Arterial Traffic Estimation Using Field Detector and Signal Phasing Data

Identifying the Need

For traffic management agencies to make better decisions regarding traffic control, accurate estimates of traffic states on arterials are essential. Several methods have been proposed to estimate the traffic states on freeway segments, but fewer methods exist for arterials because of complicated road geometries and the presence of signal control. Oftentimes estimating traffic states on arterial road links can be more challenging than on freeways.

Traffic flow at an intersection approach is significantly impacted by signal control, pedestrian traffic, cyclists, and other vehicles making separate traffic movements. In the field, numerous detectors have been installed at intersection approaches to help with the control of conflicting traffic movements. Advance detectors are normally installed about 200 feet upstream from the stop line to detect vehicle arrivals, while stop bar detectors are installed to detect a vehicle's presence at the stop point. Depending on the configuration, these detectors can consist of different loops: normal signal loop for advance detectors, and multiple loops for stop bar detectors. As a result, they have different lengths, which will impact their detection accuracy. In arterial networks, vehicle movements are generally interrupted by traffic signals. Because of that, the observed data points from a given detector that is at an intersection, particularly for one closer to the stop line, can scatter in a wide range. Therefore, traditional diagrams to estimate traffic states on freeway road links cannot directly be applied to the arterial ones, creating the need for a new kind of solution.

What is the goal?

The goal of this research is to engineer a way to accurately fuse signal phasing information from traffic signal controllers with data from loop detectors to provide precise, detailed, and timely estimates of traffic states for arterial roads.

Project Description

In this project, a novel approach was developed to estimate traffic states on arterial road links using both loop detector data and signal phasing information. The approach consisted of the following two tasks: (1) estimate the traffic flow fundamental diagrams for arterial road links that are used to categorize traffic states into different regimes; (2) develop estimation algorithms that use the newly designed trapezoidal diagram and produce estimates of traffic states and vehicle queues for the traffic movements at a given intersection approach.

At a given intersection approach, it is assumed vehicles arrive in platoons with no dispersion, which is particularly true when signals are coordinated, and intersections are narrowly spaced. Based on this assumption, the PATH team derived a trapezoidal fundamental diagram which was determined by a set of parameters including saturation flow rate, saturation speed, green ratio, detector length, and average vehicle length. The diagram included two occupancy thresholds to categorize the traffic states into three different regimes: uncongested, congested, and downstream queue spillback. The parameters used to calibrate and validate the two thresholds consisted of road geometry and detector layout, signal phase settings, and vehicle dynamics, which were obtained from the field data. The diagram was validated using a dataset with six months of detector data.

A case study was performed using field data from three intersections along Huntington Drive in the City of Arcadia in the I-210 Connected Corridors pilot. Flow-occupancy relations were obtained for both advance and stop bar detectors at the intersection approaches. After careful analysis it was determined that advance detector information was more reliable than stop bar detectors because it was less impacted by the traffic signal.

An algorithm was developed to estimate the saturation flow rates based on the data from advance detectors. Results show that the estimated saturation flow rate varies widely. The PATH team found that the low saturation flow rates could be caused by inappropriate detector placement, shared traffic movements, active pedestrian calls, and temporary lane blockages caused by the turning movements.

In the second task, estimation algorithms were further developed to categorize the traffic states at different types of detectors: three regimes for advance detectors, and two regimes for stop bar detectors. Then, algorithms were created combining traffic states from individual detectors, producing estimates of traffic states and vehicle queues for the traffic movements at an intersection approach.

Theoretically, this research shows that when traffic is congested and there are no significant left-turn and right-turn movements at multiple intersections along an arterial corridor, there is a linear relationship between the total vehicle queues and the travel times. This relationship was validated on a segment of five intersections along Huntington Drive in the city of Arcadia using detector data and Bluetooth travel times.

PATH then developed an estimation and initialization framework for the microsimulation in AIMSUN to begin traffic initialization. The I-210 AIMSUN network in the Connected Corridors project was chosen as an application example and generated simulated vehicles on the arterial road links in the City of Arcadia using the newly developed algorithms. These algorithms are applicable under different detector layouts and lane configurations and can work with conventional data sources. The proposed estimation and initialization framework can be synchronized with other large-scale simulation models since it eliminates the step of simulation warmup and generates reliable and accurate traffic states under good detector coverage and data quality.

Projected Benefits to California

Overall, the outcomes from this project provide valuable insights for both researchers and engineers to better understand arterial traffic. The proposed trapezoidal fundamental diagram reveals the basic characteristics of arterial traffic under signal control.

In addition, this study also provided the building blocks for several future research directions, such as identification of lane blockage and queue spillback, optimal signal control based on the trapezoidal fundamental diagram, and a data fusion approach with probe trajectories to improve estimation accuracy.

What is the progress to date?

The project is complete. The PATH team developed a novel estimation and initialization framework that reads field data, estimates average vehicle queues, and generates simulated vehicles in the AIMSUN microsimulation software. The framework was successfully applied to the arterial intersections in the City of Arcadia in the I-210 Connected Corridors pilot in AIMSUN.

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Final Report

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