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Ultrasonic Sensor-Based Embedded System for Vehicular Collusion Detection and Alert

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Abstract

The efficacy of an automated collision detection system is contingent upon the caliber and volume of data at its disposal. In the event that the data is deficient, incongruous, or erroneous, it has the potential to generate erroneous positive or negative outcomes, thereby compromising the system's credibility. The occurrence of false positives is observed when the system erroneously identifies genuine activity as collusion. The phenomenon of false negatives arises when the system is unable to identify instances of genuine collusion. Collusion detection systems are required to handle substantial volumes of data in real time, capable of analyzing relationships between different objects. The intricate nature of collusion can pose difficulties in devising and executing efficient systems for its detection. The present study proposes an automated anti-collision system that utilizes sensor devices to detect objects and activate an alert mechanism in the event that the vehicle approaches the object in close proximity. The study introduces a novel methodology for mitigating vehicular accidents by implementing a combined system that integrates collision detection and alert mechanisms. The proposed system comprises an ultrasonic sensor, a microprocessor, and an alarm system. The sensor transmits a signal to the microcontroller, which in turn sends a signal to the warning unit. The warning unit is designed to prevent potential accidents by emitting an audible warning signal through a buzzer. Additionally, the distance information is displayed on an LCD screen. The Proteus Design Suite is utilized for simulation purposes, while Arduino.cc is employed for implementation.

Keywords

Ultrasonic Sensor, Microcontroller, Collision Detection, Machine Learning Algorithms

1. Introduction

Road accidents have increased notably in the last decade especially with the rapid advancement in automobile technologies without a commensurate enhancement in collusion detection and alert systems. Consequently, there has been a surge in accidents caused by speeding or driver distractions. Auto collisions have been attributed to multiple factors including but not limited to distraction while driving, speeding, driving under the influence of alcohol, and recklessness [1]. Other causes that can increase the probability of accidents include insufficient road design, mutilated road signage, the absence of safety barriers, and inadequately marked pedestrian crossings, road construction due to various activities such as lane closures, detours, and uneven road surfaces. The presence of faults in automobiles, such as faulty braking mechanisms, tyres, or steering apparatus, possesses the capacity to result in collisions [2]. Natural factors can increase the probability of collisions, including unfavorable weather conditions like heavy precipitation, snowfall, and fog [3]. In recent times, a range of safety measures have been implemented that extend beyond conventional features such as seatbelts and headlights. Technological advancements have introduced several systems, including an accident detection system that employs sensors [3] [4]. The system proposed in this work differs from other solutions as it utilizes multiple ultrasonic sensors that facilitate accident detection. The utilization of an ultrasonic sensor involves the emission of sound waves to determine the distance between the sensor and an object. The sensor subsequently awaits the return of the sound wave in the event of a collision with the object. The duration of the wave's return is indicative of the distance between the sensor and the object. The system detects impediments present on the roadway and responds by engaging the vehicle's braking mechanism. The advancement in this approach is that it can facilitate the circumvention of impediments on the roadway [5] [6]. The integration of a sensor, microcontroller, and alert system has demonstrated significant efficacy in mitigating collision-related concerns. The present study employs an ultrasonic sensor to detect objects or obstacles situated in the vicinity of the vehicle, both in front and behind, and subsequently transmits a signal to the microcontroller unit. The microcontroller unit transmits a signal to the alert unit upon receiving data from the ultrasonic sensor, which subsequently informs the driver of any potential hazards.

2. Review of Literature

Collision detection and alert systems using sensors have been the focus of numerous studies in recent years. A study that investigated the development of a forward collision warning system using a low-cost radar sensor [7] focused on the development of a forward collision warning system using a low-cost radar sensor. The system was designed to detect vehicles in front of the host vehicle and provide warnings to the driver if a collision was imminent. The authors found that the system was effective in detecting potential collisions and could help reduce the risk of accidents. Other works on efficient collision detection and avoidance system for intelligent vehicles was carried out by Krishnan [8]. The author proposed an efficient collision detection and avoidance system for intelligent vehicles. The system used a combination of lidar and camera sensors to detect potential hazards and provide warnings to the driver. The authors found that the system was effective in detecting potential collisions and could help improve road safety. However, this work contrasted significantly with a study of real-time collision avoidance using stereovision and lidar [2]. This study proposed a real-time collision avoidance system using stereo vision and lidar sensors. The system was designed to detect and avoid obstacles in the vehicle's path. The authors found that the system was effective in detecting obstacles and could help improve the safety of autonomous vehicles. Intelligent collision detection system using machine learning algorithms has also been researched extensively [4] [9]. Using machine learning techniques, the approach detects potential collisions and uses a combination of sensors, such as radar and lidar, to collect data about the vehicle's surroundings. This data is then processed using machine learning algorithms to detect potential hazards, such as other vehicles or obstacles on the road [5]. The machine learning algorithms used in these systems are typically trained on large datasets of sensor data, allowing them to recognize patterns and identify potential hazards with a high degree of accuracy. The system can then provide warnings to the driver, such as visual or auditory alerts, to prompt them to take action to avoid the collision. Intelligent collision detection systems using machine learning algorithms have several advantages over traditional collision avoidance systems [10]. For instance, the approach can adapt to changing road conditions and can detect potential hazards that may not be immediately visible to the driver. It can also learn from real-world driving data, allowing the system to continually improve its accuracy and effectiveness [5]. Intelligent collision detection systems using machine learning algorithms are an important development in collision avoidance technology, and have the potential to significantly improve road safety and reduce the risk of accidents.

Collision avoidance systems have seen significant advancements in recent years, with the use of advanced sensor technologies, machine learning algorithms, and other innovative techniques. Advanced Sensor Technologies as a modern collision avoidance system uses a variety of advanced sensor technologies, such as radar, LiDAR, and cameras, to detect obstacles and other vehicles on the road [1]. These sensors provide high-resolution data, which is then analyzed by advanced machine learning algorithms to make real-time decisions about how to avoid collisions. Machine learning algorithms also play a critical role in modern collision avoidance systems. These algorithms use complex models to analyze sensor data, identify potential hazards, and make decisions about how to avoid collisions. As machine learning algorithms become more sophisticated, collision avoidance systems are becoming more effective and efficient. Another key advancement in collision avoidance systems is the use of vehicle-to-vehicle communication [11]. This technology allows vehicles to exchange information with each other, such as speed, direction, and location, in real-time. By sharing this information, vehicles can coordinate their movements to avoid collisions more effectively. Many modern vehicles now come equipped with automated emergency braking systems, which can detect potential collisions and automatically apply the brakes to avoid them. These systems use a combination of sensors and machine learning algorithms to detect potential hazards and respond quickly to avoid collisions [7] [12]. Collision avoidance systems are also becoming more effective at detecting pedestrians, cyclists, and other vulnerable road users. Advanced camera and sensor technologies, combined with machine learning algorithms, can detect and track these users, and alert drivers if a potential collision is detected.

Advanced Sensor Technologies has gained more traction in collision avoidance due to its ability to provide high-resolution data about the vehicle's surroundings in real time. This allows the collision avoidance system to detect potential hazards, such as other vehicles or obstacles on the road, and take proactive measures to avoid collisions. Current researchers have explored these benefits by applying radar sensors to detect the distance, speed, and direction of objects, while lidar sensors use lasers to create detailed 3D maps of the environment. Cameras deployed with sensors have enabled capturing images and video of the vehicle's surroundings for analysis using machine learning algorithms to identify potential hazards [8] [13]. By combining these sensors and analyzing the data they provide, collision avoidance system can make informed decisions about how to avoid collisions, such as applying the brakes or steering the vehicle away from potential hazards. This can help reduce the risk of accidents, improve road safety, and potentially save lives. Ultrasonic sensors have the capability to detect nearby objects in the vicinity of a vehicle or equipment. The aforementioned sensors transmit sound waves of high frequency and subsequently calculate the duration it takes for the waves to reflect back. In the event that an object is detected within a specified range, the system has the capability to notify the operator through the use of an alarm or visual display [6] [14]. Radar sensors which use radio waves to detect objects have the capability to detect objects at distances that exceed those achievable by ultrasonic sensors. Collision avoidance systems, such as adaptive cruise control, frequently employ them to automatically regulate the speed of a vehicle in response to the proximity of the preceding vehicle [15]. LiDAR sensors employ laser light to detect objects and are capable of providing distance measurements with a high degree of precision while Infrared sensors have the capability to detect thermal radiation emitted by objects, including living beings such as animals and humans. Pedestrian detection systems in vehicles frequently employ them. Autonomous vehicles frequently employ them for the purposes of collision avoidance and navigation. Many authors have suggested that sensors have the capability to furnish a variety of data pertaining to the ambient surroundings and can be employed for the purpose of identifying objects and notifying operators of probable collisions [1] [5] [16]. The implementation of such systems has the potential to significantly enhance safety across various domains, including but not limited to transportation and industrial machinery. Overall, these studies suggest that collision detection and alert systems using sensors can be more effective in improving road safety and reducing the risk of accidents [4]. By combining different types of sensors and using advanced machine learning algorithms, these systems can detect potential hazards and provide warnings to drivers, allowing them to take proactive measures to avoid collisions

3. Method

This research is based on the basic principles of computer vision, signal processing, and machine learning [6] [17]. Computer vision is concerned with the development of algorithms and techniques for processing and interpreting visual information from cameras and other sensors. This includes techniques such as image segmentation, feature extraction, object recognition, and tracking. Signal processing involves the analysis and manipulation of signals, such as those generated by radar and lidar sensors [4]. The method applied incorporates techniques for filtering, feature extraction, and pattern recognition. Machine learning has been used in a wide range of applications, including image recognition, speech recognition, natural language processing, recommendation systems, fraud detection, and autonomous vehicles [18] [19]. Using a machine learning approach, the proposed system is presented with a large dataset that includes features and labels. The algorithm uses this data to identify patterns and relationships in the data and creates a model that can predict the labels of new data based on the learned patterns [14] [20]. Overall, the technological theory that underpins this research work on collision detection is focused on developing effective algorithms and techniques for processing and analyzing sensor data to detect potential hazards and provide timely warnings to drivers. This work proposes to design, simulate and implement a collision detection system utilizing sensors and a microcontroller. The ultrasonic sensor is embedded in the design to detect objects in front of and behind the car and delivers a signal to the microcontroller, which then sends a signal to the warning unit to prevent a potential accident. A buzzer is deployed in the warning system as an alarm and an LCD is used to display information about the distance. "Proteus Design Suite" is used for the simulation, while "Arduino.cc" is deployed for implementation. Microcontroller-Arduino Uno is used to connect the sensors to the microcontroller allowing the microcontroller to be able to read and interpret data from sensors in real time. The sensor data is processed by the microcontroller to detect potential risks such as other vehicles or road barriers. Using the processed sensor data, the collision detection circuit design is implemented using the Proteus Simulation tool. Based on the distance, speed, and direction of other objects in the vehicle's path, the algorithm is developed to detect probable collisions. An alert system is also developed to warn the motorist of probable crashes. In this case, the alert unit is visual and consists of the buzzer, LED, and LCD all act according to the commands and conditions of the system to allow the driver ample time to avoid an accident. Testing and validation of the prototype is simulated using the Proteus Design Suite. The tool simulates collision scenarios to check that it works as it should. This validates the effectiveness of the system and accuracy in recognizing potential threats and alerting the driver in a timely manner.

The proposed system possesses unique specifications that distinguish it from pre-existing technologies in the literature. It enables both forward and backward collision avoidance by presenting distance information and danger warnings. Notably, the braking system will remain unaffected by this system. The primary operations of this system are controlled and processed by an Arduino microcontroller, which assumes responsibility for the entire process. The microcontroller is linked to an LCD screen, LEDs, and a buzzer, in addition to an Ultrasonic sensor. The microcontroller is utilized to integrate the code written using Arduino into the simulation. During the hardware development process, the interconnection of components is evaluated on a breadboard according to the circuit design in Proteus Design suite. The resulting circuit integrates both the microcontroller and sensor. Finally, the operational functionality of the transmitter and receiver is evaluated, and their interconnectivity is established through the utilization of the Arduino compiler's implementation coding. Subsequently, an analysis of the hardware is conducted to assess its operational capabilities.

- The sensors emit waves in order to obtain the necessary duration of data to determine distance and create a physical map of the space ahead of a vehicle.
- The Microcontroller serves as the central processing unit of the system, responsible for directing the functions and interplay among the various components. Its primary role involves issuing instructions to the sensor, thereby initiating the process.
- The Alert Unit, comprising of the buzzer, LED, and LCD, operates in accordance with the system's commands and conditions.

The initiation of the project involves the creation of a circuit that adheres to the component specifications, taking into account interconnectivity requirements. Components used include the Ultrasonic sensor-HR SC-04 Ultrasonic, Microcontroller-Arduino Uno, Alert machine/Buzzer-For audible warning, LCD screen-For visual warning, LED Lights-Three Colors; Green Yellow and Red are used to represent different distances and levels of alert, Connector wires-Jumper wires are required to make hardware connections and Resistors. The central component responsible for the system design is the microcontroller, specifically the Arduino Uno. This microcontroller is comprised of either 32-bit Atmel ARM or 8-bit Atmel AVR microcontrollers. The device in question possesses six analogue pins, denoted as A0 through A5, as well as a distinct segment dedicated to power pins. Additionally, it is equipped with 13 digital pins, numbered 0 through 13. The microcontroller is equipped with a range of features, including a USB connection, a power jack, an In-Circuit Serial Programming (ICSP) header, and a reset button. The initiation process involves establishing a connection between the Uno and a computer via a USB cable or energizing it with a battery. The programming of the Arduino Uno is facilitated by the utilization of the Arduino

Software. The range of the Ultrasonic sensor encompasses the detection of object distances from 3 cm to 400 cm. The design incorporates the HC-SR04 Ultrasonic sensor, a four-pin module featuring pins labelled VCC, Trigger, Echo, and Ground. The aforementioned sensor is utilized in scenarios that pertain to the measurement of distance and the detection of objects. The module is equipped with a pair of front-facing projects that resemble eyes, and these projects are responsible for generating the Ultrasonic transmitter and Receiver. The module operates based on the following formula: distance = (duration/2)/29.412. Both the Trigger and Echo pins are input/output (I/O) pins that establish a connection with the microcontroller's I/O pins. The measurement process is initiated by enabling the trigger pin, which is subsequently set to a high state for a duration of 10 microseconds before being transitioned to a low state. The transmitter initiates a wave with a frequency of 40 Hz, while the receiver (echo) awaits the return of the wave. When an object reflects a wave, the resulting signal is detected by the Echo pin, which remains in a high state for the duration of the reflected wave. The microcontroller/microprocessor unit (MCU/ MPU) measures the duration of the Echo pin's high state, which corresponds to the time taken for the wave to return to the sensor. Utilizing this method, the measurement of distance is ascertained and computed through the aforementioned formula.

4. Simulation and Results

Proteus Design Suite 8 is used for designing and simulating the circuit, having one of the tools needed for circuit design and simulation. Used as an application framework; a single application integrated with ISIS, ARES and 3D Viewer is displayed in a tabbed module. The schematic of the circuit is shown in **Figure 1**, and is constructed on a breadboard and then tested to meet predefined design specifications.

Arduino, the open-source platform on hardware and software is used to write the algorithm for the work in C++. The Arduino allows comprehensive model view, code factorization and input conversion. The Arduino **Algorithm 1** connections initialized for the system are shown in **Algorithm 1**.

Algorithm 1. Arduino algorithm 1 (connections initialized).

```
#include<LiquidCrystal.h>
const int rs =12, en = 11, d4 =5, d5 = 4, d6 = 3, d7 = 2;
LiquidCrystal lcd(rs, en, d4, d5, d6, d7);
int trigPin1 = 9;
int echoPin1 = 7;
int trigPin2 = 10;
int echoPin2 = 8;
int green =A0;
int red =A2;
int yellow =A1;
int buzzer =A3;
```

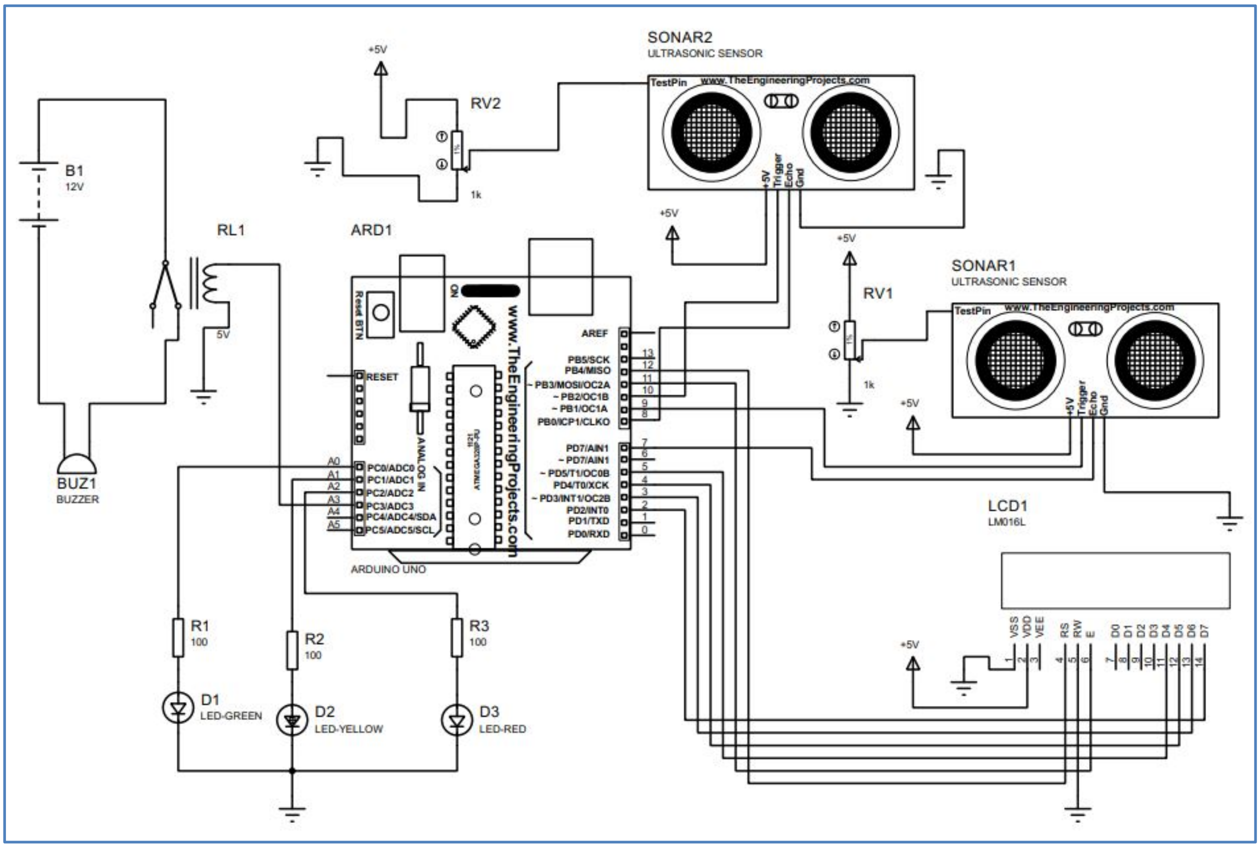

Figure 1. System circuit schematic diagram.

The code depicted in Algorithm 2 and Algorithm 3 segments is responsible for managing the operations of the ultrasonic sensor. The trig pin initiates at a low state, undergoes a 2-microsecond delay, transitions to a high state, experiences a 10-microsecond delay, and subsequently returns to a low state (Algorithm 2). The initial high pitch of the echo is utilized to ascertain the duration of the time frame. The duration is utilized to compute the distance.

The code in Algorithm 3 shows encryption of a basic algorithm to detect objects and capture their distance using an ultrasonic sensor is encrypted. Following the initialization of the ultrasonic sensor defined by trigger and echo pins (Algorithm 1), the serial communication transmits the distance readings to the system. A conditional statement sends a trigger pulse to the ultrasonic sensor to measure the time it takes for the pulse to bounce back from an object using the echo pin. The time measurement is converted to distance and the known time it takes for sound to travel. The outcome and the output of the distance reading are displayed on the LCD system (Algorithm 3).

The system's cases are presented in Figure 2, along with the corresponding simulation outcomes. In cases where the computed distance exceeds 200 units, the green LED illuminates and the LCD screen exhibits the distance value. However, the buzzer remains inactive and does not emit any auditory signals. In the case where the calculated distance is less than or equals 200 cm but greater

Algorithm 2. Arduino algorithm 2 (trig pin for the first ultrasonic sensor connected to pin 9 of Arduino).

```
long duration, distance;
digitalWrite(trigger, LOW);
delayMicroseconds(2);
digitalWrite(trigger, HIGH);
delayMicroseconds(10)
digitalWrite(trigger, LOW);
duration = pulseIn(echo,HIGH);
distance = (duration/2)/29.412;
```

Algorithm 3. Arduino object detection and distance capture algorithm.

```
If (distance>200)
{
        lcd.setCursor (0,0);
        lcd.print("NO OBSTACLE ");
        lcd.setCursor (0,2);
        lcd.print("WITHIN:");
        lcd.print ("200cm");
         digitalWrite(yellow,LOW);
         digitalWrite(green,HIGH);
         }
Else if (distance<=200 || distance>100)
{
          lcd.setCursor (0,0);
          lcd.print("OBJECT DETECTED ");
          lcd.setCursor (0,2);
          lcd.print("AT: ");
          lcd.print(distance);
          lcd.print ("cm");
          }
If (distance >= 200)
  {
             digitalWrite(red, LOW);
            }
```

than 100 cm, the yellow LED lights up and starts to blink indicating the detection of an obstacle within 200 cm and 100 cm, the LCD displays the message "Object detected" along with the distance, the buzzer turns on and off, beeping for this condition. For the Detection phase, The Ultrasonic sensors are fully implemented. For the alert and notification phase, the Alert unit is implemented.

As shown in Figure 3, the Ultra-sonic sensors respective pins are used in detection. The trigger pins are kept high for 10 us and an ultrasonic wave is set out, the echo pins go high for the period of time that equals the time taken for the ultrasonic wave to travel back, When the wave returns, an object/obstacle has been detected. The distances are then calculated using this formula-distance = (duration/2)/29.412. The ultrasonic sensor/s continuously detects the range for any nearby obstacle.

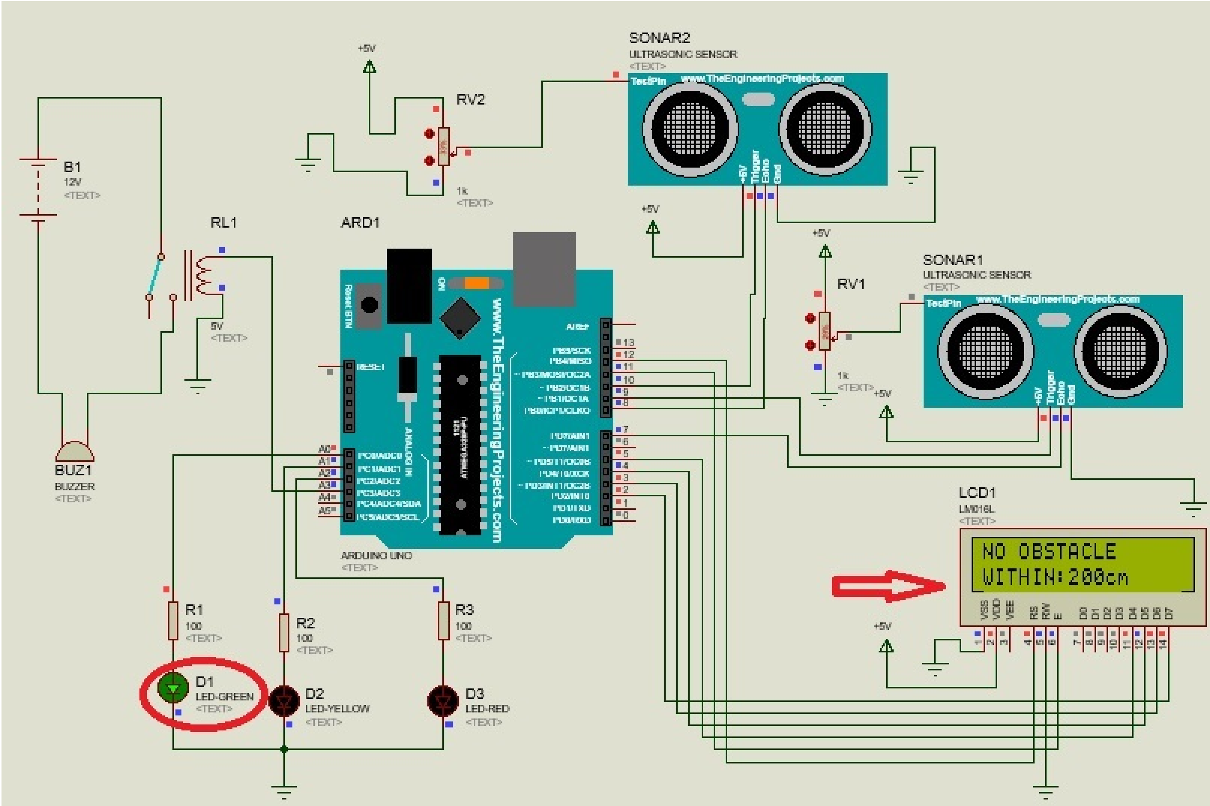

Figure 2. Case 1 of simulation (computed distance exceeds 200 units).

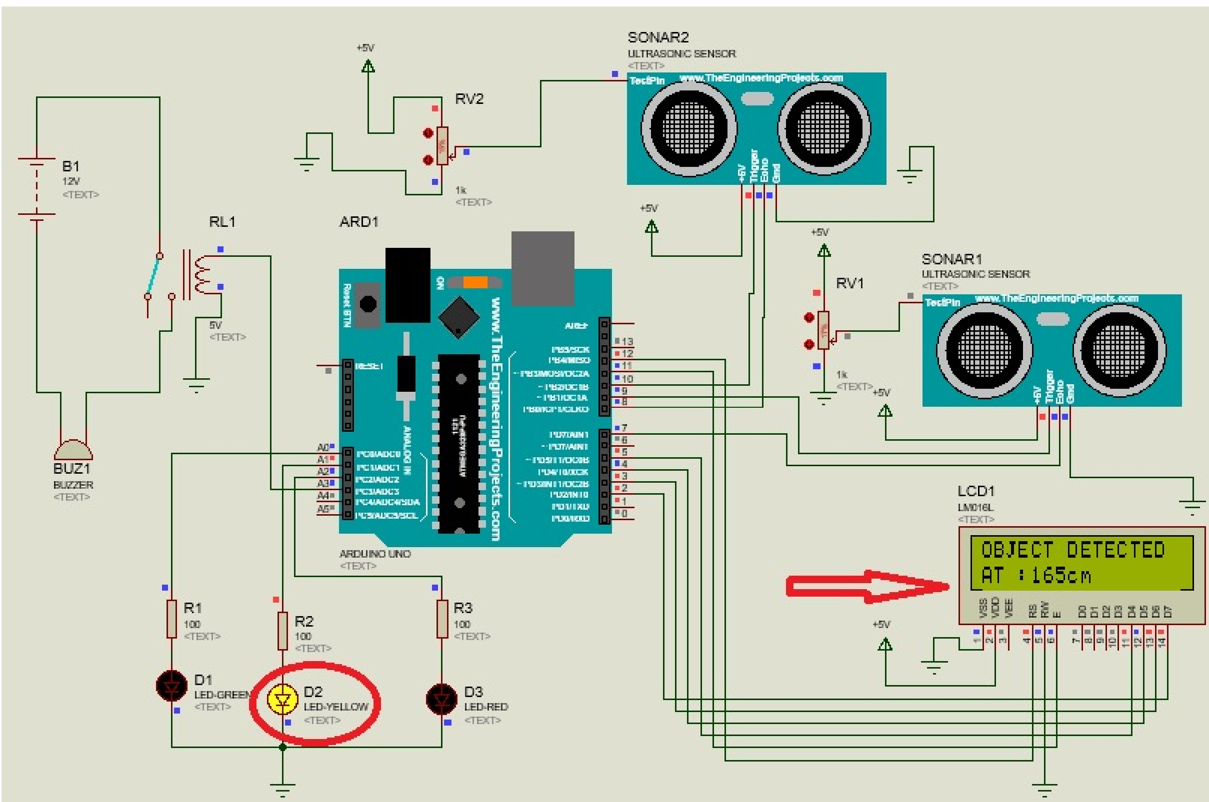

Figure 3. Case 2 of simulation (Object Detected).

The Alert and Notification phase is depicted in the simulation in **Figure 4**. Also described in the code, The Microcontroller controls the actions of the alert unit. For the testing process, proteus design suite 8 is used to design the circuit and simulate it. A potentiometer (POT-HG) is an active variable used with the test pin of the ultrasonic sensor during the simulation to change resistance. The cases for the system are shown below with the simulation results: In the case where the calculated distance is greater than 200, the green LED lights up and the LCD displays the distance, the buzzer does not go off (no sound is given off). The process of constructing the system entails meticulous adherence to the schematics derived from the circuit diagram. This involves the precise connection of pins on the breadboard to facilitate testing, followed by the meticulous soldering of components onto a board for ultimate implementation. Upon completion of the requisite circuit connections, it is imperative to upload the code onto the Arduino board utilizing the Arduino IDE.

5. Discussion

The purpose of collision detection systems is to identify possible collisions among objects situated within a tangible setting, such as automobiles on a roadway or unmanned aerial vehicles in the atmosphere. The integration of such systems can effectively mitigate the occurrence of accidents and enhance safety,

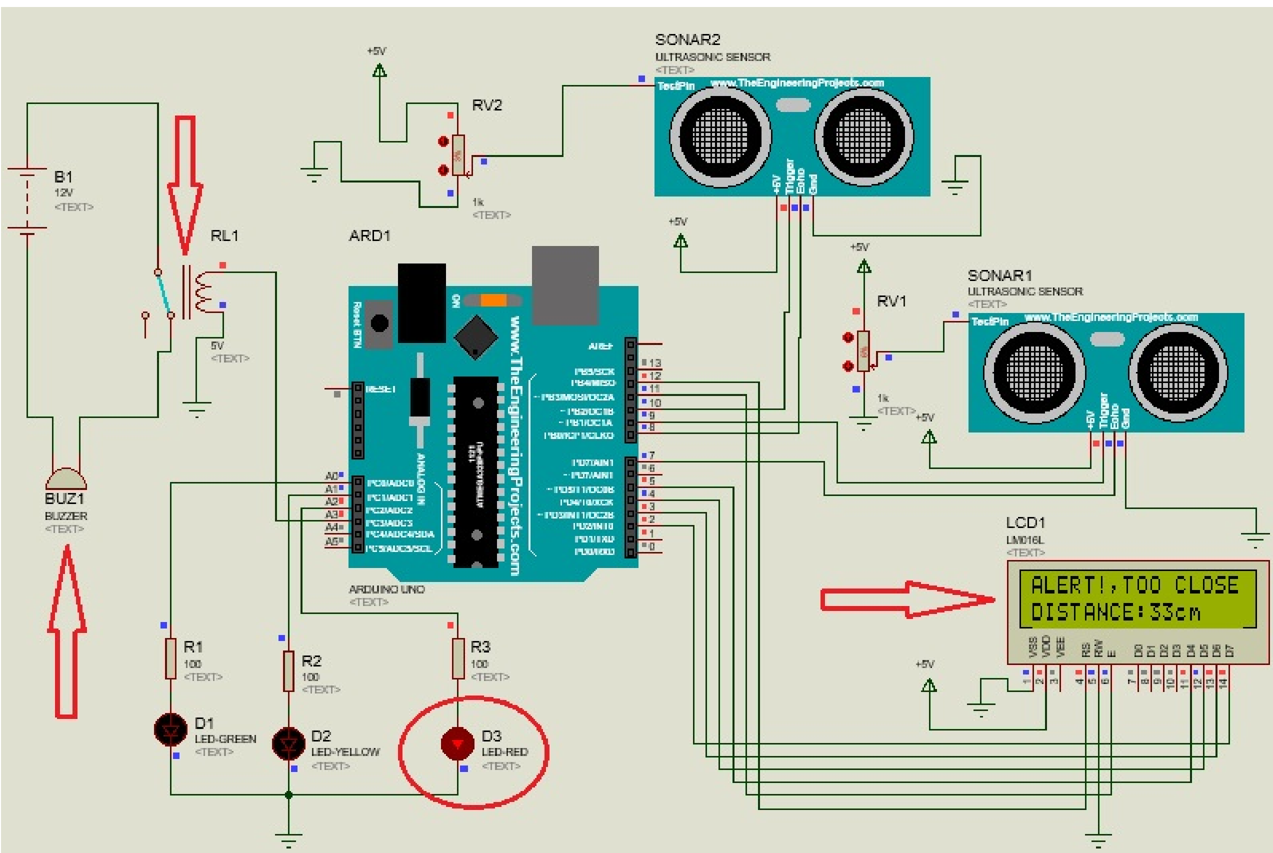

Figure 4. Case 3 of simulation (Alert Generation).

rendering them a crucial constituent of contemporary advancements such as autonomous vehicles and unmanned aerial vehicles. The operational principle of collision detection systems involves the utilization of sensors to perceive the position, velocity, and trajectory of entities within the surroundings. Subsequently, the aforementioned data is utilized by the system to compute the probability of a collision and execute suitable measures to evade it. The system may employ a variety of sensors such as cameras, radar, lidar, or others, depending on the specific application, to collect data pertaining to the surrounding environment. The requirement for precision and promptness poses a difficulty in collision detection systems. The prompt detection and accurate response to potential collisions is imperative as collisions can transpire within a brief moment. The task necessitates advanced algorithms and hardware with superior performance capabilities to enable real-time data processing. One of the challenges associated with collision detection systems pertains to the requirement of differentiating between authentic threats and erroneous positives. The ability to differentiate between a pedestrian moving on the sidewalk and a tree branch swaying in the wind is a crucial requirement for the collision detection system of an autonomous vehicle. In order to tackle this issue, collision detection systems frequently employ machine learning algorithms, which are capable of acquiring knowledge about patterns in the data and enhancing the precision of predictions. In general, collision detection systems represent a significant technological advancement with the potential to mitigate fatalities and avert mishaps. The development and execution of efficient collision detection mechanisms necessitate meticulous evaluation of the specific use case, the surrounding context, as well as the probable hazards and complexities.

The implementation of a collision detection and alert system has been shown to decrease the likelihood of vehicular accidents, enhance driving safety, facilitate route optimization for navigating challenging road conditions, and ultimately promote greater safety and security for occupants of wheeled vehicles. Therefore, it is probable that autonomous driving will have a significant impact on the transportation industry in the near future, as its primary objective is to reduce the likelihood of property damage or loss of life resulting from preventable road accidents. The project on Collision detection and alert has the potential to assume a crucial function in everyday life in the future. The system has been devised to be user-friendly and economically viable. This project exhibits a broad potential for expansion, as the system may be implemented with additional improvements. By implementing targeted adjustments to the detection and alert unit, it is possible to expand the system's sensor capacity and incorporate an additional Arduino Uno microcontroller to segregate the various units into distinct phases. The detection phase would comprise multiple sensors and an Arduino Uno microcontroller dedicated solely to detection, while the alert phase would follow a similar process. The simulation testing of the system done using proteus design suite, is shown in the two phases of the system's working process:

1) Collision Detection Phase

2) Alert and Notification Phase

The data used for the evaluation and testing of the system were obtained from feeds from the sensors. The Ultrasonic sensors were fully implemented for the Detection phase. The implementation of the Alert unit is carried out for the phase of alert and notification. Implementation of the Detection Phase is delineated in the code as well as the ultrasonic sensors' corresponding pins are wired for detection **Figure 4**. Upon activation of the trigger pins, an ultrasonic wave is emitted for a duration of 10 microseconds. Subsequently, the echo pins are elevated for a duration equivalent to the round-trip time of the ultrasonic wave. Upon the return of the sequence, the presence of an object or obstacle would be detected. The formula utilized for calculating distances allows the ultrasonic sensors to persistently ascertain the distance to any adjacent obstruction. The phase of Alert and Notification is delineated in the algorithm. The Microcontroller controls the operations of the alert unit. The circuit design and simulation for the testing process is carried out using Proteus Design Suite 8. The POT-HG, which is an active variable, is utilized in conjunction with the test pin of the ultrasonic sensor during simulation in order to modify resistance.

6. Conclusion

The present study introduces a novel approach for identifying impediments and entities on thoroughfares with the aim of mitigating vehicular collisions. Various contemporary methods have been implemented to mitigate the negative impact of vehicular collisions, such as the utilization of intelligent mobile devices for emergency communication and the integration of detection systems with mobile applications [21]. Notwithstanding their perceived efficacy in accident detection, these techniques are subject to recognized constraints. The study carried a development of a modular front and rear anti-collision warning system that is user-friendly and can be conveniently installed on a wide range of automobiles and motorcycles. The aforementioned system comprises a sensor with the capability to measure distances, LEDs, an LCD display, and a buzzer that is reinforced by a relay, thereby facilitating the production of varying degrees of auditory output. The utilization of simulation testing and Arduino IDE coding for the connection of the system to the Arduino microcontroller enhances its reliability and reduces the likelihood of malfunction or failure.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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