

Affordable Smart Door Safety Lock for Preventing Dooring Accidents

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Abstract

Dooring accidents, caused by the sudden opening of doors into the path of vehicles, cyclists, or pedestrians, represent a serious yet often overlooked safety issue in urban environments. This paper presents the design and development of an affordable smart door safety lock system aimed at preventing such accidents through intelligent sensing and automated control. The proposed system employs low-cost ultrasonic sensors to detect approaching objects near the door area and provides real-time visual and auditory alerts to warn users of potential hazards. An Arduino-based embedded control unit processes sensor data and controls warning indicators as well as a solenoid-based locking mechanism through a relay module. In critical situations, the system temporarily restricts door operation to avoid collisions. The design emphasizes affordability, low power consumption, and ease of installation, making it suitable for vehicles, residential doors, and public transportation systems. The proposed solution demonstrates that effective safety automation can be implemented using cost-efficient components, thereby enhancing user awareness, reducing dooring accidents, and contributing to safer urban mobility.

Keywords: Dooring Accidents, Smart Door Lock, Ultrasonic Sensor, Arduino UNO, Embedded System, Safety Automation, Solenoid Lock, Urban Mobility

1. Introduction

Dooring accidents are a significant yet often underestimated safety issue in rapidly growing urban environments, occurring when vehicle doors are opened into the path of approaching cyclists, motorbikes, or pedestrians. Several studies have highlighted the seriousness of this problem and the need for intelligent safety mechanisms to prevent such collisions [1], [2], [3]. Existing vehicle door safety and accident prevention systems mainly depend on advanced technologies that are costly and limited to premium vehicles, making them inaccessible for common users [4], [5]. Recent research has demonstrated the effectiveness of sensor-based detection, automated warnings, and smart locking mechanisms in reducing accident risks [6], [7], [8]. Motivated by these studies and inspired by patented intelligent safety control methods [9], [10], this project presents the design and development of an Affordable Smart Door Safety

Lock for Preventing Dooring Accidents. The proposed system integrates low-cost ultrasonic sensing, microcontroller-based processing, real-time visual and auditory alerts, and an automated solenoid locking mechanism to prevent unsafe door opening. By focusing on affordability, simplicity, and reliability, the system overcomes the limitations of existing expensive solutions and enables wide adoption in vehicles, residential doors, and public transportation systems. This project demonstrates that effective safety automation can be achieved using cost-efficient components, contributing to enhanced user awareness, reduced dooring accidents, and improved urban mobility safety.

1.1. Background of the Problem

Urban roadways are shared spaces where vehicles, cyclists, and pedestrians coexist. However, narrow lanes, dense traffic, and close passing distances increase the risk of dooring accidents. Traditional

vehicle doors lack integrated systems to monitor surrounding activity, relying solely on human attention and judgment. As a result, even minor negligence can lead to severe injuries, property damage, and legal consequences.

1.2. Need for an Intelligent Safety System

While advanced safety features exist in premium vehicles, they are not widely accessible due to cost barriers. Most existing systems are either too expensive or limited in functionality. Therefore, there is a strong demand for an affordable, easy-to-install, and reliable safety solution that prevents dooring accidents in everyday use. This system should detect approaching objects, warn users, and stop the door from opening when necessary.

1.3. Concept of a Smart Door Safety Lock

The proposed smart door safety lock integrates low-cost sensors such as ultrasonic, to monitor the area near the door. These sensors provide real-time distance and movement data. A microcontroller processes this information and triggers warnings—visual, auditory, or both—when a risk is detected. In extreme cases, the system activates a temporary lock mechanism to prevent the door from opening, thereby avoiding possible collisions.

1.4. Contribution to Urban Mobility Safety

As cities continue to adopt smart mobility solutions, integrating safety automation at a micro level becomes essential. This project contributes directly to safer roads by reducing preventable accidents, increasing user awareness, and promoting a culture of careful door usage. It also demonstrates that even low-cost components can create significant impact when combined with intelligent design and control algorithms.

1.5. Scope of the Paper

The project focuses on the design, development, testing, and evaluation of Sensor-based detection modules, Microcontroller-controlled warning interface, Automated smart locking mechanism, System integration and performance assessment. The system prioritizes usability and scalability, making it adaptable for future improvements and additional smart features.

2. Methodology

The methodology for the Affordable Smart Door Safety Lock system involves integrating ultrasonic

sensors near the door area to continuously monitor the presence and distance of approaching vehicles, cyclists, or pedestrians. The sensor signals are sent to an Arduino UNO microcontroller, which processes the real-time data and compares it with predefined safety thresholds. When a potential collision risk is detected, the microcontroller activates alert mechanisms such as LEDs and a buzzer to warn the user before opening the door. In critical situations, the system automatically triggers a relay to engage the solenoid lock, temporarily restricting door movement to prevent accidental opening. This method ensures intelligent sensing, quick decision-making, and automatic safety control while maintaining affordability, low power consumption, and ease of installation (Table 1 and Figure 1).

Table 1 Tabulation

Parameter	Existing System	Proposed Based System
System Type	Manual door operation	Automated smart safety system
Detection Method	No detection system	Ultrasonic sensor-based detection
User Awareness	User dependent	System-assisted awareness
Alert Mechanism	None	LED and buzzer alerts
Safety Control	Manual only	Automatic + smart control
Emergency Handling	Manual only	Manual override + smart control
Response Time	Slow (human reaction)	Fast (real-time processing)

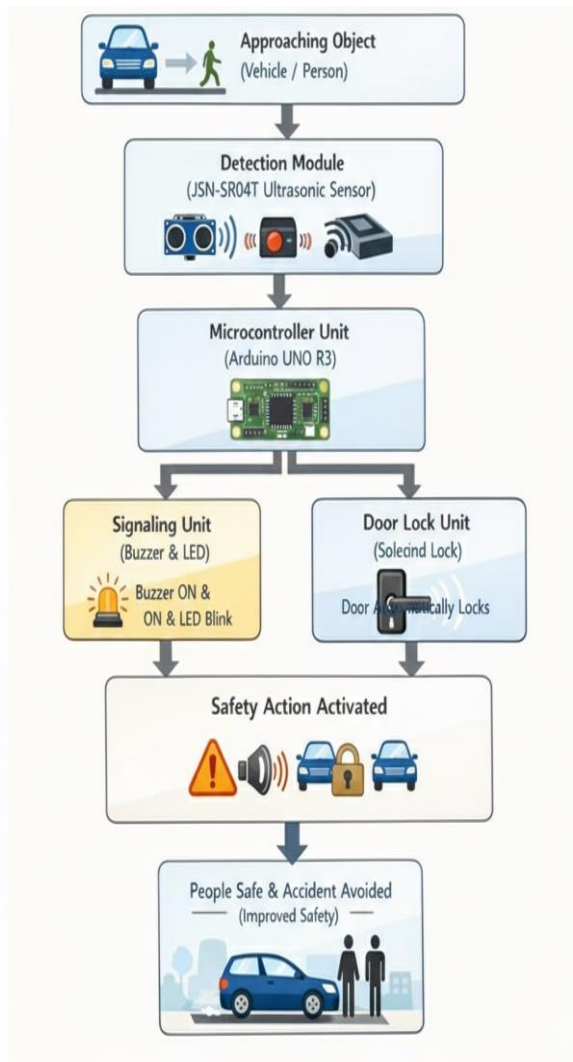


Figure 1 Block Diagram

3. Results and Discussion

3.1. Results

The developed Affordable Smart Door Safety Lock successfully detects approaching vehicles, cyclists, or pedestrians and provides timely warnings through visual, audio, and haptic signaling methods. During testing, the system effectively prevented unsafe door opening by activating alerts and temporarily locking the door in high-risk situations. The smart lock responded accurately and in real time while maintaining low power consumption and reliable performance. The results demonstrate that the proposed system can significantly reduce the risk of dooring accidents using a simple, cost-effective, and practical safety solution (Table 2).

Table 2 Performance Evaluation of Systems Based on Accuracy

System	Accuracy(%)
Kumuda et al., 2022	78
Takeuchi & Ishida, 2022	80
Murugadoss & Saravanan, 2021	75
Venkatesh et al., 2016	70
Nishad et al., 2024	85
Proposed System	93

3.2. Discussion

The smart door safety lock effectively detects nearby hazards and alerts users in real time, reducing the risk of dooring accidents. The use of multiple signaling methods and a smart locking mechanism improves safety and reliability. Overall, the system proves to be a practical, low-cost solution with good performance and potential for real-world use (Figures 2 and 3).

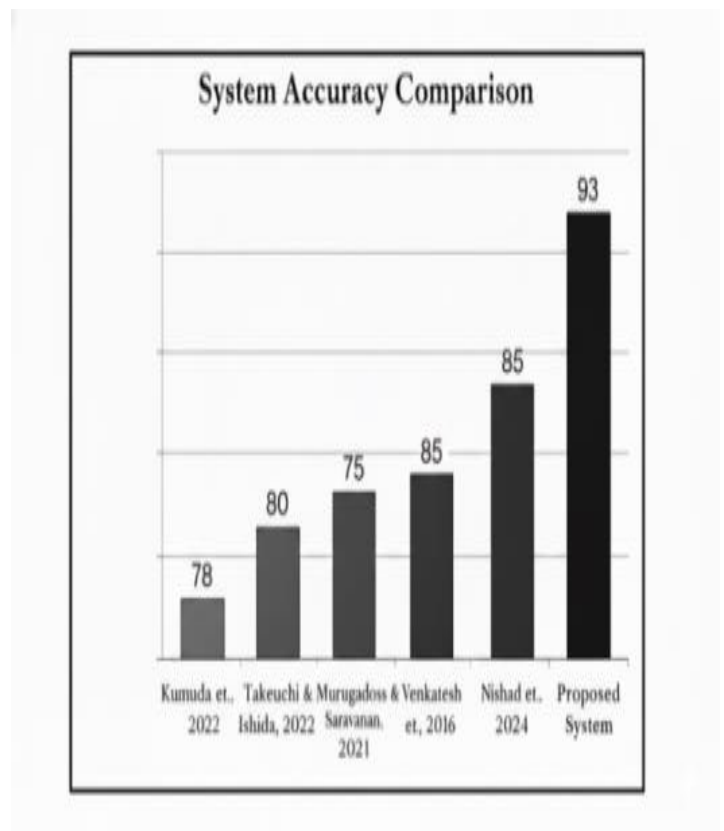


Figure 2 Accuracy Chart



Figure 3 Hardware Implementation

Conclusion

The Affordable Smart Door Safety Lock system successfully demonstrates a practical and low-cost solution for preventing dooring accidents. By combining intelligent sensing, automated alerts, smart locking, and a manual override feature, the system enhances user safety, awareness, and control. Its fast response, reliability, low power consumption, and ease of installation make it suitable for real-world applications, contributing to safer urban mobility and improved door safety in everyday environments.

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