STUDY ON TRAFFIC FLOW MEASUREMENT BASED ON LOW ALTITUDE REMOTE SENSING

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ABSTRACT

This research involves the low-altitude remote sensing technique using a high-mobility platform with the purpose of resolving traffic congestion and tracking down the causes of traffic accidents that have constantly occurred everywhere in the country. A fundamental study was conducted on the sequential image analysis for automatic measurement of traffic flow. Also, a simplified measurement system mainly consisting of a personal computer and an image processing board was prototyped. Furthermore, an ordinary road with much traffic volume was selected as traffic survey target. The traffic flow on the road was observed for each time of day to see how the remote sensing approach actually works, particularly in terms of applicability and versatility.

As a result, it has been recognized that the combined use of the low-altitude remote sensing and sequential image analysis approaches allows traffic census using the PC-based simplified measurement system, although measurements would be affected to some extent by solar radiation or vehicle color.

1. INTRODUCTION

In recent years, more than 90 percent of the Japanese households own their private car and the total number of cars in this country has exceeded 10 million. With this movement, the traffic volume in the general roads and expressways has increased to cause constant traffic congestion. The annual number of traffic accidents is as many as approximately 780,000 cases and about 10,000 citizens are killed in traffic accidents every year. These facts imply that Japan is one of the countries where traffic accidents most frequently occur. It is urgently required to track down the causes of traffic accidents and to resolve the constant traffic congestion.

The traffic flow measurement technology has evolved mainly focused on macroscopic observation and measuring of traffic volume or density. Another recent movement is the use of a traffic system making use of information technology such as

Intelligent Transport System (ITS). Based on the leading-edge communication technology, people, road and vehicle information is integrated through a network system to be used to resolve various traffic issues typified by traffic congestion or accidents.

However, establishing such a macroscopic observation or transport system such as ITS is not enough to resolve traffic congestion and identify the causes of traffic accidents. It is also mandatory to grasp microscopic traffic conditions including behavior of individual vehicles. To meet this challenge, two-dimensional traffic measurement technology is on its way to becoming available. The technology uses image sensors (video cameras) to collect traffic data, which will be used for 2-dimensional analysis of traffic conditions.

Under the situation, this research involves the low-altitude remote sensing technique using a high-mobility platform with the purpose of resolving traffic congestion and tracking down the causes of traffic accidents that have constantly occurred everywhere in the country. A fundamental study was conducted on the sequential image analysis for automatic measurement of traffic flow. Also, a simplified measurement system mainly consisting of personal computer and image processing board was prototyped. Furthermore, an ordinary road with much traffic volume was selected as the traffic survey target. The traffic flow on the road was monitored in different time periods of day to see how the remote sensing approach actually works, particularly in terms of applicability and versatility.

This research was conducted commissioned by Chugoku Technical Center, Ministry of Construction, Japan.

2. EQUIPMENT USED

2.1 Platform

To video and measure traffic flow using television cameras in order to resolve traffic congestion and track down the causes of traffic accidents that constantly occur everywhere in the country, the following points should be taken into account:

(i)Mobility: The platform should be able to be moved right away to anywhere in which an accident has occurred all over the country.

(ii) Operability: Video image should be able to be shot only through easy operation.

(iii) Flexible monitoring: Monitoring should be possible with wide angles. It is favorable to establish a monitoring frame at a high level from which objects underneath can be directly seen.

(iv) Stable image: Monitoring should be able to be made with a

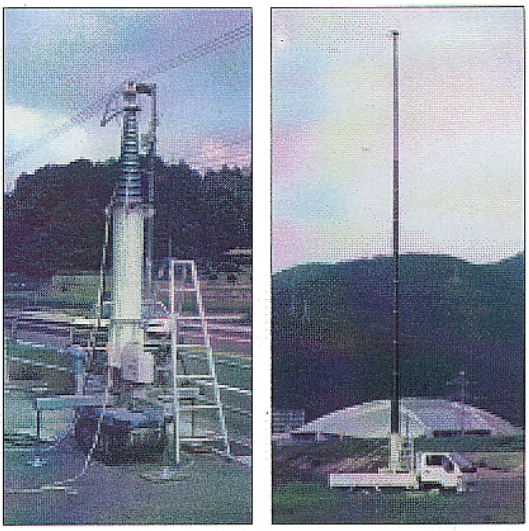


Figure 1. Appearance of elastic pole

constant angle of view. Producing images with a same angle will make the following analysis easier.

The platform for the low-altitude remote sensing system could be helicopter (flying at low altitudes), balloon, existing ground structure (e.g., building), or elastic pole. When taking the points listed above into account, balloon and elastic pole are the most potential monitoring platforms in terms of availability. Table 1 shows the result of relative evaluation of these two platform candidates according to the key points listed above:

Table 1. Evaluation of platform candidates in this research for applicability

Item	Mobility	Operability	Flexibility	Stability	Total evaluation
Balloon	○	△	○	△	△
Elastic pole	○	○	△	○	○

According to the total evaluation, elastic pole is more applicable. This research uses elastic poles as the platforms for its experimental observation accordingly. Figure 1 shows the appearance of elastic pole.

2.2 Analyzing system

Table 2 shows the analyzing system that was used for automatic measurement. Based on the premise that the system will be used in each work office of the Ministry of Construction, a compact system mainly consisting of personal computer that can easily be operated and maintained was used in this research.

Table 2. Analyzing system

Item	Equipment
Personal Computer	DELL Computer, XPS 266
Image Processing Board	HITACHI, IP-5000
Program	Microsoft, Visual C++
Digital Time Base Corrector	FOR.A, FA-310
Video	SONY, WV-SW1
Display Monitor	SONY, PVM-14N2J

3. SEQUENTIAL IMAGE ANALYSIS

Next, we studied use of the sequential image analysis for measuring traffic flow. Several approaches could be introduced to perform analysis of sequential images, including image correlation technique. Since this research involves the measurement system mainly relying on personal computer installed in the work offices at site as stated above, calculation volume necessary for analysis, development costs and general versatility were particularly taken into account to evaluate various approaches. Table 3 shows the result of the approach evaluation.

Table 3. Evaluation of sequential image analysis approaches for this research

Item	Calculation volume	Costs	General versatility	Total evaluation
Image correlation method	○	△	○	○
Optical flow method	△	△	◎	△
Edge detection method	○	○	○	○
Spatio-temporal method	◎	◎	○	◎
Differential method	○	◎	◎	◎

In overall consideration of the evaluation result, we determined to use Spatio-temporal Image Method and Differential Image Method.

4. EXPERIMENTAL OBSERVATION

A prefectural road named "Hiroshima Kaita Line" adjacent to Chugoku Technical Center, Ministry of Construction, located at Funakoshi-Minami, Aki-ku, Hiroshima, was selected as the experimental observation point. The "Hiroshima Kaita Line" is one of the main roads that come from the eastern part of Hiroshima City and lead to the center of the city. In this road, traffic is constantly heavy and traffic jam always occurs during commuting hours. The target observation point is the road section having only one lane of traffic in each direction. Still, the lane extends straight quite a long distance and the road width is wide: the distance between the sideline and the edge of the pavement is rather long. So, four-wheeled vehicles as well as motorbikes are likely to run with high speeds. In addition, some of the junctions along the road have no traffic signals. With these conditions, this road may be rated as an accident-prone place. In this experimental observation activity, elastic poles were installed on a side of one of the road junctions and extended to the maximum height (altitude: approximately 20m) to continuously monitor the road condition underneath for about an hour in the morning, afternoon and evening times each. From the image data continuously collected, a given section for 10 minutes was taken in each monitoring session to measure vehicle speed, length, trail and other factors. Figure 2 shows an example of the images collected in the target experimental observation area. Eight ground control points were provided in the target experimental observation area. An elastic pole was installed in each of the points to be equipped with a television camera on its top. Besides the video shooting, measurement was carried out referring to a three-dimensional coordinate system so as to allow conversion of image data into actual lengths by making use of the coordinate system.

Figure 2. Example of observation image

5. ANALYSIS METHOD AND RESULT

5.1 Vehicle speed and length and distance between two cars

In order to reduce the sequential image data volume and raise the calculation processing speed, spatio-temporal image processing with color image data was introduced. The sequential image analysis usually uses monochrome image data, but we chose color image data because in this research vehicles in various colors should be subjected to analysis. Figure 3 shows the analysis flow:

Spatio-temporal image can be created by first installing a measuring slit for one line at a given position in the image frame (actually located near the center of the lane in this research) to monitor vehicles that pass through over the slit. From the image data collected by the monitoring camera, image data for one line at the slit position is extracted. One-line images for successive frames are stacked to create spatio-temporal image. Figure 4 shows an example of spatio-temporal image. Basically, the lean of a vehicle in an image corresponds to the vehicle speed. Also, the vehicle length, which often relates to the vehicle type, is determined by multiplying the speed by the time in which the vehicle passes through the given position specified over the slit. The distance between two vehicles is determined based on the premise that vehicles generally run at a fixed speed. Two successive vehicles running are identified based on three factors. One is the time at which the front end of each vehicle passes a certain point. The second is the running speed of the leading vehicle. The third is the total length of the leading vehicle. The relationships among these factors are put into consideration in performing automatic measurement.

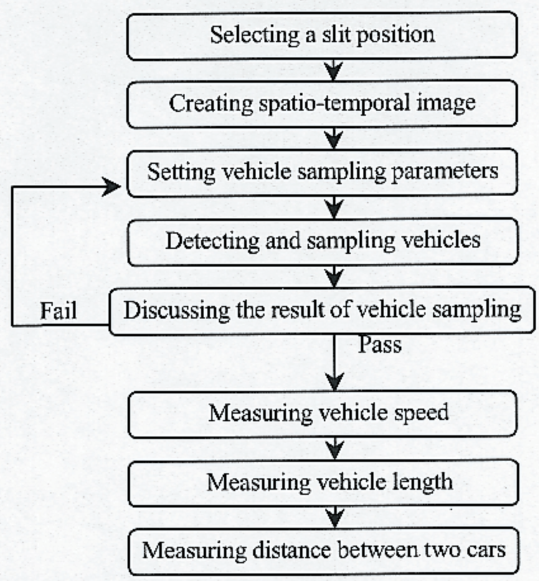


Figure 3. Flow chart for measuring vehicle speed and other factors

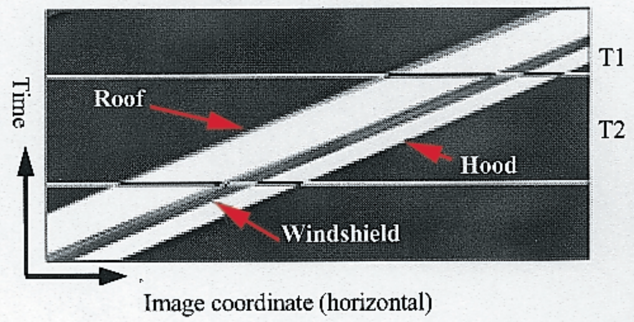


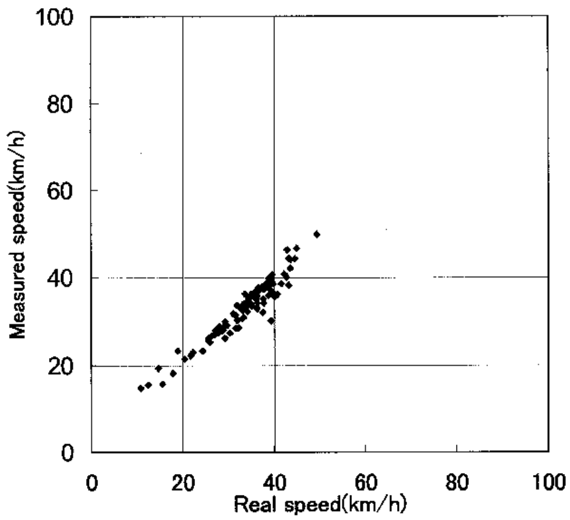
Figure 4. Example of spatio-temporal image

The parameters for sampling vehicles were set for each of the monitoring hours by cut-and-try method, so that vehicles as many as possible can be sampled for automatic measurement. Vehicles that can not be identified by automatic measurement were subjected to semi-automatic measurement by creating an "avi" file and using the image file coordinate system measurement. Still, some of those could not be measured. The proportion of those vehicles against the total measurement target vehicles were 3% (4 vehicles) for the morning hours, 6% (7 vehicles) for the afternoon, and 9% (10 vehicles) for the evening. The result implies that vehicles in colors similar to the road color are likely to be unable to be detected with poor solar radiation. It may be required to sufficiently discuss the parameter setting issue to make the automatic measurement system fully effective particularly in the evening hours.

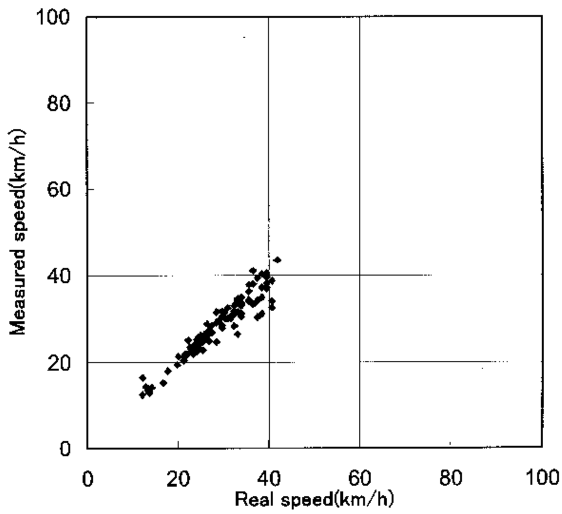
Of the vehicle speed measurement result obtained in this way, some part showing reliable data for the afternoon and evening hours thanks to relatively stable solar radiation were picked up for analysis. The result of the analysis is shown in Figure 5.

When comparing the two measurement results for the afternoon and evening hours, the measurements for the evening hours, in which the sky is getting dark, show slightly greater variance than those for the afternoon hours do. This represents that there is a clear difference in measurement result between the afternoon and evening hours also in terms of the measurement accuracy. In this experiment, approximately 93% of the total vehicles showed relative errors of within ±15%, the pass/fail criteria for analysis.

Similar tendency was also found in the measuring of vehicle length and distance between two vehicles, as the speed measurements should be used to determine these factors too.



(a) Afternoon hour



(b) Evening hour

Figure 5. Result of the vehicle speed measurement

5.2 Vehicle track

For grasping of vehicle trails, differential image approach was used to monitor vehicles that run through a road junction. This approach was selected because the forms of vehicles (outer shape) can be identified, in addition to the same reason for speed measurement. Figure 5 shows the flow chart of vehicle trail sampling using differential method. Like the measurement of vehicle speed and other factors, color images were used to process data for measurement. Note that, in this vehicle track measurement, data is not compared for different time hours since an identical condition could not occur in every monitoring session. Instead, three vehicles that came into a road junction simultaneously with the most complicated condition through each monitoring session were selected. Figure 6 shows the vehicle trails derived from

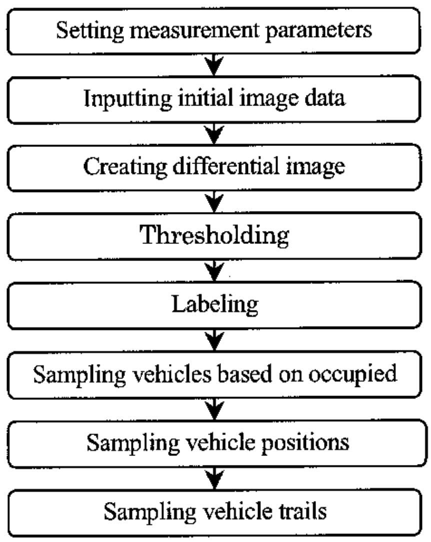


Figure 5. Flow chart of vehicle trail sampling

automatic measurement and Figure 7 a track diagram brought by automatic measurement and image analysis (the center of gravity of individual vehicles are plotted).

In Figure 7, the both approaches of automatic measurement and image analysis generally indicate almost the same track for each vehicle. This means that vehicle sampling in the road junction was successfully performed. The vehicle #2 shows a slightly greater measurement error (about 15 pixels on the image and about 35-cm in distance). This phenomenon occurred probably because the rear section of the vehicle #3 overlapped the vehicle #2 on the image. Another probable cause is that the color of the vehicle #2 is more similar to the road color comparing to the other vehicles.

6. CONCLUSIONS

This research brought the following conclusion:

(1) The PC-based simplified analysis system can be used to a sufficient degree to measure vehicle speed and length, distance between two vehicles, and vehicle trail for all the morning, afternoon and evening hours.

(2) In the measuring of vehicle speed and other factors based on spatio-temporal image approach making use of video image data obtained with elastic poles, automatic measurement was effective to more than 90% of the target vehicles for all the monitoring hours. In terms of measurement accuracy, more than 90% of the vehicles showed good results with relative error of ±15% or less.

(3) Similarly, the measurement of vehicle trail based on Differential image method using video images generally showed good results although the accuracy would be degraded in the case a vehicle overlaps another on the image screen.

The traffic flow measurement system based on the elastic poles and sequential image measurement approach used in this research may be applied in the road industry. In particular, the system can be fully used to investigate actual traffic conditions in road junctions or points where traffic accidents have frequently occurred from the standpoint of road management. The results of these investigations may be used to offer basic material in partially improving existing roads or setting up measures against traffic accidents.

To establish a more accurate measurement system with improved versatility in the future, the following challenges should be overcome:

(1) To establish a three-dimensional vehicle modeling system to reduce occlusion

(2) To accumulate investigation data collected at accident-prone locations.

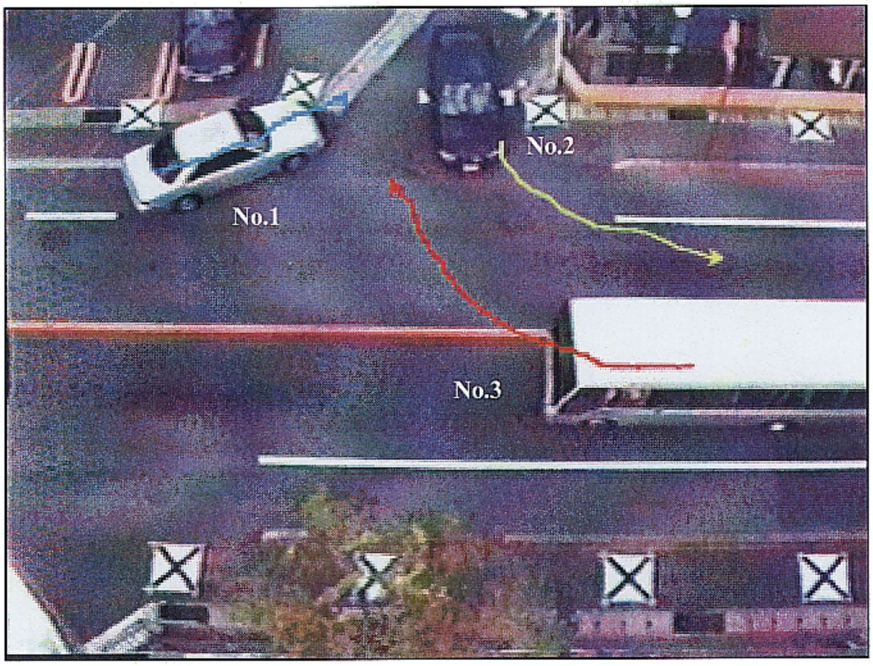


Figure 6. Result of the vehicle track derived from automatic measurement

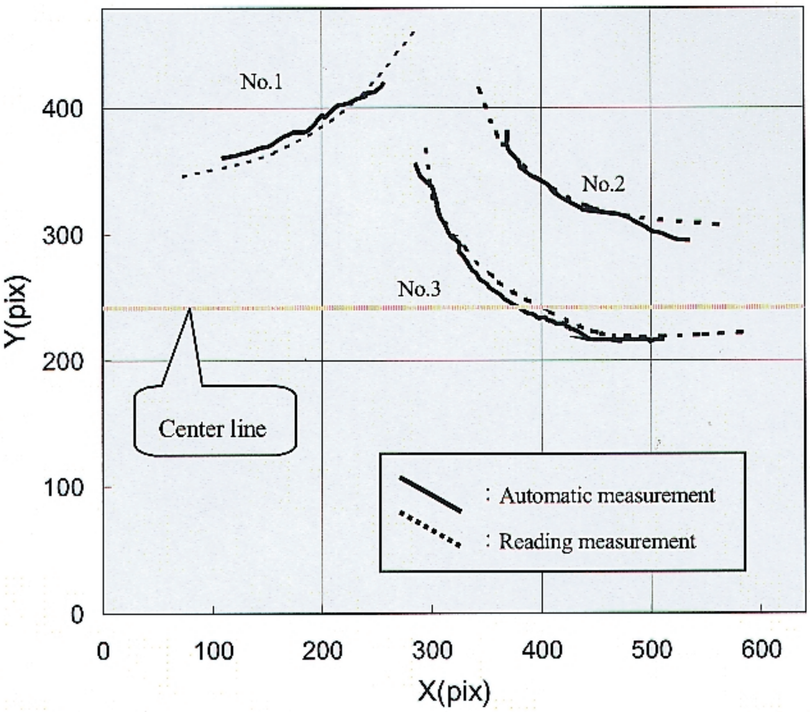


Figure 7. Result of the vehicle tracking (Comparison automatic measurement with reading measurement)