A Phase-II Project Report On

"AN INTERNET OF THINGS BASED SMART WASTE MANAGEMENT SYSTEM USING DEEP LEARNING MODEL"

Submitted to

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In partial fulfillment for the award of the degree of

Bachelor of Engineering
In
Electronics & Communication Engineering

Submitted by

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CERTIFICATE

This is to certify that the Phase-II project work seminar entitled **" An Internet of Things Based Smart Waste Management System Using Deep Learning Model"** is a bonified work carried out by **VISHWAS V(1GC17EC029), TUBA KOUSER (1GC17EC026), UZMA AYESHA(1GC17EC027), MOHAMMED REHAN(1GC16EC035)** of Ghousia College of Engineering in partial fulfillment for the award of Bachelor of Engineering in **Electronics & Communication Engineering** of the **Visvesvaraya Technological University, Belgaum** during the year **2020-2021**. It is certified that all the corrections/suggestions indicated for internal assessment have been incorporated in the report deposited in the department library. The Phase-II Project report has been approved as it satisfies the academic requirements in respect to the technical part prescribed for the above said degree.

(Signature of the Guide)	**(Signature of coordinator)**	**(Signature of the HOD)**
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ABSTRACT

Owing to a paradigm shift toward Internet of Things (IoT), researches into IoT services have been conducted in a wide range of fields. As a major application field of IoT, waste management has become one such issue. The absence of efficient waste management has caused serious environmental problems and cost issues. The existing recycle bin has also proved its ineffectiveness in the public as people do not recycle their waste properly. With the development of Internet of Things (IoT) and Artificial Intelligence (AI), the traditional waste management system can be replaced with smart sensors embedded into the system to perform real time monitoring and allow for better waste management. The project is implemented using Image processing based deep learning model. The bin consists of several compartments to segregate the waste including metal, plastic, paper, and organic waste compartment which are controlled by the servo motors. Object detection and waste classification is done in Lobe Deep Learning framework with pre-trained object detection model. Object detection which is done through a camera connected to the Raspberry Pi 4 Model B+ as the main processing unit. Infrared sensor is embedded into each waste compartment to monitor the filling level of the waste.

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CHAPTER 1

INTRODUCTION

Internet of Things (IoT) is a concept in which surrounding objects are connected through wired and wireless networks without user intervention. In the field of IoT, the objects communicate and exchange information to provide advanced intelligent services for users. Owing to the recent advances in mobile devices equipped with various sensors and communication modules, together with communication network technologies such as Wi-Fi and LTE, the IoT has gained considerable academic interests.

Internet of things (IoT) is a communication paradigm that envisions a future paradigm where everyday life objects will be equipped with a microcontroller and some form of communication protocol. One well-known product of IoT is the smart city, which can be defined as a city with smart technology, smart people, and smart collaboration. IoT shall transparently and seamlessly incorporate a large number of heterogeneous end systems while providing open access to select subsets of data for the development of a plethora of digital services. One major topic within the smart city is smart waste management. When it comes to waste management systems, the communication distance between the waste collection center and the waste collection point is a major factor in determining the system's effectiveness. However, available communication technology such as LoRa and SigFox, which operate on a low power, wide-area network (LPWAN) are able to cater to the long-distance communication needed by the waste management system while sacrificing on the rate of data transmission. Studies in the field of wireless communication in IoT have also been accelerating. Conversely, communication technology such as Bluetooth, Wi-Fi, and Zigbee offer better data transmission rates, but these are limited by their data transmission ranges.

Waste management is a costly operation as it takes up a great deal of resources and labor. Efforts have been taken by the authorities to improve waste management systems by setting up the recyclable bin and launching the 3Rs campaign (recycle, reuse and reduce). A study on public awareness of recycling activities in Kota Bharu, Kelantan Malaysia shows that only 31.8% of the total of 384 participants were involved in recycling. This shows both that the initiatives taken previously were not effective and that a smart waste management system needs to be developed to replace the existing infrastructures.

Advances in the field of IoT have made it possible to improve the existing waste management system. Sensor's implementation in the waste bin together with IoT connectivity allow for real-time monitoring, which is absent in the existing waste management system. Data such as filling level, temperature, humidity, and any necessary data can be collected from the sensors. These data can then be transferred to the cloud for storage and processing. The processed data can then be used to study and access the limitation of the existing waste management system and therefore improve the system's efficiency as a whole. IoT application in the waste bin is one step towards a smart city.

IoT-based waste management models perform a vital function in improving the standard of living and human well-being by increasing energy-efficiency, enhancing governance, and reducing cost. In Vietnam, Ton Duc Thang University has set a goal to become an elite research university in the world's top 500 universities. With the successful model and dream of a top Vietnamese university, the application of IoT technology to waste management is one aspect of this model.

In addition, deep learning has provided state-of-the-art solutions for comprehensively understanding human behaviors. With the development of deep learning and image processing algorithms, the classification of waste can be carried out with higher accuracy and in a shorter time. Classification of waste is a crucial step before the separation of waste can be performed. A deep learning method such as a convolutional neural network allows for the extraction of unique features from the image and then classifies them into each class with high accuracy. TensorFlow is an open-source, deep-learning library used for machine learning applications. It is capable of speech recognition, image classification, object detection, text classification etc. With the intelligence gained from deep learning and an IoT, which integrates millions of smart devices together, the existing infrastructure for waste management systems can be improved.

Challenges in achieving sustainable waste management have been summarized in. Insufficient technologies and facilities due to the increasing rate of waste generation have resulted in the failure to cope with landfilling. The lack of a recycling market has also hindered the effectiveness of waste recycling implementation. Waste minimization is a costly operation, the lack of funds among industry practitioners has resulted in a reluctance to apply proper waste management techniques .Besides that, insufficient regulations imposed by authorities have allowed the practitioners to apply their way of waste management .Industry practitioners do not have an awareness of the importance of implementing a regulated waste management system based on the predefined waste management hierarchy .The present methods and

infrastructures used are discussed in.The existing infrastructures are carry high operating costs and offer only limited accuracy.

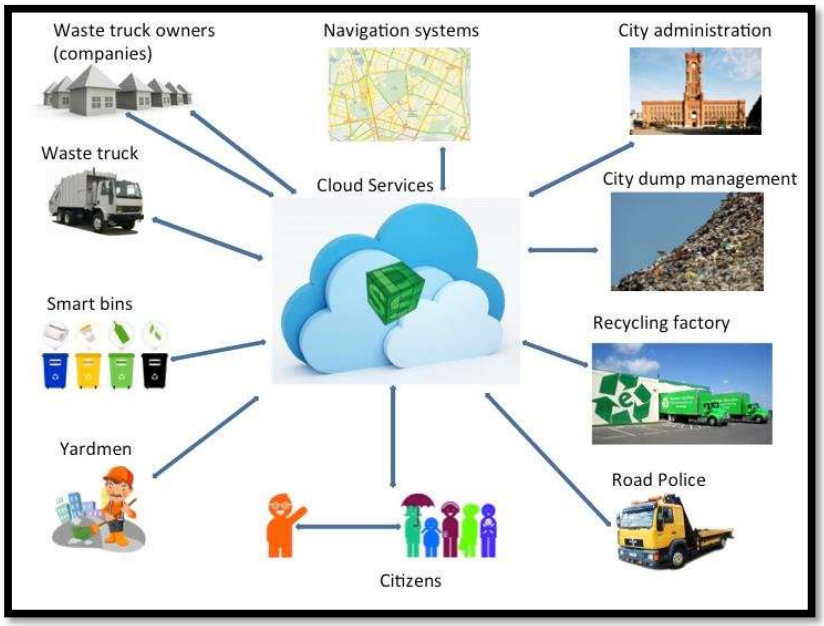


Fig 1.1 The big picture of a waste collection management system

1.1 Objective of the project

- To ensure the protection of the environment through effective waste management measures.
- To protect the health and wellbeing of people by providing an affordable waste collection service
- Reducing, Re-using, Recycling and Recovering waste.
- Treating and safely disposing of waste as a last resort.
- Promoting and ensuring the effective delivery of waste services.

1.2 Proposed System

The system consists of a conveyor where in the waste is placed or dropped first and this waste will be recognized by the tensor flow system with the help of the camera and further the waste will be categorized based on the data and it will be move to the selected category by the help of the conveyor and will be dropped to the bin of same category with the help of the servo motor .The user with the matching RFID pass Card will be allowed to drop the waste other user will not be let to put in the waste into this system.

1.3 Problem Definition

The second largest populated country in the world, India faces various hindrances to its development. Solid Waste Management is of critical concern and needs attention. Whereas many developed countries are searching for ready-made sustainable waste management solutions, India has created institutions to take on the big challenge of formal research on the topic. The current waste management practice in India involves collecting waste from sources through a community collective bin system, after which it gets transported to a low-lying landfill system with intermediate processing of Municipal Solid Waste (MSW). The open dumping practice is leading to various problems like pollution and health hazards. Both surface and groundwater are affected by this; in fact, groundwater is in a critical state. Current procedures are not ideal, hence, the solid waste management crisis. We team has planned to develop a system where we can make easy segregation of waste as paper metal plastic and bio waste which makes easy in further dumping process once it is fully segregated.

CHAPTER 2

LITERATURE SURVEY

"Waste management using Internet of Things (IoT)" Himadri Nath Saha et.al.,

Waste management is that the tactic of treating solid wastes and offers reasonably solutions for usage things that don't belong to trash. It's regarding but trash bin be used as a valuable resource. Waste management disposes of the merchandise and substances that we simply have use throughout a secure and economical manner. Researchers are finding out waste management for over a century, and for over forty years waste utilization analysis. There are eight major ways of waste management strategies, every of them divided into various classes. Those are-reduction and employ, animal feeding, recycling, composting, fermentation, landfills, burning and land application. We will begin exploitation several techniques right reception, like reduction and employ, that works to cut back the number of disposable materials used. Fortunately, IoT has the answer to assist the utilization method at each stage of the waste management.

"Professional Requalification Program for the Specialists in the Field of Waste Management"A.S. Furtatova et.al.,

The increased level of environmental pollution due to different kinds of waste, unauthorized landfills and the lack of counting and monitoring of the territories ecological conditions are problems faced by all mega-cities around the world. Nowadays, in the Russian Federation there is no system of preparing specialists in the field of waste management, which indicates the need for creating requalification program for specialists in this field. The article describes an additional professional requalification program developed at Peter the Great St. Petersburg Polytechnic University - "Environmental economics and waste management".

"Evaluation of the Waste Processing System in the Concept of Management of the Sustainable Development of the Arctic Zone of the Russia" A. A. Prianikova et.al.,

The current state of the Arctic zone of the Russian Federation needs the system of steady management in the field of ecology. This article describes a technique of development of similar system, on the basis of use of technologies for processing of waste of municipal units of the Arctic zone. The developed concept of synthesis of model of management process will

allow achieving with guarantee the objectives of management that significantly differs from the applied approaches based on the analysis. In article approach on the basis the solution of the return task of management is applied.

"Smart waste management using Internet-of-Things (IoT)" Gopal Kirshna Shyam et.al.,

To make the cities greener, safer, and more efficient, Internet of Things (IoT) can play an important role. Improvement in safety and quality of life can be achieved by connecting devices, vehicles and infrastructure all around in a city. Best technological solutions can be achieved in smart cities by making different stakeholders to work together. System integrators, network operators and technology providers have a role to play in working with governments to enable smart solutions. But, building such solutions on an open, standards-based communications platform that can be continuously used is a challenge. We present a waste collection management solution based on providing intelligence to wastebins, using an IoT prototype with sensors. It can read, collect, and transmit huge volume of data over the Internet. Such data, when put into a spatiotemporal context and processed by intelligent and optimized algorithms, can be used to dynamically manage waste collection mechanism. Simulations for several cases are carried out to investigate the benefits of such system over a traditional system. We try to replicate the scenario using Open Data from the city of Pune, India stressing on the opportunities created by this type of initiatives for several parties to innovate and contribute to the development of Smart waste management solutions.

"Smart Bin for Waste Management System" S. Sreejith et.al.,

This paper entitled "Smart Bin for Waste Management System" plays a vital role in the waste management system. A healthy domain is essential to a solid and cheerful environment. Clean and hygienic environments are a key need in human habitable environments. Smart bin is to develop a gainful and dynamic waste administration framework. In public places, dustbins are being flooded just as the waste spills out bringing about contamination. This likewise expands number of infections as huge number of bugs to breed on it. In this a smart bin is developed to monitor the level of waste, automatic disposing of waste and rain detection system. The outcome demonstrated that the detecting framework is effective and savvy and can be utilized to robotize any solid waste bin management process.

"Smart Garbage Management System" Parth Jajoo et.al.,

Swachh Bharat Abhiyan and digital India is a campaign by the government of India to keep infrastructure of the country clean and to make the cities smarter. Day by day the population of India is growing rapidly. At the same time, the garbage also is growing at the same rate. As a result the garbage management is a problem that is quite hectic issue to solve. All Citizens of India are aware about the process followed to collect the garbage in the society. The Brihan Mumbai Municipal Corporation (BMC) sometimes fails to collect the garbage in some area. It may cause pollution which leads to sanitary issues and disease. Therefore, some of the major steps have to be carried out to solve the management of waste. The existing system is collection of garbage arbitrarily. So, some of the areas get left sometimes which may lead to unodoured smell and hence public health gets affected. The smell of the garbage can also be fatal to some of the little ones in some areas. The proposed system describes the solution to the existing drawback. The proposed system monitors the garbage bin. While monitoring the garbage bin it sends the notification to the authority about the level of garbage filled. If the lower authority ignores the notification, the next notification goes to the higher authority. The proposed system will help them to actually know that where and when to go to collect the garbage. The proposed system manages the effort to check the area by visiting there. The proposed project is quite helpful for both the Brihan Mumbai Municipal Corporation (BMC) and the citizens in that area by time-to-time interaction between Brihan Mumbai Municipal Corporation (BMC) and the proposed system. Hence the proposed system makes a better way to manage garbage.

"SWM: Smart waste management for green environment" Teh Pan Fei et.al.,

Smart Waste Management (SWM) system is a waste management system that tracks the status of fill level of trash bins equipped with ultrasonic sensors and tracks GPS-equipped trash collection trucks. The problems identified are the overflowing trash bins especially in public areas with high population density and the complaints from the residents or public complaints regarding the punctuality of trash collection trucks. The objectives of the project are to design a Smart Waste Management (SWM) system based on Bootstrap platform, develop the system and test its functionality in fulfilling the requirements of the project. The methodological approach selected in this project is the waterfall methodology in which it comprises of four crucial phases: planning and analysis, system design, system implementation and system testing whereby each phase must be completed systematically prior to the

commencement of subsequent phase. It is expected that the Smart Waste Management (SWM) system would be able to fulfill all of the project's objectives. This system is aimed to address the problems of overflowing trash bins and public complaints on trash collection trucks. The development of this system brings a huge significance in which operators would be able to know which trash bins require immediate collection and request for immediate dispatch by collection trucks. This method is seen to be more efficient compared to routine collection. Operators would also be able to track the relevant dispatch trucks through this convenient system.

"Smart Systems and the Internet of Things (IOT) For Waste Management" Claude-Noel Tamakloe et.al.,

Waste management is a great concern faced by many nations in the world today. On the streets of major cities, it has become almost common to find waste which poses health hazards and other concerns to its communities and inhabitants. This project focuses on the use of smart systems and the Internet of Things (IOT), to provide an efficient and effective approach to waste management. This project designed and manufactured a prototype of a solar- powered, self-compacting smart bin with a server-side monitoring application. The prototype smart bin is capable of monitoring internal rubbish levels, compact it, freeing approximately 25 percent of the space with each compaction. The bin also monitors total weight and is capable of sending all this information to a secure server-side application. The accompanying web application monitors the state of each smart bin and proposes optimal routes for pick up. This approach will contribute to a smart and efficient waste disposal, improving the cites waste management.

"Eco-friendly IOT based waste segregation and management" B R Santhosh Kumar et.al.,

In recent years collection and segregation of waste is the major challenge faced by all metropolitan cities worldwide, this is due to the rapid increase in population, industrialization and urbanization. There is lack of knowledge about segregation of waste at the domestic level. The major problems faced due to improper waste management include health hazards to human kind, environmental issues etc. Therefore leading to an unhealthy atmosphere to survive. Segregation of wastes at junk yards is a tedious and time consuming process hence recycling of wastes is not effectual. These drawbacks can be overcome by proper waste management at domestic level. The main objective of this paper is effective and efficient methods of waste collection and segregation at domestic level based on their nature of composition i.e. metal,

plastic and biodegradable, the waste is stored accordingly in their respective segments of the dustbin.

"Smart solid waste management" Ravi Kishore Kodali et.al.,

The rapid growth in the population automatically demands better infrastructure and more facilities. Employment and attaining balance in economy is an important concern for a nation having such rapid increase in its population, which finally results into evolution of new urban areas and cities. A smart city is created upon various particular components and strong waste administration is one of these crucial viewpoints. For example, today, to address the rising issue of carbon emissions in construction process, contractual workers are obligatorily made a request to use supplies according certain standards. Subsequently, to employ such operational standards we need dynamic investment and acknowledgment from the workers in using equipment according to the endorsed technologies. Essentially, the adequacy of strong waste administration framework relies on the involvement of the considerable number of stakeholders and natives. Strong waste administration is of grave significance to a urbanized locale which confronts the consistent growth in population, rising infrastructural requests and extending inflow of migrants. Understanding the idea and setting of waste isolation is additionally a key segment in the strong waste administration handle. This is the phase where India still lingers behind as against the universal partners. In a nation like Finland, just around 7 percent of the waste gets arranged into the dumping yard and the staying around 93 percent of the waste segment is reused. This level of adequacy in actualizing the strong waste administration framework is possible just because of subjective spread of civic sense, clear understanding and acknowledgment over the idea of waste segregation.

"Waste Management Improvement in Cities using IoT" Shivam Jagtap et.al.,

Garbage collection is one of the most critical problems faced by Municipal Corporation. While implementing the waste management in cities the biggest challenge is the management of waste in cost optimal way with high performance. The current process of collecting the waste, separating it and transporting the containers everyday which is a complicated process. This paper deals with the concept of waste management and the smart system for waste management with higher benefits to the society. The proposed system for waste management will use various sensors for sensing the type of waste and separate the waste in different categories and actuator to inform the management to collect the waste container. This system

will save money and time compared to the already available process of waste management and also improves the society cleanliness.

"An IoT Based Smart Energy Management System" Jai Krishna Mishra et.al.,

Physical energy meter reading is an outdated concept, it is inefficient, prone to errors and leads to a lot of wastage of manpower and is a burden on the consumers since the energy companies pass on the cost of physically reading the meters to the consumers. Smart energy meters solve the above-mentioned problems to a great extent but replacing the older energy meters is a very expensive and a humongous task. This paper introduces an IoT based smart energy meter using the raspberry pi devices as a solution to the aforementioned issue. A small modification to the already installed old meters can make them act as prepaid smart meters. So, the need to replace the old energy meter does not arise. These meters can be easily accessed through customized web pages, smart mobile applications and relevant notifications can be sent to the customers using SMS service. These meters can be turned ON and OFF automatically once a user exhausts its prepaid threshold value or through the smart App. Consumers are notified through SMS when the threshold set value is about to breach.

"Smart Dual Dustbin Model for Waste Management in Smart Cities" G Sai Rohit et.al.,

As urbanization is spreading rapidly, there is an increase in production of waste. Waste management is a crucial issue to be considered at public places where waste is overflowed from the bins and may cause different diseases. The present work focuses to develop a model of smart dustbin which can be effectively used at public places in smart cities. The model has two dustbins (named as Dustbin A and Dustbin B) which will be kept at public places mostly. Dustbin A can be used but Dustbin B cannot be used until Dustbin A is full. Dustbin B can only be used once Dustbin A is full and then Dustbin A will not open until the waste is cleared in the Dustbin A. Whenever any dustbin is filled up, a message is sent to the concerned authority. This will avoid overflow of waste in the bin. Dustbins have automatically close and open feature depending on the presence of an obstacle. In our system, the garbage level in the dustbins is detected with the help of Ultrasonic sensor and presence of the obstacle is detected by IR Sensors and communication to the authorized control room by GSM system

"Digital Dustbin Smart Bins for Smart Cities" Mohit Panjabi et.al.,

This paper researches around the area of the solution of the garbage disposal and waste management with the help of technology. It gives a detailed model of how we can achieve the goal of 'Clean India' together with the use of sensors, cameras, servers, and even human psychology. With the revolutions taking place all over the world on the subject of the climate crisis and global warmings, it becomes a duty of every citizen to contribute to the future lifestyle. Satisfying all the parameters, at first, past researches have been compared, objectives have been defined and then a working model is thus presented. It has always been difficult to change the mind-set of a whole lot of people, and thus in this research paper, addressing this problem, the solution of such product development is given which satisfies the need of the citizens and also contributes effectively to the waste management system. The model is proved with a prototype, and all the facts& figures are provided, which are necessary.

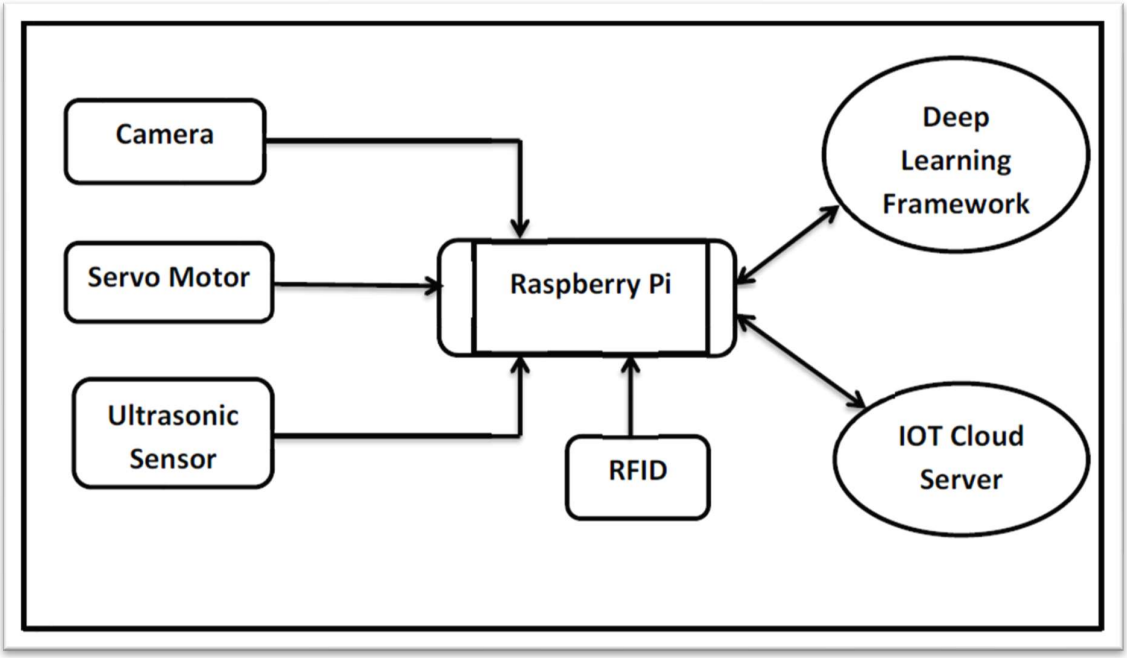
CHAPTER 3

ARCHITECTURE WORKING

Raspberry pi microprocessor is used as the heart of the system. The Camera Module is Connected to Raspberry Pi to capture the waste images for the purpose of object detection and identification. The Object detection is done with the help of pre trained model and this model is created with thousands of images which includes different objects labeled according to their Category. After the waste is identified, servo motors controlled by the Raspberry Pi will actuate the opening and closing of the lid of the waste compartment. The opening of the lid allows.

Waste to fall from the waste detection compartment into its respective waste compartment. The ultrasonic sensor is connected to Raspberry Pi to monitor the filling level of each of the bin's waste compartment, including a plastic, metal, paper, and general waste compartment. The filling level and real-time bin are collected and transferred via Internet from the bin to the server side. The data received in the server side will be processed and uploaded to cloud server and this data can be used for monitoring waste bin status from cloud. RFID Is used in this system in connection with the raspberry pie where in it allows the only authorized user to put in the waste in to the bin.

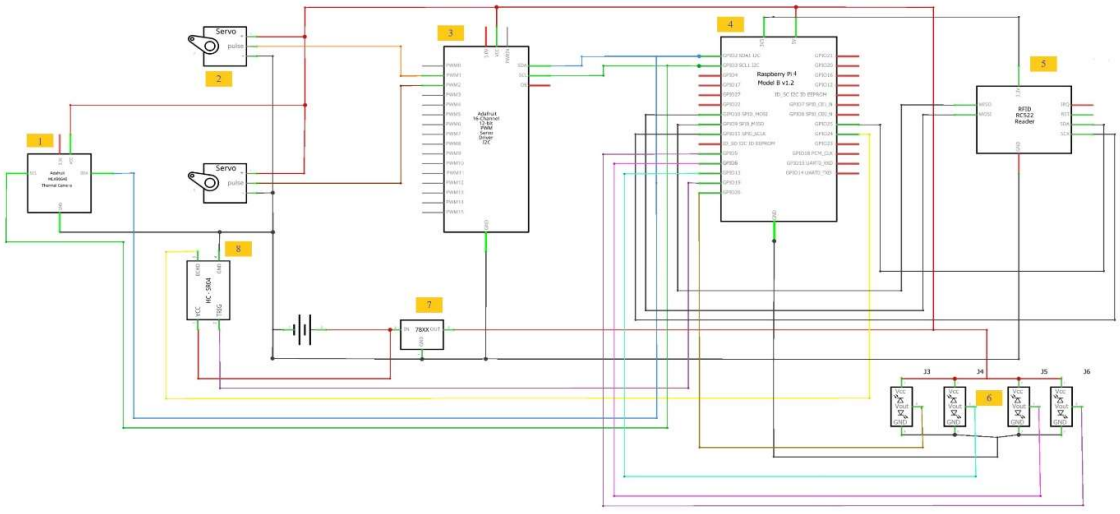
3.1 Block Diagram.



3.2 Hardware and Software Requirements.

- Raspberry Pi 4
- Webcam
- Servo MG995
- PCA9685 Servo Driver
- Power Supply for RPI
- Ultrasonic Sensor
- IR Sensor
- IC 7805 Voltage Regulator
- RC522 RFID Module
- IoT Cloud Platform
- Python IDLE
- Raspberry Pi OS
- Blynk IoT Platform

3.3 Circuit Diagram of An IoT Based Smart Waste Management System



1.Camera Module
2.Servo MG955
3.PCA9685 Servo Driver
4.Raspberry Pi 4
5.RC522 RFID Module
6.Infrared Sensor
7.IC 7805 Voltage Regulator
8.HC-SR04 Ultrasonic Sensor

Fig 3.1 An IoT Based Smart Waste Management System Circuit Diagram

RASPIBERRY PI 4

The Raspberry Pi 4 Model B is the latest version of the low-cost Raspberry Pi computer. The Pi isn't like your typical device; in its cheapest form it doesn't have a case, and is simply a credit-card sized electronic board -- of the type you might find inside a PC or laptop, but much smaller.

It costs as little as $35, although you might want to choose the $55 version with its 4GB of RAM for its better all-round performance.

WHAT IS THE RASPBERRY PI 4 CAPABLE OF?

The Raspberry Pi 4 can do a surprising amount. Amateur tech enthusiasts use Pi boards as media centers, file servers, retro games consoles, routers, and network-level ad-blockers, for starters. However that is just a taste of what's possible. There are hundreds of projects out there, where people have used the Pi to build tablets, laptops, phones, robots, smart mirrors, to take pictures on the edge of space, to run experiments on the International Space Station -- and that's without mentioning the more wacky creations -- teabag dunker anyone?

With the Pi 4 being faster, able to decode 4K video, benefiting from faster storage via USB 3.0, and faster network connections via true Gigabit Ethernet, the door is open to many new uses. It's also the first Pi that supports two screens at one -- up to dual 4K@30 displays -- a boon for creatives who want more desktop space.

Fig 3.2 Raspberry Pi 4

HOW DO I GET STARTED WITH THE RASPBERRY PI 4?

One thing to bear in mind is that in its cheapest form, the Pi is just a bare board. You'll also need a power supply, a monitor or TV, leads to connect to the monitor -- typically a micro HDMI cable -- and a mouse and keyboard.

Once you've hooked up all the cables, the easiest way for new users to get up and running on the Pi is to download the NOOBS (New Out-Of-Box Software) installer. After the download finishes, follow the instructions here and it will walk you through how to install an OS on the Pi. The installer allows you to install various operating systems, although a good choice for first time users is the official OS, which is called Raspbian.

The look and feel of Raspbian should be familiar to any recent desktop computer user. The OS, which is constantly being improved, has had several graphical overhauls, most recently to give its interface a minimalistic look, and includes an optimized web browser, an office suite, programming tools, educational games, and other software.

RASPBERRY PI 4'S SPECS

- **System-on-a-chip:** Broadcom BCM2711
- **CPU:** Quad-core 1.5GHz Arm Cortex-A72 based processor
- **GPU:** Video Core VI
- **Memory:** 1/2/4GB LPDDR4 RAM
- **Connectivity:** 802.11ac Wi-Fi / Bluetooth 5.0, Gigabit Ethernet
- **Video and sound:** 2 x micro-HDMI ports supporting 4K@60Hz displays via HDMI 2.0, MIPI DSI display port, MIPI CSI camera port, 4 pole stereo output and composite video port
- **Ports:** 2 x USB 3.0, 2 x USB 2.0
- **Power:** 5V/3A via USB-C, 5V via GPIO header
- **Expandability:** 40-pin GPIO header

A powerful feature of the Raspberry Pi is the row of GPIO (general-purpose input/output) pins along the top edge of the board. A 40-pin GPIO header is found on all current Raspberry Pi

boards (unpopulated on Pi Zero and Pi Zero W). Prior to the Pi 1 Model B+ (2014), boards comprised a shorter 26-pin header.

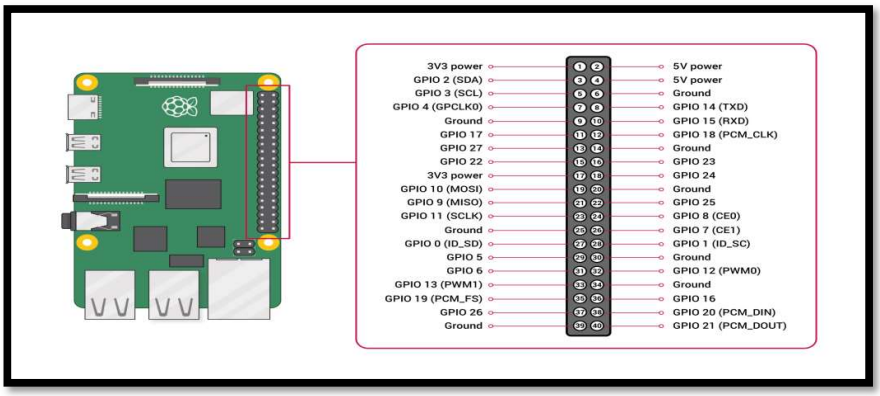


Fig 3.3 Pin Description Of Raspberry Pi

Hardware

The Raspberry Pi hardware has evolved through several versions that feature variations in the type of the central processing unit, amount of memory capacity, networking support, and peripheral-device support.

The Pi Zero models are similar, but lack the Ethernet and USB hub components. The Ethernet adapter is internally connected to an additional USB port. In Model A, A+, and the Pi Zero, the USB port is connected directly to the system on a chip (SoC). On the Pi 1 Model B+ and later models the USB/Ethernet chip contains a five-port USB hub, of which four ports are available, while the Pi 1 Model B only provides two. On the Pi Zero, the USB port is also connected directly to the SoC, but it uses a micro-USB (OTG) port. Unlike all other Pi models, the 40 pin GPIO connector is omitted on the Pi Zero, with solder-able through-holes only in the pin locations. The Pi Zero WH remedies this.

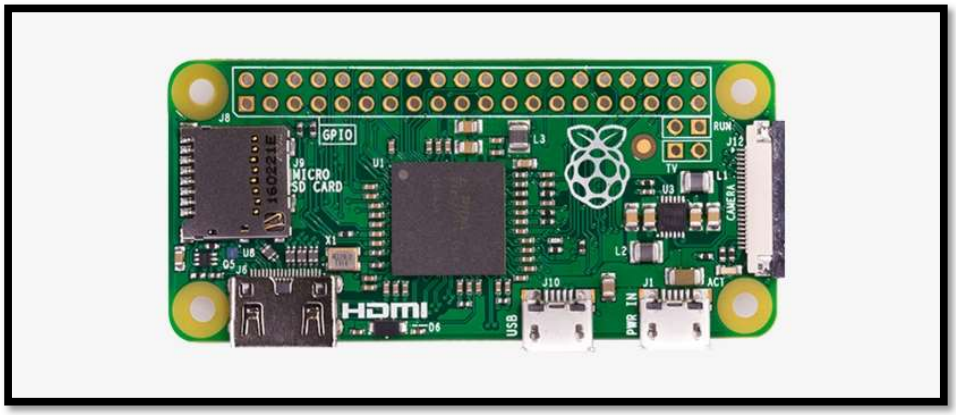


Fig 3.4 Raspberry Pi Zero W

Processor speed ranges from 700 MHz to 1.4 GHz for the Pi 3 Model B+ or 1.5 GHz for the Pi 4; on-board memory ranges from 256 MB to 1 GB random-access memory (RAM), with up to 8 GB available on the Pi 4. Secure Digital (SD) cards in Micro SDHC form factor (SDHC on early models) are used to store the operating system and program memory. The boards have one to five USB ports. For video output, HDMI and composite video are supported, with a standard 3.5 mm tip-ring-sleeve jack for audio output. Lower-level output is provided by a number of GPIO pins, which support common protocols like I²C. The B-models have an 8P8C Ethernet port and the Pi 3, Pi 4 and Pi Zero W have on-board Wi-Fi 802.11n and Bluetooth.

Processor

The Broadcom BCM2835 SoC used in the first generation Raspberry Pi includes a 700 MHz ARM1176JZF-S processor, Video Core IV graphics processing unit (GPU), and RAM. It has a level 1 (L1) cache of 16 KB and a level 2 (L2) cache of 128 KB. The level 2 cache is used primarily by the GPU. The SoC is stacked underneath the RAM chip, so only its edge is visible. The ARM1176JZ(F)-S is the same CPU used in the original iPhone, although at a higher clock rate, and mated with a much faster GPU.

The earlier V1.1 model of the Raspberry Pi 2 used a Broadcom BCM2836 SoC with a 900 MHz 32-bit, quad-core ARM Cortex-A7 processor, with 256 KB shared L2 cache. The Raspberry Pi 2 V1.2 was upgraded to a Broadcom BCM2837 SoC with a 1.2 GHz 64-bit quad-core ARM Cortex-A53 processor, the same SoC which is used on the Raspberry Pi 3, but underclocked (by default) to the same 900 MHz CPU clock speed as the V1.1. The BCM2836 SoC is no longer in production as of late 2016.

The Raspberry Pi 3 Model B uses a Broadcom BCM2837 SoC with a 1.2 GHz 64-bit quad-core ARM Cortex-A53 processor, with 512 KB shared L2 cache. The Model A+ and B+ are 1.4 GHz

Fig 3.5 Processor of Raspberry Pi

The Raspberry Pi 4 uses a Broadcom BCM2711 SoC with a 1.5 GHz 64-bit quad-core ARM Cortex-A72 processor, with 1 MB shared L2 cache. Unlike previous models, which all used a custom interrupt controller poorly suited for virtualization, the interrupt controller on this SoC is compatible with the ARM Generic Interrupt Controller (GIC) architecture 2.0, providing hardware support for interrupt distribution when using ARM virtualization capabilities.

The Raspberry Pi Zero and Zero W use the same Broadcom BCM2835 SoC as the first-generation Raspberry Pi, although now running at 1 GHz CPU clock speed. The Raspberry Pi Pico uses the RP2040 running at 133MHz.

RAM

The early designs of the Raspberry Pi Model A and B boards included only 256 MB of random-access memory (RAM). Of this, the early beta Model B boards allocated 128 MB to the GPU by default, leaving only 128 MB for the CPU. On the early 256 MB releases of models A and B, three different splits were possible. The default split was 192 MB for the CPU, which should be sufficient for standalone 1080p video decoding, or for simple 3D processing. 224 MB was for Linux processing only, with only a 1080p framebuffer, and was likely to fail for any video or 3D. 128 MB was for heavy 3D processing, possibly also with video decoding. In comparison, the Nokia 701 uses 128 MB for the Broadcom Video Core IV.

Fig 3.6 RAM of Raspberry Pi

The later Model B with 512 MB RAM, was released on 15 October 2012 and was initially released with new standard memory split files (arm256_start.elf, arm384_start.elf, arm496_start.elf) with 256 MB, 384 MB, and 496 MB CPU RAM, and with 256 MB, 128 MB, and 16 MB video RAM, respectively. But about one week later, the foundation released a new

version of start.elf that could read a new entry in config.txt (gpu_mem=xx) and could dynamically assign an amount of RAM (from 16 to 256 MB in 8 MB steps) to the GPU, obsoleting the older method of splitting memory, and a single start.elf worked the same for 256 MB and 512 MB Raspberry Pis.The Raspberry Pi 2 has 1 GB of RAM. The Raspberry Pi 3 has 1 GB of RAM in the B and B+ models, and 512 MB of RAM in the A+ model. The Raspberry Pi Zero and Zero W have 512 MB of RAM.

The Raspberry Pi 4 is available with 2, 4 or 8 GB of RAM. A 1 GB model was originally available at launch in June 2019 but was discontinued in March 2020, and the 8 GB model was introduced in May 2020.

Networking

The Model A, A+ and Pi Zero have no Ethernet circuitry and are commonly connected to a network using an external user-supplied USB Ethernet or Wi-Fi adapter. On the Model B and B+ the Ethernet port is provided by a built-in USB Ethernet adapter using the SMSC LAN9514 chip. The Raspberry Pi 3 and Pi Zero W (wireless) are equipped with 2.4 GHz Wi-Fi 802.11n (150 Mbit/s) and Bluetooth 4.1 (24 Mbit/s) based on the Broadcom BCM43438 Full MAC chip with no official support for monitor mode (though it was implemented through unofficial firmware patching) and the Pi 3 also has a 10/100 Mbit/s Ethernet port. The Raspberry Pi 3B+ features dual-band IEEE 802.11b/g/n/ac Wi-Fi, Bluetooth 4.2, and Gigabit Ethernet (limited to approximately 300 Mbit/s by the USB 2.0 bus between it and the SoC). The Raspberry Pi 4 has full gigabit Ethernet (throughput is not limited as it is not funneled via the USB chip.)

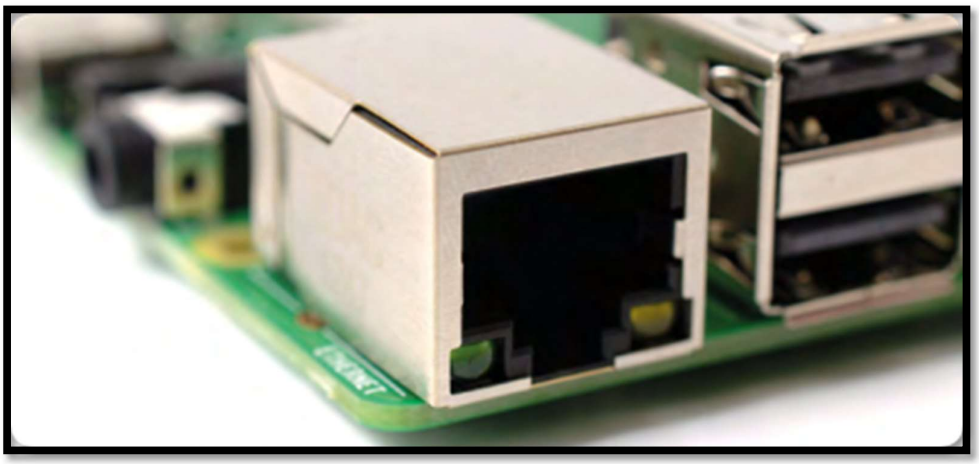


Fig 3.7 Networking Port in Raspberry Pi

WEBCAM

Fig 3.8 Webcam

A webcam – short for 'web camera' – is a digital camera that's connected to a computer. It can send live pictures from wherever it's sited to another location by means of the internet. Many desktop computer screens and laptops come with a built-in camera and microphone, but if yours doesn't, you can add a separate webcam at any time.

There are various types. Some are plugged into computers through USB ports, but others are wireless (Wi-Fi). Other features might include:

- an integral microphone
- the ability to pan and tilt
- in-built sensors that can detect movement and start recording
- a light that, when on, will let you know that the camera is in use.

There's a wide range of things that you can do with a webcam. The most common is to video chat over the internet using Skype – see our Skype guides for all the information you need to get going. And always remember, and remind your children, that any images you make available to others via your webcam could remain on the internet forever.

Servo MG995

MG995 Metal Gear Servo Motor is a high-speed standard servo can rotate approximately 180 degrees (60 in each direction) used for airplane, helicopter, RC-cars and many RC model. Provides 10kg/cm at 4.8V, and 12kgcm at 6V.

It is a Digital Servo Motor which receives and processes PWM signal faster and better. It equips sophisticated internal circuitry that provides good torque, holding power, and faster updates in response to external forces.

Fig 3.9 Servo MG995

They are packed within a tight sturdy plastic case which makes them water and dust resistant which is a very useful feature in RC planes, Boats, and RC Monster Trucks etc. It equips 3-wire JR servo plug which is compatible with Futaba connectors too.

Wire Description: -

- RED – Positive
- Brown – Negative
- Orange – Signal

Specification: -

- Weight: 55g
- Dimension: 40.7 × 19.7 × 42.9 mm
- Operating Speed (4.8V no load): 20sec / 60 deg
- Operating Speed (6.0V no load): 16sec / 60 deg (no load)
- Stall Torque (4.8V): 10kg/cm
- Stall Torque (6.0V): 12kg/cm
- Operation Voltage: 4.8 - 7.2Volts
- Gear Type: All Metal Gears
- Stable and shock proof double ball bearing design
- Dead band width: 5 µs
- Temperature range: 0 ºC – 55 ºC.
- Control System: Analog
- Operating Angle: 120degree
- Required Pulse: 900us-2100us

Features:

- The connection cable is thicker.
- Equips high-quality motor.
- High resolution
- Accurate positioning
- Fast control response
- Constant torque throughout the servo travel range
- Excellent holding power

PCA9685 SERVO DRIVER

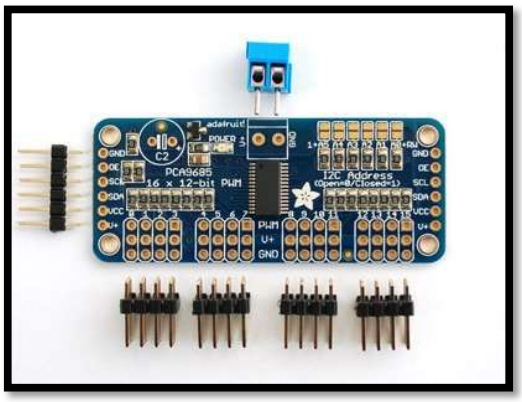


Fig 3.10 PCA9685 SERVO DRIVER

Driving servo motors with the Arduino Servo library is pretty easy, but each one consumes a precious pin - not to mention some Arduino processing power. The Adafruit 16-Channel 12-bit PWM/Servo Driver will drive up to 16 servos over I2C with only 2 pins. The on-board PWM controller will drive all 16 channels simultaneously with no additional Arduino processing overhead. What's more, you can chain up to 62 of them to control up to 992 servos - all with the same 2 pins!

Power Pins

- **GND** - This is the power and signal ground pin, must be connected
- **VCC** - This is the **logic** power pin, connect this to the logic level you want to use for the PCA9685 output, should be 3 - 5V max! It's also used for the 10K pullups on SCL/SDA so unless you have your own pullups, have it match the microcontroller's logic level too!
- **V+** - This is an *optional* power pin that will supply distributed power to the servos. If you are not using for servos you can leave disconnected. It is not used at all by the

chip. You can also inject power from the 2-pin terminal block at the top of the board. You should provide 5-6VDC if you are using servos. If you have to, you can go higher to 12VDC, but if you mess up and connect VCC to V+ you could damage your board!

Control Pins

- **SCL** - I2C clock pin, connect to your microcontrollers I2C clock line. Can use 3V or 5V logic, and has a weak pullup to **VCC**
- **SDA** - I2C data pin, connect to your microcontrollers I2C data line. Can use 3V or 5V logic, and has a weak pullup to **VCC**
- **OE** - Output enable. Can be used to quickly disable all outputs. When this pin is *low* all pins are *enabled*. When the pin is *high* the outputs are *disabled*. Pulled low by default so it's an optional pin!

Output Ports

There are 16 output ports. Each port has 3 pins: V+, GND and the PWM output. Each PWM runs completely independently *but* they must all have the same PWM frequency. That is, for LEDs you probably want 1.0 KHz but servos need 60 Hz - so you cannot use half for LEDs @ 1.0 KHz and half @ 60 Hz. They're set up for servos but you can use them for LEDs! Max current per pin is 25mA. There are 220 ohm resistors in series with all PWM Pins and the output logic is the same as **VCC** so keep that in mind if using LEDs.

Power for the Servos

Most servos are designed to run on about 5 or 6v. Keep in mind that a lot of servos moving at the same time (particularly large powerful ones) will need a lot of current. Even micro servos will draw several hundred mA when moving. Some High-torque servos will draw more than 1A each under load.

Good power choices are:

- 5v 2A switching power supply
- 5v 10A switching power supply
- 4xAA Battery Holder - 6v with Alkaline cells. 4.8v with NiMH rechargeable cells.
- 4.8 or 6v Rechargeable RC battery packs from a hobby store.

Addressing the Boards

Each board in the chain must be assigned a unique address. This is done with the address jumpers on the upper right edge of the board. The I2C base address for each board is 0x40. The binary address that you program with the address jumpers is added to the base I2C address.

To program the address offset, use a drop of solder to bridge the corresponding address jumper for each binary '1' in the address.

POWER SUPPLY FOR RPI

Fig 3.11 Power Supply Adapter

The power supply requirements differ by Raspberry Pi model. All models require a 5.1V supply, but the current supplied generally increases according to model. All models up to the Raspberry Pi 3 require a microUSB power connector, whilst the Raspberry Pi 4 uses a USB-C connector.

Exactly how much current (mA) the Raspberry Pi requires is dependent on what you connect to it. The following table gives various current requirements.

Raspberry Pi have developed their own power supplies for use with all models. These are reliable, use heavy gauge wires and are reasonably priced.

For Raspberry Pi 0-3, we recommend our 2.5A micro USB Supply. For Raspberry Pi 4, we recommend our 3A USB-C Supply

The power requirements of the Raspberry Pi increase as you make use of the various interfaces on the Raspberry Pi. The GPIO pins can draw 50mA safely, distributed across all the pins; an individual GPIO pin can only safely draw 16mA. The HDMI port uses 50mA, the camera module requires 250mA, and keyboards and mice can take as little as 100mA or over

1000mA! Check the power rating of the devices you plan to connect to the Pi and purchase a power supply accordingly.

If you need to connect a USB device that will take the power requirements above the values specified in the table above, then you must connect it to an externally-powered USB hub.

Power Supply Warnings

On all models of Raspberry Pi since the Raspberry Pi B+ (2014) except the Zero range, there is low-voltage detection circuitry that will detect if the supply voltage drops below 4.63V (+/- 5%). This will result in a warning icon being displayed on all attached displays and an entry being added to the kernel log.

If you are seeing warnings, you should improve the power supply and/or cable, as low power can cause problems with corruption of SD cards, or erratic behavior of the Pi itself; for example, unexplained crashes.

Voltages can drop for a variety of reasons, for example if the power supply itself is inadequate, the power supply cable is made of too thin wires, or you have plugged in high demand USB devices.

Back powering

Back powering occurs when USB hubs do not provide a diode to stop the hub from powering against the host computer. Other hubs will provide as much power as you want out each port. Please also be aware that some hubs will back feed the Raspberry Pi. This means that the hubs will power the Raspberry Pi through its USB cable input cable, without the need for a separate micro-USB power cable, and bypass the voltage protection. If you are using a hub that back feeds to the Raspberry Pi and the hub experiences a power surge, your Raspberry Pi could potentially be damaged.

ULTRASONIC SENSOR

An ultrasonic sensor is a device that detects an object and measures the distance to it. It measures the distance by emitting ultrasound and receiving the wave that the object reflects.

Fig 3.12 Ultrasonic Sensor

Working of an HC-SR04 Sensor

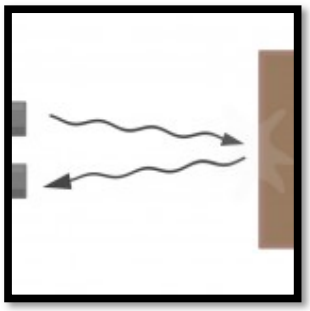


Fig 3.13 Working of HC-SR04 Sensor

Ultrasonic sound vibrates at a frequency above the range of human hearing. Transducers are the microphones used to receive and send ultrasonic sound. HC-SR04 and like other ultrasonic sensor module use a single transducer to send a pulse and to receive the echo. The sensor determines the distance to the target by measuring time lapse between sending and receiving of the ultrasonic pulses.

$$distance = \frac{speed\ of\ sound\ \times time\ taken}{2}$$

How to interface an Ultrasonic sensor with evive

The HC-RS04 Ultrasonic sensor module has 4 pins, two pins for power supply and one pin for sending out ultrasonic sound waves and one pin for receiving ultrasonic sound waves.

- VCC
- GND
- TRIG (for sending ultrasonic sound waves)
- ECHO (for receiving ultrasonic sound waves)

Now that we have a little idea about its working, let's take a look at how to interface it with evive and see it in action.

Ultrasonic sensors work by sending out a sound wave at a frequency above the range of human hearing. The transducer of the sensor acts as a microphone to receive and send the ultrasonic sound. Our ultrasonic sensors, like many others, use a single transducer to send a pulse and to receive the echo. The sensor determines the distance to a target by measuring time lapses between the sending and receiving of the ultrasonic pulse.

The working principle of this module is simple. It sends an ultrasonic pulse out at 40kHz which travels through the air and if there is an obstacle or object, it will bounce back to the sensor. By calculating the travel time and the speed of sound, the distance can be calculated.

Ultrasonic sensors are a great solution for the detection of clear objects. For liquid level measurement, applications that use infrared sensors, for instance, struggle with this particular use case because of target translucence.

For presence detection, ultrasonic sensors detect objects regardless of the color, surface, or material (unless the material is very soft like wool, as it would absorb sound.) To detect transparent and other items where optical technologies may fail, ultrasonic sensors are a reliable choice.

How are Ultrasonic Sensors used?

Our ultrasonic distance, level, and proximity sensors are commonly used with microcontroller platforms like Raspberry Pi, ARM, PIC, Arduino, Beagle Board, and more. Ultrasonic sensors transmit sound waves toward a target and will determine its distance by measuring the time it took for the reflected waves to return to the receiver.

This sensor is an electronic device that will measure the distance of a target by transmitting ultrasonic sound waves, and then will convert the reflected sound into an electrical signal. Our sensors are often used as proximity sensors. Ultrasonic sensors are also used in obstacle avoidance systems, as well as in manufacturing. Our Short Range sensors offer the opportunity for closer range detection where you may need a sensor that ranges objects as close to 2cm. These are also built with very low power requirements in mind, as well as environments where noise rejection is necessary.

Why use an Ultrasonic Sensor?

Ultrasound is reliable in any lighting environment and can be used inside or outside. Ultrasonic sensors can handle collision avoidance for a robot, and being moved often, as long as it isn't too fast.

Ultrasonics are so widely used, they can be reliably implemented in grain bin sensing applications, water level sensing, drone applications and sensing cars at your local drive-thru restaurant or bank.

Ultrasonic rangefinders are commonly used as devices to detect a collision. Ultrasonic Sensors are best used in the non-contact detection of:

- Presence
- Level

- Position
- Distance

IR SENSOR

The IR sensor module consists mainly of the IR Transmitter and Receiver, Opamp, Variable Resistor (Trimmer pot), output LED in brief.

IR LED Transmitter

IR LED emits light, in the range of Infrared frequency. IR light is invisible to us as its wavelength (700nm – 1mm) is much higher than the visible light range. IR LEDs have light emitting angle of approx. 20-60 degree and range of approx. few centimeters to several feets, it depends upon the type of IR transmitter and the manufacturer. Some transmitters have the range in kilometers. IR LED white or transparent in colour, so it can give out amount of maximum light.

Photodiode Receiver

Photodiode acts as the IR receiver as its conducts when light falls on it. Photodiode is a semiconductor which has a P-N junction, operated in Reverse Bias, means it start conducting the current in reverse direction when Light falls on it, and the amount of current flow is proportional to the amount of Light. This property makes it useful for IR detection. Photodiode looks like a LED, with a black color coating on its outer side, Black color absorbs the highest amount of light.

LM358 Opamp

LM358 is an Operational Amplifier (Op-Amp) is used as voltage comparator in the IR sensor. the comparator will compare the threshold voltage set using the preset (pin2) and the photodiode's series resistor voltage (pin3).

Photodiode's series resistor voltage drop > Threshold voltage = Opamp output is High

Photodiode's series resistor voltage drop < Threshold voltage = Opamp output is Low

When Opamp's output is high the LED at the Opamp output terminal turns ON (Indicating the detection of Object).

Variable Resistor

The variable resistor used here is a preset. It is used to calibrate the distance range at which object should be detected.

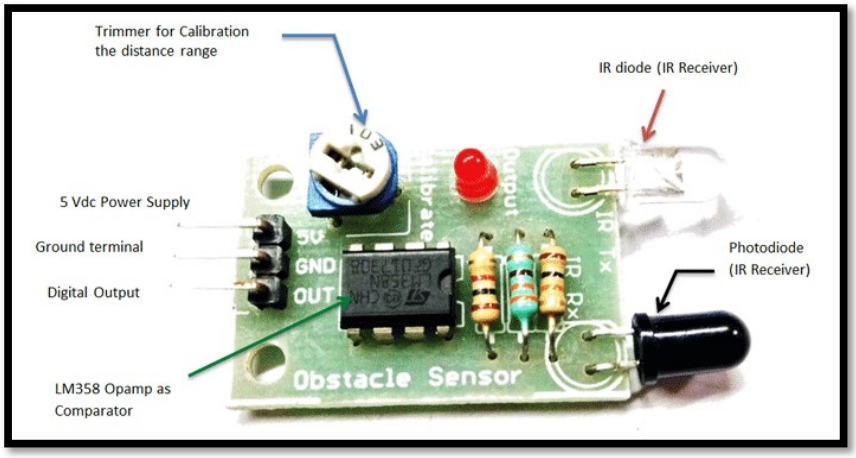


Fig 3.14 Obstacle Sensor

IR Sensor Module Feature

- 5VDC Operating voltage.
- I/O pins are 5V and 3.3V compliant.
- Range: Up to 20cm.
- Adjustable Sensing range.
- Built-in Ambient Light Sensor.
- 20mA supply current.
- Mounting hole.

Applications

- Obstacle Detection.
- Industrial safety devices.
- Wheel encoder.

7805 REGULATORS

Voltage sources in a circuit may have fluctuations resulting in not providing fixed voltage outputs. A voltage regulator IC maintains the output voltage at a constant value. 7805 IC, a member of 78xx series of fixed linear voltage regulators used to maintain such fluctuations, is a popular voltage regulator integrated circuit (IC). The xx in 78xx indicates the output voltage it provides. 7805 IC provides +5 volts regulated power supply with provisions to add a heat sink.

7805 IC Rating

- Input voltage range 7V- 35V
- Current rating I_c = 1A
- Output voltage range $V_{Max=5.2V}$, $V_{Min=4.8V}$

Pin Details of 7805 IC

Pin No.	PIN	Function	Description
1	INPUT	Input voltage (7V-35V)	In this pin of the IC positive unregulated voltage is given in regulation.
2	GROUND	Ground (0V)	In this pin where the ground is given. This pin is neutral for equally the input and output.
3	OUTPUT	Regulated output; 5V (4.8V-5.2V)	The output of the regulated 5V volt is taken out at this pin of the IC regulator.

Table No. 4.1: Pin Details of 7805 IC

As you may have noticed, there is a significant difference between the input voltage & the output voltage of the voltage regulator. This difference between the input and output voltage is released as heat. The greater the difference between the input and output voltage, more the heat generated. If the regulator does not have a heat sink to dissipate this heat, it can get destroyed and malfunction. Hence, it is advisable to limit the voltage to a maximum of 2-3 volts above the output voltage. So, we now have 2 options. Either design your circuit so that the input voltage going into the regulator is limited to 2-3 volts above the output regulated voltage or place an appropriate heatsink, that can efficiently dissipate heat.

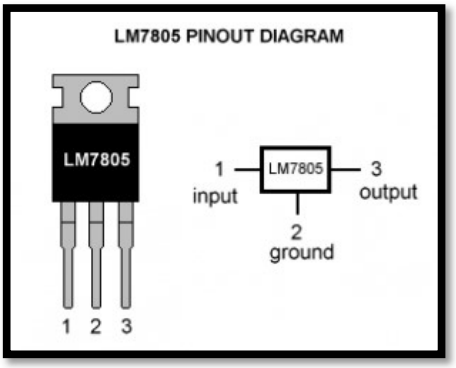


Fig 3.15 LM7805 PINOUT Diagram

Application areas for 7805 IC

7805 IC is used in a wide range of circuits. The major ones being:

- Fixed-Output Regulator
- Positive voltage Regulator in Negative voltage Configuration
- Adjustable Output Regulator
- Current Regulator
- Adjustable DC Voltage Regulator
- Regulated Dual-Supply
- Output Polarity-Reversal-Protection Circuit
- Reverse bias projection Circuit

RC522 RFID Module

The RC522 is a 13.56MHz RFID module that is based on the MFRC522 controller from NXP semiconductors. The module can supports I2C, SPI and UART and normally is shipped with a RFID card and key fob. It is commonly used in attendance systems and other person/object identification applications.

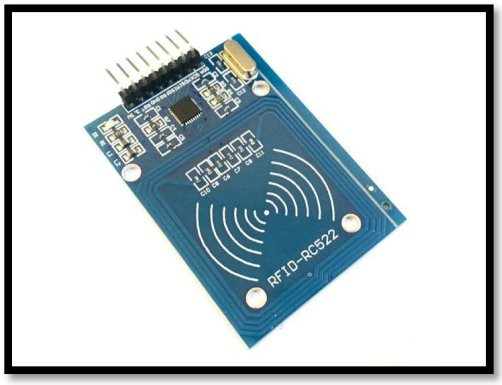


Fig 3.16 RC522 RFID Module

RC522 Pin Configuration

Pin Number	Pin Name	Description
1	VCC	Used to Power the module, typically 3.3V is used.
2	RST	Reset pin – used to reset or power down the module.
3	Ground	Connected to Ground of system.
4	IRQ	Interrupt pin – used to wake up the module when a device comes into range.
5	MISO/SCL/Tx	MISO pin when used for SPI communication, acts as SCL for I2c and Tx for UART.
6	MOSI	Master out slave in pin for SPI communication.
7	SCK	Serial Clock pin – used to provide clock source.
8	SS/SDA/Rx	Acts as Serial input (SS) for SPI communication, SDA for IIC and Rx during UART.

Table No. 4.2 Pin Details of RC522

RC522 Features

- 13.56MHz RFID module
- Operating voltage: 2.5V to 3.3V
- Communication: SPI, I2C protocol, UART
- Maximum Data Rate: 10Mbps
- Read Range: 5cm
- Current Consumption: 13-26mA
- Power down mode consumption: 10uA (min)

Where to use RC522 RFID Module

The RC522 is a RF Module that consists of a RFID reader, RFID card and a key chain. The module operates 13.56MHz which is industrial (ISM) band and hence can be used without any license problem. The module operates at 3.3V typically and hence commonly used in 3.3V designs. It is normally used in application where certain person/object has to be identified with a unique ID.

The keychain has 1kB memory in it which can be used to stored unique data. The RC522 reader module can both read and write data into these memory elements. The reader can read data only form passive tags that operate on 13.56MHz.

How to use RC522 RFID Module

The RC522 has an operating voltage between 2.5V to 3.3V and hence is normally powered by 3.3V and should be used with 3.3V communication lines. But, the communication pins of this module are 5V tolerant and hence it can be used with 5V microcontrollers also like Arduino without any additional hardware. The module supports SPI, IIC and UART communication but out of these SPI is often used since it is the fasted with a maximum data rate of 10Mbps.

Since in application, most of the time reader module will be waiting for the tag to come into proximity. The Reader can be put into power down mode to save power in battery operated applications. This can be achieved by using the IRQ pin on the module. The minimum current consumed by the module during power down mode will be 10uA only. The module can be easily used with Arduino because of its readily available RC522 RFID Arduino library from Miguel Balboa. You can visit his GitHub page for more details on how to use it with Arduino.

Applications

- Automatic billing systems
- Attendance systems
- Verification/Identification system
- Access control systems

IoT Software Programming

The first step of writing the Daspel interpreter is to choose a programming language. Based on the criteria in the section above, my supervisor and I decided to not use languages which utilizes garbage collection for memory management. This excludes languages such as Python and Java or interpreters such as Node.js. One of the reasons is that these languages have a larger memory footprint than languages with manual memory management. The second reason is that garbage collection takes time and can in some implementations cause the program to pause during runtime. IoT device issues systems operating in Realtime, shaving a pause to reclaim memory is not a scenario we want to deal with. That said, Java is the most popular programming language for IoT development, followed by JavaScript in 3rd place. It is possible that the IoT devices which are running Java are on par with the Raspberry Pi, so memory is not that big of an issue.

Python was briefly considered even though the language is interpreted and uses automatic memory management. A reason to choose Python is because the Sense HAT API is

written in Python. This would mean that only the scanner, parser and interpreter would have to be implemented.

The C, C++ is a popular language used for IoT applications and it ranks 6th on the popularity list. With C++ I'd be able to write the interpreter in pretty much the same fashion as I would do with C. The main benefit of using C++ is that the RTIMUL ib library can be uses directly. C++ also has test::String and std::Vector types defined in its standard library. Both of these types can allocate data on the heap and re-size themselves automatically. These types also implement a destructor method, meaning that when a variable which owns a std::String or std::Vector goes out of scope, the allocated data is freed automatically. The issue is that it is not possible to use these types inside of a union as unions only support primitive datatypes. To solve this, I'd have to use the Boost library and use the Any type. The Any type is capable of holding more complex data-types and provides a safe way to check the type of the value.

The implementation language is not too important for the interpreter as it's only a proof on concept which will run on a fairly powerful device. That said, if the goal was to create a more realistic implementation, It would most likely have chosen Cover Rust. This is because C has support for vastly more CPU architectures, which makes it more portable.

Python Programming Language

Python is an interpreted high-level general-purpose programming language. Python's design philosophy emphasizes code readability with its notable use of significant indentation. Its language constructs as well as its object-oriented approach aim to help programmers write clear, logical code for small and large-scale projects.

Python is dynamically-typed and garbage-collected. It supports multiple programming paradigms, including structured (particularly, procedural), object-oriented and functional programming. Python is often described as a "batteries included" language due to its comprehensive standard library.

Guido van Rossum began working on Python in the late 1980s, as a successor to the ABC programming language, and first released it in 1991 as Python 0.9.0. Python 2.0 was released in 2000 and introduced new features, such as list comprehensions and a garbage collection system using reference counting. Python 3.0 was released in 2008 and was a major revision of the language that is not completely backward-compatible and much Python 2 code does not run unmodified on Python 3. Python 2 was discontinued with version 2.7.18 in 2020.

Python consistently ranks as one of the most popular programming languages.

Why is Python so popular?

According to the TIOBE index, which measures the popularity of programming languages, Python is the third most popular programming language in the world, behind only Java and C. There are many reasons for the ubiquity of Python, including:

- **Its ease of use**. For those who are new to coding and programming, Python can be an excellent first step. It's relatively easy to learn, making it a great way to start building your programming knowledge.
- **Its simple syntax**. Python is relatively easy to read and understand, as its syntax is more like English. Its straightforward layout means that you can work out what each line of code is doing.
- **Its thriving community**. As it's an open-source language, anyone can use Python to code. What's more, there is a community that supports and develops the ecosystem, adding their own contributions and libraries.
- **Its versatility**. As we'll explore in more detail, there are many uses for Python. Whether you're interested in data visualization, artificial intelligence or web development, you can find a use for the language.

What is Python used for?

Clearly, Python is a popular and in-demand skill to learn. But what is python programming used for? We've already briefly touched on some of the areas it can be applied to, and we've expanded on these and more Python examples below. Python can be used for:

1. AI and machine learning

Because Python is such a stable, flexible, and simple programming language, it's perfect for various machine learning (ML) and artificial intelligence (AI) projects. In fact, Python is among the favourite languages among data scientists, and there are many Python machine learning and AI libraries and packages available.

2. Data analytics

Much like AI and machine learning, data analytics is another rapidly developing field that utilises Python programming. At a time when we're creating more data than ever before, there is a need for those who can collect, manipulate and organise the information.

Python for data science and analytics makes sense. The language is easy-to-learn, flexible, and well-supported, meaning it's relatively quick and easy to use for analysing data. When working with large amounts of information, it's useful for manipulating data and carrying out repetitive tasks.

3. Data visualization

Data visualization is another popular and developing area of interest. Again, it plays into many of the strengths of Python. As well as its flexibility and the fact it's open-source, Python provides a variety of graphing libraries with all kinds of features.

Whether you're looking to create a simple graphical representation or a more interactive plot, you can find a library to match your needs. Examples include Pandas Visualization and Plotly. The possibilities are vast, allowing you to transform data into meaningful insights.

4. Programming applications

You can program all kinds of applications using Python. The general-purpose language can be used to read and create file directories, create GUIs and APIs, and more. Whether it's blockchain applications, audio and video apps, or machine learning applications, you can build them all with Python.

5. Web development

Python is a great choice for web development. This is largely due to the fact that there are many Python web development frameworks to choose from, such as Django, Pyramid, and Flask. These frameworks have been used to create sites and services such as Spotify, Reddit and Mozilla.

Thanks to the extensive libraries and modules that come with Python frameworks, functions such as database access, content management, and data authorization are all possible and easily accessible. Given its versatility, it's hardly surprising that Python is so widely used in web development.

6. Game development

Although far from an industry-standard in game development, Python does have its uses in the industry. It's possible to create simple games using the programming language, which means it can be a useful tool for quickly developing a prototype. Similarly, certain functions (such as dialogue tree creation) are possible in Python.

7. Language development

The simple and elegant design of Python and its syntax means that it has inspired the creation of new programming languages. Languages such as Cobra, Coffee Script, and Go all use a similar syntax to Python.

This fact also means that Python is a useful gateway language. So, if you're totally new to programming, understanding Python can help you branch out into other areas more easily.

8. Finance

Python is increasingly being utilized in the world of finance, often in areas such as quantitative and qualitative analysis. It can be a valuable tool in determining asset price trends and predictions, as well as in automating workflows across different data sources.

9. SEO

Another slightly surprising entry on our list of Python uses is in the field of search engine optimization (SEO). It's an area that often benefits from automation, which is certainly possible through Python. Whether it's implementing changes across multiple pages or categorizing keywords, Python can help.

Emerging technologies such as natural language processing (NLP) are also likely to be relevant to those working in SEO. Python can be a powerful tool in developing these NLP skills and understanding how people search and how search engines return results.

10. Design

When asking 'what is Python used for?' you probably weren't expecting design to feature on the list. However, Python can be used to develop graphic design applications. Surprisingly, the language is used across a range of 2D imaging software, such as Paint Shop Pro and Gimp.

Raspberry Pi OS

Raspberry Pi OS is the recommended operating system for normal use on a Raspberry Pi. It is a free operating system based on Debian, optimized for the Raspberry Pi hardware. Raspberry Pi OS comes with over 35,000 packages: precompiled software bundled in a nice format for easy installation on your Raspberry Pi.

Raspberry Pi OS is a community project under active development, with an emphasis on improving the stability and performance of as many Debian packages as possible.

Raspberry Pi OS Applications

- Camera: -Information on the demonstration camera software
- OMXPlayer: -Information on the OMXPlayer command line media player
- vcgencmd: -Information on the vegencmd application for getting and setting data on the VideoCore GPU.
- vcdbg: - Information on the vcdbg application, used to recover debugging Information from the VideoCore GPU.

- tvservice: -Command line application for getting and setting information about the attached display/audio devices.
- pi-update: -Command line application for updating to pre-release and beta software.

Blynk IoT Platform

Blynk was designed for the Internet of Things. It can control hardware remotely, it can display sensor data, it can store data, vizualize it and do many other cool things. It has three main components blynk app, blynk server,blynk libraries.

Every time you press a Button in the Blynk app, the message travels to space the Blynk Cloud, where it magically finds its way to your hardware. It works the same in the opposite direction and everything happens in a blynk of an eye. However, people have difficulty harnessing the full power of these ubiquitous devices for themselves and their communities. Most smartphone users consume technology without being able to produce it, even though local problems can often be solved with mobile devices.

CHAPTER 4

METHODOLOGY

Waste management/segregation on basis of deep learning makes better difference as compared to the waste management with the old conventional method. The setup mainly consists of Main power supply for the controllers and actuators. Here at the beginning stage, we have a 230V AC voltage which is converted into 5v DC and connected to the controller and power distribution board and the motor drivers. The controller Raspberry pi is installed with the operating system and the supporting libraries to carry out the operations based on the waste management processes. Deep learning mechanism and data sets will be placed inside the storage.

The camera which traces the waste placed in to the main platform is operated with the help of the ultrasonic sensor which is in communication with the raspberry pi also a RFID which is in connection with the raspberry pi tracks a valid user tag with its matching frequency and allows the user to dump the waste. Once the camera detects the type of the waste with help of the deep learning technique the controller provides the signal to the servo motors via servo motor driver controller. The motor rotates in to the appropriate bin and the platform holding the waste changes the angle and makes the waste to fall into the bin to which the motor had directed the path. The cycle keeps in loop whenever a valid user tag is used to dump the waste.

Here the whole system uses the deep learning method where the system is already saved with approx. 8000 images on different categories using Lobe Deep Learning Tool for best classifying result and the bins are equipped with Infrared sensors to look the bin is empty or full once any of the bin is full the admin will get the bin full notification through the mobile App.

4.1 Lobe Deep Learning Tool

Lobe is an Automated Deep Learning Tool for People who don't know Programming. Lobe has developed a platform to build deep learning models primarily machine vision models using a visual interface and without writing code. This is aimed at users without extensive background in programming.

Lobe is an easy-to-use visual tool that lets you build custom deep learning models, quickly train them, and ship them directly in your app without writing any code. Start by dragging in a folder of training examples from your desktop. Lobe automatically builds you a

custom deep learning model and begins training. When you're done, you can export a trained model and ship it directly in your app. Built on top of the deep learning frameworks TensorFlow and Keras, Lobe enables better control every layer of the model. Tune hyperparameters, add layers, and design completely new architectures using hundreds of advanced building block lobes.

4.2 Object Detection Model

Raspberry Pi is used to preprocess the data collected from the sensors, and the data is uploaded to the database through IoT Platform for cloud analysis. A Statistical Analysis System is proposed to analyze and process the data, which requires high computational power. In our proposed system, we have decided to utilize the mobility of Raspberry Pi, a mobile CPU together with Lobe Deep Learning Tool, a lightweight model and a mobile architecture to perform waste classification on the board itself instead of uploading it to the database for cloud analysis. This allows us to reduce the latency in waste classification. Moreover, the bin itself is scattered around the city where connectivity to the database might not be feasible. For example, a 5MP image has a typical file size of 15.0MB.

The pre-trained object detection model is trained using images of waste as a training dataset. The sample image used as a dataset to train the model, and Approx. 8000 images of waste with a different orientation, background, and lighting condition are collected. Before the training, images of waste are labeled by class to perform supervised learning where we feed in training data with known classes for the model to perform training. After waste images are collected and labeled, they are used to train the object detection model until the model consistently achieves an error of less than 1.0000. A frozen inference graph is generated and exported to Raspberry Pi to perform object detection. The threshold for the accuracy of the model is determined based on the mean average precision (mAP) score of the model obtained from evaluating test images as well as test results obtained during real-time waste detection.

Waste will be first dropped into the retractable platform to perform waste detection using the inference graph generated previously. After the class of the waste is identified, the retractable lid of the specific waste compartment will be actuated and opened by a servo motor. Then, the retractable platform will be lowered to allow the waste with the help of gravity to fall into the specific waste compartment.

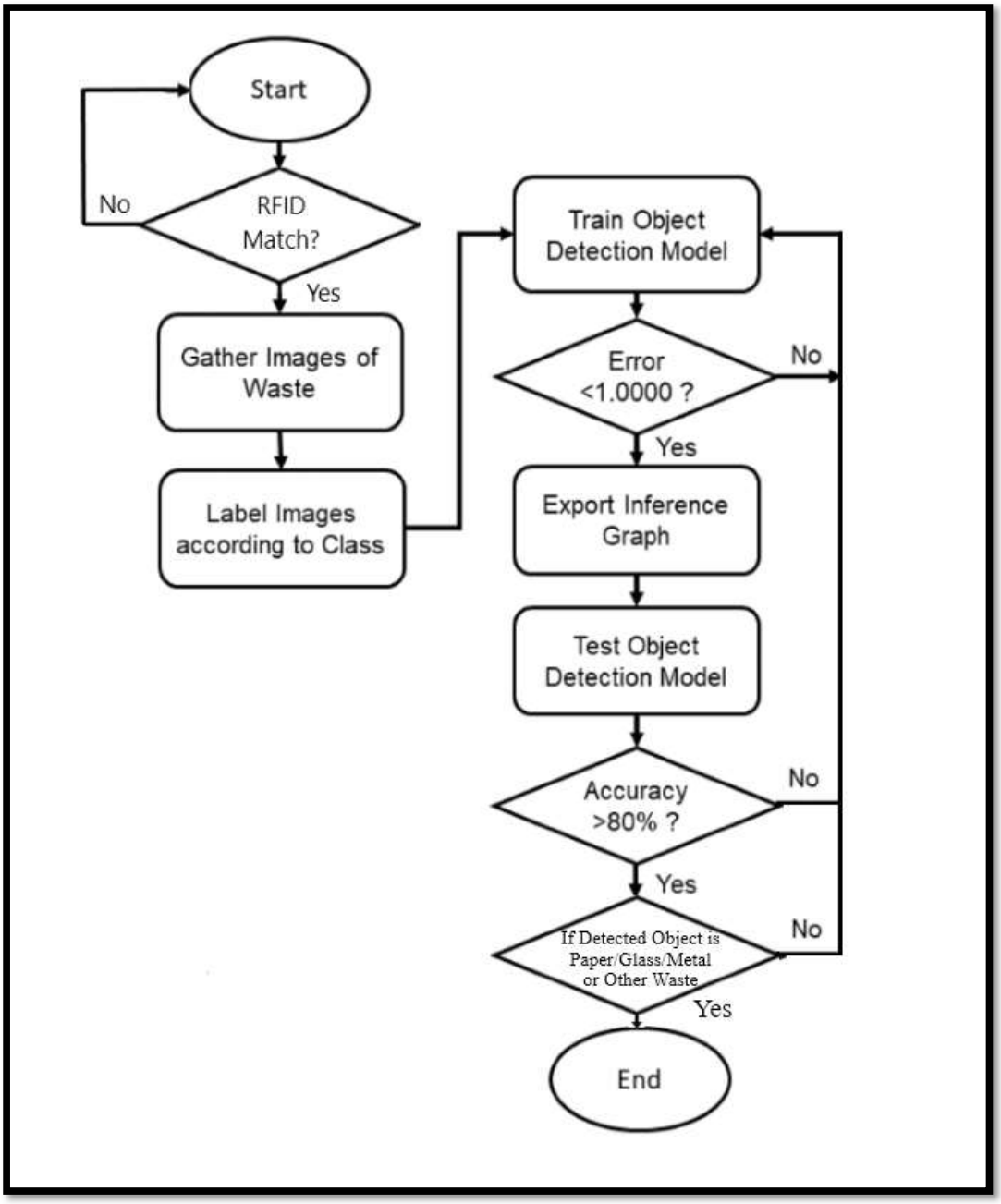


Fig 4.1 Flowchart of obtaining object detection model

4.3 Algorithm for Waste Detection Mechanism of Bin

The ultrasonic sensor is used to detect the presence of waste inside the waste detection compartment by comparing the distance before and after the presence of waste. For example, the total distance traveled by the ultrasonic sound wave is 0.50m when the compartment is empty (measured according to the length of the waste detection compartment). If there is a presence of waste in the waste detection compartment, the total distance traveled by the ultrasonic sound wave would be shortened as it is reflected by the surface of the waste. At the

same time, the camera is constantly capturing images of waste and sending them to Raspberry Pi to perform waste classification. If the type of waste is not in one of the classes (metal, plastic, or paper), then the waste is unidentified and the system will classify it as general waste based on the data obtained from the ultrasonic sensor that senses the presence of waste. These steps are taken to reduce the amount of training dataset required to train the waste detection model by eliminating the need to prepare the training dataset of general waste and by reducing the computational cost. The system is designed and trained to classify and segregate waste based on the image of the waste. The waste image dataset is prepared with different capturing angles, lighting conditions, and backgrounds. Hence, the system is able to classify the waste thrown at different orientations and positions. However, if the waste is covered with a foreign item such as a garbage bag, it will be identified as general waste.

The Algorithm for Waste Detection Mechanism of Bin is shown below:

1. Drop waste into retractable platform.
2. Ultrasonic Sensor detect presence of waste.
3. Camera capture image of waste and send to Raspberry Pi.
4. Raspberry Pi perform waste image classification using Lobe Deep Learning Tool.
5. **if** *waste = paper* **then** Open paper compartment's retractable lid; Open retractable platform.
6. **elseif** *waste = metal* **then** Open metal compartment's retractable lid; Open retractable platform.
7. **elseif** *waste = plastic* **then** Open plastic compartment's retractable lid; Open retractable platform.
8. **elseif** *waste=Organic* **then** Open Organic compartment's retractable lid; Open retractable platform.
9. **else** Open retractable platform.
10. **end** Close retractable lid and retractable platform

4.4 Advantages

- Real time information on the fill level of the dustbin.
- Deployment of dustbin based on the actual needs.
- Cost Reduction and resource optimization.
- Improves Environment quality -Fewer smells -Cleaner cities
- Intelligent management of the services in the city.
- Effective usage of dustbins.

4.5 Disadvantages

- System requires more number of waste bins for separate waste collection as per population in the city. This results into high initial cost due to expensive smart dustbins compare to other methods.
- Sensor nodes used in the dustbins have limited memory size.
- Wireless technologies used in the system such as Zigbee and Wi-fi have shorter range and lower data speed. In RFID based systems, RFID tags are affected by surrounding metal objects (if any).
- It reduces man power requirements which results into increase in unemployment for unskilled people.

4.6 Application

- This can be best used by municipal corporation for their betterment of management regarding collection of wastes.
- With the help of proper technology (GPS & SOFTWARE APPLICATIONS) we can guide the trucks to choose the shortest path.
- It also favours the “SMART CITY” project and “DIGITAL INDIA”.
- The ultimate goal of IoT applications in waste management is producing leaner operations and delivering higher quality services to citizens.

CHAPTER 5

RESULTS

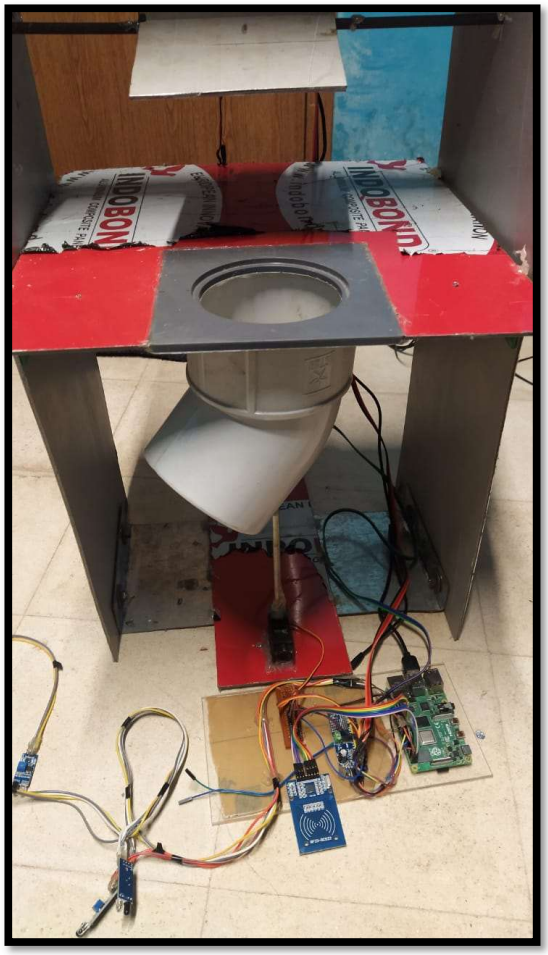


Fig 5.1 Working Model of our Project

Fig 5.4 Ultrasonic Sensor to detect Presence of Waste

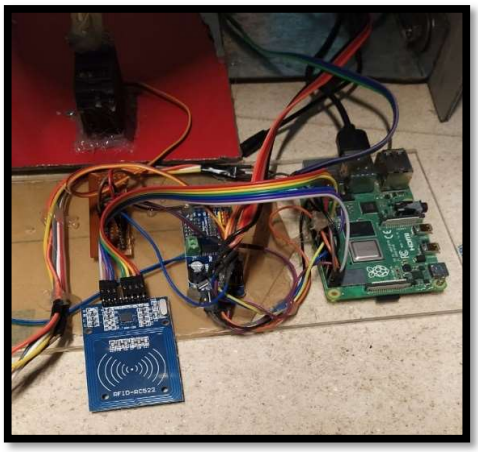


Fig 5.2 Control Panel of System

Waste to fall from the waste detection compartment into its respective waste compartment. The ultrasonic sensor is connected to Raspberry Pi to monitor the filling level of each of the bin's waste compartment, including a plastic, metal, paper, and Organic waste compartment. The filling level and real-time bin are collected and transferred via Internet from the bin to the server side. The data received in the server side will be processed and uploaded to cloud server and this data can be used for monitoring waste bin status from cloud. RFID Is used in this system in connection with the raspberry pie where in it allows the only authorized user to put in the waste in to the bin.

Here at the beginning stage, we have a 230V AC voltage which is converted into 5v DC and connected to the controller and power distribution board and the motor drivers. The controller Raspberry pi is installed with the operating system and the supporting libraries to carry out the operations based on the waste management processes. Deep learning mechanism and data sets will be placed inside the storage.

The camera which traces the waste placed in to the main platform is operated with the help of the ultrasonic sensor which is in communication with the raspberry pi also a RFID which is in connection with the raspberry pi tracks a valid user tag with its matching frequency and allows the user to dump the waste. Once the camera detects the type of the waste with help of the deep learning technique the controller provides the signal to the servo motors via servo motor driver controller. The motor rotates in to the appropriate bin and the platform holding the waste changes the angle and makes the waste to fall into the bin to which the motor had directed the path. The cycle keeps in loop whenever a valid user tag is used to dump the waste.

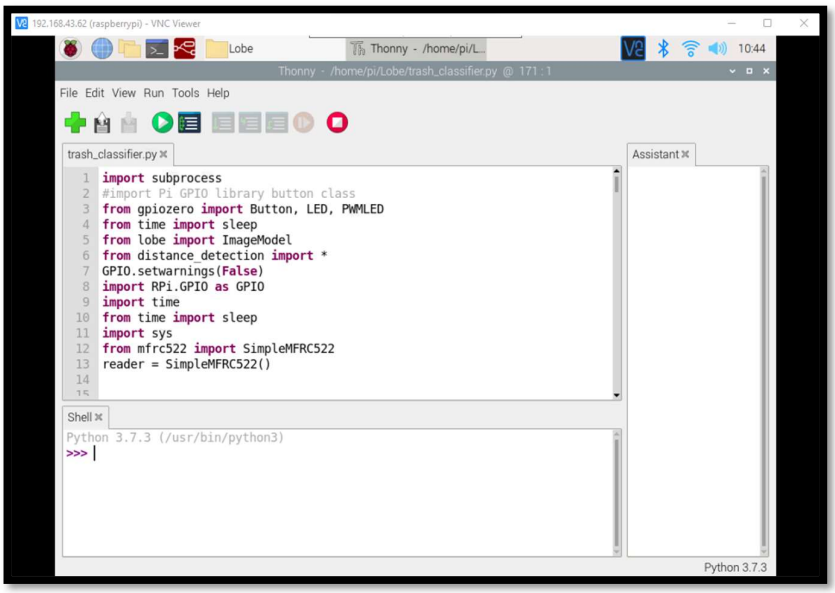


Fig 5.4 Code Debug in the Raspberry Pi OS

The pre-trained object detection model is trained using images of waste as a training dataset. The sample image used as a dataset to train the model, and Approx. 8000 images of waste with a different orientation, background, and lighting condition are collected. Before the training, images of waste are labeled by class to perform supervised learning where we feed in training data with known classes for the model to perform training.

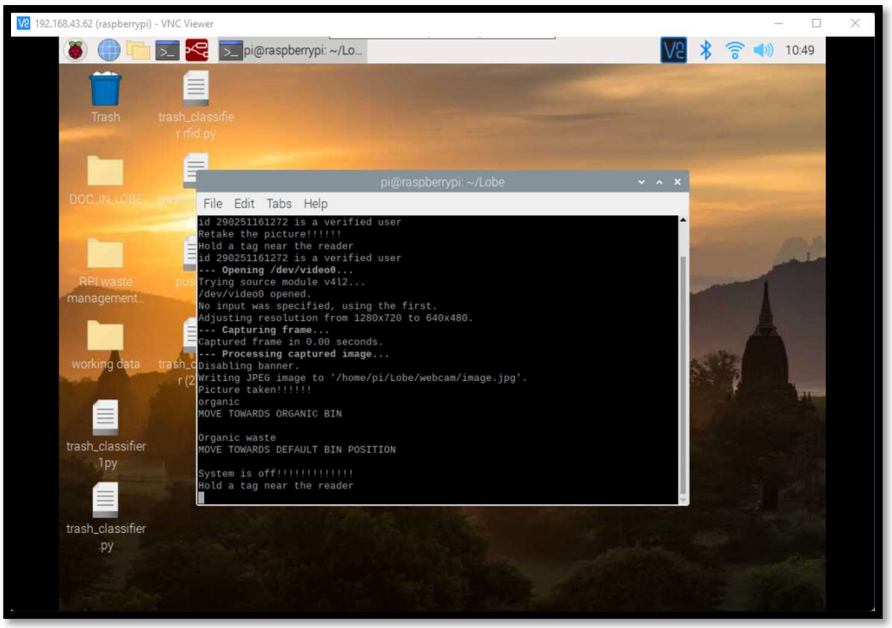


Fig 5.5 Waste Classification and Segregation Implemented with the help of Python

Here the whole system uses the deep learning method where the system is already saved with images on different categories using Lobe Deep Learning Tool for best classifying result and the bins are equipped with Infrared sensors to look the bin is empty or full once any of the bin is full the admin will get the bin full notification through the mobile App.

CONCLUSION

EXPECTED OUTCOME

The expected outcomes of this Project are an integrated system model for the useful collection of waste with the help of Deep Learning and IoT-based bins and to reduce the operational cost of the existing municipal system. The designed system is equipped with Ultrasonic sensors to detect the level of waste inside the bins. The system consists of a conveyor where in the waste is placed or dropped first and this waste will be recognized by the Lobe Deep Learning Tool with the help of the camera and further the waste will be categorized based on the data and it will be move to the selected category by the help of the conveyor and will be dropped to the bin of same category with the help of the servo motor. The user with the matching RFID pass Card will be allowed to drop the waste other user will not be let to put in the waste into this system.

FUTURE SCOPE

- Integration of many bins each with unique id can be done by implementing principles of IOT.
- Many times garbage dustbin overflow and many animals like dog or rat enters inside or near the dustbin. This creates a bad scene. Also some birds are also trying to take out garbage from dustbin.
- Database can be created for each bin by using SQL technology.
- Automated system can be developed which is able to pick up waste in and around the bin, segregate them and put them in respective bins.

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