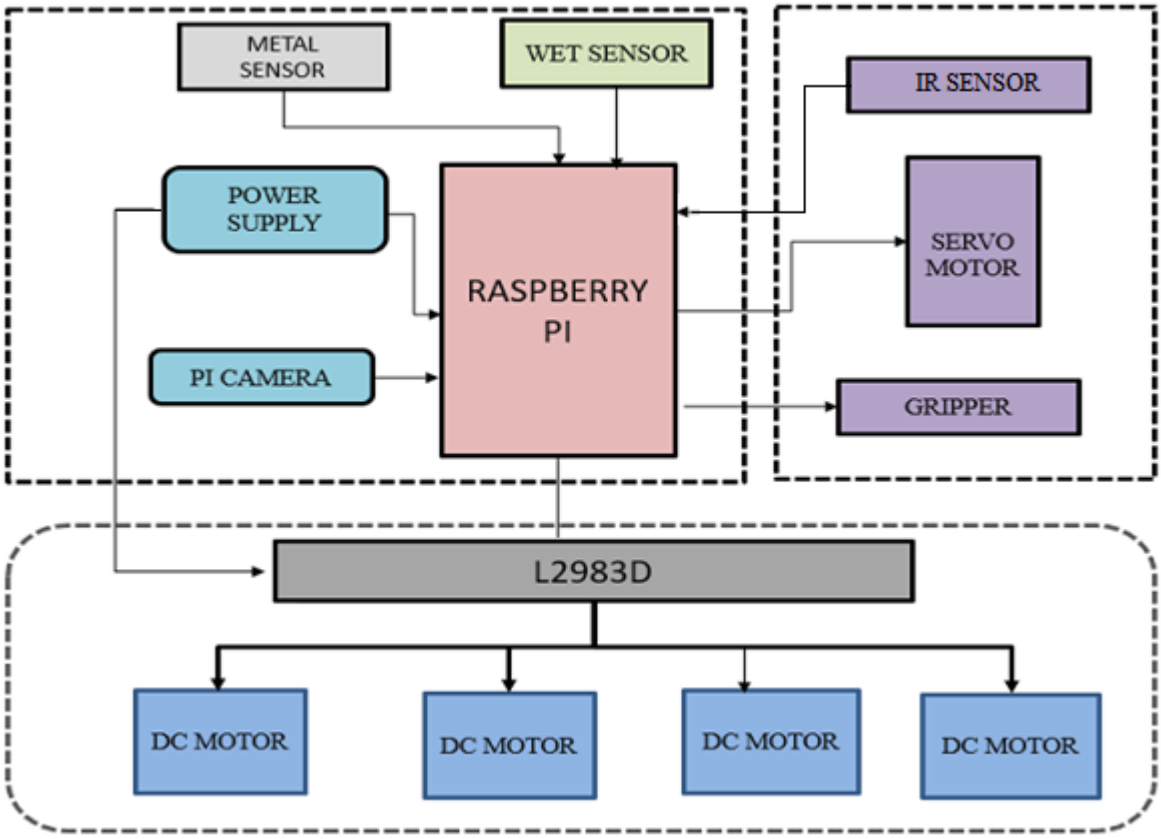

Fig.6.Hardware block diagram

4.1 Raspberry Pi

The raspberry pi is a small single board computers developed in the United Kingdom, by the Raspberry Pi Foundation to promote the teaching of basic computer in schools and in developed countries. It is credit card sized minicomputer that plugs onto your television, keyboard and mouse. This is great for two reasons, the first is that it provides extremely cheap access to a computer and second it is a great tool for learning about computers. The raspberry Pi has the ability to interact with outside world, and has been used in a wide array of digital maker projects.

4.2 Interfacing Servo Motor with Raspberry Pi

The tower pro MG90S servo motor used in this work, which consists of three Pins which include PWM (orange or yellow), VCC (red) and ground (brown).In order to control a Servo Motor, one need to use a technique called Pulse PWM. The frequency of the PWM signal is a fixed value and dependent on the type of the servo motor. Here, in this work three servo motors are used; one is connected in the base, one in the arm and the other to the gripper. The connection of one servo motor to Raspberry Pi is shown in figure 6.

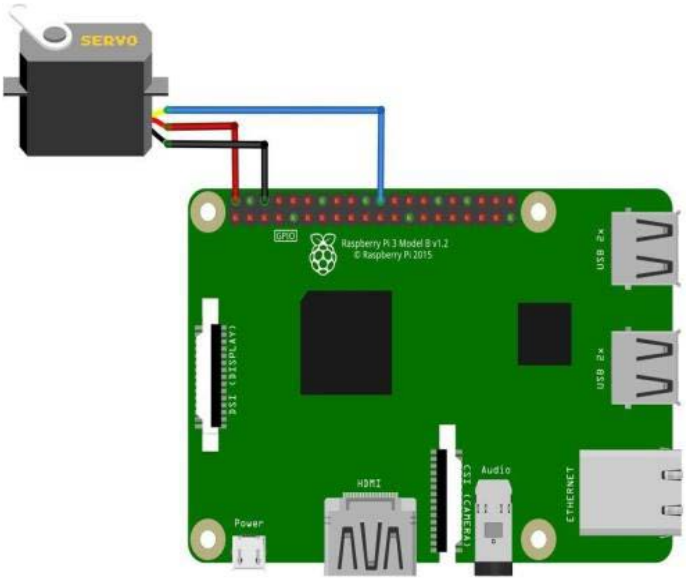

Fig.6.Servo Motor interface

4.2.1 Controlling the Robotic ARM with 3DOF for pick and place function

A robotic arm is a programmable mechanism comprising two or more segments linked by means of joints into a kinematic chain. Each joint in the chain is a servo or another motor providing either rotational or linear displacement of the segments. The number of linkages in the structure defines how many freedom degrees (DOF) it has—typically, ranging from two to the human arm maximum of seven. The basic function of a pick and place robot is done by its joints. Joints are analogous to human joints and are used to join the two consecutive rigid bodies in the robot. They can be rotary joint or linear joint. To add a joint to any link of a robot, we need to know about the degrees of freedom and degrees of movement for that body part. Degrees of freedom implement the linear and rotational movement of the body and Degrees of movement imply the number of axis the body can move.

A simple pick and place robot consists of two rigid bodies on a moving base, connected together with rotary joint. A rotary joint is a one which provides rotation in 360 degrees around any one of the axes. Movement of robot through its forward/backward/left/right motion. Robotic arm is an electro mechanical system with functions similar to that to that human arm. Totally three mg 995 servo motors are used for movement of arm. The first one is used for movement of forward and backward and the second one is for side ward, the third one is for opening and closing of gripper to hold the objects.

Fig.7. 3 DoF Robot ARM

A gripper is a device which enables the holding of an object to be manipulated. The easier way to describe a gripper is to think of the human hand. Just like a hand, a gripper enables holding, tightening, handling and releasing of an object.
A gripper is just one component of an automated system. A gripper can be attached to a robot or it can be part of a fixed automation system.

Fig.8. Gripper

4.3 Interfacing DC Motor with Raspberry Pi

DC Motor is generally used to convert direct current electrical energy into mechanical energy. A DC motor is a class of rotary electrical motor. The interfacing L298N Motor Driver Module with Raspberry Pi for DC Motor interface is shown in figure 9.

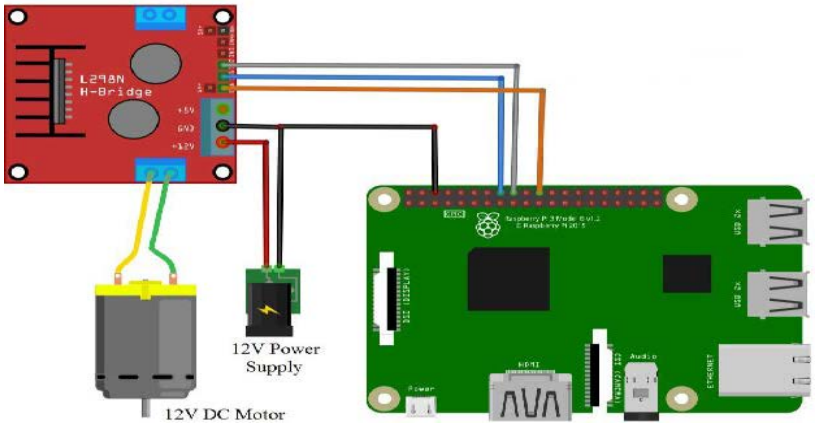

Fig.9.Circuit connection of DC Motor and Pi

Four DC motors are interfaced to Raspberry pi with the help of two L298N drivers. The chassis is the base frame of a Rover. Here, in this work chassis is used to place the robotic ARM above it. The chassis is in a hexagon shape with a radius of (21x21) cm. The chassis is installed with four wheels connected to DC motor, for the forward, backward, left and right movement of the chassis is shown in figure 10.

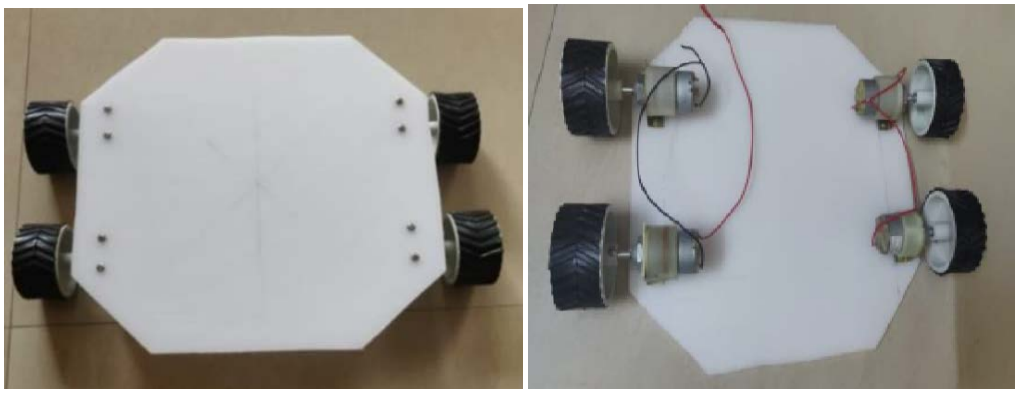

Fig.10.DC Motor connected to Chassis

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4.4 Interfacing Pi Cam with Raspberry Pi

Pi camera is used as a camera which can take Pictures and also high definition video. Raspberry Pi board has camera serial interface to which we can attach Pi camera module directly. Raspberry Pi is connected to CSI port using 15-Pin ribbon cable is shown in figure 11.

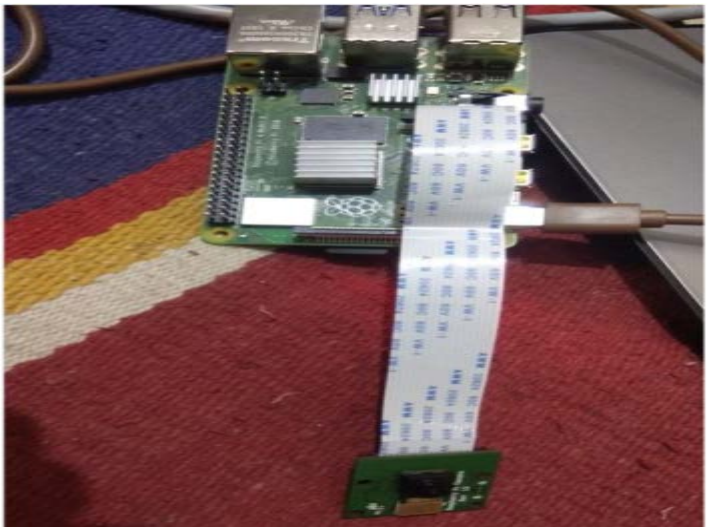

Fig.11. Pi Camera connected to Raspberry Pi

The below is the sample python code for image capturing from Pi camera

```
import picamera
import time
camera = picamera.PiCamera()
camera.vflip = True
camera.capture('example.jpg')
```

4.5 Infrared Sensor

An infrared sensor emits or detects infrared radiation to sense its surroundings. It is an electronic device which emits radiation in order to sense if any obstacles are present in the surroundings. IR sensor is also known as obstacle detector.

4.5.1 Connecting IR Sensor to Raspberry Pi

The IR Sensor Module has three Pins: VCC, GND and Data. Connect the VCC and GND Pins of the IR Sensor to +5V and GND Pins of the Raspberry Pi. Then connect the Data Pin of the IR Sensor to any GPIO pin of Pi.

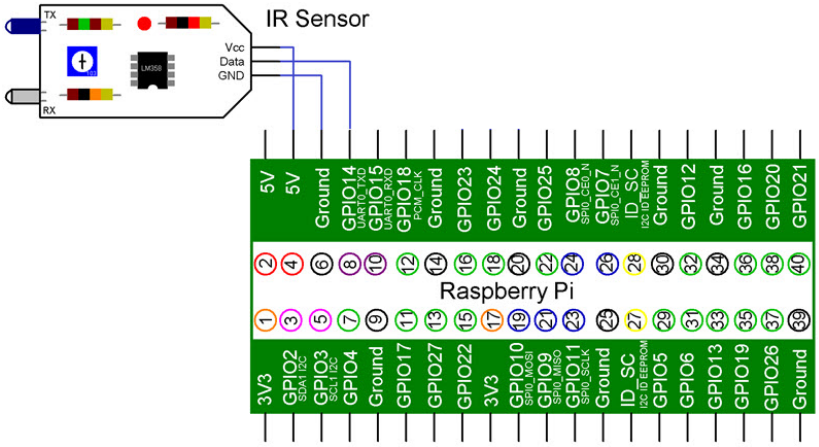

Fig.11.Connection of IR Sensor with Raspberry PI

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4.6 Soil Moisture Sensor (Wet Sensors)

The soil moisture sensor is used to measure the volumetric water content of soil. It uses the principle of capacitance to measure dielectric permittivity of the surrounding medium. The dielectric permittivity is a function of water content. The sensor creates a voltage proportional to the dielectric permittivity, and therefore the water content in the soil. The water content of a wet waste material will be more as compared to dry waste. This concept is used to separate wet waste from dry waste.

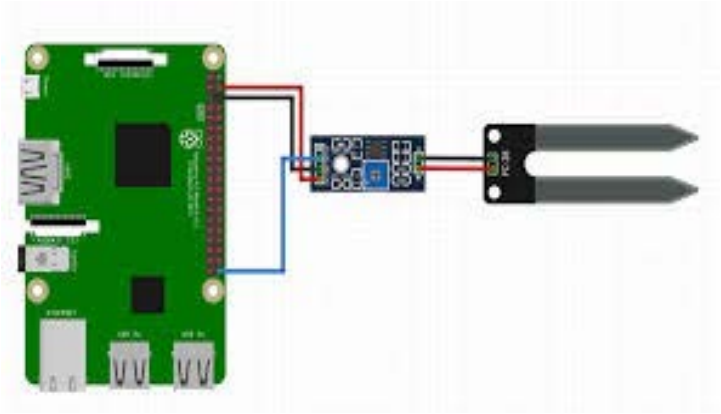
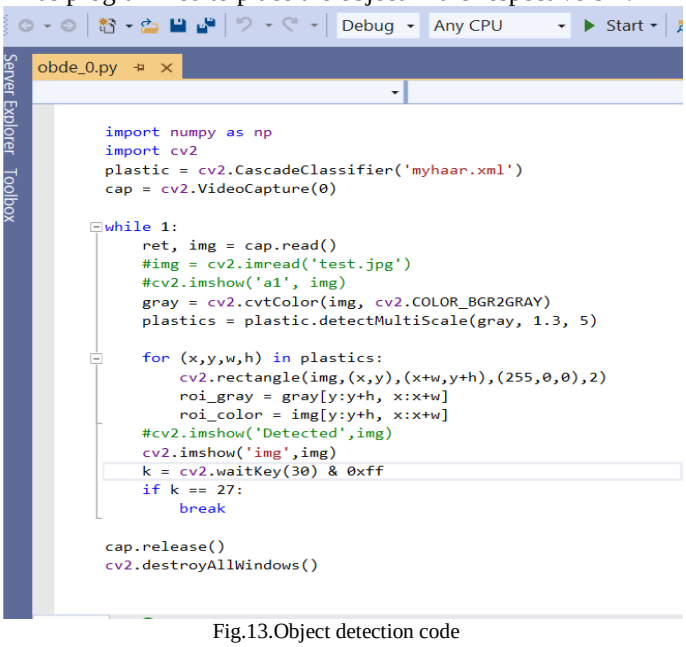


Fig.12.Connection of Moisture Sensor with Raspberry Pi

B. Software Implementation

For the identification and classification of waste, image processing is used. Waste is separated by four terms plastic, paper, metal and glass. Upon installing Opencv, first attempt was the template matching algorithm but on further research object detection algorithm for the image processing was implemented in our design. This algorithm involves creating haar cascade files for the different type of materials; we aim to distinguish mainly plastic, glass and wood. The object detection was carried out in the software Visual studio.
Initially haar XML file “myhaar.xml” for plastic image database was created, .xml haar cascade classifier file for each type of waste is created in a similar way and the snippet code for object detection is shown in figure. Once Image is classified and recognized, the robotic ARM as programmed to place the object in the respective bin.




```
import numpy as np
import cv2
plastic = cv2.CascadeClassifier('myhaar.xml')
cap = cv2.VideoCapture(0)

while 1:
    ret, img = cap.read()
    #img = cv2.imread('test.jpg')
    #cv2.imshow('a1', img)
    gray = cv2.cvtColor(img, cv2.COLOR_BGR2GRAY)
    plastics = plastic.detectMultiScale(gray, 1.3, 5)

    for (x,y,w,h) in plastics:
        cv2.rectangle(img,(x,y),(x+w,y+h),(255,0,0),2)
        roi_gray = gray[y:y+h, x:x+w]
        roi_color = img[y:y+h, x:x+w]
    #cv2.imshow('Detected',img)
    cv2.imshow('img',img)
    k = cv2.waitKey(30) & 0xff
    if k == 27:
        break

cap.release()
cv2.destroyAllWindows()
```

Fig.13.Object detection code

5. Conclusion and Future Scope

The designed robot assisted by image processing to pick and place waste will minimize human effort of segregating. Hence it will increase hygiene in the society and help in keeping environment clean. The use of image processing to segregate waste as plastic, wet and dry will give us more accurate and reliable output than the use of sensors to detect them as used in most of the previous studies. The advantage of this work is its contribution in making a Smart city. Among the many challenges that a city faces, waste management is of utmost importance. The discarded waste can be then processed to recover materials in an effective way and convert them to energy as usable fuels. This can be further advance by making use of machine learning and artificial intelligence to make it humanoid waste segregation robot.

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