Voice controlled Robot for waste Segregation From Open Space for sustainable Management

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Abstract

The concept and development of a voice-activated robot for garbage segregation from public areas is presented in this work. The suggested method uses voice commands to steer the robot's motion and distinguish between various waste materials, including metal, glass, and plastic. To navigate through the congested environment and identify things based on their color and shape, the robot is outfitted with a camera, sensors, and a Raspberry Pi microprocessor. The waste is categorized and separated by the system using machine learning algorithms, and the separated waste is subsequently gathered in different bins. The suggested method can be used in a variety of open areas, including parks, beaches, and public areas, and it is anticipated to decrease the amount of time and human labor needed for trash segregation. Number of experiments were conducted to assess the effectiveness of the suggested system, and the findings indicate that it can achieve a high degree of waste segregation accuracy.

Keywords: Automation, Waste segregation, Raspberry Pi, Voice Control. Sustainable waste management

1 INTRODUCTION:

One essential component of efficient waste management is trash segregation. Sorting waste into distinct categories according to its type is crucial because it allows for the recycling of valuable materials and lowers the quantity of waste that ends up in landfills. However, physical trash segregation can be labor-intensive and time-consuming, especially in public areas like parks and beaches. Using the Raspberry Pi as the underlying hardware platform, we suggest a voice-activated robot for garbage segregation from public areas in order to overcome this difficulty. Using a camera and sensors, the suggested system is made to move through the crowded surroundings and identify various waste materials, including metal, glass, and plastic .After the waste has been classified and separated using machine learning algorithms, it is collected in different containers. The robot is controlled by voice instructions, which makes it simple to use and lessens the need for manual involvement. Create an economical and effective waste segregation system by using the Raspberry Pi as the underlying hardware platform. The Raspberry Pi offers a robust computing platform that is perfect for robotics applications due to its compatibility with a wide range of sensors and actuators. Furthermore, the Raspberry Pi is a desirable platform for creating creative solutions because to the availability of open-source libraries and the assistance of a sizable developer and enthusiast community. With the Raspberry Pi serving as the underlying hardware platform, we demonstrate in this paper the design and development of a voice-controlled robot for garbage segregation from open spaces. Through trials, we assess the efficacy of the suggested system and show that it can achieve a high degree of waste segregation accuracy. In rapidly expanding cities, particularly in developing nations like India, managing urban waste has become a significant concern. The issue is particularly severe in low-income areas, where unsafe and untidy garbage disposal is a result of congested living arrangements, inadequate infrastructure, and financial difficulties. There are glaring gaps in the collection and sorting of rubbish in the central suburbs of Mumbai, which are home to many of the city's poorer citizens. Even though the Brihanmumbai Municipal Corporation (BMC) has started implementing extensive changes to enhance garbage management, these initiatives frequently fail or are uneven at the local level, especially in heavily populated regions and informal settlements. (Indian Times, 2025).

The suggested method is a crucial instrument for efficient waste management since it may lessen the time and human labor needed for garbage segregation in public areas. The Mumbai **city proper** (municipal limits) had around **12.5 million** people as per recent sources Between 7,000 and 8,000 tonnes of solid trash are produced daily in Mumbai. Out of that, sanitary and special care waste makes up about 70–80 tones each day. Additionally, the amount of C&D waste produced each day is rather high roughly 8,500 tonnes even though BMC's two C&D processing facilities, Dahisar and Shilphata, have a capacity of about 1,200 tonnes per day each (albeit they are not running at full capacity In addition to being the capital of the state of Maharashtra, Mumbai is known as the commercial hub of India. Mazagaon, Colaba, Wadala, Old Woman's Island, Parel, Mahim, and Matunga-Sion are the seven islands that made up the city. The current state of Mumbai City is the outcome of extensive growth on the seven aforementioned islands. **Table 1** shows dry waste segregation Centre , under BMC ,Mumbai India

2 OBJECTIVE :

In order to promote effective and environmentally friendly trash management techniques, the goal of this paper is to build and implement a voice-controlled robot that uses a Raspberry Pi to separate rubbish from open spaces. In order to minimize human labor and enhance environmental cleanliness, the project intends to create an intelligent and user-friendly system that can recognize and classify various waste types with voice commands. Along with offering a scalable and affordable solution for trash segregation in public areas, the project also seeks to promote the use of open-source hardware and software.

3 METHODOLOGY :

The Raspberry Pi microcontroller, which is programmable in Python, was used to construct the voice-activated robot. The E-speak Speech Recognition API was used to create the robot's speech recognition engine. The OpenCV library was used to construct the robot's image processing capabilities. The robot's motors and sensors were controlled via control libraries like the PiGPIO library.

An open space setting was used to evaluate the robot's operation, and trash was strewn all around the test area. Based on the type of waste, the robot was designed to separate the items. The robot was able to move forward, backward, left, right, and stop using voice commands. Additionally, voice instructions were utilized to specify which waste materials such as plastic, paper, metal, and glass were to be collected.

Table 1 Dry waste segregation centre , BMC , Mumbai India

Ward	Number of Rag pickers	Area in Sq.m	Daily intake in Kgs
A	76	4849	8350
B	12	204	3540
C	8	60	5230
D	85	81.2	12200
E	6	25	1020
F/S	41	188	17750
F/N	36	676	11800
G/S	9	115	4740
G/N	17	243	8600
H/E	8	120	7070
H/W	112	800	12690
K/E	12	581	7060
K/W	32	540	24020
P/S	15	159.7	6870
P/N	6	1644.81	3700
R/S	10	300	6550
R/C	10	975	4980
R/N	14	300	7710
L	25	400	9550
M/E	20	300	6200
M/W	12	156	2440
N	78	50	7240
S	108	50	3660
T	26	240	5610
Total	778	13057.71	188580

4 HARDWARE OVERVIEW

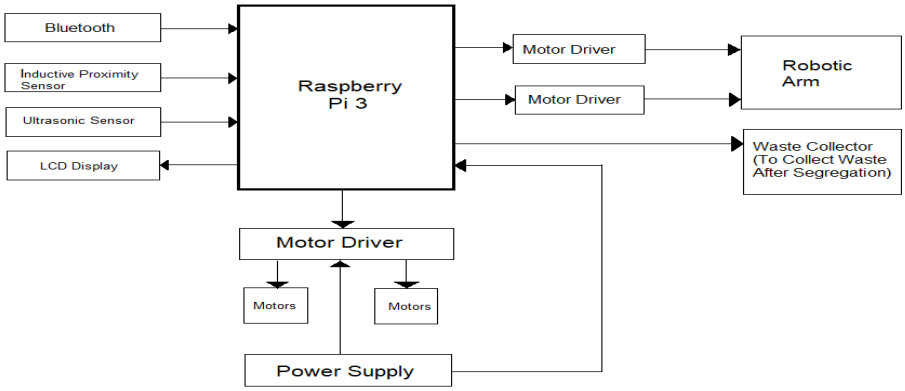

Fig1: Block Diagram of Voice Controlled

Fig1 shows block diagram of system , Raspberry Pi is a key component in this project all components like Ultrasonic sensor, Camera module, Inductive Proximity Sensor are connected to the Raspberry Pi and they are act as a input devices from which Raspberry Pi take input and act according to it. The other components are connected to the Raspberry Pi are motor drivers which are further connected to motors of robotic arm and chessi. Raspberry Pi is connected to the Wifi and there is one device which is also connected to the same WiFi network for voice control. The voice-controlled robot for waste segregation from open space involves the use of several components. Some of the key components used in this project are:

Raspberry Pi 3B+ : The Raspberry Pi serves as the brain of the robot, controlling its movement and processing voice commands. It also interfaces with other components to provide a cohesive system. We are using WiFi module to provide voice commands to our robot which is built-in in Raspberry Pi.

Motor Driver :In our project we are using motor driver L298N for controlling the motors. L298N based motor driver module is a powerful driver, it can able to handle DC motors and Stepper motors at a time. The motor driver controls the movement of the robot by converting the signals from the Raspberry

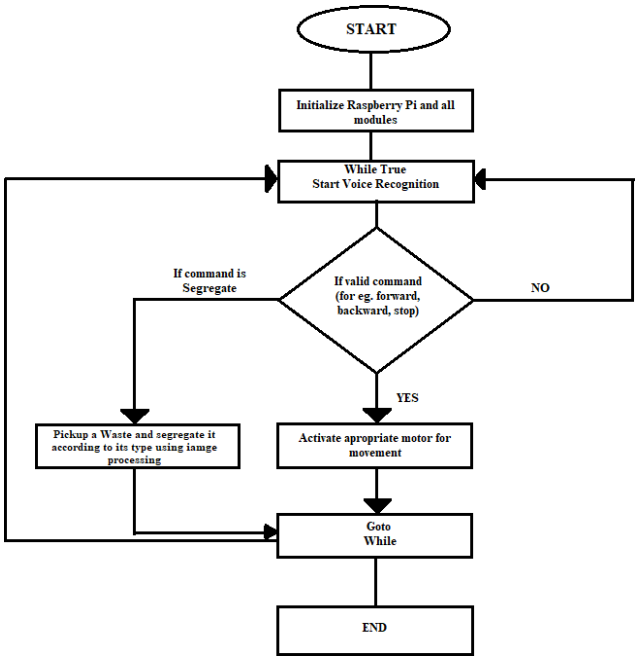

Fig 2 Flow diagram

Servo motor: Servo motors can rotate with great precision. Servo motors are used where we want to move some object at specific angle or at specific distance. In our project we are going to use servo motors in a robotic arm. Servo motors are used to control the movement of the arms and grippers of the robot, allowing it to pick up and move waste materials.

DC Motors : DC Motors are electrical motors which convert DC electrical energy into mechanical energy for the movement. A DC motor is the main component to move the chassis from one place to another.

Camera Module: A camera module is used to capture images of the waste materials and send them to the Raspberry Pi for processing.

Ultrasonic Sensor: Ultrasonic sensors are used to detect obstacles and to measure the distance of the robot from the waste materials. The sensors use ultrasonic waves to detect the presence of objects and calculate the distance to them. In our case we are using ultrasonic sensor to avoid the collision of our robot from surrounding objects.

Power Supply: A good power source is needed for our project to work smoothly. For that we have used 12V lithium ion battery which gives enough power to our components to work properly. It is very handy and very powerful so we can easily use this without any complications.

5 SOFTWARE REQUIREMENT :

The flow diagram for supplying automatic trash segregation is shown in **Fig. 2**. To use voice commands to guide a robot along a specific path, collect trash, and sort it according to the type of garbage, we required a lot of software. The project makes use of the software:

Operating System: An operating system, in this case the Raspbian operating system, is the first piece of software needed for the voice-activated robot. The Debian Linux distribution serves as the foundation for Raspbian, the official operating system for the Raspberry Pi.

Python: The voice-controlled robot software requires a programming language to control the robot's movements. In this case, Python will be used. Python is a high-level programming language with a vast library of built-in functions that makes it easy to program the robot's movements.
Speech Recognition: A speech recognition engine is required by the voice-controlled robot software in order to translate voice orders into actions. One of the most popular voice recognition engines is Google's voice Recognition API, a free cloud-based service. Instead of that, though, we are using the eSpeak module to recognize our voice commands and make them work.

Image Processing: The robot will require an image processing library in order to recognize the waste materials that require separation. OpenCV is a popular open-source computer vision program that is widely used for image processing.
Control Libraries: Libraries will be required to control the robot's motors, sensors, and other movements. Libraries such as the PiGPIO library, which provides low-level control over the Raspberry Pi's GPIO pins, will be required.
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RESULTS: The robot's task is to gather trash materials scattered across the test area as well as waste materials from an open area. The robot's movements are controlled by voice commands, and its motors and sensors are managed by the PiGPIO library. The robot reacts rapidly to verbal commands and moves with accuracy and fluidity. By avoiding obstacles in its path, the robot can reach the waste material that needs to be collected. We will be able to get the following results by sorting waste materials according to trash kind utilizing voice commands. Among the waste products the robot will be able to collect and sort are glass, metal, paper, and plastic. The robot's capacity for picture interpretation. The results can be achieved by sorting waste materials according to trash kind using voice instructions. The robot will be capable of collecting and sorting waste materials such as glass, metal, paper, and plastic. The robot's capacity to decipher images enabled it to recognize and properly segregate different kinds of garbage. Currently, the robotic arm and 6-wheel chassis are fully integrated and functional. **Fig. 3** displays a screen shot of the voice-controlled robot, which can be controlled by a variety of spoken commands, including start, stop, forward, backward, left, and right. place in and waste, correspondingly. To determine the type of trash, segregate it, pick it up, and put it in the proper dustbin, image processing is used. **Fig 4 and 5** shows how a robot recognizes metal and disposes of it in the proper trash, as well as how image processing is initiated. **Fig6 and 7** shows how image processing is initiated, and a robot detects plastic and then takes it up and disposes of it in the proper trash.

Fig3 Voice controlled Prototype Robot System

Fig4 Image processing initiated and Robot picking metal

Fig5 Robot placing metal in dustbin

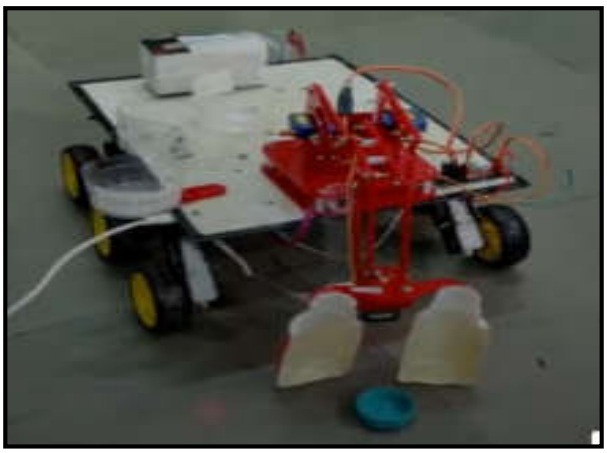

Fig6 Image processing initiated and Robot picking plastic

Fig 7 Robot placing plastic in respective dustbin

CONCLUSIONS:

A voice-controlled robot for rubbish segregation from open places that was powered by a Raspberry Pi was able to collect and sort waste materials according to their categorization by using voice commands. Thanks to its image processing abilities and control libraries, the robot was able to properly collect and segregate waste materials while avoiding impediments. This technology has the potential to improve garbage management practices, and further research and development may lead to more effective and efficient trash segregation systems. The system may actually be powered by solar-based renewable energy, however alignment and time synchronization are quite challenging and need to be improved for future growth at larger scale . The strategy is mainly found to be both economically and environmentally feasible for open space and more sustainable.

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