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Roadway Traffic Flow Estimation using Video Imagery Data Collected from Transit Bus Cameras

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Abstract Transit vehicles are increasingly equipped with sensors serving a variety of purposes. Recently it has become common to equip transit buses with exterior-looking cameras for security and liability purposes. Given that transit buses traverse routes repeatedly and on a regular basis, they offer an opportunity to serve as mobile sensing platforms to assess various aspects of the environment along and immediately surrounding the routes they serve. In this study, a methodology and empirical study are presented in which traffic flows are estimated from video imagery collected from exterior-looking cameras mounted on transit buses. A variant of the "moving observer method" of estimating traffic flow is developed to be applied to each pass of a transit bus on a segment to derive vehicle flows from the video data. The resulting roadway segment traffic flow estimates are compared to flows determined from conventional road tube data collected concurrently.

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Moreover, spatial and temporal traffic flow patterns over a street network are cross-checked against known traffic flow patterns. Furthermore, a statistical model of the differences between transit bus-based traffic flow estimates and road tube measurements is developed and estimated. In addition, a statistical model aimed at investigating the nature of the variability of the transit bus-based flow estimates is also developed and estimated. The results collectively support the technical feasibility of using transit buses as sensing platforms to estimate traffic flows across a spatially extensive urban network and the ability to do so at a desirable level of confidence.

Keywords: Traffic flow estimates, video imagery, transit buses, mobile sensing platforms, moving observer method.

1 Introduction

Traffic flow estimates are typically derived from vehicle counts collected at fixed locations using either permanent sensors (e.g., inductive loop detectors), temporary sensors (e.g., pneumatic tube detectors), or manual human observers. It is infeasible to deploy fixed-location sensors or human observers on every segment of spatially extensive networks and, thus, most road segments are either unmonitored or are monitored on a very infrequent basis. In contrast, transit buses regularly and repeatedly traverse a large portion of the urban roadway network. If traffic count data could be collected using buses as mobile sensing platforms at low marginal cost and processed to produce reasonable traffic flow estimates, the extensive and repetitive coverage of roadway segments by transit buses could potentially be exploited to determine traffic flows in urban areas with much greater spatial coverage and update rates than are presently available.

Recently, it has become common to equip transit buses with exterior- and interior-looking cameras for security and liability purposes. In this study a method is developed for estimating roadway traffic flows from imagery collected by exterior-looking video cameras installed on transit buses. Taking advantage of such video imagery comes at a relatively small marginal cost. The accuracy of estimating traffic flows is empirically assessed and investigated in this study.

At the root of the developed traffic flow estimation method are probe vehicle-based studies and, in particular, the *moving observer method*. Conventional probe vehicle and floating car studies have been commonly used to collect travel time, delays, and stops, and they are becoming increasingly common for real time travel time measurement. As originally conceived, the moving observer method suffers from two major limitations. First, it requires a dedicated vehicle and two people – someone to drive and someone to count vehicles. Second, a single pass of the moving observer over a roadway segment will be brief and result in a short-duration observation that is subject to high variability in flow conditions from, for example, nature of travel demand, signal phasing, major or minor incidents, and behavior of drivers of detected vehicles.

Using transit buses as sensing platforms can mitigate these limitations. The transit vehicle is already in service. Therefore, a dedicated vehicle and driver are not required. And, since camera sensors are mounted on transit buses, the need for a data collector is eliminated. Each individual pass of the transit bus will still result in a short-duration observation, but the repeated (many times per day, days per week, weeks per year) traversal of the same road segments by outward-looking-camera-equipped busses leads to multiple, independent observations that can be aggregated to reduce the limitations of single pass, short-duration observations and potentially yield meaningful traffic flow estimates.

2 Data

Two datasets were collected and analyzed as part of this study. Road tubes were installed on ten roadway segment-directions that are part of or in the vicinity of The Ohio State University (OSU) campus in Columbus. Resulting traffic counts aggregated at a 15-minute resolution over the course of one day from 7 am to 7 pm are available for this study. In addition, video imagery collected from cameras mounted in the top rear driver-side corner of OSU's Campus Area Bus Service (CABS) buses serving three routes that traverse the ten roadway segment-directions are also available on the same day for this study.

A graphical user interface (GUI) was developed for the purpose of this study to allow individuals to semi-manually count vehicles crossing each bus in the opposite direction along with the location and time-stamp of these crossings. A human video processor clicks on a GUI button each time a vehicle crosses the bus whose video imagery is used, which results, once applied repeatedly, in a dataset of vehicle counts, their locations, and time-stamps. (For an operational implementation, naturally, this process must be automated using computer vision techniques.) The available video imagery is processed in this manner producing vehicle counts for a total of 597 bus passes (approximately four to five passes per hour for each segment-direction) over the ten segment-directions on the same day and over the same period the roadway tube data are available.

3 Methodology and Analysis

Traditionally, traffic flow data are collected by recording vehicles passing a fixed location over an interval of time. To estimate the traffic flows from the video imagery collected using a bus's camera, a variant of the moving observer estimation method was developed in this study. In the traditional method, the moving observer method estimates traffic flow in one direction (say Direction 1) on a segment when the observer makes a "loop" consisting of two "legs": One leg that involves observing Direction 1 traffic while the observer travels on the segment in Direction 2 (in the opposite direction across the centerline), and a second leg that involves observing Direction 1 traffic (specifically, vehicles that overtake and are overtaken by the moving observer) while the observer travels in the other direction (Direction 1). The two legs should be traversed closely enough in time so that the Direction 1 flow can be considered homogeneous during the time when the observer is traversing both legs.

If video imagery is only available from a few buses, many hours may pass between traversal of the two legs of the segment. Or, the bus route may be such that the bus only traverses in a single direction. Therefore, a modification of the moving observer method was developed to estimate traffic flows from the first leg (estimating Direction 1 traffic while the transit bus travels only in Direction 2).

Roadway segment traffic flow estimates for each bus pass are compared to road tube data concurrently collected. Segment-direction flow rates for a time-of day period are determined by averaging the flow rate estimates obtained from individual transit bus passes occurring during the period. Based on these time-of-day period flows, spatial and temporal traffic flow patterns over a street network are cross-checked against known traffic flow patterns. Furthermore, a statistical model of the differences between transit bus-based traffic flow estimates and road tube measurements is developed and estimated. In addition, a statistical model aimed at investigating the nature of the variability of the transit bus-based flow estimates is also developed and estimated.

4 Results and Conclusions

Comparisons with traffic flow estimates obtained from road tube data demonstrate that the individual pass flow estimates behave like estimates derived from short-term traditional estimates. The spatial and temporal patterns in the set of segment flow rates correspond well to known traffic flow patterns. Statistically significant and meaningful relations are found between the difference between transit bus-based flow estimates and road tube estimates on the one hand and the variability of bus-based estimates and number of passes used to estimate the average flow on the other hand. Other statistically significant and meaningful relations are found between the variability of transit bus-based estimates and the traffic volume and the duration of the bus observation interval. The results, including these relations, collectively support the technical feasibility of using transit buses as sensing platforms to estimate traffic flows across a spatially extensive urban network and the ability to do so a desirable level of confidence.