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Advanced adaptive cruise control and vehicle to vehicle communication using LiDAR

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Abstract The ACC system is a type of driving assistance that helps reduce the burden on a driver. It operates by controlling the vehicle's acceleration and deceleration to maintain a certain speed or avoid a collision. In order to improve the accuracy of its operation, this paper proposes a method that uses radar to detect the presence of the preceding vehicle. It also takes into account the vehicle sideslip angle and the distance between the two vehicles. The proposed method can help improve the driving stability. In addition, we are currently using the vehicle-to-vehicle communication technology in our system. This type of inter-vehicle communication is not widely used yet and is a new paradigm in the field of communication. One of the main advantages of this type of communication is that it doesn't rely on third-party networks such as cellular networks. Despite the various advantages of this technology, it still has a long way to go before it can be fully deployed. The increasing number of operators who are interested in this technology has led to the development of more effective and efficient V2V solutions. This paper aims to provide a comprehensive analysis of the various challenges and benefits of this type of communication. The paper also focuses on the various security issues that are associated with this technology. One of these is the potential interference. This issue can prevent the system from operating efficiently. In order to address this issue, the paper suggests an improved architectural solution that can help prevent this type of interference. The proposed work also proposes a standardized space for the various components of the V2V system. This will allow them to easily integrate into the system. Vehicle-to-Vehicle communication is a type of wireless communication that is designed to allow cars to talk to one another.

Keywords: NRF24L01, Light Detection and Ranging, autonomous driving, safety, emergency braking, lane keeping

1. Introduction

The rising number of traffic accidents has highlighted the need for new technologies that can help prevent injuries and minimize the damage caused by these accidents. One of these is the use of advanced driving assistance systems such as the Adaptive Cruise Control. This system can help a vehicle maintain a safe distance from the car ahead.

This system uses sensors such as cameras and radar to monitor the road ahead, and it can detect other vehicles in the area. It then adjusts the vehicle's speed in order to avoid hitting the other cars. It is regarded as the first step in the development of automotive collision warning systems. The rapid emergence and worldwide interest in this technology will lead to the development of new products that will integrate this system into various vehicle platforms. These products will need to be equipped with various sensors and systems.

The complexity of ACC makes it an ideal product to demonstrate principles related to system engineering. Wireless communication is the method through which vehicles can share information with each other using V2V technology. This allows them to perform various functions such as merging onto a road, heading in a direction, and moving at speed. The use of V2V technology can enhance the system's capabilities by allowing it to collect more information about the vehicles in the area and the road ahead. This technology can also help prevent accidents by providing the necessary information to the driver in order to make an informed decision.

The use of V2V technology can also help prevent accidents by allowing it to collect more information about the vehicles in the area and the road ahead. This technology can additionally help prevent accidents by providing the necessary information to the driver in order to make an informed decision. Some of the applications that are expected to benefit from this technology include the use of electronic brake lights and blind spot warning. Staying connected allows vehicles to communicate with each other and improve their situational awareness. For instance, one car can send out a warning to another about road hazards or traffic delays.

The goal of this project is to develop a vehicle-to-car communication system that will allow cars to maintain safe distance and avoid accidents. It will be using an Arduino UNO and a LIDAR sensor to control the cars. In addition, this system

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will also be able to establish wireless communication between the vehicles. LIDAR uses laser beams to "see" the world around us in 3D. This technology provides a complete representation of the environment, allowing computers and machines to accurately identify and navigate through it. This project is semi-autonomous, which means that it allows drivers to switch between manual and automated driving modes.

In this study, the research objective is to design and implement an ACC and V2V system that effectively maintains safe distances among vehicles, automatically limits vehicle speed, and establishes wireless information exchange. By addressing these objectives, we aim to contribute to advancements in intelligent transportation systems and enhance road safety. Our proposed method holds significant promise in mitigating accidents, improving traffic management, and paving the way for a safer and more efficient driving experience.

2. System Specifications

The implementation of an effective Adaptive Cruise Control (ACC) and Vehicle-to-Vehicle (V2V) system relies on the integration of various hardware components. In this section, we provide an overview of the key components used in our system and their role in enhancing ACC functionality.

The central control platform of our system is Arduino Uno, a widely used microcontroller board known for its versatility and ease of use. It serves as the brain of the system, responsible for processing data, executing control algorithms, and coordinating the interaction between different subsystems.

To accurately measure the distance between the host vehicle and the preceding vehicle, we utilize the TF-Luna LiDAR sensor. LiDAR (Light Detection and Ranging) technology employs laser beams to provide precise distance measurements, enabling our system to maintain a safe following distance and adjust the vehicle's speed accordingly.

For seamless wireless communication between vehicles, we employ the NRF24L01 module, which operates on radio frequency. This module facilitates the exchange of critical information, such as speed and position, between vehicles in real time, enabling efficient coordination and enhanced safety measures. Additionally, we incorporate other essential components such as the RCWL-0516 Microwave Radar sensor to detect the presence of vehicles in the blind spot, and an LCD with an I2C module to display relevant information to the driver.

A detailed description of the components used is given below:

2.1. Arduino Uno

The ATmega328P microcontroller is the basis for this open-source board. It allows users to develop their own embedded systems and operating voltage is 5 Volts, Usable Pins: A0-A5, Max resolution: 10 bits, Time taken to read data: 100 µ sec and Min reading rate: 10,000 times a sec (Figure 1).

Figure 1 Arduino Uno.

2.2. TF-LUNA Micro LiDAR

The TF-Luna is a single-point laser range detector, which is based on the TOF principle (Figure 2). It features an electrical and optical design that allows it to accurately and precisely measure the distance. It can be used in various applications where accuracy and reliability are critical. The product's algorithms are designed to meet the diverse requirements of different environments. The operating range is up to 8m, distance resolution = 1cm, power consumption: ≤0.35W, frame rate: 1-250Hz (Default 100Hz), FOV: 2°, Weight: <=5g.

Figure 2 TF-LUNA Micro LiDAR.

2.3. NRF24L01 Module

The nRF24L01 is a single chip 2.4GHz transceiver with an embedded baseband protocol engine designed for ultra-low power wireless applications.

A single chip 2.4GHz radio transceiver known as nRF24L1 utilizes an embedded baseband engine (Figure 3). It is ideal for low-power wireless devices that operate in the ISM range of 2.400 to 2.4835GHz. The minimal external components needed for its design include a microcontroller and a few passive components. The nRF24L01 can be used with a serial peripheral interface to configure and operate its various functions. The device's register map allows users to access all of its configuration details. A wide range of applications can benefit from the nRF24L01. It is a type of wireless control device, which can be used in various areas such as industrial and medical equipment. Maximum operating speeds up to 2Mbps, GFSK modulation efficiency, Anti-interference ability. Particularly suitable for industrial control applications. Built-in hardware CRC error detection, Multipoint communication address control. Low-power 1.9 ~ 3.6V, only 1uA on Power down mode. Built-in 2.4Ghz antenna. Built-in voltage regulator. Standard DIP Pitch Interface for embedded applications.

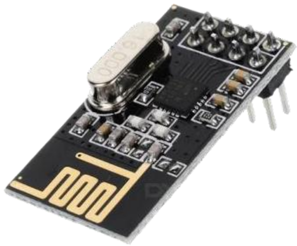

Figure 3 NRF24L01 Module.

2.4. RCWL-0516 Microwave Radar Sensor

The Microwave Radar Sensor Model RCWL-0516 is designed to be used in combination with security lights and burglar alarms (Figure 4). It does not detect movement within its detection range, but it can detect objects moving away from it. Unlike the traditional PIR sensor, this model uses a microwave Doppler radar to identify moving objects. The sensitivity range of this model is 2 meters. When activated, its output pin will switch from low to high in the 3.3 V range. It will return to its idle state after about 2 to 3 seconds. operating voltage (VDC): 4 to 28, operating current: 2.8mA (typical); 3mA (max), detecting range: 5-9m, transmitting power: 20mW (typical); 30mW (max), output voltage(V): 3.2 to 3.4V, output control low & high level: 0V & 3.3V, operating temperature (C): 20 to 80.

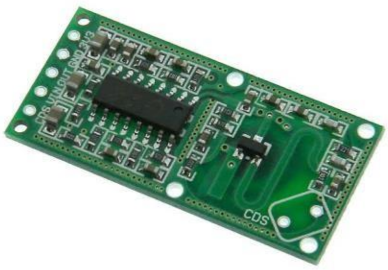

Figure 4 RCWL-0516 Microwave Radar.

2.5. 16x2 (1602) Character Green Backlight LCD Display

A basic 16-character Alphanumeric display with a green background and black text is featured on this model. It uses the HD44780 parallel chipset. The LCD screen comes with an LED backlight and can be used in 4 or 8 bit mode (Figure 5). It requires 6 general I/O channels to operate with model: LCD1602, interface: I2C, interface address: 0x27, character colour: white, supply voltage: 5V, board dimensions (L x W x H) mm: 80 x 36 x 18.

Figure 5 16x2 (1602) LCD Display.

2.6. I2C Module

The I2C LCD Daughter board is compatible with 16x2 or 20x4 character display modules that support 4-bit mode (Figure 6). All of the character modules that are sold on our site support this mode, and almost all of the commercially available ones do as well. The PCF8574 LCD Daughter board is equipped with a PCF8574I2C chip, which converts I2C data to parallel information for the display. There are a variety of websites that show how to use this board with an Arduino. The default I2C address of the board is 0x3F, but it can be changed to allow up to three displays to be controlled using one I2C bus.

Figure 6 I2C Module.

2.7. L298N Based Motor Driver Module – 2A

The L298N motor driver module is designed to drive Stepper and DC motors. It features a 78M05 5V regulator and an L298 motor driver IC (Figure 7). It can control up to four motors, and two can be operated with speed and directional control.

Figure 7 L298N-2A.

3. System Architecture & Methodology

- The system utilizes various sensors to gather data about the surrounding environment (Figure 8). This includes LiDAR (Light Detection and Ranging) and radar sensors. LiDAR provides accurate distance measurements by emitting laser beams and analyzing the reflected signals, while radar sensors use radio waves to detect objects and measure their distance and velocity.
- The Arduino Uno serves as the central processing unit of the system. It receives data from the sensors and performs real-time calculations and control operations based on the received inputs. The Arduino Uno is responsible for executing the ACC and V2V algorithms, as well as controlling the vehicle's speed and displaying relevant information.
- The ACC algorithm is designed to maintain a safe following distance between the host vehicle and the preceding vehicle. It processes the distance measurements from the LiDAR sensor and calculates the relative speed between the vehicles. Based on this information, the algorithm adjusts the speed of the host vehicle to maintain the desired distance, ensuring safe and efficient driving.
- The NRF24L01 module is a crucial component for enabling wireless communication between vehicles. It allows the system to exchange data with nearby vehicles, including information such as speed, position, and heading. The V2V communication mechanism enables cooperative actions, such as issuing warnings about hazards or sharing information for safe overtaking. The NRF24L01 module handles the transmission and reception of data between vehicles.
- The LCD (Liquid Crystal Display) serves as the output interface of the system. It displays important information to the driver, such as the current speed, distance to the preceding vehicle, and overtaking status. The display provides visual feedback and alerts the driver about the system's actions and recommendations.
- The motor control component(L298N-2A) interfaces with the vehicle's braking and acceleration mechanisms. It receives control signals from the Arduino Uno, which are determined based on the ACC algorithm's calculations. The motor control adjusts the vehicle's speed by controlling the throttle and applying the brakes as necessary.
- The power supply unit ensures the proper functioning of all the system components by providing the necessary electrical power. It supplies power to the sensors, Arduino Uno, NRF24L01 module, LCD display, motor control, and other supporting components.

- The driver switch is an important component that allows the driver to turn on or off the ACC and V2V system. When the switch is in the "on" position, the ACC and V2V functionalities are active, and the system operates according to the algorithms and communication protocols. When the switch is in the "off" position, the ACC and V2V functionalities are disabled, and the vehicle operates in manual mode without automated speed control or V2V communication.

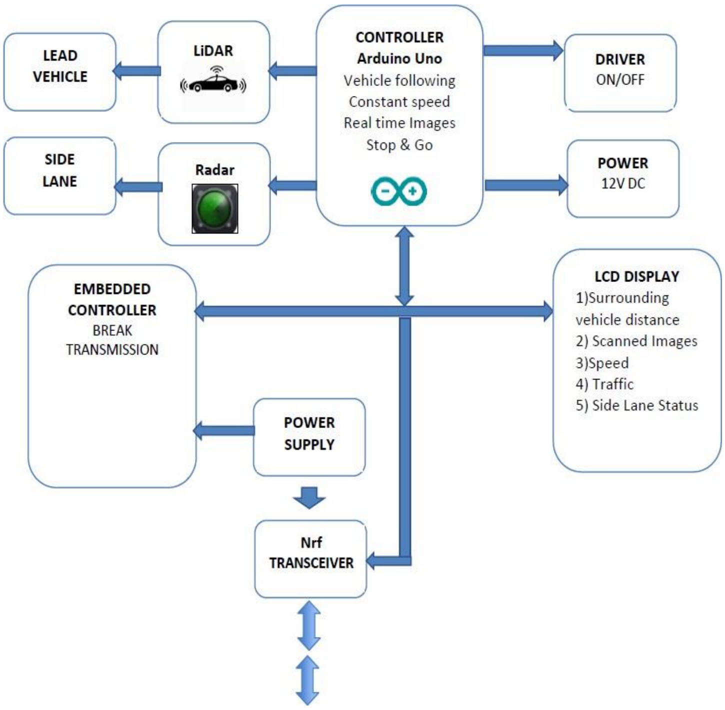

Figure 8 Block Diagram of Proposed System.

Algorithms

a. ACC algorithm:

- STEP 1 – Input from LiDAR.
  The LiDAR sensor detects the distance between the host vehicle and the preceding vehicle. It uses laser beams to measure the time it takes for the beams to reflect back from objects, allowing for accurate distance measurements.
- STEP 2 – Detect the preceding vehicle.
  Using the LiDAR data, the system identifies the presence of a preceding vehicle by analyzing the distance measurements. If a vehicle is detected within a specific range, it confirms the presence of a preceding vehicle.
- STEP 3 – Find Preceding vehicle speed.
  To determine the speed of the preceding vehicle, the system analyzes the changes in distance measurements over time. By comparing consecutive distance readings, it calculates the relative velocity of the preceding vehicle.
- STEP 4 – Find the vehicle's local speed.
  The system measures the local speed of the host vehicle using sensors such as wheel speed sensors(in this case we are using motor driver for speed adjustments). This provides the necessary information to calculate the relative speed between the host and preceding vehicles.
- STEP 5 – Find Headway distance.
  The headway distance refers to the distance between the host vehicle and the preceding vehicle. It is calculated by subtracting the length of the preceding vehicle from the measured distance.
- STEP 6 – Start reducing the speed of local vehicle according to the Headway distance.
  Based on the headway distance, the system adjusts the speed of the host vehicle to maintain a safe following distance. It may reduce the speed gradually to ensure a safe buffer between the vehicles.
- STEP 7 – Issue a warning if vehicle is too close to the preceding vehicle.
  If the system determines that the host vehicle is approaching the preceding vehicle too closely, it generates a warning signal. This warning can be in the form of a visual or auditory alert to notify the driver to take appropriate action and emergency breaks can be applied in this case(in case any object comes in front of the vehicle, while the vehicle is in ACC mode).
- STEP 8 – Apply Emergency breaks if vehicle is too close to the preceding vehicle.

In critical situations where the host vehicle is dangerously close to the preceding vehicle, the system triggers the emergency braking mechanism. This action helps prevent a collision by rapidly decelerating the host vehicle.

b. V2V algorithm:

- STEP 1 – Collect data from side Lane through LiDAR and Radar.
  The system utilizes LiDAR and Radar sensors to gather data from the side lane. These sensors provide information about the distance and presence of vehicles in the adjacent lane.
- STEP 2 – Check if vehicle is approaching from side lane.
  By analyzing the data collected from the LiDAR and Radar sensors, the system determines if a vehicle is approaching from the side lane. It evaluates the distance and relative velocity of the approaching vehicle.
- STEP 3 – Transmit the information through NRF24L01.
  If a vehicle is detected approaching from the side lane, the system transmits this information through the NRF24L01 module. This module enables wireless communication and allows for the exchange of data between vehicles.
- STEP 4 – Collect data from Surrounding Vehicles through NRF24L01 module.
  The system receives data from other vehicles in the vicinity via the NRF24L01 module. This data includes information such as speed, position, and heading of the surrounding vehicles.
- STEP 5 – Check if the side lane is free to overtake.
  Using the collected data, the system evaluates the availability of the side lane for overtaking. It assesses the position and speed of the surrounding vehicles to determine if it is safe to change lanes and overtake.
- STEP 6 – If the lane is free to overtake, display “Free to overtake”.
  If the system determines that the side lane is clear and safe for overtaking, it displays the message "Free to overtake" on the appropriate display, such as an LCD screen. This indicates to the driver that it is permissible to change lanes and proceed with overtaking.
- STEP 7 – If the lane is not free to overtake, display “Don’t Overtake”.
  If the system determines that it is not safe to overtake due to the presence of other vehicles in the side lane, it displays the message "Don't Overtake" on the display. This serves as a warning to the driver to refrain from attempting an overtaking manoeuvre.

4. Results

The image shows the simulation code for sending and receiving messages between the vehicle and the Arduino (Figure 9).

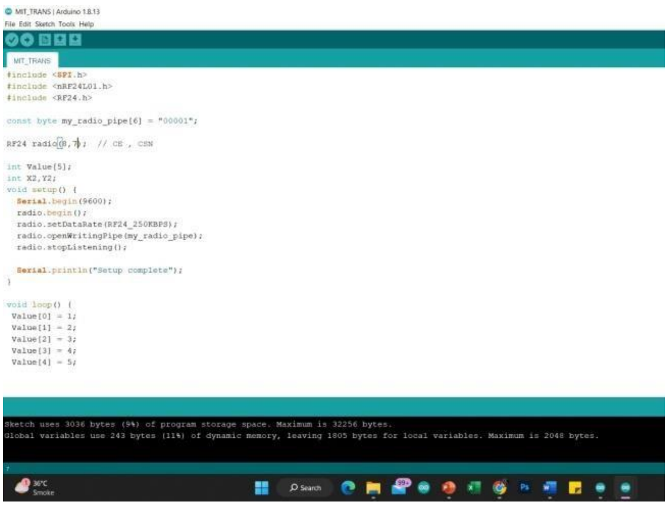

Figure 9 Transceiver Code for V2V Communication.

- The data transmission between two different systems is shown in the image above in Figure 10
- The data collected by both systems include the distance between the vehicles in front and the ones in the opposite lane.
- The hardware model of the project is shown in Figure 11, which includes all the necessary components.
- The displayed data in the dashboard of the car is shown in the Figure 12, which indicates that the system has detected an object in the road ahead.
- The data collected by the system will be displayed on the dashboard of the car whenever it does not detect an object in the road ahead. This means that the vehicle can safely overtake another car if it does not detect an object in the road ahead.

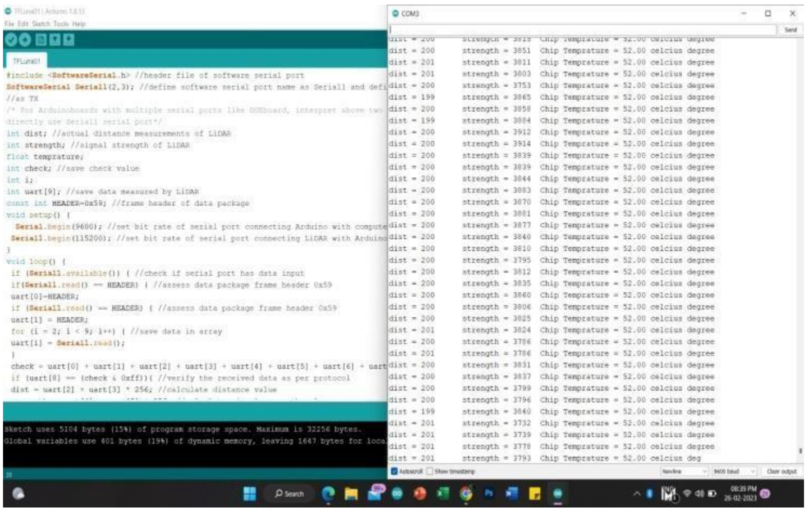

Figure 10 Simulation results of V2V Communication.

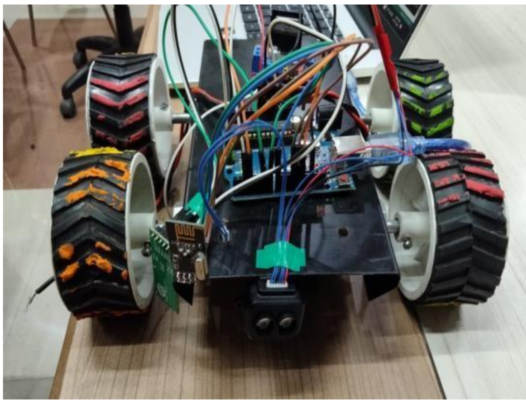

Figure 11 Hardware model of the Proposed System.

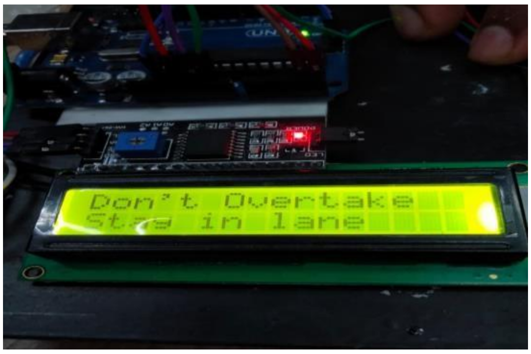

Figure 12 Data to be displayed in the vehicle.

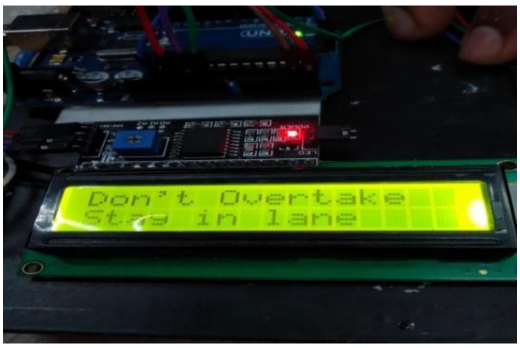

Figure 13 Data to be displayed (When the lane is clear).

5. Observations

The proposed system's results can be used to make observations (Table 1).

Table 1 Observation table for ACC System.

Distance	Speed (RPM)
5	0
10	50
15	100
20	150
25	200
30	300
>40	300

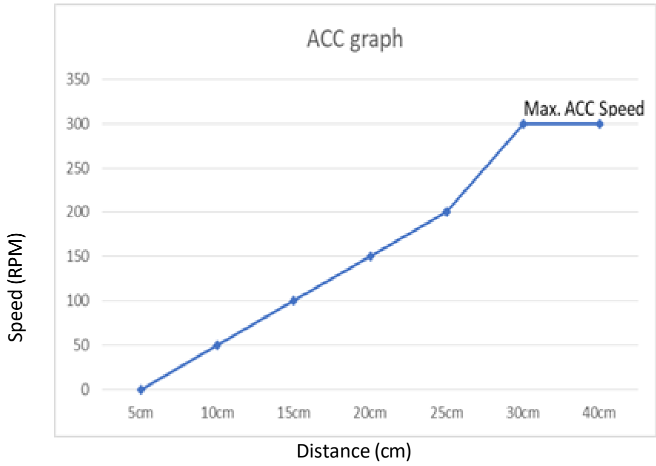

Figure 14 Graphical representation of Adaptive Cruise Control system.

The presented data is derived from the proposed ACC system using graphical representations. Table 2 indicates the optimal result for overtaking safely or not.

Table 2 Observation table for V2V System.

Vehicle in blind spot	Vehicle in opposite lane	Vehicle in front of preceding vehicle	Overtake Safe?
×	×	×	✓
×	×	✓	×
×	✓	×	×
×	✓	✓	×
✓	×	×	×
✓	×	✓	×
✓	✓	×	×
✓	✓	✓	×

- The dashboard displays a message that says "OVERTAKE" if all the conditions are met for safe overtaking.
- The dashboard displays a message that says "DON'T OVERTAKE" if the conditions are not satisfactory.

5. Observations

Driver error is a leading cause of fatalities in car accidents. There is a huge improvement in vehicle safety by implementing various technologies such as anti-lock braking systems (ABS), airbags, and obstacle avoidance systems. However, these technologies do not prevent accidents. The use of the ACC system can help the driver in making sure that the vehicle is moving smoothly and avoiding accidents. In poor weather conditions or when driving in foggy areas, the driver might not be able to see the distance between the vehicles in front of them. But with the help of the system, the driver can actually drive in these conditions more easily. The Adaptive Cruise Control system has the potential to reduce the accidents that occur. It was developed to provide a safer and more comfortable riding experience for the driver. This system eliminates the need for the driver to operate the brake and switch manually, which helps reduce the burden on the vehicle. The benefits of the ACC system include its ability to provide a fuel-efficient and reliable driving experience. It also helps reduce the risk of accidents by accelerating and braking automatically. The main objective of this technology is to prevent costly and deadly traffic accidents by implementing vehicle-to-vehicle communication. These systems can help alert other cars on the road when a departing vehicle approaches. Similarly, they can detect vehicles traveling across paths and alert them.

7. Conclusions

The conclusion of the report emphasizes the significance of implementing the Advanced Adaptive Cruise Control (ACC) system and Vehicle-to-Vehicle (V2V) communication technology in improving road safety and minimizing accidents caused by driver mistakes. The ACC system acts as a driving assistant, providing assistance to drivers and minimizing the risk of accidents. It enables drivers to navigate through challenging conditions such as fog or poor weather by accurately maintaining distances between vehicles. By reducing the burden on drivers and automating acceleration and deceleration, the ACC system promotes comfort, fuel efficiency, and safer driving practices.

The integration of V2V communication technology further enhances the safety aspect of the system. By enabling vehicles to exchange critical information, such as speed and position, the system aims to eliminate costly and life-threatening traffic collisions. The communication between vehicles allows for timely warnings and alerts, facilitating proactive decision-making and enhancing overall road safety. The V2V system, coupled with ACC, provides a comprehensive approach to preventing accidents and mitigating their impact.

Overall, the combination of ACC and V2V technology has the potential to significantly reduce the number of accidents, improve fuel efficiency, and enhance driving comfort. The system's ability to automate certain driving operations and facilitate real-time communication between vehicles promotes a safer and more reliable driving experience. By implementing these advanced technologies, we can pave the way for a future with enhanced road safety and reduced fatalities.

An onboard diagnostics system, also known as an OBD, helps the vehicle’s electronic control unit (ECU) identify the malfunction of the vehicle systems and take immediate corrective measures to prevent the hazards and accidents. This type of system enhances the passenger and driver’s safety (Sutar and Shinde 2018).

This tool can help you send and receive vehicle and diagnostic messages. It can also validate the response of the engine. It is very user-friendly and has a variety of features such as message logging (Sutar and Shinde 2017).

A device that can continuously monitor the status of a driver’s safety in real-time using a computer vision system. This device is made up of various components, such as a video camera, a Raspberry Pi, and an alarm system (Kulkarni and Shinde 2017).

The device can operate and switch on and off the lights when the vehicle enters or departs the road tunnel. It uses an IR sensor to detect the energy consumption in the tunnel and has a load cell that can switch the circuits (Potdar et al 2017).

Ethical considerations

Not applicable.

Conflict of Interest

The authors declare no conflicts of interest.

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