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COMPUTER ORGANISATION AND ARCHITECHTURE LAB [15B17CI373]

Distance-Based Multi-Modal Safety Alert System

PROJECT SYNOPSIS

SUBMITTED TO:

Dr. Naveen Chauhan

SUBMITTED BY(BATCH B13):

ASMI VAISH 23803006

LOVISH KUMAR 23803014

KALPNA MISHRA 23803020

Introduction

In today's world, technology has blended deeply with almost every aspect of human life. Industries, transportation networks, and even domestic settings rely heavily on automation and smart monitoring tools to function smoothly. As machines and vehicles operate at faster speeds and with greater complexity, the margin for human error also increases. A small delay in detecting an obstacle or misjudging distance can lead to serious consequences such as collisions, equipment damage, or even personal injury. This growing dependency on automated systems has created a strong need for reliable distance- monitoring solutions that can sense obstacles and alert the user before an accident occurs.

To address this requirement, the proposed project introduces a real-time obstacle sensing and alert mechanism built using an HC-SR04 ultrasonic sensor interfaced with an Arduino Uno. The sensor emits ultrasonic pulses, detects the reflected wave, and calculates the distance of the object based on the time taken for the signal to return. These values are then processed by the microcontroller, which categorizes proximity into three levels and displays them through a green, yellow, and red LED indicator system. In situations where the obstacle is dangerously close, the system further triggers an audible warning using a buzzer, ensuring that the user is immediately alerted.

One of the key strengths of the system lies in its simplicity and adaptability. It runs on very low power, uses easily available components, and can be expanded with additional features such as Bluetooth connectivity, displays, IoT integration, or motor-based scanning. Due to its compact structure and flexible behaviour, this project holds practical importance in several fields including automated parking assistance, autonomous robots, factory safety monitoring, mobility aids for visually impaired individuals, and smart automation labs.

Problem Statement

Collisions and accidental impacts commonly occur not just because obstacles exist, but because they are not detected early enough. Human response time is limited, and in environments where visibility is blocked or movement space is narrow, the chances of impact increase significantly. Blind spots, low-light conditions, congested machinery areas, and distracted operation all contribute to delayed reaction. A small oversight in such situations can cause damage to vehicles or equipment, halt operations, or worse—lead to severe injuries.

Most existing systems either lack real-time feedback or are expensive to implement. This creates a practical gap where an affordable and responsive proximity detection system can prove highly beneficial. Therefore, this project focuses on developing an adaptive microcontroller-based obstacle alert mechanism capable of sensing the distance of an object and warning the user instantly through LEDs and buzzer notifications.
The aim is to minimise accidents by ensuring that obstacles are detected before contact, giving the user enough time to take corrective action.

Objectives of the System

The main aim of this project is to design a simple yet reliable system capable of detecting obstacles and informing the user before a collision occurs. To achieve this, the project focuses on developing a compact electronic setup supported by real-time sensing and adaptive alert generation. The key objectives are:

- To build a device that can detect the presence of obstacles instantly and continuously without manual intervention.

- To measure distance accurately using the principle of ultrasonic wave transmission and reflection.

- To trigger visual alerts through LEDs and an audio alert through a buzzer depending on how close the obstacle is, ensuring quick user awareness.

- To design the system in a way that remains low in cost, easy to assemble, and can be expanded with more features if required.

- To provide a solution that improves safety and can be implemented in various environments such as homes, industrial spaces, automated machines, parking systems, and vehicles.

These objectives contribute toward developing a practical safety-based model that is affordable, responsive, and flexible enough to be improved further.

Proposed System Overview

The system is built around the HC-SR04 Ultrasonic Sensor, a widely used module known for its accuracy and reliability. The sensor continuously emits ultrasonic pulses and listens for the reflected echo. When the waves bounce back from an obstacle, the return time is measured and converted into distance by the Arduino Uno microcontroller. This measured value is then compared against predefined threshold ranges to determine the current safety level.

To ensure clear perception, three different alert stages are implemented:

Distance Range	Zone Classification	Output Response
> 25 cm	Safe Zone	Green LED turns ON
10–25 cm	Warning/Moderate Zone	Yellow LED turns ON
< 10 cm	Critical/Danger Zone	Red LED + Buzzer activate

This approach allows the user to visually and audibly understand when an object is approaching too close. The microcontroller runs this calculation continuously using Time-of-Flight measurement, enabling the device to respond instantly as the environment around it changes. The system does not require calibration every time it runs, which makes it highly suitable for real-world applications where conditions may vary.

Methodology / Working Principle

The working of the system is based on the behavior of ultrasonic waves and their ability to measure distance using the echo principle. The HC-SR04 ultrasonic sensor continuously emits high-frequency sound pulses through its transmitter. When these pulses encounter a solid object, they get reflected back and are received by the echo pin of the sensor. The time taken between transmission and reception forms the foundation of distance calculation.
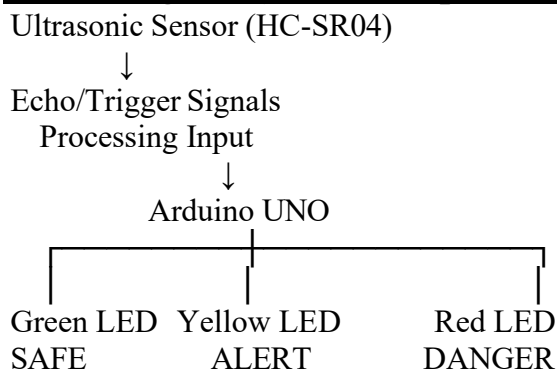
The Arduino Uno acts as the processing unit of the system. It records the returning echo time using the pulseIn() function and calculates the distance of the obstacle using the formula:

Distance = (Time × Speed of Sound) ÷ 2

Once the distance is computed, it is compared against predefined threshold levels. Based on the results, the Arduino activates one of the three alert modes – Green LED for safe distance, Yellow LED for caution, and Red LED with buzzer for danger range. This logic allows the user to instantly recognize how close an object is and respond accordingly.

The loop continuously executes this process, enabling real-time monitoring without manual intervention. This makes the circuit independent, intelligent and reliable in practical use-cases where continuous scanning is required.

Block Diagram (Textual Representation)

```
Ultrasonic Sensor (HC-SR04)
            ↓
Echo/Trigger Signals
    Processing Input
                ↓
        Arduino UNO
    ┌───────────┼───────────────┐
    │           │               │
Green LED   Yellow LED       Red LED
SAFE          ALERT         DANGER
```

The block diagram reflects how data flows from sensing → processing → output alerts. This simplified architecture keeps the system stable, responsive, and easy to modify.

Hardware Requirements

The project uses commonly available, inexpensive components, making it suitable for academic prototyping as well as practical implementation. The required components are:

- Arduino Uno Development Board – main controller for processing signals
- Ultrasonic Sensor (HC-SR04) – for distance measurement using echo reflection
- LEDs (Red, Yellow, Green) – to visually indicate safe, medium and danger ranges
- Buzzer (Active/Passive) – to alert user during critical distance
- 220Ω Resistors – to limit current and protect LEDs
- Mini Breadboard – for circuit assembly and prototyping
- Male-Male Jumper Wires – for connections between components
- USB Cable for Programming – to upload Arduino code and power the setup

These components collectively form a low-power, compact and scalable obstacle detection system.

Applications

This model can be implemented across numerous real-world environments. Some notable applications include:

- Smart Vehicle Parking & Reverse Alert Systems, preventing dents and accidents.
- Robotic Obstacle Avoidance Units, enabling safe autonomous navigation.
- Industrial Machine Safety to avoid collisions in production zones.
- Warehouse Shelf Navigation, reducing human effort and accident chances.
- Blind / Disabled Assistance Tools for mobility guidance and safety support.
- Home Automation & Security Modules, detecting intrusions or object proximity.
- Autonomous Guided Vehicles (AGVs) for smart industrial transport.
- Educational Projects, research experiments, and early-stage robotics development.

Its simplicity and reliability make it versatile across both educational and professional domains.

Conclusion

The developed Adaptive Obstacle Sensing and Alert Mechanism successfully meets the goal of real-time proximity detection and warning. By classifying distances into safe, caution and danger levels, the system alerts users well before a collision takes place, allowing corrective action. The combination of ultrasonic sensing with LED and buzzer output ensures fast visibility and instant response, making the setup effective for safety-critical applications.

With low component cost, minimal power usage, and high expandability, the design holds great practical value. Future enhancements like LCD/7-segment display, wireless control, IoT-based data monitoring, servo-motor rotation for 180° scanning, and AI-predicted behavior can transform the prototype into a more advanced safety device suitable for large-scale deployment in vehicles, automation labs, and intelligent robotics.