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Auto Cruise Control System using Fuzzy Logic

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1. ABSTRACT

Adaptive Cruise Control (ACC) is an advanced driver assistance technology that automatically adjusts the speed of a vehicle to maintain a safe distance from the vehicle ahead. This paper presents the design and implementation of a low-cost adaptive cruise control system using an ultrasonic sensor andATmega16 microcontroller. The ultrasonic sensor continuously measures the distance between the prototype vehicle and obstacles in front. Based on the measured distance, the microcontroller dynamically adjusts the motor speed using PWM control to maintain safe operation. The system also implements emergency braking when the distance becomes critically small. MATLAB simulation was performed to validate the control behavior and hardware implementation was developed using a DC motor driver and LCD display for monitoring system parameters. Experimental results demonstrate that the proposed system successfully adapts vehicle speed according to obstacle distance and provides smooth acceleration and deceleration. The proposedprototype provides a simple and cost-effective approach for implementing adaptive cruise control insmall autonomous vehicles.

Keywords -Adaptive Cruise Control Ultrasonic Sensor ATmega16 Embedded Systems Autonomous Vehicles Distance Control PWM Motor Control.

2. INTRODUCTION

In recent years, the rapid development of intelligent transportation systems and autonomous vehicle technologies has significantly transformed the automotive industry. Modern vehicles are increasingly equipped with Advanced Driver Assistance Systems (ADAS) that aim to improve road safety, reduce driver workload, and enhance overall driving comfort. These technologies assist drivers in various driving situations by monitoring the surrounding environment and automatically responding to potential hazards. Among the various ADAS technologies, Adaptive Cruise Control (ACC) has emerged as one of the most important and widely researched systems.

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Traditional cruise control systems were designed to maintain a constant vehicle speed set by the driver. While this feature helps reduce driver fatigue during long highway journeys, it lacks the ability to respond to changes in traffic conditions. For example, when a slower vehicle appears ahead, the driver must manually intervene by applying the brakes or reducing the speed. This limitation reduces the effectiveness of conventional cruise control systems, particularly in dynamic traffic environments.

adaptive Cruise Control addresses this limitation by automatically adjusting the vehicle's speed based on the distance to the vehicle ahead. The system continuously monitors the distance between the host vehicle and the leading vehicle and modifies the throttle or braking action to maintain a safe following distance. By doing so, ACC enhances driving comfort while also improving road safety. In real-world automotive applications, ACC systems commonly utilize radar sensors, LiDAR sensors, or camera-based vision systems to detect objects and measure distances. Although these sensors provide high accuracy and long detection ranges, they are often expensive and require complex signal processing, making them less suitable for low-cost prototype development and educational applications.

For small-scale autonomous vehicle prototypes and research experiments, ultrasonic sensors provide a practical and cost-effective alternative for distance measurement. Ultrasonic sensors operate by transmitting high-frequency sound waves and measuring the time required for the echo signal to return after reflecting from an obstacle. Based on the time-of-flight of the ultrasonic wave, the distance between the sensor and the obstacle can be calculated accurately for short ranges. Due to their low cost, ease of interfacing, and reliable short-range detection capability, ultrasonic sensors are widely used in robotic systems, obstacle avoidance mechanisms, and parking assistance systems.This researchfocuses on the design and implementation of a prototype Adaptive Cruise Control system using an ultrasonic sensor and an ATmega16 microcontroller. The proposed system continuously measures the distance between the vehicle prototype and obstacles located in front of it. Based on the measured distance, the microcontroller dynamically adjusts the speed of the vehicle by controlling the pulse width modulation (PWM) signal supplied to the DC motors. Different distance thresholds are defined in the control algorithm to regulate the motor speed and maintain safe operation. The proposed system also incorporates additional safety mechanisms, including smooth acceleration, controlled deceleration, and emergency braking when the obstacle distance becomes critically small. These mechanisms ensure stable and reliable vehicle behavior under different operating conditions. A 16×2 LCD display is integrated into the system to provide real-time monitoring of parameters such as obstacle distance and estimated vehicle speed.

To evaluate the effectiveness of the proposed control strategy, both simulation and hardware implementation approaches are utilized. MATLAB simulation is used to analyze the system response under various distance scenarios and to validate the control algorithm before hardware deployment. After successful simulation, a hardware prototype is developed using the ATmega16 microcontroller, ultrasonic sensor, motor driver circuit, and DC motors. Experimental testing demonstrates that the system successfully adjusts the vehicle speed according to obstacle distance and performs reliable emergency stopping when required.The main objective of this research is to demonstrate a simple, low-cost, and efficient implementation of adaptive cruise control suitable for small robotic vehicles and educational research platforms. The proposed system serves as a foundation for further research in autonomous vehicle control systems and can be extended with advanced control algorithms such as PID control, sensor fusion, and machine learning-based decision-making techniques in future work.

3. LITERATURE SURVEY

Adaptive Cruise Control (ACC) has become an important research topic in the field of intelligent transportation systems and autonomous vehicles. The main objective of ACC is to automatically maintain a safe distance between vehicles by adjusting the speed of the following vehicle according to traffic conditions. Researchers have explored different sensing technologies, control algorithms, and embedded platforms to implement ACC systems with improved reliability, safety, and efficiency.

Traditional adaptive cruise control systems used in modern automobiles primarily rely on radar-based sensing technology. Radar sensors provide accurate long-range distance measurement and work effectively in different weather conditions such as fog, rain, and dust. Many commercial automotive companies have adopted radar-based ACC systems due to their reliability and precision. However, radar sensors are relatively expensive and require complex

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signal processing circuits, which makes them less suitable for low-cost prototype development and academic experimentation.

In addition to radar sensors, some researchers have explored the use of LiDAR (Light Detection and Ranging) technology for obstacle detection in adaptive cruise control systems. LiDAR sensors offer high-resolution distance measurement and accurate environmental mapping. These sensors are widely used in autonomous vehicles and advanced robotics applications. Despite their high accuracy, LiDAR sensors are expensive and consume significant power, which limits their usage in small embedded systems and educational prototypes.

Several studies have also focused on improving system responsiveness and safety by implementing emergency braking mechanisms. Emergency braking is triggered when the detected obstacle distance falls below a critical threshold, immediately stopping the vehicle to prevent collisions. Such safety mechanisms are essential in adaptive cruise control systems to ensure reliable operation in dynamic environments.

In recent years, simulation tools such as MATLAB and Simulink have been widely used to model and analyze adaptive cruise control algorithms before hardware implementation. Simulation allows researchers to evaluate system performance, tune control parameters, and analyze different traffic scenarios without risking hardware damage. MATLAB-based simulations also help in visualizing system response, vehicle speed variation, and distance control behavior under different operating conditions.

Based on the review of existing research, it is evident that most commercial ACC systems rely on expensive sensing technologies and complex control architectures. For educational and prototype development purposes, there is a need for a simpler and cost-effective solution that can demonstrate the fundamental principles of adaptive cruise control. Therefore, this work focuses on the design and implementation of a low-cost adaptive cruise control prototype using an ultrasonic sensor and an ATmega16 microcontroller. The system uses pulse-width modulation (PWM) to control motor speed and adjusts vehicle motion according to the measured obstacle distance. MATLAB simulation is also used to analyze system behavior and validate the control strategy before hardware testing.The first step in the system design is distance sensing using an ultrasonic sensor. The ultrasonic sensor operates by transmitting high-frequency sound waves and measuring the time taken for the reflected signal to return from an obstacle. Based on this time-of-flight measurement, the distance between the vehicle and the obstacle is calculated.

The sensor provides accurate short-range distance measurements and is widely used in obstacle detection applications.

The measured distance data is sent to the ATmega16 microcontroller, which acts as the main control unit of the system. The microcontroller continuously monitors the distance readings and determines the appropriate motor speed based on predefined distance thresholds. These thresholds are programmed in the embedded control algorithm to ensure safe vehicle operation.

The motor speed is controlled using Pulse Width Modulation (PWM). PWM allows the microcontroller to adjust the effective voltage supplied to the DC motors by varying the duty cycle of the signal. When the detected obstacle distance is large, the PWM duty cycle increases, resulting in higher motor speed. As the obstacle approaches, the PWM duty cycle decreases, reducing the motor speed.

To ensure smooth vehicle movement, the system incorporates a soft-start and smooth deceleration mechanism. Instead of sudden speed changes, the microcontroller gradually increases or decreases the PWM duty cycle. This prevents abrupt motion and improves system stability.

An emergency braking feature is also implemented in the system. When the detected obstacle distance falls below a predefined safety threshold, the system immediately stops the motors to avoid collision. This safety mechanism ensures reliable operation in dynamic environments.

The entire system is implemented and tested using both MATLAB simulation and hardware prototype development. MATLAB simulation is used to analyze system behavior under different distance conditions and validate the control algorithm. After simulation validation, the system is implemented using an ATmega16 microcontroller, ultrasonic sensor, motor driver circuit, andLCD display for real-time monitoring

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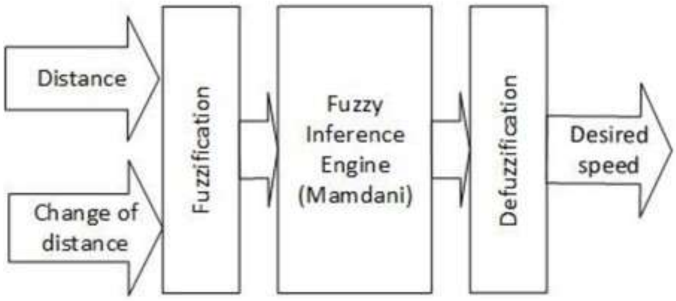
4. METHODOLOGY

The proposed Adaptive Cruise Control (ACC) system is designed to automatically regulate the speed of a vehicle based on the distance from obstacles detected in front of the vehicle. The system integrates an ultrasonic sensor for distance measurement, an ATmega16 microcontroller for processing and control, and DC motors whose speed is regulated using Pulse Width Modulation (PWM).

5. BLOCK DIAGRAM



6. RESULT AND DISCUSSION

The performance of the proposed Adaptive Cruise Control system was evaluated through both simulation and hardware implementation. The objective of the experiment was to verify the ability of the system to adjust the vehicle speed automatically based on obstacle distance.

In the MATLAB simulation environment, the control algorithm was tested under different distance conditions to observe the system response. The simulation results showed that the vehicle speed decreases gradually as the distance to the obstacle decreases. When the obstacle is far away, the system allows the vehicle to move at maximum speed. As the obstacle approaches, the speed is reduced proportionally to maintain a safe distance.

Hardware testing was performed using an ATmega16 microcontroller, ultrasonic sensor, motor driver circuit, and DC motors. The ultrasonic sensor successfully measured obstacle distance in real time and transmitted the data to the microcontroller. Based on the measured distance, the microcontroller generated appropriate PWM signals to control the motor speed.

The experimental results demonstrate that the system effectively adjusts motor speed according to obstacle distance. When the obstacle distance falls below the safety threshold, the emergency braking mechanism stops the motors immediately, preventing potential collisions.

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The LCD display successfully shows real-time information including the measured distance and calculated vehicle speed. This
feature helps users observe system behavior during operation.
Overall, the results confirm that the proposed Adaptive Cruise Control prototype operates successfully and demonstrates reliable obstacle detection, smooth speed regulation, and effective collision avoidance.

7. CONCLUSION

In this research work, a prototype Adaptive Cruise Control system was successfully designed and implemented using an ultrasonic sensor and an ATmega16 microcontroller. The system measures the distance between the vehicle and obstacles and automatically adjusts the vehicle speed using PWM motor control.
The proposed system demonstrates smooth speed regulation through soft acceleration and controlled deceleration mechanisms. The integration of an emergency braking feature enhances system safety by stopping the vehicle when the obstacle distance becomes critically small.Both MATLAB simulation and hardware implementation confirm the effectiveness of the proposed control strategy. The system successfully maintains safe operation under different distance conditions and provides reliable obstacle detection. The developed prototype demonstrates that a simpleand cost-effective adaptive cruise control system can be implemented using basic sensors and embedded microcontrollers. This work provides a foundation for further research in autonomous vehicle control and intelligent transportation systems.

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FUTURE SCOPE

Although the proposed Adaptive Cruise Control system demonstrates effective obstacle detection and speed regulation, several improvements can be made in future research.
One possible enhancement is the use of advanced sensors such as radar or LiDAR to achieve longer detection range and higher accuracy. These sensors can improve system reliability in real-world automotive environments. Another potential improvement is the implementation of advanced control algorithms such as PID control, fuzzy logic control, or machine learning-based control strategies. These techniques can provide smoother speed regulation and better system responsiveness.
The system can also be extended by integrating additional sensors such as cameras for vision-based obstacle detection and lane detection. This would allow the development of a more advanced autonomous driving assistance system.
Future work may also involve integrating wireless communication modules to enable vehicle-to-vehicle (V2V) communication for cooperative adaptive cruise control systems.

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