

# Cooperative Adaptive Cruise Control

## *Motivation*

Software-based electronic control systems are increasingly being used in the automotive industry to provide convenience and safety features to vehicle drivers and passengers, with increasing levels of automation and control authority. A growing trend is to assist the driver in maintaining safe control over the motion of the vehicle in a variety of circumstances including, but not limited to, congested traffic conditions, adverse weather and road conditions, varying states of health of vehicle equipment, and varying skill levels of drivers.

Previously such assist has been provided in the form of information or warnings to the driver, but increasingly such assist will be provided by actively manipulating actuators that control vehicle longitudinal acceleration and deceleration, lateral direction, and vertical displacement. The long term trend is towards partial or even fully autonomous operation of a single vehicle, or even of groups of vehicles.

## *Cooperative Adaptive Cruise Control Description*

The Cooperative Adaptive Cruise Control system (hereafter CACC) attempts to maintain a constant forward vehicle speed, as specified by the driver. In addition, using a combination of forward radar and camera sensors, CACC detects when another vehicle (called the target vehicle) is in its forward path and adjusts its own speed via throttle and braking control to maintain a safe following distance behind it. The vehicle also receives GPS information (location, speed, and direction) from vehicles ahead of it, and broadcasts GPS information to vehicles behind it. This additional information can be used to set up a platoon of vehicles that follow a lead vehicle, with safe spacing between each vehicle. Each vehicle in the platoon uses a combination of GPS information from vehicles in front of it, together with information from its own radar and vision sensors, to control its throttle and brakes to achieve a safe following distance. In turn, each vehicle broadcasts its own GPS information to vehicles behind it.

The CACC system also incorporates additional features that provide convenience and safety to the driver. Multiple features – such as adaptive cruise control, lane keeping / lane centering, and curve speed assist – may desire to apply varying amounts of throttle and braking torque at various rates and under various conditions. The interactions between these features must be comprehended with respect to the impact of software faults on the safe operation of the vehicle. For example, if one feature intends to accelerate the vehicle while another feature intends to decelerate the vehicle, the vehicle supervisory controller must know enough about the system context to determine which intent is most appropriate to be commanded to the actuators. One feature that desires deceleration (curve speed warning, for example) may be more appropriate for the given context than another feature that desires acceleration (adaptive cruise control, for example). In that case, the vehicle supervisory controller may arbitrate by allowing the first feature to override the second feature. Such arbitration relationships must be comprehended by the software fault tolerance architecture.

Cooperative adaptive cruise control (CACC) consists of the following sub-systems:

- 1) Radar Sensing
  - a. Detect, id and track target vehicles
  - b. Identify target vehicle id via transponder for purposes of establishing DSRC communication link.
  
- 2) Radio Communication
  - a. Communicate with target vehicle
  - b. Communicate with trailing vehicle
  - c. Communicate with infrastructure
  
- 3) Electronic Throttle control

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- a. Regulate vehicle speed to commanded speed by adding and removing power.
- 4) Brake by wire
  - a. Regulate vehicle speed by applying brakes when commanded to bring vehicle speed down to commanded speed.
- 5) Radar Transponder
  - a. When asked, gives vehicle id information to requesting trailing vehicle in order to establish radio link between vehicles.
- 6) GPS system
  - a. Maintains accurate vehicle position, speed and direction information
  - b. Aids radar system in differentiating between vehicle targets from known fixed targets and compensate for curves/hills in roadway.
  - c. Aids vehicle controller in the event of transponder/radar failure to maintain platoon function.
- 7) Camera Sensing
  - a. Visually identify target vehicle and estimate distance and relative speed.
- 8) Vehicle Controller
  - a. Coordinates all sub-systems
  - b. Detects vehicle speed, speed of lead vehicle and adjusts to maintain 'safe' distance.
  - c. Maintains state of vehicle and operating environment information.
  - d. Commands brake and throttle.
  - e. Receives information from radar system
  - f. Sends and receives information from radio system

## **Scenarios**

Scenario One: Fully working system as described above. Vehicle is in platoon of two and is the trailing vehicle. Everything is working as expected and there is a task in the vehicle controller that cannot start due to lack of memory. While we do not as a rule use dynamically allocated memory, each instance of a task starting, procedure called, or object created does indeed require memory be allocated by the OS. To further add to this, let's say that the vehicle controller (VC) does create individual objects to track targets. One of them is the lead vehicle, others are vehicles that are not part of the platoon. These objects will likely be created and destroyed dynamically. So that could be the cause of our memory leak. So either way we need an instrument to detect failure to start task. Further we need to be able to diagnose lack of memory and decide how to recover.

Scenario Two: Fully working system as described. Vehicle is in platoon of two and is trailing vehicle. Everything is working according to plan when the radio system no longer responds. Assuming the radio system also has some dynamic object creation/destruction to track communication links to multiple vehicles and to the infrastructure. So if a failed garbage collection scheme occurred, we may be able to restart the radio system by command from the VC.

Scenario Three: Fully working system as described above. A coding error in the arbitration logic within the vehicle supervisory controller, not caught during system verification and testing, results in a large acceleration command to the throttle controller that is inappropriate given the current system context. An independent monitoring function detects the discrepancy between the commanded value to the throttle controller and the system context based on system inputs and state variables, and determines that the throttle command must be reduced to a more moderate value.

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