To Measure the Velocity Distribution of the Car on a Highway with the Airborne Three-line Scanner (TLS) System

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ABSTRACT

Three-line scanner (TLS) system has the linear CCD sensors mounted in parallel position on the focal plane of the camera objective . When set the scanning direction of TLS camera in right angle to the bow of airplane , it is possible to get image data of the terrain in forward, nadir and backward direction according to the push broom principle. As the scanning interval is regulated by a quartz crystal oscillator, when the scanning direction on image data define as X axis, Y axis (traveling direction of airplane) is able to regard as Time line. TLS camera has three parallel scanning line in different view point, and this means it is possible to scan objects in different area at same time. From the side of object, it is scanned in thrice at different time. According to these facts, To compare two image data of different scanning line, the moving object appears on the different position in image data, and the fixed object is still on the same position. And if the distance of movement (dX) is measured from image data (road , building, etc.), as the difference of line in Y axis means time (dT), the velocity of object is calculated from these two parameter. (dX / dT)
This paper introduces one of application with using these method to measure automobiles velocity witch running on a highway with TLS system.

1. BACK GROUND

Recently in Japan, as expansion of highway networks, numbers of vehicle used as a way of transportation have been increasing. Especially, at middle of August and Year end to new Year term so called homecoming season, traffic congestion have occurred at several special spots in every seasons by concentrate of traffic.
Many studies to find the mechanism or the structural factor of traffic congestion, had done for the purpose of preventing or decreasing them.
Usually, there are two kinds of typical data, speed and numbers per period at a static point, of distribution of vehicles are able to measured.
The method to measure velocity of vehicles in dynamical and spatial has been also studied.

2. THE PRINCIPLE OF MEASUREMENT OF VELOCITY WITH TLS

TLS(Three-Line Scanner : Photo 1) camera is a line sensor camera equipped three CCD line sensor in one optical system.

To measure the velocity of vehicles on highway from image data by TLS, attach a TLS camera system (TLS camera , a digital data recorder and a controller) to the airplane which has the bottom window for the aerial

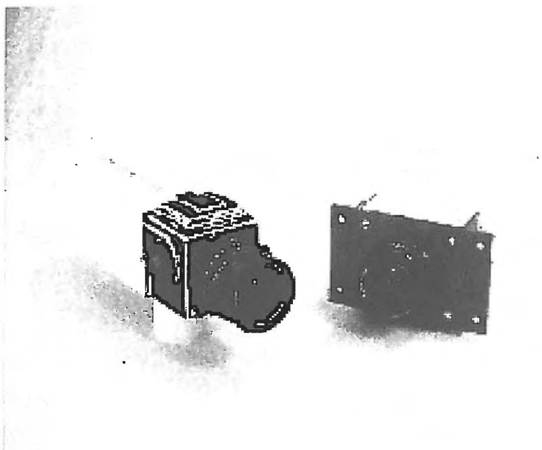

Photo 1 TLS Camera(LEFT:5000dot, RIGHT:7500dot)

photograph, a digital data recorder and controller. And to analysis the acquired data which flew the sky of the highway of the measuring, the speed of the vehicles can be measured. The principle of measurement velocity of vehicle form digital image by TLS system s mentioned below.

2.1. Image data acquisition by TLS and velocity measuring

Toward the movement direction, and the image data acquired by the line sensor are the images seen from the angle which was always fixed. Therefore, if two and more line sensor is arranged in parallel in the focus of optics, the image data seen from the visual angle which plural was different from are acquired. The measuring treatment of the three-dimensional coordinate by stereo matching method can be done by the image data acquired by two line sensors' being arranged fundamentally in parallel in one optics.
But, when the form of the applicable thing is unevenness, it has the possibility that the image of the perfect whole isn't taken from two points of view.
Therefore, TLS is the system which the part of the loss reduced as much as possible by image data from three different points of view to include three line sensors into one optics being acquired. Like this, TLS is the system developed fundamentally for the purpose of coordinate measuring of the three-dimensional space by stereo matching processing.

TLS is the line camera which included three line sensors into one optics. Three line sensors are arranged so that the direction of the arrangement of CCD may become parallel to each other, and it faces in the proceeding direction, and arranged to intersect with the right angle. It can take pictures of three image data of a former direction image, a downward image and the image for the back at the same time with three line sensors. (Figure 1)

Because TLS is moved when an airplane is moved, in the fixed time interval, image data which the same zone from three directions are acquired. Three line sensors of TLS acquire the image data of the ground of three visual angles at the same time. This is equal to the point of the ground being acquired three times by the line sensor as the image data in three different moment.

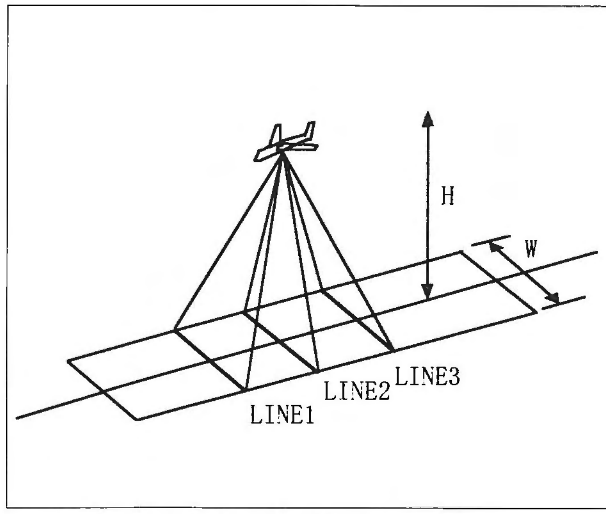

Figure 1 Aircraft loading type TLS

Therefore, three image data acquired by TLS have these two characteristics.

(1) They are the image data acquired from the different visual angle.
(2) They are the image data of the same area acquired in different moment.

Because image acquisition time is different, it is shown that a distance from the fixed point is different in the object moved through the ground when two image data acquired by TLS carried on the aircraft are compared.

The speed of the vehicles can be calculated with the following process by these characteristics' being used.

(1) TLS carried on the airplane acquires the image data of the highway from the sky.
(2) The time difference (ΔT) that the vehicles of the measuring object are located on the image when two image data are compared is measured.
(3) When two image data are compared, the distance difference (ΔD) from the ground fixed point of the vehicles on each image is measured.
(4) The speed of the vehicles is calculated by this two value.

3. THE SPECIFICATION OF TLS

The fundamental specification of the TLS system is shown in the table 1. 3 CCD line sensors of 7500 element are installed in TLS camera. And, The wide-angle lens of f= 38.4mm is included as optics. Image data can be acquired in the width of about 800m at hight occasion 500m.

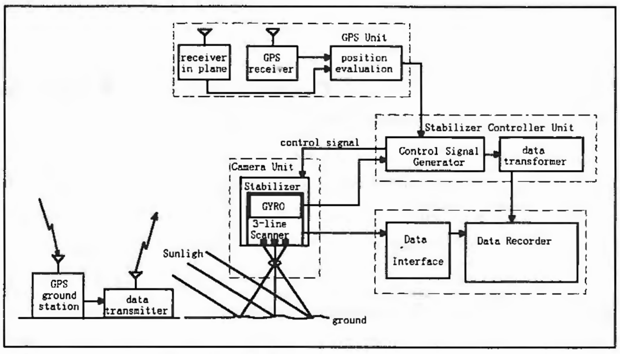

Figure 2 TLS system image

Therefore, when the image data of highway are acquired, a flight course doesn't need to be traced precisely in accordance with the curve of the road. An highway is always within the photography range of TLS if the pilot of the airplane almost controls an airplane along the highway.

The speed of the record device of TLS is (32MByte/sec), and a record device can record the image data of 3 line at the same time at the rate of 500 scanning in 1 second. The image of the general TLS system is shown in the figure 2.

Table 1 TLS mechanical specifications

ELEMENTS	SPECIFICATION
SENSOR	7500DOT CCD LINE SENSOR ×3
ELEMENT SIZE	9μm×9μm
PITCH	9μm
LENZ	ZEISS Biogon 38. 4mm f4.5~22
STEREO ANGLE	21°
RESOLUTION	10bit
SAMPLING RATE	10MHz
RECORD SPEED	32MB/s
MONITOR TV	10" MONITOR

4. THE PROCESS OF SPEED MEASURING

The speed of the vehicles is measured from the image data acquired by TLS by the following four-step treatment.

(1) Correct to the straight line of the image data. (Formation of the time scale image data)
(2) Formation of the ground coordinate normalization image (distance scale image)
(3) Recognition of the vehicles and Measuring coordinate of the position and time.
(4) Measuring of the amount of movement and the movement time

Each content of treatment is shown next.

4.1 Correct to the straight line of the image data. (Process[1] Formation of the time scale image data)

The image acquired by TLS contains distortion by the change in a posture of the airplane and the optical cause. (Figure 3)

Figure 3 TLS original picture figure data

When coordinate measuring is done with stereo matching method, a spatial coordinate must be corrected by the posture data as for the image data. (Figure 4)
But, a movement distance must be calculated properly with the case which the speed of the vehicles is measured with. For this purpose, the efficiency of the work is better to use the image modified a road may become in a straight line rather than to use the image that a road is modified properly as a curve.
And, the compensation of the distance isn't carried out at this moment to measure the difference in time when it is acquired. The part of a white line which painted on the road is searched by the software.
Then, image data for 1 line are shifted right and left, and software corrects data so that a road may be a straight line. With the white line painted on the road is used, this compensation treatment is done automatically by the software.
The image data formed by this treatment are called a time scale image. . (Figure 5)

4.2 Formation of the ground coordinate normalization image (Process[2] distance scale image)

A position can be limited absolutely by many bulletin boards, the sign and a structure thing like a fence on the highway. And, an overpass, an underpass, and some geographical features such as a bridge or a tunnel can limit a position. And, the boundary line (white 8m· blank 12m) of the lane which was painted in white can use as index to compensate of the relative distance to divide a lane, too. The time scale image formed by the Process[1] is transformed to image which is corrected length in the distance direction by these position indexes.

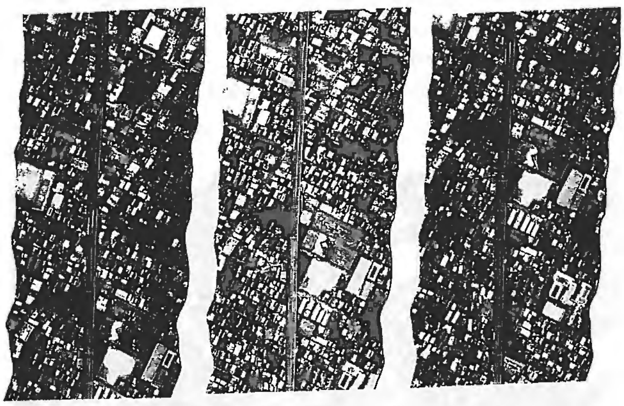

Figure 4 TLS posture compensation image data

Concretely, the position of these applicable things that these positions are absolutely confirmed by the map, in the time scale image is detected by human eyes. At this time, The image of front view is the image of the condition seen from the oblique direction.

Therefore, a deviation from the absolute position becomes big as an applicable thing leaves the surface of the earth side. So, an applicable thing to make position index as close a thing as possible to the ground side.

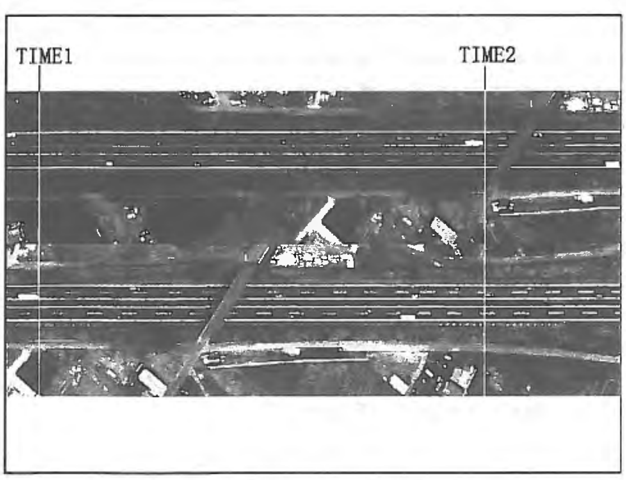

Figure 5 Time scale image
(Upper: downward view bottom: front view)

Index point looks for a position in the time scale direction on each image as 4 points per 1km.

Image data are corrected in the direction of the time scale so that a distance between two points which adjoin it and the ratio of the length in screen may become fixed. The image data formed with these processes are called a distance scale image. (Figure 6)

4.3 Recognition of the vehicles and Measuring coordinate of the position and time (Process[3])

An image is indicated on the monitor TV screen of the computer, and vehicles are recognized with the human eyes under the present condition. As for the position data of the vehicles, it can be acquired by clicking on the vehicles in monitor screen by the mouse.
The position of the vehicles is acquired from the {time scale image and the space scale image} of two sets made by two image data of front view and downward view. Time data (T1, T2) and absolute position data (P1, P2) of the vehicles can be calculated from these data.

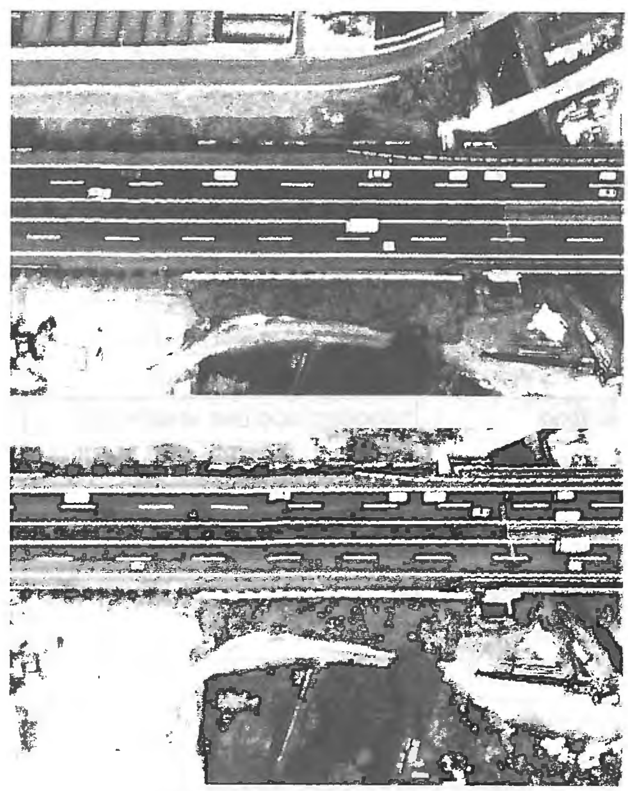

Figure 6 Distance scale image
(Upper : downward view bottom : front view)

4.4 Measuring of the amount of movement and the movement time (Process[4])

The movement distance (ΔD) and the movement time (ΔT) of the vehicles can be calculated by absolute position data (P1, P2) and time data (T1, T2) acquired by the Process(3) by the next formula.

Movement distance $(\Delta D) = P2 - P1$
Movement time $(\Delta T) = T2 - T1$

The speed (V) of the vehicles is calculated by the following formula from these results.

$$Speed(V) = \Delta D/\Delta T \quad or,\ Speed(V) = (P2-P1)/(T2-T1)$$

5. THE VERIFICATION OF THE MEASURING ACCURACY

With the present system, when correcting as a straight line, a road in image is corrected based on the time data. For that reason, in distance scale image, The deviation of the position occurs on the image, and becomes the error of distance measuring at the case of the proceeding direction of the airplane is not a straight line by the influence of the wind or When a road curves.
An error by the difference in the angle that it intersects with the line which TLS scans, and 2 lane road (center interval 5m) is calculated In the following. (Figure 7)

As the angle that a road and a line make changing, the amount of deviation becomes big corresponding to the amount of change of the angle in the center position of two lanes on the image. Because the bend condition of the road and the flight course of the airplane changes continuously, precision in the long distance can't be defined uniformly. But, precision can be verified in the time only targeting measuring of the speed based on the distance that vehicles are moved is about 110m in 4 seconds which is a difference in time of 2 images.

The difference in distance between the lanes is about 2.9m when the angle that a road and a line make it changes from 0 degree to 30 degrees.

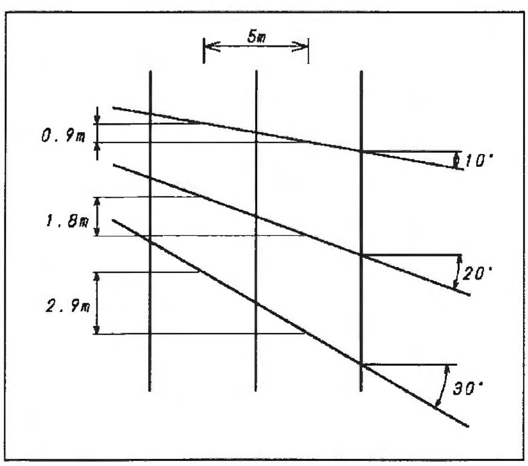

Figure 7 The deviation of the position by the angle of the road and the line

The error of 2.9m occurs in the distance that vehicles were actually moved on the image by the lane when the distance while it changes is 110m (the distance that the vehicles of 100km per hour are moved in 4 seconds). This is the same as the case of when the radius of the curve is 210m (210R) or the case of the posture change rate of the airplane is 8 degree/sec. Differences in the distance of 2.9m become about 2.6% of the errors because a movement distance changes about 1.1m every time a speed changes by a unit when measuring is done in the 1km/h unit. An error becomes big in the section where the radius of the curve is small and when the posture of the airplane and a direction changed rapidly. Therefore, how to correct it when position information is acquired from the image, must be examined.

But, because there is no place where the radius of the curve is small too much in the case of the highway, an error can be made small by being careful that the posture of the airplane doesn't change rapidly very much.

6. RESULT OF FIELD TEST

An airplane actually flew for the purpose of the data acquisition, in about 12 killometer section (section of the Tohoku highway top) in the going home season in middle of August, 1997. The conditions of the traffic congestion were acquired by TLS as the image data, and analytic treatment was carried out.

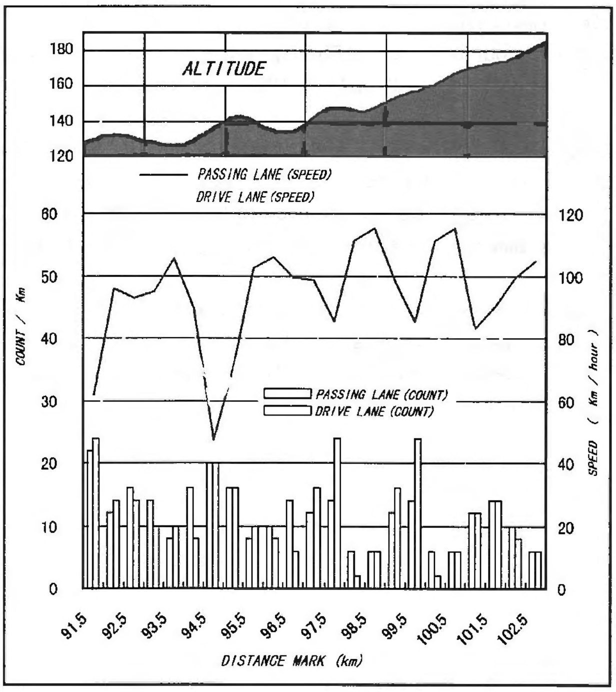

Figure 8 Result of Measureing

As for the flight altitude in the image data acquisition, a flight speed was 200km per hour about 500m on the average. A treatment result is shown as figure 8.
It shows the bottom peak of speed at the area from bottom of Sag Part (93.5km) to top of Bump part (96.0km). These geographical peculiarity is one of results of traffic congestion.

7. CONCLUSION

As it was stated first, such a spatial and dynamic velocity measuring method is the first trial.
As for the meaning which acquired image data have, and the way of using it, research is done from now.
And, the recognition of the vehicles was enforced by this research by the visual observation.
But, as for this part, it wants to make it a future subject from software's expecting that automation is fully possible.

8. ACKNOWLEDGEMENT

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