KLE TECHNOLOGICAL UNIVERSITY
Creating Value, Leveraging Knowledge
Belagavi Campus
DR. M. S. SHESHGIRI COLLEGE OF ENGINEERING AND TECHNOLOGY

Department of Electronics and Communication Engineering

Report on Minor Project

ADVANCED CRUISE CONTROL SYSTEM

By:

1. **Akash Potdar** USN: 02FE22BEC003
2. **Ayan Kudachi** USN: 02FE22BEC013
3. **Pallavi Lad** USN: 02FE22BEC046
4. **Vaibhavi Patil** USN: 02FE22BEC048

Semester: VI, 2024-2025

Under the guidance of
Dr.Arun Tigadi

KLE TECHNOLOGICAL UNIVERSITY | Belagavi Campus

Creating Value, Leveraging Knowledge

DR. M. S. SHESHGIRI COLLEGE OF ENGINEERING AND TECHNOLOGY

2024-2025

DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

CERTIFICATE

This is to certify that project entitled **"Advanced Cruise Control System"** is a bonafide work carried out by the student team of **" Akash Potdar (02FE22BEC003), Ayan Kudachi (02FE22BEC013), Pallavi Lad (02FE22BEC046), Vaibhavi Patil (02FE22BEC048)"**. The project report has been approved as it satisfies the requirements with respect to the Minor Project work prescribed by the university curriculum for B.E. (VI Semester) in Department of Electronics and Communication Engineering of KLE Technological University Dr. M. S. Sheshgiri CET Belagavi campus for the academic year 2024-2025.

Dr. Arun Tigadi **Guide**	**Dr. Dattaprasad A. Torse** **Head of Department**	**Dr. S. F. Patil** **Principal**

External Viva:

Name of Examiners **Signature with date**

1.

2.

ACKNOWLEDGMENT

We would like to express our sincere gratitude to the following individuals and organizations who have played a significant role in the development of the Remote Patient Monitoring System.

We would like to express our sincere gratitude to our guide, Dr. Arun Tigadi, whose invaluable guidance and unwavering support have been instrumental throughout the entirety of our project.

We take the opportunity to thank our project coordinator Prof. Ashwini Desai, for providing us motivation and encouragement.

We are grateful to our Head of the Department Dr. Dattaprasad Torse, for granting us the privilege to work on this project and for his valuable support throughout.

We take the opportunity to thank our Principal Dr. S. F. Patil, for providing us the opportunity to undergo the project.

We acknowledge the contributions of all the team members who participated in this project. Each team member brought unique skills and perspectives, contributing to the development of different elements of the project.

We extend our thanks to KLE Dr. MSSCET for providing the necessary resources and infrastructure to carry out this project. Their support was vital in enabling us to conduct the required research, acquire relevant knowledge, and access computing resources.

We take this opportunity to thank all the teaching and non-teaching staff of Electronics and Communication Department for their cooperation and suggestions during the project.

-The project team

Contents

List of Figures **v**

List of Tables **v**

1 Introduction **2**
- 1.1 Motivation . . . 2
- 1.2 Objectives . . . 2

2 Literature Survey **3**

3 Project Planing **5**
- 3.1 Gantt Chart . . . 5
- 3.2 Work Breakdown Structure . . . 6

4 Components Specification **7**
- 4.1 ESP32 Development Board . . . 7
- 4.2 Camera Module . . . 7
- 4.3 Ultrasonic Sensor . . . 7
- 4.4 DC Motor . . . 7

5 Methodology **8**
- 5.1 System Overview . . . 8
- 5.2 Sensor Integration and Control Logic . . . 8
- 5.3 Advanced Cruise Control (MATLAB/Simulink): . . . 9
- 5.4 Braking System Simulation . . . 11
- 5.5 Bill Of Materials . . . 12

6 Results and Discussion **12**

7 Applications **13**
- 7.1 Highway Driving Assistance . . . 13
- 7.2 Traffic Jam and Stop-and-Go Situations . . . 13
- 7.3 Integration with Driver Assistance Systems . . . 14
- 7.4 Fuel Efficiency Optimization . . . 14
- 7.5 Enhanced Safety in Adverse Conditions . . . 14
- 7.6 Application in Electric and Autonomous Vehicles . . . 14

8 Advantages **14**

9 Future Work **14**

10 Conclusion **15**

List of Figures

1 Gantt Chart 5
2 Work breakdown Structure 6
3 Block Diagram 8
4 Implementation of Advanced Cruise Control System on Simulink 10
5 ACC Simulation Results 10
6 Implementation of Braking System 11
7 Braking System Results 11
8 Hardware Implementation 12

List of Tables

1 Bill of Materials 12

Abstract

Driving long distances on highways often requires constant acceleration and deceleration, which can lead to driver fatigue and increase the risk of accidents. The growing demand for intelligent transportation systems has led to the development of solutions like Advanced Cruise Control (ACC). This mini project presents a real-time ACC system that uses embedded hardware and sensor integration to dynamically adjust the speed of a vehicle.The system is designed using an ESP32 microcontroller as the central processing unit, integrated with a camera module for object detection, an ultrasonic sensor for distance measurement, and a DC motor to simulate vehicle motion. The camera detects objects or pedestrians in front of the vehicle, while the ultrasonic sensor accurately measures the distance to obstacles. Based on this sensor data, the ESP32 adjusts the motor speed to maintain a safe following distance.The system decelerates when an object or pedestrian is detected within a defined threshold range. If the object remains in close proximity, the system brings the motor to a complete stop, effectively mimicking braking. Once the path is clear, the system gradually reaccelerates, with the set cruising speed. This intelligent control behavior enhances driver comfort and ensures safer travel by minimizing human error and responding dynamically to real-world conditions. The project demonstrates the effective integration of real-time sensing, decision-making, and actuation to build an efficient embedded system for driver assistance.

1 Introduction

Driving long distances, particularly on highways or in stop-and-go traffic, can be physically and mentally exhausting for drivers. Constant acceleration, deceleration, and the need to maintain a safe following distance demand high levels of attention and control. Fatigue from such tasks often leads to delayed reaction times and increases the probability of accidents. With growing concerns over road safety and the push towards automation in the automotive industry, systems like Advanced Cruise Control (ACC) have become vital components of modern vehicles.

Advanced Cruise Control, also known as Adaptive Cruise Control, is an intelligent driver-assistance system that automatically adjusts the vehicle's speed based on real-time traffic conditions. Unlike traditional cruise control systems that maintain a fixed speed, ACC uses sensors and microcontrollers to detect vehicles or obstacles ahead and actively changes the vehicle's speed to maintain a safe distance. This functionality significantly reduces the driver's workload and enhances safety and comfort during extended drives.

In this minor project, we aim to develop a prototype ACC system using a combination of embedded hardware and simulation tools. The system is built around the ESP32 microcontroller, chosen for its processing power, Wi-Fi/Bluetooth support, and GPIO flexibility. A camera module is used for basic object detection, while an ultrasonic sensor accurately measures the distance to nearby obstacles. A DC motor represents the vehicle's movement, and the system adjusts its speed based on sensor feedback.

This project not only provides practical insights into the design and development of an intelligent control system but also contributes to the broader vision of smart mobility solutions. The integration of sensors, simulation, and control logic showcases how embedded systems can be employed to build safer, more intelligent vehicles capable of adapting to dynamic road environments.

1.1 Motivation

Long-distance travel often requires continuous control of vehicle acceleration and deceleration, which can lead to mental fatigue and slower reaction times in drivers. With the increasing number of vehicles on roads, the need for intelligent driver assistance systems has become more prominent.

Our motivation stems from the growing demand for smarter, safer transportation technologies that reduce human error and enhance driving comfort. An Advanced Cruise Control system not only improves safety but also contributes to fuel efficiency and smoother traffic flow by automating speed regulation based on real-time surroundings.

1.2 Objectives

- To design an Advanced Cruise Control system that automatically regulates vehicle speed based on the distance from the vehicle ahead.
- To integrate hardware components including Raspberry Pi, camera module, ultrasonic sensor, and DC motor for real-time object detection and response.
- To develop and test a Simulink-based simulation model that replicates the control strategy and validates system logic.
- To ensure the system decelerates when obstacles are detected and reaccelerates when the path is clear.
- To demonstrate the feasibility of combining simulation and embedded control for intelligent driver assistance.

2 Literature Survey

Advanced Cruise Control (ACC), also referred to as Adaptive Cruise Control, has gained increasing attention in recent years due to its potential to improve road safety, reduce driver fatigue, and enhance overall driving comfort. As the automotive industry moves toward greater levels of automation and the integration of intelligent transportation systems, researchers and engineers are actively exploring various implementations of ACC using embedded platforms, sensor fusion, and advanced control algorithms. These implementations aim to create systems capable of dynamically adjusting vehicle speed in response to real-time traffic conditions, maintaining safe following distances, and seamlessly coordinating throttle and brake actions. The continuous evolution of ACC technologies reflects a broader shift toward smarter, safer, and more energy-efficient mobility solutions.

Ruiyu Hou et al. [3] proposed an Adaptive Cruise Control (ACC) strategy that dynamically adapts to individual driving styles to enhance both safety and comfort. By incorporating real-time driving style recognition—classifying drivers as aggressive, moderate, or conservative—the system adjusts its control parameters accordingly using a Model Predictive Control (MPC) framework. This personalized approach enables the vehicle to respond more naturally in various traffic scenarios, ensuring smoother acceleration and braking. Simulation results show that the proposed strategy outperforms traditional ACC systems by offering improved responsiveness and driver comfort, marking a step forward in intelligent and user-centric vehicles

Duc Lich Luu, Ciprian Lupu, and Thien Van Nguyen [4] introduced a two-layer control architecture for Adaptive Cruise Control (ACC) systems. The upper-level controller computes the desired acceleration based on sensor inputs to maintain a safe distance from the lead vehicle, while the lower-level controller adjusts the throttle angle to generate the necessary torque. A simplified longitudinal vehicle dynamics model is employed to design the lower-level controller. The system's effectiveness is validated through simulations conducted in MATLAB/Simulink, demonstrating its capability to maintain desired distances and safe speeds from preceding vehicles

Recent advancements in Adaptive Cruise Control (ACC) systems focus on enhancing safety, comfort, and responsiveness in dynamic traffic environments. One approach [1] combines Artificial Neural Networks (ANN) with Fuzzy Inference Systems (FIS), where ANN learns traffic patterns and FIS ensures robust decision-making for adaptive speed control. This hybrid model improves accuracy in maintaining safe distances. Another method, proposed by Jiawei Tian et al [8], utilizes Model Predictive Control (MPC) with a high-order kinematic model that considers distance, velocity, acceleration, and jerk. A constraint softening technique is introduced to improve robustness against large feedback corrections. Both systems show improved performance in simulations. Integrating ANN-FIS learning with MPC optimization can further advance intelligent transportation solutions.

Chen Yang and Bin Liu [9] focused on developing an adaptive cruise control (ACC) system tailored for electric vehicles (EVs). The study emphasizes the unique characteristics of EVs, such as regenerative braking and battery management, in designing the ACC system. The proposed system aims to enhance energy efficiency, safety, and driving comfort by integrating advanced control algorithms and vehicle dynamics models. Simulation results demonstrate the effectiveness of the ACC system in maintaining optimal vehicle speed and distance, thereby contributing to the advancement of intelligent transportation systems for EVs.

Ritesh Kumar Sharma et al. [6] focuses on developing a vehicle cruise control system. The study investigates various control strategies, including traditional and advanced methods, to enhance the performance of the cruise control system. Simulation results demonstrate the effectiveness of the proposed system in maintaining desired speed and improving overall vehicle stability. The research contributes to the advancement of automotive control systems, aiming to enhance driver comfort and safety.

Dany Ghraizi, Reine Talj, and Clovis Francis [2] presented an ACC system based on Deep Reinforcement Learning (DRL) to improve decision-making in autonomous vehicles. Using a discrete action space (accelerate, decelerate, maintain speed), the approach simplifies control while ensuring interpretability. A multi-objective reward function guides the agent to balance safety, responsiveness, and realistic driving behavior. Trained in car-following scenarios, the DRL agent outperforms traditional models like IDM in maintaining safe distances and avoiding collisions. The method shows promise for extension to more complex tasks like lane changes..The paper A Deep Reinforcement Learning Decision-Making Approach for Adaptive Cruise Control in Autonomous Vehicles presents an ACC system based on Deep Reinforcement Learning (DRL) to improve decision-making in autonomous vehicles. Using a discrete action space (accelerate, decelerate, maintain speed), the approach simplifies control while ensuring interpretability. A multi-objective reward function guides the agent to balance safety, responsiveness, and realistic driving behavior. Trained in car-following scenarios, the DRL agent outperforms traditional models like IDM in maintaining safe distances and avoiding collisions. The method shows promise for extension to more complex tasks like lane changes.

Some other researchers have proposed advanced strategies to enhance Adaptive Cruise Control (ACC) systems.Suleiman, Vlasov, Dobriborsci, Tung, and Hung [7] proposed and simulated various lane change prediction algorithms to enhance Adaptive Cruise Control (ACC) systems using MATLAB/Simulink. The study evaluates machine learning models such as Fine K-Nearest Neighbor (KNN), Wide Neural Network (WNN), Fine Gaussian Support Vector Machine (SVM), and Fine Decision Tree for predicting lane changes of surrounding vehicles. These algorithms aim to reduce response delay and improve collision avoidance in ACC systems, particularly when integrated with Model Predictive Control (MPC).W. Yi et al. [10] focused on connected vehicle communication to predict traffic flow and improve responsiveness during sudden braking, enhancing safety and fuel efficiency. Saputro et al [5] developed an Adaptive Cruise Control (ACC) system for electric vehicle prototypes using a PID control method. The system uses sensors to adjust speed and maintain safe distances in real time. Experimental results demonstrate improved response and stability, supporting its suitability for EV applications.

In summary, while high-end ACC systems are already in commercial use, ongoing research and prototype development at the academic level continue to explore cost-effective, scalable, and modular solutions. Our work aligns with this trend, offering a robust entry-level ACC implementation using accessible technology that can be extended into more advanced systems in the future.

3 Project Planing

Project planning is critical for ensuring project success by clearly defining objectives, identifying tasks, and setting timelines. A well-structured plan enables efficient resource allocation, ensuring that the right personnel, tools, and materials are available at the right time to meet project demands. It also facilitates effective risk management by anticipating potential challenges and devising strategies to mitigate them, thereby minimizing disruptions. Additionally, project planning helps maintain focus and alignment among team members, ensuring everyone understands their roles and responsibilities, which fosters collaboration and accountability. By enhancing communication, it allows for smooth coordination across departments or stakeholders, enabling quick resolution of issues and ensuring transparency. Furthermore, a comprehensive plan ensures that project milestones are achieved within budget and scope, reducing the likelihood of scope creep and cost overruns. Ultimately, project planning lays the foundation for delivering high-quality outcomes while meeting stakeholder expectations.

3.1 Gantt Chart

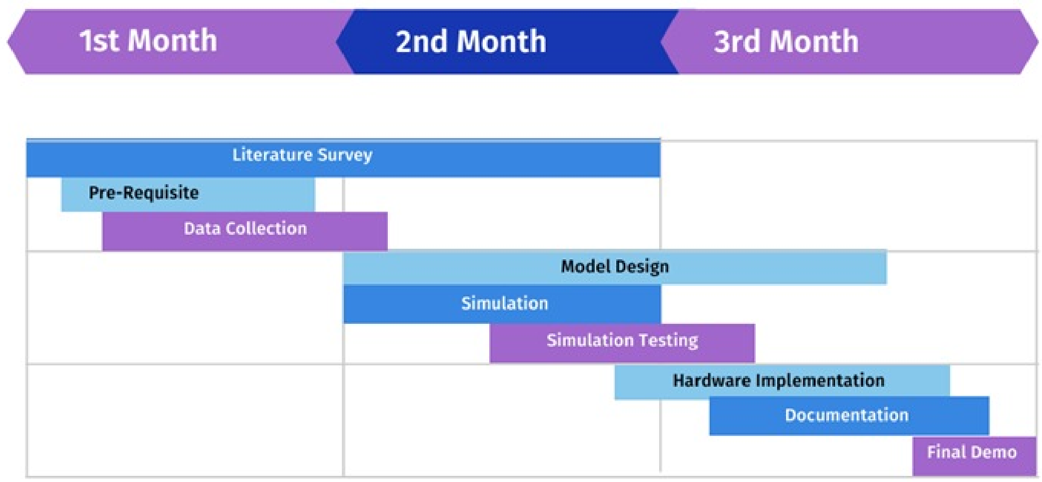

Figure 1: Gantt Chart

A Gantt chart is a visual project management tool that represents the timeline of a project. It displays tasks or activities as horizontal bars along a timeline, with the length of each bar indicating the duration of a task.The Gantt chart helps project managers track progress, manage deadlines, and visualize how tasks overlap or depend on one another. It is widely used for scheduling, resource allocation, and ensuring timely completion of projects.

3.2 Work Breakdown Structure

A Work Breakdown Structure (WBS) is a project management tool that divides a project into smaller, manageable components or tasks. It organizes the work into a hierarchy, making it easier to plan, assign resources, and track progress. The WBS helps clarify the scope of the project, ensuring that all required work is identified. It also enhances communication among team members andstakeholders, assigns responsibilities, and improves time and resource management. By breaking down complex projects into manageable parts, it makes it easier to estimate costs, schedule timelines, and monitor progress

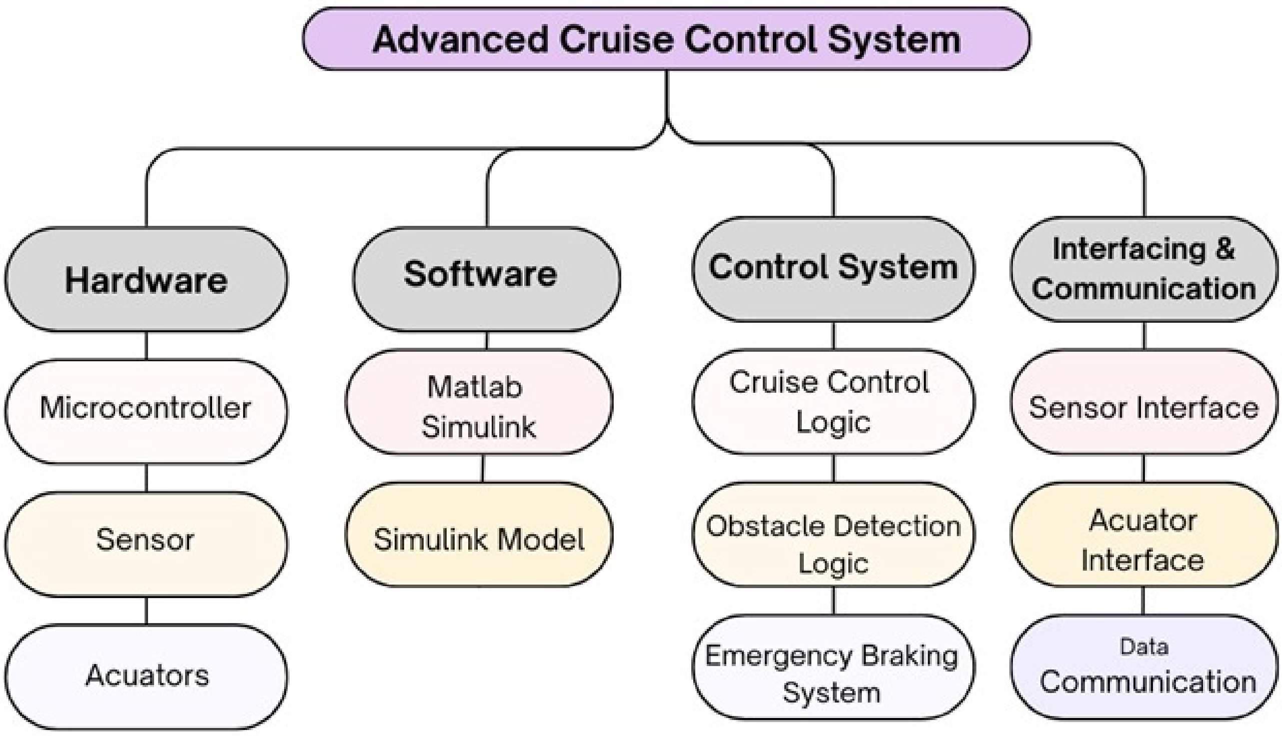

Figure 2: Work breakdown Structure

4 Components Specification

This section outlines the key hardware components used in the development of the Advanced Cruise Control System. Each component plays a vital role in sensing, processing, or executing commands that simulate vehicle behavior based on real-world inputs.

4.1 ESP32 Development Board

- Dual-core 32-bit LX6 processor, up to 240 MHz.
- 520 KB SRAM and 448 KB ROM.
- Supports Wi-Fi (2.4 GHz) and Bluetooth v4.2.
- Offers 34 programmable pins.
- Used to process ultrasonic sensor data, control the motor, and handle camera input (with additional interfacing).

4.2 Camera Module

- Used for basic object detection in front of the vehicle.
- Interfaces directly with ESP32 or via an ESP32-CAM module.
- Capable of capturing video sufficient for prototyping.
- Used in conjunction with simple image processing or decision logic for obstacle detection.

4.3 Ultrasonic Sensor

- Detects distance between the vehicle and objects ahead.
- Operating voltage: 5V DC; range: 2 cm to 400 cm.
- Sends ultrasonic pulses and receives echoes to calculate distance using time-of-flight.
- Data used to trigger motor speed changes in response to obstacle proximity.

4.4 DC Motor

- Simulates vehicle motion in the prototype setup.
- The speed is varied based on input from the camera and ultrasonic sensor.
- Represents acceleration, deceleration, or halting of the vehicle.

5 Methodology

The Advanced Cruise Control System was developed using both simulation tools and physical hardware to design, test, and validate the functionality. The methodology includes sensor integration, real-time data processing using the ESP32 microcontroller, and simulation in MATLAB/Simulink to emulate the behavior before implementation.

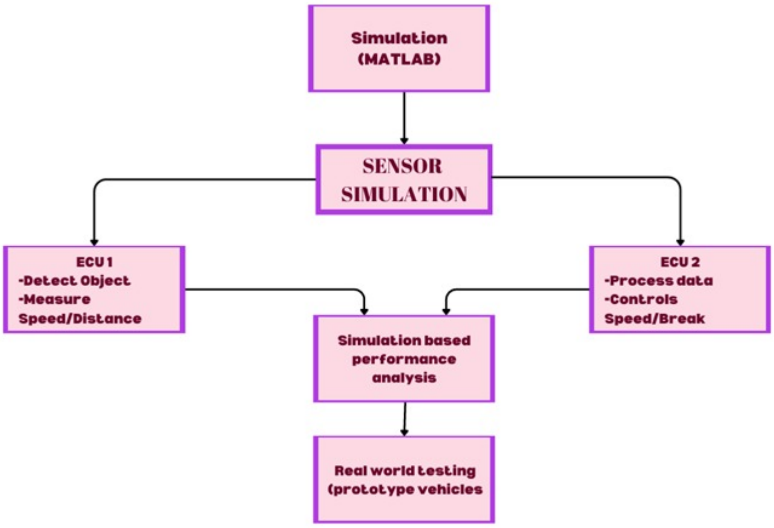

Figure 3: Block Diagram

5.1 System Overview

The system architecture consists of:

- ESP32 microcontroller as the central control unit.
- Ultrasonic sensor to detect the distance of obstacles in front of the vehicle.
- Camera module (ESP32-CAM) for basic object recognition or real-time video feed (if implemented).
- DC motor to simulate vehicle motion.
- Motor driver to interface and control the motor's speed and direction.

The ESP32 collects data from the sensors and processes it using conditional logic. If an object is detected within a predefined threshold, the system decelerates the motor (vehicle slows down or stops). When the object moves away, the system gradually reaccelerates.

5.2 Sensor Integration and Control Logic

The Advanced Cruise Control System relies on seamless integration of multiple sensors with the ESP32 microcontroller to enable real-time decision-making and motor control. At the core of this system is the ultrasonic sensor, which is used to measure the distance between the vehicle and any obstacle in front of it. The sensor operates by emitting an ultrasonic pulse and measuring the time it takes for the echo to return after hitting an object. This time delay is used to calculate the distance using the speed of sound. The ESP32 receives this echo signal and processes the duration to determine the proximity of obstacles with high accuracy. Based on this distance data, the microcontroller makes real-time decisions about whether the vehicle should continue moving at the same speed, reduce speed, or come to a halt.

The camera module, either through an ESP32-CAM or an external interface, is used to capture visual data of the environment. Although not used for complex object recognition in this prototype, it can detect the presence of large objects or be used for future enhancements involving basic visual alerts. Image data may be processed on-board or externally depending on the processing load. The control logic implemented in the ESP32 is responsible for analyzing sensor inputs and generating appropriate outputs in the form of PWM signals to the motor driver module. These PWM signals determine the speed of the DC motor, which in this system represents the motion of the vehicle.

If the ultrasonic sensor detects that the distance to an object ahead is less than a predefined safe threshold, the ESP32 reduces the motor's speed by adjusting the PWM duty cycle or, in critical cases, stops the motor altogether. Once the object is no longer within the danger zone, the system gradually increases the motor speed, simulating the vehicle accelerating back to cruising mode. This logic mimics real-world adaptive cruise control behavior and ensures the system maintains a safe following distance. The integration of sensor data with motor control logic, executed in real time by the ESP32, forms the core of this intelligent driving assistance prototype. In order to maintain a safe following distance, the ultrasonic sensor continuously monitors the presence of obstacles in its range. If an object or vehicle remains stationary within this range for an extended period, the system includes a manual override switch. This switch allows the driver to temporarily exit the ACC mode and manually proceed, ensuring the vehicle does not remain halted unnecessarily in prolonged traffic conditions or due to false detections.

5.3 Advanced Cruise Control (MATLAB/Simulink):

The simulation was developed in MATLAB/Simulink to evaluate the control strategy of the Adaptive Cruise Control (ACC) system before deploying it on hardware. The model consists of two vehicles: a lead car and an ego car (the vehicle under control). The lead car's motion is governed by predefined acceleration, initial position, and initial velocity parameters. Its output includes actual position and velocity, which serve as inputs for calculating the relative distance and relative velocity between the two vehicles.The ACC logic block receives the following inputs:

- Set velocity (desired cruising speed for the ego car),
- Time gap (desired safe time headway),
- Relative distance and relative velocity (computed from lead and ego cars).

Based on these inputs, the ACC controller computes the longitudinal acceleration required for the ego car to maintain a safe following distance. This output is then fed into the ego car dynamics block, which simulates the ego car's response in terms of position and velocity.The simulation output consists of three plots: acceleration, velocity, and inter-vehicle distance.

- Acceleration Plot: This plot shows the variation in acceleration for both the ego and lead cars over time. Initially, the ego car accelerates to catch up with the lead car, then adjusts its acceleration based on the relative distance. Whenever the lead car changes speed, the ego car responds appropriately to maintain a safe gap. Noticeable deceleration phases indicate obstacle response and safety regulation.
- Velocity Plot: The ego car (red line) attempts to match the lead car's velocity (blue line) while respecting the set speed (black dashed line). The ego car closely follows the velocity profile of the lead car, showcasing the system's ability to adapt its speed dynamically. Oscillations reflect adjustments made to prevent collisions or unsafe following distances.

- Distance Between Two Cars: This plot compares the actual distance between the lead and ego car with the computed safe distance. The ego vehicle maintains a greater-than-safe distance for most of the simulation, ensuring safety. The sinusoidal pattern in the lead car's motion (caused by variable acceleration) is reflected in the ego car's trailing behavior.

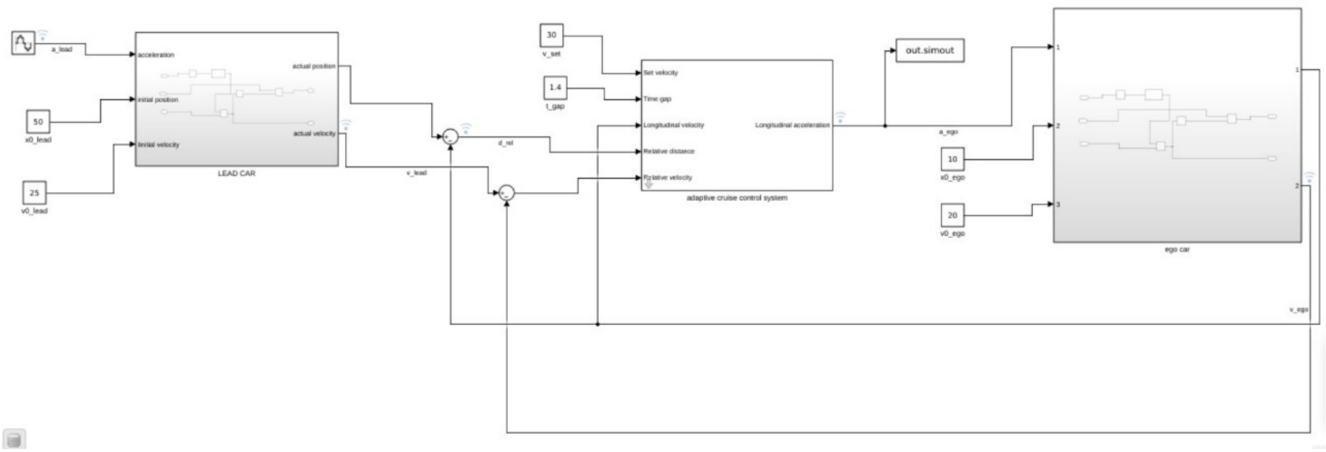

Figure 4: Implementation of Advanced Cruise Control System on Simulink

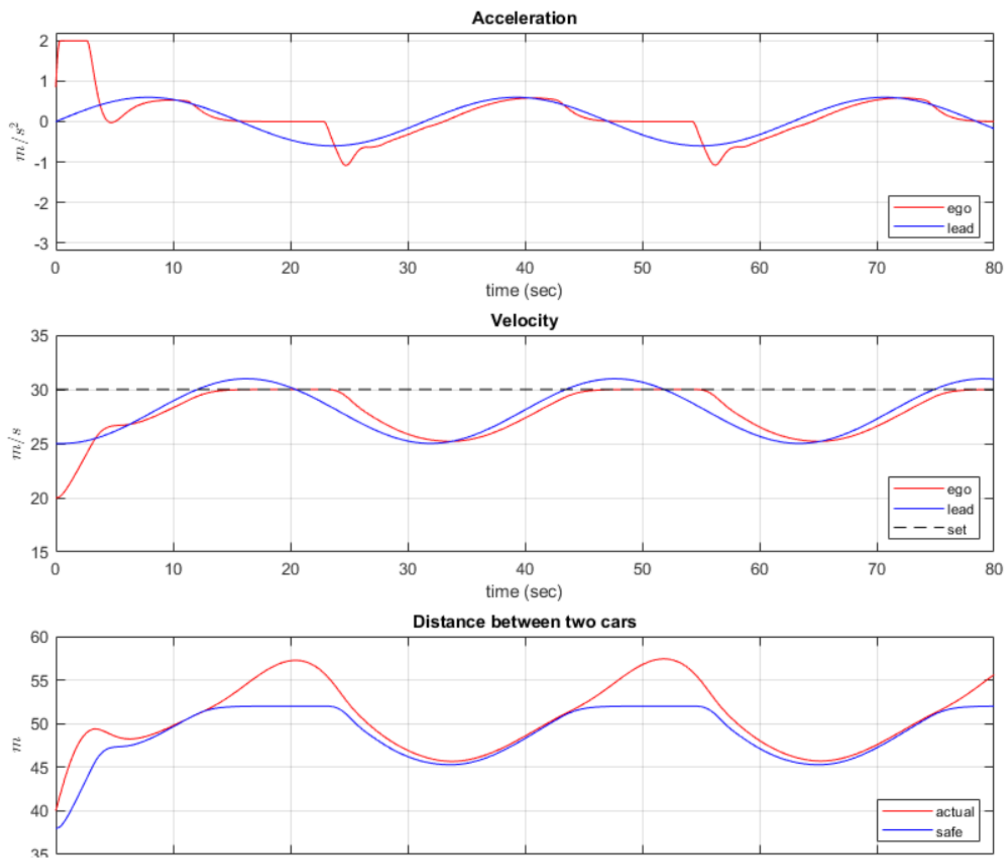

Figure 5: ACC Simulation Results

5.4 Braking System Simulation

To enhance vehicle safety in emergency conditions, a braking system simulation was developed using Simulink. The model replicates an Anti-lock Braking System (ABS) by controlling wheel slip to optimize braking performance and minimize stopping distance.The simulation begins with a preset desired slip ratio (e.g., 0.2) which serves as a reference for braking efficiency. The relative slip between the wheel and road surface is continuously calculated by comparing the vehicle speed and wheel speed. A controller block calculates the error between the actual and desired slip and adjusts the brake torque accordingly to maintain optimal slip, ensuring that the wheels do not lock during braking.

The tyre torque vs. slip curve governs the friction behavior under varying slip conditions. The model incorporates vehicle dynamics to calculate wheel speed, vehicle speed, angular speed, and stopping distance. As shown in the simulation result, the vehicle speed decreases smoothly with controlled deceleration, coming to a complete stop within 15 seconds. The curve indicates effective modulation of braking force to achieve a balance between fast stopping and stability.This braking model complements the Adaptive Cruise Control system by ensuring that braking actions—whether manual or autonomous—are safe, efficient, and prevent wheel lock under varying conditions.

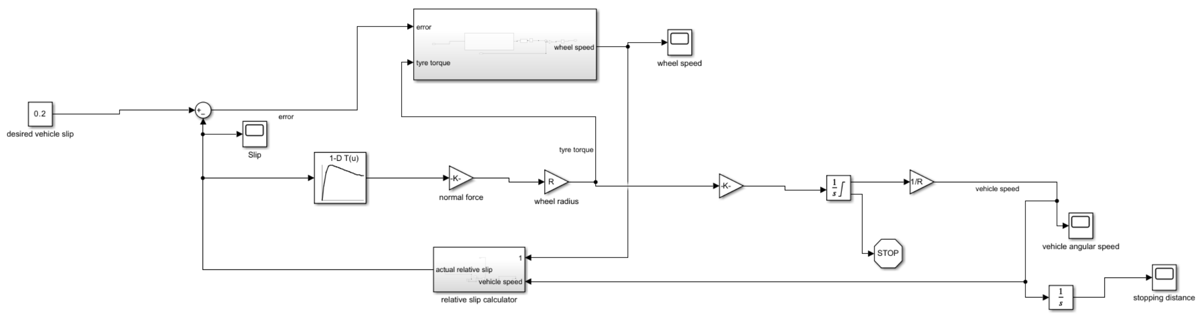

Figure 6: Implementation of Braking System

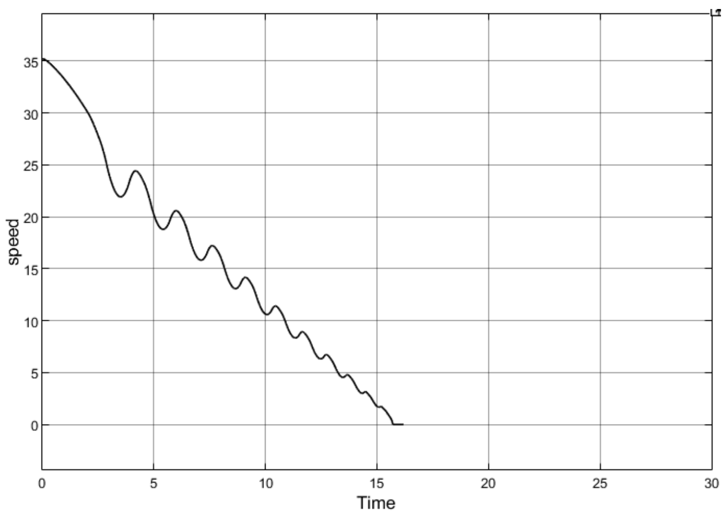

Figure 7: Braking System Results

5.5 Bill Of Materials

Sl. No	Component	Quantity	Unit Cost ()	Total Cost ()
1	ESP32 Dev Board	1	400	400
2	Ultrasonic Sensor (HC-SR04)	1	150	150
3	ESP32-CAM Module	1	550	550
4	DC Motor	1	100	100
5	Motor Driver (L298N)	1	120	120
6	Jumper Wires	30	1	30
7	Breadboard	1	80	80
8	5V Regulated Supply	1	100	100
			Total	**1530**

Table 1: Bill of Materials

6 Results and Discussion

Figure 8: Hardware Implementation

The Advanced Cruise Control System was tested both through simulation using MATLAB/Simulink and with a physical hardware prototype using the ESP32 microcontroller. These two approaches allowed for comprehensive validation of the control logic and real-time performance of the system.

In the simulation phase, a model of the ACC logic was developed in Simulink to replicate the behavior of a vehicle responding to the presence or absence of obstacles. The simulation used sensor input blocks to emulate ultrasonic readings, which were fed into a control logic subsystem that regulated vehicle speed. The simulated results confirmed that the system maintained a stable cruising speed when no object was detected and began to decelerate smoothly as an obstacle entered the defined detection range. The motor speed dropped proportionally with the decreasing distance and came to a halt if the object was within a critical zone. Once the object was removed from the field of detection, the simulation showed a smooth reacceleration, validating the effectiveness of the closed-loop feedback system. The simulation helped in tuning the safe distance thresholds, PWM ranges, and response timings before transferring the logic to the physical system.

The hardware testing of the ACC system involved integrating the ultrasonic sensor, ESP32 microcontroller, DC motor, and motor driver. During testing, the ultrasonic sensor reliably detected obstacles within a range of 5 to 100 centimeters. The ESP32 processed the distance data in real time and adjusted the PWM signals sent to the motor driver accordingly. When no object was present, the motor maintained a steady speed, simulating the cruising state of a vehicle. When an object was placed within 20 cm of the sensor, the ESP32 gradually reduced the motor speed and eventually brought it to a stop, imitating braking action. Upon removing the object, the microcontroller restored the PWM duty cycle step-by-step, leading to smooth reacceleration.

However, certain limitations were observed during hardware testing. Occasionally, external factors such as ambient light or soft materials interfered with ultrasonic sensing, resulting in minor fluctuations in measured distance. Also, due to the processing constraints of the ESP32-CAM module, complex visual processing could not be implemented in real time.

Overall, the project successfully demonstrated that a low-cost, embedded ACC system can effectively manage real-time speed control based on obstacle detection.

7 Applications

The Advanced Cruise Control (ACC) system developed in this project demonstrates practical use cases across multiple domains within the automotive and transportation sectors. As modern vehicles increasingly integrate automation and driver-assistance features, systems like ACC play a crucial role in enhancing safety, comfort, and driving efficiency. Below are the key applications of the ACC system.

7.1 Highway Driving Assistance

One of the primary applications of the ACC system is in long-distance highway driving. By maintaining a constant speed and automatically adjusting it based on traffic conditions, the system significantly reduces the physical and mental strain on the driver. It ensures a safe following distance from the vehicle ahead, reducing the likelihood of rear-end collisions due to delayed human response.

7.2 Traffic Jam and Stop-and-Go Situations

ACC systems are particularly useful in congested urban environments and stop-and-go traffic scenarios. The system can decelerate or even halt the vehicle when traffic slows down and resume movement when the path is clear. This improves fuel efficiency, reduces unnecessary braking and acceleration, and enhances driving comfort in heavy traffic.

7.3 Integration with Driver Assistance Systems

The ACC system serves as a building block for higher-level driver assistance features. When integrated with systems like lane keeping assist, emergency braking, and blind-spot detection, it contributes to the foundation of semi-autonomous driving. This integration ensures a coordinated response to various road scenarios, improving overall vehicle intelligence and safety.

7.4 Fuel Efficiency Optimization

Maintaining a consistent speed and reducing unnecessary acceleration or braking directly contributes to better fuel economy. ACC systems minimize sudden speed changes, allowing the engine to operate more efficiently. Over time, this results in reduced fuel consumption and lower emissions, especially in long-haul and commercial driving applications.

7.5 Enhanced Safety in Adverse Conditions

In low-visibility conditions such as fog, rain, or nighttime driving, human reaction time can be impaired. The ACC system, relying on sensors for obstacle detection, can continue to operate effectively in such conditions and provide an additional layer of safety by ensuring the vehicle maintains a safe distance from others, even when visibility is compromised.

7.6 Application in Electric and Autonomous Vehicles

ACC is a key component in electric and autonomous vehicles, where smooth and predictive driving is essential for energy conservation and passenger comfort. In autonomous platforms, the ACC system works in tandem with navigation and perception modules to enable intelligent decision-making. Its energy-aware speed modulation helps extend battery life in electric vehicles.

8 Advantages

- Improved Road Safety: Automatically maintains a safe distance from the vehicle ahead, reducing the risk of rear-end collisions and human error.
- Driver Comfort: Minimizes the need for manual acceleration and braking, especially during long drives or heavy traffic conditions.
- Real-Time Response: Quickly adjusts vehicle speed based on sensor feedback, enabling timely deceleration and acceleration as road conditions change.
- Fuel Efficiency: Maintains consistent speeds and avoids unnecessary braking or acceleration, which helps improve fuel economy and reduce emissions.
- Cost-Effective Implementation: Built using affordable and easily available components like ESP32, ultrasonic sensors, and DC motors, making it suitable for low-cost vehicle platforms.

9 Future Work

In future developments, the Advanced Cruise Control System can be significantly enhanced by integrating computer vision for object classification using lightweight machine learning models. Replacing basic threshold-based logic with more advanced algorithms such as fuzzy logic or PID controllers would improve the system's responsiveness and provide smoother acceleration and deceleration. Additionally, incorporating sensor fusion techniques—by combining ultrasonic, infrared, or LiDAR sensors—would improve accuracy and reliability in complex or low-visibility environments.

Another promising direction is the inclusion of wireless communication capabilities to support vehicle-to-vehicle (V2V) or vehicle-to-infrastructure (V2I) interaction, allowing for coordinated traffic behavior and safer autonomous navigation. Enhancing power efficiency and enabling real-time data logging with cloud integration could also make the system more practical for long-term use. With these improvements and thorough real-world testing, the system could transition from a basic prototype to a deployable driver-assistance module suitable for future smart and autonomous vehicles.

10 Conclusion

The development of the Advanced Cruise Control (ACC) System represents a significant step forward in enhancing vehicle safety, driver comfort, and the potential for future autonomous driving technologies. By combining hardware components such as the ESP32 microcontroller, ultrasonic sensors, and a camera module, this system demonstrates the ability to maintain a safe following distance and adjust the vehicle's speed based on real-time environmental conditions.

Through simulation and hardware testing, the ACC system was able to successfully detect obstacles and respond by decelerating or stopping the vehicle as needed. The system's modular design ensures that it can be easily adapted and extended with additional sensors or features, such as advanced object recognition or driver health monitoring, which could lead to more sophisticated and autonomous systems in the future.

While the current prototype shows promising results, there are areas for improvement, such as integrating more advanced sensors, optimizing object detection, and improving power efficiency. These future improvements will make the system more reliable and versatile, paving the way for more intelligent, safe, and efficient driving solutions.

Overall, this project not only showcases the potential of adaptive cruise control in the automotive sector but also lays the groundwork for future advancements in vehicle automation, contributing to the vision of safer and more autonomous transportation systems.

References

[1] Nivedhitha G., Pranav Karthikeyan, and K.R.M. Vijaya Chandrakala. Adaptive cruise control system in transportation systems using artificial neural network based fuzzy inference system. In *2025 International Conference on Intelligent Computing and Control Systems (ICICCS)*, pages 64–69, 2025.

[2] Dany Ghraizi, Reine Talj, and Clovis Francis. A deep reinforcement learning decision-making approach for adaptive cruise control in autonomous vehicles. In *2023 21st International Conference on Advanced Robotics (ICAR)*, pages 71–78, 2023.

[3] Ruiyu Hou, Fei Hui, Ruimin Kuang, and Ruining Yang. Research on adaptive cruise control strategy considering driving style. In *2023 9th International Conference on Mechanical and Electronics Engineering (ICMEE)*, pages 322–327, 2023.

[4] Duc Lich Luu, Ciprian Lupu, and Thien Van Nguyen. Design and simulation implementation for adaptive cruise control systems of vehicles. In *2019 22nd International Conference on Control Systems and Computer Science (CSCS)*, pages 1–6, 2019.

[5] Joko Slamet Saputro, M. Shafiy Widi Kresno Wibisono, Joko Hariyono, Miftahul Anwar, and Warindi. Design of an adaptive cruise control system using pid control method on

electric vehicle prototypes. In *2023 International Conference on Advanced Mechatronics, Intelligent Manufacture and Industrial Automation (ICAMIMIA)*, pages 599–605, 2023.

[6] Ritesh Kumar Sharma. Simulation and design of a vehicle cruise control system. In *2022 8th International Conference on Signal Processing and Communication (ICSC)*, pages 659–662, 2022.

[7] Leila Suleiman, Sergey Vlasov, Dmitrii Dobriborsci, Nguyen Khac Tung, and Nguyen Minh Hung. Lane change prediction algorithms for adaptive cruise control system simulation in matlab/simulink. In *2024 10th International Conference on Control, Decision and Information Technologies (CoDIT)*, pages 2407–2412, 2024.

[8] Jiawei Tian. Vehicle adaptive cruise control based on model predictive algorithm. In *2024 International Conference on Intelligent Robotics and Automatic Control (IRAC)*, pages 467–470, 2024.

[9] Chen Yang and Bin Liu. Research on adaptive cruise control system for electric vehicles. In *2024 5th International Conference on Electronic Communication and Artificial Intelligence (ICECAI)*, pages 645–648, 2024.

[10] Wei Yi, Zhi Zhang, Wei Huang, HuiHong Wang, Ju Huang, and YiTing Wang. Enhanced adaptive cruise control strategy for improving driving safety in connected vehicle environment. In *2021 6th International Conference on Transportation Information and Safety (ICTIS)*, pages 805–810, 2021.