TRAFFIC PARAMETERS EVALUATION
OF
VIDEO VEHICLE DETECTOR UNDER SNOW CONDITION

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1. Abstract

Along with the development of road traffic systems, video vehicle detectors that can gather various traffic conditions are much expected recently. However, conventional gray-scale based video detectors do not work well under adverse conditions such as shadows, rainy nights, twilight and congestion. To solve this problem, we have developed a stereo-based video vehicle detector [1][2], and its superb vehicle detection accuracy has been confirmed by various field tests [5]. The focus here is to evaluate the performances of our video vehicle detector under snow condition. It is very difficult to preserve stable performances during periods of snowfall for conventional video detectors [3]. We ran field tests under snow condition, and have ascertained the excellent performance of the stereo-based our video vehicle detector.

2. Introduction

For the realization of Intelligent Transportation Systems (ITS), their input devices for gathering various traffic data play a pivotal role and it is necessary to detect each individual vehicle accurately. Inductive loop detectors (ILDs) are widely used in most traffic control systems such as SCOOT, SCAT, UTOPIA, etc. because of their simple concept and high accuracy. However, ILDs need to be installed under the surface of the road, which leads to high installation and maintenance cost and they are vulnerability to damage during road construction. Video vehicle detectors, on the other hand, are not subject to these problems. Furthermore, they have many advantages over other detectors:

- Multiple lane surveillance by one video vehicle detector;
- Collection of far richer information including vehicle presence, traffic volume, occupancy, vehicle speed, classification, queue length, etc.;
- Availability of visual traffic surveillance on TV monitor.

In the above mentioned, collection of vehicle speed is very useful advantage. It is good for supplying the traffic conditions (e.g. smooth/congestion/jam) to drivers in the ITS industry.

Therefore, video detectors have become widely adopted, as the best alternatives to ILDs and some of them have been available commercially from several years ago. For most conventional video detectors, “Background Difference”, “Frame Difference” and “Space Difference” are typical image processing approaches for detecting vehicles. These approaches are essentially based on a subtraction of gray levels on video image. However, it is very difficult to define a vehicle by its gray level. Because the gray level changes with different operating conditions including weather conditions (clouds, rain, snow etc.) and environmental conditions (twilight, shadow, overlapping, light reflection etc.), which leads to unstable performances of the video detectors [3]. In order to solve this problem, we turned our attentions to stereo approaches, and developed an effective video vehicle detector our video vehicle detector[2]. Our video vehicle detector detects vehicles from their three-dimensional (3-D) information, which can hardly be affected by the changes in the weather and environmental conditions. The high performance of our video vehicle detector has been verified under adverse conditions such as “shadow”, “overlapping”, “low contrast” and “light reflection” in the field tests [5].

The object of this study is to widen the application of video detector to frigid region. Though more detailed evaluations under snow condition are necessary in applying video detector to frigid region, few studies on its performances under snow condition have been conducted. Here we attempted to evaluate our video vehicle detector under snow condition. Generally, video detectors suffer from the effects of snow, which may deteriorate its ability of detecting vehicles. Some negative effects predicted are listed as follows:

- Noises of snowfalls in input video image.
- Low contrast between white colored cars and road covered with snow.
- Poor visibility caused by snow adhered to camera windows.

These are difficult problems for vehicle detection. Our video vehicle detector, however, is supposed to have great possibilities of detecting vehicles accurately even under snow condition because of its robustness against the changes of environmental conditions.

In our study, in order to apply our video vehicle detector to snow conditions, we made some improvements only on its hardware configuration and evaluated its ability of detecting vehicles under snow condition in field tests. First we will describe the detection algorithm of our video vehicle detector briefly and then show the results of the field tests, and finally conclude this paper.

3. Silhouette Vision

Different from most conventional gray level based video detectors, our video vehicle detector detects each individual vehicle using the 3-D information of its shape. In our video vehicle detector, a stereo camera is used to obtain the 3-D information. The stereo camera consists of a pair of vertically displaced cameras, and the axes of these two cameras are adjusted to parallel. On the basis of the principle of the triangle measurement, the 3-D coordinates of each feature point on video image can be calculated. In our video vehicle detector, not all the 3-D data, only the smallest necessary quantity is used to detect vehicles. We found that the side silhouette of a vehicle represents the smallest necessary quantity, which is an essential characteristic of a vehicle, and a vehicle can be easily detected or recognized by vehicle's side silhouette model matching. A vehicle's side silhouette can be obtained through a simple side coordinates projection of 3-D data.

Therefore, with our video vehicle detector described above, vehicles can be detected accurately in real time, despite the changes of environmental conditions.

4. Countermeasures for snow condition

During periods of winter, it is necessary to solve the following problems, which occur frequently. Those problems are, for examples, noises of snowfalls in input image, snow accumulating which alters the pattern of the road surface severely, snow adhered to camera windows leading to a poor visibility and vehicle detection difficulty, extremely cold temperature, etc. In our video vehicle detector, in order to overcome these problems, some improvements have been made only on its hardware configuration. The shutter speed of the stereo camera is controlled automatically in real time in order to obtain input images that are most suitable for vehicle detection. Furthermore, heater glass is adopted for windows of the stereo camera to prevent snow adhering to them and a heater installed in the camera unit. As for its algorism for detecting vehicles that is robust against the changes of environmental conditions, we have made no other improvements on it for this study.

5. Field test

The field test site was selected on a two-lane road in Sapporo city, Japan. Figure 1 is a video image at the field test site. The stereo-camera is mounted on a pole, 1.5 meters aside from the roadside, at a height of about 6 meters above the ground. Figure 2 shows the stereo-camera unit at the field test site. The parameters of the stereo-camera unit are as follows.

- Focus length of lenses: 6.86[mm].
- Base length of the stereo-camera: 500[mm].
- Install direction of stereo-camera: Vertical.

Figure 1 Test Site **Figure 2 Stereo Camera Unit**

6. Evaluation

We picked some conditions as follows:

- Clouds without snowfalls (daytime, twilight, night).
- Medium snowfalls of 2cm/h (twilight)
- Heavy snowfalls of 6 cm/h (daytime).
- Snowstorm of 2 cm/h with a strong wind (daytime).

We evaluated traffic volume data of two lanes in every 5 minutes interval and individual vehicle speed as the output of the video detection system. The baseline volume data were collected by counting manually. The baseline speed data were collected from measuring positions of a vehicle every video frame on TV monitor. True counts and true speed are plotted on the horizontal axis, and our video vehicle detector's counts and speed are plotted on the vertical axis. On traffic volume and speed scatter plots, a linear 45-degree line represents accurate vehicle detection.

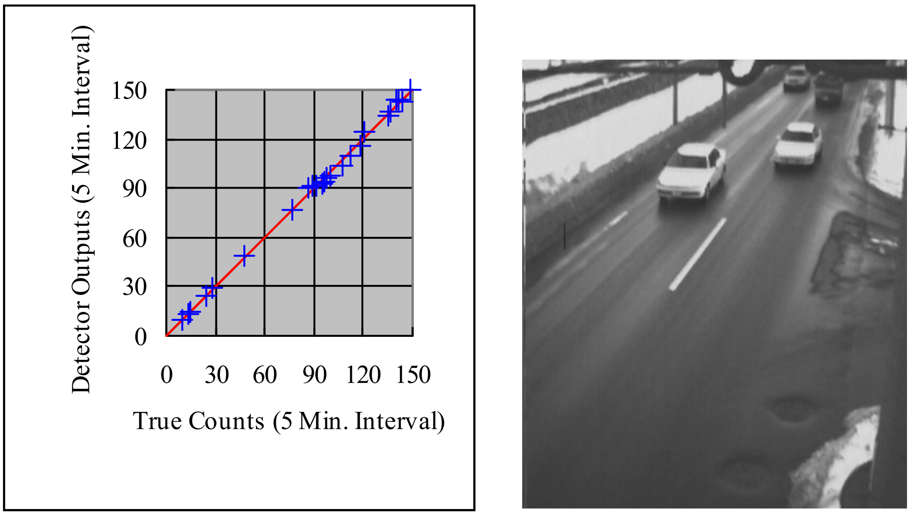
- VOLUME -

Figures 3(a)-(d) shows the test results with a sample image obtained in clouds without snowfalls, medium snowfalls, heavy snowfalls, snowstorm, respectively.

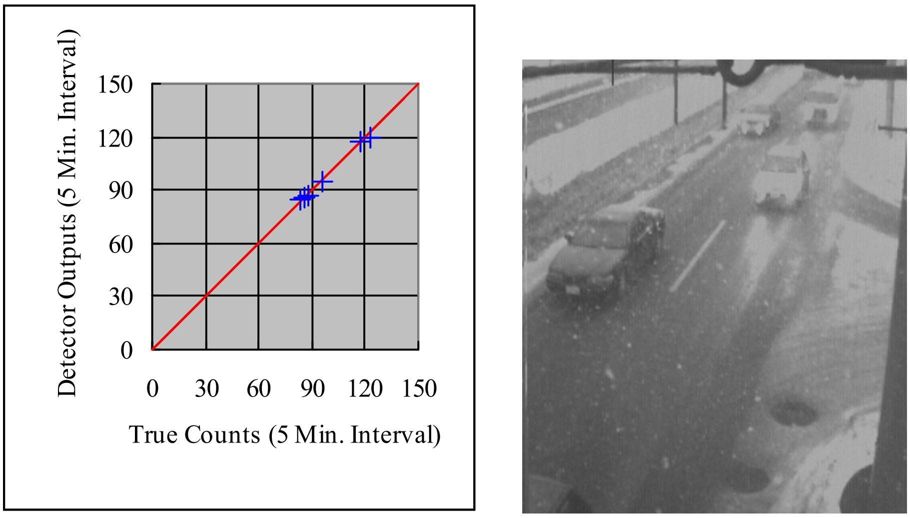
The results may be summarized as follows:

- Under cloudy conditions without snowfalls, the average of vehicle detection accuracy was 98.5%.
- Under medium snowfalls condition, the average of vehicle detection accuracy was 98.8%. We obtained as excellent vehicle accuracy under this medium snowfalls condition as that under cloudy condition without snowfalls.

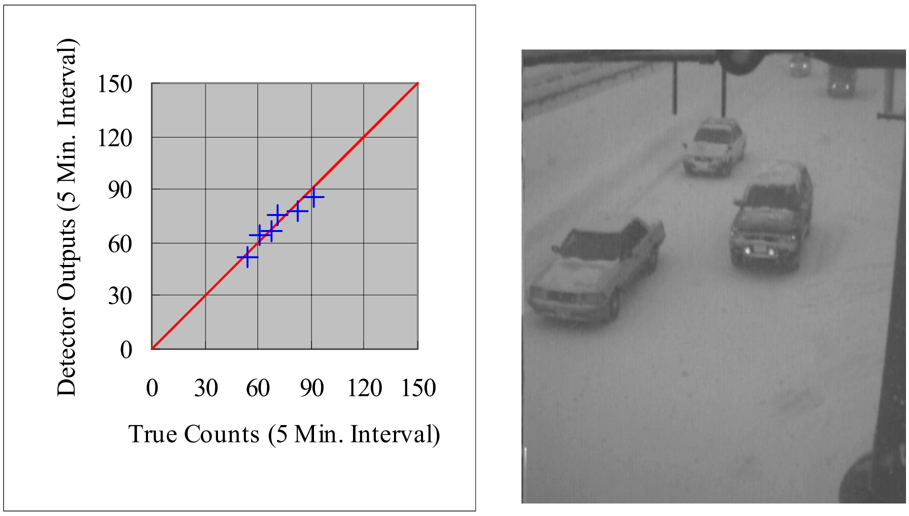
- Under heavy snowfalls condition, the average of vehicle detection accuracy was 95.2% and found to be a little lowered.
- Under snowstorm condition, the average of vehicle detection accuracy fell to 89.0%.



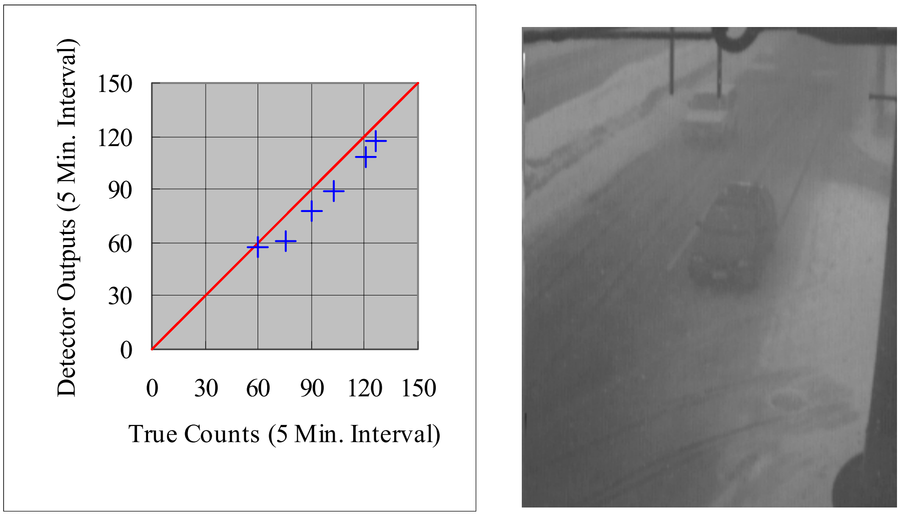
(a) Clouds without snowfalls(daytime, twilight, night)



(b) Medium snowfalls(twilight)



(c) Heavy snowfalls (daytime)



(d) Snowstorm(daytime)

Figure 3 Traffic Volume Scatter Plots

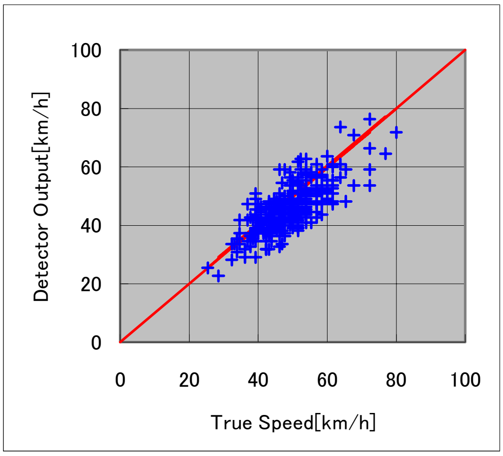
- SPEED -

Figures 4(a)-(c) shows the test results.

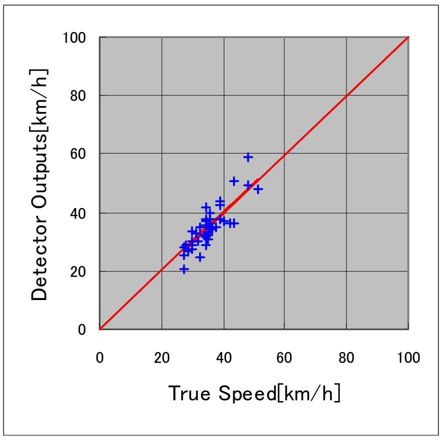
The results may be summarized as follows:

- Under cloudy conditions without snowfalls, vehicle speed measurement accuracy was 88.9%.
- Under heavy snowfalls condition, vehicle speed measurement accuracy was 89.6%.
- Under snowstorm condition, vehicle speed measurement accuracy was 87.5% and found to be a little lowered.

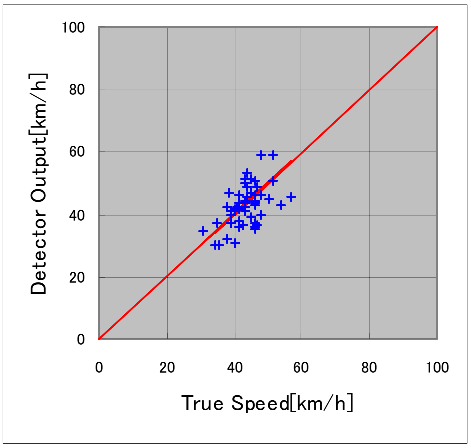
We obtained as excellent vehicle speed measurement accuracy under this heavy snowfalls and snowstorm condition as that under cloudy condition without snowfalls.



(a) Clouds Without Snowfalls (Daytime)



(b) Heavy Snowfalls (Daytime)



(b) Snowstorm (Daytime)

Figure 4 Individual Vehicle Speed Scatter Plots

7. Discussion

In this field test, under medium snowfalls and even heavy snowfalls, we obtained excellent vehicle detection accuracy comparable to those under cloudy conditions without snowfalls. These results have demonstrated that our video vehicle detector can be applicable to snow conditions. Under such snowstorm as we experienced, however, the huge amount of snowfall in input images extremely deteriorated the visibility of the video images, which resulted in vehicle detection difficulty and the lowered performances of our video vehicle detector. When the visibility is extremely worsened under such condition as snowstorm, a warning function that strengthens the reliability of video vehicle detector' output must be take into consideration.

On the other hand, under heavy snowfalls and even snowstorm, we obtained excellent vehicle speed accuracy comparable to those under cloudy conditions without snowfalls. These results have also demonstrated that our video vehicle detector can be applicable to snow conditions.

Satisfactory results of vehicle detection and speed have been observed during snowfalls and snow accumulated on the road surface. We have confirmed that our video vehicle detector can be applicable to the frigid regions where snow falls frequently in winter.

8. Future work

In the future, a warning function will be added to our video vehicle detector when it cannot detect vehicles normally under the extremely severe conditions, which prevent the performance of the whole system from being affected seriously.
Furthermore, there is often that a traffic lane of a vehicle is different from a traffic lane of the summer by the snow of the roadside in the winter season. At such a time, the difference causes an error with vehicle detection performance on the basis of a traffic lane of the summer. We will develop the algorithm that traffic volume with the all traffic lanes can measure because tracking does a traveling position of an individual vehicle in also a crossing direction of a road as a reduction of this error. Besides, we will develop the similar algorithm that can measure traffic volume every traffic lane, which met a traffic lane of the changing winter season, because tracking does a traveling position of an individual vehicle in also a crossing direction of a road. In addition, this algorithm leads to improvement of a vehicle measurement error at a lane changing of a vehicle.

9. Conclusion

In order to apply our video vehicle detector to snow conditions, we made some improvements only on its hardware configuration. Its high performances of vehicle detection and its speed measurement under various snow conditions have been verified in the field tests. Our video vehicle detector, the stereo-based video vehicle detector, which detects each individual vehicle accurately, can provide a wide variety of traffic data even in winter. We are confident that our video vehicle detector will be of benefit to the development of ITS.

10. References

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