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A Unified Sensor System For Real-Time Obstacle Detection And Metal Sensing On Arduino

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Abstract:

This project presents a compact embedded system designed to detect both obstacles and metallic objects using an Arduino Uno microcontroller. The system employs an ultrasonic sensor (HC-SR04) to identify obstacles by transmitting sound waves and calculating distance based on the reflected signal. When an obstacle is detected within a critical range, the Arduino initiates an avoidance action by reversing the device.
The metal detection subsystem operates on the principle of electromagnetic induction. A copper coil connected to an LC oscillator generates a magnetic field, and when a metallic object enters this field, the inductance of the coil changes, altering the oscillator frequency. The Arduino monitors this variation and activates a buzzer and LED to indicate the presence of metal.
The proposed system is simple, low-cost, and user-friendly. It is suitable for applications such as small mobile robots, assistive tools for visually impaired users, and basic security-scanning devices. This work demonstrates how multiple sensing modalities can be integrated into a single microcontroller-based platform to achieve multifunctional sensing capabilities.

Index Terms— Arduino, obstacle detection, metal detection, ultrasonic sensor, inductive sensing, embedded systems.

1. INTRODUCTION

Sensors and microcontrollers play a crucial role in modern electronic systems, enabling machines to operate intelligently, safely, and interactively. Obstacle detection and metal detection are widely used features in robotics, industrial automation, security systems, and assistive technologies. Although these functions are typically implemented using separate hardware modules, integrating both capabilities into a single compact system increases efficiency, functionality, and affordability.
This project, titled **"Arduino-Based Obstacle Detection and Metal Detector Device,"** aims to combine ultrasonic obstacle detection and inductive metal sensing into one practical embedded system. The objective is to design a low-cost device capable of detecting obstacles using an ultrasonic sensor and identifying metallic objects using a copper-coil-based metal detector circuit. Both sensing units are controlled through an Arduino Uno microcontroller to demonstrate how sensor fusion can be effectively implemented at a basic embedded-systems level.
The device is portable, battery-powered, and easy to construct. It provides immediate visual and audio alerts when an obstacle or metallic object is detected. Due to its simplicity and hands-on nature, this project is well suited for educational purposes, particularly for students learning embedded system design, sensor interfacing, and microcontroller programming.

Ultrasonic sensors, in particular, are widely adopted for obstacle detection in autonomous robots because they are inexpensive, reliable, and unaffected by lighting variations. For instance, J. Ma presents a framework utilizing multiple ultrasonic sensors for real-time obstacle detection and avoidance, demonstrating improved accuracy compared to single-sensor systems. Similarly, the study “Obstacle Avoiding Robot using Arduino UNO and HC-SR04 Ultrasonic Sensor” showcases a prototype capable of navigating unknown environments through effective obstacle detection.

On the other hand, Arduino-based metal detection systems commonly rely on inductive coils paired with microcontroller-based signal processing. Yousif Elfatih Yousif, in “Design and Simulation of Metal Detection System,” demonstrates the use of inductive sensing techniques integrated with an Arduino platform. Additionally, the work “Development and Implementation of a Low-Cost Metal Detector Device” introduces a more advanced pulse-induction (PI)–based design incorporating an Arduino controller, LCD display, and Bluetooth communication for real-time data visualization.

The **Arduino-Based Smart Robot Car for Object Detection and Navigation** system demonstrated effective navigation in dynamic environments, validating its design methodology and confirming that such an approach is suitable for small-scale object detection and autonomous navigation applications [1]. A related study on a **Basic Obstacle-Avoiding Vehicle Using Arduino UNO** [2] showed that incorporating a colour-recognition module enhances the system’s environmental adaptability, enabling both obstacle detection and colour-based navigation cues. This highlights the potential for building intelligent and responsive autonomous robots.

The **Multifunctional Obstacle-Avoidance Arduino Robot Car** [3] further indicates that expanding beyond basic ultrasonic sensing—through the integration of cameras or machine-learning-based modules—significantly improves capability and broadens future applications, laying the foundation for areas such as autonomous navigation and surveillance.

In the area of metal sensing, the **Design of an Arduino-Based Metal Detector Robot** [4] achieved successful metal detection within its tested range and demonstrated effective remote control via a smartphone Bluetooth interface, though the detection radius remained modest. A similar work, **Design of a Metal-Detecting Arduino Remote-Controlled Robot** [5], reported accurate and fast detection performance with improved maneuverability at low cost, confirming the practicality of such systems for remote metal-detection operations.

Studies combining robotic mobility with communication technologies also show promising results. The **Automatic Metal Detection Robot for Mining Areas with IoT Configuration** [6] proved effective as a safer alternative to manual metal detection in hazardous zones, with IoT integration enabling enhanced remote monitoring. Likewise, the **Design of an Arduino-Based Robot Car Metal Detector Using a Design-Thinking Approach** [7] produced a cost-effective system suitable for tasks such as locating misplaced items, although limitations such as short detection range and sensitivity to surface conditions were noted.

Research on obstacle-avoidance systems continues to demonstrate the value of sensor integration. For example, **Obstacle-Avoiding Car Using Arduino** [8] again emphasizes that combining colour recognition with ultrasonic sensing improves environmental interaction and supports intelligent navigation. Additional work on **Metal-Detecting Arduino Remote-Controlled Robots** [9] confirms that such vehicles can achieve fast and accurate metal detection with ease of control, reinforcing their feasibility. Finally, the **Metal-Detecting Robot Using IoT** [10] achieved high-precision detection during field testing and incorporated solar-powered, remotely operated functionality, reducing human exposure to hazardous environments.

2. Design of a Dual-Function Robot Using Ultrasonic Obstacle Detection and LC-Oscillator Metal Detection

Fig 1

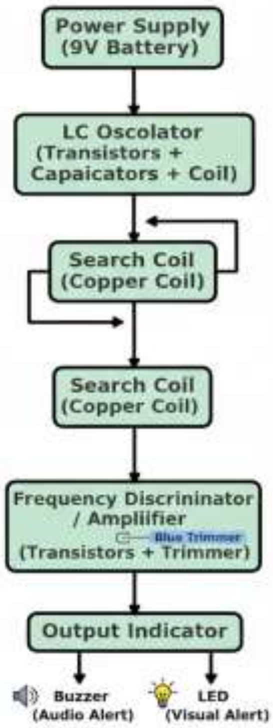


Fig 2

Fig. 1. Block diagram of the obstacle-detection system

Figure 1 illustrates the obstacle-detection module in which the Arduino Uno serves as the primary control unit. The onboard LEDs indicate the presence of power supply. An L298N motor-driver module is used to control the movement of the robot. The ultrasonic sensor is mounted at the front of the device; when it detects an obstacle, the trigger pin transmits ultrasonic pulses, and the echo pin receives the reflected waves. Using the time of flight, the Arduino calculates the distance to the obstacle. If the obstacle is too close, the robot reverses, makes a slight right turn, and checks for a clear path before continuing forward.

Fig. 2. LC-oscillator-based metal-detection circuit

Figure 2 shows the signal flow inside a typical LC-oscillator-based metal-detection system. A 9V battery powers the metal-detection circuit to ensure a stable DC supply suitable for LC oscillators and amplifier circuits. When a metallic object approaches the coil, the inductance of the coil changes, causing a shift in the oscillator's frequency. This frequency shift forms the basis for metal detection. The diagram includes two search coils that generate a magnetic field; when a metal object enters this field, it disturbs the oscillation frequency, allowing the Arduino to identify the presence of metal. The coil assembly is typically mounted at the bottom of the metal-detector robot.

3. Research Objective

The primary objective of this study is to design and develop a compact, low-cost embedded system capable of performing both obstacle detection and metal sensing. The proposed system employs an Arduino microcontroller for sensor data acquisition and processing, supported by visual and auditory alert mechanisms such as LEDs and a buzzer. Obstacle detection is achieved using an ultrasonic sensor positioned at the front of the device, while metal sensing is implemented through a copper-coil–based single-transistor detection circuit. Collectively, these components contribute to the development of an integrated, multifunctional prototype.

Existing literature reports considerable progress in Arduino-based obstacle detection and metal-sensing technologies, primarily due to the platform's affordability, ease of programming, and compatibility with diverse sensor modules. However, prior research has largely examined these functionalities independently. The present review therefore focuses on two major domains—obstacle detection and metal detection—and identifies a significant gap in integrating both capabilities into a single embedded system.
Although multiple studies have explored Arduino-driven obstacle avoidance or metal detection individually, there remains a notable lack of systems capable of navigating their environment while concurrently scanning for metallic objects. Most existing designs emphasize either mobile obstacle avoidance or stationary metal detection. Integrating ultrasonic sensing with inductive metal-detection coils under unified Arduino control provides an opportunity to develop a multifunctional system that supports safe navigation alongside real-time metal scanning.
Such a system offers practical applicability in a variety of fields, including underground cable tracing, security inspection robotics, environmental monitoring, and educational robotics platforms. In response to the identified research gap, this project aims to develop an Arduino-based prototype that combines ultrasonic obstacle detection and metal sensing within a unified embedded architecture, incorporating appropriate output indicators (LEDs, buzzers, LCD) and optional mobile-based interfaces to enhance usability and functional versatility.

3. IMPLEMENTATION

The implementation of the proposed system provides an overview of both the hardware architecture and the functional operation of the obstacle-detection and metal-detection units. The design explains the components used, the circuit configuration, and the working principles that enable the dual-sensing capabilities of the embedded system.

3.1 Working Principle of Obstacle Detection

The obstacle-detection unit uses an ultrasonic sensor based on the principle of echo ranging. The sensor emits high-frequency ultrasonic pulses that reflect off nearby objects and return to the sensor. By measuring the time interval between transmission and reception of the pulse, the Arduino computes the distance to the object using the following formula:

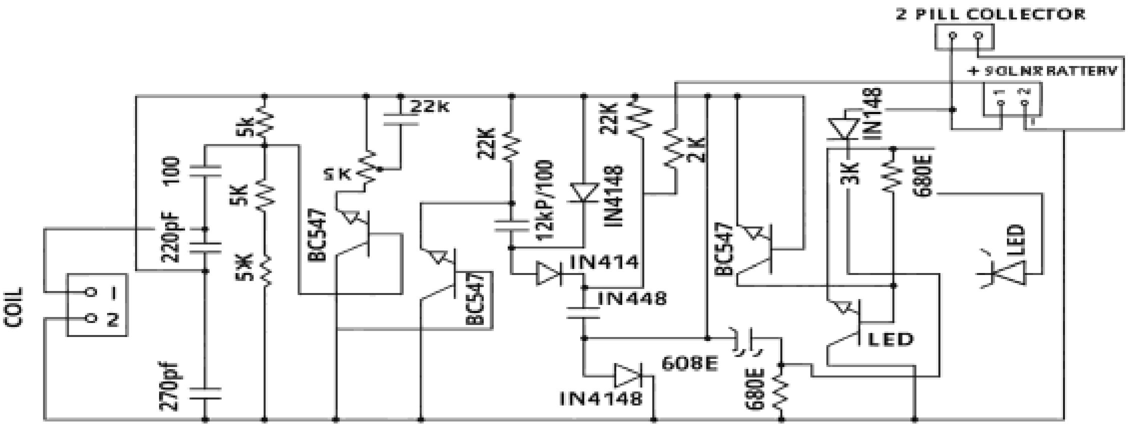
$$\text{Distance} = \frac{\text{Speed of Sound} \times \text{Time}}{2}$$

The division by two accounts for the round-trip travel of the sound wave. When an object is detected within a predefined threshold, the Arduino triggers corrective movement—such as reversing and turning—before continuing forward navigation.

3.2 Proposed Metal Detector Circuit

The metal-detection subsystem is built using a copper coil integrated into an LC-oscillator-based circuit. The coil generates a magnetic field when energized. When a metallic object enters this field, the inductance of the coil changes, causing a variation in the oscillator's frequency. This frequency shift serves as the basis for detecting the presence of metal.
A single-transistor amplification stage is used to stabilize and amplify the oscillations. The Arduino monitors variations in frequency or amplitude and triggers visual or audio alerts (LED/buzzer) when metal is detected. Power is supplied through a stable 9V source to ensure reliable oscillator operation.

This type of circuit operates based on the principle of frequency disturbance in an LC-oscillator–coil system. The copper search coil, positioned at the bottom of the device, generates an electromagnetic field when energized. When the circuit is powered, the transistor–capacitor network forms a high-frequency LC oscillator, with the coil functioning as the inductive element (L).
When a metallic object approaches the coil, it disturbs the surrounding electromagnetic field and alters the inductance of the coil. This inductance variation causes a corresponding shift in the oscillator's frequency. The circuit detects this frequency change, and the transistor amplifies the resulting signal variation. Depending on the type of metal, the frequency may increase (typically for non-ferrous metals) or decrease (for ferrous metals).
The entire circuit is powered by a 9V battery, and upon detecting a significant frequency shift indicative of a metal object, the system activates an audible buzzer to alert the user.



4. SYSTEM OVERVIEW

In the proposed system, the Arduino Uno acts as the central controller and is powered by AA cells. It coordinates all sensing and movement functions. Visual and audio alerts are provided through LEDs and a buzzer.

An L298N motor driver module is used to control the movement of the robot. The ultrasonic sensor is mounted at the front; it continuously scans for obstacles. The Arduino sends trigger pulses through the TRIG pin, and the ECHO pin receives the reflected sound waves. Using this information, the Arduino calculates the distance to the obstacle.

If an obstacle is detected too close to the robot, the system automatically moves backward, makes a slight right turn, and checks again for clear space. If no obstacle is detected, it resumes its forward movement.

For metal detection, a copper coil is used to generate a magnetic field. When a metal object enters this magnetic field, the inductance of the coil changes. This causes a shift in the oscillator frequency in the metal detector circuit. The circuit senses this variation, and the buzzer alerts the user when metal is detected.

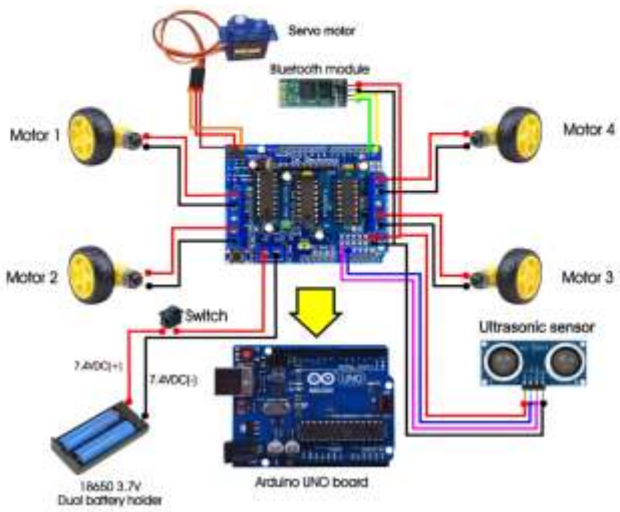
Finally, both modules—obstacle detection and metal detection—are integrated into a single system. Although they operate independently, their integration results in efficient overall performance, minimal hardware cost, and low energy consumption.

5. RESULTS AND DISCUSSION

5.1 Obstacle Detection

The system successfully detects obstacles within a range of **2 cm to 5 cm**, and the identification accuracy remains consistent in both **indoor** and **outdoor** environments. As an object approaches the sensor, the **buzzer frequency increases**, providing an effective auditory warning. Additionally, the **LED offers clear visual feedback**, enhancing the user's awareness of nearby obstacles.

The vehicle responds promptly by navigating around objects and demonstrates smooth movement without collisions, confirming the reliability of the obstacle detection mechanism.



5.2 Metal Detection Results

The metal detection module reliably identifies small metallic objects such as **coins, keys, and small tools** when brought near the sensing coil. The system operates effectively within a detection range of **3–5 cm**, depending on the coil dimensions and surrounding conditions.

When a metallic object enters the electromagnetic field of the copper coil, it causes a **shift in the oscillator frequency**. This variation is detected and amplified by the transistor circuitry. Upon successful detection, both the **buzzer** and **LED** provide clear audio-visual indications, confirming the presence of metal.

5.3 Features of the Proposed Model

The integrated system demonstrates stable and interference-free operation, allowing both the obstacle detection and metal sensing modules to function simultaneously without performance degradation. The overall power consumption remains low, contributing to extended operational time and suitability for portable, battery-powered applications. The combined architecture ensures consistent system behavior, efficient resource utilization, and enhanced usability for mobile embedded platforms.

6.CONCLUSION

The Arduino-based Obstacle Detection and Metal Detector device successfully integrates two different sensing techniques into a single embedded system. The ultrasonic sensor provides accurate distance measurement, while the metal detector reliably identifies metallic objects. The system is low-cost, easy to build, and useful for applications in robotics, assistive technologies, and basic security. With further enhancements, it can be developed into more advanced detection tools, such as obstacle-avoiding robots, underground metal detectors, industrial object sorters, and even as a prototype for landmine detection.

FUTURE SCOPE

1. Add IoT support for remote monitoring and control.
2. Implement Bluetooth or Wi-Fi alerts for real-time notifications.
3. Design a compact PCB to reduce size and improve portability.
4. Enhance the metal detection range for better sensitivity.
5. Integrate machine learning algorithms for metal type classification.

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