DEVELOPMENT OF SIMPLE MOBILE MAPPING SYSTEM FOR THE CONSTRUCTION OF ROAD FOUNDATION DATA

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ABSTRACT:

Road Administration in Japan is now proceeding with the framework to realize smooth, safe and comfortable traffic by building up detailed spatial data of roadsides. Photographic survey and ground survey have been jointly employed so far for the measurement of spatial survey of roadside. However, it is difficult to construct the spatial data of urban areas in Japan at large scale because the aerial photograph has excessively many areas concealed by obstacles, and as a result, the burden of ground survey becomes too weighty. Therefore, there is a big problem in the increase of cost and maintenance of quality resulting from repeated implementation of aerial survey and ground survey.

In addition, there is a limitation in the applicable scope of GSP survey in the ground survey because of the influence of surrounding tall structures. As a result, the measurement is made mainly by total station (hereinafter called “TS”).

With such situations as a background, we developed the spatial data measurement using mobile mapping system and discussed the possibility of cost reduction and quality improvement. This system is composed of GPS / INS and position / posture sensor that measures vehicles as well as measuring vehicle equipped with stereo CCD area camera and PC which controls the camera and dedicated stereo mapping system.

In this presentation, we will show the outline of mobile mapping system developed by as and describe the items we discussed until the decision of system construction.

1. CONSTRUCTION

1.1 Background of system development

Among the information necessary for the road administrator to provide the services, keen attention is directed to the spatial data which have high commonality. These spatial data are the large scaled data conforming as much as possible to the geographic information standard, and it is planned to improve the efficiency of the business of road administrators and to provide the services with high added value to the residents through GIS system.

In general, aerial photograph survey which is excellent in the efficiency is used for the generation of spatial data of wide area, and ground survey is used for the concealed areas in the aerial photograph. We calculated the ratio of costs by process as shown in Figure 1-1 based on the experiences in the business of generating large scaled spatial data at a certain city. This was a business to measure the position information of the road administration structures located on the national road and add the attribute data thereon. This was an area having many dead angles in the aerial photograph (Figure 1-2).

As is clear from the Figure 1-1, the ratio of site survey is very large following the mapping / edition. In this business, the big problem was the increase of cost resulting from the repeated re-investigation at each process and maintenance of quality due to the site survey carried out by plural teams. And therefore, it is required to solve these problems in the construction of large scaled spatial data of urban areas.

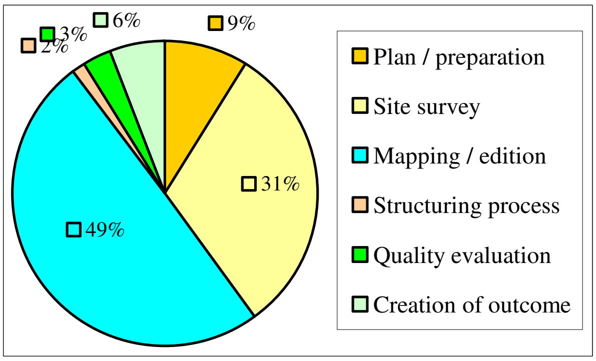

Figure 1-1: An example of cost to generate spatial data by the process

Figure 1-2: Image photograph of study area

1.2 Issues in generating spatial data of urban areas

The representative issues in constructing large scaled spatial data of urban roadside will be pointed as follows.

Limitation in the method of aerial measurement:
In the construction of spatial data at the level of 1 / 500, it has become clear that there are many areas where the photographic mapping cannot be applied, the role of supplemental site survey becomes high as a result, and it is difficult to construct the data because the processes of aerial measurement and site measurement are repeated in a complicated manner.
Limitation of GPS survey:
The methods such as RTK and VRS of GSP are expected to provide prompt measurement of many unknown points and improve the efficiency, but the measurement is made mainly by TS because the applicable scope of GSP is very small in the urban area due to the influence of surrounding structures. It is therefore difficult to take advantage of the superiority of GPS in the urban area.
Necessity of side survey:
In constructing the spatial data, it is necessary to investigate the attributes that the ground structures have, and therefore, it is necessary to implement the site investigation all over the subject area. If any omission is found to the investigation, it is inevitable to make re-investigation, and if the number of data confirmation increases, the cost will be come higher as a matter of course.

1.3 Development policy and expected effect

In order to solve the issues stated in the above, we aim to construct the spatial data generation system by adding mobile mapping technology to aerial photograph survey technique and ground survey technique. There is a tendency as its background that free conception is required to reduce the cost, improve the quality and enhance the added value. Namely, it is required to select the method according to the degree of quality required for each ground structure instead of seeking for high precision uniformly regardless of the objects. This is based on the notion to place importance on the quality as the cost performance will not be preferable if the method is limited.
The effects expected to the mobile mapping technology are as follows.

(1) Role as the supplemental data to aerial photograph
This technology has the role of supplemental data to aerial photograph by measuring from the ground the objects concealed by forest or high bridge in the aerial photograph.

(2) Improvement of efficiency of ground survey
GPS has problem in use at urban area if it is used alone, but it is possible to acquire continuous position information by integrating it with IMU of automatic navigation system. And therefore, it is possible to improve the efficiency of ground work which is one of the issues of TS survey.

(3) Reduction of site complementary survey
The reproducibility of the site can be easily maintained by recording the situation of site in detail, and the cost of investigation will be reduced as the re-investigation of site is avoided.
As stated in the above, it is possible to widely reduce the production processes and production cost of spatial data by developing the mobile mapping technology.

2. OUTLINE OF SPATIAL DATA ACQUIRED

2.1 Structure of spatial data

The spatial data to be acquired is defined by the data specifications conforming to the international standard (ISO / RC211) and has the basic structure as shown in Figure 2-1.

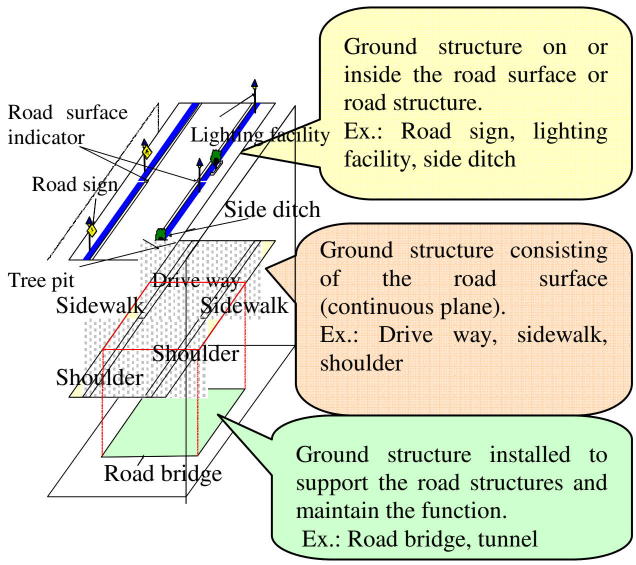

Figure 2-1: Basic structure of spatial data

2.2 Information about the acquisition of spatial data

Acquisition information of spatial data is the following attribute information.
Spatial attribute:
Indicating the coordinates and shape of ground structure
Thematic attribute:
Indicating the type of ground structure
Temporal attribute:
Date of construction, etc.
Besides the above, there are definitions about the relation among the ground structures. Since the lighting equipment, signal and sign are added on the pole shown in Figure 2-2, there is a relation between these ground structure and the pole, and therefore, it is necessary to acquire the information about such relation.

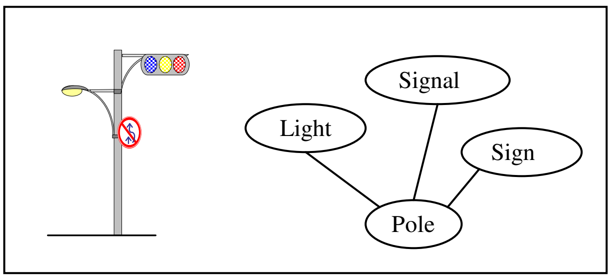

Figure 2-2: Example of relationship among the ground structures (pole)

2.3 Measuring accuracy of spatial data

The measuring accuracy of spatial data is as follows (Figure 2-1).

(1) 25 cm or less (accuracy at the level of 1 / 500) in case of the border line of ground structure (edge of road or sidewalk, edge

of road shoulder, etc.) which consists of the road surface having the area

(2) 70 cm or less (accuracy at the level of 1 / 1,000) in case of the facilities (telephone pole, manhole, etc.) located on the road
The accuracy at the level of 1 / 500 or 1 / 1,000 means the value specified in Public Survey Work Regulation of the Ministry of Land, Infrastructure and Transport..

3. REQUIREMENTS OF DEVELOPMENT

The conditions precedent and requirements for the development of mobile mapping technology are as follows.

3.1 Condition precedent

(1) Study area
The study area is the road area. There are high bridge and multi-level crossing over a part of road, and these portions are concealed in the aerial photograph taken from the above. Therefore, it is necessary to acquire the data of these parts.

(2) Speed of vehicles
In the general national road, the vehicles are not allowed to stop on the car lane excepting at the time of stop signal at the crossing of congestion of traffic. As a result, measurement is made while the vehicle is traveling, and therefore, the photo shooting distance will vary according to the speed of vehicle if the shutter interval is fixed.

3.2 Requirements of system development

(1) Scope to be measured
The spatial data to be measured are located at every direction as shown in Figure 3-1, and therefore, all of these information must be measured.

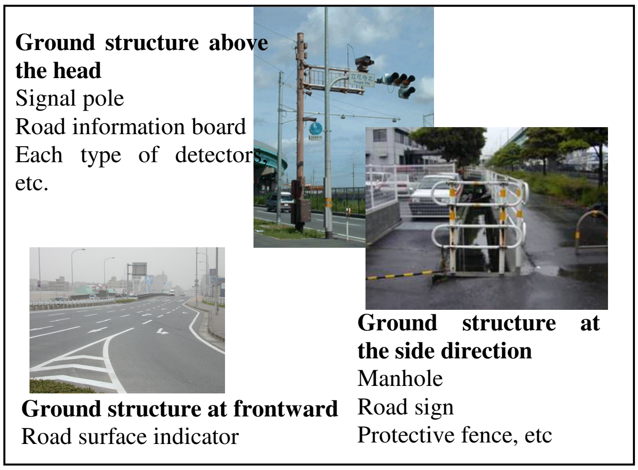

Figure 3-1: Scope of measurement and spatial data to be measured

(2) Maintenance of measuring accuracy
As stated in Section 2.3, the measuring accuracy is as follows.

1) 25 cm or less in case of the border line having the area such as the edge of road or sidewalk and the edge of road shoulder

2) 70 cm or less in case of the ground structure on the road such as telephone pole, manhole and toad sign

The accuracy will not be uniform but vary according to the type of ground structure.

(3) Necessity to measure the attributes of ground structures and relation information
As stated in Section 2.2, it is necessary to acquire thematic attributes and relation information of the spatial data.
For example, the acquisition of classification or code number is specified by regulations for the guide board and road sign that indicate the destination, and therefore, the measuring method must be able to identify these numbers. Also, as for the acquisition of relation information, it is required to identify the ground structured added to the pole (sign, signal, etc.).

(4) Must be compatible with photographic survey and ground survey
We do not expect that all the spatial data will be completed by the mobile mapping technology. Cooperation is necessary with other measuring methods in order for the efficient measurement, and therefore, it is necessary to have compatibility with the data acquired by other methods.

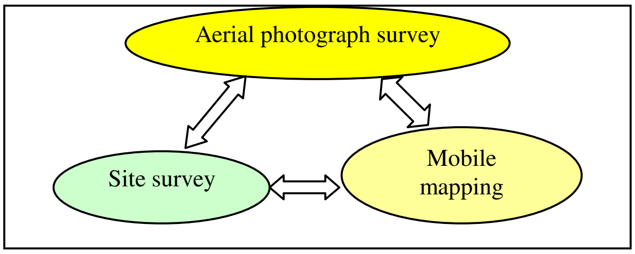

Figure 3-2: System of spatial data generation

4. DISCUSSION ON THE SYSTEM CONFIGURATION

The basis of the mobile mapping system to be developed is to calculate the correct position and posture of platform (automobile) using GPS / IMU technology and acquire the spatial data of ground structures located at roadside (attribute information such as position, type, shape, etc.) by non-contact type measuring sensor mounted on the platform.

4.1 Discussion on the system configuration

In discussing the system configuration, we must select the objects measuring sensor and position self measuring sensor to be mounted on the platform. We also discuss the method to synchronize each sensor and the measuring vehicle which is used as the platform, as well as their installation method.

(1) Selection of objects measuring sensor
In a rough classification, there are area sensor and line sensor as the method of non-contact measurement of the ground structures on the roadside. The characteristics of these sensor are shown in Table 4-1. As the condition for selection, it is pointed out that the sensor should have enough spatial resolution to identify the detailed characteristics of ground structures. The digital video sensors are excluded because their spatial resolution of image is insufficient.

Table 4-1: Comparison of area sensor and line sensor

Item of comparison	Area sensor	Line sensor
Measuring method	Stereo mapping is possible (interpreted by person)	Stereo mapping is difficult (mainly automatic processing)
Visibility	Same as ordinary photograph	It is difficult for human being to understand
Condition for system development	It is possible to use existing mapping system	It is difficult to develop the automatic processing system
Handling of data	Only the management of stereo image pair and is easy	Management is difficult because it depends on traveling speed
Spatial resolution	A little low comparing with line sensor	There are larger number of pixels per line

As a result as shown in the above, the area sensor is more advantageous because the spatial attributes can be acquired using existing mapping system and system development is easier. Also, although the spatial resolution is a little inferior, it can be supplemented by the shooting interval of stereo images. Therefore, we will start developing employing the area sensor.
When the area sensor is used for stereo measurement, long base line is necessary as much as possible to enhance the accuracy of depth direction. However, since there is a restraint that the sensor is mounted on a vehicle, 2 m is considered to be the limit for the base line. Seeing from the experiences obtained from applied photograph measurements, the ratio from 1 / 5 to 1 / 20 is realistic as for the ratio between base line length and photo taking distance, and as a result, the measuring range is necessarily limited to 10 ~ 40 m.
The biggest problem in measuring objects is the spatial resolution resulting from the distance to object and focal length of lens. The smallest ground structure on the road is eye induction indicator of 3 cm in width, and it is necessary to identify this line on the image. The level of 2 million pixels is required as the area sensor that can realize this requirement.
When the vehicle is driven at the speed of 40 km per hour, the car travels 11 m per one second (Figure 3-3). Since the range where stereo photographing is possible is 30 m (10 ~ 40 m), it will be possible to cover overlapping rate and total line based on the work efficiency if the photograph is taken at the rate of one picture per one second.

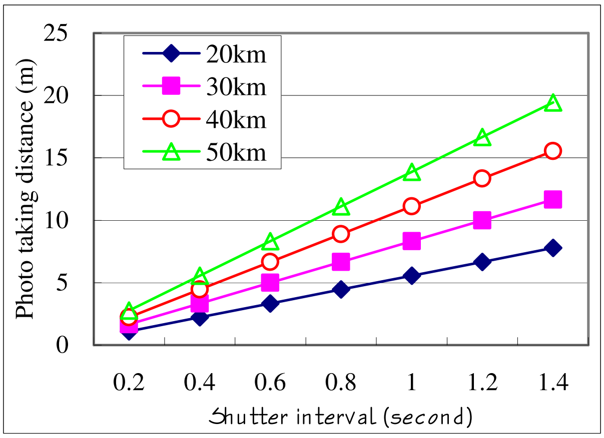

Figure 3-3: Shutter interval and photo taking distance of camera sensor

(2) Selection of position self measuring sensor
Since the required accuracy is within 25 cm as stated in the section of requirements for development, the accuracy of a few cm is required for the position coordinates of camera acquired by the position self measuring sensor. POS / LV system made by Applanix is appropriate to realize this requirement. This system is able to record GPS data of 1 PPS and IMU data of 200 PPS. There are three models of POS / LV 420, 320 and 220 in the products made by this company, and the high end model of POS / LV 420 is considered to be most proper taking into account the reduction of accuracy due to concealment of GPS.

(3) Time synchronization of cameras
It is an important problem to synchronize the time among 2 stereo cameras and position self measuring sensor. To solve this problem, we will adjust the timing of action of each equipment using trigger generator. This trigger generator activate picture shooting trigger using the GPS data of 1 PPS outputted from POS / LV described in the above as the reference time. Each stereo camera receives this synchronization signal and activates the shutter of digital camera. In this way, time synchronization is realized using the GPS time as the key.

(4) Selection of measuring vehicle
In this section, we will discuss the measuring vehicle (car) used as the platform of this system.
* Higher position of sensor installation is preferable to reduce the influence of obstacles (car height).
* The longer base line of stereo measurement is desirable to secure the accuracy of depth direction (car width).
* As for position self measuring sensor, the longer base line using 2 GPS for the correction of heading angle is preferable (car length).
* Special large sized car is not realistic from the viewpoint of cost and operation.
By the reasons stated in the above, one-box wagon is considered to be most proper as the type of measuring vehicle.

(5) Installation method of each sensor
In this system, stereo camera and position self measuring sensor (GPS / IMU) are mounted on the measuring vehicle. In order to determine the position and inclination of camera sensor accurately, it is necessary to mount these sensors on one solid body and maintain the relative position among the sensors. For this purpose, a roof carrier commercially available is equipped on the top of measuring vehicle, a highly solid rack is installed on it, and all the sensors are fixed on the rack. By measuring the relative positional relation among the sensors in advance, the information of position and posture obtained from position self measuring sensor can be correctly reflected on the information of camera position.
Two-way observation will be the basis for the actual measurement. Namely, measurement will be made on only the ground structures at the traveling lane and those at the opposite lane will be neglected. As a result, the ground structures to be measured are distributed mainly at the left frontward direction, and therefore, it would be appropriate to install the stereo camera so as to face the left frontward direction.

4.2 Discussion on the data analysis and processing system

(1) Stereo image photographing system
Stereo image photographing system is composed of host PC and trigger generator, and is required to have the following functions.

* Image display function: Necessary to confirm the image quality (photographing range, focus adjustment)
* Function to control synchronization signal: Control of trigger generator (control of start and stop of stereo image photographing)
* GUI application is necessary to operate the above functions.
The problem in recording high resolution digital image is the time to write the data on HDD, and therefore, it is desirable to install PC exclusively used for image recording. The risk of frame missing is reduced by making image recording PC independent from image display PC. Furthermore, the time loss of writing on HDD can be reduced by distributing the tasks to plural PC's.

(2) Calibration inside the camera
The internal correction value will be measured for each stereo camera. It is essential to maintain the required measuring accuracy as the cameras used are not measuring camera and wide angle lenses are used. The correction value is measured for the following items.
*Focal length
*PPS (principal point of symmetry)
*PPA (principal point of auto collimation)
*Radial distortion
Photographic measurement software sold on the market will be used for the measurement of correction value. The correction value measured in this way will be inputted as the correction term of camera data by the stereo measuring system described later.

(3) Calibration outside the camera
External position correction value is measure for stereo camera by the following procedures.
* Establishment of reference point site
The reference point site will be established. This reference point site is established to work out position of stereo camera by spatial backward intersection. About 8 points having depth against the stereo model will be set up as the reference point and measured by total station, etc.
* Measurement of position and inclination of vehicle
Position self measuring system and stereo camera are mounted on the vehicle and reference points are photographed in stereo. At the same position, the position rotation angle of measuring vehicle is measured by the position self measuring system.
* Calculation of correction value
The external position of each camera is calculated by spatial backward intersection from the stereo image photographed and coordinates values of reference point group. Also, the external position of vehicle origin point (IMU) from the calculation value of position self measuring system, and the three dimensional relation between two external positions calculated will be taken as the correction value.
The correction value measured will be inputted as the correction term for the post processing made by position self measuring sensor.
Secular change is expected to this correction value due to physical factors such as attachment and detachment of camera. Therefore, it is desirable to establish the reference point site for correction value measurement on permanent basis and operate them under consistent environment.

(4) Position self measurement and processing system
As POS / LV 420 is used as position self measuring sensor, the analysis and processing software of Applanix will be applied. This software is composed mainly of following three functions.
* GPS analysis and processing function
Analyzes and processes the GPS data of 1PPS sent from ground GPS key station and GPS mobile station.
* Integration processing of GPS and INS
Supplements the analyzed and processed GPS data of 1 PPS with IMU data of 200 PPS and generates three dimensional locus data of 200 PPS.
* Referencing process of external position
Calculates the external position factors of each image including external position correction value of camera (three dimensional offset amount from IMU) into the three dimensional locus data of 200 PPS.

(5) Stereo measuring system
The following functions will be equipped with stereo measuring system based on the requirements for development.
* Function to generate patch of stereo pair
Function to connect GIS data and stereo image data with the GPS time as the key. Also, the function to search for the photographing pair of the same time and automatically generate the stereo pair parameter.
* Measuring system platform and data format capable of mapping and site survey as well as data exchange of bilateral direction
Not only the input and edition of geometric figure but also input of attributes will be made possible. It will also be made possible to directly supplement the portion that could not measured by aerial photographing survey. In addition, it will be made possible to input the site investigation to both of aerial photographing survey and this system.
* Function to retrieve the stereo model
It is required to retrieve the necessary stereo pair from several thousands of image files. The function to retrieve GIS-like stereo model with the location and time sequence as the key
* Function to automatically convert the reference coordinates group of measurement
The function to automatically convert the difference of reference coordinates group between the aerial photographing survey and close photographing survey
* Input and edition interface
The interface of input and edition tool used for aerial photographing survey, site investigation and this system will be standardized. As a result, the discrepancies among the various processes and workers will be reduced and seamless working process will be realized.

5. DISCUSSION RESULT OF MOBILE MAPPING SYSTEM AND CONSIDERATION RELATED THERETO

5.1 System configuration employed

In this Section, the overall configuration of mobile mapping system is shown in Figure 5-1 and the configuration of measuring vehicle in Figure 5-2.

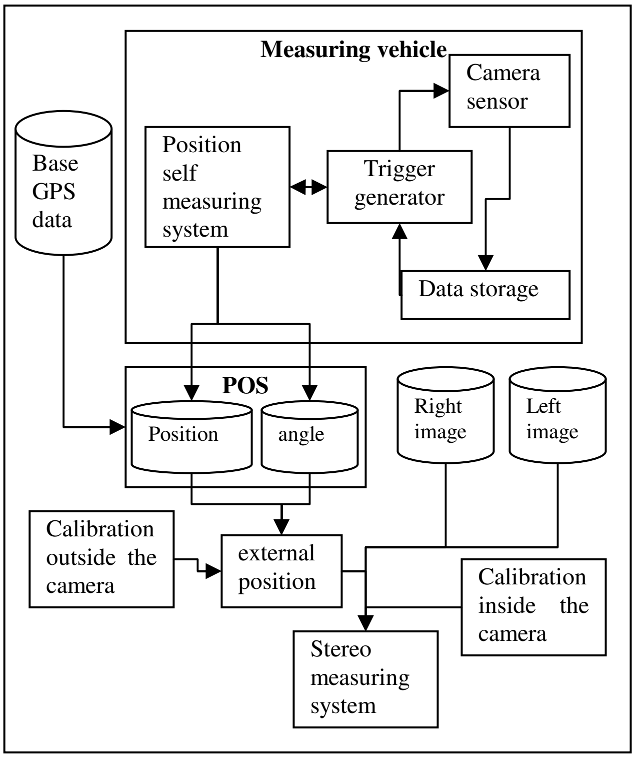

Figure 5-1: Outline of mobile mapping system

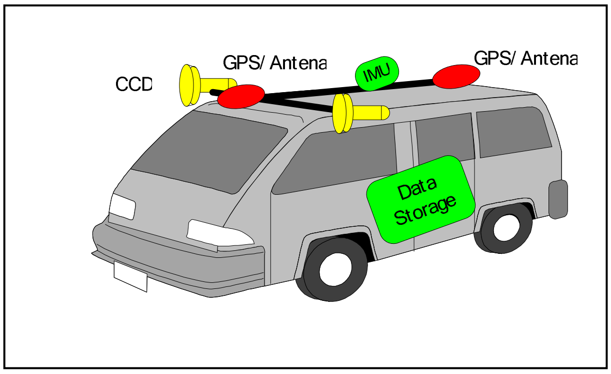

Figure 5-2: Image of measuring vehicle

As a result of discussion in Chapter 4, we decided the configuration of each system as follows.

5.2 System configuration (hardware)

* Stereo camera system 1 / F: Dalstar 2M30SA
* POS (GPS / IMU device): Applanix POS / LV 420
* On-board controller, image storage: Trigger generator, data recording PC

5.3 System configuration (software)

* Position self measuring software: Applanix POS processing
* Calibration software: Photo-Modeler 5.0
* Data integration and measuring software: Dedicated mapping system and data control system

5.4 Evaluation of system configuration

We evaluated the following items referred to in the system requirements.

(1) Maintenance of measuring range
As the object ground structures are distributed at all the areas of car lane, we decided the following items covering the front side, upside and flank side (sidewalk) of the road.
* Stereo camera will be installed so as to face the left frontward.
* Measurable distance will be 10 ~ 40 m by maintaining the stereo base line at 2 m, and stereo measurement of all area of car lane is possible at the sampling rate of one shot per one second if the speed of vehicle is 40 km / h.
As a result of discussing the conditions to satisfy the development requirement, it has become clear that a simple system using 2 sets of camera sensor will be adequate, by which the developing cost will be significantly reduced.

(2) Maintenance of measuring accuracy
Applanix POS / LV 420 will be used for position self measuring sensor and analysis processing, and 2 million pixels will be employed for camera sensor to accomplish the measuring accuracy of 25 cm. It is expected that the necessary accuracy of this system will be maintained by these outfits.

(3) Acquisition of attributes information of ground structures
The stereo measuring system makes it possible to input the attributes in addition to the input and edition of position information of ground structures. In addition, related information of ground structures can be added to this function, and as a result, it will become possible to measure all the information of spatial data to be acquired by one tool.

(4) Compatibility with existing survey techniques
This stereo system realizes the functions of data management and mapping as well as the site survey and bilateral data exchange. As a result, it is possible to dispense with troublesome work of data conversion and improve the efficiency of works, and it is expected to enhance the quality by avoiding the errors at the time of conversion.
In addition, the efficiency will be enhanced with this stereo measuring system as it realizes the processing of plural coordinates groups that has been difficult with the mapping system currently commercially available.

6. SUMMARY

In developing the mobile mapping system, we extracted and discussed the assumed issues and decided the system to be employed. As a result, this system is composed of measuring vehicle, stereo image photographing system, camera calibration system, position self measuring and processing system and stereo measuring system, and satisfies the development requirements.

However, this system is at the stage of development and the comprehensive verification is yet to be made now. Therefore, the issue in the future is to conduct the verification experiment and evaluation at the stage where the initial development is completed.

7. BIBLIOGRAPHY

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