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SIDE-BY-SIDE EVALUATION OF VVDC AND CITILOG'S MEDIATD VIDEO DETECTION SYSTEMS

by

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16. ABSTRACT

Vehicle detection and classification data are important inputs for traffic operation, pavement design, and transportation planning. However, such data are not directly measurable by single-loop detectors, the most widely deployed type of traffic sensor in the existing roadway infrastructure. A number of commercial video-based traffic detection systems were developed for collecting traffic count and classification data by using widely available surveillance cameras. Performance evaluation of these systems is of practical importance for traffic engineers to correctly choose the appropriate systems for their specific applications. In this study, a side-by-side evaluation of Citilog's MediaTD video detection system and the Video-based Vehicle Detection and Classification (VVDC) system was conducted. To sufficiently examine the practicality and robustness of both systems, six representative test scenarios were employed. These test scenarios included challenging video detection situations, such as transient light changes, slight camera vibrations, serious light reflection, and severe congestion. Test results indicate that both systems worked well under certain test conditions but resulted in significant errors under some challenging test conditions. The VVDC system performed better than the MediaTD system in most of the selected test scenarios. However, since the test scenarios were very limited, the comparison results of this study may not be general enough to apply to other locations and roadway conditions.

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Executive Summary

Vehicle detection and classification data are important inputs for traffic operation, pavement design, and transportation planning. However, such data are not directly measurable by single-loop detectors, the most widely deployed type of traffic sensor in the existing roadway infrastructure. A number of commercial video-based traffic detection systems were developed for collecting traffic count and classification data by using widely available surveillance cameras. Performance evaluation of these systems is of practical importance for traffic engineers to correctly choose the appropriate systems for their specific applications. In this study, a side-by-side evaluation of Citilog's MediaTD video detection system and the Video-based Vehicle Detection and Classification (VVDC) system was conducted. To sufficiently examine the practicality and robustness of both systems, six representative test scenarios were employed. These test scenarios included challenging video detection situations, such as transient light changes, slight camera vibrations, serious light reflection, and severe congestion. Test results indicate that both systems worked well under certain test conditions but resulted in significant errors under some challenging test conditions. The VVDC system performed better than the MediaTD system in most of the selected test scenarios. However, since the test scenarios were very limited, the comparison results of this study may not be general enough to apply to other locations and roadway conditions.

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1. Problem Statement

Due to the extensive applications of surveillance cameras in traffic control and management, video data has been used as an important source for monitoring traffic systems. In order to provide better traffic information, automated traffic data collection from surveillance video camera images is essential. The research on image processing for traffic data collection was initiated in the mid 1970s in the United States, Japan, etc. (Michalopoulos, 1991). Several video-based traffic data collection systems have been developed. Applications of these systems received controversial feedbacks. This indicates that a video-based traffic data collection system needs to be evaluated before wide range deployment.

This report concerns the performance evaluations of the MediaTD software (Version 1.1) developed by Citilog, Inc. and the Video-based Vehicle Detection and Classification (VVDC) System (Version 1.0) developed by the Smart Transportation Applications and Research Laboratory (STAR Lab) at the University of Washington. This research was initiated and funded by the Washington State Department of Transportation (WSDOT).

The testing strategy chosen was to determine the counting accuracy of various aspects of the software programs at different locations and under varied lighting and weather conditions. The scenarios included conditions such as slightly shaking cameras, occluded vehicles, varying lighting conditions, and several weather conditions, such as rain and wind.

2. Background

Transportation agencies are increasingly relying on a broad array of sensors to provide information to motorists about traffic conditions. When Traffic Systems Management Centers (TSMC) first appeared in many US cities, they depended primarily on inductive loop sensors to provide volume and occupancy data. These sensors were fine for providing very coarse information about the state of roadways in an agency's jurisdiction, but operators had little idea what traffic actually looked like. What they needed was a much richer data source: video cameras. Video cameras provide operators with a better view of roadway conditions, and, if deployed widely enough, they can also be used to detect incidents and other traffic anomalies. These capabilities of video cameras motivated the installations of surveillance video cameras at transportation agencies over the past two decades. Fenichell et al. (1995) showed that surveillance video cameras had a market share of over 17% for newly installed traffic detection devices.

Agencies all over the country have invested in surveillance cameras to monitor freeway performance from Seattle to Virginia and Chicago to California, while countless cities have also opted to use cameras for local intersection control. Currently, these surveillance video cameras are used by traffic operators to manually verify traffic conditions on the road. Potential detection capabilities associated with the rich video data are not properly utilized.

Video detection technologies have been developed to extract traffic data from video images. Most of these new video-based technologies rely on background subtraction as their primary means of detection. They take a constantly updated background image and use it to determine which objects in the video image are vehicles and which are static pieces of background. Some more recent and revolutionary work is based on pattern recognition, actually recognizing the car as a car by identifying its various features, such as headlights and windshields.

The MediaTD system developed by Citilog has a function to detect vehicle volume, lane occupancy, and average speed (Citilog, 2003). If this detection function works well, it can make a good use of the over 200 surveillance video cameras deployed along freeway corridors in the greater Seattle area. Therefore, the Washington State Department of Transportation (WSDOT) wants to know the accuracy of this system in collecting roadway traffic data, especially volume data. The VVDC system developed by the STAR Lab at the University of Washington was chosen as the reference system for the MediaTD system evaluation. Details of the VVDC system can be found in Wang et al. (2006).

3. Research Objectives

The objectives of this study are:

- To evaluate the accuracy of the Citilog MediaTD system in collecting roadway traffic volume data; and
- To compare the accuracy of the Citilog MediaTD system with that of the VVDC system.

4. Methodology

The objectives of this project will be fulfilled through the following four steps:

- Selection of Study Sites;
- Data collection;
- Testing of the Citilog MediaTD and VVDC software;
- Comparison of the two systems; and

A description of the steps is as follows.

4.1 Step 1 – Study Site Selection

The STAR Lab has a surveillance video camera (COHU i-dome) installed on the roof of More Hall on the UW campus. The position of this camera can be best adjusted to collect traffic data on the Stevens Way.

Using the fiber optic connection between the STAR Lab and the Traffic System Management Center (TSMC), the research team can find a good testing location on I-5. This position should represent typical traffic flow conditions on freeways. Another test location should be from the Evergreen Point Bridge on SR-520. The reason to choose this site is to evaluate the performance of the video systems when using images from vibrating video cameras. This is an important feature to test because many video cameras vibrate to certain degree due to wind or dynamic infrastructure loading.

4.2 Step 2 – Data Collection

At least 10 minutes of video data will be collected at each test site. These video data should cover different traffic flow, shadow, occlusion, and weather conditions. All these data should be recorded on high quality videotape.

4.3 Step 3 - Test of the Citilog MediaTD System and the VVDC System

Since the WSDOT is interested to do a side-by-side comparison between the Citilog MediaTD system and the VVDC system, we will conduct parallel tests simultaneously for the two systems. Vehicle detection results will be logged and video recorded for analysis in Step 4.

4.4 Step 4 – Comparison of the Two Systems

Each scenario will be manually counted and counted by both systems. Analyses will be conducted to compare the detection results from the two systems and determine their error modes. The accuracy of each system will be described in terms of count and absolute error. Error-prone conditions, if any, for the two systems will be identified.

5. System Tests

5.1 Test Sites

The three locations that were chosen for this study were the SR-520 Midspan camera, the I-5 45th Street camera, and the Stevens Way camera setup on top of More

Hall at the University of Washington. Figures 1 through 3 show a snapshot for each of the three test locations.

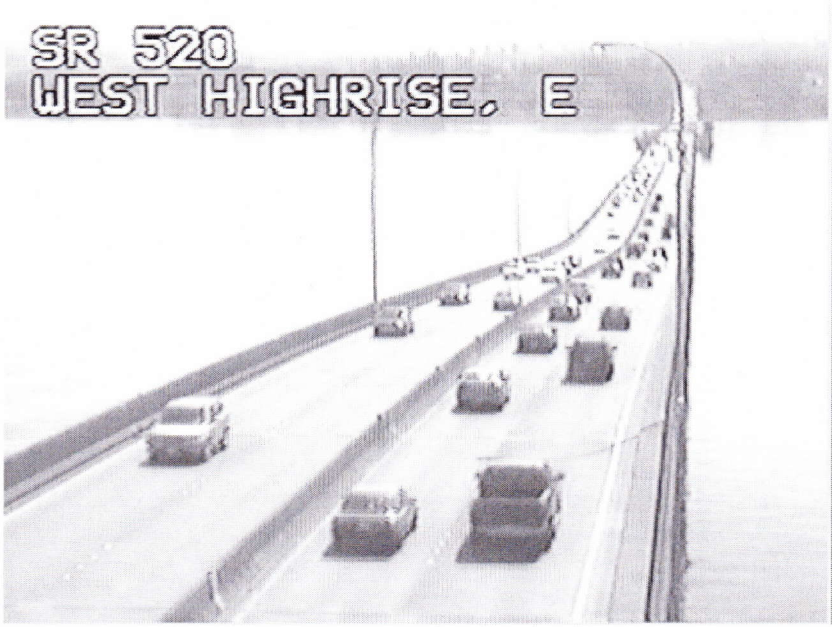

Figure 1 A Snapshot of Test Location of the SR-520 Midspan

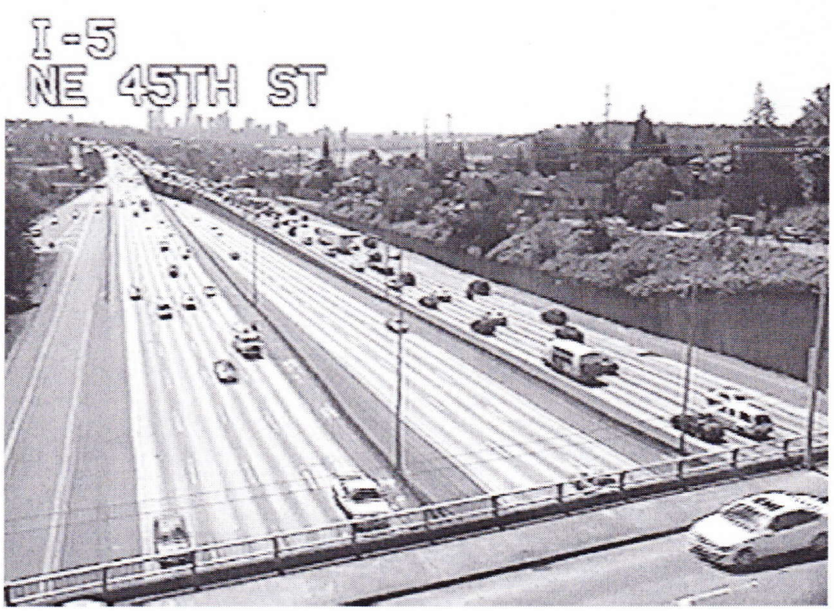

Figure 2 A Snapshot of Test Location of the I-5 45th Street

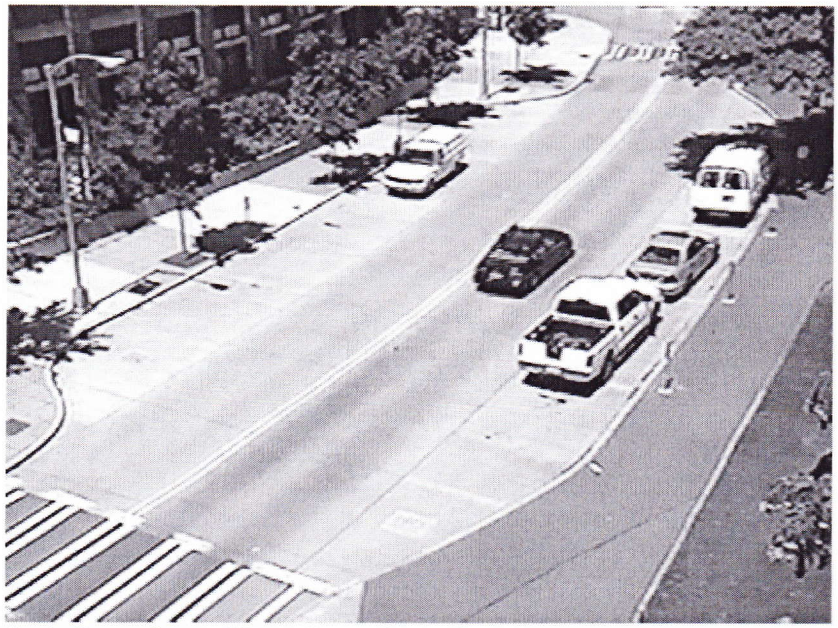

Figure 3 A Snapshot of Test Location of the Stevens Way, UW Campus

The SR-520 Midspan location was chosen for several reasons. This view provides a good test site for vibration and shaking of the camera, testing of a bridge situation, and weather and lighting conditions. The I-5 45th Street camera provided the opportunity to test for a typical heavily congested highway situation as well as allowing for testing of a multilane highway. The Stevens Way location allowed for testing a very controlled, low volume of traffic situation. Another major advantage for using this location was the ability to directly control the camera's pan-tilt-zoom functions at the STAR Lab.

5.2 Test Scenarios

It was decided that it would be advantageous to test each of the systems under different weather, lighting, and angle conditions to determine the accuracy of the systems as a function of these variables. Most situations cannot always be ideal because the camera infrastructure is fixed and costly to expand or upgrade. Rain, wind, daylight, nighttime, day-night transition times, and various angles are all important for testing the systems against. Most video detection systems have serious trouble operating under nighttime conditions because of the camera's interpretation of the headlights and the lack of background reference for lanes and roadway. It is known that the current version (1.0) of the VVDC system works only in day-time. Research on the VVDC system is continuing at the STAR Lab to make it capable of night-time detection.

The evaluation scenarios that were determined to be best suited for testing the Citilog and VVDC systems against were rain, vibration, and heavy versus light traffic situations. Angle conditions are essentially fixed based on the lack of control of the camera infrastructure for the testing, except for the Stevens Way camera, which is under the direct control of the University of Washington's STAR Lab. In the event that further research is indicated the day-night transition and nighttime operating conditions are prime fields for study.

Six test scenarios were selected. Each scenario contains 15 minutes of test video. At total of 90 minutes of video data were extracted from the collected video data and used for testing the two systems. The six test scenarios are:

(1) Stevens Way Regular Condition
(2) State Route (SR) 520 Sunny Condition
(3) SR-520 Shaky Condition
(4) SR-520 Rainy Condition
(5) Interstate 5 (I-5) at NE 45th Street Open Traffic Condition
(6) I-5 at 45th Street Congested Traffic Condition

5.3 Test System Configuration

To guarantee the best performance of each system, the MediaRT system was remotely configured by technicians at Citilog through the Internet for each test locations. The VVDC system was configured by the research team at the STAR Lab.

The screenshots below show the interface and example configuration of each video detection system. Figure 4 is a screenshot of the VVDC system. Figure 5 is a screenshot of the MediaRT system.

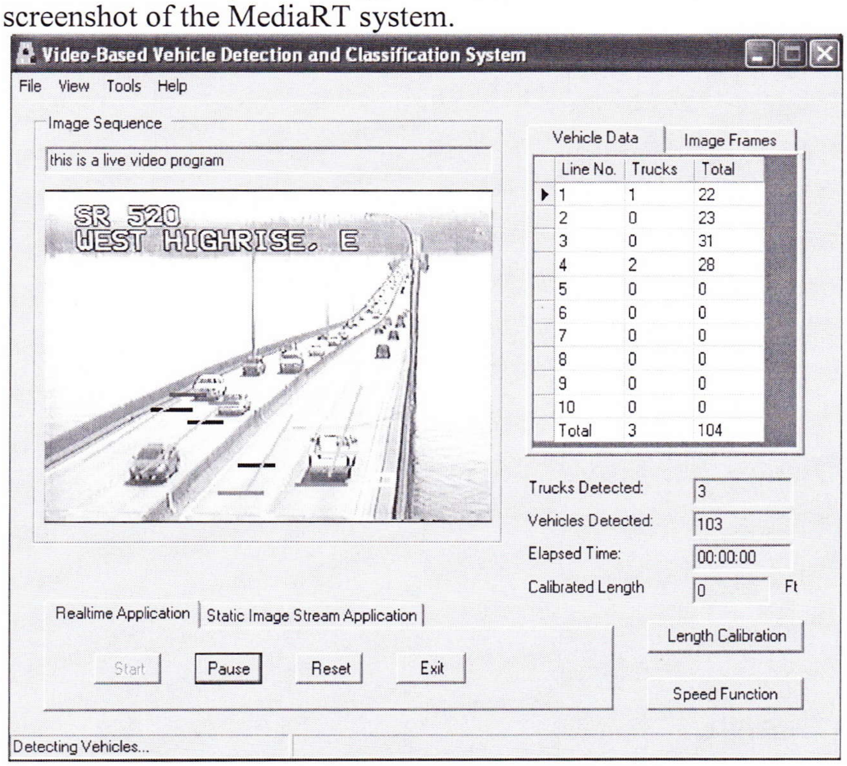

Figure 4 VVDC Interface

The two video-based detection systems were tested using exactly the same sets of data.

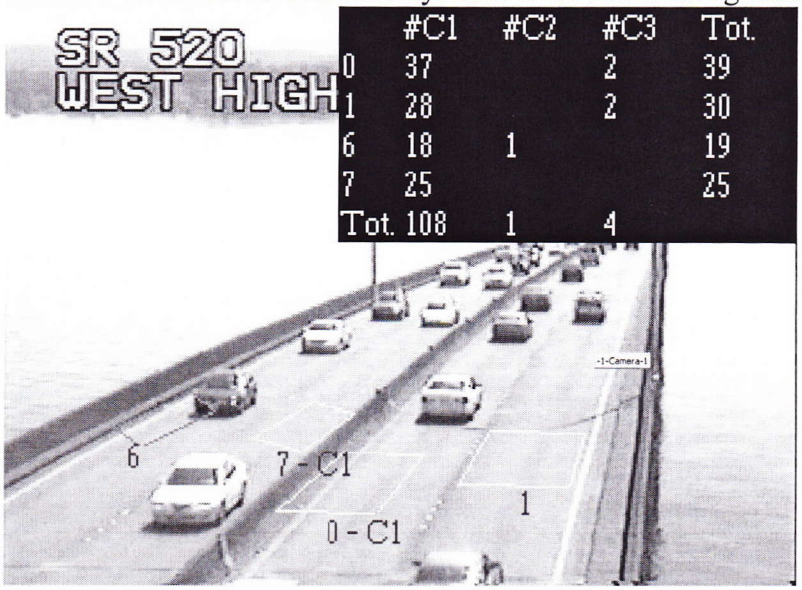

Figure 5 MediaTD Analysis Screen

6. Test Results

Below are the tables that were obtained from examinations of the three locations chosen for this evaluation. Data presented in the tables include outputs from the VVDC system, the MediaRT system, and a manual count for each of the locations. The manual count was done to provide a baseline for the other data. Table 1 presents the test results for the VVDC system for each test location. Table 2 shows the test results for the MediaRT video detection system. Test experiments under challenging environmental conditions including, severe camera vibrations, rainy lighting reflection, serious congestion, and transient light changes, are conducted for the SR-520 and I-5 test sites, and the results are illustrated in both tables. Additionally, to facilitate the comparisons, an error item is defined as absolute errors of misclassification and miscounts divided by the ground-truth data.

Table 1 Test Results for the VVDC System

		Ground Truth		VVDC								Error	
				Truck				Volumes					
Location	Lane	Trucks	Total	Count	Over Class	Under Class	Total Error	Count	False	Missed	Volume Error	Total	Percentage
Stevens Way Right Lane #1 right to left	1	3	35	3	+0	-0	0	35	+0	-0	0	0	0%
	2	2	38	2	+0	-0	0	38	+0	-0	0	0	0%
State Route 520 Sunny Condition Lanes numbered right to left	1	3	352	3	+2	-2	4	352	+3	-3	6	10	3%
	2	1	436	8	+7	-0	7	430	+1	-7	8	15	3%
	3	1	354	10	+9	-0	9	345	+0	-9	9	18	5%
	4	2	375	16	+14	-0	14	368	+0	-7	7	21	6%
State Route 520 Shaky Condition Lanes numbered right to left	1	22	355	19	+1	-5	6	349	0	-6	6	12	3%
	2	7	436	11	+4	-0	4	442	+6	-0	6	10	2%
	3	1	435	16	+15	-0	15	431	0	-4	4	19	4%
	4	13	382	13	+2	-2	4	402	+20	-0	20	24	6%
State Route 520 Rainy Condition Lanes numbered right to left	1	12	331	19	+7	-0	7	323	+2	-10	12	19	6%
	2	10	380	4	+0	-6	6	363	+0	-17	17	23	6%
	3	3	346	47	+44	-0	44	334	+0	-12	12	56	16%
	4	19	339	119	+100	-0	100	339	+3	-3	6	106	31%
Interstate 5 45th Street Open Traffic Lanes numbered outside to inside	1	15	180	NA[1]	NA	NA	NA	179	+4	-5	9	NA	5%
	2	31	324	NA	NA	NA	NA	321	+6	-9	15	NA	5%
	3	38	339	NA	NA	NA	NA	345	+10	-4	14	NA	4%
	4	14	294	NA	NA	NA	NA	303	+12	-3	15	NA	5%
Interstate 5 45th Street Congested Traffic Lanes numbered outside to inside	1	5	263	NA	NA	NA	NA	329	+66	-0	66	NA	25%
	2	5	300	NA	NA	NA	NA	367	+67	-0	67	NA	22%
	3	18	317	NA	NA	NA	NA	366	+49	-0	49	NA	15%
	4	9	349	NA	NA	NA	NA	389	+40	-0	40	NA	11%

[1]Not Applicable (NA) to I5 & 45th St.

Table 2 Test Results for the Citilog System

		Ground Truth				Citilog Results			Errors							
Location	Lane	Trucks (C3)	Trucks (C2+C3)	Cars (C1)	Total	Trucks (C2+C3)	Cars (C1)	Total	Under Class	Over Class	Combined Count	Multiple Count	False Count	Missed Count	Total	Percent
Stevens Way	1	3	4	31	35	1	34	35	3	0	0	0	0	2	5	14%
	2	2	4	34	38	2	38	40	4	0	1	0	0	0	5	13%
State Route 520 Sunny Condition	1	2	3	349	352	24	303	327	0	2	20	0	0	21	43	12%
	2	0	1	435	436	30	372	402	0	0	29	0	0	31	60	14%
	3	1	1	353	354	24	302	326	0	0	24	0	0	25	49	14%
	4	1	2	373	375	25	319	344	0	0	24	0	0	27	51	14%
State Route 520 Shaky Condition	1	13	29	326	355	54	281	335	1	9	18	0	0	18	46	13%
	2	3	7	429	436	24	416	440	0	2	15	0	11	17	45	10%
	3	1	1	434	435	34	360	394	0	0	33	0	0	36	69	16%
	4	6	13	369	382	39	381	420	4	0	18	0	45	20	87	23%
State Route 520 Rainy Condition	1	5	12	319	331	41	263	304	0	11	22	0	0	20	53	16%
	2	2	10	370	380	38	320	358	0	12	18	0	0	22	52	14%
	3	1	3	343	346	47	282	329	0	15	27	0	25	30	97	28%
	4	7	19	320	339	32	284	316	2	1	13	0	3	16	35	10%
I5 & 45th Street Open Traffic	1	6	15	165	180	NA	NA	210	NA	NA	NA	20	0	1	21	12%
	2	13	31	293	324	NA	NA	401	NA	NA	NA	65	0	2	67	21%
	3	24	38	301	339	NA	NA	424	NA	NA	NA	58	0	0	58	17%
	4	1	14	280	294	NA	NA	312	NA	NA	NA	15	0	0	15	5%
I5 & 45th Street Congested Traffic	1	2	5	258	263	NA	NA	449	NA	NA	NA	187	0	1	188	71%
	2	1	5	295	300	NA	NA	608	NA	NA	NA	309	0	1	310	103%
	3	11	18	299	317	NA	NA	452	NA	NA	NA	166	0	31	197	62%
	4	4	9	340	349	NA	NA	646	NA	NA	NA	300	0	3	303	87%

Definitions:

Under Class - A long vehicle (C3 or C2) counted as a shorter vehicle. C3's counting as C2's ignored for State Route 520 and Not Applicable (NA) to I5 & 45th St.

Over Class - A short vehicle (C1) counted as a longer vehicle. C2's counting as C3's ignored for State Route 520 and Not Applicable to I5 at 45th Street.

Combination - Two or more vehicles counted together as a longer vehicle. The first vehicle is a combination error and subsequent vehicles are considered Missed

Multiple - A single vehicle counted more than once.

False - A count generated with no vehicle in the detection zone.

Missed - No count generated when a vehicle is in the detection zone.

7. Analysis and Discussion

There were significant differences between each system for the data collected. Occlusion seemed to heavily influence the results in some cases and not as much in others. The camera angles and the distances to the roadway also played major parts in the ability of each system to collect data from their respective mask schemes. Another concern is mask placement to avoid multiple counts and occlusion. Each of these may have contributed to the large range in results found in the data presented above.

Another complicating factor for analysis is that the two systems use different classification schemes. The VVDC system classifies vehicles as short or long vehicles based on a user specified length threshold and MediaTD classifies vehicles into classes 1, 2 and 3. For the purposes of this test, a VVDC system classified long vehicle and a MediaRT class 3 vehicle are equivalent to a full size bus or a semi truck with a full size trailer.

For the Stevens Way test (scenario 1) both systems performed adequately with VVDC scoring perfectly on count totals and catching all of the buses as long vehicles. For MediaTD the count totals are near perfect but would both be slightly over counted if the missed counts were included. The discrepancy comes from some bicyclists and pedestrians that were counted. Due to the low number of vehicles on the Stevens Way, percent error is misleading with each error being equivalent to approximately three percent error rather than the fraction of a percent each error represents in subsequent tests.

SR-520 (scenarios 2, 3, and 4) presented greater challenges to both systems with the shaking camera, shifting lighting and rain. For all tests the farthest lane (lane 4) on both systems showed a propensity to over count trucks. This is due to two major factors, occlusion by trucks in the neighboring lane and overlapping cars from the two lanes. One car in the outer lane drives through the sensing region and triggers a count but a car trailing slightly in the adjacent lane protrudes slightly in to the sensing region as well causing it to be registered as a longer vehicle. The protruding vehicle would not normally be enough to be counted but is sufficient to maintain a count that results in severe over-counting problems.

For the sunny condition tested as a baseline condition on SR-520, both systems performed their best for the SR-520 tests. The VVDC system had total errors of three to six percent. MediaTD's errors were almost totally in the form of combined counts, counting two or more cars as a truck. They comprised nearly all of the errors for this scenario (scenario 2). Overall MediaTD had twelve to fourteen percent error for the scenario.

The shaking scenario on SR-520 (scenario 3) caused both systems to have greater errors. The second and fourth lanes that had their sensor regions laid out in such a way that they rested on the dividing barrier and outer barrier of the road had greater error.

These two lanes had greater errors because the shaking of the camera would cause the sensor regions to cross and recross the divide between barrier and road. For MediaTD nearly half the error in those two lanes was due to false counts generated by the shaking. Otherwise the errors were consistent with the sunny results, with the vast majority of error coming from combined counts. VVDC had less of a problem with the shaking but it was still pronounced. In general, the reliability of the data was compromised for both systems when the camera started shaking excessively.

When heavy rain (Scenario 4) started to fall on SR-520, the plumes kicked up by the tires made small vehicles register as larger vehicles by making them appear longer. Adjacent lanes occasionally registered counts as vehicles passing in the adjacent lanes kicked out wider plumes. VVDC's long vehicle discrimination suffered greatly in the rain with one lane recording approximately one hundred false trucks. The other lanes were not as bad with forty-four, seven and zero extra trucks. MediaTD had problems with the rain but not on the same scale with long vehicle counts inflated by ten to fifteen and the usual combination counts. One lane had twenty-five false counts. The data quality suffers for both systems when heavy rain begins to fall.

MediaTD has two modes of counting, one for free flow that was tested on Stevens Way and SR-520 and one for congested urban traffic. The testing on I-5 at NE 45th Street (scenarios 5 and 6) was conducted to evaluate urban mode's accuracy. Urban mode does not classify vehicles it simply counts them and is intended for use during congested conditions that render the free flow mode useless due to the combination problem. The VVDC system has only one mode and was operated the same for these tests as in previous tests. For comparison purposes only the total VVDC counts will be used here. First the test was run with open free flowing traffic (scenario 5) as a baseline for comparing against the congested stop and go traffic (scenario 6) of the next test. MediaTD recorded errors of five to twenty-one percent in the open condition versus approximately five percent for the VVDC system. A common error for MediaTD was to register two to four counts for each large vehicle.

The congested condition at the NE 45th Street really challenged the two systems. MediaTD recorded from half again to double the actual number of vehicles passing in each lane. VVDC did better but still had an unacceptably high error rate. This scenario defeated both systems.

8. Conclusions

In this study, a side-by-side evaluation of Citilog's MediaTD video detection system and the VVDC system was conducted. To sufficiently examine the practicality and robustness of both systems, six representative test scenarios were employed. These test scenarios included challenging video detection situations, such as transient light changes, slight camera vibrations, serious light reflection, and severe congestion.

Test results indicate that both systems worked well under certain test conditions but resulted in significant errors under some challenging test conditions. Overall the VVDC system did better under congested conditions and had a better open flow classification rate, but suffers more from adverse weather. MediaTD has better weather tolerance, but the combination problem weighs it down. Some of the problems could be alleviated by better, more stable, camera positions. Better in this case meaning high and as square to traffic flow as possible, probably with one camera centered on every two or three lanes so that occlusion would be minimized. However, the implementation of such projects is beyond the scope of this report.

This study concludes that the VVDC system performed better than the MediaTD system in most of the selected test scenarios. However, since the test scenarios were very limited, the comparison results of this study may not be general enough to apply to other locations and roadway conditions.

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