RESEARCH PROJECT REPORT

ON

"Obstacles Detection System Using Radar Sensor and Ultrasonic Sensor"

SUBMITTED TO

Fergusson College (Autonomous)

FOR THE DEGREE OF

M.Sc.
(ELECTRONIC SCIENCE)

BY

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Chapter 1: Introduction

1.1 Importance of Project:

In today's fast-paced world, automation and smart sensing technologies play a crucial role in enhancing safety and efficiency. Obstacle detection systems are fundamental in applications such as autonomous vehicles, robotics, industrial automation, and assistive technology for the visually impaired. These systems help prevent collisions and improve situational awareness by accurately identifying objects in their environment. The integration of the HB100 radar sensor, ESP32 microcontroller, and ultrasonic sensors offers a cost-effective, reliable, and flexible solution for obstacle detection across various domains.

1.2 Problem Definition:

Traditional obstacle detection systems often suffer from limitations like poor accuracy in diverse environmental conditions, high power consumption, or high cost. Infrared-based systems, for example, can be affected by ambient light, while camera-based systems require complex image processing. The purpose of this project is to design and implement a robust and efficient obstacle detection system that overcomes these challenges by combining microwave and ultrasonic sensing with a versatile ESP32 controller.

1.3 Aim and Objectives:

Aim: To design and implement a real-time obstacle detection system for railway tracks using the HB100 Doppler radar sensor and ESP32 microcontroller, in order to enhance train safety by detecting motion-based obstacles in the path of a train.

Objectives:

I. To interface the HB100 microwave Doppler radar sensor with the ESP32 microcontroller.

II. To develop a signal processing circuit for amplifying and filtering the HB100 sensor's analog output.

III. To detect moving obstacles (e.g., humans, animals, vehicles) on or near the railway track using radar-based motion sensing.

Chapter2: Fundamental of Project

2.1 Literature Survey:

1. Automatic Motion Detection and Distance Measurement Using Doppler Radar

- **Published in**: International Journal of Emerging Trends in Engineering Research (IJETER), July 2023.
- **Authors**: G. Viswanath, A. Mounika, P. Naga Lakshmi, E. Ramesh.
- **Summary**: This paper presents a system that utilizes the HB100 Doppler radar sensor and an Arduino microcontroller to detect motion, measure velocity, and calculate the distance of an object. The system analyzes the frequency shift of the reflected signal to determine the speed and direction of the object. Applications include security systems, traffic monitoring, and industrial automation.

2. Design and Analysis of Doppler Radar-Based Vehicle Speed Detection

- **Published in**: International Journal of Scientific & Technology Research (IJSTR), June 2016.
- **Authors**: Yi Mon.
- **Summary**: This study focuses on designing a vehicle speed detection system using the HB100 Doppler radar sensor. The system employs an amplification circuit and a microcontroller to process the radar's output, calculate the frequency shift, and display the vehicle's speed on an LCD. The design emphasizes the use of an LM324 op-amp for amplification and a PIC16F887 microcontroller for processing.

3. Vehicle Safety Enhancement with Doppler Radar System

- **Institution**: Tunku Abdul Rahman University College, Malaysia.
- **Author**: Lim Cui Yuan.
- **Summary**: This project aims to enhance vehicle safety by integrating a Doppler radar system using the HB100 sensor with an Arduino Mega. The system estimates the speed and distance of approaching vehicles by analyzing the frequency shift of the received signal. Simulations in MATLAB were conducted to model the radar system's performance, achieving accuracies of 95.5% and 94.4% for vehicle and pedestrian detection, respectively.

4. Using the HB100 Microwave Doppler Radar to Detect Speed

- **Platform**: UrukTech.
- **Overview**: This practical guide demonstrates how to use the HB100 radar sensor to detect the speed of moving objects. It provides insights into the sensor's internal structure, signal processing techniques, and the formula to calculate speed based on the Doppler frequency shift. The guide also discusses the use of frequency measurement libraries to interface with microcontrollers for real-time speed detection.

2.2 Basic Theory:

1. ESP32:

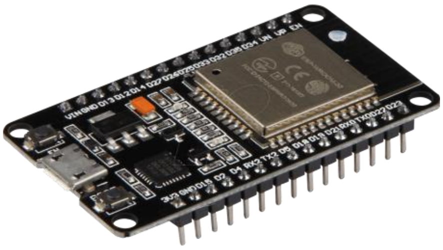


Fig 2.1:ESP32 Microcontroller

This is ESP WROOM 32 MCU Module. ESP WROOM 32 is a powerful, generic WiFi-BT-BLE MCU module that targets a wide variety of applications, ranging from low-power sensor networks to the most demanding tasks, such as voice encoding, music streaming, and MP3 decoding. it is a powerful and versatile microcontroller developed by Espressif Systems, widely used in the core of this module is the ESP32s chip, which is designed to be scalable and adaptive. ESP-WROOM-32 development board containing Tensilica Xtensa Dual-Core 32-bit LX6 microprocessor operates at 80 to 240 MHz adjustable clock frequency. It comes with 448 KB of ROM, 520 KB of on-chip SRAM, and 4MB of Flash Memory. The ESP32-WROOM is a versatile and powerful microcontroller module that combines Wi-Fi, Bluetooth, and extensive peripheral support, making it ideal for IoT, automation, and embedded systems. Its low power consumption and security features make it a preferred choice for developers worldwide.

2. HB100 Radar Sensor:

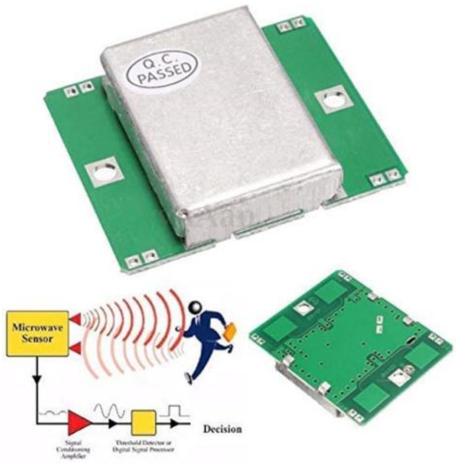


Fig2.2HB100Radar Sensor

The HB100 is a X-Band Bi-Static Doppler transceiver module, also known as a microwave Doppler radar, that utilizes the Doppler principle to detect motion. It operates at a frequency of 10.525 GHz and is designed for applications like motion detection, alarms, and automatic door control. HB100 transmits continuous microwave signals at 10.525 GHz. When these waves hit a moving object, they are reflected back with a frequency shift (Doppler Shift). The module mixes the transmitted and received signals to generate an IF (Intermediate Frequency) signal that represents the speed and direction of the moving object. This signal can be processed using an op-amp or directly by a microcontroller (if strong enough) to detect motion.

<u>Specifications:</u>

- Operating Frequency: **10.525 GHz (X-Band).**
- Detection Range: **Up to 20 meters.**
- Power Output: **Minimum 13 dBm EIRP.**
- Operating Voltage: **Typically 5V.**
- Current Consumption: **Low current consumption, typically 30mA.**
- Doppler Principle: **The module emits microwaves and detects the frequency shift of reflected signals caused by moving objects.**
- Applications: **Motion detection, alarms, lighting control, automatic doors, vehicle speed measurement.**

3. Ultrasonic Sensor:

Fig2.3 Ultrasonic Sensor

An ultrasonic sensor is an electronic device that measures the distance to an object by using ultrasonic sound waves. It is widely used in robotics, automation, and obstacle detection systems due to its simplicity and effectiveness at short ranges. Ultrasonic sensors operate on the principle of echolocation, similar to how bats navigate. The sensor has two main components:

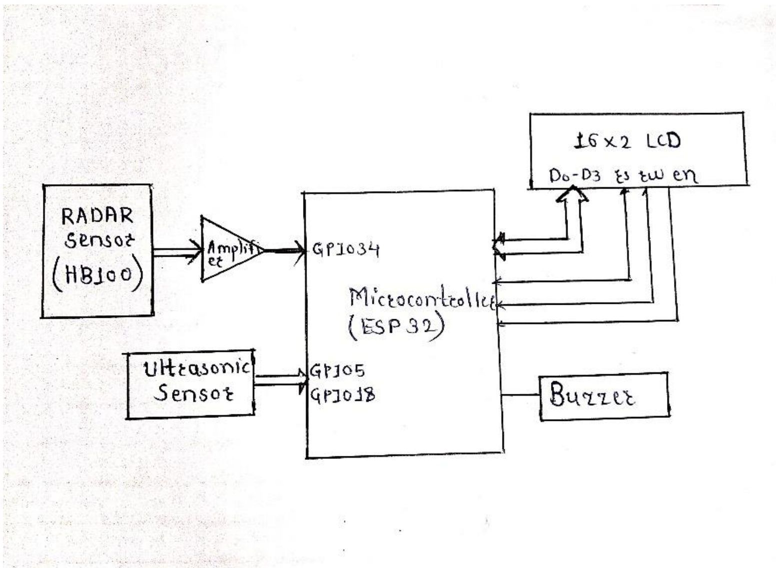
1. Transmitter (Trigger): Emits a burst of ultrasonic sound waves at a frequency typically around 40 kHz.
2. Receiver (Echo): Detects the reflected wave after it bounces off an object.

Chapter 3: Project Proposal

3.1 System Specification:

- Microcontroller: ESP32 (dual-core, Wi-Fi/Bluetooth-enabled, 3.3V logic)
- Radar Sensor: HB100 Microwave Doppler Radar Module (10.525 GHz)
- Ultrasonic Sensor: HC-SR04
- Power Supply: 5V DC regulated
- Output: Obstacle detection indication via serial monitor
- Programming Interface: Arduino IDE
- Display : Serial Monitor

3.2 System Block Diagram:



The block diagram illustrates the structure of the Obstacle Detection System using HB100 Radar Sensor, ESP32 Microcontroller, and Ultrasonic Sensor.

HB100 Radar Sensor: This module detects motion using the Doppler effect. The analog signal output is first passed through an amplifier circuit to strengthen the weak signal for processing.

Amplifier Output is connected to GPIO34 of the ESP32 microcontroller, which reads the signal to detect moving obstacles.

Ultrasonic Sensor (HC-SR04) is connected to GPIO5 (Trigger) and GPIO18 (Echo) pins of the ESP32. It measures distance by sending and receiving ultrasonic waves.

The ESP32 Microcontroller processes input signals from both sensors to determine the presence and distance of obstacles.

A 16x2 LCD Display is interfaced with the ESP32 using digital I/O pins (D0–D3, RS, RW, EN) to show real-time data such as distance and motion detection status.

A 16x2 LCD Display is interfaced with the ESP32 using digital I/O pins (D0–D3, RS, RW, EN) to show real-time data such as distance and motion detection status.

A buzzer is also connected to the ESP32 to provide an audio alert when an obstacle is detected within a predefined range.

3.3 Method of Implementation:

1. Sensor Integration: The HB100 radar module and ultrasonic sensor are interfaced with the ESP32 using digital/analog I/O pins. The ESP32 reads the Doppler shift from HB100 for motion detection and distance data from the ultrasonic sensor.

2. Output Triggering: Based on predefined conditions (e.g., distance < 20 cm or motion detected), an output device such as an buzzer is triggered to indicate an obstacle.

3. Testing and Calibration: The system undergoes multiple iterations of testing under different lighting, distance, and object speed conditions to fine-tune detection accuracy.

3.4 Task Vs Time Schedule:

Serial no.	**Task Description**	**Duration**
1.	Literature Review and Component Research	1 Week
2.	Sensor Interfacing with ESP32	1Week
3.	Coding and Debugging(Arduino IDE)	1Week
4.	Output Module Implementation	1Week
5.	Testing Calibration, and Result Analysis	2Weeks
6.	Report Writing	3Days

Chapter4. Planning Resources

4.1 Hardware:

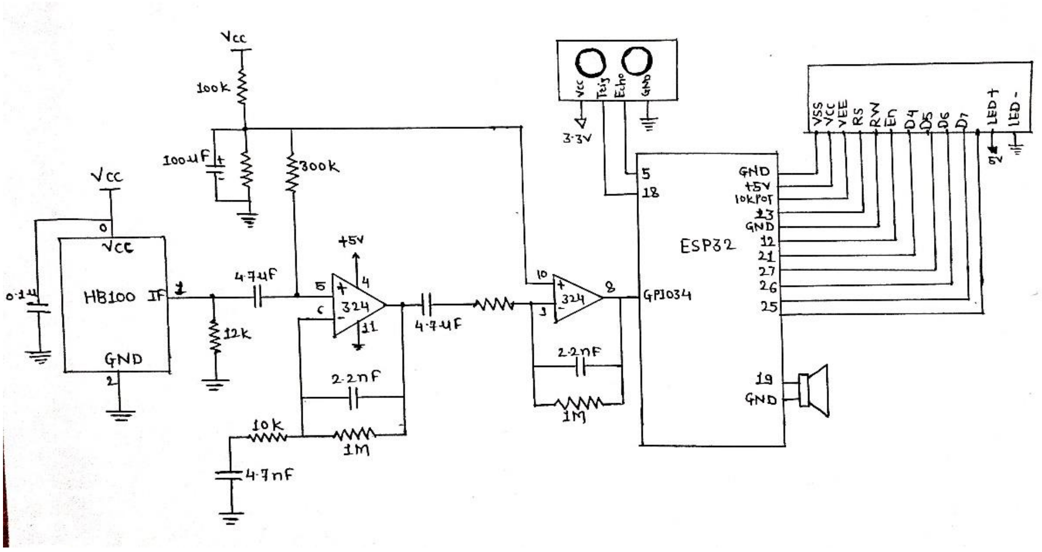


Fig 4.1: Circuit Diagram

This is a circuit diagram for an Obstacle Detection System using:

Main Components:

1. HB100 Microwave Motion Sensor
2. Ultrasonic Sensor (HC-SR04)
3. Operational Amplifier (LM324)
4. ESP32 Microcontroller
5. LCD Display

1. HB100 Radar Module:

Pin 1 (Vcc) and Pin 2 (GND) power the module.IF output (Pin 3) sends a low-frequency signal based on detected motion.

The signal passes through a high-pass filter (capacitor + resistor network) to remove DC offset.

2. Signal Conditioning (Op-Amp LM324):

Two op-amps from LM324 are used here.

The signal is amplified and filtered using RC and capacitor networks.
The first stage amplifies the raw signal.
The second stage (also with LPF network) further processes the output.

3. Ultrasonic Sensor (HC-SR04):
Powered with 3.3V from ESP32.
Trigger and Echo pins are connected to ESP32 GPIO pins for distance measurement.

4. ESP32 Microcontroller:
Takes inputs from:
Ultrasonic sensor (Trig/Echo)
Processed radar signal from op-amp
Controls:
LCD Display (via 4-bit mode)
Buzzer (through GPIO pin 19)

6. Buzzer Output:
Connected to GPIO19 of ESP32.
Used for alerting when an obstacle is detected.

Working:

1. Power ON the system using a regulated 5V DC source.
2. The ESP32 initializes and begins reading inputs from both sensors.
3. The Ultrasonic Sensor sends a sound pulse and measures the time taken for the echo to return, calculating the distance to an obstacle.
4. The HB100 Radar Sensor, through the amplifier, detects motion and sends signals indicating object movement.
5. The ESP32 processes both inputs. If an object is detected within a certain range (e.g., < 20 cm), or if motion is detected, the buzzer is activated, and relevant data is shown on the LCD display.
6. This continuous loop allows real-time monitoring of nearby obstacles.

4.2 Software:

```
#define HB100_PIN 34
#define MIN_THRESHOLD 2
#define MAX_THRESHOLD 200
#define SAMPLES_COUNT 8
#define DETECTION_COUNT 2
#define RESET_COUNT 8

const float VOLTAGE_CONVERSION = 3.3 / 4095.0;

// Ultrasonic Sensor Setup
#define TRIG_PIN 5
#define ECHO_PIN 18
#define BUZZER_PIN 19

// Variables
int readings[SAMPLES_COUNT];
int readIndex = 0;
int total = 0;
int average = 0;
int lastAverage = 0;
bool motionDetected = false;
int significantChanges = 0;
int lowChangeCount = 0;

void setup() {
  Serial.begin(115200);

  // Initialize HB100 readings
  for (int i = 0; i < SAMPLES_COUNT; i++) {
    readings[i] = analogRead(HB100_PIN);
    total += readings[i];
    delay(10);
```

```
  }
  lastAverage = total / SAMPLES_COUNT;

  // Ultrasonic + buzzer setup
  pinMode(TRIG_PIN, OUTPUT);
  pinMode(ECHO_PIN, INPUT);
  pinMode(BUZZER_PIN, OUTPUT);
  digitalWrite(BUZZER_PIN, LOW);
}

void loop() {
  // --- HB100 motion detection ---
  total = total - readings[readIndex];
  readings[readIndex] = analogRead(HB100_PIN);
  total = total + readings[readIndex];
  readIndex = (readIndex + 1) % SAMPLES_COUNT;
  average = total / SAMPLES_COUNT;

  int change = abs(average - lastAverage);
  float voltage = readings[readIndex] * VOLTAGE_CONVERSION;

  // Simulated speed estimation
  float simulatedSpeed = change * 0.1; // Adjust scale if needed

  if (change >= MIN_THRESHOLD && change <= MAX_THRESHOLD) {
    significantChanges++;
    lowChangeCount = 0;
    if (significantChanges >= DETECTION_COUNT && !motionDetected) {
      motionDetected = true;
    }
  } else {
    lowChangeCount++;
    if (lowChangeCount >= RESET_COUNT) {
      significantChanges = 0;
      if (motionDetected) {
```

```
      motionDetected = false;
    }
  }
}

lastAverage = average;

// --- Ultrasonic distance measurement ---
digitalWrite(TRIG_PIN, LOW);
delayMicroseconds(2);
digitalWrite(TRIG_PIN, HIGH);
delayMicroseconds(10);
digitalWrite(TRIG_PIN, LOW);

long duration = pulseIn(ECHO_PIN, HIGH, 30000); // timeout at 30 ms (~500 cm)
int distance = duration > 0 ? duration * 0.0344 / 2 : 0;

// --- Buzzer trigger logic ---
if (distance <= 50 && distance > 0 && motionDetected && distance <= 30) {
  digitalWrite(BUZZER_PIN, HIGH);
} else {
  digitalWrite(BUZZER_PIN, LOW);
}

// --- Serial output ---
Serial.print("Sensor Value: ");
Serial.print(readings[readIndex]);
Serial.print(" | Change: ");
Serial.print(change);
Serial.print(" | Distance: ");
Serial.print(distance);
Serial.print(" cm | Estimated Speed: ");
Serial.print(simulatedSpeed, 2);
Serial.println(" units");
```

```
  delay(500);
}
```

4.3 Miscellaneous:

Soldering Kit for final hardware assembly

Multimeter for electrical measurements and continuity testing

Jumper wires, resistors, small casing if prototyping case is needed

4.4 Bill Of Material:

Sr.no	Component	Quantity
1.	ESP32 Board	1
2.	HB100 Radar Sensor	1
3.	Ultrasonic Sensor	1
4.	LCD	1
5.	Capcitor 100uf,0.1uf,4.7uf,2.2nf	7
6.	Resistor 100k,3000K,1.2k,10k,8.2k,1M,12k	8
7.	LM324	2
8.	Breadboard	1

.

Chapter 5.Experimentation and Result

5.1 Experimentation Setup

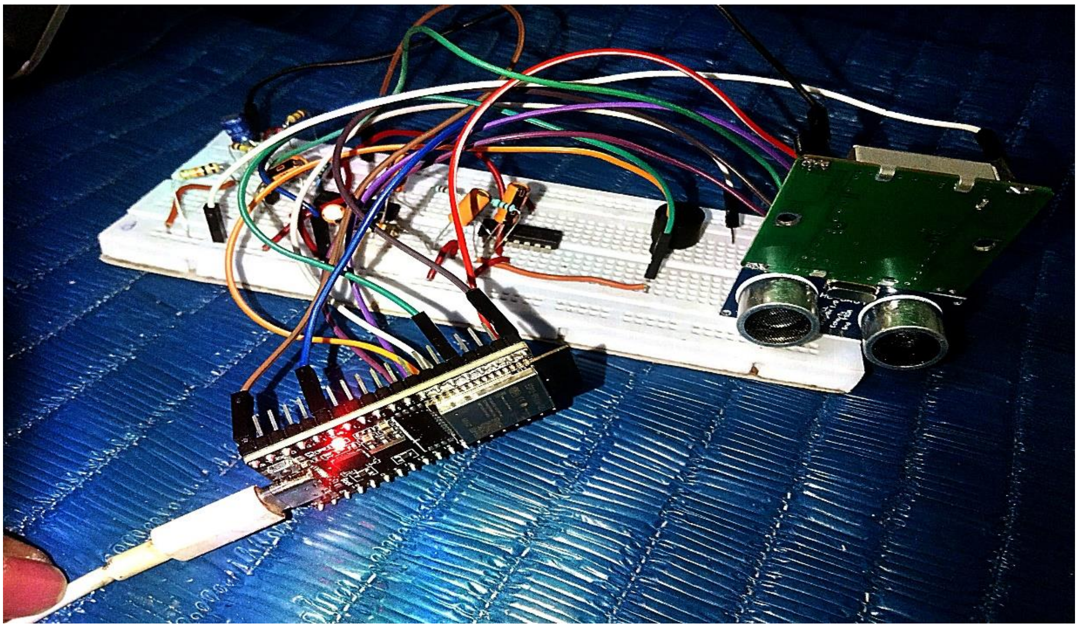


Fig 5.1Experiment Setup

5.2 When Obstacle is Steady or Absent:

```
Output    Serial Monitor ×
Not connected. Select a board and a port to connect automatically.
Sensor Value: 1495 | Change: 81 | Distance: 57 cm | Estimated Speed: 0.00 cm/s
Sensor Value: 1606 | Change: 90 | Distance: 57 cm | Estimated Speed: 0.00 cm/s
Sensor Value: 1717 | Change: 83 | Distance: 57 cm | Estimated Speed: 0.00 cm/s
Sensor Value: 1821 | Change: 77 | Distance: 56 cm | Estimated Speed: 0.00 cm/s
Sensor Value: 1903 | Change: 70 | Distance: 57 cm | Estimated Speed: 0.00 cm/s
Sensor Value: 1984 | Change: 66 | Distance: 57 cm | Estimated Speed: 0.00 cm/s
Sensor Value: 2081 | Change: 61 | Distance: 176 cm | Estimated Speed: 0.00 cm/s
Sensor Value: 2149 | Change: 54 | Distance: 57 cm | Estimated Speed: 0.00 cm/s
Sensor Value: 2215 | Change: 47 | Distance: 57 cm | Estimated Speed: 0.00 cm/s
Sensor Value: 2271 | Change: 43 | Distance: 54 cm | Estimated Speed: 0.00 cm/s
```

Fig 5.2 When Obstacle is Steady or Absent

5.3 When is Object is Moving

Output   Serial Monitor ×

Not connected. Select a board and a port to connect automatically.

```
Obstacle is detected
Sensor Value: 2657 | Change: 14 | Distance: 10 cm | Estimated Speed: 7.00 cm/s
Obstacle is detected
Sensor Value: 2619 | Change: 15 | Distance: 20 cm | Estimated Speed: 7.50 cm/s
Obstacle is detected
Sensor Value: 2923 | Change: 23 | Distance: 9 cm | Estimated Speed: 11.50 cm/s
Obstacle is detected
Sensor Value: 2815 | Change: 17 | Distance: 20 cm | Estimated Speed: 8.50 cm/s
Obstacle is detected
Sensor Value: 2827 | Change: 4 | Distance: 11 cm | Estimated Speed: 2.00 cm/s
```

Fig 5.3 When is Object is Moving

Chapter 6. Summary and Future Scope

6.1 Summary:

The project successfully implemented an Obstacle Detection System using an HB100 Radar Sensor, Ultrasonic Sensor, and an ESP32 Microcontroller. The system is capable of detecting both static and moving objects with decent accuracy and provides real-time feedback through a buzzer and a 16x2 LCD display.

Key achievements include:

- Accurate distance measurement using the ultrasonic sensor.
- Effective motion detection using the Doppler-based HB100 radar sensor.
- Integration of both sensors to enhance detection reliability.
- Real-time visual and audio alert mechanisms.
- Low power and cost-effective implementation suitable for embedded applications.

6.2 Future Scope:

<u>IoT Integration</u>: The ESP32 can be connected to Wi-Fi to send obstacle data to a web server or mobile app for remote monitoring.

<u>Machine Learning Enhancement:</u> Object classification (e.g., human, vehicle, furniture) could be introduced using ML models.

Battery Optimization: A portable version can be developed with low-power sleep modes.

<u>Environmental Applications</u>: The system can be adapted for smart cars, robotic navigation, home automation, and blind assistance systems.

<u>Sensor Fusion Upgrades</u>: Integration with IR sensors, LIDAR, or camera modules could further improve detection range and accuracy.