GEO-SPATIAL GRASPING OF PAVEMENT WITH MOBILE MAPPING

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ABSTRACT

Our company has a specialized measuring vehicle for continuously identifying the deterioration of pavement surface of road. This measuring vehicle is called the "Roadman". It is mainly used for measuring the crack, rut and flatness (vertical asperities). However, the measuring results are merely depicted on the virtual 2-dimensional coordinates.
On the other hand, it is necessary to continuously acquire the coordinates of road surface while the vehicle is running in order for geo-spatial grasping the paved road conditions. If this technique is realized, it would be come possible to acquire the spatial data by a mobile measuring equipment such as "Roadman" and express the roughness of road surface on the 3-dimensional coordinates.
While establishing the basic techniques of mobile mapping, we have developed the measuring techniques and equipment which are compatible with international roughness index (IRI) which has come into the limelight in recent years as a new evaluation method of road surface.

1 INTRODUCTION

1.1 Using method of measuring vehicle in the past

In Japan, the road surface condition survey vehicles have been used as a tool for preparing result report of road surface condition survey project which was conducted by the Ministry of Construction, Ministry of Transport, Japan Highway Public Corporation and road management agents for the purpose to reasonably and efficiently manage and maintain the road pavement. The objects of measurement are highway, general roads and airport, etc. The measurement results are analyzed by specialized machine, from which maintenance control index (MCI) and pavement rehabilitation index (PRI) are worked out by the general purpose computers. These evaluation indices are contributing to the maintenance and control plans of paved road as they are summarized as maps together with the road control data such as traffic volume and road side conditions or constructed as a database and used for pavement control assistance system (GIS).
However, the measuring vehicles have been hardly used other than for a series of operations to calculate the evaluation value from the investigation results.

1.2 Using method of measuring vehicle in the future

So far, our company has developed 5 measuring vehicles. The measuring vehicle developed most recently is called "Roadman No. 5" (hereinafter called RM 5). One of the features of RM 5 is the ability to simultaneously make measurement and distant control of image data (digital) compiled from pitching angle and rolling angle acquired by INS as well as X coordinates, Y coordinates and H (height) data acquired by front monitor camera. This means that we can approach to more accurate grasping of shape (spatial information) of paved road. We will be able to change the conventional method of data use to depict the shape of rut on the virtual 2-dimensional coordinates and confirm its depth and effective width. Also, it will open a new way for the measuring vehicle as the spatial information measuring equipment if the real time is introduced to the data processing which is currently implemented as post processing and if the accuracy is improved to a higher level.

Figure 1. Measuring vehicle (RM5)

2 PRINCIPLE OF 3 FACTORS MEASUREMENT OF ROAD SURFACE CONDITIONS BY RM 5

RM 5 if the measuring vehicle jointly developed by our company and Komatsu Engineering Co., Ltd. The measuring principle of RM 5 is outlined in the following.

2.1 Measurement of crack (flying spot image method)

1 W air cooled argon laser radiated perpendicularly is scanned at high speed to traversal direction (for whole lane width) by a special scanner. Then, the delicate difference in the strength of brightness of light strips reflected from the road surface is read by optical detector, which is converted into quanta of 256 levels and recorded on the video tape compatible with high density hi-vision. Continuous shooting is possible by accumulating the data of reflected light volume of laser beam with the width of some millimeters continuously for the running direction of vehicle. Cracking rate is calculated by interpreting these data by a processor. The maintenance control index is calculated from these values, Refer to Fig. 6 for the image of cracks.

2.2 Measurement of rut (laser scanning range finder method)

We are employing laser scanning range finder method by which 1 W air cooled argon laser radiated perpendicularly is recorded by CCD camera (black and white solid image shooting camera) located at slant position. sampling interval can be set optionally (the number of baseline is a multiple of 25 cm), and the continuous measurement is also possible. Digital recording is made on 8 mm magnetic tape (see Fig. 6).

2.3 Measurement of flatness (laser video light point displacement method)

The reflection of laser beam radiated perpendicularly on the road surface is read by non-contact displacement meter and is used for the detection of height from the road surface. Similarly in the case of rut, the displacement data detected by laser displacement meters located at the interval of 1.5 m are digitally recorded on 8 mm magnetic tape. The data of another one spot (the data of 3 spots at the interval of 1.5 m are necessary for the determination of flatness) is substituted by the displacement data at the intersection of extension line of laser displacement data and scanning line of rut.

3 MEASUREMENT OF OTHER DATA BY RM 5

3.1 Measurement of lengthwise profile of road surface

Generally in using INS for measurement of moving object, 3 axes (X, Y, Z) acceleration of gyrocompass is converted into perpendicular acceleration, and perpendicular up and down change obtained by dual integration is used as the data of height, in most cases. In contrast, the method developed by our company and Komatsu Engineering Co., Ltd. uses the rolling angle and vehicle height data in stead of 3 axes acceleration of gyrocompass to obtain the traversal inclination and calculate the profile of running (extension) direction (lengthwise profile) from this data and pitching angle.

As for the procedure of measurement processing, the distance matching of data is made, first of all, by using the distance signal of measuring vehicle. In concrete, the temporal data of pitching angle and rolling angle measured by INS are changed to distance data. In this case, the displacement data are simultaneously measure by the car height sensor located at the position of ruts at left and right sides. From these data, the inclination between vehicle and road surface and the profile of road are calculated by post processing, and are converted into absolute coordinates by D GPS. It is possible to obtain accurate data by this method even when the perpendicular up and down displacement of gyrocompass is inaccurate in case of gradual slope or a road where a specific acceleration is applied. In other words, the influence of effective frequency of gyrocompass will become less significant.

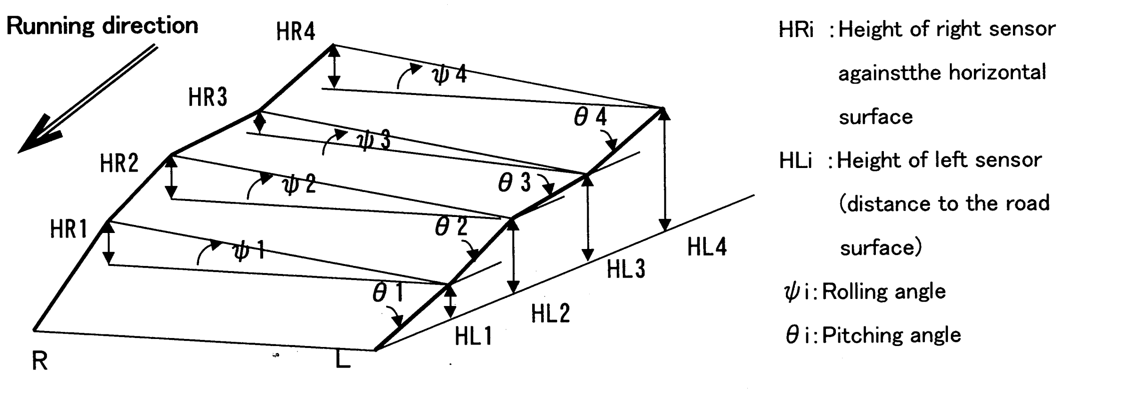

Figure 2. Running image of measuring vehicle and method to calculate the profile of extension direction

Fig. 2 is a conceptual drawing of calculation method. Based on the car height data (HLi) obtained by displacement sensor at the left side of vehicle (L), the height of right side displacement sensor from the horizontal surface is calculated from the rolling angle (ψi) obtained from gyrocompass and the distance between right and left displacement sensors (RL). The height of vehicle from the horizontal surface at the position of right displacement sensor is obtained by deducting car height data of left displacement sensor from the height right displacement sensor. This height is equal to the height of left sensor from the horizontal surface of vehicle, and the traversal inclination of road surface can be calculated from the reference horizontal surface using trigonometric function. The results of displacement volume of height calculated from this data and pitching angle (θ i) obtained by gyrocompass as well as the measuring distance are the lengthwise profile of the road.

3.2 Measurement of GPS coordinates data

The purpose to use GPS is to correct the accumulated error of height data obtained from INS, and on the contrary, to use the GPS data by interpolating them with INS data if the measurement accuracy of GPS is improved. At present, there still remain some practical problems in using RTK for the measuring method of GPS in case of moving measurement (different from experimental measurement of the section of some hundred meters without any obstacles). First of all, we will improve the technical reliability with D GPS. In addition, we have equipped the vehicle with GPS device excellent in moving measurement which can acquire the data of RKT measurement to enhance the accuracy towards the real time measurement in the near future.
As for the means of data communication, we use BEACON which has been currently employed by Water Channel Department of Maritime Safety Agency in stead of electronic control point. The reason why we employed BEACON is because the blank areas were almost removed throughout Japan by 1998 fiscal year, it has longer signal transmission distance comparing with electronic control point, and we considered it has high practicality as there is no necessity to establish a fixed point at the time of measurement. The signal reception is recorded every second by the dedicated personal computer mounted on measuring vehicle (base station: Pro_Beacon).

3.3 Measurement of forward direction image data

The forward direction monitoring TV camera records the digital data on DV video tape. Since the data are interlinked with speed meter of measuring vehicle at the time of recording, it has become possible to control the digital image by distance not by time (refer to Fig. 6). Linkage of these image data with each measurement (coordinates) data and the technique to extract geographical information are the issues to be solved in the future.

4 USE OF ROAD SURFACE PROFILE DATA

4.1 Linkage with the rut (traversal profile) dat

We considered it possible to depict 3-dimensional profile of paved road surface by using traversal data of road surface represented by the rut among the data obtained by measuring vehicle and the inertia data including D GPS, and we developed a data conversion tool for this purpose.

4.1.1 Recording form of rut data: The rut data are recorded in binary form of 480 points on 8 mm magnetic tape. These data are converted by the indoor processing machine into the coordinate data with X axis showing the traversal direction of the interval of 1 cm and Y axis showing the height of rut (depth). Normally, these data are recorded on the magnetic tape of half width, and after being processed by general purpose computer for determining the width position, they are used for the calculation of rut volume and flatness (3m σ) and for preparing the results of road surface survey projects. Fig. 3 shows one cross section of traversal profile.

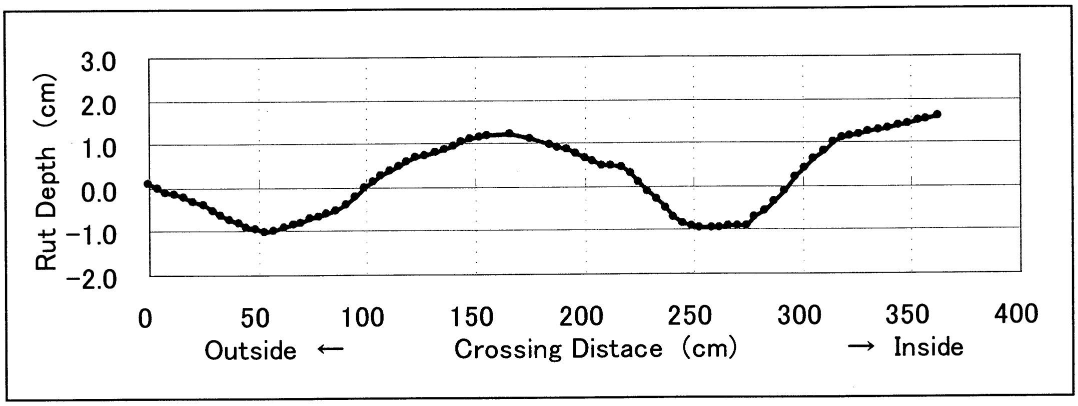

Figure 3. Expression of 2 dimensional relative coordinates of rut (of one cross section)

4.1.2 Recording form of lengthwise profile and D GPS data: The measured data are recorded on the same 8 mm magnetic tape as the rut data in binary form and are read by the indoor processing machine together with D GPS data recorded by the personal computer mounted on the measuring vehicle. The processing machine makes distance matching among the data of pitching angle and rolling angle of gyrocompass, lengthwise profile obtained by calculation and D GPS, and output the resulting data as one file. This output data is CSV format (text data punctuated by comma). D GPS data contain both of raw data [degree, minutes, second, height of oval object] and orthogonal coordinates [X, Y, H] (m) of flat surface, and the conversion to orthogonal coordinates is made simultaneously in the measuring vehicle. Fig. 4 shows the measurement results of lengthwise profile which has been adjusted to be at the same height as the altitude data of D GPS at the place of the distance 0 meter. Although there is observed a drift due to the properties of INS, it can be said that the characteristics of road surface have been fairly grasped at the stage of profile data.

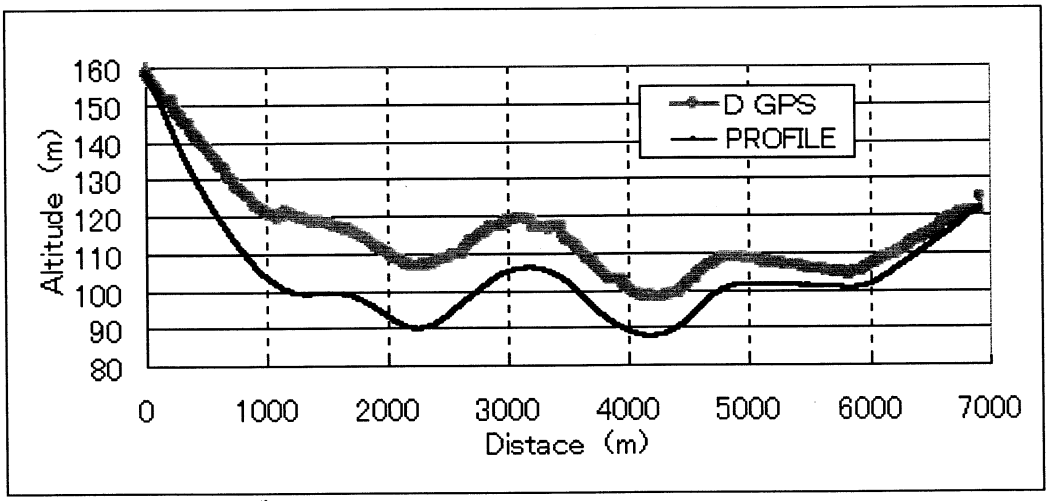

Figure 4. Comparison of lengthwise profile and altitude data of D GPS

4.2 Three dimensional expression of rut (traversal profile)

The lengthwise profile data are not the data of ground height of road surface in a precise sense, but they indicate the height of car height sensor installed outside the measuring vehicle at the position of rut, and INS used for the slope correction is installed below the floor of measuring vehicle. Also, the altitude data of D GPS are the data indicating the position of receiver located at the upper part of measuring vehicle. Therefore, it is necessary to decide the reference

value by working out the offset value for each data in order to convert them into 3 dimensional data.
The minimum measuring interval of rut data is 50 cm. A picture drawn by aligning the reference value of each inertia data at the interval 50 cm is shown in Fig. 5.

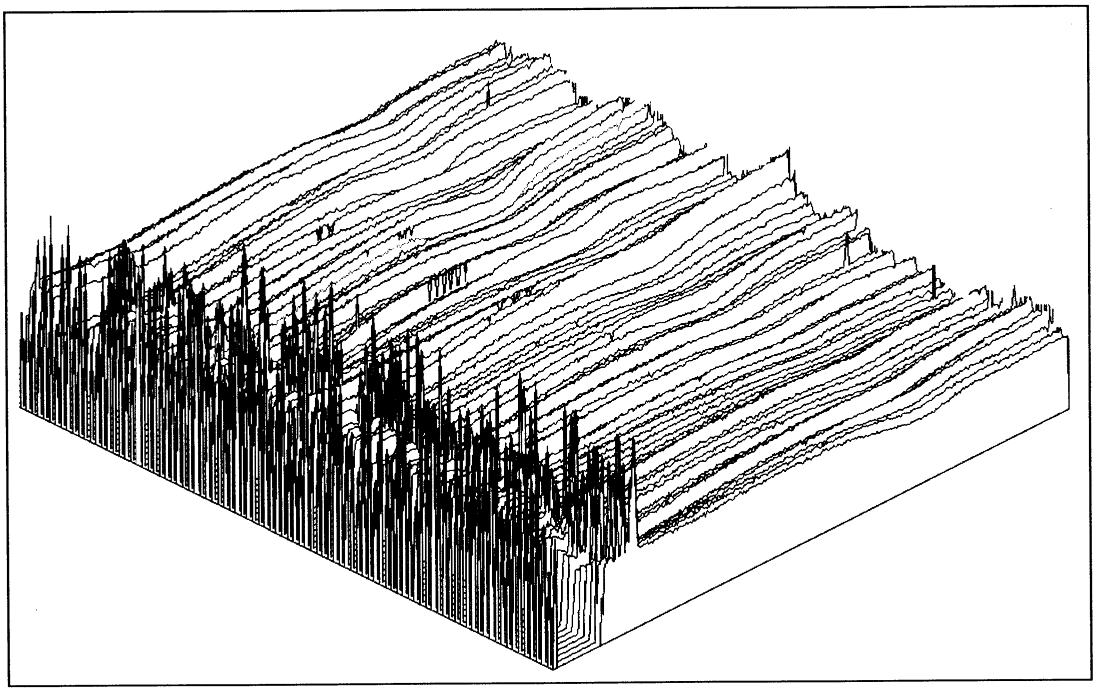

Figure 5. Three dimensional expression of traverse cross section profile

4.3 An approach to the evaluation of riding comfortableness

We are positioning the lengthwise profile data at the interval of 25 cm measured by RM 5 as the data compatible with the international roughness index (IRI) which is gathering attention as a new evaluation index of paved road.
So far, crack and rut have been the main factors to evaluate the deterioration of paved road, but more importance has been placed on the riding comfortableness in the recent years. IRI is an index proposed by the World Bank in 1986. The calculation is made by driving a quarter car model (abstract virtual vehicle made by using one wheel from 4 wheels of 2 shafts of car) on the measured profile, aggregating its output (displacement in the up and down movement), and standardizing by dividing the aggregated value by the length of profile; and the resulting value is aggregate roughness index, and the unit is shown in the form of slope (in / mile, m / km, mm / m, etc.). There is a tendency in the recent years to employ the riding comfortableness as an index to show the service ability of road pavement.
In the past, riding comfortableness has been evaluated by the flatness (volume of lengthwise asperities) but this data has low correlation with other measurement data, and it is said that the comparison cannot be made with the data of long cycled winding of highway to which high flatness is required as well as with the data of runway of airport. Also, it is not unified evaluation index to compare the measurement results of paved and unpaved roads. IRI index is said to be an index which provides comprehensive evaluation including these factors
As the biggest obstacle for the calculation of good IRI, it has been said that the noise component around 0.065 cycle / m (wavelength: 15.4 m) and 0.42 cycle / m (wavelength: 2.4 m) gives the greatest influence. The lengthwise profile data measure by RM 5 has won a specific evaluation for the calculation of IRI. However, it has become clear as a result of frequency analysis such as Fast Fourier Transform that the noise component becomes large at the high frequency of 0.50 cycle (wavelength: 2.0 m) or more. It is considered that this problem can be solved by enhancing the precision of calibration table such as the adjustment of frequency properties of sensor.

5 FUTURE DEVELOPMENT

5.1 Measuring characteristic of RM 5

The measuring accuracy of RM 5 is as shown in Table 1.

Table 1. List of measuring capacity of RM 5

	Crack	Rut	Flatness (vertical asperities)	Profile of extension Direction (lengthwise profile)
Measuring range	Width 4.0 m	Width 4.0 m	1 measuring line (OWP)	2 measuring line (OWP, IWP)
Measuring interval	Continuous	Minimum 50 cm	Minimum 25 cm	Minimum 25 cm
Measuring speed	0-80km/h	0-100km/h	0-100km/h	0-100km/h
Measuring condition	Dry, night time only	Dry, night time only	Dry, night time only	Dry
Measuring accuracy	1 mm or more of crack width	+/- 3,, against profile meter	+/- 30% against profile meter	+/- 10 mm / sampling interval

The qualification test is conducted at the rate of once a year to the road surface condition survey vehicles in our country. The judgment criteria of the test is the measurement accuracy factors from crack to flatness shown in the Table 1. Also, since the CCD camera used for recording is of 60 Hz, the measuring interval of flatness and lengthwise profile data becomes 50 cm at minimum and that of rut 100 cm at minimum when the speed of vehicle exceeds 54 km / hour.

As for D GPS, the accuracy of horizontal position is within +/- 10 cm, and that of height within +/- 1 m. As for the accuracy of height, it is not of the accuracy that can correct the INS data by the data received every second. In order to improve the accuracy of grasping road surface condition and aim at the full scaled acquisition of spatial information data, it should be necessary to lessen the dependency of measuring interval on the speed and to enhance the accuracy of GPS data which form the basis of coordinates data.

5.2 Issues in the future

RM 5 at present is equipped with an ability to acquire basic data necessary for mobile mapping, but has no ability to combine them and provide the data of higher added values. Namely, the data shown in Fig 6 are recorded simultaneously but are stored separately on different media. And they are analyzed and processed by different indoor processing machines.

The future issues necessary for acquiring spatial data using mobile mapping are pointed out in the following.

(1) Change in GPS measuring method

(2) Establishment of method to interpolate GPS data with INS data (at present, X, Y coordinates data are left uncorrected)

(3) Automatic extraction of necessary objects from digital image and real time measurement of its coordinates

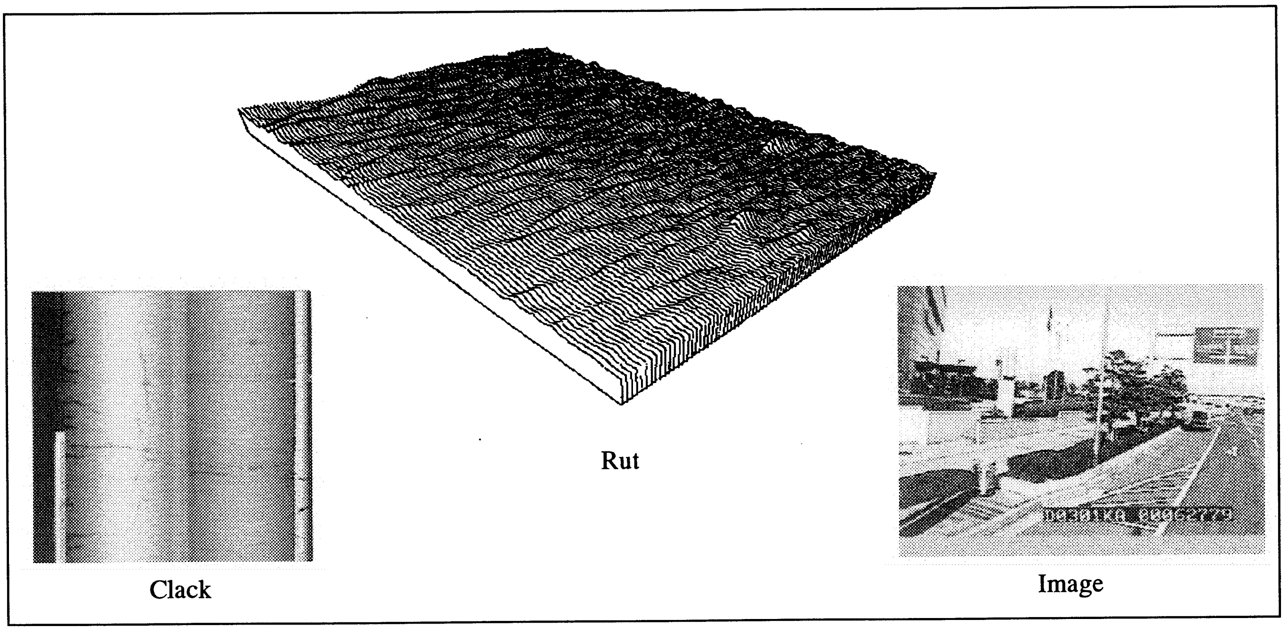

Figure 6. Data provided by RM 5

If these techniques and systems may have been developed, the following will be realized, which will contribute to the improvement of business efficiency.

(1) It will be possible to hazard (safety) information such as accident and congestion helpful for ITS based on the pavement surface profile information

(2) Provision of information relating to the position of crack on runway of airport

(3) It will be possible to enhance the level of navigation system such as provision of accurate information of the intersection of urban highways having the hierarchy structure

(4) It will be possible to obtain the coordinates of object from GPS, measure not only the road surface but also the position of road structures, and use these data for the correction of road facility maps

Lastly, the volume of data used for mobile mapping is huge. It is necessary to judge the propriety of these data on real time in order to measure the data of huge volume efficiently. Therefore, it should be necessary to place the real time processing of data always at the center of target of measuring technology development

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