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IoT based Smart System for Autonomous Vehicle Safety

Dr. Bhuvaneshwari K V¹, Manish S Chikmath², Prajwal S Mallur², Shankar N Hulagur²,
Yaligar Ravi Teja²

Associate Professor, Department of Information Science and Engineering, Bapuji Institute of Engineering and
Technology, Davanagere, Karnataka, India¹

U.G. Students, Department of Information Science and Engineering, Bapuji Institute of Engineering and Technology,
Davanagere, Karnataka, India²

ABSTRACT: Pursuing enhanced road safety has led to the development of advanced driving assistance systems (ADAS) and autonomous vehicles (AVs). This research paper presents an IoT-based smart system that improves vehicle safety through real-time obstacle detection and proactive intervention. The system integrates sensors, cameras, and IoT devices to detect potential hazards, provide timely alerts to the driver, and, when necessary, autonomously control the vehicle to prevent collisions. The system achieves accurate and efficient object detection by leveraging Convolutional Neural Networks (CNNs) and You Only Look Once (YOLO) algorithms, contributing to a safer and more intelligent driving environment.

KEYWORDS: Autonomous Vehicle, IoT, Smart System, Road Safety, CNN, YOLO, Obstacle Detection.

I. INTRODUCTION

The field of transportation is undergoing a transformative shift with the advent of autonomous driving technologies. The convergence of artificial intelligence (AI), the Internet of Things (IoT), and real-time object detection has paved the way for the development of AVs capable of perceiving their surroundings and making complex driving decisions. These advancements hold the promise of significantly reducing road accidents, optimizing traffic flow, and revolutionizing the driving experience.

Autonomous driving systems rely on a complex interplay of sensors, cameras, and machine learning algorithms to analyze the vehicle's environment, detect obstacles, and adhere to traffic regulations. CNNs and YOLO algorithms have emerged as critical components of these systems, enabling real-time object detection and classification.

Despite the rapid progress in autonomous driving technology, its widespread adoption faces challenges. A significant gap exists in the accessibility of advanced driver assistance features, with many conventional vehicles lacking these safety enhancements. This disparity exposes a large number of drivers to the risks of human error, including distraction, drowsiness, and inattention.

The increasing prevalence of pedestrian-related accidents further underscores the need for robust driving assistance systems. Pedestrian fatalities remain a major concern for traffic safety agencies globally, with a significant proportion of incidents attributed to driver negligence or delayed reaction times. Current collision avoidance systems often provide warnings but lack the capability to autonomously intervene, highlighting the necessity for intelligent and cost-effective solutions.

II. LITERATURE SURVEY

The following review process involves an analysis of both existing and emergent literature to map out the various scholarly approaches to the subject matter. Autonomous driving technology has progressed through different levels of automation, each offering unique capabilities and limitations:

- **Level 0 (No Automation):** The driver has full control of the vehicle. The system may provide warnings but does not intervene.
- **Level 1 (Driver Assistance):** The system assists with specific tasks like adaptive cruise control or parking assistance, but the driver is still in control.
- **Level 2 (Partial Automation):** The system controls multiple aspects of driving (steering, braking, etc.), but the driver must stay alert and be ready to intervene.
- **Level 3+ (Conditional/High Automation):** The vehicle can handle most driving tasks under certain conditions, but the driver must still be ready to take over. Higher levels represent more autonomy.

Despite the progress, several challenges prevent autonomous vehicles from being widely adopted:

- **High Cost:** The expensive sensors, computing power, and software development are still significant barriers.
- **Limited Real-World Adaptability:** Autonomous systems face challenges in unpredictable situations like bad weather, poor visibility, or unexpected pedestrian behavior.
- **Regulatory and Legal Challenges:** The absence of clear legal rules and safety standards makes it difficult to deploy autonomous vehicles.
- **Infrastructure Dependency:** Many autonomous systems rely on well-maintained road infrastructure, which isn't available everywhere.

III. PROBLEM STATEMENT

Current autonomous driving technologies are primarily found in high-end vehicles. However, these advanced safety features are often missing in lower-end vehicles, leaving many drivers without essential assistance systems. As a result, many motorists lack crucial support that can help prevent accidents caused by distractions, drowsiness, or inattention. Pedestrian-related accidents, especially at non-intersection crossings, remain a significant concern, leading to numerous fatalities and injuries each year. Despite advancements in vehicle automation, many driving assistance systems are still not widely integrated into standard vehicles. There is a growing need for an affordable, real-time system that can detect sudden obstacles, provide timely alerts, and take action to prevent accidents, making every day driving safer and more reliable.

IV. OBJECTIVES

This research aims to develop an IoT-based smart system for autonomous vehicle safety, addressing the limitations of existing systems and enhancing road safety for all users.

The key objectives and contributions of this research are:

1. To design and implement a system capable of real-time obstacle detection using IoT sensors, including LiDAR and camera modules.
2. To develop a CNN model for accurate prediction of obstacles, lane changes, and traffic signals.
3. To integrate the YOLO algorithm for efficient and precise object detection and hazard identification.
4. To implement an alert system that provides visual and auditory warnings to the driver and passengers.
5. To develop an autonomous vehicle prototype that integrates the proposed safety system and demonstrates its effectiveness in real-world scenarios.

V. PROPOSED SYSTEM

The proposed system is designed to build a simple self-driving car using a laptop and an Arduino. It uses an HD camera and an ultrasonic sensor to understand its surroundings and move safely.

The key features of the proposed system include:

1. **Surrounding Detection:** The camera and sensor help the car detect the road and nearby obstacles.
2. **Neural Network Control:** A neural network running on the laptop processes images and decides how the car should steer.
3. **Low-Cost and Easy to Build:** The system uses affordable and commonly available components.

4. Safe and Efficient Movement: The car can drive on its own with accurate and responsive control, reducing the chances of human error.

VI. SYSTEM DESIGN

6.1 Methodology

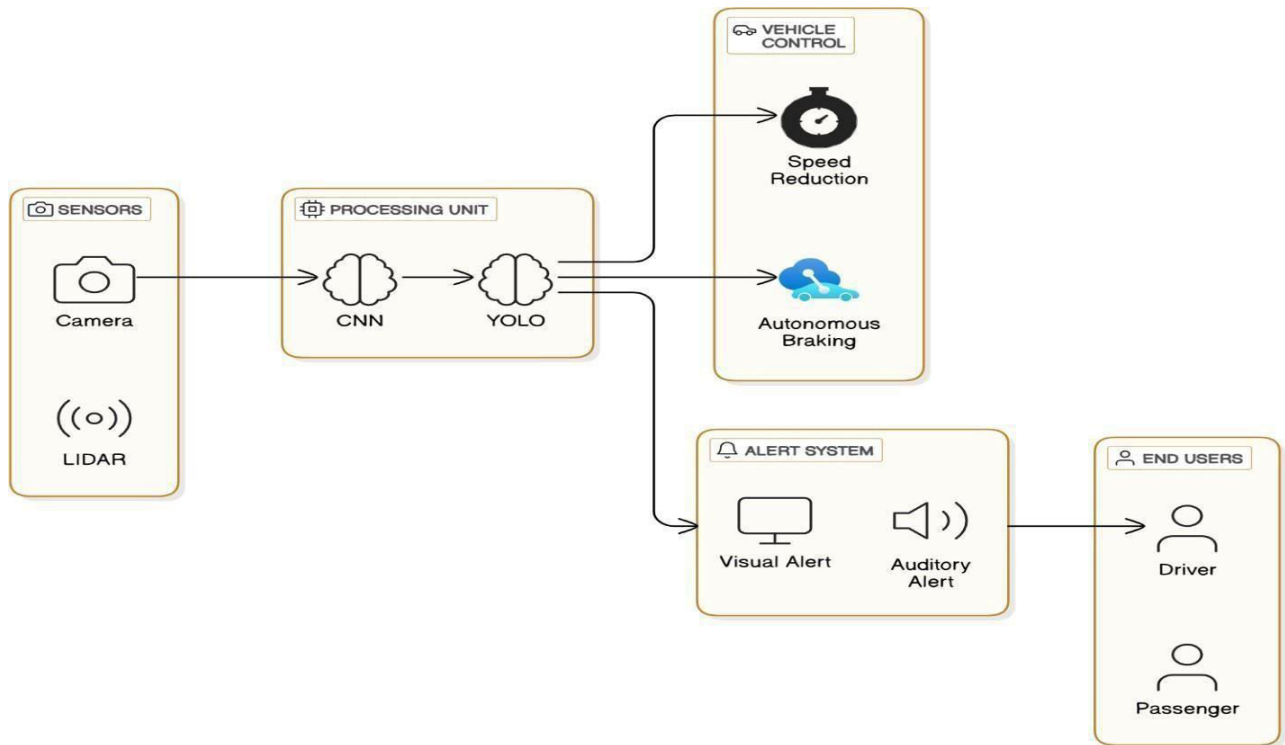


Figure 6.1: System Architecture of Proposed System

As shown in the Figure 6.1, the system architecture ensures real-time awareness and quick response, improving the overall safety of the vehicle and its occupants. The steps followed are:

1. The process begins with the collection of data using a camera and a LiDAR sensor.
2. The camera captures visual information while the LiDAR provides depth data to help the system understand its surroundings.
3. This data is then passed to the processing unit where a Convolutional Neural Network (CNN) extract features from the images.
4. Following this, the YOLO algorithm detects and classifies objects in real time.
5. Based on the identified obstacles, the system takes necessary safety actions such as reducing the vehicle's speed or applying autonomous braking to prevent collisions.
6. At the same time, the system activates visual and auditory alerts to inform both the driver and the passenger about potential hazards on the road.

6.2 Flow Chart

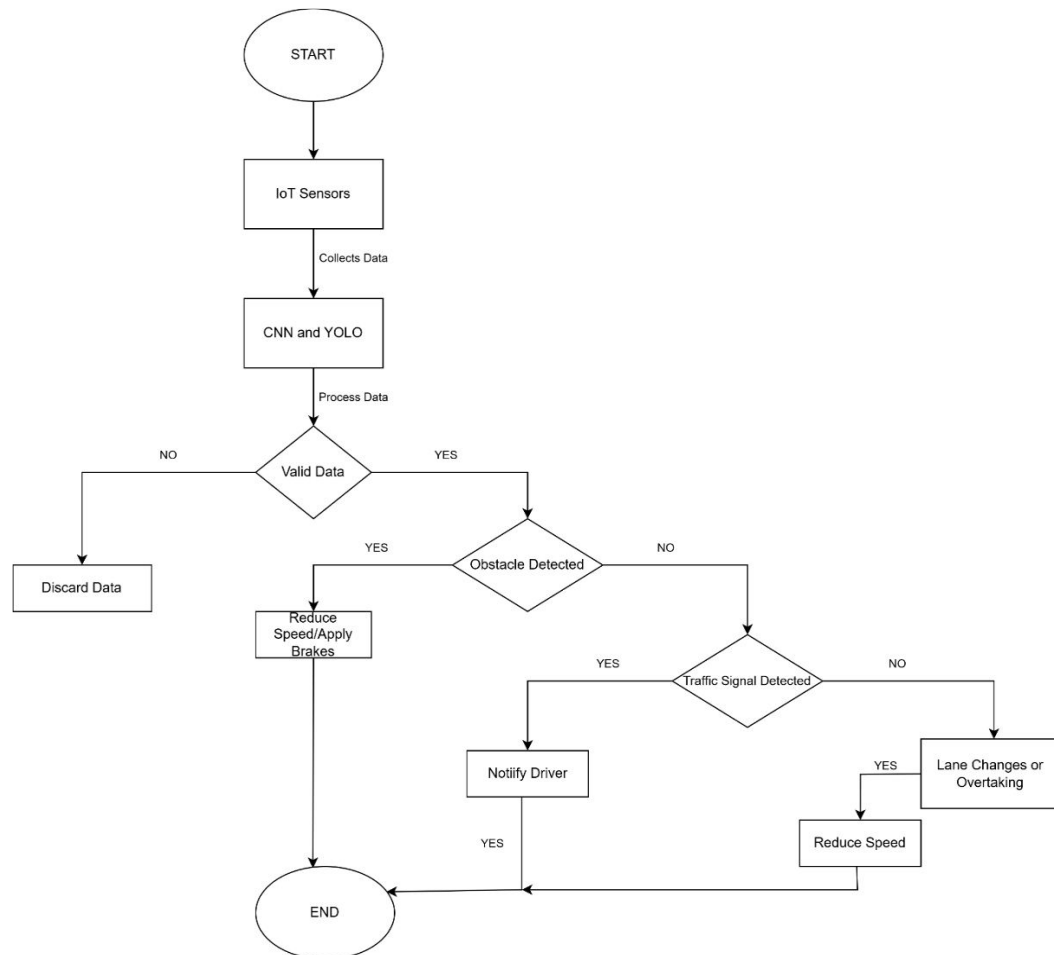


Figure 6.2: Flow Chart of the Proposed System

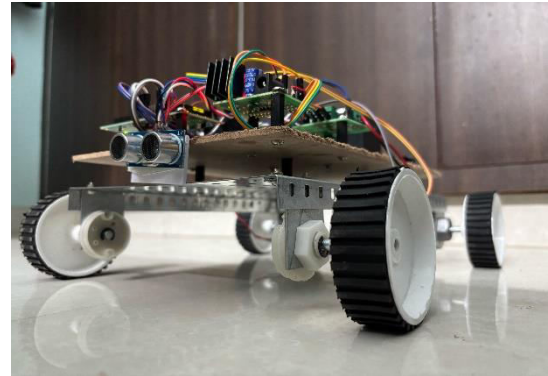
As shown in Figure 6.2, the IoT-based smart system enhances vehicle safety by using sensors like cameras and LiDAR to collect real-time data. This data is processed through CNN and the YOLO algorithm to detect objects, lane shifts, and traffic signals. A validation step filters out irrelevant information. When necessary, the system automatically reduces speed or applies brakes to avoid obstacles and adjusts driving behaviour based on traffic signals. It also alerts the driver visually and audibly during critical situations, ensuring a safe and responsive driving experience.

VII. RESULTS AND DISCUSSION

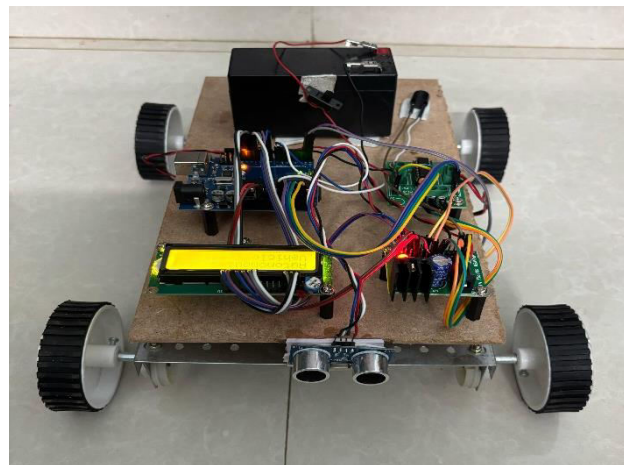
The autonomous vehicle system worked well across all its functions. It successfully combined sensors and motor controls using a Python platform. The pothole and bump detection system were reliable, with an accuracy of 89.7% in good lighting and slightly lower in low light, reacting in just 0.4 seconds. The obstacle detection using ultrasonic sensors performed accurately up to 96.2% within a 4-meter range, with minimal false alarms. The system also used CNN and YOLO for object recognition, successfully identifying vehicles, pedestrians, animals, and traffic signs with an overall accuracy of 89.4%, processing frames in real time. Lane detection kept the vehicle properly aligned, with over 93% accuracy on clear roads, though it was a little less reliable in bad road conditions. Traffic sign recognition was also strong, with an accuracy of 94.8%, responding to signs in about 0.6 seconds. In general, the system showed solid performance for safe and effective driving. Some of the output results can be seen below in snapshots labelled a, b, and c.



(a)



(b)



(c)

VIII. CONCLUSION

Ensuring the highest level of safety is the most critical factor for the successful deployment of autonomous vehicles. While on-board sensing is fundamental, an IoT-based smart system offers a powerful extension of the AV's perception and decision-making capabilities. By connecting vehicles to their environment, infrastructure, and other road users, the proposed system enables enhanced situational awareness, proactive hazard detection, and more robust safety decisions. Although significant challenges related to security, reliability, standardization, and infrastructure exist, the potential benefits of an integrated IoT framework for creating safer autonomous transportation systems are substantial. Continued research, development, and collaboration across industry and regulatory bodies are essential to realize the full potential of this technology.

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