



Collision Avoidance System for Autonomous Car Prototype – An Overview

Vijaya Samundeswari.K.¹, Geetha Priya.A², Kiruthiga Devi.B³, Malar Divya Dharshini.M.⁴

¹Assistant Professor, Department of ECE, Arunai Engineering College (Autonomous),
Tiruvannamalai.

^{2,3,4}Final Year Students, Department of ECE, Arunai Engineering College (Autonomous),
Tiruvannamalai.

Abstract

In 1995, a modern forward collision avoidance system was demonstrated in 1995 by Hughes Research Laboratories in California, funded by Delco Electronics and using radar technology. A Collision Avoidance System (CAS) for an autonomous car prototype is an active safety mechanism designed to detect obstacles in a vehicle's path and take autonomous action—such as braking or steering—to prevent or mitigate a collision. In prototype development, these systems act independently of the driver, often using embedded systems, microcontrollers, and various sensors to manage speed and trajectory. The working mechanism of a Collision Avoidance System (CAS) involves continuous monitoring of the surroundings using sensors such as radar, lidar, cameras, or transponders. These sensors collect real-time data about the distance, speed, and direction of nearby vehicles, aircraft, or obstacles. The information is sent to a central processing unit, which analyzes the data to predict the possibility of a collision. If a potential threat is detected, the system first issues audio, visual, or haptic warnings to the driver or pilot. Collision Avoidance Systems are highly relevant for India, which continues to face a severe transport safety challenge. As per recent government data, road accident

deaths reached about 1.77 lakh in 2024, averaging nearly 485 deaths per day across the country.

N Keywords: Collision Avoidance System, prototype, Algorithms, Microcontroller and Kavach.

Introduction

The development of collision avoidance systems for autonomous car prototypes has its origins in both early automotive safety research of the mid-20th century and rapid advancements in sensor technology during the 1990s and 2000s, designed to enhance active safety and enable autonomous maneuvering. 1950s, The first reported prototype designed with a smart collision warning system was the Cadillac Cyclone XP-74, developed by General Motors in 1959, which used radar-based sensors near the headlights to detect frontal obstacles. 1990s, The concept shifted toward commercial application in the early 1990s with systems like the Distance Warning system introduced by Mitsubishi Debonair in Japan, which utilized lidar. In 1995, A modern forward collision avoidance system was demonstrated in 1995 by Hughes Research Laboratories in California, funded by Delco Electronics and using radar technology.



Review of Literatures

[1].In this paper, they are explained about the forward collision warning system based on a laser scanner that is able to detect several potential danger situations. Decision algorithms try to determine the most convenient manoeuvre when evaluating the obstacles' positions and speeds, road geometry, *etc.* Once detected, the presented system can act on the actuators of the ego-vehicle as well as transmit this information to other vehicles circulating in the same area using vehicle-to-vehicle communications. The system has been tested for overtaking manoeuvres under different scenarios and the correct actions have been performed¹. [2].In this paper, discussed the prototype implementation and testing the vehicle collision avoidance system algorithms which can be further implemented in real time vehicles. This has been performed using free scale smart car controlled by Texas Instruments (TI) CC3200 Launchpad. Prototype implementation of collision avoidance system algorithms is necessary for the efficient real time implementation in order to analyses the defects in the algorithm in advance. The hardware electrical and electronic components necessary for controlling the movement of the prototype vehicle and initiating necessary actions for collision avoidance are discussed. The software for the vehicle movement control through the TI CC3200 Launchpad is written using Energia software². [3].Nowadays, the number of accidents is so high and uncertain. Accidents cause worst damage, serious injury and even death. These accidents are mostly caused by delay of the driver to hit the brake. Preventive measure such as improving visibility, auto headlights, windshield wipers, tire traction,

etc. were deployed to reduce the probability of getting into an accident. Now we are at the stage of actively avoiding accidents as well as providing maximum protection to the vehicle occupants and even pedestrians. Hence in this paper, we make an attempt to propose a new automated vehicle collision avoidance system. This project is designed to develop a new system that can solve this problem where drivers may not brake manually but the vehicles can stop automatically due to obstacles by using sensors. Thus, this paper focuses on the development of a sensor based embedded system that can assist the drivers to avoid any sort of collision on the road in order to save the precious lives and also to prevent the financial loss³. [4].In this paper, the prototype of an autonomous vehicle is discussed, which is capable of obstacle avoidance using an ultrasonic sensor for its movement and avoidance. An Arduino microcontroller is used to achieve the desired operation. In order to achieve the desired task of the proposed system, a proper methodology is followed which combines appropriate selection of hardware components as well as logic design of actions for obstacle avoidance. The proposed system can easily detect an obstacle, and move accordingly towards the safe path, by first detecting and then verifying the safe path. This can be very useful if implemented in real life. It can ultimately reduce the chances of accidents of trains and road vehicles which will save lots of lives. It can also detect broken roads and train tracks, which may result in reducing the chances of accidents to some extent. The accuracy of the autonomous vehicle depends on the output received by the ultrasonic sensor; therefore, it is not affected by the lighting environment. The prototype has been tested in various



experimental settings and achieves appropriate results⁴. [5]. In this article, the advancement of autonomous driving systems, the need for effective emergency avoidance path planning has become increasingly important. To enhance safety, the predicted paths of surrounding vehicles anticipate risks and incorporate them into avoidance strategies, enabling more efficient and stable driving. Although the artificial potential field (APF) method is commonly employed for path planning due to its simplicity and effectiveness, it can suffer from the local minimum problem when using gradient descent, causing the vehicle to become stuck before reaching the target. To address this issue and improve the efficiency and stability of path planning, this study proposes integrating prediction data into the APF and optimizing the control points of the quintic Bézier curve using sequential quadratic planning. The validity of the proposed method was confirmed through simulation using IPG Car Maker 12.0.1 and MATLAB/Simulink 2022b⁵.

Existing Work

In conventional vehicles, collision avoidance mainly depends on the driver's ability to observe surroundings and react quickly. Basic safety mechanisms like brakes, horns, and mirrors are used to prevent accidents. Some modern vehicles include advanced systems such as parking sensors and driver assistance technologies. However, these systems are often limited in functionality and require human input for decision-making. They may not perform effectively in situations requiring rapid response or in low-visibility conditions. Driver fatigue, distraction, or impaired judgment can significantly reduce the

effectiveness of these safety measures. Conventional systems also lack real-time data processing and predictive capabilities, making it difficult to anticipate and prevent potential collisions in complex traffic scenarios.

Proposed Methodology

The proposed system introduces an automated collision avoidance mechanism using embedded systems and sensors. It eliminates the dependency on driver reaction by enabling the vehicle to sense obstacles and act automatically. The microcontroller continuously receives data from sensors and evaluates the situation in real-time. If an obstacle is detected within a critical distance, the system activates the relay to stop the motor and triggers a buzzer alert. The LCD displays system status and distance information. This solution is cost-effective, efficient, and suitable for small-scale autonomous vehicle prototypes. The system operates with low power consumption and can be easily integrated into existing vehicle models. Its modular design allows additional sensors or features to be added in the future, improving accuracy and functionality. It enhances safety by reducing human error and ensures consistent performance under different environmental conditions.

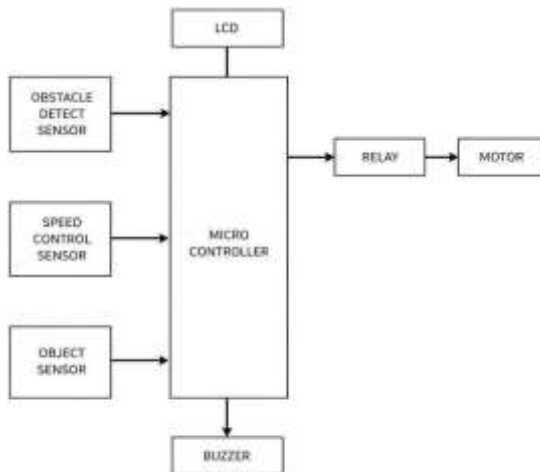
Statement of the Problems

Collision avoidance systems (CAS) in autonomous car prototypes face significant technical, environmental, and computational challenges, primarily centering on the trade-off between reaction speed and detection accuracy, along with sensor limitations. While these systems are designed to improve safety over human drivers, prototypes often struggle with false



positives, complex traffic scenarios, and edge cases.

Block Diagram



Objectives of the Study

To trace the origin and growth of the Collision Avoidance System for Autonomous Car Prototype. To know the various components of Collision Avoidance System for Autonomous Car Prototype. To identify and analyse the factors Collision Avoidance System for Autonomous Car Prototype.

detection (e.g., up to 5 meters) due to low cost and high accuracy in close-range environments. LiDAR (Light Detection and Ranging): Uses laser pulses for high-resolution 3D mapping of the environment, offering precise distance measurements. IR Sensors (Infrared): Used for detecting nearby obstacles.

Collision Avoidance System (CAS)

Working Mechanism

The working mechanism of a Collision Avoidance System (CAS) involves continuous monitoring of the surroundings using sensors such as radar, lidar, cameras, or transponders. These sensors collect real-time data about the distance, speed, and direction of nearby vehicles, aircraft, or obstacles. The information is sent to a central processing unit, which analyzes the data to predict the possibility of a collision. If a potential threat is detected, the system first issues audio, visual, or haptic warnings to the driver or pilot. If the user does not respond in time, the system may automatically take corrective actions, such as applying brakes, steering away, or changing course, to prevent the collision.

Collision Avoidance Systems Benefits

Detects obstacles, vehicles, or aircraft in the path and warns or intervenes to avoid collisions. Reduces injuries and fatalities by minimizing human error. Provides early warning: Alerts the driver or pilot before a dangerous situation develops. Some systems apply brakes or change course automatically if the user does not react. Uses sensors, radar, cameras, or GPS to give a better understanding of surroundings. Prevents crashes, lowering repair costs, insurance claims, and downtime

Factors of a prototype CAS

A Collision Avoidance System (CAS) for an autonomous car prototype relies on a multi-layered framework combining sensor perception, real-time algorithms, and actuator control. The core purpose is to identify, analyze, and mitigate potential collision risks—commonly rear-end collisions (60%+) and side-swipes in urban, often unsignalized, intersection environments.



Perception Factors (Sensors and Data Fusion)

The accuracy of the prototype depends heavily on the input received from sensors, often categorized by range and environmental robustness.

Ultrasonic Sensors: Ideal for short-range detection (<5m), such as low-speed parking maneuvers or urban prototypes. They are inexpensive, have low power consumption, but lower resolution. **LiDAR:** Provides high-resolution, 3D point cloud maps of the environment for precise obstacle localization. Essential for dynamic obstacle detection but computationally intensive. **Cameras:** Essential for scene understanding (traffic signs, lane markings, object classification). Often used with Machine Learning (YOLO/CNN) for object detection. **Radar:** Used for measuring the distance and speed of objects. Highly reliable in poor visibility conditions (rain, fog, night) where cameras may fail. **Sensor Fusion:** Combining complementary sensors (e.g., Radar + Camera) enhances accuracy. For a prototype, combining LiDAR or Ultrasonic with cameras often offers a balance of precision and cost. **Algorithmic Factors (Decision-Making)**

Algorithms translate sensor data into safe actions, categorized into path planning, decision-making, and machine learning. **Obstacle Detection and Object Classification:** Algorithms must detect if an object is moving (dynamic) or static.

Time-to-Collision (TTC) Calculation: A critical factor, measuring the time remaining before contact under constant velocity.

Path Planning Algorithms:

A (A-star) & Dijkstra: Used for efficient, short paths in structured environments.

Rapidly Exploring Random Tree (RRT): Suitable for dynamic obstacles and uncertain road conditions.

Artificial Potential Field (APF): Creates a virtual field where obstacles repel and targets attract, useful for real-time avoidance but prone to local minima.

Machine Learning (AI): Convolutional Neural Networks (CNN) is used for high-precision obstacle recognition in dynamic scenarios.

Actuation Factors (System Response)

Autonomous Emergency Braking (AEB): Initiates automatic braking if a collision is imminent to prevent accidents or reduce impact.

Emergency Steering: Deviation of the vehicle's trajectory to escape hazardous situations when braking alone is insufficient.

Warning Systems: Auditory or visual alerts sent to the operator before automated intervention.

Environmental and Operational Factors

Lighting Environment: Night-time operations significantly increase collision risk, requiring better sensor robustness.

Weather Conditions: Rain, fog, and snow can severely degrade LiDAR and camera performance, increasing reliance on radar.

Road Conditions: Complexity of intersections, construction zones, and surface friction.

Traffic Scenario: Dynamic environments (e.g., pedestrians, other cars) versus static environments.

Prototype Implementation Factors

Microcontroller: Efficient processing unit (e.g., Arduino, Raspberry Pi, TI CC3200) to process sensor data in real-time (<0.1s latency).

Actuator Control: Motor drivers (H-Bridge) and servo motors for steering and speed management.

Calibration: The threshold distances for warning and breaking ($= \text{StoppingDistance}, = 1.5$



Stopping Distance) must be calibrated to vehicle speed and tire friction.

Conclusion

A collision avoidance system is a safety system designed to warn, alert, or assist drivers to avoid imminent collisions and reduce the risk of incidents. Collision avoidance systems use a variety of technologies and sensors, such as radar, lasers, cameras, GPS, and artificial intelligence. The use of ultrasonic and laser sensors provides accurate detection of surrounding objects, allowing the system to take corrective actions (stop or steer) in real-time without human intervention. The active collision avoidance system enhances safety by reducing accidents caused by human error, such as distraction, fatigue, or slows braking reaction times. Prototype experiments on platforms like free scale smart cars or Turtle Bots have proven that these systems can accurately avoid collisions at low speeds, with success rates often reaching 100% in controlled, structured scenarios.

References:

- [1].Felipe Jiménez et al.,” Autonomous Manoeuvring Systems for Collision Avoidance on Single Carriageway Roads”, *Sensors (Basel)*. 2012 Nov 29; 12(12):16498–16521. doi: 10.3390/s121216498.
- [2].M. Ramasubramanian¹, S. Neelakrishna, S. Sainath and V. Krishnaveni, “ Prototype Implementation of Vehicle Collision Avoidance System Algorithms”, *Applied Mathematics & Information Sciences an International Journal*, Appl. Math. Inf. Sci. 11, No. 5, 1407-1417 (2017).
- [3].Mathu et al, “Vehicle Collision Avoidance System”, *International Research Journal of Engineering and Technology (IRJET)*, Volume: 07 Issue: 06 | June 2020, pp.1206-1210.
- [4].Khan et al. “ A Prototype of Obstacle Avoidance for Autonomous Vehicle”, *Iraqi Journal of Science*, 2022, Vol. 63, No. 5, pp: 2203-2210,DOI:10.24996/ij.s.2022.63.5.33.
- [5].Sumin Ahn et al., Collision Avoidance Path Planning for Automated Vehicles Using Prediction Information and Artificial Potential Field, *Sensors* 2024, 24(22), 7292; <https://doi.org/10.3390/s24227292>.
- [6] E. Ferrero, S. Alessandrini, A. Balanzino, “Impact of the electric vehicles on the air pollution from a highway”, *Applied Energy Journal*. 169, 450–459, (2016).
- [7] L.A.W. Ellingsen, B. Singh, A.H. Strømman, “The size and range effect: lifecycle greenhouse gas emissions of electric vehicles”, *Environmental Research Letters*, No. 11, (2016).
- [8] C.C. Chan, “An overview of electric vehicle technology”. *Proceedings of the IEEE*. 81(9), 1202–1213, (1993).
- [9] C.C. Chan, K.T. Chau, “Modern Electric Vehicle Technology”, *Oxford Science publications*, (2001). Tianjin, China”. *Transport Policy Journal*. 56, 29–40, (2017).