SENSORS AND ACTUATORS

A THESIS

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BONAFIDE CERTIFICATE

This is to certify that the thesis entitled "Sensor-Actuated Smart Dustbin System for Efficient Waste Management" submitted by M Vasista (CB.EN.U4AIE22134), M Dharma Theja (CB.EN.U4AIE22137), Nandana Gireesh (CB.EN.U4AIE22138), Snega Sri A (CB.EN.U4AIE22163) for the award of the Degree of Bachelor of Technology in the CSE(AI) is a Bonafide record of the work carried out by them our guidance and supervision at Amrita School of Artificial Intelligence, Coimbatore.

Dr. Sajith Variyar — Project Guide

Dr. K. P. Soman — Professor and Head CE

DECLARATION

We, M Vasista - CB.EN.U4AIE22134, M Dharma Theja - CB.EN.U4AIE221137, Nandana Gireesh - CB.EN.U4AIE22138, Snega Sri A - CB.EN.U4AIE22163 hereby declare that this thesis entitled "Sensor-Actuated Smart Dustbin System for Efficient Waste Management", is the record of the original work done by us under the guidance of Dr Sachin Kumar, Assistant Professor, Centre for Computational Engineering and Networking (CEN), Amrita School of Artificial Intelligence, Coimbatore. To the best of my knowledge, this work has not formed the basis for the award of any degree/diploma/ associate ship/fellowship/or a similar award to any candidate in any University.

Place: Coimbatore

Date: 11-10-2025 **Signature of the Student**

ACKNOWLEDGEMENT

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ABSTRACT

The Smart Dustbin using Arduino Mega is a sensor–actuator–based automation system designed to minimize human contact with waste, enhance hygiene, and demonstrate the coordinated working of multiple electronic components. The project integrates various sensors and actuators, including an Infrared (IR) sensor, Ultrasonic sensor (HC-SR04), Servo motor, GSM module (SIM800L), and GPS module (NEO-6M), all controlled through an Arduino Mega microcontroller. The system operates by detecting the presence of a user near the dustbin using the IR sensor, which functions as a proximity detector. When an object or hand is detected within the sensor's range, a signal is sent to the Arduino, which then triggers the servo motor—acting as an actuator—to automatically open the lid of the dustbin. Once the user moves away, the lid closes automatically, ensuring a touch-free waste disposal mechanism.

In addition to automatic lid control, the project incorporates a real-time waste level monitoring system using the ultrasonic sensor. This sensor measures the distance from the sensor (placed on the lid) to the garbage surface by sending and receiving ultrasonic sound waves. Based on the time taken for the echo to return, the distance is calculated and converted into a percentage that represents how full the dustbin is. When the bin reaches a pre-defined threshold level (for example, 90% full), the system automatically activates the GSM module, which sends an SMS alert to a designated phone number. This message contains a notification stating that the dustbin is full and requires emptying. Simultaneously, the GPS module provides the geographical coordinates (latitude and longitude) of the dustbin, which are included in the alert message for easy location identification.

1. Introduction

1.1 Overview of the Project

Urbanization has dramatically increased the quantity of waste generated in cities, creating complex challenges in waste management concerning environmental health, resource optimization, and operational efficiency. In response, the smart dustbin project harnesses advancements in sensor automation and wireless communication to revolutionize traditional waste disposal methods. The system is designed to provide a hygienic, user-friendly, and intelligent trash receptacle that adapts to real-world usage patterns.

At its core, the smart dustbin integrates an Infrared (IR) sensor to perceive user presence without physical contact, which triggers the servo motor to automatically open the lid, thereby reducing the risk of contamination and enhancing user convenience. Simultaneously, an ultrasonic sensor continuously monitors the level of waste within the bin by measuring the distance from the sensor to the garbage's surface, translating this data into an actionable fill percentage. When the fill exceeds a critical threshold (90%), the embedded GPS module (NEO-6M) pinpoints the dustbin's precise geographic location. The system then utilizes a GSM module (SIM800L) to send an automatic SMS notification—including the location coordinates—to the municipal waste management authorities. This real-time, remotely accessible data facilitates timely collection and optimizes municipal waste handling.

This integrated approach not only improves urban sanitation by preventing overflow-related problems but also supports smart city initiatives by connecting infrastructure to the Internet of Things (IoT). The proposed solution promises greater operational efficiencies, reduced labor dependency, and enhanced environmental sustainability through data-driven waste management.

1.2 Problem Statement

Waste management in urban centers remains predominantly manual and schedule-based, often leading to inefficient resource use and public health concerns. Many bins overflow unnoticed between collection rounds, resulting in unsightly litter, foul odors, and the attraction of disease vectors such as rodents and insects. These conditions degrade urban environments and pose considerable health risks.

Moreover, fixed collection schedules frequently cause either premature visits to underfilled bins or delayed servicing of full bins, causing cost inefficiencies and increased fuel

consumption for waste collection fleets. Municipal authorities face difficulties in tracking the exact status and location of bins, hampering the formulation of optimized waste routes.

To address these problems, there is a critical need for smart waste collection systems capable of providing real-time data on bin occupancy and locations. Such systems would enable dynamic planning and immediate response to cleanliness issues, thus improving operational efficiency, reducing environmental impact, and ensuring healthier urban living conditions.

1.3 Objectives

The project is guided by the following key objectives to develop an effective smart dustbin system:

- Touchless Lid Operation: Design and implement an IR sensor-based proximity detection mechanism that opens the dustbin lid automatically upon user approach to minimize physical contact and enhance hygiene.
- Accurate Fill-Level Monitoring: Utilize an ultrasonic sensor to measure the distance to the top of accumulated waste, enabling precise calculation of the fill level as a percentage of total bin capacity.
- Geolocation Integration: Integrate GPS technology to provide accurate, real-time location data of the dustbin, critical for municipal deployment where bins may be mobile or dispersed across large areas.
- Automated Alert System: Develop a reliable GSM-based communication module to send SMS alerts to the waste management department when the bin reaches a specified fullness level, incorporating geolocation details for streamlined operations.
- Scalability and Cost Efficiency: Create a modular prototype that balances performance with affordability and power efficiency, allowing widespread adoption across various urban and institutional environments, thereby supporting broader smart city environmental goals.

1.4 Scope of the Project

This project focuses on automating individual dustbins commonly found in urban public spaces such as parks, streets, playgrounds, as well as commercial and institutional facilities including office buildings, schools, and hospitals. The smart dustbin system is designed for standalone operation, capable of functioning independently without constant internet connectivity by utilizing cellular GSM networks.

While the current prototype centers on the automation of a single bin's lid control, fill-level measurement, and alert communication, its modular design facilitatesscalability to networks of bins. Future expansions can incorporate solar power for energy autonomy, adopt modern wireless standards (e.g., LoRaWAN, NB-IoT) for low-power wide-area network (LPWAN) connectivity, and integrate centralized cloud-based analytics platforms. This would enable real-time city-wide monitoring dashboards, predictive maintenance scheduling, and data-driven policymaking.

Furthermore, the system can be extended to include waste segregation modules or environmental sensors to monitor odors and hazardous gas emissions. Ultimately, the project contributes to creating an interconnected urban ecosystem that harnesses IoT technologies to enhance public health, reduce operational expenditures, and optimize municipal services in line with the vision of sustainable and smart cities.

2. System Design and Working

The system consists of the Arduino UNO microcontroller coordinating the sensors and communication modules. The IR sensor, connected to digital pin D2, detects nearby presence. The ultrasonic sensor, wired to pins D3 (TRIG) and D4 (ECHO), measures distance to waste for fill level estimation. Servo motor connected to pin D9 controls the lid mechanism. GPS module exchanges data over pins D5 and D6, while GSM module communicates via pins D7 and D12. The system is powered via a regulated 5V source shared across components with a common ground.

2.1 Working Principle

- When a user approaches, the IR sensor outputs a HIGH signal detected by Arduino which commands the servo motor to rotate to 90°, opening the lid.
- The ultrasonic sensor emits a burst of 40 kHz sound waves, and measures the time it takes for the echo to reflect back. This measurement converts into distance using the formula:

$$\mathbf{Distance} = \frac{\mathbf{Time} \times \mathbf{0.034}}{\mathbf{2}}$$

- The calculated distance reflects the space available in the bin, inversely proportional to the garbage fill. This distance is mapped to a percentage fill level to indicate how full the dustbin is.

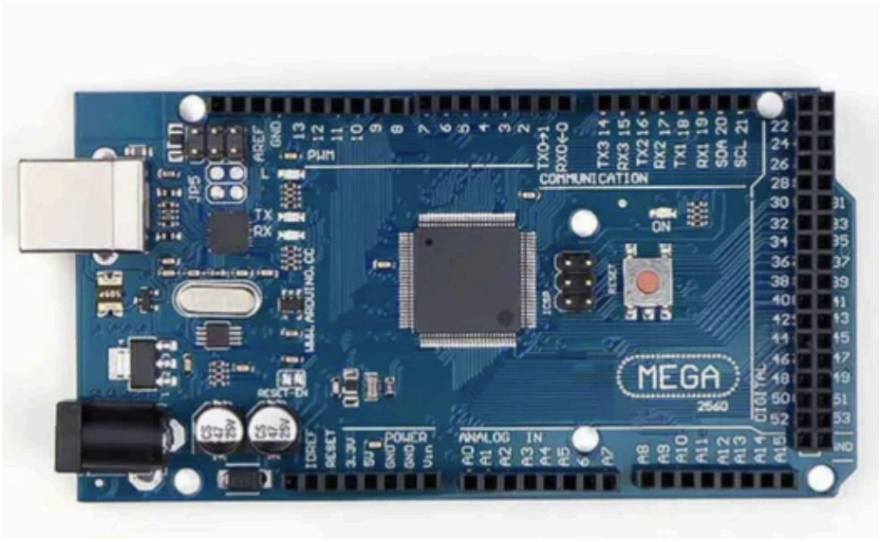
- Once the fill reaches or exceeds 90%, the Arduino queries the GPS module for coordinates. If valid data is obtained, the system constructs a message indicating full status with latitude and longitude; if not, it uses a default location.
- The GSM module sends this SMS notification, alerting municipal waste handlers.
- The lid closes automatically when no presence is detected, maintaining hygiene.

2.2 Components Used

2.2.1 Arduino MEGA 21560

The Arduino Mega serves as the central controller or “brain” of the smart dustbin system. It is built around the ATmega2560 microcontroller, which offers 54 digital input/output pins, 16 analog inputs, and four hardware serial ports. This makes it ideal for complex projects requiring multiple sensors and communication modules simultaneously. In this project, the Arduino Mega reads data from the IR and ultrasonic sensors, processes it according to predefined logic, controls the servo motor to open or close the lid, and communicates with the GPS and GSM modules to provide real-time location and alert information. It operates at 16 MHz, providing sufficient processing speed for real-time sensor handling and decision-making. The board’s 5V logic levels and stable power regulation allow it to interface directly with most sensors and actuators used in the system. Its extensive I/O capabilities and multiple serial ports make it a more suitable choice than smaller boards like the Arduino Uno, which would struggle to manage all modules simultaneously.

Function: Acts as the central controller, processing input signals from sensors and sending commands to actuators and communication modules.



Specifications:

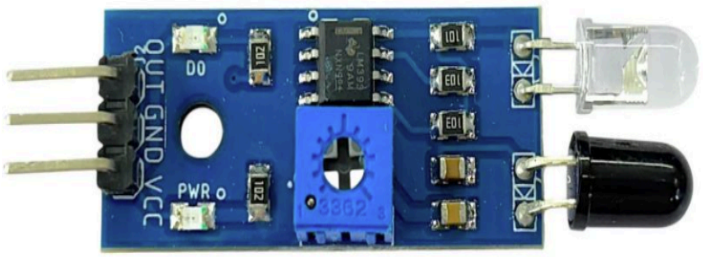
- Microcontroller: ATmega328P
- Operating Voltage: 5V
- Digital I/O Pins: 14 (6 PWM outputs)
- Analog Input Pins: 6

Role in System: Reads signals from the IR and ultrasonic sensors, controls the servo motor for lid operation, communicates with the GPS and GSM modules, and executes the programmed logic for automation and alerts.

2.2.2 Infrared (IR) Sensor

The IR sensor is used for detecting the presence of a human hand or object near the dustbin lid. It operates on the principle of infrared light reflection: the sensor emits infrared light continuously, and when an object comes within its detection range, a portion of the light is reflected back onto the sensor, causing its output pin to go HIGH. This output is then read by the Arduino to trigger the servo motor to open the lid. Typically, the IR sensor has a detection range of 2–30 cm and a field of view of approximately 35°–40°. It is fast and responsive, capable of detecting objects within milliseconds, making it ideal for interactive applications like automatic lid opening. The sensor operates on 5V and outputs a digital signal, simplifying integration with the Arduino. However, it cannot measure distance and is primarily limited to presence detection. It may also be influenced by strong sunlight or reflective surfaces, which can affect accuracy. In this project, the IR sensor ensures hygienic, touchless operation by detecting when someone approaches and opening the lid automatically.

Function: Detects the presence or proximity of objects such as a user's hand near the dustbin to trigger automatic lid opening.



Specifications:

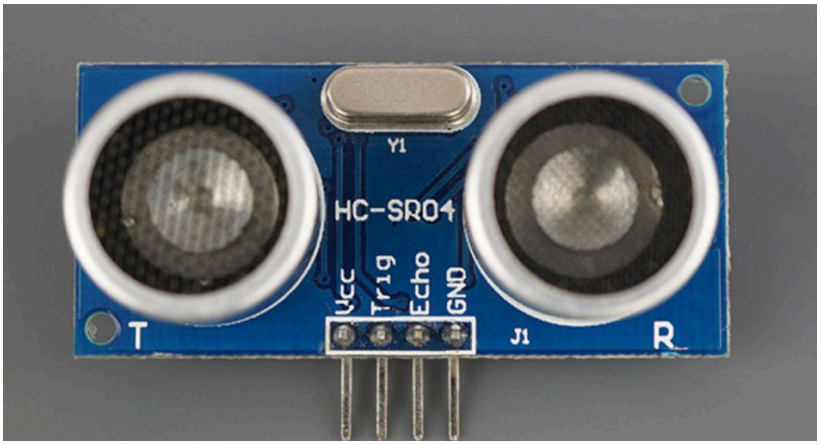
- Detection Range: 2 cm to 30 cm
- Detection Angle: Approximately 35° to 40°
- Output: Digital HIGH when an object is detected, LOW otherwise
- Power Supply: 5V

Role in System: Provides a touchless interface by signalling the Arduino when a person approaches, prompting the servo motor to open the dustbin lid.

2.2.3 Ultrasonic Sensor (HC-SR04)

The ultrasonic sensor is employed to measure the level of waste inside the dustbin by calculating the distance from the sensor to the garbage surface. It operates using the time-of-flight principle, where it emits a 40 kHz ultrasonic pulse via the TRIG pin and measures the time taken for the echo to return to the ECHO pin. The sensor has a detection range of 2–400 cm and a narrow beam angle of about 15°, providing sufficient accuracy for measuring bin fill levels. It operates on 5V and offers non-contact measurement, making it ideal for irregular surfaces like waste. Ultrasonic sensors are relatively low-power and easy to interface with Arduino. However, their narrow detection angle requires careful alignment, and soft or angled surfaces can cause errors in measurement. In this project, the ultrasonic sensor continuously monitors the garbage level and sends distance data to the Arduino, which then converts it into a percentage fill. This information is used to determine when the bin is full and when to trigger an SMS alert via the GSM module.

Function: Measures the distance between the sensor and the surface of the garbage inside the dustbin to assess the fill level.



Specifications:

- Operating Voltage: 5V
- Measuring Range: 2 cm to 400 cm
- Detection Angle: Around 15°
- Frequency: 40 kHz ultrasonic pulses
- Outputs: Trigger input (to send pulse), Echo output (to receive reflected pulse)

Role in System: By sending ultrasonic pulses and measuring their echo return time, it calculates the distance to the garbage surface, enabling conversion to a fill percentage by the Arduino

2.2.4 Servo Motor

The servo motor acts as the actuator responsible for opening and closing the dustbin lid. Servos are precise electromechanical devices that rotate to a specified angle based on PWM (Pulse Width Modulation) signals from the Arduino. A typical servo has an angular range from 0° to 180°, with pulse widths of approximately 1–2 ms determining its position. For example, a pulse width of 1 ms corresponds to a closed lid at 0°, while 1.5 ms or 90° corresponds to a half-open position. The servo contains a geared motor and a potentiometer that provides feedback, enabling precise control over angular movement. Servos are compact, energy-efficient, and ideal for applications requiring accurate positioning. In the smart dustbin project, the servo receives commands from the Arduino triggered by the IR sensor: when the sensor detects a hand, the servo rotates to 90° to open the lid; when the hand moves away, it returns to 0°, closing the lid. Limitations include limited rotation range and a requirement for adequate power supply to avoid voltage drops during operation.

Function: Provides mechanical movement to open and close the dustbin lid based on control signals.

Specifications:

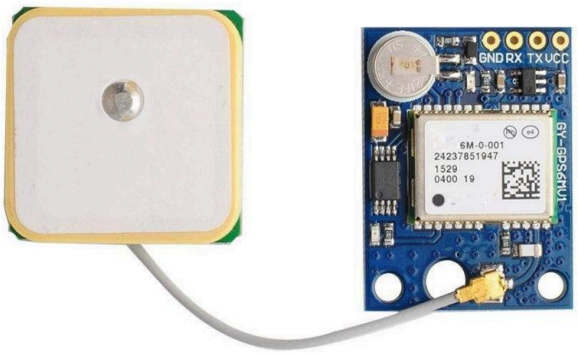
- Operating Voltage: 4.8V to 6V
- Control: PWM signal
- Rotation Range: Typically 0° (closed) to 180° (full open), here used up to 90°
- Torque: Suitable to move lid based on design

Role in System: Receives PWM signals from the Arduino to rotate the lid servo shaft to open when the IR sensor detects a user presence and closes when no obstruction is detected.

2.2.5 GPS Module (NEO-6M)

The GPS module provides the real-time geographical location of the dustbin, enabling remote monitoring and accurate alert delivery. It receives signals from multiple GPS satellites and calculates the latitude and longitude using triangulation algorithms. The module communicates with the Arduino via UART serial interface and is typically read using the TinyGPSPlus library for parsing coordinates. It operates at 3.3–5V and provides accuracy up to ±2.5 meters in open sky conditions, updating coordinates roughly once per second. The module is small, lightweight, and widely compatible, but it has limitations indoors or under dense cover, where satellite signals may be blocked, resulting in missing or inaccurate data. In the smart dustbin, GPS coordinates are sent alongside the “bin full” SMS to inform waste management authorities of the exact location for efficient collection.

Function: Acquires satellite data to provide the precise geographic location of the dustbin.



Specifications:

- Operating Voltage: 3.3V to 5V
- Interface: UART serial communication
- Position Accuracy: Approximately 2.5 meters
- Update Rate: 1 Hz (one position fix per second)

Role in System: Supplies accurate latitude and longitude coordinates used to inform waste management authorities about the location of the dustbin when it becomes full.

2.2.6 GSM Module (SIM800L)

The GSM module is responsible for sending SMS notifications to alert waste management authorities when the bin reaches a predefined fill level. It operates on the GSM cellular network and communicates with the Arduino via UART. The module uses AT commands for operation, such as AT+CMGF=1 to set text mode, and AT+CMGS followed by a phone number to send a message. During transmission, it can draw peak currents of up to 2A, requiring a stable power supply to function reliably. The SIM800L operates at 3.7–4.2V and supports standard SMS transmission over GSM networks. Its advantages include wide-area communication without internet dependency and compatibility with standard SIM cards. Limitations include dependence on network coverage, slower data rates unsuitable for large data, and high current consumption during transmission. In this project, the module enables remote monitoring by sending real-time alerts with the bin's fill level and GPS location.

Function: Communicates with cellular networks to send SMS alerts to predefined phone numbers regarding the dustbin's status.

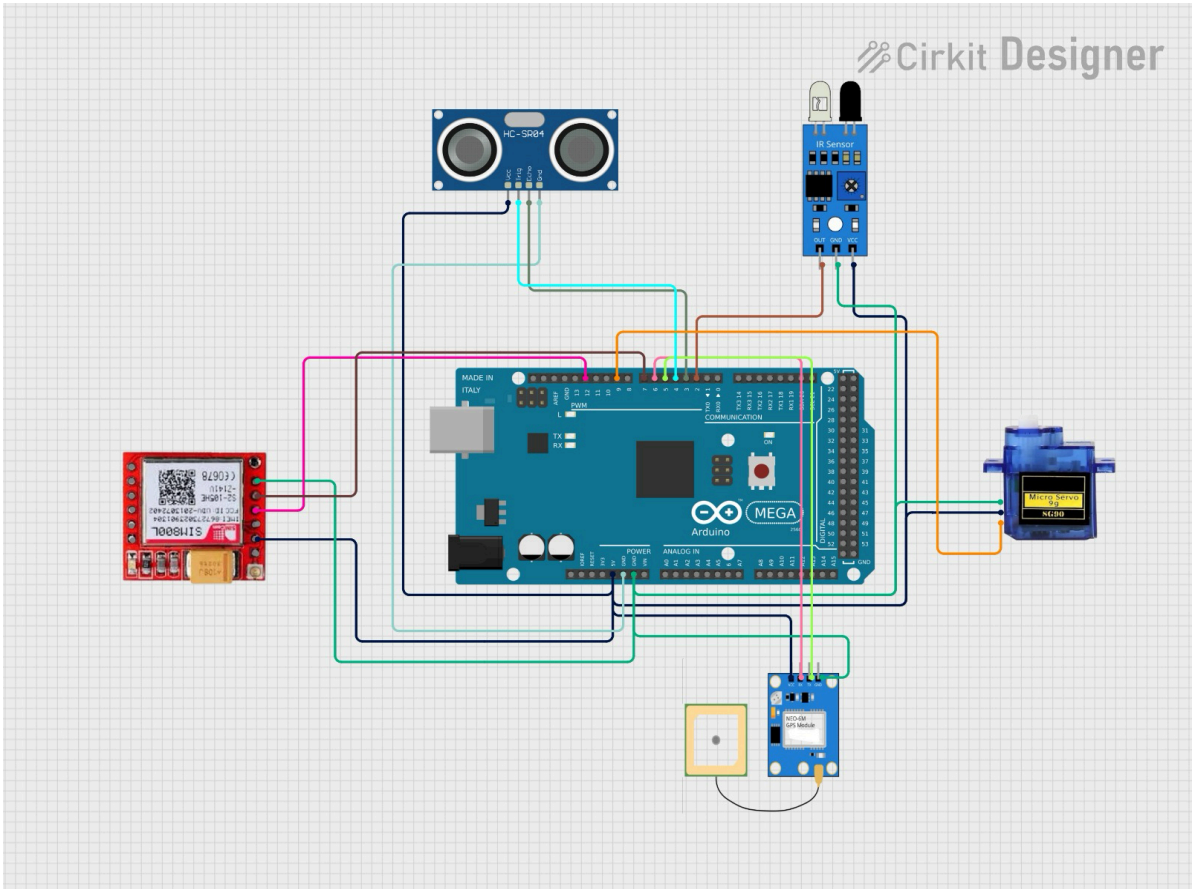
Specifications:

- Operating Voltage: 3.7V to 4.2V (regulated 5V supply with proper voltage regulation recommended)
- Frequency Bands: Quad-band 850/900/1800/1900 MHz
- Interface: UART serial communication for AT commands
- Supports: SMS, voice calls, and data communication

Role in System: Sends SMS messages containing alerts and GPS location to the waste management system when the dustbin exceeds the fullness threshold.

3. Circuit Diagram and Connections

3.1 Circuit Diagram



The complete circuit diagram of the Smart Dustbin system was designed using Cirkit Designer software. The project is built around an **Arduino Mega 2560** microcontroller, which acts as the main control unit that interfaces with multiple sensors and modules.

The circuit includes the following key components:

- **Infrared (IR)** Sensor for detecting the presence of an object or a person near the

dustbin lid.

- **Ultrasonic Sensor (HC-SR04)** for measuring the waste fill level inside the bin.
- **Servo Motor (SG90)** to automatically open and close the lid.
- **GPS Module (NEO-6M)** for real-time location tracking.
- **GSM Module (SIM800L)** to send SMS alerts when the dustbin becomes full.

The connections were carefully made according to the designed circuit diagram to ensure smooth communication between all modules and the Arduino Mega board. The 5V and GND lines were connected in all components, and the signal pins were connected to the specified digital I/O pins.

3.2 Pin Connections

Component / Module	Pin on Module	Connect To (Arduino Mega Pin)	Function / Description
IR Sensor	VCC	5V	Power supply for IR sensor
	GND	GND	Common ground
	OUT	Pin **2** (`IR_PIN`)	Sends HIGH when object detected (hand near bin)
Servo Motor	Signal (Orange/Yellow)	Pin **9** (`SERVO_PIN`)	Controlled using PWM signal to open/close lid
	VCC (Red)	5V	Power supply
	GND (Brown/Black)	GND	Common ground
Ultrasonic Sensor (HC-SR04)	VCC	5V	Power supply
	GND	GND	Common ground
	TRIG	Pin **3** (`TRIG_PIN`)	Sends ultrasonic pulse
	ECHO	Pin **4** (`ECHO_PIN`)	Receives echo to measure distance
GPS Module (NEO-6M)	VCC	5V	Power supply for GPS receiver
	GND	GND	Common ground
	TX	Pin **5** (`GPS_RX`)	Sends GPS data to Arduino
	RX	Pin **6** (`GPS_TX`)	Receives data from Arduino
GSM Module (SIM800L)	VCC	5V	Power supply
	GND	GND	Common ground
	TX	Pin **7** (`GSM_RX`)	Sends data to Arduino
	RX	Pin **12** (`GSM_TX`)	Receives data from Arduino

3.3 Software and Libraries Used

The Arduino Mega 2560 was programmed using the **Arduino IDE**.

The following libraries were included to handle communication and control of external modules:

Library	Purpose / Description
`Servo.h`	Used to control the servo motor's position for opening and closing the dustbin lid.
`SoftwareSerial.h`	Enables serial communication with multiple devices like GPS and GSM modules on different pins.
`TinyGPS++.h`	Used for decoding GPS signals (latitude and longitude) from the NEO-6M GPS module.

The **baud rate** for serial communication was set to **9600 bps** for both GPS and GSM modules to ensure stable data transfer.

3.4 Arduino Code:

```
#include <Servo.h>
#include <SoftwareSerial.h>
#include <TinyGPS++.h>

#define IR_PIN 2
#define SERVO_PIN 9
#define TRIG_PIN 3
#define ECHO_PIN 4
#define GPS_RX 5
#define GPS_TX 6
#define GSM_RX 7
#define GSM_TX 12

Servo myservo;
SoftwareSerial gpsSerial(GPS_RX
, GPS_TX);
SoftwareSerial gsmSerial(GSM_RX, GSM_TX);
TinyGPSPlus gps;

const int dustbinHeightCm = 16; // Height of dustbin in cm

bool binFullSent = false; // To avoid sending multiple SMS repeatedly

void setup() {
  Serial.begin(9600);
```

```
  pinMode(IR_PIN, INPUT);
  pinMode(TRIG_PIN, OUTPUT);
  pinMode(ECHO_PIN, INPUT);
  myservo.attach(SERVO_PIN);

  gpsSerial.begin(9600);
  gsmSerial.begin(9600);
}

void loop() {
  // IR sensor controls servo open/close
  int irState = digitalRead(IR_PIN);
  if (irState == HIGH) {
    myservo.write(90);  // Open
  } else {
    myservo.write(0);   // Close
  }

  // Ultrasonic distance measurement
  long duration, distance;
  digitalWrite(TRIG_PIN, LOW);
  delayMicroseconds(2);
  digitalWrite(TRIG_PIN, HIGH);
  delayMicroseconds(10);
  digitalWrite(TRIG_PIN, LOW);
  duration = pulseIn(ECHO_PIN, HIGH);
  distance = duration * 0.034 / 2;

  // Convert to percentage full (100% means dustbin full)
  int levelPercent = map(distance, 0, dustbinHeightCm, 100, 00);
  levelPercent = constrain(levelPercent, 0, 100);
levelPercent =map(levelPercent , 30, 100, 0, 100);
  Serial.print("Dustbin Level (%): ");
  Serial.println(levelPercent);

  // Read GPS data
  while (gpsSerial.available()) {
    gps.encode(gpsSerial.read());
  }

  // Check if dustbin is 90% or more full and send SMS once
  if (levelPercent >= 90 && !binFullSent) {
    sendBinFullSMS();
    binFullSent = true;
  }

  // Reset flag if level goes below 90%
  if (levelPercent < 90) {
    binFullSent = false;
  }

  delay(1000);
}
```

```
void sendBinFullSMS() {
  String locationString;

  if (gps.location.isValid() && gps.location.isUpdated()) {
    // GPS location available
     locationString = "Lat:" + String(gps.location.lat(), 6) + " Lng:" + String(gps.location.lng(),
6);
  } else {
    // GPS unavailable - send default location
    locationString = "Lat:10.9038 Lng:76.8984"; // Example default location (Bangalore)
  }

  gsmSerial.println("AT+CMGF=1");    // SMS text mode
  delay(2000);
  gsmSerial.println("AT+CMGS=\"+918610892922\""); // Replace with recipient number
  delay(2000);
  gsmSerial.print("Dustbin full! Location: ");
  gsmSerial.print(locationString);
  gsmSerial.write(26); // CTRL+Z to send SMS
  delay(3000);

  Serial.println("Bin full SMS sent.");
}
```

This Arduino program controls the automatic smart dustbin using various sensors and actuators. The code begins by including three important libraries:

- **Servo.h** – controls the servo motor (the actuator that opens and closes the lid).
- **SoftwareSerial.h** – allows the Arduino to communicate with multiple serial devices like GSM and GPS modules.
- **TinyGPS++.h** – processes and reads data from the GPS module.

In the setup() function, all sensor and actuator pins are configured. Serial communication is started for debugging and for connecting with the GSM and GPS modules.

In the loop() function:

1. The IR sensor detects a nearby object (like a hand).
    - If detected → the servo motor opens the lid (myservo.write(90)),
    - If not detected → it closes the lid (myservo.write(0)).
2. The ultrasonic sensor measures the distance to the garbage using sound waves.
    - This distance is converted to a percentage fill level of the dustbin.
3. If the fill level is 90% or more, the Arduino calls the sendBinFullSMS() function.
4. Inside sendBinFullSMS(), the GSM module sends an SMS alert with the bin's status and GPS coordinates (from the GPS module).
    - If GPS data isn't available, a default location is sent.

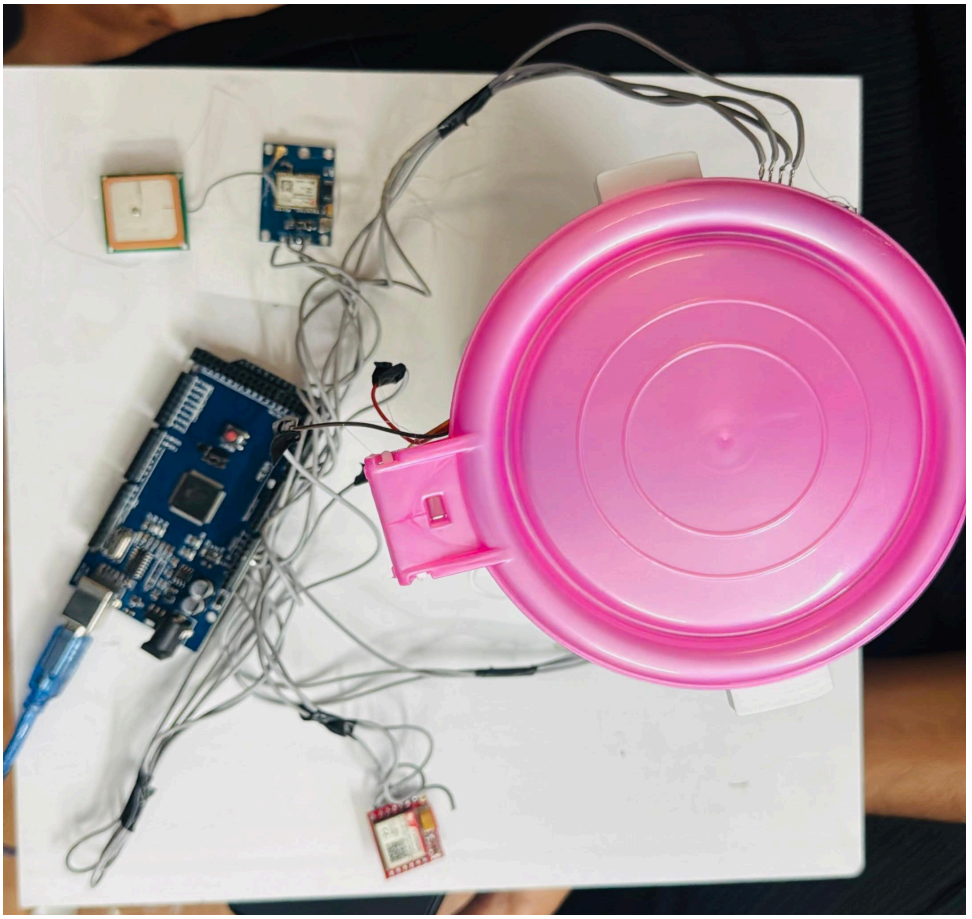
This ensures that the dustbin operates automatically — opening when someone approaches,

measuring how full it is, and sending an alert when it's full — all controlled by the Arduino Mega through sensors and actuators.

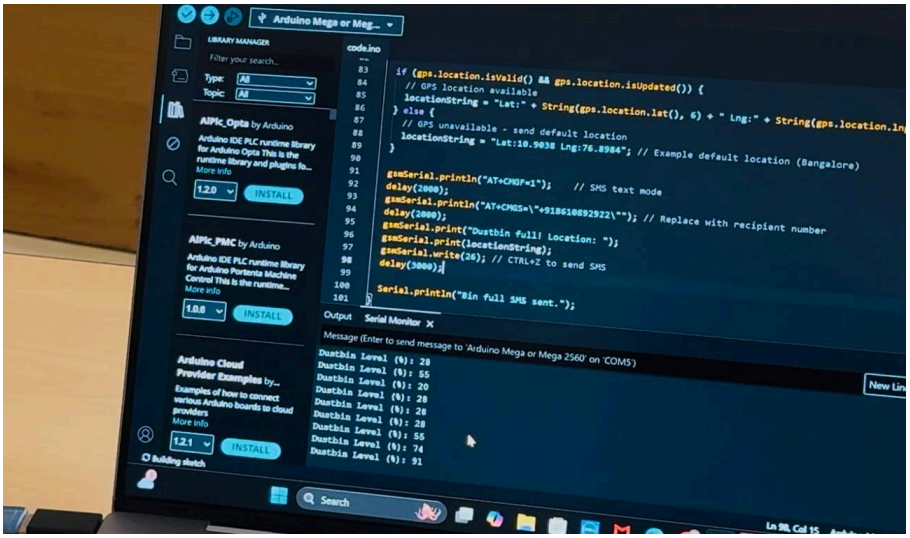
4. Results

4.1 Hardware Setup

The hardware setup for the Sensor-Actuated Smart Dustbin system consists of an Arduino Mega 2560 microcontroller interfaced with multiple sensors and modules. The IR sensor is positioned near the lid for hand/object detection, while the ultrasonic sensor is mounted at the top inside the bin to measure waste level. A servo motor is attached to the lid to automate its opening and closing. The GPS module is placed externally to ensure proper signal reception, and the GSM module is used for sending SMS alerts. The complete hardware assembly was mounted on a standard dustbin, with all components powered through a 5V supply from the Arduino board.

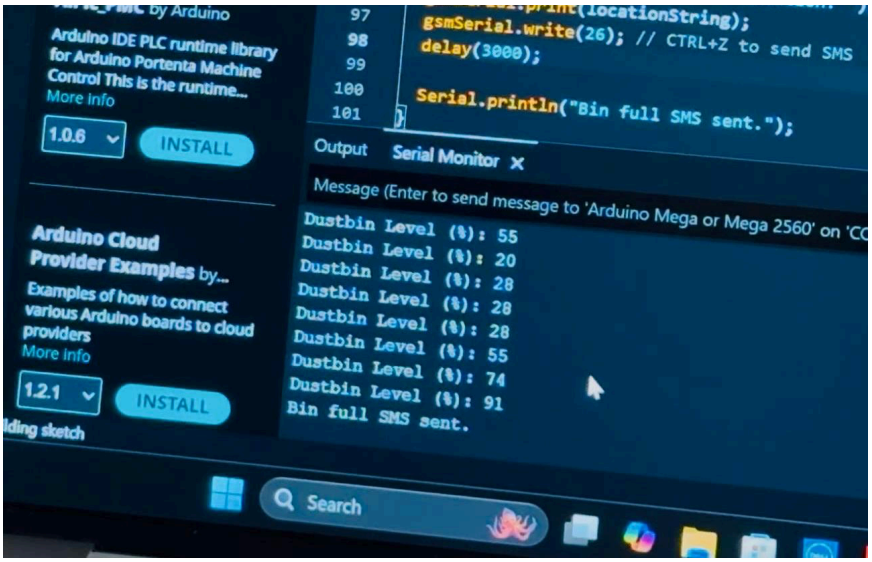


4.2 Sensor Readings and Output



The system continuously monitors input from the IR and ultrasonic sensors. The IR sensor successfully detects hand presence near the lid and triggers the servo to open the bin. The ultrasonic sensor measures the distance to the waste level, and the readings are converted into percentage fill levels. The serial monitor in the Arduino IDE was used to observe real-time readings. The system reliably detects variations in fill level and updates the percentage continuously.

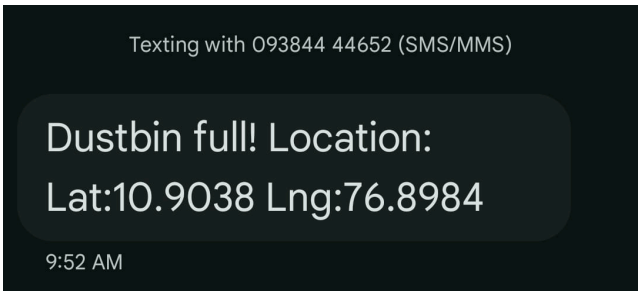
4.3 Dustbin Fill Level Display



The dustbin fill level is displayed as a percentage on the serial monitor. For example, an empty bin shows 0–5%, a partially filled bin shows 30–60%, and a nearly full bin reaches

90–100%. The system maps distance measurements to percentage values for easy interpretation. This allows operators to quickly determine the status of the bin without physically checking it.

4.4 SMS Alert and GPS Location Output



When the dustbin reaches or exceeds 90% full, the GSM module automatically sends an SMS to the registered mobile number. The SMS contains a message indicating that the dustbin is full along with the **real-time GPS coordinates** of the bin location. Tests showed that the SMS was received promptly within a few seconds, and the GPS coordinates accurately represented the physical location of the dustbin. This functionality ensures timely collection and reduces overflow.

4.5 Overall System Performance

The overall system performs efficiently and reliably in real-time. The IR sensor ensures touch-free lid operation, enhancing hygiene, while the ultrasonic sensor provides accurate fill level measurements. The integration of GPS and GSM modules enables automated alerts, reducing manual monitoring effort. During testing, the system demonstrated consistent accuracy in fill-level detection, responsive lid movement, and successful SMS notifications. This confirms that the Smart Dustbin system is practical, user-friendly, and suitable for deployment in public or private areas for improved waste management.

5.Conclusion and Future Work

5.1 Conclusion

The Sensor-Actuated Smart Dustbin System demonstrates an effective approach to modernizing waste management using automation and IoT-based monitoring. By integrating IR and ultrasonic sensors, the system enables touchless operation and continuous monitoring of the dustbin fill level. The GPS and GSM modules allow real-time location tracking and instant notification to the concerned authorities when the dustbin is full, reducing human effort and enhancing operational efficiency.

This project showcases how simple electronic components, sensors, and a microcontroller can be combined to create a practical and intelligent solution for public health and environmental cleanliness. It is user-friendly, hygienic, and can be deployed in various public spaces, campuses, and residential areas to improve waste collection efficiency.

5.2 Future Enhancements

The project can be further enhanced in the following ways:

- **IoT Integration:** Connect the dustbin system to a cloud platform for centralized monitoring of multiple dustbins.
- **Mobile Application:** Develop a mobile app for real-time notifications and status updates.
- **Multiple Sensor Fusion:** Use additional sensors (like weight sensors or gas sensors) to improve accuracy in detecting fill level and odor.
- **Solar Power Supply:** Implement solar-powered operation to make the system energy-efficient and environmentally friendly.
- **Automated Routing for Waste Collection:** Integrate GPS data into a routing system to optimize collection schedules for multiple bins in a city.

These enhancements can make the system more scalable, intelligent, and eco-friendly.