Microscopic Estimation of Arterial Vehicle Positions in a Low Penetration Rate Connected Vehicle Environment

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INTRODUCTION

Vehicle communication among vehicles and roadside infrastructure, known as connected vehicles, is expected to provide higher resolution real-time vehicle data, which will allow more efficient traffic monitoring and control. Adoption of connected vehicle technology among the vehicle fleet may be gradual or limited, with many drivers unable or unwilling to transmit their locations. Additionally, many connected-vehicle mobility applications do not experience benefits when fewer than 20 percent to 30 percent of roadway vehicles participate.

In an effort to improve the performance of connected vehicle applications at low connected vehicle penetration rates, we propose a novel technique to estimate the positions of non-communicating (unequipped) vehicles based on the behaviors of communicating (equipped) vehicles along a signalized arterial. Unequipped vehicle positions are estimated based on observed gaps in a stopped queue, and the longitudinal movement of these estimated vehicles is simulated microscopically using a commercial traffic simulation software package.

The location estimation algorithm is generic and could be applied to other connected vehicle applications to improve performance at low penetration rates.

BACKGROUND

In a connected vehicle environment, equipped vehicles can share their locations, speeds, headings, and many other data in real-time with nearby vehicles and the surrounding infrastructure via wireless communication. This data can be used to improve traffic monitoring and control applications, although research has shown that applications are only useful when a minimum percentage of vehicles can participate.

OBJECTIVES

- Can the locations of some unequipped vehicles be estimated from the behavior of a few equipped vehicles?
- Can these estimated locations then be used to improve the performance of connected vehicle mobility applications?

PROCEDURE

Step 1: Define Communication Vehicle. First, gaps greater than 10.5 meters (unobserved) between stopped vehicles within 50 meters of the stop bar. These gaps suggest the presence of an unobserved unequipped vehicle.

Step 2: Simulate Inserted Vehicle Movement. The movements of inserted vehicles are simulated in a single lane of a stopped queue using the Predictive Microscopic Estimation Algorithm (PMSA). The movements of these inserted vehicles are based on the observed behavior of the equipped vehicles. Vissim®'s COSM engine allows the simulator to monitor real-time positions of individual vehicles.

Step 3: Simulate Equipped Vehicle. Inserted vehicles are deleted from the simulation if their position overlaps an equipped vehicle or they reach the end of the network.

Step 4: Calculate Effective Penetration Rate. A “correct” insertion rate is one relationship with a newly unequipped vehicle in the same lane, at the same time, within minimum headway less than the required accuracy distance.

\[ P_{R} = \frac{\text{No. Equipped Vehicles + No. Correct Insertions} - \text{No. Incorrect Insertions}}{\text{No. Equipped Vehicles + No. Unequipped Vehicles}} \]

EVALUATION

A Sample of Vehicle Trajectories at 15% Effective Penetration Rate on a Single Lane

APPLICATION: CONNECTED VEHICLE TRAFFIC SIGNAL CONTROL

To test its effectiveness, the location estimation algorithm was applied to the Predictive Microscopic Estimation Algorithm (PMSA) for traffic signal control.

CONCLUSIONS

First attempt to measure the positions of individual unequipped vehicles on arterials without restrictive assumptions.

In simulations, the algorithm made more correct than incorrect estimates of unequipped vehicle locations in the same lane and at the same time, within minimum headway less than the required accuracy distance.

Improved the performance of connected vehicle traffic signal control strategy at equipped and unequipped vehicle-penetration rates between 10 percent and 25 percent, with worse performance at 50 percent penetration.

The proposed location estimation technique may prove beneficial to other connected vehicle algorithms, such as queue length estimation for transit signal priority or ramp metering at low penetration rates.

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