

# A Low-Cost Real-Time Anti-Collision Warning System for Vehicular Safety

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**Abstract:** Road accidents, particularly rear-end collisions, remain a major global concern due to increasing vehicle density and human error. This paper presents the design and hardware implementation of an anti-collision warning system aimed at enhancing driver safety. The system utilizes distance-measuring sensors, a microcontroller unit, and alert mechanisms to detect obstacles and provide real-time warnings. The proposed model demonstrates a cost-effective and efficient solution suitable for integration into modern vehicles. Experimental results indicate reliable obstacle detection and timely alert generation under varying conditions.

**Keywords:** Anti-collision warning system, embedded systems, ultrasonic sensor, microcontroller, road safety, ADAS.

## 1. Introduction

Road safety has become a critical concern worldwide due to the rapid increase in vehicular traffic and the corresponding rise in road accidents. A significant proportion of these accidents are caused by rear-end collisions, often resulting from driver inattention, delayed reaction time, or poor visibility conditions [1]. To mitigate such risks, advanced driver assistance systems (ADAS) have been developed, among which anti-collision warning systems play a vital role [2]. These systems are designed to detect obstacles or vehicles in close proximity and alert the driver in real time, thereby reducing the likelihood of accidents.

The hardware implementation of an anti-collision warning system involves the integration of sensors such as ultrasonic, radar, or LiDAR modules, along with microcontrollers and alert mechanisms [3]. By processing distance measurements and relative motion data, the system can generate timely warnings through visual, auditory, or haptic feedback [4]. Recent advancements in embedded systems and sensor technologies have enabled the development of cost-effective and reliable hardware solutions suitable for real-world deployment [5]. This paper focuses on the design and hardware implementation of an anti-collision warning system, highlighting its architecture, components, and performance evaluation under various operating conditions.

## 2. Hardware Implementation of Anti-Collision Warning System

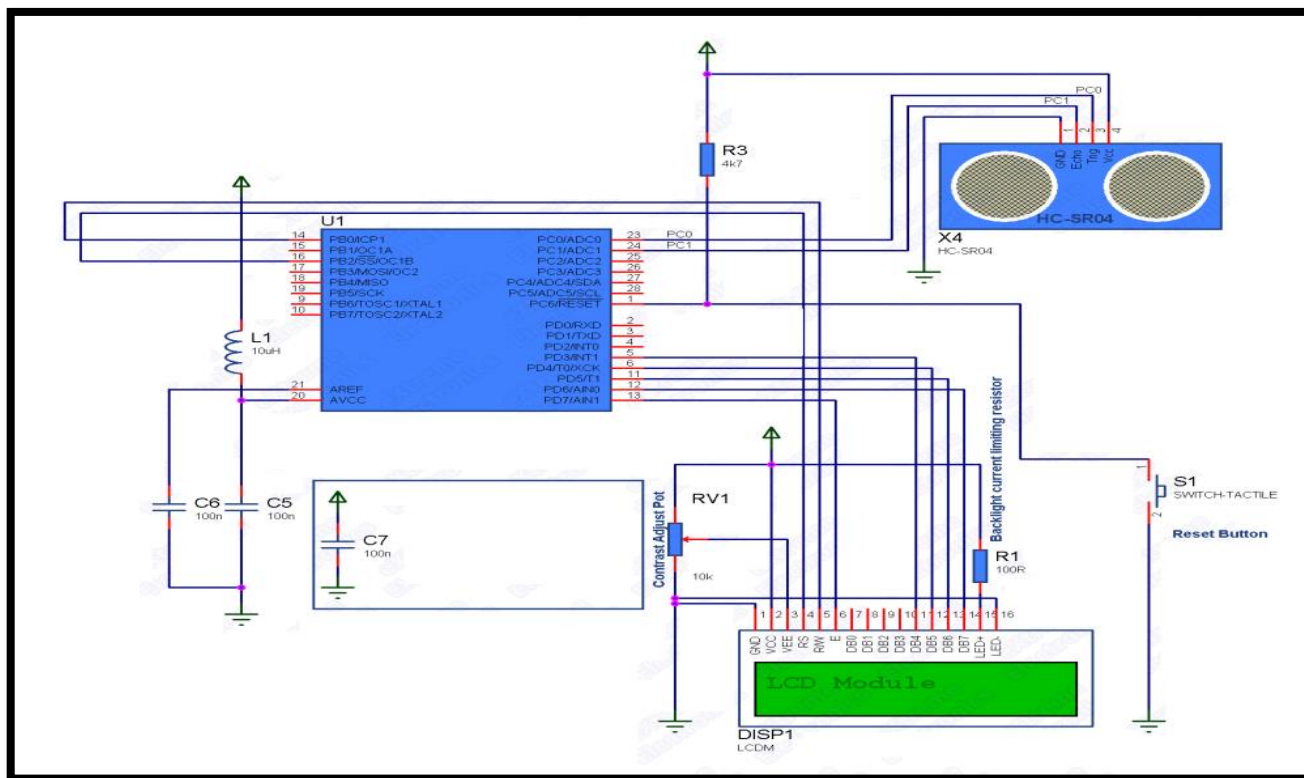
With the successful simulation of multi-target distance measurement at different locations, an anti-collision warning system has been designed and implemented to enhance vehicular safety. For practical deployment, a low-cost ultrasonic sensing approach is adopted as an alternative to conventional radar systems for short-

range applications [6]. The proposed system predicts safe distances and provides early warnings to the driver. It employs an HC-SR04 ultrasonic sensor interfaced with an ATmega8L microcontroller to detect obstacles in the vehicle's path. The microcontroller generates a trigger pulse, causing the sensor to emit a 40 kHz ultrasonic wave, which reflects off obstacles and returns as an echo signal. The distance is calculated based on the echo time and displayed on a 16×2 LCD panel [7].

Furthermore, a three-level warning mechanism is implemented to ensure driver awareness. When an object is detected within 60 cm, a visual alert is generated; at 40 cm, an additional warning indicates the need for braking; and at critical proximity, both visual and audio alerts are activated to prompt immediate action [8]. To enhance system capability, X-Bee wireless communication is integrated for real-time data transmission to a computer, where MATLAB is used for data acquisition, visualization, and analysis of driving patterns [9]. The system operates on a regulated 5V power supply, making it suitable for vehicular integration. This hardware implementation demonstrates an efficient, low-cost solution for real-time collision avoidance in short-range scenarios.

### **3. Block Diagram Description**

The proposed system consists of a microcontroller-based embedded design that integrates sensing, processing, and display units. At the core of the system is the microcontroller (U1), which interfaces with an ultrasonic sensor (HC-SR04) to measure distance. The sensor transmits and receives ultrasonic waves, and the echo signal is processed by the microcontroller to calculate the distance. The measured data is then displayed on a 16×2 LCD module, which is connected to the microcontroller through multiple data and control lines. A potentiometer (RV1) is used to adjust the LCD contrast, while a current-limiting resistor (R1) controls the backlight intensity. The circuit also includes a reset switch (S1) for system reinitialization. Power stability is ensured decoupling capacitors (C5, C6, C7) and an inductor (L1) for noise filtering. Overall, the system efficiently integrates sensing, processing, and user display to provide real-time distance measurement.



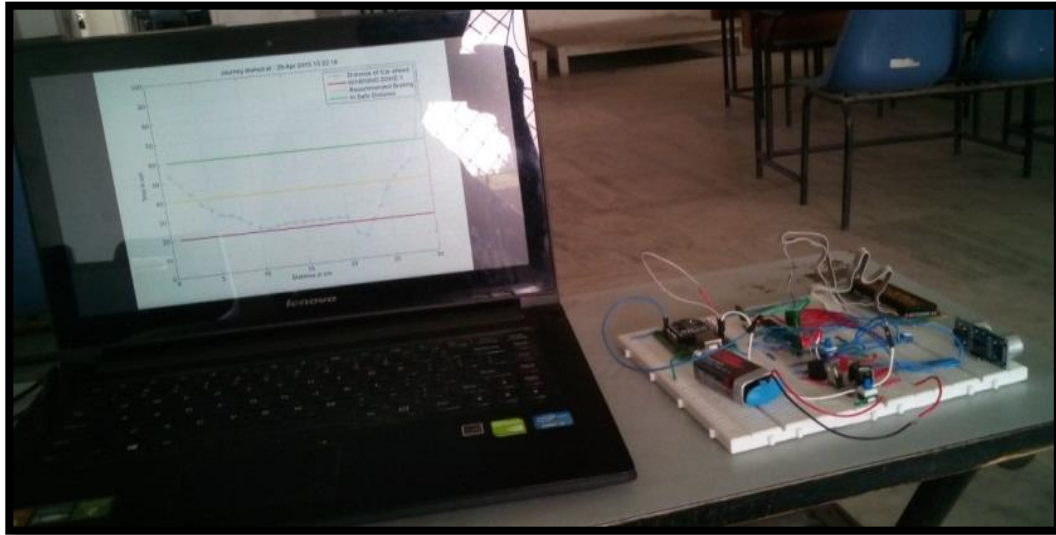
**Fig.1:** Circuit diagram of Anti-Collision Warning System

### 4.Experimental Setup

The experimental setup of the proposed anti-collision warning system consists of a microcontroller-based embedded platform integrated with an ultrasonic sensing module and wireless communication interface. The system utilizes an HC-SR04 ultrasonic sensor interfaced with an ATmega8L microcontroller to measure the distance between the vehicle and nearby obstacles. The microcontroller processes the received echo signal and computes the distance, which is further used to generate warning signals based on predefined safety thresholds.

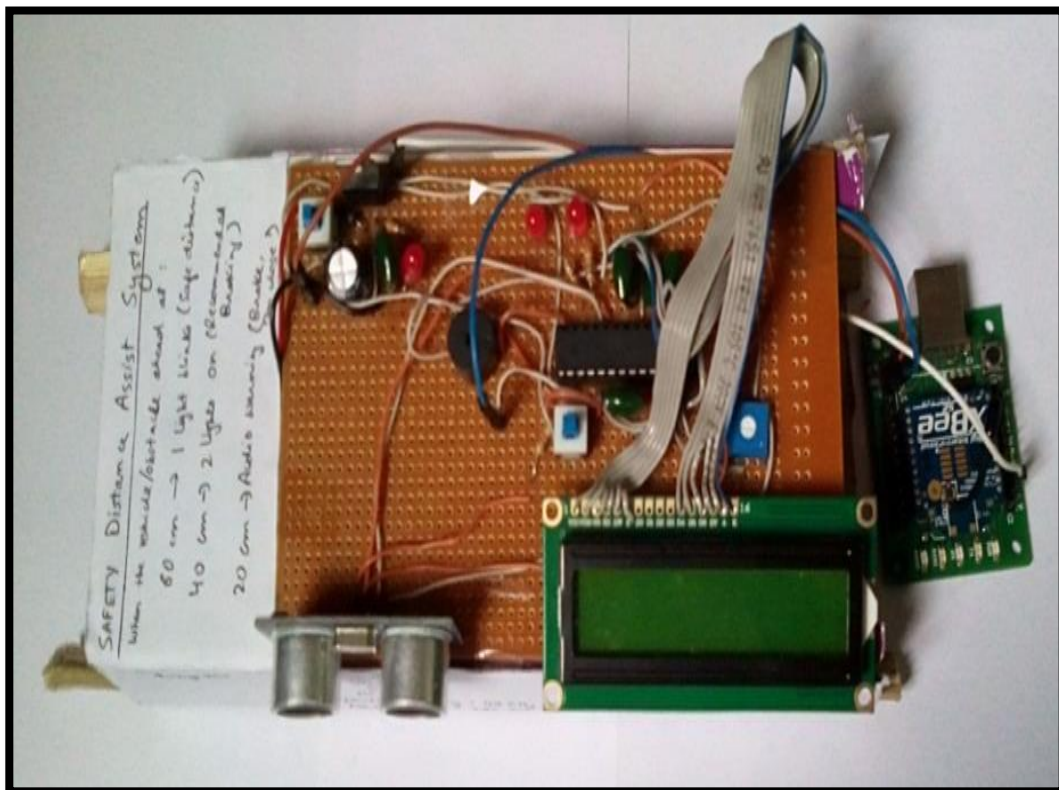
A three-level alert mechanism is implemented using visual (LED indicators) and audio (buzzer) outputs to notify the driver at different proximity levels. The hardware prototype is assembled on a development board and powered by a regulated 5V supply. Additionally, XBee wireless modules are employed to transmit real-time sensor data to a computer system for monitoring and analysis.

The received data is visualized using MATLAB, where distance variations and driver response patterns are plotted, as observed in the experimental results. The setup demonstrates reliable short-range obstacle



**Fig.-2: Hardware implementation of Anti-Collision Warning System.**

detection and effective communication between the embedded system and the monitoring interface, validating the practical feasibility of the proposed anti-collision warning system.



**Fig.-3: Top View of the Anti-Collision Warning System.**

## 5. Test Results

This paper analyzes a time-series graph representing the distance between a host vehicle and a leading vehicle over a 30-second interval. The study evaluates system behavior under predefined safety thresholds, including a warning zone and a safe braking region. Observations indicate dynamic fluctuations in distance, with critical intervals where the vehicle enters unsafe proximity. The analysis highlights the effectiveness of threshold-based alerts in collision avoidance systems.

Maintaining a safe following distance is critical for road safety and collision avoidance. Modern Advanced Driver Assistance Systems (ADAS) rely on continuous monitoring of inter-vehicular distance and predefined thresholds to issue warnings or initiate braking. This paper examines a dataset visualized as a graph showing distance variation over time, identifying key safety states and transitions.

## 6. SYSTEM MODEL AND THRESHOLDS

The graph defines three critical regions:

- **Safe Distance Region:** Distance  $\geq 40$  cm (green line)
- **Warning Zone:**  $20 \text{ cm} \leq \text{Distance} < 40$  cm (yellow region)
- **Critical/Braking Zone:** Distance  $< 20$  cm (red line threshold)

The blue dashed curve represents the real-time measured distance between vehicles.

## 7. DATA ANALYSIS

Fig.-4 presents the variation of the distance between a host vehicle and a preceding vehicle over time for a journey initiated at 01:15:25 on 07-May-2015. The horizontal axis denotes time in seconds, while the vertical axis represents the inter-vehicle distance in centimeters. The blue curve indicates that the distance remains relatively stable within the safe region (above 60 cm) during the initial phase, with minor fluctuations around 55–60 cm. A brief increase in distance is observed between approximately 10 s and 15 s, reaching a peak slightly above the safe threshold, suggesting a temporary reduction in relative speed or increased spacing. Subsequently, the distance exhibits a gradual decline, crossing the safe threshold (60 cm) and entering the recommended braking zone (40–60 cm). As time progresses beyond 20 s, the distance continues to decrease and approaches the lower bound of the recommended braking region, nearing 40 cm but remaining above the critical warning threshold of 20 cm. This trend indicates a controlled reduction in spacing, where timely braking or speed adjustment is implied. Overall, the graph demonstrates a transition from safe following conditions to a cautionary state, highlighting the importance of continuous monitoring and adaptive braking to maintain safe inter-vehicle distances and prevent potential collision scenarios.

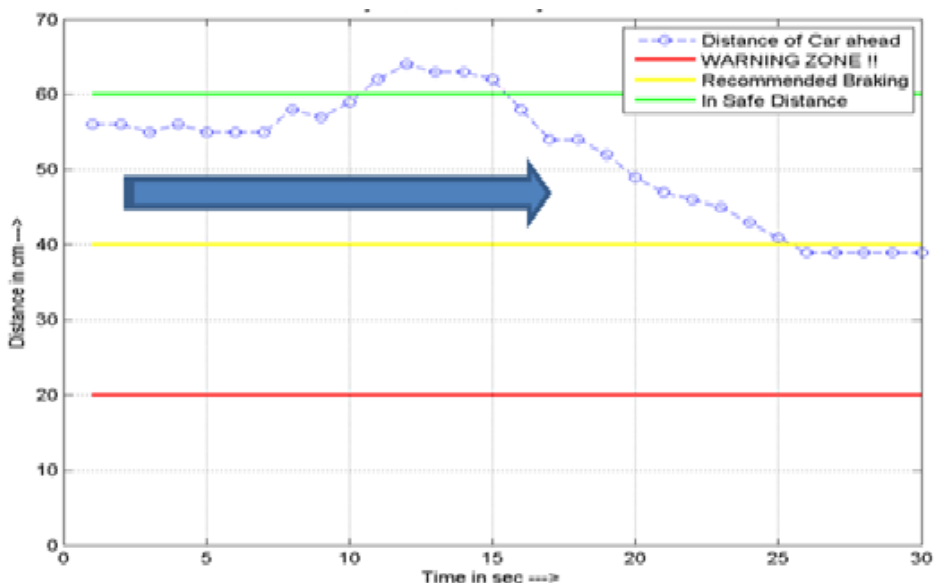


Fig.-4: Test vehicle in between safe distance and recommended braking

Fig.-5 illustrates the temporal variation of the inter-vehicle distance during a driving session that commenced. The x-axis represents time in seconds, while the y-axis denotes the distance (in centimeters) between the host vehicle and the vehicle ahead.

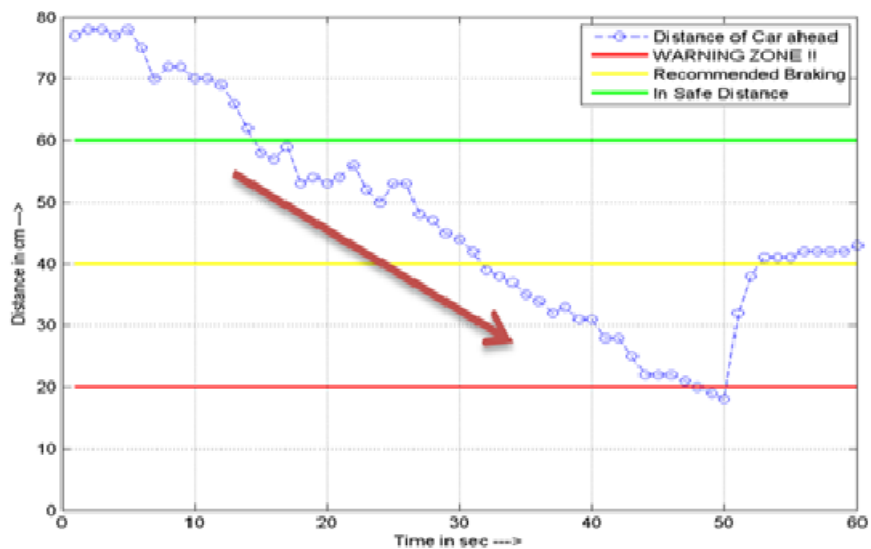


Fig.-5: Test vehicle is coming rapidly towards recommended warning zone.

The plotted blue curve indicates a gradual decrease in distance from approximately 78 cm at the beginning of the observation to nearly 20 cm around the 50-second mark, reflecting a continuous closing gap between the two vehicles. Three threshold zones are superimposed to evaluate driving safety: a green line at 60 cm

indicating a safe following distance, a yellow line at 40 cm representing a recommended braking zone, and a red line at 20 cm denoting a critical warning zone. As the distance falls below the safe threshold, the system transitions from a safe state to a cautionary state, and eventually into the warning zone, suggesting the need for immediate braking intervention. Notably, after reaching the minimum distance, a sudden increase in separation is observed, implying corrective action such as braking or acceleration by either vehicle. Overall, the graph demonstrates the effectiveness of threshold-based distance monitoring in identifying and responding to potential rear-end collision risks in real time. Fig.-6 & 7 depicts the vehicle in between warning and recommended braking zone and Vehicle is out of danger.

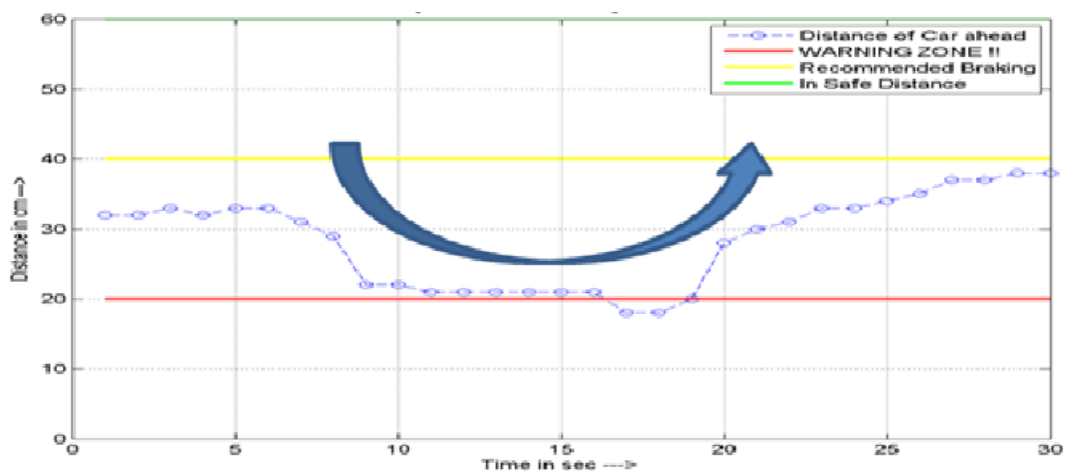


Fig.-6: Test vehicle in between warning and recommended braking zone

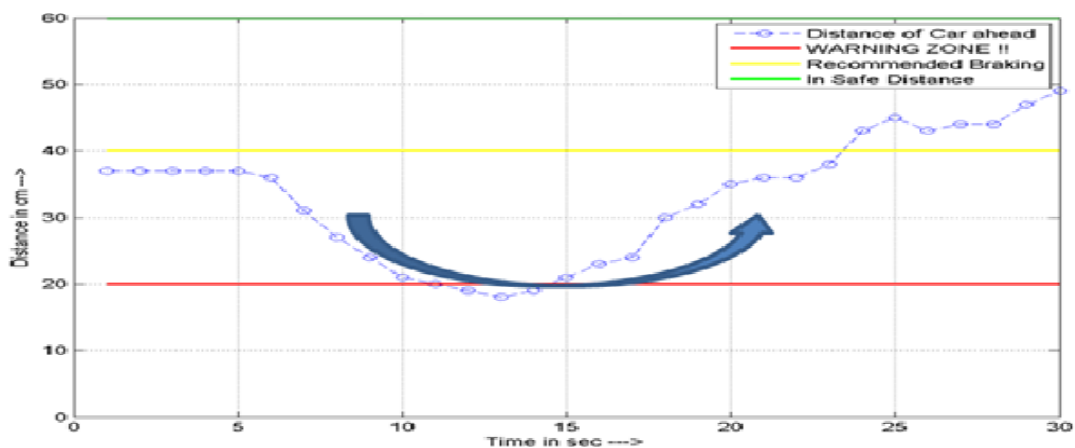


Fig.-7: Test vehicle is out of danger.

## 8. PERFORMANCE EVALUATION

The system demonstrates strong responsiveness by effectively detecting unsafe distances as the vehicle enters the defined critical zone, thereby enabling timely intervention. Furthermore, the system exhibits stability in its operation, as evidenced by its ability to maintain a gradual and controlled increase in distance following the implementation of corrective actions, ensuring smooth and predictable behavior. Additionally, the effectiveness of the predefined thresholds is clearly observed, as they successfully delineate safe and unsafe regions, thereby enhancing the clarity and reliability of the decision-making process.

## 9. Limitations of the system

The proposed ultrasonic (US) sensor-based anti-collision warning system exhibits several inherent limitations. Firstly, the sensing capability of the ultrasonic sensor is restricted to a maximum range of approximately 2 meters, which limits its effectiveness in detecting distant obstacles. Secondly, during data transmission, the XBee module occasionally produces peak or erroneous distance values due to signal inconsistencies, resulting in temporary inaccuracies before stabilizing at the receiver end. Furthermore, the system functions solely as a warning mechanism and does not incorporate autonomous control; thus, the responsibility for taking corrective action remains entirely with the driver. Finally, the absence of automation in the system reduces its overall efficiency and reliability, as it lacks the ability to independently intervene or prevent potential collisions.

## 10. Conclusions

This paper presented a hardware implementation of an anti-collision warning system using ultrasonic sensing technology and embedded systems. The proposed system is cost-effective, reliable, and capable of real-time obstacle detection. It can significantly reduce the risk of collisions, especially in low-speed scenarios. Future work may include integration with radar or LiDAR systems and machine learning algorithms for improved accuracy and adaptability.

## References:

[1] World Health Organization, *Global Status Report on Road Safety*, 2018

- [2] S. Thrun et al., “Stanley: The robot that won the DARPA Grand Challenge,” *Journal of Field Robotics*, vol. 23, no. 9, pp. 661–692, 2006.
- [3] J. Borenstein and Y. Koren, “Obstacle avoidance with ultrasonic sensors,” *IEEE Journal of Robotics and Automation*, vol. 4, no. 2, pp. 213–218, 1988.
- [4] R. Bishop, “A survey of intelligent vehicle applications worldwide,” *IEEE Intelligent Systems*, vol. 15, no. 1, pp. 78–81, 2000.
- [5] H. Winner, S. Hakuli, F. Lotz, and C. Singer, *Handbook of Driver Assistance Systems*, Springer, 2016.
- [6] J. Borenstein and Y. Koren, “Obstacle avoidance with ultrasonic sensors,” *IEEE Journal of Robotics and Automation*, vol. 4, no. 2, pp. 213–218, 1988.
- [7] A. Kumar and D. Singh, “Microcontroller-based distance measurement using ultrasonic sensor,” *International Journal of Engineering Research*, 2019.
- [8] R. Bishop, “A survey of intelligent vehicle applications worldwide,” *IEEE Intelligent Systems*, vol. 15, no. 1, pp. 78–81, 2000.
- [9] Digi International, “XBee Wireless Modules Datasheet,” 2020.