Project Proposal: Adaptive Cruise Control

Miaomiao Zhao, Narayani Vedam
Department of Electrical and Computer Engineering

Paul Edward
Department of Mechanical Engineering

I. Abstract

Cruise control systems have been found in American cars since the mid 1970s, and a recent development in these systems is the advent of adaptive cruise control. However, these systems have been developed around linearized equations of motion, which are not a completely accurate representation of the system dynamics. This paper aims to investigate and address the conditions when these linearized dynamics do not apply.

II. Background

Automated Highway Systems (AHS) is a novel concept that has been recently envisioned by American automotive control researchers. AHS is a vehicle-highway system that support hands-off and feet-off driving in dedicated lanes. Such a system would both increase the number of cars that could be on a highway, while also decreasing congestion. With the rapid development of self-driving vehicles, interest in such a system has increased.

Adaptive Cruise Control systems (ACC) have been a recent step in this direction. ACC systems are being developed because of their predicted ability to increase driving safety and comfort. Additionally, ACC will have positive impact on traffic-flow performance and reduce emissions and fuel consumption [1]. These systems can currently be found in the upper segment of the passenger car market (e.g., the BMW 500 series) [2].

ACC is a radar-based system, which can reduce the speed of the commanded vehicle below the speed set by the driver to provide controlled following of sensed preceding targets. A speed command is generated based in part, on the relationship between the source vehicles velocity and the velocity of the preceding target, and the drivers acceleration is limited accordingly, to adapt the source vehicle speed to that of the target [3].

III. Motivation

In most of the earlier works, due to the complexity of the equations of motion, automotive systems have been linearized about an operating point. Linear controllers using PID, optimal control, etc. [4], [5] and nonlinear controllers using techniques like the sliding control method [6], [7], multiple surface approach [7], [8], etc. have been adopted to deal with linearized models. However, these control methods may not apply under all conditions.

The equation of motion for a vehicle, given as,

$$M\dot{V} + \frac{\rho}{2}C_D S_{ref}(V+V_W)^2 + F_{rr} = \frac{g_A T_b}{r_W} - W_V \sin\theta \quad (1)$$

is the nonlinear system that will be considered. Of particular interest is the comparison of the impact of both linear and nonlinear control systems when the vehicle transitions from one mode of cruise control to another. When switching between an ACC system and a traditional velocity-based cruise control system, large differences between the vehicle speed and the desired velocity may yield jerks which are not desirable .

IV. Objective

This paper aims to analyze the nonlinear dynamic system, incorporating the system represented by Eq. (1) into the plant model, and finding control techniques to ensure stable operation of the cruise control system, which will maintain the vehicle at a constant speed while ensuring a constant headway with respect to a leading vehicle.

V. Aim

Work on this project is proposed to occur between February 28th, 2014, and May 2nd, 2014. The objective of this project will be met by pursuing and completing the following two aims:

#1: Analyse the nonlinear system to determine the regions of stability, types of stability, equilibrium points, and the existence of any limit cycles;

#2: Devise suitable control methods to realise the objectives;

#3: Model and analyse the resulting system with an appropriate controller(s) in a suitable virtual environment to demonstrate the validity of the proposed technique(s).

VI. Projected Timeline

TABLE I
Timeline

Project Task	Due Date
Task #1	3/28/2013
Task #2	4/25/2013
Project Report	5/02/2013

VII. Expected Outcomes:

1. Organize research work into paper to be submitted to and reviewed by Dr. Aaron Ames.

2. Present research findings to Dr. Aaron Ames after the completion of this paper.

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