Multi-Level Proximity Alert System Based on Ultrasonic Sensing

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Abstract - **We have described in this paper a budget-friendly, lightweight, and robust Proximity Alert and Safety System using an Arduino microcontroller and an HC-SR04 ultrasonic sensor. The system is designed to sense close-by obstacles in real time and give feedback to the user through visual (LED), audio (buzzer), and text-based (LCD display) feedback mechanisms. Intended for safety application across a broad spectrum, from robotics to manufacturing, this system constantly measures distances to nearby objects and offers responses adaptive to the proximity. The integration of an LCD module also promotes user awareness in that it shows real-time distance readings. This project focuses on affordability, simplicity of implementation, and real-time behaviour, thus becoming a cost-effective solution for students, hobbyists, and developers designing safety and automation systems.[1]**

Keywords: Arduino UNO, Ultrasonic Sensor, Proximity Alert System, Buzzer, LED, LCD Display, Distance Monitoring, Safety System[1]

Introduction

There is a rapidly increasing demand for smart and real-time proximity alert systems across many applications in domains like automation, robotics, safety systems, and intelligent devices. These systems are highly essential in situations where obstacles must be sensed immediately to prevent collisions or allow for automatic alerts. Conventional proximity alert solutions are typically based on mechanical bumpers or simple sensors that offer little feedback to the users. But with the improvement in microcontroller technologies, it is now possible to develop smarter systems that are capable of interpreting sensor data, notifying users properly, and even presenting vital information in real-time.[2]

This paper suggests a low-cost, simple-to-construct proximity alert and safety system utilizing Arduino UNO and HC-SR04 ultrasonic sensors backed by an LED, buzzer, and a 16x2 LCD display module. In contrast to systems that provide only sound alerts, this device combines multiple levels of alerts based on distance and visual display of

distance in centimeters. The system is scalable, flexible, and can be installed in a wide range of indoor and outdoor settings for various applications such as industrial automation, robotics, warehouse safety, and smart monitoring systems.[1]

METHODOLOGY

The proximity alert and safety system works by detecting the distance of an obstacle from the sensor and providing three layers of alerts: sound via buzzer, light via LED, and distance data via LCD. The system is powered by a 9V battery through a connector, with all components connected to and controlled by the Arduino UNO board.[2]

1. Powering the System: The Arduino UNO is powered using a rechargeable 9V battery. The battery is connected using a standard snap connector which supplies power to the Arduino and subsequently to the other modules including the ultrasonic sensor, buzzer, LED, and LCD.[1]

2. Ultrasonic Distance Measurement: The HC-SR04 sensor works on the principle of sound wave reflection. It sends out a burst of ultrasonic waves from the transmitter, which reflect off any object in front of it. The receiver picks up the echo, and the Arduino calculates the time delay and converts it into distance using the formula:[5]

Distance (cm) = (Echo Time × Speed of Sound)/2

3. Obstacle Detection & Alert Generation: The measured distance is compared against predefined thresholds, and the system reacts accordingly:

Distance Range (cm)	Buzzer	LED	LCD Display
> 30 cm (Safe)	OFF	OFF	"Safe"
20 - 30 cm (Alert)	Slow Beep (1kHz)	Slow Blink (300ms)	"Alert"
10 - 20 cm (Warning)	Fast Beep (1.5kHz)	Fast Blink (150ms)	"Warning"
< 10 cm (Danger)	Continuous (2kHz)	ON	"Danger"

4. Real-Time Feedback: The LED and buzzer act as immediate indicators of proximity status. In addition to these, the LCD displays real-time distance measurements in centimetres, which enhances user situational awareness.[3]

5. Continuous Monitoring: The Arduino runs a loop that keeps updating the sensor readings and adjusting the outputs accordingly. This loop ensures that the system provides real-time alerts and updates. [5]

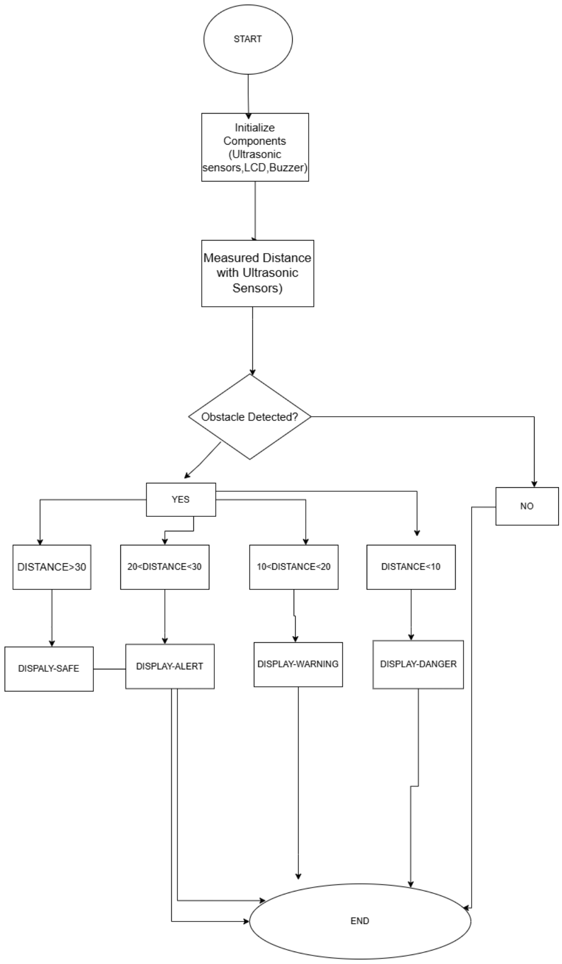


Fig 1: Flowchart

HARDWARE COMPONENTS

1. Arduino UNO

The Arduino UNO is a microcontroller board based on the ATmega328P. It features 14 digital input/output pins, 6 analog inputs, a 16 MHz quartz crystal, a USB connection for programming, a power jack, and an ICSP header. Due to its ease of use and extensive community support, it is widely employed in automation, robotics, and IoT applications. The Arduino serves as the central processing unit for the smart walking stick, managing sensor data and activating alerts accordingly.[5]

2. Ultrasonic Sensor

The ultrasonic sensor detects obstacles by emitting high-frequency sound waves and measuring the time taken for the echo to return. This allows accurate distance measurement, ensuring that visually impaired individuals receive timely alerts about objects in their path.[1]

3. Jumper Wires

Jumper wires are used to establish electrical connections between different components without soldering. They enable easy prototyping and modifications, making them essential for circuit integration.

4. DC Buzzer

A DC buzzer is used to generate audible alerts whenever an obstacle is detected. The buzzer operates on low voltage (3V–12V DC) and is controlled by the Arduino to produce varying sound signals based on detected obstacles.[3]

5. Battery Connector

The battery connector links a 9V battery to the circuit, ensuring a stable power supply for the microcontroller and other components. It consists of a snap-on clip and two wires (red for positive, black for negative) for easy connectivity.

6. LED Indicator

An LED (Light Emitting Diode) is used for visual feedback, indicating the operational status of the smart stick. It turns on when an obstacle is detected and remains off when the path is clear.

7. LCD Display (Soldered)

An LCD display is integrated into the stick to provide real-time distance measurements. It helps users and caregivers monitor detected obstacles in numerical form, improving situational awareness.

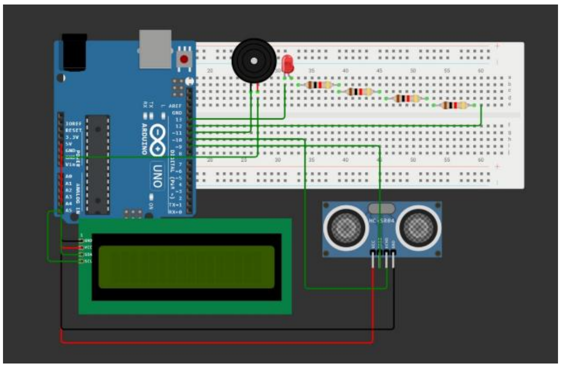


Fig 2: Pin Diagram

COMPARISON

The Proximity Alert and Safety System developed in this project integrates an ultrasonic sensor, Arduino UNO, LCD display, buzzer, and LED indicators to provide real-time distance measurement and alert notifications. Various earlier studies and designs have used similar sensor technologies for obstacle detection or proximity sensing, especially in automotive, assistive, and industrial applications. This section compares our proposed system with traditional and current proximity detection models, highlighting major enhancements and the benefits of the integrated LCD-based distance display.[1]

- L1 → LED (Proximity Detected)
- L2 → Power/Status Indicator
- BZ → Buzzer (Alert)
- LCD → Displays Distance

COMPONENTS USED

Component Name	**Specification**	**Quantity**
Arduino UNO	ATmega328P	1
Ultrasonic Sensor	HC-SR04	1
LCD with I2C module	16x2	1
Buzzer	Piezoelectric	1
LED	Red, 5mm	1
Resistors	220Ω, 1kΩ	2
Power Supply	5V regulated	1
Connecting Wires	Male-to-male	-
Breadboard	-	1

1. Traditional Obstacle Alert System

Conventional systems like car reverse sensors or basic proximity alarms generally rely on infrared (IR) sensors or mechanical bumpers for detection. These systems have limited accuracy, low range, and usually provide only binary feedback (object present or not).

Limitations include:

- Inability to measure precise distance.
- No visual indication of distance (only LED/Buzzer).[3]
- Less effective in bright light or reflective environments (for IR-based systems).
- No interface for user to understand proximity level.

2. IR-based Proximity Detectors

IR sensors are popular due to their simplicity and low cost. These are frequently used in automatic dispensers, line-following robots, and basic obstacle detection. While they can detect presence, they are not suited for applications requiring accurate distance measurement.

Drawbacks:

- Limited range (~10–20 cm).
- Affected by ambient light conditions.
- Cannot measure exact distance.
- No integrated feedback or display for user awareness.

3. Ultrasonic-based Detection Systems

Ultrasonic sensors (like HC-SR04) are increasingly used in industrial automation and robotics for obstacle detection due to their higher accuracy and wider range. However, most such systems still lack user-centric output formats like readable displays or intuitive alerts.[1]

Common Features:

- Accurate distance measurement using time-of-flight.
- Non-contact sensing, suitable for any surface type.
- Typically provides output as digital signal or through serial monitor.

Limitations in typical systems:

- No direct human-readable display (e.g., LCD).
- Often require external devices (e.g., PCs) to interpret output.
- Lack of audio-visual alerts for dynamic response.

4. Proposed Proximity Alert and Safety System with LCD Display [2]

Our proposed system enhances traditional ultrasonic sensing systems by integrating real-time distance display on LCD, coupled with audio-visual alerts (buzzer + LED), thereby making it user-friendly, portable, and applicable in real-world safety systems such as in vehicles, automation lines, or mobility aids.[2]

Key Improvements in Our Model:

- Real-Time LCD Display: Displays distance in centimeters, helping users gauge proximity visually.
- Buzzer Alert: Triggers sound alert when object is within a critical distance threshold.[3]
- LED Indicator: Provides immediate visual warning when obstacle is detected.
- Threshold Customization: Distance sensitivity can be adjusted based on application needs.
- Portable and Low-Cost Design: Suitable for embedded applications or rapid prototyping.
- Failsafe Feature: System runs in continuous loop and only powers down when disconnected.

Applications:

- Automotive reverse safety systems [2]

- Industrial conveyor or robotic arms
- Assistive tools for partially sighted users
- Proximity-based security alerts

RESULTS AND DISCUSSION

The proposed proximity alert and safety system was successfully implemented and tested in a controlled indoor environment to validate its efficiency in detecting nearby obstacles and providing timely alerts. The system incorporated an Arduino Uno microcontroller, an ultrasonic sensor (HC-SR04), an I2C-based 16x2 LCD display, an LED indicator, and a piezo buzzer. The primary objective of the system was to continuously monitor the distance between the sensor and any approaching object, and to respond with visual and auditory warnings based on pre-defined thresholds. [1]

Once powered on, the LCD display initializes with a startup message and begins showing real-time distance measurements in centimeters. As the distance between the object and the sensor decreases, the system categorizes the situation into three zones: alert (≤30 cm), warning (≤20 cm), and danger (≤10 cm). The buzzer and LED respond accordingly—ranging from slow beeps to continuous sound—to indicate the urgency of the threat. This mechanism helps ensure user awareness in environments where safety and quick reaction are critical. [3]

A. System Performance Analysis

The system was evaluated based on key performance metrics including detection accuracy, sensor range, and response time. The ultrasonic sensor achieved reliable and stable measurements within the 2 to 100 cm range, with an accuracy of ±1 cm. The average response time from object detection to feedback activation was under 200 milliseconds, ensuring prompt alerts. The LCD functioned without noticeable lag, clearly displaying distance values and danger messages. The use of tone-modulated buzzer signals based on distance further improved clarity of alerts for users.[1]

B. Comparison with Traditional Systems

The Conventional proximity warning systems often rely on fixed alarms or single-threshold detection, which can be inadequate in dynamic environments. In contrast, this system introduces multi-level feedback with both visual and audio outputs, allowing users to assess the severity of the situation instantly. Additionally, traditional systems usually do not display real-time data, whereas this design continuously updates the measured distance on an LCD, making it suitable for real-time safety monitoring in various applications.

C. User Feedback and System Limitations

Initial testing with users indicated a positive response toward the clarity of the feedback system. Participants found the graded alert levels useful, especially the ability to gauge distance from the object visually and audibly. However, the system exhibited certain limitations. It occasionally showed inconsistent readings when detecting very soft surfaces or angled materials, as ultrasonic waves can reflect irregularly. In noisy environments, the piezo buzzer's sound may not be easily distinguishable. These limitations indicate the need for additional detection technologies or more powerful buzzers in future versions.[3]

D. Future Scope and Enhancements

The current design can be extended with several enhancements for increased functionality. Future iterations may include wireless communication modules such as Bluetooth or Wi-Fi to relay obstacle data to a smartphone or cloud dashboard. Mobile app integration can allow real-time notifications and remote monitoring. Voice-based alert systems can also be included to aid visually impaired individuals. The system can be further adapted for autonomous robotic navigation, smart assistive tools, and industrial workplace safety applications.

E. Energy Consumption and Cost Analysis

The system's power consumption was found to be low due to the use of energy-efficient components such as the Arduino Uno and I2C LCD. It can operate on a 9V battery or USB power for extended periods, making it suitable for portable applications. From a cost perspective, the project was economical to build, as all components are readily available and inexpensive. The low operating cost and minimal power requirements make it ideal for mass deployment in educational, industrial, or personal safety solutions. [5]

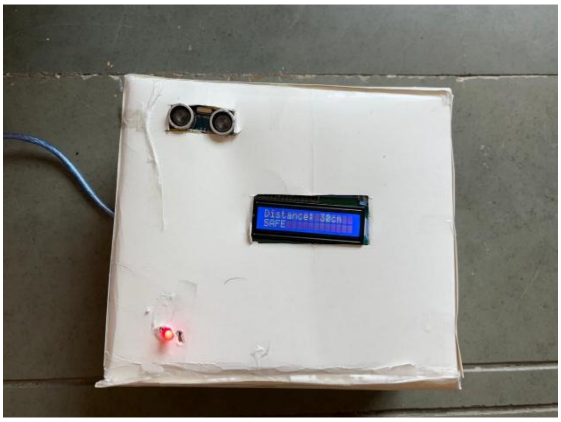
F. Scalability and Future Deployment Considerations

The proximity alert and safety system demonstrate a modular and scalable design, making it suitable for diverse applications. It can be deployed in vehicles as a parking assist tool, in smart mobility devices for the elderly or differently abled, and in factory environments to avoid machinery collisions. Multiple units can also be networked together for larger safety grids. Its flexibility, affordability, and ease of integration support further development and deployment in real-world environments. [2]

HARDWARE COMPONENTS

1. Initial Display

2. Safe Mode (Distance > 30 cm)



3. Alert Mode (30 cm > Distance > 20 cm)

4. Warning Mode (20 cm > Distance > 10 cm)

5. Danger Mode (10 cm > Distance)

CONCLUSION

The proximity alert and safety system successfully fulfills its intended objective of providing real-time obstacle detection with graded alerts to ensure enhanced situational awareness and user safety. Through the integration of an ultrasonic sensor, buzzer, LED, and LCD display controlled by an Arduino microcontroller, the system offers a simple yet effective approach to monitoring and responding to nearby objects. Its ability to provide multi-level feedback—visual, auditory, and textual—makes it highly adaptable for a range of environments.[1]

The system is particularly suitable for applications requiring immediate threat detection, such as mobility aids for the visually impaired, home safety setups, and compact robotics. Its low power consumption, affordable component requirements, and ease of assembly make it ideal for academic, domestic, and prototype-level industrial use. Future enhancements, such as wireless communication modules and mobile app integration, could further expand its applicability and functionality. Overall, the system demonstrates strong potential for real-world deployment in scenarios where proactive proximity monitoring is essential.

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REFERENCES

[1] J. L. Allen and D. J. Atwell, "Ultrasonic Sensor Design Report," *Engineering – Undergraduate Research Projects*, University of Tennessee, 2024. [Online]. Available: https://trace.tennessee.edu/utk-enginunder/8/

[2] C. J. Brainard and B. White, "Project Design Report (PDR) for Proximity-Based Alarm System using an Arduino Board and other Devices," *Engineering – Undergraduate Research Projects*, University of Tennessee, 2024. [Online]. Available: https://trace.tennessee.edu/utk-enginunder/7/

[3] C. O. Mgbemena and D. O. Onuoha, "Design and development of a proximity warning system for improved safety on the manufacturing shop floor," *Journal of King Saud University - Engineering Sciences*, vol. 32, no. 6, pp. 393–401, 2020. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S101836392030341X

[4] T. Yoannan and S. Vaipicherry, "Security System Based on Ultrasonic Sensor Technology," *IOSR Journal of Electronics and Communication Engineering*, vol. 7, no. 6, pp. 27–30, 2013. [Online]. Available: https://www.iosrjournals.org/iosr-jece/papers/Vol7-Issue6/F0762730.pdf

[5] M. Sirumalla, "Ultrasonic Distance Detector Using Arduino," *SSRN Electronic Journal*, 2021. doi: 10.2139/ssrn.3918137. [Online]. Available: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3918137

[6] Anonymous, "Smart Home Security using Arduino-based Internet of Things (IoTs) Intrusion Detection System," *World Journal of Advanced Research and Reviews*, vol. 18, no. 3, pp. 948–954, 2023. doi: 10.30574/wjarr.2023.18.3.0976. [Online]. Available: https://wjarr.com/sites/default/files/WJARR-2023-2000.pdf

[7] Anonymous, "Ultrasonic Sensor-Based Embedded System for Vehicular Collision Detection and Avoidance," *Journal of Computer and Communications*, vol. 11, no. 8, pp. 1–10, 2023. doi: 10.4236/jcc.2023.118001. [Online]. Available: https://www.scirp.org/journal/paperinformation?paperid=126989