ADAPTIVE CRUISE CONTROL USING ULTRASONIC SENSOR

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Abstract:

This paper presents an Adaptive Cruise Control (ACC) and Collision Avoidance (CA) system for vehicle autonomous driving. The control scheme is designed to improve drivers comfort during multi-vehicle driving situations and to completely avoid rear-end collision using severe braking and lane change maneuver. In order to create such an application, the proposed system consists of a longitudinal control strategy for multi-vehicle ACC with severe braking, a lateral control strategy for lane change, and a decision unit for integration of two strategies. The longitudinal control strategy was used to achieve comfort behavior of subject vehicle in normal-driving situations and to achieve safe behavior in sever-braking situations. The lateral control strategy is used to generate a trajectory for lane change and follow the generated trajectory in order to avoid collision.

Keywords: Adaptive cruise control, Collision avoidance, Lane change, Ultrasonic sensor, RFID Technology, RFID Principles.

1. Introduction

Traffic crashes cause deaths of millions of people every year. Researchers tried to overcome this fatal problem by developing passive safety systems like seat belts, air bags and crash zones. Although these passive measures helped a lot, there must be more effective ways of holding accidents at acceptable levels. This goal is closer to realization through advances in preventive and active safety systems. Collision Warning (CW) System is an important jump from passive to active safety systems. CW System tries to detect any collision risk between two vehicles by means of radar and internal-vehicular sensor information. If the system detects collision risk, it will warn the driver so that a possible accident can be avoided. The concept of assisting driver in longitudinal vehicle control to avoid collisions has been a major focal point
Adaptive cruise control (ACC) is an enhanced version of conventional cruise control; this can detect a lead vehicle and allows a driver to follow it at a preset time headway and speed by controlling. The ACC system uses the sensor devices to measure the distance between vehicles. The ACC vehicle will accelerate back to the original cruise speed. When these limitations are coupled with a low level of situation awareness, potential hazards may increase rather than decrease. Model predictive control was used to design the ACC system in with the objectives of comfort, fuel-economy, safety and car-following.

1.1 Objective
Adaptive Cruises Control is introduced in the vehicle to reduce the speed of the car by longitudinal control. Ultrasonic distance sensor calculates the distance between the front vehicles. After detecting the distance the speed of the ACC vehicle would be automatically adjusted for safe inter-distance. Once safe inter-distance is reached, the speed would return to the desired speed set by the driver. The usage of lateral control of the vehicle is for lane change to avoid collision.

1.2 Literature Survey
In the study paper [1] examines drivers’ adaptation using a conceptual model of adaptive behavior developed and examined quantitatively using logistic regression techniques. And several factors that influence drivers’ response, including the environment, selected gap setting, speed, and drivers’ age. Safety consequences and the design of future ACC systems based on drivers’ adaptation to these factors are discussed. The lane changes detection is detail description is given in this paper [2] and the performance and safety benefits of the control system are investigated via simulations using various driving scenarios. The behavior of the driver while driving and also the comfort zone of the driver using the ACC is explained in the paper [3].

As of November 2001, BMW started introducing its new ACC system, which will be available in the 7series. This new ACC system was described by Prestl et al.[5] F43G as a complete system including technology and properties of the
radar to a human machine interface. They also studied the safety aspects of ACC. BMW’s intentions with the ACC system is to enhance the driver’s comfort and to support the driver in follow situations. The system was developed in close cooperation with Robert Bosch GmbH, which designed and built the ACC sensor. This module is also use information about the current gear, which is provided by BMW’s Transmission Control Unit.

- Situation specific control functions: Set Speed Controller, Follow Controller and Curve controller;
- Combination and selection respectively as well as limitation of the specific control values in the Mixer;
- Conversion of the acceleration value into desired values for the actuator systems in the Longitudinal Controller;
- Actuator systems that realize controller output.

With Navlab at Carnegie Mellon University, Thorpe et. al F47G developed a Free Agent system, which fully automates driving[8]. Their strategy was to surround the vehicles with sensors, putting all the sensing and decision making in the vehicles to make them fully automated. The automated vehicles were equipped with a vision system, and a radar system. Since the most important mission for the automated vehicle was to increase the safety on the highways, the Free Agent was designed to keep a safe space around the vehicle. The Free Agent aims to have a large enough headway between vehicles that high bandwidth throttle and brake servo not needed. Since only low bandwidth control is needed, the existing cruise control could be used to perform all the throttle actuation. The Free Agent was demonstrated in August 1997 for the UN National Automated Highway System Consortium. During the demo several of the common actions at highways were performed, but not any cut-in or critical situations

A new Collision Warning (CW) Algorithm for vehicle with ACC is explained in the paper [4]. Many algorithms were evaluated according to expected performance criteria. The proposed algorithm was tested using the MEKARACC Simulator along with the other algorithms for specified scenarios. The proposed algorithm gave more realistic warnings than the other velocity based warning algorithms. A vehicle-to-vehicle distance control algorithm for stop-and-go cruise control has been proposed [6]. Vehicle desired acceleration for vehicle-to-vehicle distance control has been designed using linear quadratic optimal control theory. The vehicle with the ACC technique performs in the curved surface with the speed control and also the lateral stability [11].

Nonlinear Model Predictive Control (NMPC) is applied in adaptive cruise control (ACC) system, State-dependent algorithm, as an approach to control the brake and throttle opening position. [7] By designing the two separate
controllers in order to regulate the brake and throttle opening position can be eliminated and both systems are controlled by a single state-dependent NMPC.

The main contributions of the thesis are:

- An experimental platform for adaptive cruise control and driver modeling;
- Contribution to the description of human driver’s longitudinal driver behavior using dynamic models;
- The use of system identification methods to obtain the driver models useful for adaptive cruise control

1.3 Overview of ACC System

ACC operates in two different modes depending on the situation of the traffic ahead; cruise control (CC) mode and ACC control mode (follow mode). It operates in the CC mode when the road in front of the ACC equipped vehicle is clear, i.e. there is no vehicle within clearance distance. In this situation vehicle travels at the desired cruising speed (reference speed) specified by the driver. Once it has approached other vehicles travelling at lower speed it switch to the time gap control (ACC) mode. In this mode ACC attempts to keep the vehicle within the desired distance headway by controlling the speed of the vehicle (Fig. 2). The distance headway can be customized by the driver in term of time headway. In the ACC mode the new reference speed is introduced into the CC system according to the speed of the leader vehicle in order to maintain the vehicle within the desired distance headway. The transition between the modes is performed automatically depending on the traffic condition ahead and the desired cruising speed.

If during the ACC mode the speed of the ACC equipped vehicle reaches the desired cruising speed, it will enter the CC mode regardless of the situation in front. In other words, if the desired cruising speed is less than the leader vehicle’s speed, the system will switch to the CC mode; otherwise it keeps following the leader vehicle in the desired distance headway specified by driver. If a vehicle is detected in the lane ahead, the ACC system adjusts the speed of the vehicle by slowing the engine or by gently applying the brakes, and then holds the appropriate constant distance. The driver is able to choose between three different settings for constant distance. If the vehicle ahead happens to brake suddenly, the driver has to apply the brakes. And because the radar beams are cone-shaped, and thus not very wide directly ahead of the car, the driver needs to be aware of other vehicles that pull out suddenly in front. Accordingly, the system automates the longitudinal vehicle control partially to reduce driver's workload. Since ACC is designed for flowing traffic flow and adjusts the speed according to traffic conditions, it means that non-moving objects, such as vehicles in a traffic jam, are...
not picked up by the system. Therefore, the control rules of ACC system that are already implemented by many automobile manufacturers differ from each other. Especially the ACC system should be considered while study the car-following safety behavior in congested traffic, as a result, it is much necessary to develop car-following safety algorithm based on adaptive cruise control.

![Fig 2. ACC Vehicle Relationship.](image)

### 1.3.1 Acc Definitions

**ACC vehicle** – the subject vehicle equipped with the ACC system.

**Active brake control** – a function which causes application of the brakes without driver application of the brake pedal.

**Clearance** – distance from the forward vehicle's trailing surface to the ACC vehicle's leading surface.

**Forward vehicle** – any one of the vehicles in front of and moving in the same direction and travelling on the same roadway as the ACC vehicle.

**Set speed** – the desired cruise control travel speed set by the driver and is the maximum desired speed of the vehicle.

**Target vehicle** – one of the forward vehicles in the path of the ACC vehicle that is closest to the ACC vehicle. **Time gap** – the time interval between the ACC vehicle and the target vehicle. The 'time gap' is related to the 'clearance' and vehicle speed by:

\[
\text{Time gap} = \text{clearance} / \text{ACC vehicle speed}
\]

**Acc System States**

**ACC off state** – direct access to the 'ACC active' state is disabled.

**ACC standby state** – system is ready for activation by the driver.

**ACC active state** – the ACC system is in active control of the vehicle's speed.
ACC speed control state – a sub state of 'ACC active' state in which no forward vehicles are present such that the ACC system is controlling vehicle speed to the 'set speed' as is typical with conventional cruise control systems.

ACC time gap control state – a sub state of 'ACC active' state in which time gap, or headway, between the ACC vehicle and the target vehicle is being controlled.

1.4 Operational Overview

The driver interface for the ACC system is very similar to a conventional cruise control system. The driver operates the system via a set of switches on the steering wheel. The switches are the same as for a conventional cruise control system except for the addition of two switches to control the time gap between the ACC vehicle and the target vehicle. In addition there are a series of text messages that can be displayed on the instrument cluster to inform the driver of the state of the ACC system and to provide any necessary warnings. The driver engages the ACC system by first pressing the ON switch which places the system into the 'ACC standby' state. The driver then presses the Set switch to enter the 'ACC active' state at which point the ACC system attempts to control the vehicle to the driver's set speed dependent upon the traffic environment.

2. System Design: Cruise control combined with ultrasonic distance sensor senses the headway of the front vehicle.
If the lead vehicle is near to the host vehicle then throttle and brake sensor detects it and the adaptive cruise control system is activated and the flow of the fluid to the motor is controlled then the speed of the vehicle is reduced. IR sensor in the module will detects the lane changes of the host vehicle.

3. Simulation Results

The Proteus simulation of Fig.14 implies the simulation overview of the adaptive cruise control in proteus software is as follows. Here when the acc vehicle is nearing to the lead vehicle then the sensor detects and if the distance is beyond the safer distance then the speed of the vehicle is reduced gradually.

![Fig 14. ACC system overview.](image)

In fig 15 implies that if the lead vehicle is at the distance of 9m from the acc vehicle then the throttle and brake sensor is at 71% and speed of the vehicle is shown in the form of the waveform. Then the speed of the acc vehicle is reduced and the digital oscilloscope the waveform of the speed is showed the breadth of the waveform is of more.

![Fig 15 ACC result when the distance is 9m.](image)
Fig 16 implies that if the lead vehicle is at the distance of 5m from the host vehicle then the throttle and brake sensor is at 50% and speed of the vehicle is shown in the form of the waveform. Then the speed of the acc vehicle is reduced and the digital oscilloscope the waveform of the speed is showed the breadth of the waveform is of more. By comparing with the previous simulation the changes in the speed can be determined.

![Fig 16 ACC result when the distance is 5m.](image)

Fig 17 implies that if the lead vehicle is at the distance of 3m from the host vehicle then the throttle and brake sensor is at 25% and speed of the vehicle is shown in the form of the waveform. By comparing with the previous simulation the changes in the speed can be determined.

![Fig 17 ACC simulation result when the distance is 3m.](image)
The speed is gradually decreased and the speed is maintained constant till the distance between the two vehicles cross more than the safer distance. Once the distance between the two vehicles increases then the speed will increase to the drivers desired speed.

4. Hardware Prototypes

PIC microcontroller 16f877A is interfaced with the LCD display where it acts as a speedometer. The ultrasonic sensor and the IR pair sensor is also interfaced with the PIC controller, where ultrasonic sensor is for measuring the distance and IR sensor is used to identify the lane changes in this project by the noise of the buzzer.

![Hardware overview](image)

**Fig 19 Hardware overview.**

ACC Mode:

In fig 22 implies that, if vehicle need to run in ACC mode then we need to press the acc mode key, in acc mode even though we apply the brake it won’t make any changes in the speed of the vehicle. And in this figure we can observe the speed of the acc vehicle is 233 and the distance of another vehicle is 45 cm.
In fig 23 implies that if the vehicle is running in the acc mode then, the distance between the two vehicle is like 12 cm then the speed of the our vehicle is 220 and by comparing to the precious figure the speed of the current vehicle is reducing gradually according to the distance of the rear end vehicle.
In fig 24 implies that, when the vehicle is running in the acc mode and if the vehicle is changing the lane then the ir sensor will detect that and inform to the driver through the buzzer sound.

Fig 24. Lane change detection in acc mode.

5. Conclusions

The vehicle control strategy for an adaptive cruise control with collision avoidance which can perform severe-braking and the lane-change maneuver have been presented. In order to integrate the longitudinal control strategy and the lane change support strategy. The longitudinal control is based on the adaptive cruise control with severe braking technique that considered multi-vehicle traffic situation. The lane change support is used to generate the trajectory and perform lane change maneuver through maintaining the longitudinal and lateral acceleration accepted by the drivers. The performance of a controlled vehicle with the proposed control system has been investigated via simulations using real driving data and several virtual scenarios. It has been shown that the proposed control system can provide with natural following performance in a safe normal driving situation and can prevent the vehicle-to-vehicle distance from dropping to an unsafe level by using a severe braking or a lane-change maneuver depending on the driving situation.

6. References

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