Intersection Management Using In-Vehicle Speed Advisory/Adaptation

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Introduction

Since the initialization of research based on Vehicle Infrastructure Integration (VII) and Connected Vehicles (CVs), numerous in-vehicle technologies are being deployed that make use of wireless communications. These advanced technologies lay the foundation for the proposed research effort to test vehicle speed advisory and adaptation systems on intersection performance. The main idea of the speed advisory system is to display a suggested speed to the driver who has the choice to follow or ignore the advice. Alternatively, the speed adaptation system entails automatic control of the vehicle speed using advanced cruise control systems. Our research group has developed a simulation/optimization tool that manages intersection operations entitled iCACC. The main idea of this tool is to optimize the trajectories of vehicles approaching an intersection to prevent crashes and reduce the total intersection delay simultaneously. Simulations using this tool showed significant savings in total delay and fuel consumption when compared to traditional intersection control. Consequently, this research effort proposes a field test of the iCACC tool using the Smart Road's CV test-bed. The research will attempt to study five different cases in the field experiments, namely: signal control with no exchanged information (base case), signal control with displayed speed advisory and green/red time countdown, flashing signal control with speed advisory, flashing signal control with speed adaptation and finally, a roundabout case study. The research findings are expected to provide researchers, automobile manufacturers and decision makers with information regarding the degree of acceptance of drivers and the potential of such systems for use in intersection control.

Problem Statement

There has been research conducted to develop speed control systems at intersections; however, none of these approaches explicitly attempted to minimize the total intersection delay. Previous research efforts have made simplifying assumptions and failed to capture the impact of various aspects in studying speed control (automation) systems on intersection operations.

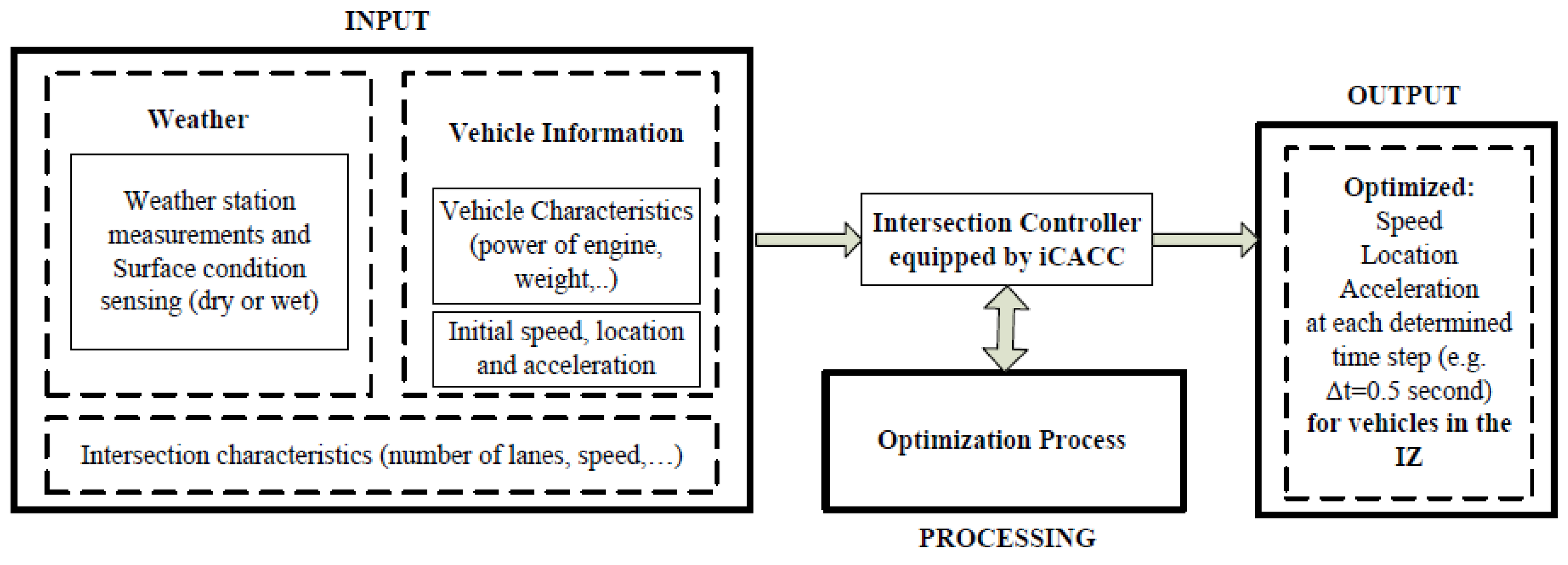
These limitations include:

1. All previous simulation tools manage the movement of automated vehicles without optimizing the global benefit (i.e. total intersection delay). Some algorithms only optimized conflicting vehicle trajectories not the entire intersection operation and others simply applied First Come First Serve (FCFS) rule for managing the intersection.
2. Most of the simulators/algorithms do not use vehicle physical characteristics (e.g. vehicle power, mass and engine capacity) in the simulation of vehicle acceleration and deceleration behavior; instead these are assumed to be constant.
3. None of the previous research efforts studied the impact of different vehicle classes/types on the intersection operation.
4. Most of the previous studies ignored the level of penetration (automation) in developing their proposed algorithms.
5. None of the previous research considered the latency and uncertainty in exchanged information in the simulation evaluations.
6. Most of the previous research efforts did not consider driver interference and driver acceptance of the system.
7. In a number of studies, the functionality, architecture, or design of the CACC systems were not described; however, field testing of advanced cruise control systems at intersection has been done by very few researchers.
8. None of the previous research efforts addressed the concept of speed adaptation or advanced cruise control systems at roundabouts, although the number of roundabouts in the US has increased significantly in the last decade.

Research Objective

The goal of the proposed research effort is to apply and validate the iCACC tool in a real environment using CV technology. The basic idea of the proposed tool is to optimize the speed of vehicles approaching an intersection in order to ensure no crashes occur and minimize the total intersection delay. The optimum speed concept will be tested for two different methods, namely: speed advisory and speed adaptation. In the first method, the speed will be displayed to the driver as an advisory message with the driver having the freedom to follow the system recommendation. In other words, the driver will have full control of the vehicle speed with the iCACC system as a driver assistance device. In the second method, the iCACC controls the vehicle longitudinal motion and identifies the optimum cruise speed using the modified ACC system. In this method, the speed is controlled by the vehicle itself; however the driver can override the system by pressing the brake pedal in case of an emergency.

The tool has the ability to model any type of intersection control and takes as inputs: the traffic volumes, intersection characteristics, weather conditions, vehicle physical characteristics and the level of penetration of the system. Subsequently, the iCACC optimizes all levels of automation, i.e. from legacy vehicles (e.g. standard vehicles with no automation) to fully autonomous vehicles.



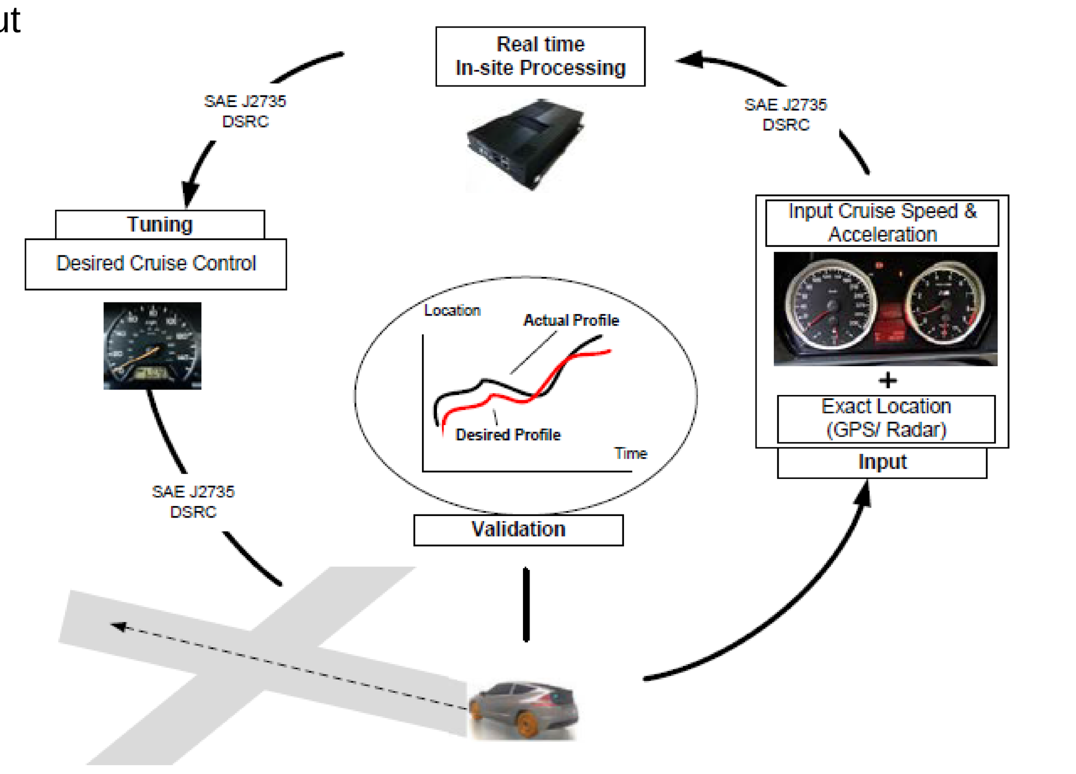
The Layout of the iCACC Tool

Overview of iCACC Tool

In general, the tool determines the optimum vehicle trajectories that ensure no conflicts occur while minimizing the total intersection delay each time step. All computations are done at the intersection controller which communicates speed decisions to CACC-equipped vehicles. Non-equipped vehicles are assumed to yield to vehicles approaching the intersection. The tool assumes that non-equipped vehicles are tracked using some form real-time tracking that could be video detection and/or road side units (RSUs), similar to the instrumentation at the three intersections in the Blacksburg test-bed. The tool seeks the efficiency of vehicle flow through the intersection by controlling the arrival time of vehicles at the intersection box and minimizing vehicle stop-and-go actions. Hence, the idea of controlling the arrival time of each vehicle at the intersection box is quite similar to the concept of metered single-lane entrance ramps. In other words, the iCACC controls the flow of vehicles to the intersection to ensure that they can smoothly enter into with minimum delays.

Experimental Scenarios

1. Signal Control (Base Case)
2. Signal Control with in-vehicle display; speed advisory and green/red time countdown
3. Flashing Signal Control with in-vehicle display; speed advisory
4. Flashing Signal Control with in-vehicle speed adaptation
5. Roundabout



The Experiment Structure: Input, Processing, Tuning and Validation

Anticipated Results and Benefits

It is anticipated the results of this research will be a valuable addition to the proposed simulation/optimization tool. This research will be unique given that none of the previous research efforts developed an optimization tool that is calibrated using field results in a CV environment. In addition, the research findings would allow for the characterization of parameters for use in simulation of the potential benefits of such a system.
The proposed tool has been successfully tested in a simulation test-bed; however implementing it in a field test will address many assumptions. However, the field testing of the proposed tool will be able to address some of the unanswered questions raised by many researchers where a few of them could be listed as follows:
Solicit driver acceptance of automation systems;

1. Solicit driver interaction to displayed speed advisory and/or self-controlled vehicles;
2. Identify possible demographic characteristic effects (age, gender, etc.) on driver acceptance of in-vehicle technologies;
3. Quantify the error in the information (location, speed, etc.) exchanged between V2V and V2I;
4. The latency and inaccuracy in communications between the intersection controller and different vehicles;
5. The impact of non-automated (non-equipped) vehicles on "smart" intersection performance.

Roundabout Location at Virginia Tech Main Campus, Blacksburg, VA

CVI UTC   MORGAN STATE UNIVERSITY   VirginiaTech Transportation Institute   University of Virginia