Evaluation of Single-Loop Detector Vehicle-Classification Algorithms using an Archived Data User Service System

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ABSTRACT

Truck traffic on the nation's freeways is forecast to grow significantly in the near future. Managing the transportation system to ensure the efficient and reliable movement of trucks and the freight they carry is of vital importance. Knowledge of truck volume on freeway corridors will therefore be increasingly important. Until recently, classifying vehicles by their length was done using dual inductive-loop detectors, automatic vehicle classifiers, or manual counting; however, these techniques have limited availability. Recently, several algorithms have been developed to estimate vehicle classifications based on data from single-loop detectors. We evaluate one such algorithm using the Portland Transportation Archive Listing (PORTAL). PORTAL is the Portland, Oregon region's ADUS and has been archiving speed, volume, and occupancy data from almost 500 loop detectors on the metropolitan freeway systems since July 2004. We implement a vehicle-classification algorithm in PORTAL developed by Wang and Nihan. The results are displayed graphically using techniques such as cumulative volume plots so that the results are accessible to PORTAL's users, which include traffic managers and engineers and university researchers. We evaluate this algorithm by comparing their performance to manual counts and automated video detection counts obtained by Portland State University researchers in a recent study. By using the PORTAL ADUS, we are able to validate the performance of a single loop detector vehicle classification algorithm under a wide variety of conditions.

INTRODUCTION

Freeways all over the U.S. have inductive loop detectors installed in the roadway infrastructure. Archived loop detector data from the Portland Transportation Archive Listing (PORTAL) ITS data archive project can be used as yet another tool for analyzing vehicle classification. Currently, the inductive loop detectors in the Portland freeway system are configured as dual-loop speed traps; however they are currently functioning essentially as single-loop detectors by virtue of the way that speed is calculated. Dual-loop detectors have the technology to directly measure parameters such as speed and vehicle length, while single-loop detectors can only perform estimates based on an assumed average vehicle length. Currently in Portland, the measured count and occupancy values over 20-second periods are used to estimate an average vehicle speed for the interval. With so many roadways already having single-loop detectors installed, or using dual-loop detectors as single-loop detectors, determining vehicle-classification can be rather challenging. Therefore, it is important for researchers to develop algorithms to estimate vehicle lengths and speeds from single-loop detector data. Such algorithms can be used for vehicle-classification and can replace or add to manual counting techniques.

Until the Portland freeway detectors can be reconfigured to take advantage of the dual loop speed traps for direct speed and vehicle length measurement, the algorithm developed by Wang and Nihan has been implemented within the PORTAL framework for counting truck volumes based on the effectively single-loop detector data in PORTAL's data archiving system. With this algorithm integrated into PORTAL it is possible to use archived data to stress test the algorithm, and compare it with other data collection techniques, such as manual count, and video Autoscope counts.

RESEARCH OBJECTIVES

This project has several objectives. First, the ability of researchers and public agencies to collect freight data using the existing ODOT CCTV camera network was tested. This was accomplished by coordinating camera positioning with the ODOT traffic management operation center and the successful connection of the fiber optic data feed to the Intelligent Transportation Systems (ITS) Laboratory at Portland State University. Second, it was demonstrated that traffic recorded on DVD-Rs could be processed with the Autoscope RackVision hardware unit and accompanying software, and done in such a way that a methodology was established that can be used for future data collection experiments. Third, the robustness of the Nihan-Wang algorithm was established for data collected in the Portland metropolitan region.

STUDY AREA

Four study areas were chosen for this project. As shown in Figure 1 they are:

- I-5 SB at Marine Drive in North Portland, OR
- I-84 WB at Sandy Blvd/37th Ave in Southeast Portland, OR
- I-5 NB at Lower Boones Ferry Road in Tualatin, OR
- OR-217 at SW Hall Blvd. in Tigard, OR

Figure 1: Site Map

It was important to select locations that had high volumes of truck traffic, and were able to be recorded by ODOT's CCTV network in a manner that allowed the recorded video to be processed using the Autoscope RackVision and accompanying software package. Furthermore, it was necessary that the CCTV camera could be positioned in such a manner that enabled the field of vision to include the location of the inductive loop detectors that are located in each highway lane. The data fidelity of each loop detector was an important consideration in site selection, since high quality data was needed as an input into the Nihan-Wang algorithm. This was necessary so that the robustness of vehicle classification estimations produced by the algorithm could be adequately tested versus ground truth data.

Figure 2: Lower Boones Ferry Road Camera Image

The land use patterns near each location contribute to the high percentage of trucks observed at the study locations. The Marine Drive site is located near a large area of industrial-zoned land in the northern quadrant of Portland. There are many large warehousing and distribution facilities located in that section of the city, which produce a large number of truck trips. The site is also in close proximity to several Port of Portland marine terminals, and much of the traffic generated and attracted to this area travels past the Marine Drive interchange on I-5. Finally, this location serves interstate trucking routes that run through the states of Oregon, Washington and California. Similarly, the I-5 interchange (see sample video image in Figure 2) at Lower Boones Ferry Road carries high volumes of truck traffic from the regions located south of Portland, and I-84 carries traffic entering Portland from the east. The location at SW Hall Blvd along Oregon-217 is along a prime freight route that connects the cities of Tigard, Tualatin, Lake Oswego and Beaverton. The OR-217 corridor serves dozens of large big-box retailers, warehouses and the Portland metropolitan region's largest shopping mall complex, Washington Square. OR-217 also is located in the fastest growing area of the metropolitan area, is congested for large parts of the day, and is currently being studied for lane expansion and other capacity improvements.

DATA ANALYSIS

The inductive loop detector recorded on highways in the Portland metropolitan region is stored in Portland State University' archived traffic database, the Portland Region Transportation Archival Listing, or PORTAL. The detectors in the freeway system are configured as dual-loop speed traps, but they are currently functioning as single loops. The detectors record volume and occupancy data aggregated at 20-second intervals. This current configuration does not allow direct measurement of speed or vehicle lengths. This paper explores the vehicle classification algorithm developed by Wang and Nihan at the University of Washington and compares it against ground truth data, and data created using video image processing.

It is hoped that PORTAL will provide traffic researchers the ability to quickly glance at traffic or study deeply the affects of long and short vehicles on traffic flow. With the newness of vehicle classification PORTAL intends to use its online system to help validate algorithms and vehicle detection tools. Future additions to the PORTAL vehicle classification features includes but not limited to; adding other truck count algorithms, adding percent truck graphs and tables, and possible data fidelity studies. Figure 3 is an example plot showing truck percentages for a day at one of the study locations. Figure 4 provides a contour plot of truck volume percentage for the I-5 Northbound corridor on Dec 15, 2005; the graph shows data at a 5-minute aggregation level. For I-5 Northbound on Dec 15, 2005, the average percent trucks in a 5-minute period was 14.35%, with a standard deviation of 12.57%. The volume-weighted average truck percentage for 5-minute periods for the entire day was 18%, with a standard deviation of 13.09%.

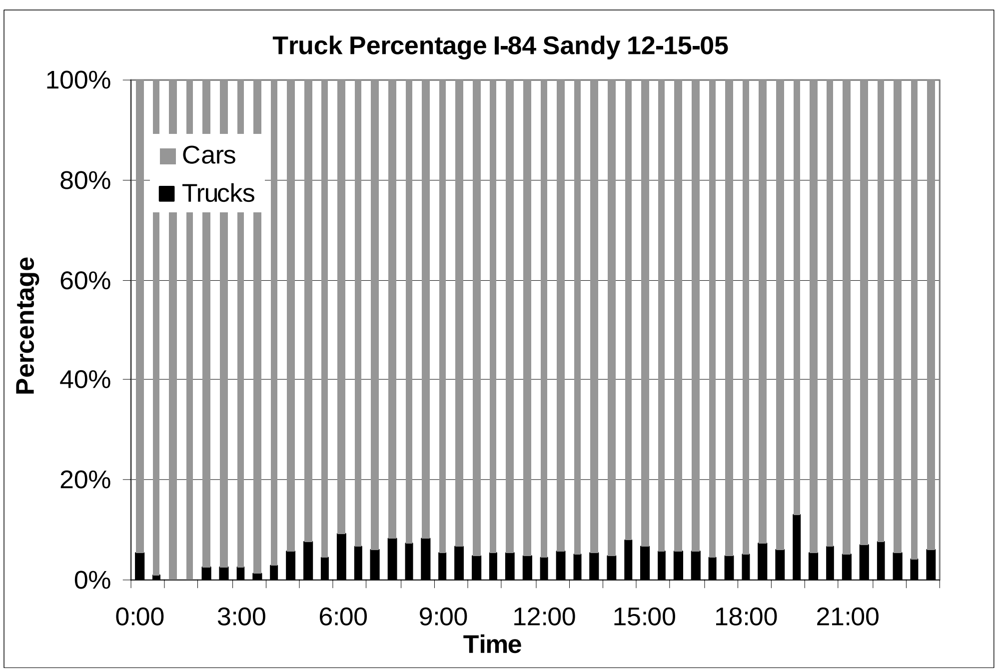

Figure 3: Hourly Truck (Long Vehicle) Percent I-84 Westbound at Sandy Blvd, Dec 15, 2005

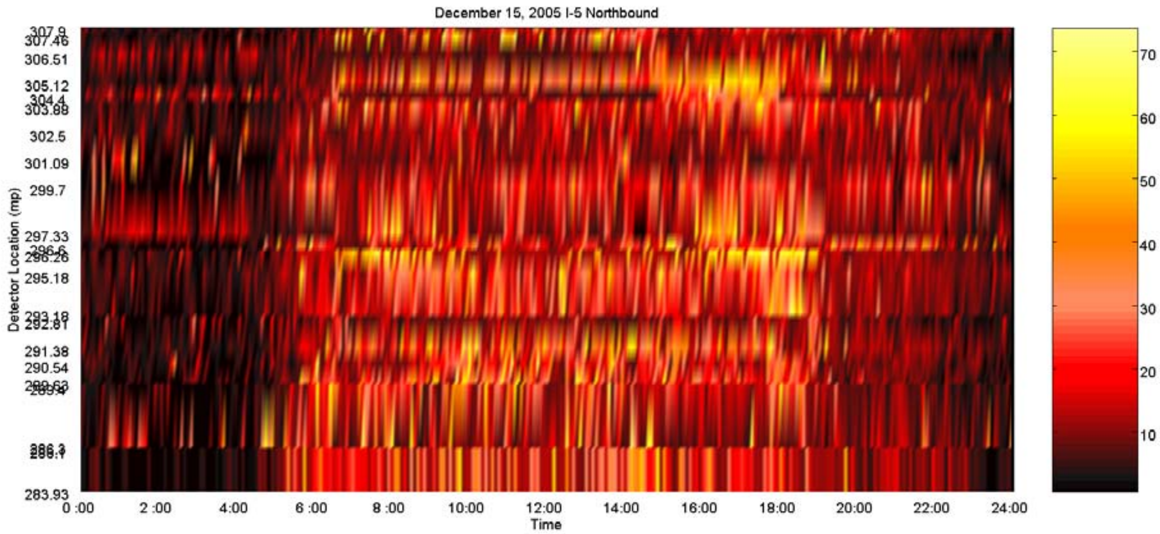

Figure 4: Truck Percent Contour Plot (interpolated): I-5 Northbound, Dec 15, 2005

For each of the three data sets for a given period of observation, a series of eight plots were made to provide a graphical representation of the volume and speed data. Two types of graphs were made. Figure 5 illustrates the first showing the comparison between measured volumes for each data collection method. Figure 6 illustrates the second type using a volume scaling factor to create an oblique plot which shows volume differences between the measured volume and the scaling factor.

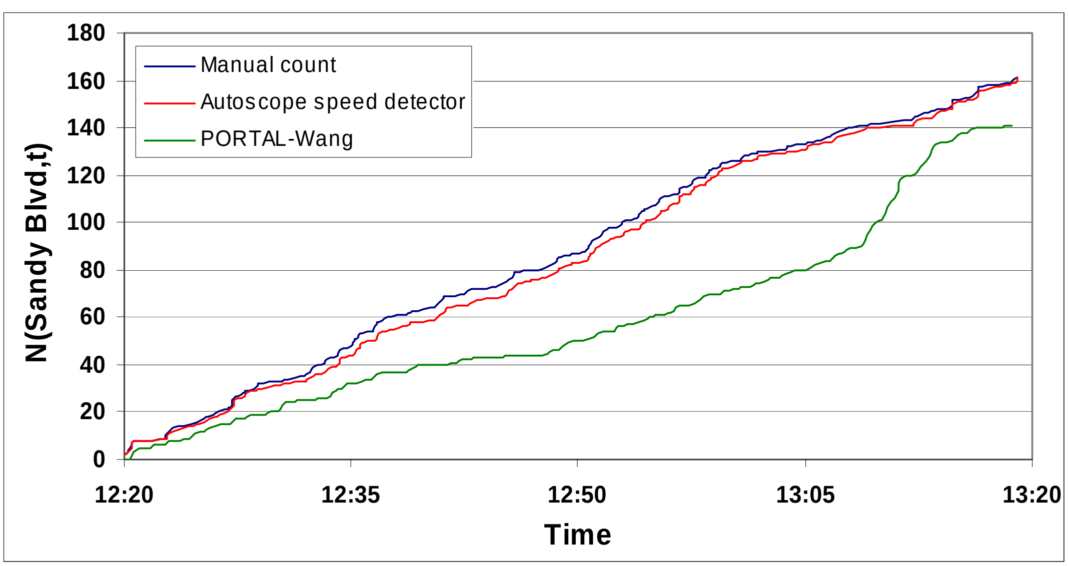

Figure 5: Cumulative Long Vehicle Count

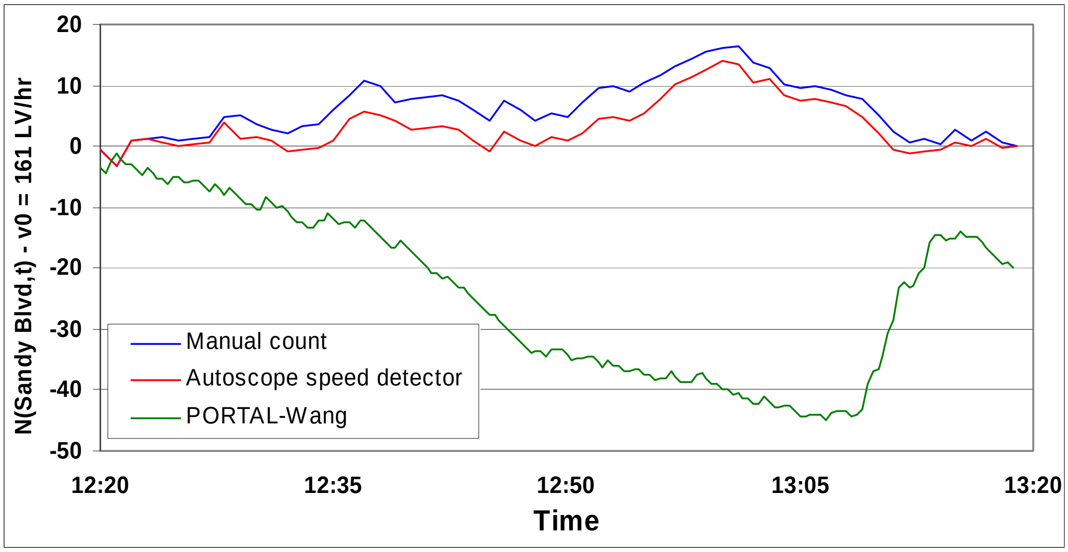

Figure 6: Cumulative Long Vehicle Count – Oblique Plot

In order to demonstrate some of the relationships between the differences found during the study, a number of graphical illustrations have been completed. These include comparing ground truth data versus the three count mechanisms, ground truth versus truck volumes, percent differences between count mechanisms, measured flow histograms, flow as related to total and percent count errors, and relationships between speed measurements and count errors. Figure 7 illustrates the comparison of truck count to ground truth.

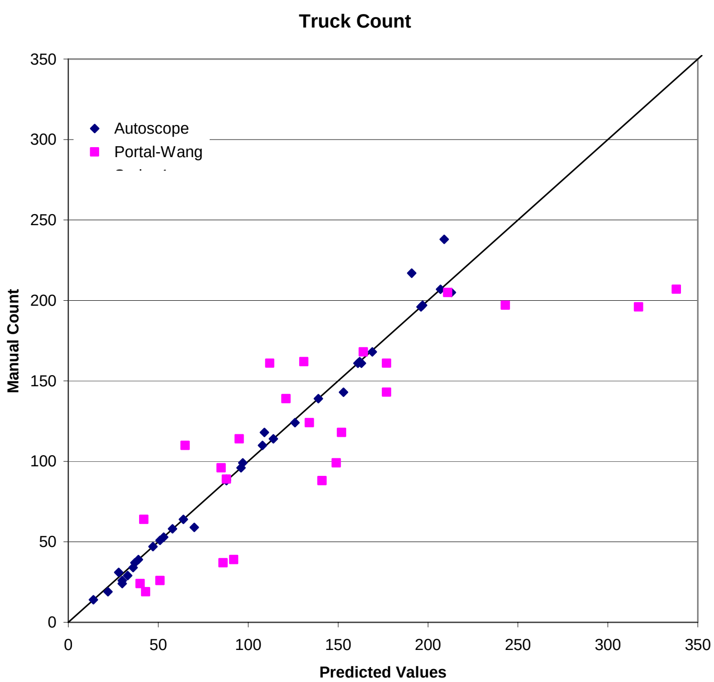

Figure 7: Comparison of Truck Count Mechanisms to Ground Truth

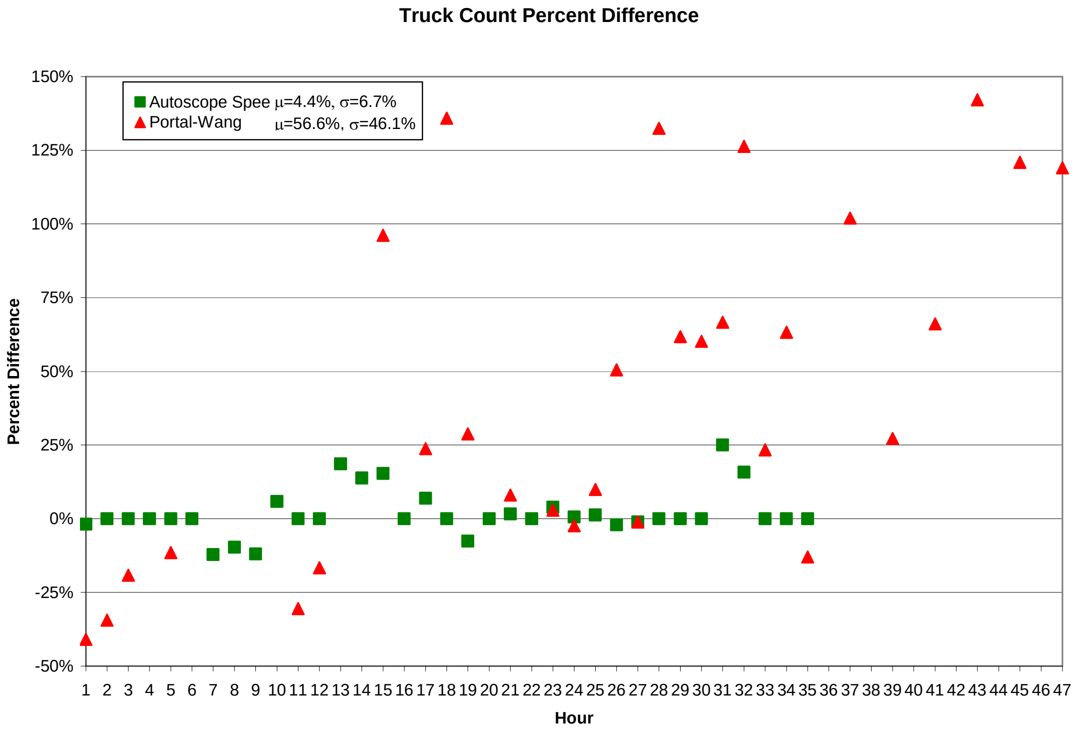

Figure 8: Truck Count Percent Difference

The primary interest in this research was to determine whether there are potential systematic means for estimating truck traffic flows on the freeway network of the Portland metropolitan region. Toward this end, Figure 8 shows the percent difference for the two truck counting mechanisms as compared to ground truth for all 47 data periods (where data were available). As shown, the Autoscope Speed method displayed an average of 4.4% error with most points near the zero *x*-axis. The PORTAL-Wang method exhibited truck counts that were more scattered.

FINDINGS

It is shown that the Autoscope is an effective tool for determining truck and passenger vehicle volume counts. In addition, it can produce good estimates of individual vehicle speeds. This experiment has shown that the Autoscope, when used under the available CCTV camera conditions (the various positions, locations and heights of highway cameras located around the Portland region) in the Portland region does not produce accurate measurements of vehicle length. It is noted that while vehicle lengths are overall incorrect, in many circumstances a histogram of all vehicle lengths measured during a time period conforms closely to a generalized histograms made based on manual observations of vehicle lengths. It is possible to use such histograms in a way that makes it worthwhile to estimate long and short vehicle volumes with Autoscope.

The Wang-Nihan algorithm results are less clear. In certain situations, the algorithm does a good job of predicting long vehicle volumes. In others, the algorithm over or underestimates truck volumes. The analysis of the estimation error patterns is inconclusive – there are inconsistencies during period of heavy traffic and light traffic, both when the volume of trucks is low, and when trucks constitute a larger percentage of the traffic stream. Sources of error may lie in the choice of study locations when they correspond to areas with poor detector performance. Further research needs to be undertaken in order to understand where the errors are coming from and if it is possible to tweak detector performance to result in more accurate truck counts**.**

CONCLUSIONS

It is shown that there is a current need for collecting freight data. One method for doing so is by using the existing ITS infrastructure readily available in metropolitan regions around the country – inductive loop detectors, surveillance cameras, data processing algorithms and software programs, communication networks and data archiving and retrieval technologies. These technologies can produce favorable results – good, useable data – when care is taken to design data collection experiments and implement methodologies that produce verifiable data. Coordination and cooperation between researchers, state and local DOTs, and other stakeholders helps to speed the data collection process and to enable worthwhile data to be collected. Overall, the technologies used in this experiment show some promise in terms of their long-range abilities to produce freight data in an automated way.

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