DISCUSSION ON THE AUTOMATIC MEASUREMENT OF TRAFFIC FLOW BY VIDEO CAMERA MOUNTED ON BALLOON

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ABSTRACT:

It is necessary to objectively monitor the running speed and running locus of the vehicles traveling on existing road to solve the traffic congestion or to design the intersections. Monitoring by video camera is effective for this purpose, but it has a drawback in installation cost and selection of installation places. In this study, we attempted to use unmanned balloon photographing as the traffic measurement system so that monitoring can be done easily at any optional place along the roads. Namely, a video camera was mounted on balloon and the balloon was sent up to take the video image of traffic flows just below the balloon. We applied image matching continuously to the video images to identify the running speed and running locus of individual cars in the image. The magnitude of tremble of video image due to the vibration of balloon was measured by applying image matching together with the vehicles. Then, we obtained the real running distance of vehicles by subtracting influence of tremble from the movement of vehicles. In order to evaluate the measuring accuracy, we acquired the video image and measured the test vehicle which traveled at pre-determined speed and locus. As a result, it has become clear that excellent results are obtained both for running speed and running locus only if the automatic tracing of vehicle by stereo matching is successful. In some cases, however, significant measurement error was observed when automatic tracing was difficult because of the influence of color or pattern of the road. With this respect, we proposed a method to improve the accuracy of automatic tracing of vehicles in this study.

1. **Introduction**

It is necessary to monitor and analyze the current state of road traffic in order to solve the problems such as ever increasing traffic congestion and accidents. Installation of industrial television (ITV) is now under way on main national roads and highways in Japan, and the monitoring system by video image is partly in operation.

However, excepting the places where permanent monitoring is necessary, installation of video camera has been difficult because of the high cost of construction. Also, it is difficult to find out a location at suburbs to install camera to shoot the road from proper altitude and at proper angle because there is few tall buildings along the roads.

It is necessary to measure the running speed, running locus and kinds of vehicles to implement various kinds of traffic plan and management such as design and improvement of road shape, traffic control to mitigate congestion and road repairing plans. At the places where the video images taken from high altitude are not available, only the possible way of measurement is the qualitative observation made by human eyes at the road side. Therefore, it is desirous to develop a measuring system which can shoot video images of road from high altitude at any places. Also, it is desirous to develop a computer based automatic measurement system to measure the speed and locus of moving cars, because the number of vehicles to be monitored is so large.

In this study, we mounted a video camera on unmanned balloon, and took the picture of road . Then we attempted to identify the running speed, running locus and kinds of each vehicle in the video image by applying image processing thereto. We applied image matching for measuring the location of moving cars and for automatic tracing of vehicles. As for the apparent movement of cars resulting from the vibration of balloon caused by the winds at upper air, we worked out the movement of camera by automatically tracing the ground control points(GCPs), and made corrections to the movement of cars.

This paper reports about the results of accuracy verification test of the methods described above and the development of improving methods.

2. Configuration of observation/Measurement System

(1) Observation system

As shown in Figure 1, we mounted a video camera on an airship type balloon. The total length of balloon is 5.2m and maximum diameter is 2.6m. When filled with $21m^3$ of helium gas, it can lift up the photographing equipment of around 5 kg to the altitude of 250m. The balloon has two mooring ropes, which are used to adjust the height of balloon according to the wind condition.

The video camera mounted on the balloon is deck integrated type VHS-C camera. The size of CCD is 1/3 inch. Lens is 7 - 41mm zoom lens. Photographing direction and zooming can be controlled by wireless operation from the ground. The number of pixels composing the video image is 660 for horizontal direction and 400 for vertical direction.

In photographing the road, we placed circle mark of about 1m in diameter as ground control points at 6 or more positions and adjusted the camera so that both of these control points and vehicles can be confined in a video frame.

(2) Measurement system

As the basic study for the automatic system of traffic measurement based on computer, we employed the measuring method as shown in Figure 2 in our study. Individual function were realized by image processing equipment and EWS.

After unloading the video tape on which the pictures were taken at upper air, the tape is replayed and stored as digital image in the frame memory device. At present, it is possible to record the data for only 8 seconds, but the moving images for longer time can be continuously stored on the computer memory if digital video, etc. will come to be in use more commonly in the future.

6 or more ground control points are specified in the first frame of video image which is composed of plural number of frames. Also, the initial position of the vehicles to be monitored is specified in the image. In the future, we are considering to automatically distinguish the vehicle bodies from background(road) and to mechanically select the vehicles subject to the automatic tracing. At present, the number of vehicles which can be specified and traced simultaneously in one image is around 10.

As for the ground control points and cars for which the initial position was specified, the image coordinates are measured sequentially in the continuous frames at the frequency of 1/60 second. In this study, we used Quick Vector made by OKK Inc. (Japan) for real time image matching.

Image coordinates of 10 cars and 6 ground control points (GCPs) are outputted to and recorded in engineering workstation every 1/60 second. Eventually, actual length conversion factor is calculated from map coordinates and image coordinates of ground control points, and position coordinates of cars are outputted in the form conforming to the map coordinates using

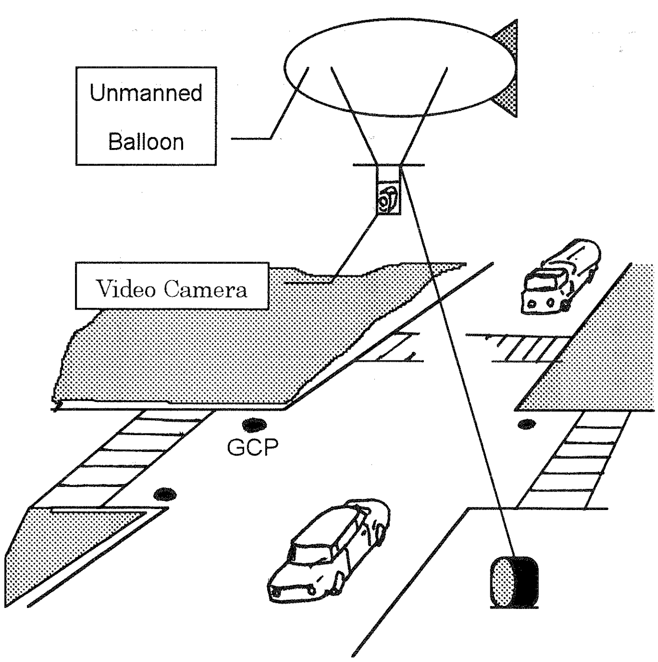


Figure 1 Diagram of the observation using unmanned balloon

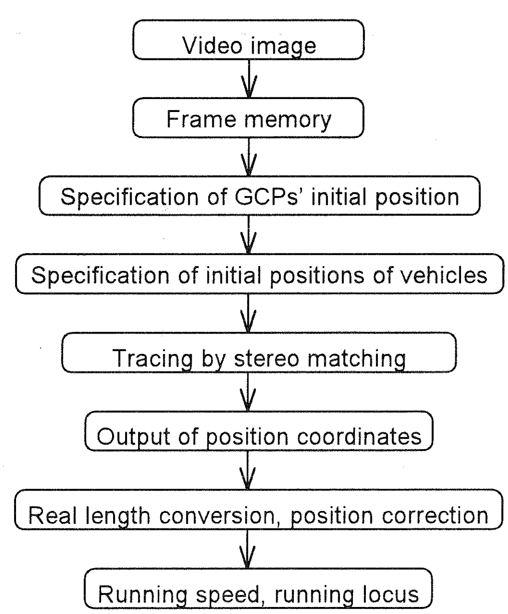


Figure 2 Flow chart of measurement

perspective transformation. In this process, the apparent movement of cars in the image due to the vibration of balloon is eliminated, and real moving distance will be identified.

3. Method of Experimental Measurement

We implemented experiments to take video image and measure the test vehicle in order to verify the accuracy of the measurement made by computer.

As for the test run section, we specified each one section separately for running speed measurement and running locus measurement.

For the measurement experiment of running speed, we specified straight section of the length about 20 m on the normal traffic road, and shot the video image of the test vehicle running through the section. At the same time, we recorded the actual running speed by measuring the passing time of the test vehicle using a stop watch. We used 2 normal size passenger cars and one large sized car as the test vehicles. Of these normal size passenger car, one has a car body of white color, and the other had the black color. Also, we took video images by changing the altitude of balloon to 3 different levels of 50m, 100m and 150m. The running speed of test vehicle was specified at 4 speeds of 15, 30, 45 and 60 km/h, and the test was made for 5 times for each speed. The number of test run is 70.

In the measurement experiment of running locus, we turned a car to the left at the radius of 5m, 10m and 15m on the test section where the left turn had been assumed, and took the video image of it from the upper air by the balloon mounted video camera. The altitude of balloon at the time of photographing was 100m and 150m. Also, we considered the movement of vehicle at the intersection. Namely, we specified two patterns; one is to stop for two seconds in the mid-way of left turning and then re-start to continue the turn, and the other is to turn the corner to the left without stopping at the same speed. 60 cases were measured in total. We used normal size passenger car of white body color as the test vehicle.

4. Measuring Results of Running Speed and Discussion

As for the accuracy of measuring result of running speed, we compared the values of actual measurement and value of automatic measurement from the following viewpoints. 1)Comparison by the kind of cars, 2) Comparison by running speed ,3)Comparison by observation altitude

(1) Comparison of measuring results by the kind of cars

In this study, the image correlation was calculated by converting the video image into binary value in order to implement matching processing on real time. The measuring accuracy was compared by the type of car because it was expected that the classification of car body in binary value would vary according to the type of vehicle. Figure 3 shows the difference between actual speed and measured speed based on the video image

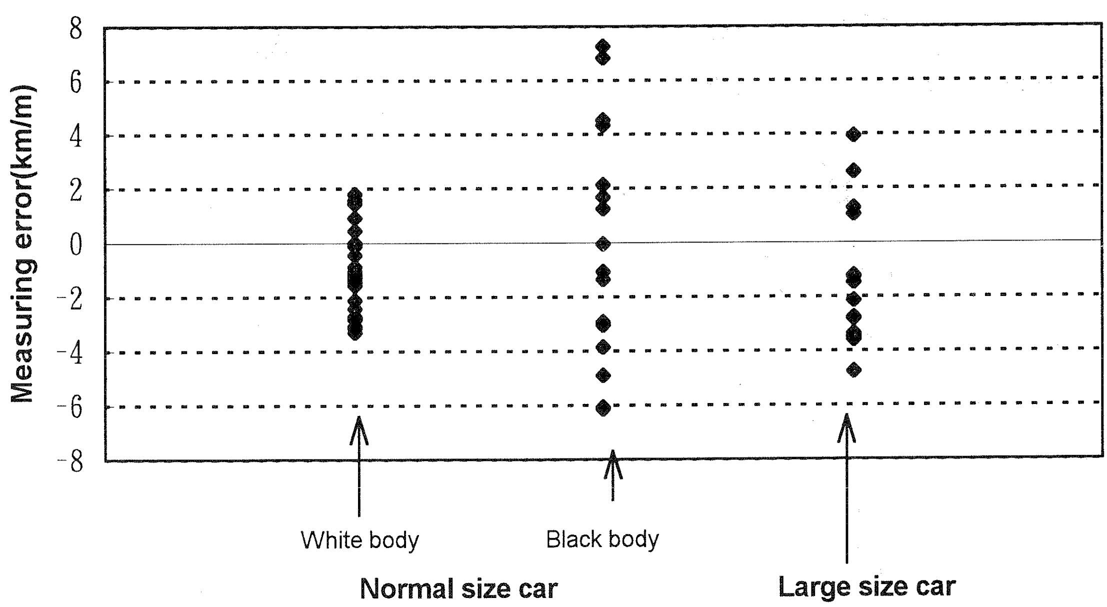


Figure 3 Measuring error of running speed by kinds of cars

taken at 50m high above the ground.

The car of black body showed larger measuring error and larger fluctuation in measured value comparing with other kinds of car. This is because tracing of car by matching was incomplete in many cases. When the body color is black, it was difficult to distinguish the car from the asphalt surface of road having the similar color, and matching tended to be incomplete.

(2) Comparison of measuring results by running speed

Figure 4 shows the measuring results of white car as an example of comparison by running speed.

The measuring results are roughly classified into two groups. One is the group which has small deviation from the actual measured value and the other is the group having the larger deviation. The difference of these groups has resulted from the successful or unsuccessful matching in image correlation. In case of the group having larger deviation, there was a rainfall during the test run, and there were puddles and speckled patterns on the road. As a result, matching was not well done because it was difficult to distinguish the car body from road surface.

In case of the group with successful matching, large difference was not observed in the measured value from the actual value even when the running speed was different. The same can be said to the large sized vehicle. Seeing from the spatial resolution of video camera and photographing altitude, the range of measured value had been considered to be about 5 km/h of the actual value. Among the measuring results, those with successful matching showed a result almost consistent with this expectation.

(3) Comparison by observation altitude

Assuming the cases where the balloon is sent up around the intersection, we compared the measuring accuracy by different observation altitudes of 50m, 100m and 150m. In this experiment , it was possible to cover the same area at any altitude by adjusting zoom lens. Therefore, hardly any difference was observed in the measuring result when the difference of altitude is within the extent of 50m -150m.

Based on the discussion made in the above, the methods of taking video image and measurement used in this study are considered to provide the measuring values which are close to the accuracy logically determined by the performance of CCD camera and photographing altitude only if matching under the image correlation is in good condition.

5. Measuring Results of Running Locus and Discussion

In the discussion on measuring result of running locus, we verified the measurement accuracy when the loci of vehicles turning at three different radii of 5m, 10m and 15m were measured. The viewpoints of discussion were (1)appropriateness of measuring results, (2) comparison of the results taken at different observation altitude and (3) evaluation of the influence of mid-way stop at turning.

(1) **Appropriateness of measuring results**

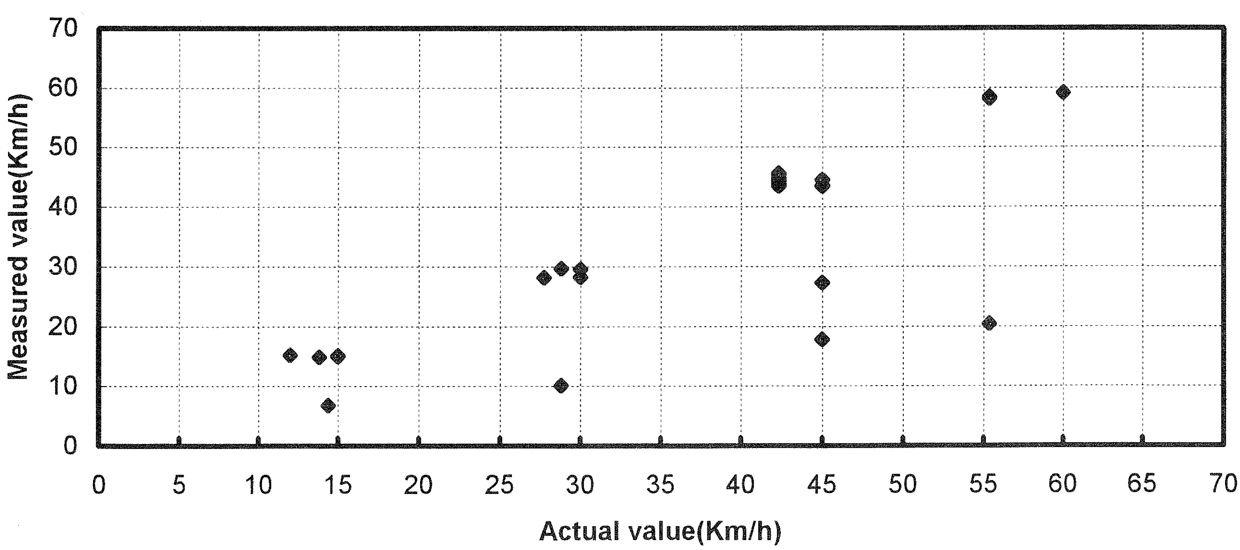


Figure 4 Actual running speed and measured value
(in case of photographing altitude 50m, white normal size car)

An example of running locus measurement is shown in Figure 5. The specified turning radius (15m) and measuring results are shown in this Figure. The measured locus of 5 times running are overlaid in the figure. The measured values represent the locus of right front edge of the vehicle.

As for the measuring result of running locus, we could obtain the measured values within 0.5m from the specified radius in general for any turning radius. The measuring results were generally satisfactory excepting that discontinuity took place in the locus for about 10 cm when the system switched over the image for correlation.

(2) Comparison of the results taken at different observation altitude

In this study, the same pattern of test run was observed from two different altitude of 100m and 150m. We could obtain almost similar results both from 100m and 150m altitude photographing because this extent of difference could be offset by the adjustment of zoom lens of video camera. So ,it may be better to select the high observation altitude so as to minimize the displacement of image.

(3) Influence of mid-way stop at turning

The car was stopped (for 2 seconds) at the mid-way of leftward turn in this experiment. We confirmed whether the deviation took place during the stop, and found that no significant deviation occurred to the locus. We could also obtain the graph to show the change of running speed including those of mid-way stop. As a result, we could confirm that mid-way stop does not give any significant influence on the measurement in case of our measuring system.

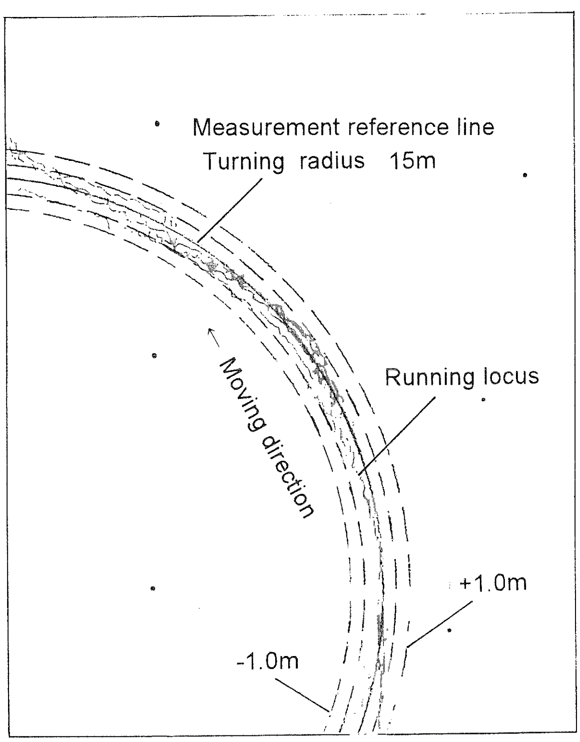


Figure 5 Example of running locus measurement result (Observation altitude 100m, Turning radius 15m)

From the above, we confirmed that appropriate results are obtained in general in the measurement of running locus. Partly, there were cases where matching was impossible because the road surface and vehicle could not be distinguished each other just like in the cases of speed measurement, therefore, we are planning to add pre-processing to photographing condition to make it robust.

6. Application for the Identification of Car Type

We attempted to identify the car type utilizing the measuring results of running speed. If it is possible to classify the running cars into the rough two groups of normal size car and large sized car, it will be quite effective in saving energy in the current traffic investigations.

In this experiment, we calculated length of cars passing through the test section using the following formula, and discussed the possibility to identify the type of car by the difference of length.

$$L = \sum_{n=1}^{T} v_n \cdot t_n - w$$

Where, L: Car length;

W: Length of measuring section

v: Measured Speed of car (each 1/60 second)

t: Unit time of measurement (1/60 second)

T: Time when the car passed the section

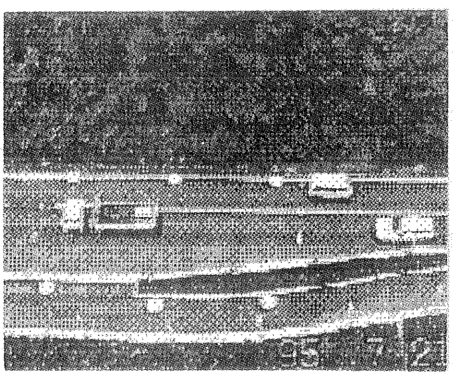
n: Number of video field

When this method was applied to the video image used for the measurement of running speed, the measuring error of maximum 2.5m was observed in case of normal size white car and maximum 1.5 in case of large sized car. In case of the car with black body, the measuring error close to 4.5m was observed at maximum. It is barely possible to distinguish normal size white passenger car from large sized car as there is a difference of 3m or more in the length between the normal size and large sized cars, but the judgment is quite unstable. The main cause of these errors would be the accumulation of error involved in measuring the speed at the unit of 1/60 and measuring error of passing time of the section. The reason why the error is larger in case of black car body is attributable to the fact that car body cannot be distinguished from road surface of asphalt at the automatic tracing by image matching.

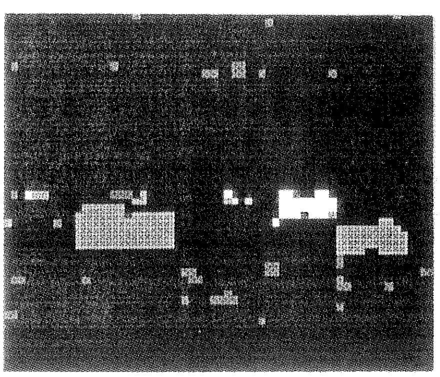
From the above results, it is considered better to employ another method such as the extraction of contours of vehicle to identify the type of car.

7. Issues in the Future

As a result of experiment, it has become clear that the measuring accuracy expected from CCD camera and photographing altitude can be realized if the pattern on road surface and vehicle can be clearly distinguished by the image analysis. On the other hand, in case of the simple recognition method of car body such as binary value processing, it was almost impossible to distinguish a car body from the marks and complicated patterns of road after rainfall, and automatic tracing of car was difficult in many cases. Therefore, it is necessary to realize robust processing for the condition of road surface. As an improvement for the processing method, we are now studying the method to implement corresponding points retrieval to the total area of two video images which are temporally continuous, and extract the contours of moving object. Figure 6 shows the extraction result by improved method of the contours of vehicle for which automatic tracing was impossible at the experiment this time. It is considered that automatic tracing of car body will become far more stable by applying this method. The problem is that the hardware which can process this method on real time has not been developed so far. Since the algorithm has already been known, it is desirous to incorporate into hardware.



(a) Original video image



(b) Extracted contours of cars

Figure 6 Extraction result of the contours of car

If the contour of vehicle can be extracted, it will be possible to distinguish normal size car from large sized car by measuring the area inside the contour or calculating the circumference of contour. It is expected to lead to the improvement identification rate comparing with the measurement of car length which was attempted in this experiment.

8. Conclusion

In this study, we made basic discussion on the method to automatically measure the image taken by video camera mounted on balloon so that monitoring of traffic flow and measurement of vehicle movement can be easily implement at optional place.

Using the video camera mounted on balloon, the vehicles traveling below and the GCPs placed around the road are recorded as video image. By the video image analysis made on computer, matching based on image correlation and automatic tracing are made simultaneously to vehicles and GCPs to be monitored. The image coordinates obtained as a result of automatic tracing are converted into actual length, from which running locus and running speed of vehicle are calculated.

We made experiments to verify the measurement accuracy of this method. As a result, it was possible to make satisfactory measurement if the running vehicles and road surface could be distinguished on the image.

On the other hand, there are some cases where matching happened to be defective and automatic tracing was impossible because of the marks painted on the road or disorder of color of road surface resulting from rainfall ,etc. To cope with this problem, we are currently making improvements to provide robust measurement by changing pre-processing of matching.

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