# PROJECT REPORT
# On
# S.O.N.I.C
# (SMART OBSTACLE-NAVIGATION & INTELLIGENT CONTROL)

Robotics & Drone Lab [22MEC 37N]

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## ABSTRACT:

The advancement of automation necessitates intelligent systems for ensuring human safety in hazardous or inaccessible environments. This project introduces **S.O.N.I.C – Smart Obstacle-Navigation & Intelligent Control**, a highly practical and affordable voice-controlled rover designed for remote accident response. SONIC is engineered to explore dangerous regions and provide real-time situational awareness, thereby eliminating the risk to human life. The prototype integrates several core features: wireless control through voice commands for hands-free operation,  ultrasonic sensors for autonomous obstacle detection, and an MQ-2 gas/smoke sensor for early hazard alerts. By combining robust mobility with comprehensive environmental sensing, SONIC offers an effective, low-cost solution for disaster inspection and safety monitoring. The system's successful demonstration validates its use as a foundational tool for education, research, and improving emergency response capabilities.

## TABLE OF CONTENTS:

# CHAPTER 1 – INTRODUCTION

Ensuring safety in hazardous environments is a major challenge, especially when conditions such as gas leaks, smoke, or unstable structures make direct human entry unsafe. In such situations, using a robotic system to examine the surroundings from a distance can significantly reduce risk and improve decision-making. With advancements in embedded systems and sensor technology, it has become possible to design compact and intelligent robots capable of navigating difficult environments.

The project SONIC – Smart Obstacle-Navigation & Intelligent Control is developed to address this need. SONIC is a voice-controlled rover that can move through unknown or unsafe areas while detecting obstacles and sensing harmful gases or smoke. Instead of manual intervention, the rover responds to wireless voice commands, making the operation hands-free and convenient during emergencies.

By integrating obstacle detection, gas sensing, and intelligent control in a single platform, SONIC offers a reliable solution for remote inspection and safety monitoring. Its design focuses on user-friendly operation, quick response, and improved protection for individuals who would otherwise have to enter dangerous locations. This makes SONIC a valuable tool for enhancing safety and supporting effective emergency handling.

# CHAPTER 2 – LITERATURE REVIEW

Voice-controlled robots have gained importance in recent years due to their hands-free operation and ease of use. Studies show that Bluetooth and IoT-based voice interfaces make robotic movement more intuitive compared to traditional remote-controlled systems. Research on safety and navigation robots highlights the effectiveness of integrating sensors to assist in hazardous environment monitoring and decision-making.

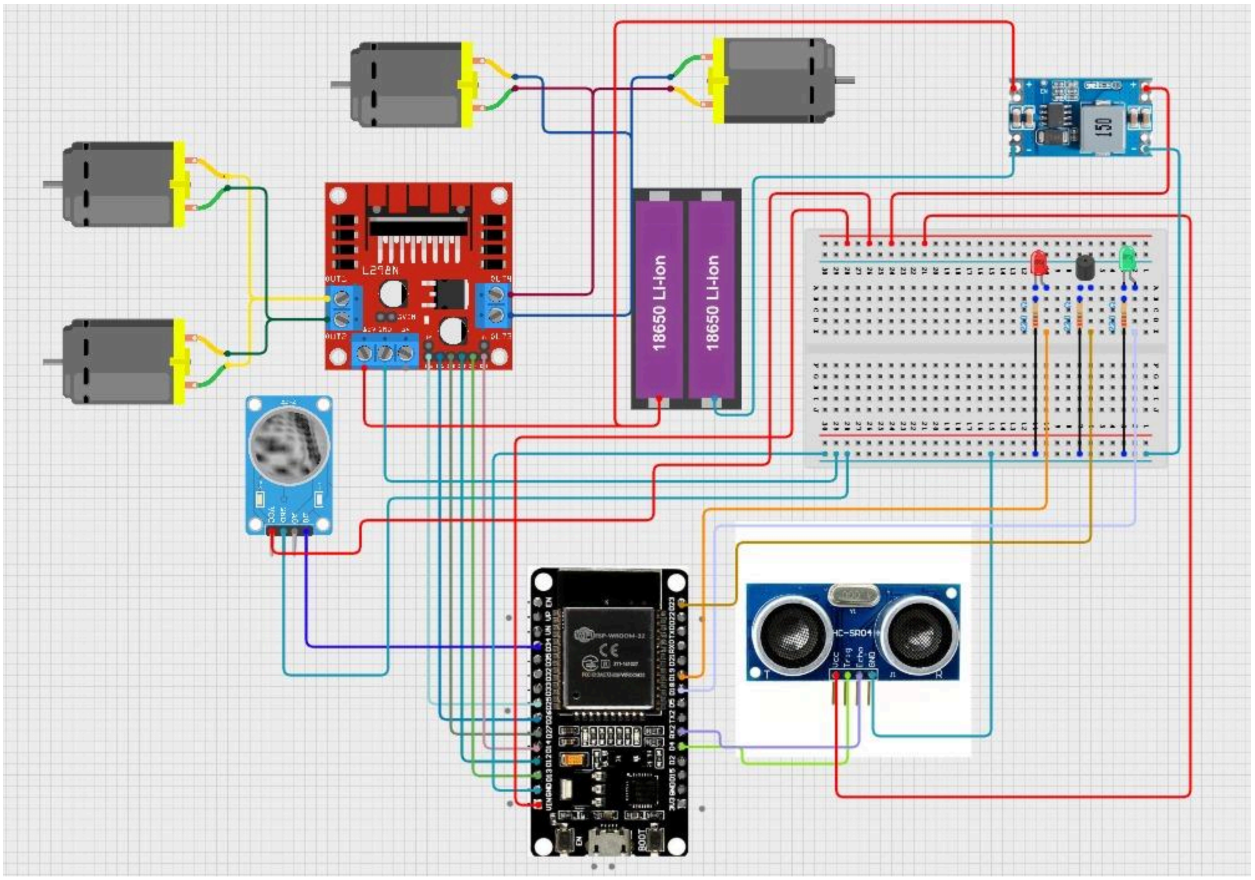
Previous works in gas-alert and fire-detection systems demonstrate the use of sensors as early warning mechanisms to identify harmful conditions, especially in industrial and confined spaces. Similarly, many obstacle-avoidance robots rely on ultrasonic sensors for reliable distance measurement and safe movement through unknown areas. Although these systems achieve specific objectives, several existing designs remain costly, complex, or limited in terms of multi-sensor integration.

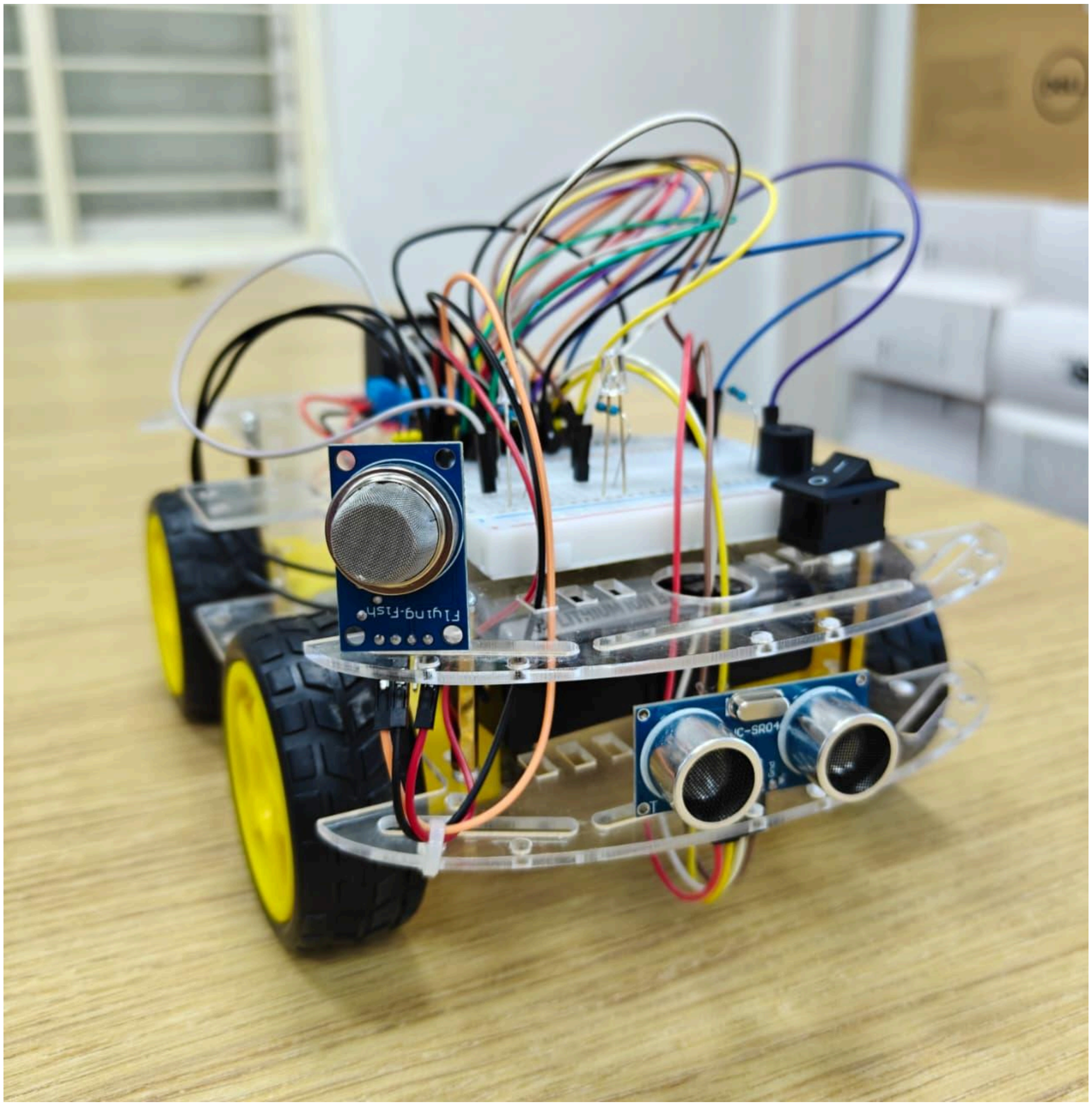
To address these gaps, the project **SONIC** focuses on creating a practical, cost-effective rover that combines essential features such as voice control, gas sensing, and obstacle detection into a single platform. This approach makes the system suitable for remote inspection and emergency response while remaining simple enough for academic and field applications.

# CHAPTER 3 – SYSTEM DESIGN & METHODOLOGY:

**S.O.N.I.C:Smart Obstacle Navigation & Intelligent Control**

## CIRCUIT DIAGRAM:




Flying-Fish
HC-SR04

**APPARATUS TABLE:**

| Component | Quantity |
|---|---|
| ESP32 Development Board (DOIT ESP32 DEVKIT V1) | 1 |
| DC geared motors | 4 |
| L298N Motor Driver | 1 |
| 18650 Li-ion battery | 2 |
| 5V Step-down buck converter | 1 |
| HC-SR04 Ultrasonic sensor | 1 |
| Gas sensor (MQ-2) | 1 |
| Breadboard | 1 |
| Buzzer | 1 |
| LED’s:<br>Green<br>Red | <br>1<br>1 |
| Jumper wires:<br>M-m<br>M-f<br>f-f | as required |
| Switch | 1 |

**ESP32 Development Board (DOIT ESP32 DEVKIT V1):**

The DOIT ESP32 DEVKIT V1 is a powerful, low-cost microcontroller board based on the ESP32 chip, featuring built-in Wi-Fi and Bluetooth for IoT projects. It has a fast dual-core processor, plenty of GPIO pins, and supports interfaces like ADC, DAC and PWM. The board works on 3.3V logic and can be programmed easily using the Arduino IDE, ESP-IDF, or MicroPython.

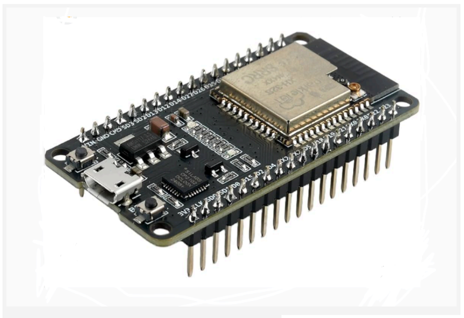


Fig 3.1

## DC Geared Motor:

A DC geared motor is a DC motor combined with a gearbox to reduce speed and increase torque. The motor itself rotates at high speed but with low usable force, so the attached gear system slows the output shaft while boosting its turning power. This makes DC geared motors ideal for applications that need controlled, powerful movement, such as robots, wheels, conveyor belts, and automated mechanisms. They run on DC supply, are simple to control, and provide stable, high-torque performance at lower speeds.

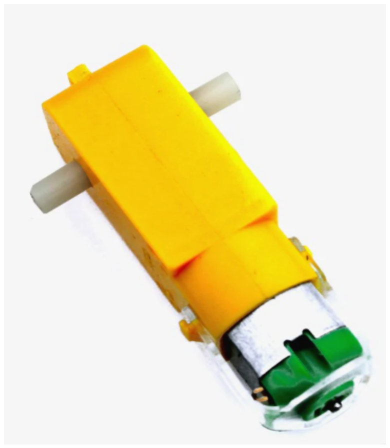
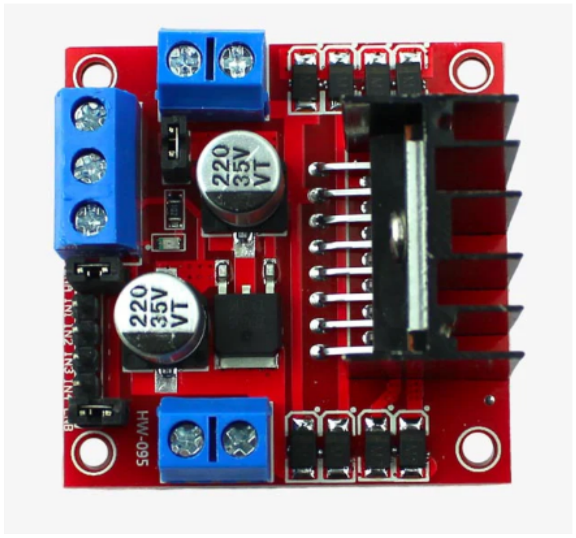


Fig 3.2

**L298N Motor driver:**

The L298N motor driver is a dual H-bridge module used to control the speed and direction of DC motors in robotics and automation projects. Microcontrollers like the ESP32 cannot directly power motors because motors require higher current, so the L298N acts as an interface by taking control signals from the microcontroller and supplying sufficient power to the motors. It can run two DC motors independently, allowing forward, reverse, and speed control using PWM signals. With its built-in heat sink, 5V regulator, and easy-to-use input pins (IN1–IN4, ENA/ENB), the L298N is one of the most commonly



used and reliable motor drivers in small robots and rovers.

Fig 3.3

## 18650 Li-ion battery:

A 18650 Li-ion battery is a rechargeable lithium-ion cell commonly used in power banks, laptops, flashlights, and DIY electronics. Its name comes from its size: 18 mm in diameter and 65 mm in length. These batteries typically provide 3.7V nominal voltage and capacities ranging from 2000 to 3500 mAh, offering high energy density in a compact size. They are lightweight, long-lasting, and capable of delivering high current, making them ideal for portable and high-power devices. However, they must be used with proper charging circuits and protection to prevent overcharging, deep discharging, or overheating.

Fig 3.4

## 5V Step-down buck converter:

A 5V step-down buck converter is an electronic power module that reduces a higher input voltage, such as 12V or 9V, down to a stable 5V output. It uses a switching regulator instead of linear regulation, making it much more efficient and generating less heat. These converters are commonly used in battery-powered projects, microcontroller boards, sensors, and other circuits that require a steady 5V supply. They allow devices to operate safely by providing a regulated voltage while minimising power loss.

Fig 3.5

## HC-SR04 Ultrasonic sensor:

The HC-SR04 ultrasonic sensor is a commonly used distance-measuring module that uses ultrasonic waves to detect how far an object is. It works by sending out a sound pulse from the trigger pin and then measuring the time it takes for the echo to return to the echo pin. Using this time, it calculates distance accurately, usually within 2 cm to 400 cm. It operates on 5V and is widely used in obstacle detection, robotics, automation, and level measurement because it is inexpensive, reliable, and easy to interface with Arduino, ESP32, and other microcontrollers.

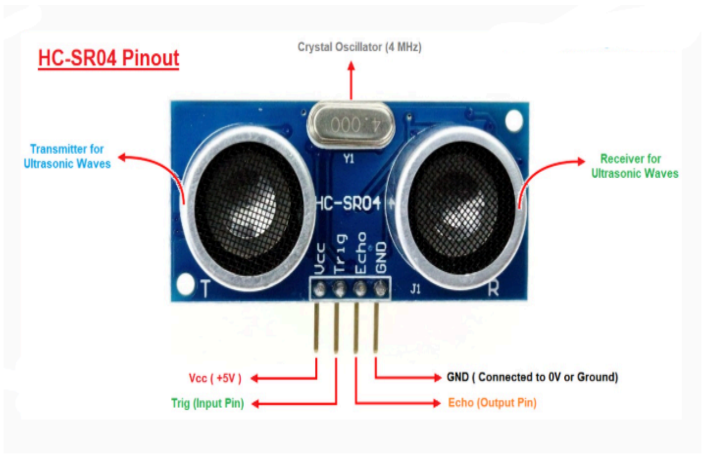

HC-SR04 Pinout
Crystal Oscillator (4 MHz)
Transmitter for Ultrasonic Waves
Receiver for Ultrasonic Waves
HC-SR04
Y1
Vcc
Trig
Echo
GND
T
J1
R
Vcc ( +5V )
Trig (Input Pin)
GND ( Connected to 0V or Ground)
Echo (Output Pin)

Fig 3.7

## Gas sensor(MQ-2):

The MQ-2 gas sensor is a low-cost, widely used sensor designed to detect gases like LPG, methane, propane, hydrogen, smoke, and alcohol vapours. It contains a sensitive material that changes resistance when exposed to these gases, allowing the sensor to output an analog signal proportional to gas concentration. Operated typically at 5V, the MQ-2 is commonly used in gas leak detectors, safety alarms, and home automation systems. Although not highly precise, it is reliable for general gas detection and easy to interface with microcontrollers such as Arduino or ESP32.

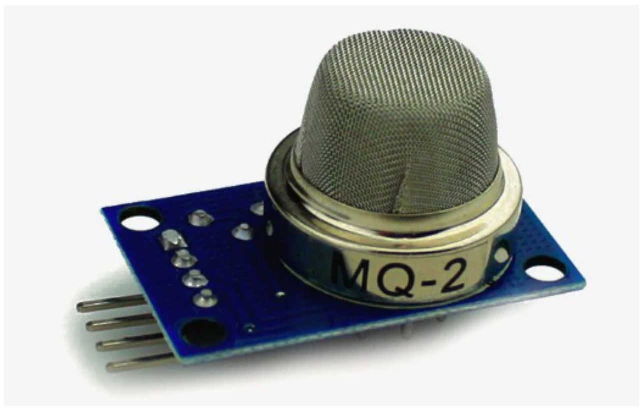


Fig 3.8

## Bread board:

A breadboard is a solderless prototyping board used to quickly assemble and test electronic circuits. It contains interconnected rows of holes that allow components and jumper wires to be inserted easily without permanent connections.

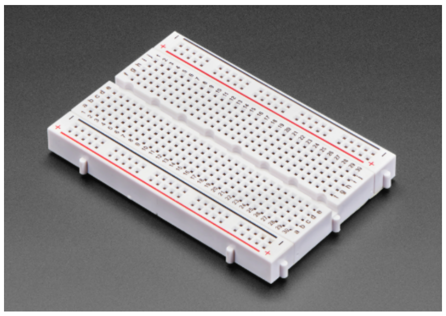


Fig 3.9

## Buzzer:

A buzzer is an electronic sound-producing device commonly used for alerts, warnings, and notifications in various circuits. It works by converting electrical energy into sound through the vibration of a small internal diaphragm

Fig 3.10

## LED’s:

A Light Emitting Diode (LED) is a small semiconductor device that produces light when an electric current passes through it. LEDs are widely used in electronic circuits because they are energy-efficient, long-lasting, and available in various colors. They serve as indicators to show power status, signal activity, or provide visual feedback in devices. LEDs require a current-limiting resistor to prevent damage, and their compact size and low power consumption make them ideal for use in embedded systems, displays, sensors, and lighting applications.

Fig 3.11

## Jumper wires:

Jumper wires are small connecting wires used to link components on a breadboard, development board, or other electronic circuit without soldering. They come in three main types—male-to-male, male-to-female, and female-to-female—allowing flexible connections between pins, sensors, modules, and microcontrollers. Jumper wires make prototyping fast and easy by providing temporary, reusable connections, and they are essential for assembling and testing circuits during project development.

Fig 3.12

## Switch:

A switch is an electrical component used to control the flow of current in a circuit. By opening or closing the circuit, a switch can turn a device or system on or off.

Fig 3.13

## PROCEDURE:

### Step 1: Requirement Analysis and Problem Definition

The first step involved identifying the need for a compact, low-cost rover capable of remote navigation and hazard detection in environments containing obstacles, smoke, or limited visibility. The finalized features were: voice-controlled movement, obstacle detection, gas detection with alerts, and Bluetooth-based manual control.

### Step 2: Selection of Components

Based on the requirements, the following hardware was selected:

1. ESP32 Dev Board for robot control and Bluetooth communication
2. L298N Motor Driver for driving the DC motors
3. HC-SR04 Ultrasonic Sensor for obstacle detection
4. MQ-2 Gas Sensor for smoke/gas detection
5. LEDs and Buzzer for visual and audio alerts
6. 12V battery system with a 5V buck converter for powering the ESP32 and sensors

## Step 3: Designing the Block Diagram and Power Layout

A block diagram was prepared showing interconnections between the ESP32, motor driver, ultrasonic sensor, gas sensor, buzzer, and LEDs.

1. The L298N received 12V directly from the battery.
2. The ESP32, ultrasonic sensor, MQ-2, LEDs, and buzzer received regulated 5V through the buck converter.
3. All components shared a common ground connection for stable operation.

## Step 4: Hardware Assembly and Wiring

All components were mounted on the 4-wheel chassis and connected as follows:

1. ESP32 → L298N for motor control (IN1–IN4 pins)
2. ESP32 → HC-SR04 trigger and echo pins
3. ESP32 → MQ-2 digital output pin
4. ESP32 → LEDs and buzzer for alert indication
5. Buck converter → 5V to ESP32 and sensors
6. All grounds connected to a common ground rail

## Step 5: Stage-wise Testing of Each Module

1. Each module was tested individually before integration:
2. Motor driver test (forward, reverse, left, right, stop)
3. Ultrasonic sensor distance reading verification
4. MQ-2 gas detection threshold testing
5. LED and buzzer alert functionality
6. Bluetooth test using MIT App Inventor for manual commands
   Any wiring or logic errors were corrected during this stage.

## Step 6: Integration of Control Logic (Coding)

The main ESP32 program was developed by combining sensor inputs and motor control. The code included:

1. Motor control functions for forward, backward, left, right, and stop
2. Ultrasonic distance measurement for autonomous obstacle detection
3. MQ-2 gas alert logic using LEDs and buzzer
4. Bluetooth command handling (‘F’, ‘B’, ‘L’, ‘R’, ‘S’)
5. Mode switching between Manual (‘M’) and Autonomous (‘A’)
6. Safety protocols ensuring the rover stops when gas is detected or obstacles are too close

**Sketch.ino:**

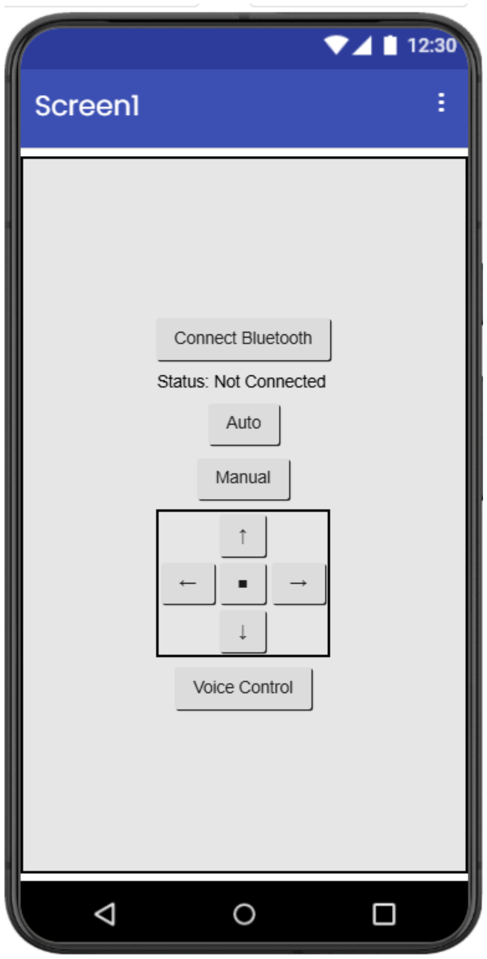
```
#include <BluetoothSerial.h>
BluetoothSerial SerialBT;

// === Pin Definitions === //
#define TRIG 5          // Ultrasonic sensor trigger pin
#define ECHO 18         // Ultrasonic sensor echo pin
#define GAS_AO 34       // MQ-2 gas sensor analog output

#define BUZZER 19       // Buzzer pin
#define LED_RED 22      // Red LED for alerts
#define LED_GREEN 23    // Green LED for normal status

#define IN1 27          // Motor driver input 1
#define IN2 26          // Motor driver input 2
#define IN3 25          // Motor driver input 3
#define IN4 33          // Motor driver input 4

#define ENA 13          // Motor A enable (PWM)
#define ENB 12          // Motor B enable (PWM)

long duration;
int distance;
int gasDetected;

bool autonomous = false;   // Mode flag: false = Manual, true = Autonomous

const int ALARM_THRESHOLD = 500;  // Gas sensor threshold
int Speed = 200;                  // Motor speed (0-255)

// ---- Function Prototypes ---- //
void moveForward();
void moveBackward();
void turnLeft();
void turnRight();
void stopRobot();
void autonomousDrive();

void setup(){
  Serial.begin(115200);
  SerialBT.begin("SONICbtl");  // Bluetooth device name

  pinMode(TRIG, OUTPUT);
  pinMode(ECHO, INPUT);
  pinMode(BUZZER, OUTPUT);
  pinMode(LED_RED, OUTPUT);
  pinMode(LED_GREEN, OUTPUT);

  pinMode(IN1, OUTPUT);
  pinMode(IN2, OUTPUT);
  pinMode(IN3, OUTPUT);
  pinMode(IN4, OUTPUT);

  // Set initial motor speed
  analogWrite(ENA, Speed);
  analogWrite(ENB, Speed);

  Serial.println("Accident Rover Online");
}

void loop(){
  delay(50);

  // ----- Gas Sensor Monitoring -----
  gasDetected = analogRead(GAS_AO);

  if(gasDetected >= ALARM_THRESHOLD){
    stopRobot();                     // Stop movement
    digitalWrite(LED_RED, HIGH);     // Alert indicator
    digitalWrite(LED_GREEN, LOW);
    tone(BUZZER, 2000);              // Activate buzzer
    delay(200);
    return;                          // Skip remaining code
  }
  else {
    digitalWrite(LED_RED, LOW);
    digitalWrite(LED_GREEN, HIGH);
    noTone(BUZZER);
  }

  // ----- Bluetooth Manual Control -----
  if(SerialBT.available()){
    char c = SerialBT.read();

    if(c == 'M'){                    // Switch to manual mode
      autonomous = false;
      stopRobot();
    }
    if(c == 'A'){                        // Switch to autonomous mode
      autonomous = true;
    }

    // Manual driving commands
    if(!autonomous){
      if(c == 'F') moveForward();
      if(c == 'B') moveBackward();
      if(c == 'L') turnLeft();
      if(c == 'R') turnRight();
      if(c == 'S') stopRobot();
    }
  }

  // ----- Autonomous Driving -----
  if(autonomous) autonomousDrive();
}

// =================== AUTONOMOUS AVOIDANCE =================== //
void autonomousDrive(){
  // Trigger ultrasonic pulse
  digitalWrite(TRIG, LOW);
  delayMicroseconds(2);
  digitalWrite(TRIG, HIGH);
  delayMicroseconds(10);
  digitalWrite(TRIG, LOW);

  // Measure echo time
  duration = pulseIn(ECHO, HIGH);
  distance = duration * 0.034 / 2;    // Convert to centimeters

  // Obstacle handling
  if(distance < 20){
    stopRobot();
    delay(200);
    moveBackward();
    delay(500);
    turnRight();
    delay(700);
    stopRobot();
    delay(100);
  }
  else {
    moveForward();
    digitalWrite(LED_GREEN, HIGH);
    digitalWrite(LED_RED, LOW);
    noTone(BUZZER);
  }
}

// ==================== MOTOR CONTROLS ======================= //
void moveForward(){
  digitalWrite(IN1, HIGH);
  digitalWrite(IN2, LOW);
  digitalWrite(IN3, HIGH);
  digitalWrite(IN4, LOW);
}

void moveBackward(){
  digitalWrite(IN1, LOW);
  digitalWrite(IN2, HIGH);
  digitalWrite(IN3, LOW);
  digitalWrite(IN4, HIGH);
}

void turnLeft(){
  digitalWrite(IN1, LOW);
  digitalWrite(IN2, HIGH);
  digitalWrite(IN3, HIGH);
  digitalWrite(IN4, LOW);
}

void turnRight(){
  digitalWrite(IN1, HIGH);
  digitalWrite(IN2, LOW);
  digitalWrite(IN3, LOW);
  digitalWrite(IN4, HIGH);
}

void stopRobot(){
  digitalWrite(IN1, LOW);
  digitalWrite(IN2, LOW);
  digitalWrite(IN3, LOW);
  digitalWrite(IN4, LOW);
```

```
}
```

**Step 7: Mobile App Interface (MIT App Inventor):**

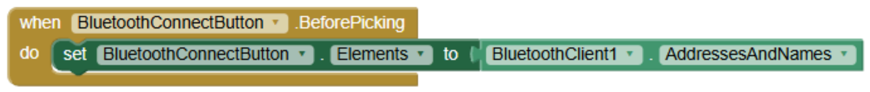
A custom mobile application was designed in MIT App Inventor to control the rover via Bluetooth. The interface included manual control buttons for forward, backward, left, right, and stop, along with a toggle for Manual/Auto modes and a voice-control option using the SpeechRecognizer component.

Bluetooth connectivity was implemented using the BluetoothClient module.
The app scans for nearby devices, detects the ESP32 (named “SONICbtl”), and establishes a connection. Once connected, the app sends single-character control commands (‘F’, ‘B’, ‘L’, ‘R’, ‘S’, ‘A’, ‘M’) to the ESP32 over Bluetooth.
These commands are received by the microcontroller in real-time and directly trigger the respective movement or mode changes.

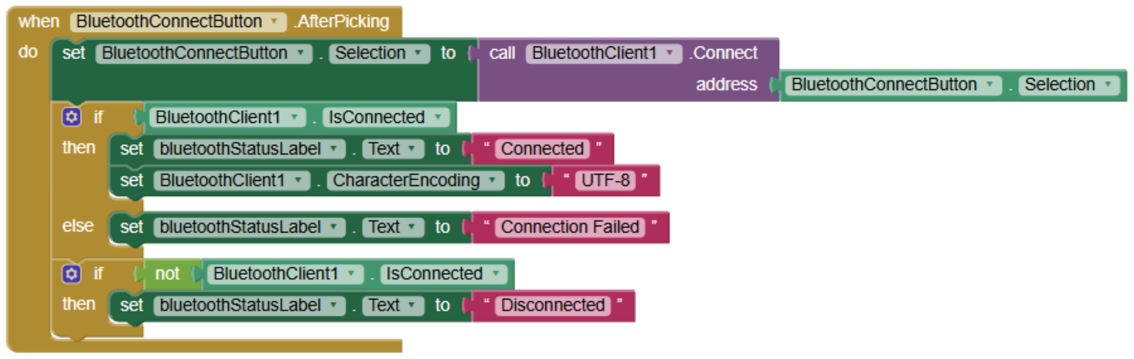


**Code Blocks in MIT App Inventer:**

**Bluetooth Connection:**

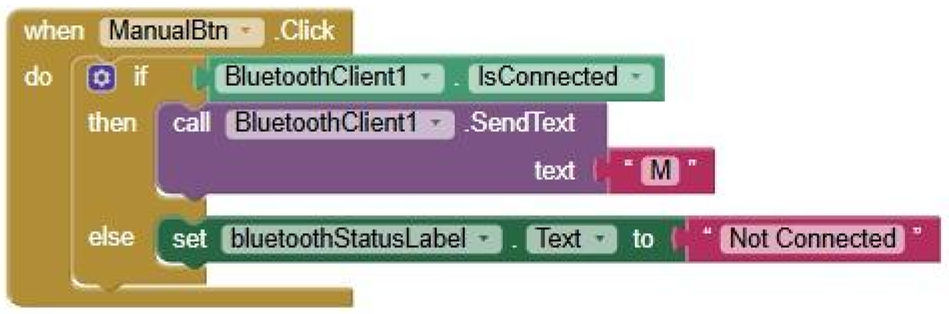


```
when BluetoothConnectButton .BeforePicking
do  set BluetoothConnectButton . Elements to BluetoothClient1 . AddressesAndNames
```

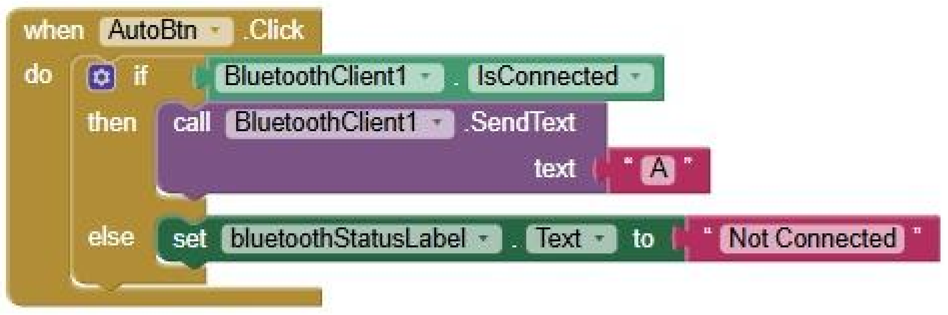


```
when BluetoothConnectButton .AfterPicking
do  set BluetoothConnectButton . Selection to call BluetoothClient1 .Connect
                                                          address BluetoothConnectButton . Selection
    if BluetoothClient1 . IsConnected
    then set bluetoothStatusLabel . Text to " Connected "
         set BluetoothClient1 . CharacterEncoding to " UTF-8 "
    else set bluetoothStatusLabel . Text to " Connection Failed "
    if not BluetoothClient1 . IsConnected
    then set bluetoothStatusLabel . Text to " Disconnected "
```

**Auto/Manual Modes:**

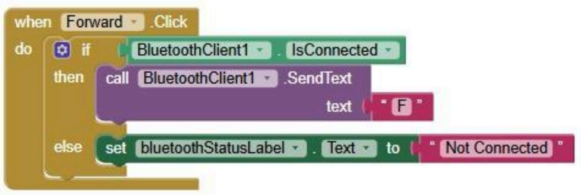


```
when ManualBtn .Click
do  if BluetoothClient1 . IsConnected
    then call BluetoothClient1 .SendText
                              text " M "
    else set bluetoothStatusLabel . Text to " Not Connected "
```

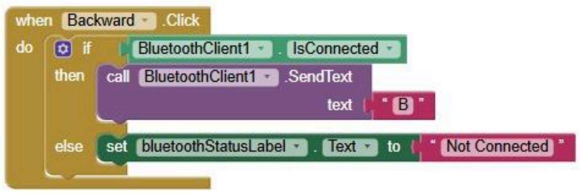


```
when AutoBtn .Click
do  if BluetoothClient1 . IsConnected
    then call BluetoothClient1 .SendText
                              text " A "
    else set bluetoothStatusLabel . Text to " Not Connected "
```

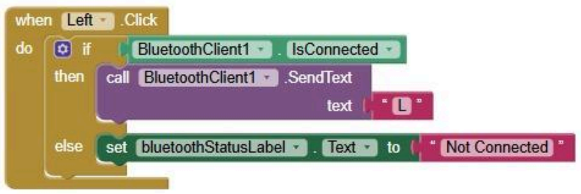
## Movement Controls:



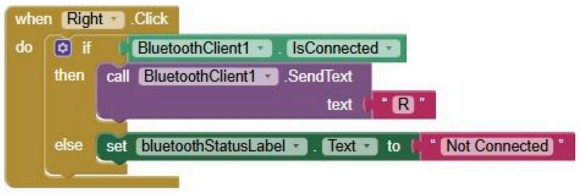
```
when Forward .Click
do  if BluetoothClient1 . IsConnected
    then call BluetoothClient1 .SendText
                              text " F "
    else set bluetoothStatusLabel . Text to " Not Connected "
```



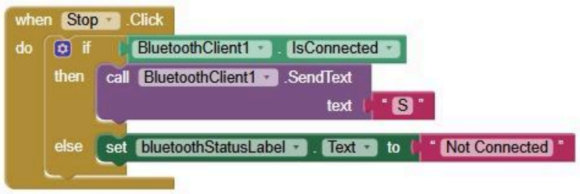
```
when Backward .Click
do  if BluetoothClient1 . IsConnected
    then call BluetoothClient1 .SendText
                              text " B "
    else set bluetoothStatusLabel . Text to " Not Connected "
```



```
when Left .Click
do  if BluetoothClient1 . IsConnected
    then call BluetoothClient1 .SendText
                              text " L "
    else set bluetoothStatusLabel . Text to " Not Connected "
```

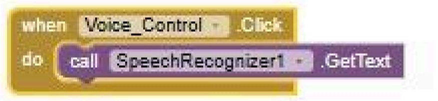


```
when Right .Click
do  if BluetoothClient1 . IsConnected
    then call BluetoothClient1 .SendText
                              text " R "
    else set bluetoothStatusLabel . Text to " Not Connected "
```

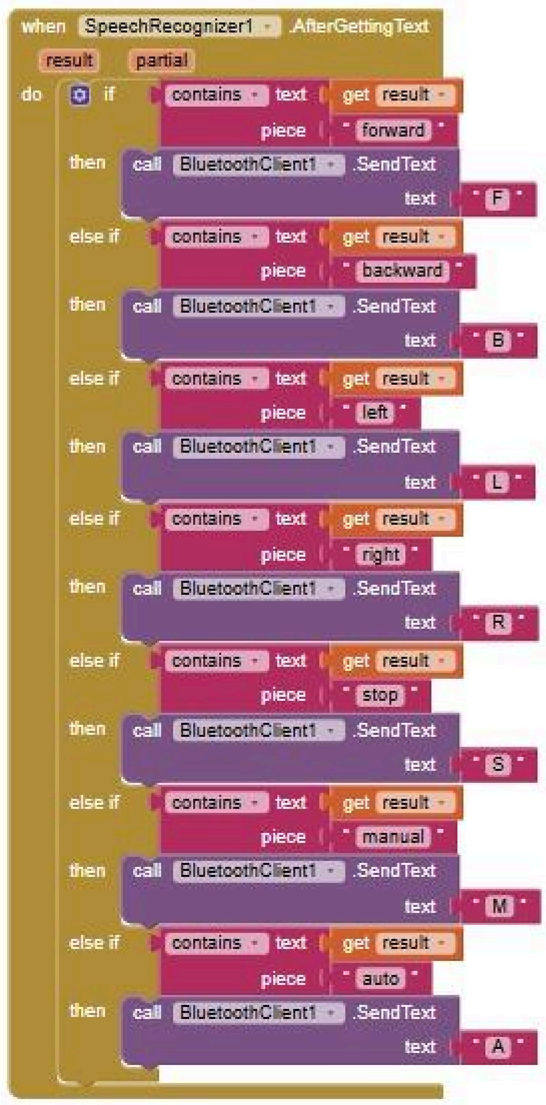


```
when Stop .Click
do  if BluetoothClient1 . IsConnected
    then call BluetoothClient1 .SendText
                              text " S "
    else set bluetoothStatusLabel . Text to " Not Connected "
```

## Voice Control:



```
when Voice_Control .Click
do  call SpeechRecognizer1 .GetText
```



```
when SpeechRecognizer1 .AfterGettingText
  result   partial
do  if       contains text  get result
                      piece " forward "
    then     call BluetoothClient1 .SendText
                                   text " F "
    else if  contains text  get result
                      piece " backward "
    then     call BluetoothClient1 .SendText
                                   text " B "
    else if  contains text  get result
                      piece " left "
    then     call BluetoothClient1 .SendText
                                   text " L "
    else if  contains text  get result
                      piece " right "
    then     call BluetoothClient1 .SendText
                                   text " R "
    else if  contains text  get result
                      piece " stop "
    then     call BluetoothClient1 .SendText
                                   text " S "
    else if  contains text  get result
                      piece " manual "
    then     call BluetoothClient1 .SendText
                                   text " M "
    else if  contains text  get result
                      piece " auto "
    then     call BluetoothClient1 .SendText
                                   text " A "
```

## Step 8: System Integration and Final Testing

1. All modules were integrated, and the rover was fully operated through Bluetooth with both manual and voice commands.
   Testing included:
2. Navigation accuracy
3. Response delay over Bluetooth
4. Obstacle avoidance performance using the ultrasonic sensor
5. Gas detection and alert triggering using MQ-2

Any bugs were fixed, and the control parameters were fine-tuned for smoother operation.

## Step 9: Final Deployment and Demonstration

1. The completed rover was demonstrated in a simulated accident-site scenario.
2. It successfully performed:
3. Voice-controlled navigation
4. Obstacle detection and automatic stopping
5. Gas leak detection with buzzer alerts
6. Real-time video transmission
7. This validated the functionality and usefulness of the proposed system.

**PRECAUTIONS:**

1. Ensure all electrical connections are tight and properly insulated.

2. Use the correct power supply voltage for motors, sensors, and the controller.

3. Avoid touching hot components, such as the MQ-2 smoke sensor, during operation.

4. Test the rover in an open space to prevent accidental collisions.

5. Keep the camera lens clean and avoid exposing it to direct harsh light.

6. Do not operate the rover with damaged or swollen batteries.

7. Keep flammable materials away while testing the smoke detection.

8. Calibrate all sensors before final operation to ensure accurate readings

# CHAPTER 4 – RESULTS & DISCUSSION

The prototype performed effectively in real-time navigation and monitoring. The rover responded accurately to Bluetooth-based manual controls and voice commands such as “forward,” “back,” “left,” “right,” and “stop” through the MIT App Inventor interface. The ESP32-CAM provided a clear live video feed over Wi-Fi, allowing the user to visually monitor the rover’s surroundings.

The ultrasonic sensor worked reliably, stopping the rover whenever an obstacle was detected at close range, which ensured safe movement in both manual and semi-automatic modes. The MQ-2 gas sensor also responded correctly by identifying the presence of gas and activating the buzzer and LED alerts.

Overall, the combination of Bluetooth control, voice input, and onboard safety sensors proved stable and practical. The system demonstrated potential for accident response, indoor inspection, and basic surveillance tasks, making it a low-cost and versatile solution.

# CHAPTER 5 – CONCLUSION

The SONIC rover effectively integrates robotics, wireless communication, and environmental safety into a practical project suitable for real-world applications. The prototype demonstrates that even with limited resources, intelligent robots can be built to reduce risks to human life during hazardous incidents. Future improvements may include GPS tracking, thermal imaging, night vision, or autonomous mapping. The project contributes to accessible engineering solutions by providing a foundation for future research and innovation in safety-oriented robotics.

## References:

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