Autonomous System for Detecting Drainage Blockages in Urban Areas

Submitted

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DECLARATION

I/We declare that the project work contained in this report is original and it has been done by me under the guidance of my project guide.

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Date: 16-03-2025 **Signature of the Student**

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CERTIFICATE

This is to certify that (Student Name) bearing (Regd. No.:) has satisfactorily completed Mini Project Entitled in partial fulfillment of the requirements as prescribed by University for VIIIth semester, Bachelor of Technology in “Electrical, Electronics and Communication Engineering” and submitted this report during the academic year 2024-2025.

[Signature of the Guide] **[Signature of HOD]**

Dr. Ramesha.M

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Chapter 1: Introduction

Urban drainage systems are increasingly being overwhelmed by clogs resulting from garbage, plastic trash, grease, and other types of debris. These clogs have serious impacts, such as flooding, water pollution, and public health risks, particularly in the event of heavy rainfall. With urbanization ongoing and climatic patterns becoming more erratic, the number and intensity of drainage problems are on the rise.

Now, the detection and removal of clogged drains primarily depend on hand checks and human-intervention-heavy cleaning processes. The conventional practice is not just time-consuming but also inefficient as clogs get detected only when they have already resulted in tremendous losses, i.e., city floods.

In an attempt to mitigate this, this project focuses on designing a smart autonomous robot system to probe drainage networks in order to monitor clogging in real-time. Fitted with state-of-the-art cameras and sensors, the robot will spot areas where the obstructions can be present and feed data into the maintenance staff to ensure urgent response. With its capacity for early warning and advance response, the system will enhance drainage maintenance efficiency, reduce the threat of floods, and create a contribution to healthier and more secure cities.

1.1 Overview of the problem statement

The goal of this project is to develop an autonomous robot that can detect and locate blockages in drainage pipes. This robot will help cities find and fix blockages quickly, reducing flooding and health problems while cutting down on manual labor. The system will use cameras and sensors to spot issues and provide real-time data, making the process of managing drainage systems more efficient and effective

1.2 Objectives and goals

1. **Build a Robotic System:** Design a robot that can navigate through drainage pipes and detect blockages.
2. **Quickly Detect Blockages:** Employ sensors and cameras to rapidly detect blockages in the drainage system.
3. **Less ManualLabor:** Reduce manual intervention for cleaning and inspecting drains, making it safer and more efficient.
4. **Enhance Drainage Maintenance:** Assist cities in maintaining their drainage systems clean and operational by feeding back real-time data on blockages.
5. **Prevent Flooding and Health Complications:** By promptly repairing blockages, minimize flooding and prevent the spread of waterborne diseases.
6. **Leverage Technology for Improved Solutions**: Use sophisticated tools such as cameras, sensors, and data analysis to enhance the way drainage blockages are addressed.

Chapter 2: Literature Review

In this chapter, we summarize literature and technologies regarding drainage blockage detection and robotics. Important references are:

1. **IoT-Based Smart Drain Monitoring Systems:** Research has demonstrated that IoT-based systems are able to monitor drainage systems and trigger alert messages upon detecting blockages. IoT-based systems apply sensors to detect water levels and blockages, sending real-time information to maintenance personnel.

2. **Robot Systems for Drainage Maintenance**: A number of projects have undertaken the application of robots to inspect and clean drainage systems. Robots used have cameras, sensors, and mechanical arms that can go through pipes and clear obstructions.
3. **Urban Flooding and Drainage Problem:** Research identifies the role of drainage blockages as a cause of urban flooding, public health concerns, and infrastructure problems. Proper maintenance of the drainage system is important to avoid these problems.
4. **Smart Cities and Urban Development** The incorporation of smart technologies, including IoT and robotics, in urban infrastructure is growing in significance for the control of drainage systems and other essential services.

Chapter 3: Strategic Analysis and Problem Definition

3.1 SWOT Analysis

➢ **Strengths:**

- Independence of operation minimizes manual intervention.
- Instant transmission of data enables prompt action on blockages.
- Sophisticated sensors and cameras ensure reliable detection of blockages.

➢ **Weaknesses:**

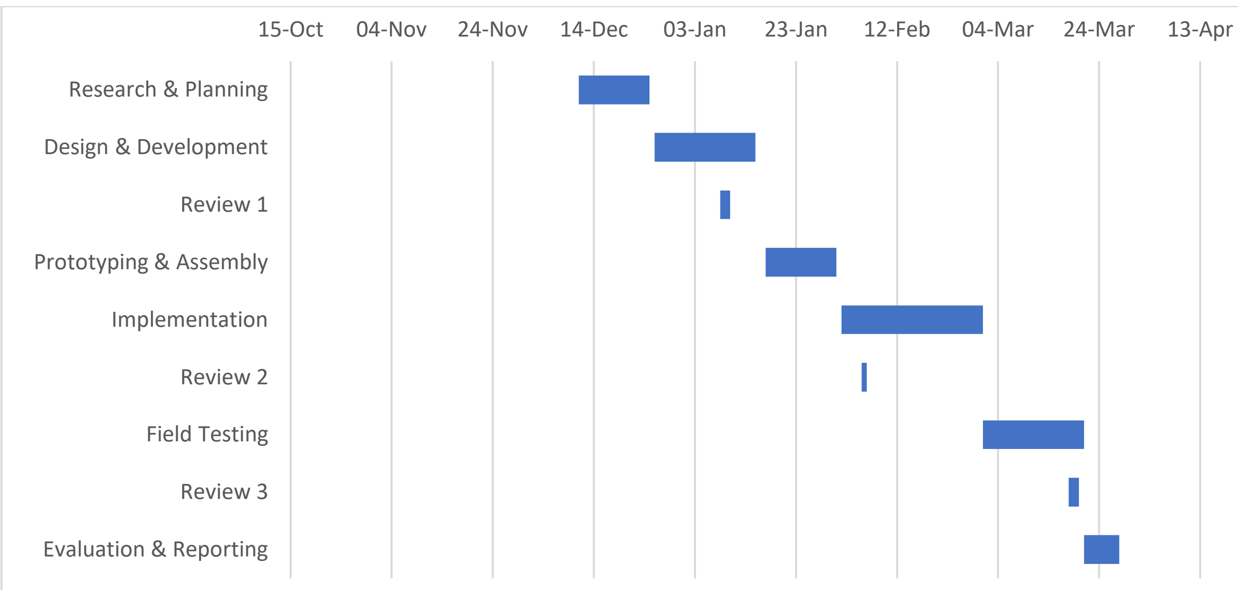
- High upfront cost of development and implementation.

Limited potential for exploration of intricate or broken drainage.

➢ **Opportunities:**
- Integration with intelligent city infrastructure for improved city management.
- Possible expansion of the system to other cities and jurisdictions.

➢ **Threats:**
- Hostile environmental conditions (e.g., waterlogging,) can compromise robot performance.
- Resistance to the implementation of new technologies in conventional maintenance practices.

3.2 Project Plan - GANTT Chart



3.3 Refinement of problem statement

The problem statement is refined to create an autonomous robotic system that can identify and pinpoint blockages in urban drainage systems through the use of sophisticated sensors, cameras, and real-time data transmission. The system is designed to enhance the efficiency of drainage maintenance, minimize the risk of flooding, and promote public health.

Chapter 4: Methodology

4.1 Description of the approach

The problem statement is made more specific in order to develop an independent robotic system capable of detecting and locating clogs in city drainage systems using advanced sensors, cameras, and real-time data exchange. The system aims to improve drainage maintenance efficiency, reduce the possibility of flooding, and enhance public health.

4.2 Tools and techniques utilized

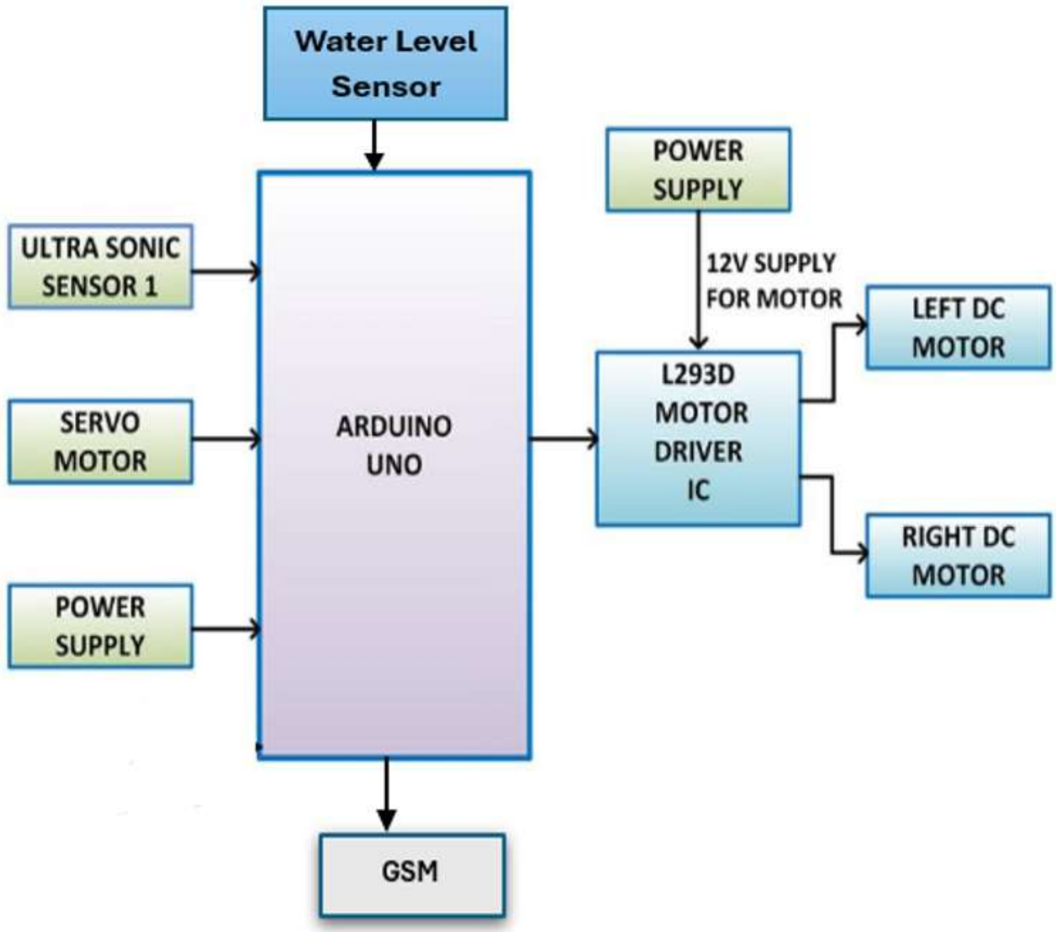
- **Hardware**:
    - **ArduinoUNO**: Microcontroller to process sensor readings and manage the robot.
    - **GSM Module**: For real-time data transmission to maintenance teams.
    - **Ultrasonic Sensors**: For detecting obstacles and measuring distances.
    - **Water Level Sensors**: For tracking water levels in the drainage system.
    - **Servo Motors**: For managing the movement of the robot and mechanical arms.
    - **Cameras**: For visual inspection of drainage pipes.
- **Software**:
    - **Arduino IDE**: To program the microcontroller.
    - **IoT Platforms**: For data transfer and cloud storage.
    - **Navigation Algorithms**: For autonomous navigation and obstacle avoidance.

- **Design**:
    - **Chassis:** Waterproof and robust material (e.g., ABS plastic) to sustain tough conditions.
    - **Tracks/Wheels:** Rubberized for improved grip in slippery conditions.
    - **Enclosure:** Sealed to keep electronic parts away from water damage.

4.3 Design considerations

- **Mobility:** The robot must be able to navigate through narrow and complex drainage pipes.
- **Durability:** The system must withstand harsh environmental conditions, including waterlogging and debris.
- **Communication:** Reliable data transmission is essential for real-time monitoring and quick response to blockages.
- **Power Supply:** The robot must have sufficient battery capacity for extended operation.

4.4 Structural diagram



Chapter 5: Implementation

5.1 Description of how the project was executed

The project was carried out in two phases:

- **Phase 1:** Planning and research, literature review, component selection, and robotic system design.
- **Phase 2:** Prototype development, field testing, and verification of the robot's performance in actual drainage systems.

5.2 Hardware Assembly

1.1 Chassis and Frame Construction

- **Chassis Material:** The frame of the robot is built out of waterproof, strong, yet light materials like ABS plastic or aluminum alloy for it to handle tough drainage environments.
- **Tracks/Wheels:** Wheels or rubberized tracks are fixed to the frame to help provide grip in slick and uneven drainage surfaces.
- **Arm Design:** A servo motor-powered claw mechanism is incorporated into the chassis to catch and dislodge trash when necessary.

1.2 Component Integration

- **Arduino UNO R3:** The microcontroller board is attached to the chassis and linked to several sensors and modules.
- **Sensors:**
  - **Ultrasonic Sensor:** Attached at the front of the robot for detecting obstacles and distances.
  - **Water Level Sensor:** Mounted at the base of the robot to sense water levels in the drain.

    - **Infrared (IR) Sensor**: Employed for sensing blockages and debris.
    - **Camera:** A standard HD CCTV camera is mounted for visual inspection of the drainage pipelines.
- **GSM Module:** Wired to the Arduino to facilitate real-time data transmission to the monitoring center.
- **Servo Motors:** For wheel and claw mechanism movement.

1.3 Power Supply

- A rechargeable battery pack is mounted to power the robot, such that it can run independently for a long period of time.

2. Software Development

2.1 Arduino Programming

- The Arduino UNO is coded with the Arduino IDE to manage the movement of the robot, sensor data acquisition, and communication with the GSM module.
- **Key Functions**:
    - **Obstacle Detection**: The ultrasonic sensor identifies obstacles and provides feedback to the Arduino, which then modifies the path of the robot accordingly.
    - **Blockage Detection**: The IR sensor and camera collaborate to detect blockages. The Arduino reads this information and sends notifications through the GSM module.
    - **Data Transmission**: The GSM module transmits real-time data, such as blockage location and intensity, to the monitoring station.

2.2 Real-Time Monitoring Dashboard

- A web-based dashboard or mobile application is developed to display real-time data from the robot, including:
    - Live video stream from the camera.

- Blockage position and intensity.
- Water level information.
- Location and status of the robot

- The dashboard enables the authorities to observe the drainage system and take swift action whenever blockages are reported.

2.3 Code

```
#include <AFMotor.h>
#include <SoftwareSerial.h>

// GSM module setup
SoftwareSerial mySerial(6, 7); // RX, TX for SIM900A
const char* mobileNumber = "+919347265708"; // Mobile number to send SMS
bool smsSent = false;      // Flag to prevent multiple SMS sends

// Ultrasonic sensor pins
#define echoPin 9   // Echo pin on pin 9
#define trigPin 10  // Trigger pin on pin 10

// Initialize the four motors
AF_DCMotor front_left(1, MOTOR12_64KHZ);
AF_DCMotor rear_left(2, MOTOR12_64KHZ);
AF_DCMotor front_right(3, MOTOR12_64KHZ);
AF_DCMotor rear_right(4, MOTOR12_64KHZ);

int count = 1;
int Direction = 1;
int distance = 0;

void setup() {
  Serial.begin(9600);
  pinMode(trigPin, OUTPUT);
  pinMode(echoPin, INPUT);
  mySerial.begin(9600);
  Serial.println("GSM Modem and Motors Ready");
  delay(3000);
  // sendSMS();
}

void loop() {
  // Measure distance with ultrasonic sensor
  digitalWrite(trigPin, LOW);
  delayMicroseconds(2);
  digitalWrite(trigPin, HIGH);
  delayMicroseconds(10);
  digitalWrite(trigPin, LOW);

  int duration = pulseIn(echoPin, HIGH);
  distance = (duration - 10) * 0.034 / 2;

  Serial.print("Distance: ");
  Serial.print(distance);
  Serial.println(" cm");
```

```
  Serial.print("count: ");
  Serial.println(count);

  if (distance < 10 && Direction == 1 && !smsSent) {
    Direction = -1;
    stopMotors();
    sendSMS();
    smsSent = true;
  }

  // if (distance < 10 && Direction == 1) {
  //   Direction = -1;
  //   stopMotors();
  //   delay(2000);
  // }
  if (count <= 1 && Direction == -1) {
    Direction = 0;
  }

  if (Direction == 1) {
    moveForward();
    count = count + 1;
  }
  if (Direction == -1) {
    moveBackward();
    count = count - 1;
  }
  if (Direction == 0) {
    stopMotors();
    count = 1;
    Direction = 1;
    distance = 0;
    smsSent = false;
    delay(5000);
  }

  if (mySerial.available()) {
    Serial.write(mySerial.read());
  }
}
```

```
// Motor control functions
void stopMotors() {
  front_left.setSpeed(0);
  rear_left.setSpeed(0);
  front_right.setSpeed(0);
  rear_right.setSpeed(0);
  front_left.run(RELEASE);
  rear_left.run(RELEASE);
  front_right.run(RELEASE);
  rear_right.run(RELEASE);
}
void moveForward() {
  front_left.setSpeed(255);
  rear_left.setSpeed(255);
  front_right.setSpeed(255);
  rear_right.setSpeed(255);
  front_left.run(FORWARD);
  rear_left.run(FORWARD);
  front_right.run(FORWARD);
  rear_right.run(FORWARD);
}
void moveBackward() {
  front_left.setSpeed(255);
  rear_left.setSpeed(255);
  front_right.setSpeed(255);
  rear_right.setSpeed(255);
  front_left.run(BACKWARD);
  rear_left.run(BACKWARD);
  front_right.run(BACKWARD);
  rear_right.run(BACKWARD);
}

// Function to send an SMS
void sendSMS() {
  Serial.println("Sending SMS through GSM Modem");
  mySerial.println("AT+CMGF=1");
  delay(1000);
  mySerial.print("AT+CMGS=\"");
  mySerial.print(mobileNumber);
  mySerial.println("\"\r");
  delay(1000);
  mySerial.println("Object detected by the radar!");
  delay(100);
  mySerial.println((char)26);
  delay(1000);
  Serial.print("SMS Sent to ");
  Serial.println(mobileNumber);
}
```

3. Testing and Validation

3.1 Laboratory Testing

- The robot is
  tested under laboratory conditions to verify that all the components are working as required.
- **Tests Conducted**:
  - Obstacle detection with the ultrasonic sensor.
  - Blockage detection with the IR sensor and camera.
  - Data transmission through the GSM module.

3.2 Field Testing

- The robot is put in real drainage systems to confirm its performance under real-world scenarios.
- **Key Metrics**:
  - Blockage detection accuracy.
  - Navigation through intricate drainage networks.
  - Reliability in challenging conditions (e.g., waterlogging, debris).
  - Dependability of real-time data delivery.

5.3 Challenges faced and solutions implemented

- **Challenge:** Ability to pass through narrow and winding drainage pipes.
  Solution: Rubberized tracks and servo motors to improve traction and maneuverability.
- **Challenge:** Transmission of real-time data in underground conditions.
  Solution: GSM module for secure communication and tracking.

Chapter 6: Results

6.1 outcomes

- Successful design of a prototype robotic system to detect and locate drainage blockages.
- Real-time data transfer to a central monitoring system for prompt response to blockages.
- Increased efficiency in drainage maintenance, with reduced time and labor needed for manual inspection.

6.2 Interpretation of results

The findings show that the autonomous robotic system is efficient at detecting and identifying blockages in urban drainage networks. The capability of the system to send real-time information ensures that action is taken in time, and the risk of flooding and public health risk is minimized.

6.3 Comparison with existing literature or technologies

The system developed performs better than the conventional manual inspection technique with respect to speed and efficiency. It also stands comparison with current IoT-based drainage monitoring systems, providing extra features like autonomous navigation and real-time data transmission.

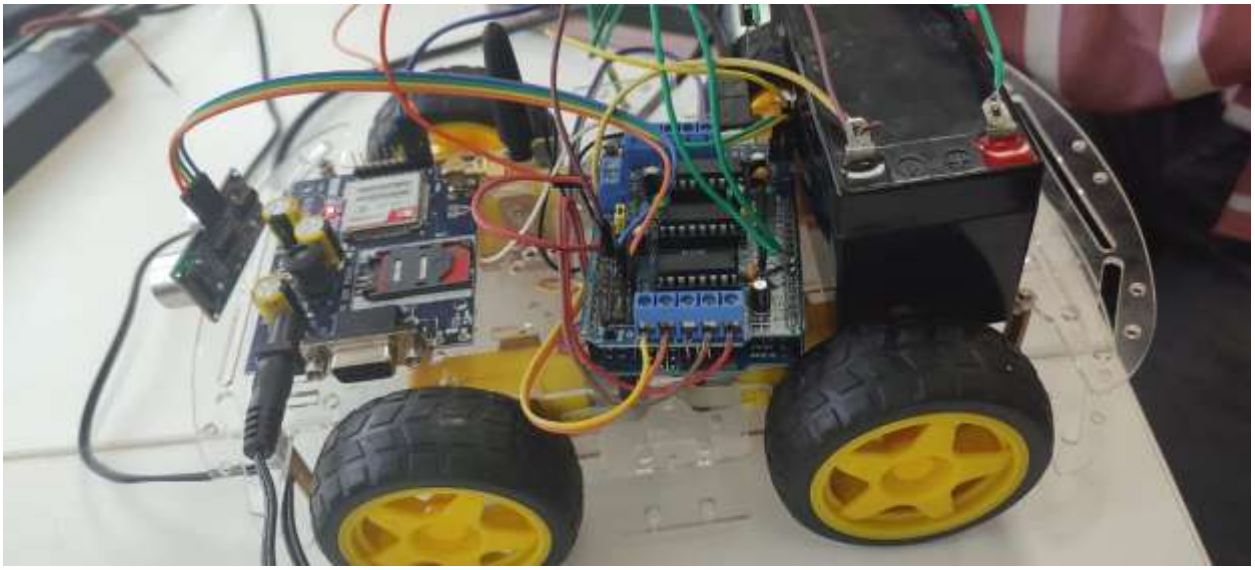
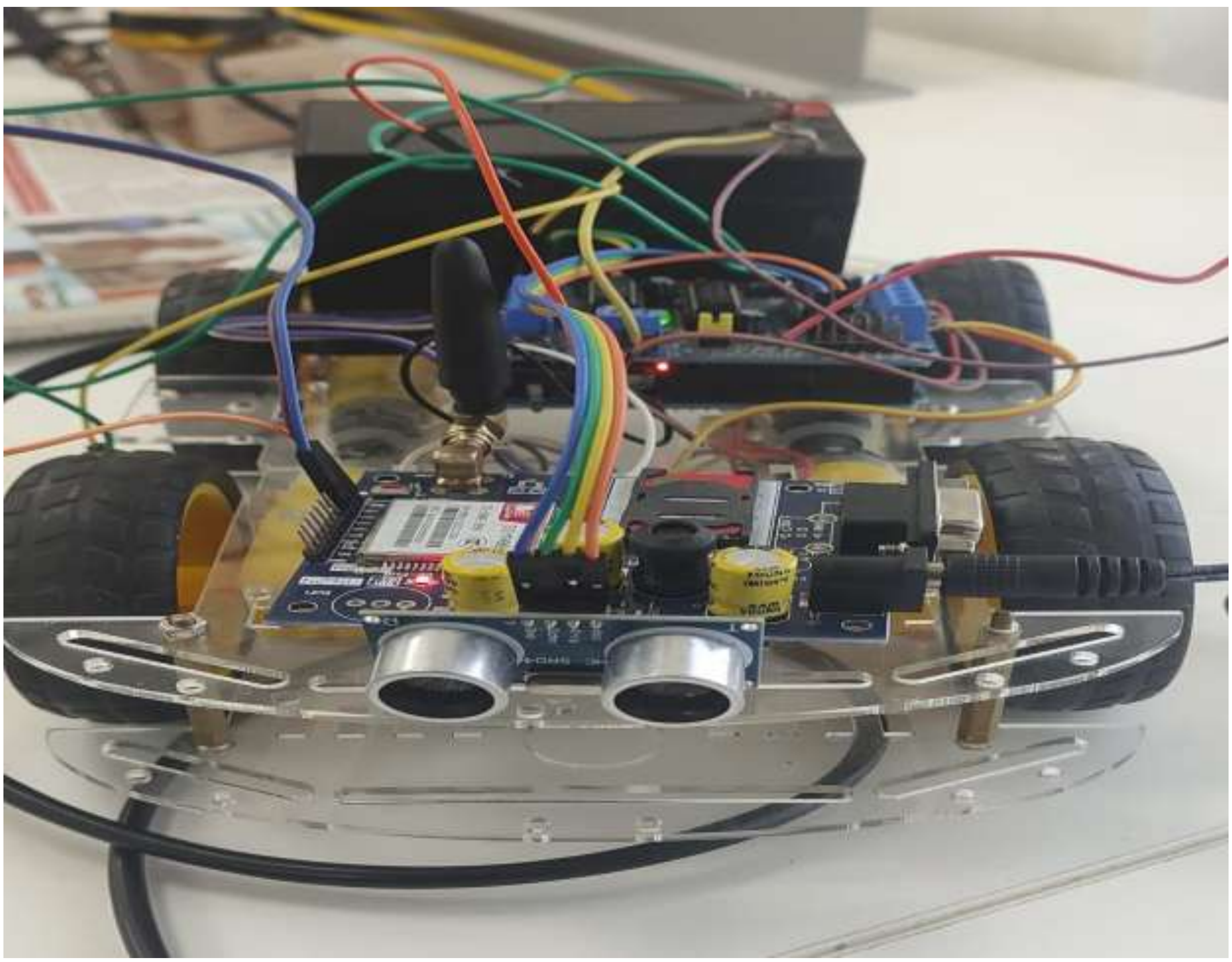


Fig: Robot



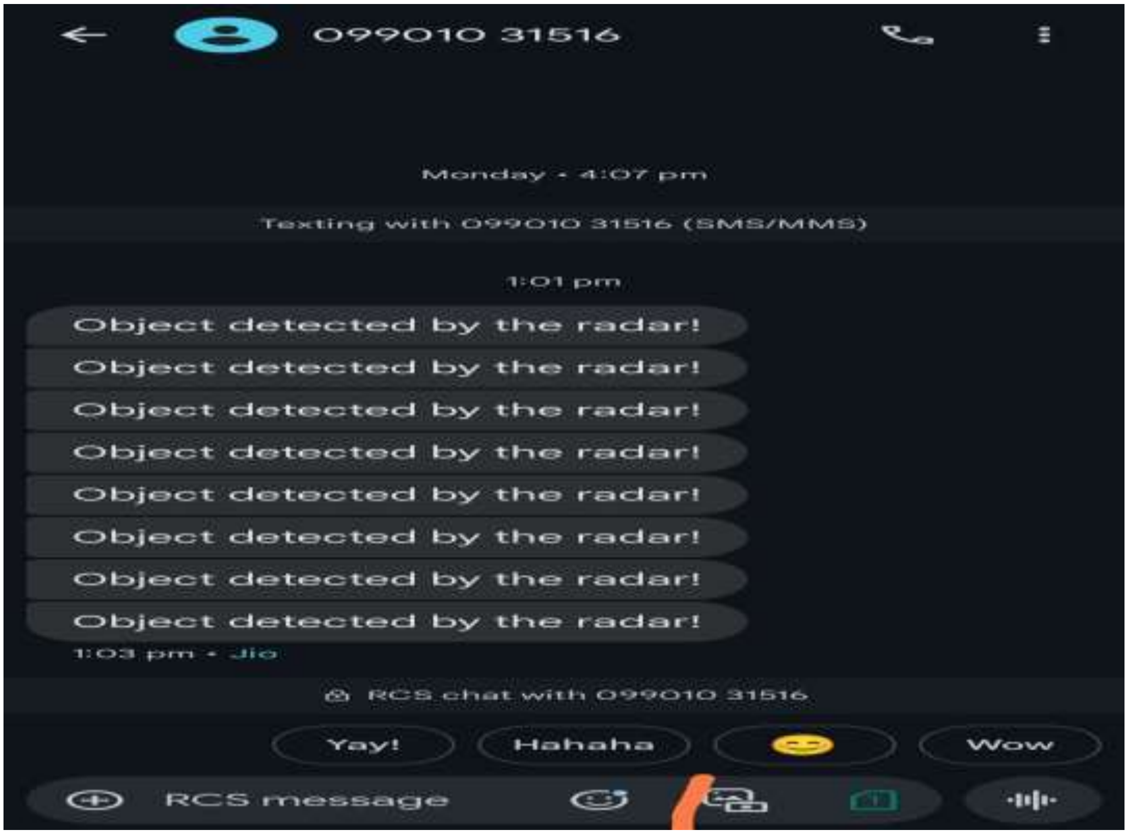


Fig: Output

Chapter 7: Conclusion

The project successfully established an autonomous robotic system to identify and pinpoint drainage blockages in urban settings. The capacity of the system to autonomously traverse drainage pipes, identify blockages, and relay real-time information renders it an invaluable resource to enhance urban drainage maintenance. The project points towards the prospect of integrating new-age technologies, like robotics and IoT, in urban infrastructure to deal with pertinent challenges like drainage blockages and urban flooding.

Chapter 8: Future Work

- **Development of a Mobile App:** Design a mobile app enabling maintenance crews and the general public to track drainage conditions in real-time.

- **Integration with Smart City Infrastructure:** Investigate the potential integration of the robotic system with large-scale smart city projects towards improved urban governance.

- **Improved Navigation Algorithms:** Enhance the robot's navigation in complicated and ruined drainage systems.

- **Waste Filtration System:** Design a system to remove solid waste from drainage systems to avoid clogging in the future.

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