Vehicle Safety System With Automated Number Plate Detection

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Abstract— This paper presents a low-cost Vehicle Safety System with Automated Number Plate Detection aimed at reducing rear- end collisions. The system uses two Arduino Uno boards, each installed in a vehicle, and Zigbee modules for real-time communication. When vehicles come too close, warning messages are displayed on LCD screens in both vehicles. An additional feature includes a webcam for automatic number plate detection using OCR, enabling vehicle identification during unsafe events. The prototype enhances driver awareness and supports post- incident analysis, offering a scalable solution for intelligent transportation systems.

Keywords— Vehicle safety, Arduino Uno, Zigbee communication, LCD display, number plate detection, OCR.

INTRODUCTION

In today's fast-paced world, road transportation has become a fundamental part of daily life. However, with the increasing number of vehicles on the road, the risk of accidents—especially rear-end collisions caused by inadequate distance between vehicles—has grown significantly. Many of these incidents are the result of human error, lack of attention, or the absence of real-time feedback mechanisms in vehicles. While high-end vehicles are equipped with advanced driver assistance systems (ADAS), such technologies are often to expensive to be implemented in mid- or low-range vehicles.

The integration of advanced technologies in vehicle safety systems has led to the development of Automated Number Plate Detection (ANPD) systems. These systems utilize computer vision and image processing to detect and recognize vehicle license plates, enabling efficient identification and tracking of vehicles.

ANPD systems play a crucial role in enhancing vehicle safety, streamlining traffic management, and aiding law enforcement agencies. By accurately detecting and reading license plates, these systems contribute to improved road safety, increased efficiency, and enhanced security, ultimately making transportation ecosystems safer and more reliable.

To bridge this gap this research introduces a Vehicle Safety System with **Automated Number Plate Detection,** designed to provide a low-cost yet effective solution to improve vehicle safety. The primary aim of the system is to detect when two vehicles come dangerously close and to alert the drivers immediately to prevent potential collisions. This is achieved using Arduino Uno microcontrollers, with one installed in each vehicle. These microcontrollers are connected via Zigbee communication modules, which enable wireless, Realtime data exchange between the vehicles.

When the distance between two vehicles falls below a predefined safe limit, a warning message is automatically displayed on **LCD screens** installed inside both vehicles, alerting the drivers to take action. This proactive approach significantly enhances the chances of accident prevention.

Adding to this safety mechanism, the system also features an **automated number plate detection module** using a

webcam and **optical character recognition (OCR)** technology. This additional feature captures and identifies the number plate of nearby vehicles, which can be especially useful in the event of a safety violation or incident. It helps in tracking and logging vehicle details for further analysis or reporting.

The proposed system is designed to be simple, modular, and cost-effective, making it suitable for widespread use in developing countries or in areas where advanced vehicle safety systems are not commonly available. By combining real-time vehicle distance monitoring with automated number plate recognition, this project aims to make roads safer and smarter.

I. EASE OF USE

One of key advantage of the proposed **Vehicle Safety System with Automated Number Plate Detection** is its simplicity and ease of use for drivers and vehicle operators. The system is designed to operate autonomously with minimal human intervention ensuring that safety measures are maintained without requiring constant driver input.

A. Plug-and-Play Hardware

The components used—**Arduino Uno**, **ZigBee modules**, **LCD screens**, and a **webcam**—are compact and easy to install. Each component connects through simple interfaces (like USB or serial communication), making it possible to deploy the system in most standard vehicles without modifying existing vehicle systems. Installation can be completed using basic tools and requires only fundamental knowledge of electronics, making it accessible for general users or technicians. Once installed, the system initializes automatically when the vehicle is powered on.

B. Automatic Distance Detection

The **ZigBee modules** allow real-time communication between vehicles within range. Each Arduino processes distance data continuously and determines if the vehicles are at a safe distance. The system uses a predefined threshold value—based on speed or distance calibration— to automatically assess potential risk. When vehicles approach within this critical range, the system immediately recognizes the unsafe condition and triggers a response, all without any manual driver input. This automation helps reduce human error and ensures consistent monitoring regardless of the driver's attention.

C. Visual Warnings via LCD

Once a potential hazard is detected, the system promptly displays a **warning message** on the **LCD screen** mounted inside the vehicle. The message is designed to be short, clear, and immediately noticeable—such as "Unsafe Distance!" or "Maintain Distance." This helps the driver take corrective action in real time. Because the warning is visual rather than auditory, it avoids contributing to noise pollution inside the vehicle and prevents unnecessary stress or distraction, especially in already noisy environments
Units

D. Hands-Free Number Plate Detection

The number plate detection feature adds a valuable safety and identification layer. A **webcam**, connected to the Arduino or a companion processor (e.g., Raspberry Pi for more advanced image processing), continuously captures video or still frames. These images are then processed using basic **optical character recognition (OCR)** algorithms to detect and extract vehicle registration numbers. This entire process is automated and happens in the background, requiring no input or interaction from the driver. It can also be triggered only when an unsafe distance is detected, conserving resources while capturing essential data in critical moments.

E. Low Maintenance and Cost

The system uses **low-power,** modular components that are widely available and inexpensive. Most of the hardware has long life cycles and minimal maintenance requirements. If a component fails, it can be easily swapped out or reprogrammed, making the system sustainable for long-term use. Furthermore, since the core of the system is based on open-source platforms, updates or improvements can be made without proprietary restrictions. This lowers the overall cost and makes the system highly adaptable for future enhancements

II. SYSTEM DESIGN AND IMPLEMENTATION

A. Hardware design

The proposed Vehicle Safety System is built using simple, low-cost, and easily programmable components. At the core of each vehicle module is an **Arduino Uno ,**microcontroller, which processes real-time data and controls the system. For wireless communication between the two vehicles, a **ZigBee module** is interfaced with each Arduino to exchange proximity data and detect unsafe distances. A **16x2 LCD display** is connected to the Arduino to provide immediate visual alerts to the driver when a safety threshold is breached. Additionally, one vehicle is equipped with a **USB webcam**, which captures images of front vehicle's number plate when an unsafe distance is detected. The image is processed using **OCR** tools such as OpenCV and Tesseract on a laptop or Raspberry Pi. The entire system is powered using a **9V battery or USB power bank**, making it suitable for integration in to any standard vehicle without major modifications. Each component—**Arduino Uno, ZigBee, LCD, and Webcam**—is chosen for its compatibility, reliability, and ease of use in a mobile embedded environment.

Key Hardware specifications include:

- **Arduino uno:** ATmega328P microcontroller, 14 digital I/O pins, 6 analog inputs, 16 MHz clock.
- **ZigBee Module:** IEEE 802.15.4 compliant, 2.4 GHz frequency, low power consumption, 250 kbps speed.
- **LCD Display:** 16x2 character display, HD44780 controller, 5V operation, backlit display.
- **Webcam:** USB 2.0 interface, 720p resolution (min), 30 fps, plug-and-play compatibility.

- **Power Supply:** 9V or 12V battery / USB 5V power supply depending on setup.
- **Power Source (Battery or USB):** Powers the system components in each vehicle.

Figure 1. Arduino Uno (ATmega328P)

B. Software and Firmware Setup

The system firmware is developed using the **Arduino programming environment**, while the number plate detection software is implemented in **Python** using **OpenCV** and **Tesseract OCR**. The setup and workflow are as follows:

1. **Initialize Zigbee communication** for vehicle-tovehicle data exchange.
2. **Monitor proximity status** based on predefined logic or sensor input.
3. **Transmit or receive data** via Zigbee to/from the nearby vehicle.
4. **Trigger warning alert** on the 16x2 LCD if unsafe proximity is detected.
5. **Capture an image** using the webcam when a proximity violation is detected.
6. **Convert the image to grayscale** and preprocess using OpenCV (e.g., edge detection, filtering).
7. Detect the number plate region using contour detection or a Haar cascade classifier.
8. **Extract text** from the plate region using Tesseract OCR.
9. **Log the number plate and timestamp** locally or in a database for record-keeping.

Libraries used include:

- WiFi.h
- LiquidCrystal.h
- SoftwareSerial.h
- ArduinoJson.h
- OpenCV (cv2)
- Pytesseract

C. Communication Testing Between Vehicles

The ZigBee modules tested for two-way data transmission between the two vehicles. Using serial monitoring tools, the exchange of proximity data was verified. The system maintained a stable and low-latency connection, with updates being transmitted in near real-time. Communication reliability was consistent even with minor obstacles or signal interference. *D. Alert Display and Distance Violation Simulation*

Vehicles were placed at varying distances to simulate real-world conditions. When the distance dropped below the defined safety limit, the Arduino successfully triggered the LCD to display a warning message such as "Unsafe Distance." This validated the response mechanism and confirmed that alerts were activated accurately and promptly.

E. Image Capture and Number Plate Detection

Upon detecting an unsafe distance, the system initiated the webcam to capture an image of the front vehicle. The image was then processed using OpenCV for preprocessing tasks such as grayscale conversion, edge detection, and contour analysis. The number plate area was extracted using shape analysis or Haar cascade classifiers. Tesseract OCR was applied to the extracted region to convert the visual characters into machine-readable text. The recognized plate number, along with a timestamp, was logged locally for later verification.

III. FUNCTIONAL WORKFLOW OF THE SYSTEM

A. System Initialization and Communication Setup

Upon powering the system, each Arduino Uno initializes its respective components. The Zigbee modules are configured to establish a wireless peer-to-peer communication channel between the two vehicles. Concurrently, the LCD displays are set to their default state, ready to render real-time warning messages upon triggering.

B. Real-Time Distance Monitoring

The primary safety functionality revolves around continuous monitoring of the inter-vehicle distance using Zigbee signal strength and predefined thresholds. Each Arduino microcontroller evaluates the proximity data received from its corresponding Zigbee module. If the computed distance falls below a critical threshold, the system identifies the situation as potentially hazardous.

C. Warning Alert and Message Display

Once an unsafe distance is detected, both Arduino units simultaneously trigger an alert. This results in the activation of the LCD displays in both vehicles, which promptly show a warning message, such as **"WARNING: UNSAFE DISTANCE"**. This visual cue is designed to alert drivers in real-time, enabling them to take corrective actions to avoid collision.

D. Number Plate Detection (Auxiliary Feature)

To complement the safety mechanism, an automated number plate detection module is incorporated as an additional feature. A webcam mounted on one of the vehicles capture real-time images of the adjacent vehicle's license plate. The captured image undergoes preprocessing, character segmentation, and Optical Character Recognition (OCR) using appropriate image processing algorithms. The extracted alphanumeric data is then stored locally or can be transmitted to a centralized database for record-keeping or legal reference.

RESULT

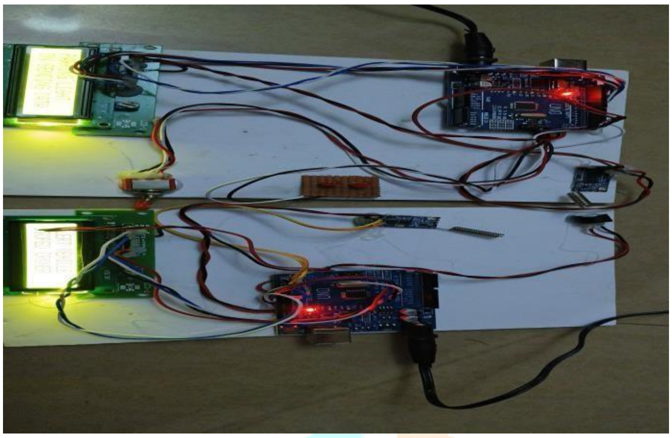

Figure 2. Warning message displayed in the LCD

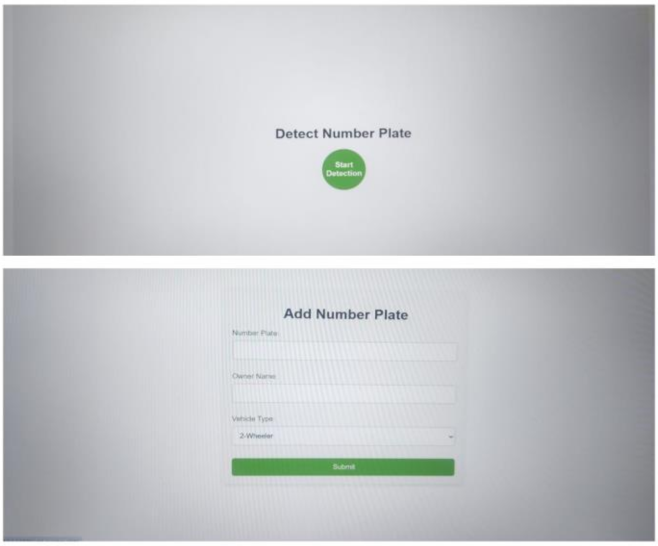

Figure 3. Number Plate Detection result

CONCLUSION

This paper presents a cost-effective and practical solution to enhance vehicular safety through the integration of proximity detection and automated number plate recognition. The proposed system utilizes Arduino Uno microcontrollers, Zigbee modules, and LCD displays to monitor the distance between vehicles and alert drivers when a potentially dangerous situation arises. The inclusion of an automated number plate detection module using a webcam and image processing techniques adds an additional layer of functionality, allowing the system to identify nearby vehicles and contribute to post-incident analysis or reporting.

The real-time communication and response capabilities of the system demonstrate its potential effectiveness in reducing rear-end collisions and promoting safer driving habits. Furthermore, the modular and scalable nature of the design makes it adaptable for use in various traffic environments and vehicle types.

Future enhancements may include integrating GPS for location-based alerts, cloud connectivity for remote monitoring, and AI-powered decision-making to improve detection accuracy. Overall, the developed system represents a significant step toward smarter and safer transportation solutions.

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