Software Requirements Specification

for

Urban Waste Segregating Robotic Arm Using Machine Learning.

Version 1.0

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1. Introduction

1.1 Purpose

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. 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 area is reached.

1.2 Product Scope

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.

1.3 References

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2. Methodology

2.1 Machine Learning

There are multiple traditional ways in which UWSRA can get the garbage detected in the image, but all these methods are not robust and don't have accuracy anywhere near to the humans. To get an accuracy that is what the humans have achieved, AGDC needs to use Machine Learning approach. These approaches have already reached to near human accuracy, and some have also surpassed humans

2.2 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.

2.3 Object Detection

For detecting the garbage from the image, UWSRA uses CNN for obtaining the bounding box around the image portion of garbage under test. This is where UWSRA performs the task of object detection. Object detection refers to identifying instances of objects of a particular class (such as bottles, vegetables, cat or dog.) in images and videos in digital format. UWSRA uses object detection for classifying the garbage with the rest of the objects in the image. The object detection algorithm enables UWSRA to identify places in the image or video where the object of interest i.e. garbage is resting. To make an object detection algorithm for UWSRA, pre-trained data model is used and letting UWSRA in detecting the objects lying in front of the robot. The model was trained to give output in the form of four coordinates of the bounding box around the

garbage. This trained model is then transferred to the Raspberry Pi microprocessor board for carrying out the detection process for the robot. The team is working to train a custom object detection model which will be able to detect all the types of garbage.

2.4 OpenCV

OPENCV (Open Source Computer Vision Library) is an open source computer vision and machinelearning 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 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.

2.5 TensorFlow

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.

2.6 Assumptions and Dependencies

Assumptions

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

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. System Requirements

3.1 Hardware Requirements:

Raspberry pi-The Rasp-berry Pi is a series of small single-board computers with CPU: 32-bit and contains a SOC (System On Chip – Has multicore processor, GPU, ROM, I/O Peripherals inside it.), DDR RAM memory, Ethernet port, USB host, micro HDMI on it. The Raspberry Pi is a low cost,

credit-card sized computer that plugs into a computer monitor or TV, and uses a standard keyboard and mouse.

Pi-Camera-The Raspberry Pi camera module can be used to take high-definition video, as well as stills photographs. The camera consists of a small (25mm by 20mm by 9mm) circuit board, which connects to the Raspberry Pi's Camera Serial Interface (CSI) bus connector via a flexible ribbon cable. The camera's image sensor has a native resolution of five megapixels and has a fixed focus lens.

Memory Card-A memory card is an electronic flash memory data storage device used for storing digital information. These are commonly used in portable electronic devices, such as digital cameras, mobile phones, laptop computers, tablets etc

Robotic Arm-A robotic arm is a type of mechanical arm, usually programmable with similar functions to a human arm; the arm may be the sum total of the mechanism or may be part of a more complex robot. The links of such a manipulator are connected by joints allowing either rotational motion (such as in and articulated robot) or translational (linear) displacement.

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.

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.

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.

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.

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.

Regular wheels - 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 - 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.

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.

Tensorflow : TensorFlow is Google Brain's second-generation system. While the reference implementation runs on single devices, TensorFlow can run on multiple CPUs and GPUs (with optional CUDA and SYCL extensions for general-purpose computing on graphics processing units). TensorFlow is available on 64-bit Linux, macOS, Windows, and mobile computing platforms including Android and iOS. Its flexible architecture allows for the easy deployment of computation across a variety of platforms (CPUs, GPUs, TPUs), and from desktops to clusters of servers to mobile and edge devices.

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.

SSD(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.

Arduino Programming Languages (C/C++) - 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.

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.

4. System Features

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.

5. Working of the device

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.

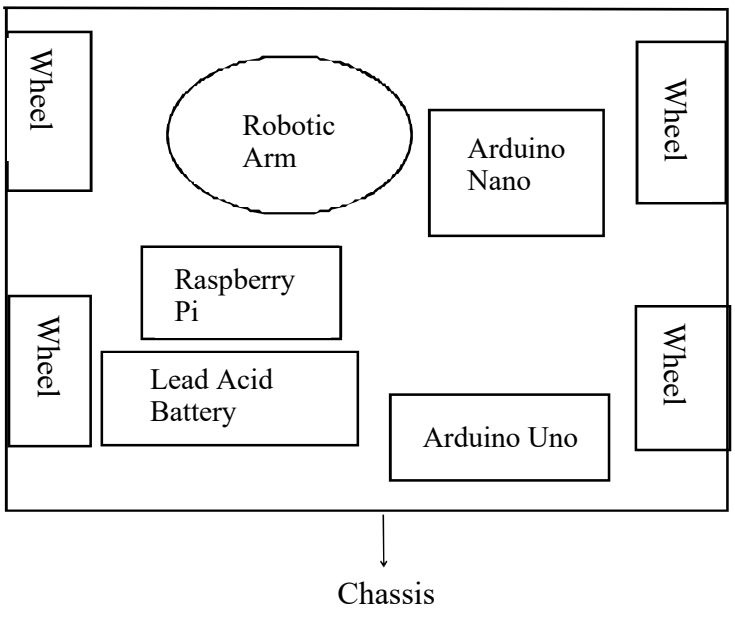
The process starts off by the pi camera clicking the picture of the waste. The image is then sent to the system via MQTT. Here, the system acts as a subscriber and the Pi acts as a publisher. Object detection algorithm will be made to run on the captured image. The object detection algorithm is trained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

- Fruit waste
- Paper
- Leaf

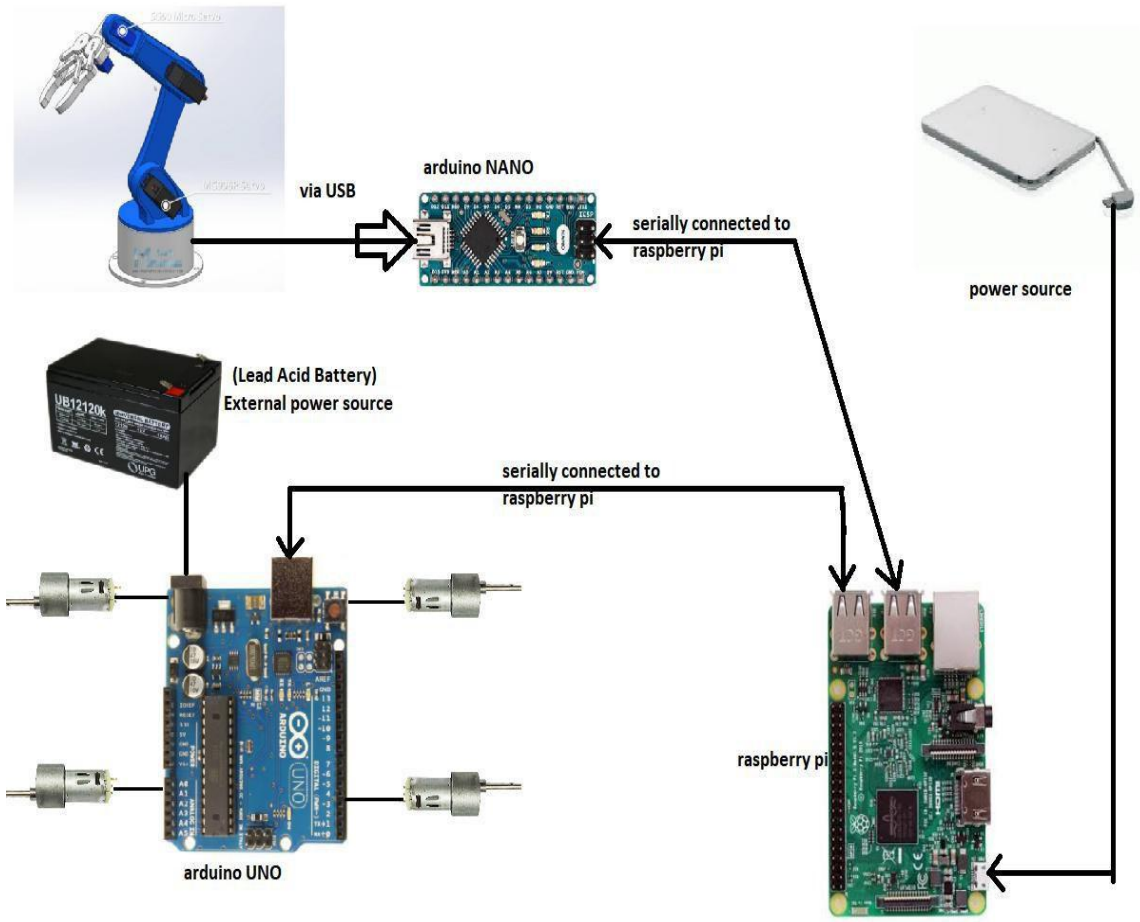
The Id, class and coordinates of the captured image will be printed as an output and a string of variables will be created. This string of variables is shared to the Raspberry Pi via MQTT. Here, the system acts as a publisher and the Pi acts as a subscriber. Now, the Pi reads the string and extracts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

6. Analysis Model

6.1 Architecture of the system

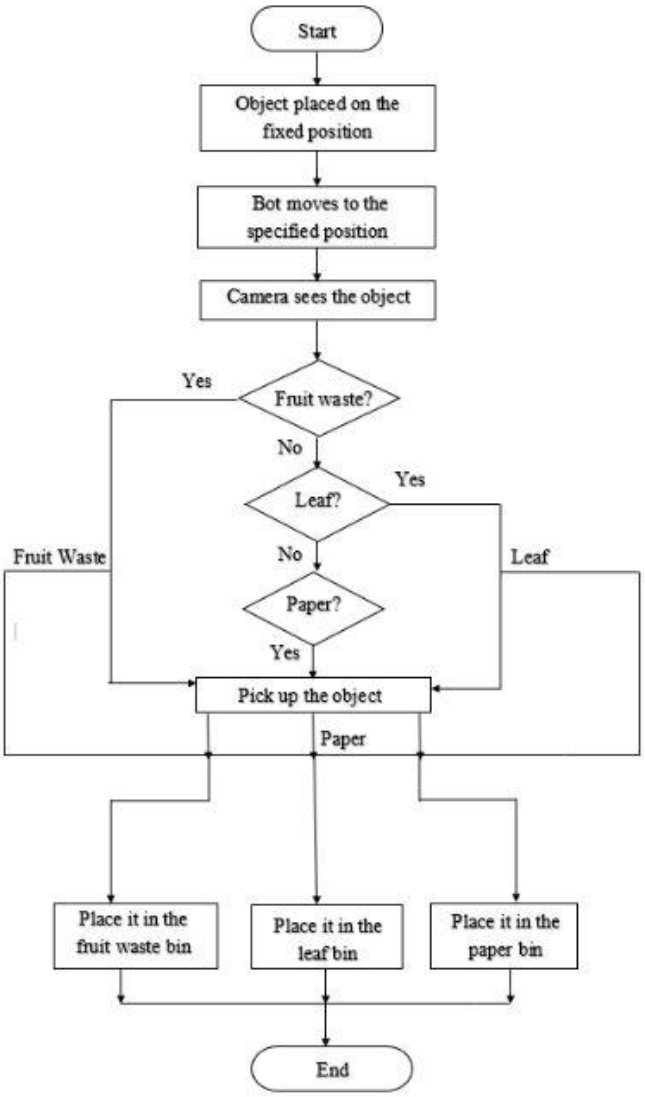


6.2 Design of the proposed system

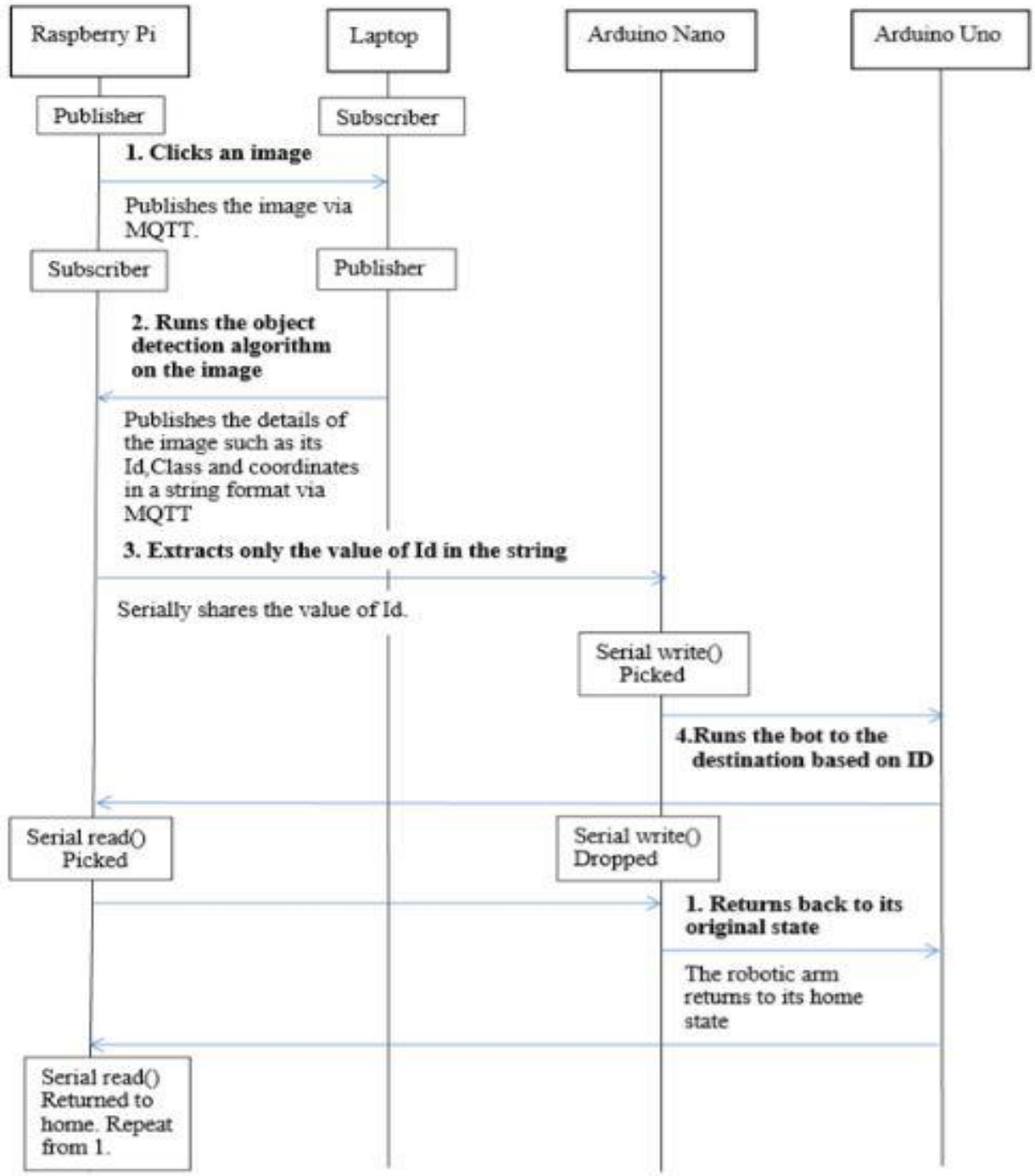


- Wired connection is made between the robotic arm and Arduino nano. Arduino nano controls the movements of the robotic arm.
- Arduino nano and Arduino uno are connected to the Raspberry Pi serially.
- Lead Acid Battery acts as an external power source to Arduino Uno. It has a voltage capacity of 12V.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

6.3 Flow Chart



6.4 Sequence Diagram



Appendix : Summary

If we tie all the above mentioned concepts in one system, then it will make an automatic waste detection, collection and segregation robot. We just have to set this system in one corner of the ground or at the starting of the road. The camera will capture the image and the image is shared to the system where machine learning algorithms will check for the type of waste. Once the details of the image such as Id,class and Coordinates

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.