Smart Waste Management: Automatic Waste Collection, Segregation and Disposal

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***Abstract*— Urban waste management presents a growing number of problems that necessitate creative and long-lasting solutions. This research report proposes a Waste Collecting Robot—an autonomous, intelligent robot created to revolutionize waste collection and management in urban settings—as a solution to these problems. This study gives a thorough analysis of the Waste Collecting Robot project with an emphasis on its functionality, design, and prospective effects. The main goals of this project are to increase waste collection efficiency, decrease reliance on human labor, and help create a cleaner, greener urban environment.**

***Keywords*— Robot Design and technology, LFR, Metal detection, Autonomous Robotic Arm Control**

INTRODUCTION

In recent years, the task of managing municipal solid trash in rapidly expanding urban areas has grown in complexity and importance. The generation of waste has significantly increased as a result of urbanization, population growth, and shifting consumer habits, placing a pressure on conventional waste management systems. Traditional waste collection and disposal techniques are frequently ineffective, expensive, and unsustainable from an environmental standpoint. In response to these difficulties, "Smart Waste Management" has developed as a viable approach to transform how we manage waste in urban settings.

Smart Waste Management uses connection, data analytics, and modern technology to build a waste management ecosystem that is more effective, sustainable, and flexible. By using sensors, the and other novel ideas, this creative method exceeds the constraints of conventional systems. Automation to improve waste collection can cut costs, reduce environmental impact, and include communities in ethical waste disposal methods.

The fundamental idea behind smart waste management is to turn trash cans into sentient beings capable of communication and real-time monitoring. These intelligent bins have sensors that monitor temperature, fill levels, and other pertinent information. This information is sent wirelessly to a centralized control system. The analysis of this data enables quick responses to problems like overflows or repair needs by forecasting trash generation patterns, planning efficient collection routes, and monitoring the condition of waste containers.

Furthermore, user-friendly interfaces, mobile applications, and educational initiatives are all part of how smart waste management systems foster environmental awareness and community involvement.

Waste reduction and recycling initiatives can be actively supported by locals and businesses, helping towns achieve their overall sustainability goals.

This study investigates the many facets of smart waste management, including its technological foundations, environmental advantages, cost-effectiveness, and scalability. In order to address the difficulties of waste management in urban areas, it also highlights real-world case studies and success stories from towns and municipalities that have adopted smart trash management. Smart Waste Management is a shining example of innovation as we move toward sustainable urban living. It has the ability to make cities cleaner, greener, and more livable for future generations.

METHODOLOGY

The designed trash collecting bot has three major parts- I) Line following Robot that carries a bin and robotic arm, II) A robotic arm to collect the trash, III) Bin containing sensors to segregate trash.

Figure.1: Whole Robot Structure

A. *LFR (Line Following Robot)*

Components Required:

1. Robot chassis with wheels and motors
2. 5 IR sensor modules
3. Microcontroller (Arduino)
4. Motor driver module (BTS 7960)
5. Power supply (4200 mAh 11.1 V Li-po battery)
6. Wheels and motor for movement
7. Line to follow (a black line on a white surface)

Function:

1. **Sensor Installation:** The 5 IR sensor modules are mounted underneath the robot chassis, facing the

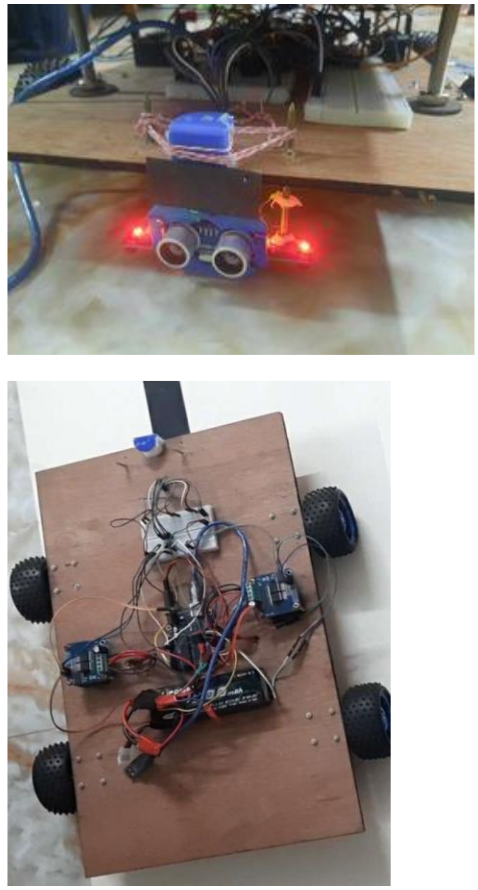

Figure.2: LFR Structure with circuit connections, wheel and motors

ground. These sensors will be positioned in a line or array, slightly apart from each other.

2. **Sensor Calibration:** The IR sensors has been calibrated to distinguish between the line (black) and the background (white or a lighter color). This involves adjusting the sensor's sensitivity and threshold values.
3. **Control System:** A microcontroller (Arduino) is used to control the robot's movements. Connect the microcontroller to the sensor modules and motor driver module.
4. **Line Detection:** The IR sensors emit infrared light onto the ground, and they measure the amount of light reflected back. When the sensor is over a black line, it reflects less light compared to when it's over a white surface. The microcontroller reads the sensor values and decides how to adjust the robot's movement.
5. **Motor Control:** The microcontroller adjusts the motor speeds of the robot's wheels to correct the error and keep the robot following the line. If the robot

detects that it's deviating to the left, it will increase the right motor's speed, and vice versa.

6. **Turns and Crossroads:** To handle turns and crossroads, the microcontroller can be programmed to respond to specific patterns in the sensor data. When all sensors are off the line, the robot knows it has reached a crossroad or an endpoint. If it reaches the end of the line it back tracks its previous path.
7. **Stopping:** The robot is programmed to stop when ultrasonic sensor senses any trash.

B. Robotic Arm

The arm works autonomously when the LFR detects a trash and stops accordingly. It is an arm with 6 degrees of freedom. The construction of the arm was done as follows-

Components Required:

1. 3D printed parts and screws
2. 6 servo motors
3. Microcontroller (Arduino)
4. Power supply (4200 mAh 11.1 V Li-po battery)

Design:

The individual parts were designed in Solid Works and then 3D printed. After that they were assembled to make the complete structure. A total of six servos were used to control different parts.

TABLE 1. SERVO MOTOR CONTROLS

	Servo Model used	axis	Position (in degrees)	
			Max	Min
Base	MG 996R	Rotational(x-y axis)	180	0
Shoulder	MG 996R	z-axis	180	0
Elbow	MG 996R	z-axis	180	0
Roll	SG90	rotational	180	0
Pitch	SG90	rotational	180	0
Grip	SG90	x-y axis	180	0

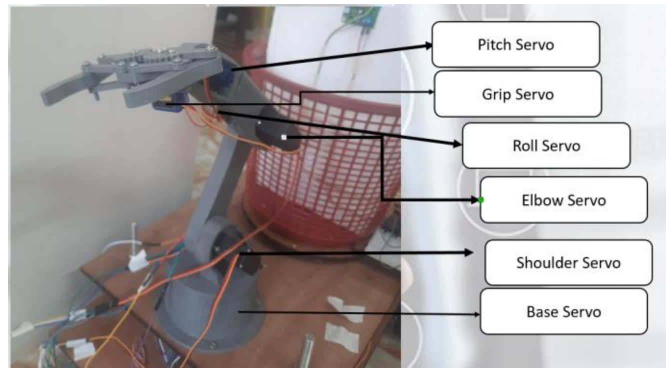

Figure.3: Robotic Arm With Motor Placememts Indicated

Function:

A complicated mechanical system that can move and manipulate things in three dimensions with a high degree of freedom is a six degrees of freedom (6-DOF) robotic arm. Together, these degrees of freedom enable the robotic arm to carry out a variety of activities. Each degree of freedom corresponds to a certain manner the arm can move. The six degrees of freedom and their purposes are broken down as follows:

Base Rotation (Axis 1): The base rotation of a robotic arm is commonly considered to be the first degree of freedom. As a result, the arm can move horizontally (yaw) along the vertical axis by pivoting left and right. This level of flexibility aids in pointing the arm in the direction of the intended target.

Shoulder Rotation (Axis 2): The second degree of freedom is the rotation at the shoulder joint, allowing the arm to move up and down along the horizontal axis (pitch). This movement raises and lowers the arm, changing its elevation.

Elbow Rotation (Axis 3): The elbow joint offers the third degree of freedom, allowing the arm to bend and straighten as well as provide vertical movement along the length of the arm (roll). The reach and inclination of the arm are altered by this motion.

Wrist Pitch (Axis 4): The end-effector (the tool or hand at the end of the arm) can pitch up and down thanks to the fourth degree of freedom, which is commonly found at the wrist. The end-effector's orientation can be adjusted with the help of this movement.

Wrist Yaw (Axis 5): The wrist's capacity to yaw or twist from side to side represents the fifth degree of freedom. The end-effector can bend and align with the target or adjust to different angles thanks to its rotation.

Wrist Roll (Axis 6): The wrist's capacity to roll, which is the sixth and final degree of freedom, enables the end-effector to rotate around its longitudinal axis. The tool or object manipulation orientation of the end-effector can be changed with the use of this rotation.

When the LFR stops, the shoulder and elbow goes down to as the angle defined. The angle definitions are set in such a manner that it autonomously grabs the waste matter. The grip goes to 180° to be open and then grabs the waste by going to 0°. In similar manner, there is a specific angle for elbow up-down and shoulder up-down. After the collection of waste, the base rotates 180° , then it holds the waste in front of the metal sensor for detection. A delay has been added to hold the waste. After detection, the bin completes rotation and then the arm drops the waste to the bin by turning on the grip.

C. Trash segregation (Metallic and Non-Metallic)

The metal sensor detects metallic object and sends a signal to the microcontroller. The microcontroller rotates the bin 180 degrees using a servo motor. There is an appropriate delay before the bin rotates to correspond with the arm. The bin rotates back after another preset delay.

Components Required:

1. MD-60 metal sensor kit
2. Servo motor (MG 996R)
3. Microcontroller (Arduino Uno)
4. Power supply (4200 mAh 11.1 V Li-po battery)

Figure.4: Metal Sensor Used

TABLE 2. METAL DETECTION RANGE

Objects Detected	Metal Sensor Kit Used	Detection range	
		Max	Min
Switchblade	MD-60 kit	10mm	5mm
Battery	MD-60 ki	20mm	15mm
Metal Can	MD-60 kit	30mm	25 mm

Design:

The MD-60 metal sensor kit is attached to a PVC sheet which segregates the bin into two parts. One half is used to store non-metallic trash, the other for metallic trash. The servo motor is attached below the bin, with a circular plywood section in-between them. The Arduino and battery is attached with that plywood section to prevent the connection from the bin getting detached.

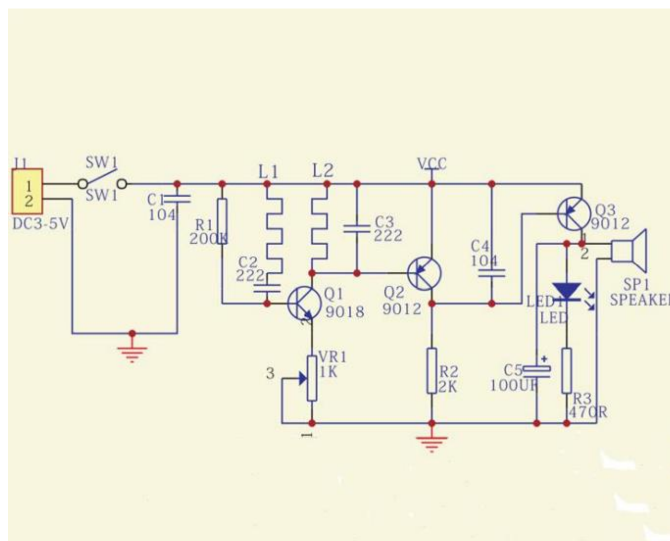

Figure.5: Metal Sensor Detector circuit

Function:

On the PCB of this module, there is a continuous running coil track as well as a number of electronic components. That primarily consists of a buzzer, an LED, a capacitor, and a resistor. Instead of connecting the buzzer, we connected it to the microcontroller to send the signal, commanding the bin to rotate the bin 180 degrees when metal is detected. A smooth circuit is also included in this metal detector module. It emits smooth waves. The signal is continuously released when the circuit is turned on. Additionally, Q1 transistor supplies the necessary power pulse that enables the tuned circuit to produce the signal.

Procedure for non-metallic objects:

The Q1 transistor creates an amplified signal as the signal travels through the coil, which causes an oscillation with amplitude to occur at the coil's beginning point (L1). (With the help of VR1, a variable resistor, we may adjust the amplitude.) Q2 transistors then amplify this signal after that. Furthermore, the 100uf capacitor cannot charge due to the 2k resistor. The signal towards Arduino remains inactive as a result of the Q3 transistor going into inactive state.

Procedure for metallic objects:

In this instance, the oscillating amplitude is accompanied by a reduction in the magnetic field amplitude on the coil (L2). The Q2 (9012-transistor) thereafter stops functioning. Additionally, Q3 (transistor 9012) produces a tiny voltage between the base and the emitter. Consequently, generating a tiny voltage in Arduino pins will cross the preset threshold value which in turn will rotate the servo motor.

With the use of this metal detecting equipment, we can detect metal components up to 60mm away. Additionally, we must supply this module with a voltage between 3 and 5 volts.

LIMITATIONS

The Waste collecting and segregating robot that we designed can only differentiate between two types of wastes, which are metal and non metal. Another most significant shortcoming is that it detects every object as trash. The robot does not have the path remembering ability , although it is autonomous, but it follows a line following path.

IMPLEMENTATION

The designed robot can be implemented in student halls or malls where trashes will be disposed on a line. The Robot will collect those trashes, segregate them using sensor and put it in the bin accordingly.

FUTURE IMPROVEMENTS

Image Processing can be added to make the waste collecting system more accurate such that it detects only trashes ,not every other objects. Also instead of LFR, a totally self autonomous path remembering robot can be developed by adding more advancements.

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