DEVELOPMENT OF ROAD INFORMATION SYSTEM USING DIGITAL PHOTOGRAMMETRY

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ABSTRACT

Lately, digital photogrammetry based on the principles of photographic survey has been more and more applied to various high-tech industries and becomes one of more interesting focuses of study than ever.

Thus, this study aims to develop a roadway information system by means of digital photogrammetry. Data acquired from digital photogrammetry were processed via Delphi, an object-oriented programming language to develop a computer aided program, that allows us to build up the information on road horizontal alignment(BC, EC, R, IP), road vertical alignment and road facilities. And the developed program could maximize the visual effects better than traditional programs, because it used many image data.

1. Introduction

In modern society, the road is an essential SOC and the multipurpose national facility which is used as the space for national underground facilities and the space of disaster prevention, and forms urban residence (Lee, 2000) .Currently, lots of road expansion and paving works are ongoing to prepare for the increase of traffic volume and to secure safety of road transportation. Sometimes, important data on such roads that was completed long before were destroyed or lost in the process of being relegated to other department. For those roads, it takes much time and cost to obtain basic information (Gillieron.et.al,2001) .

Especially, current increase of traffic volume made it unsatisfactory to use traditional road survey method in obtaining road information. There were many studies to produce road information by attaching GPS to mobile vehicles, but those couldn't secure the visual view of roads, but only produced 3-dimensional position information(Domenico et al., 2001, Ellum et al.,2000,2001)

When using digital photogrammetry to determine the 3-d position of an object, such a method that inputs camera position in approximate value and then calculates the position through space intersection and space resection has many problems(Hobib,2000).

In this study, mass of information from DGPS was used to determine the shooting point of digital photogrammetry. Instead of attaching marks to the target road, natural points were used as orientation ones, and then evaluated whether or not the accuracy was within admittable range. Through digital photogrammetry, the author obtained the 3-d position of the road of which design information was not available, and a set of road alignment information and facility information with which roads could be efficiently and economically managed in case it is required to increase the visual effect of roads for maintenance and to construct and improve the road facilities for ensuring of safety. To provide basic information for new construction and repairing of the facilities, the author developed a software program to educe plane and profile alignment information of road using Delphi, an objective-oriented language, and made a sub program to get facilities information so as to identify both image and position information for road safety. This process is shown in Fig. 1.

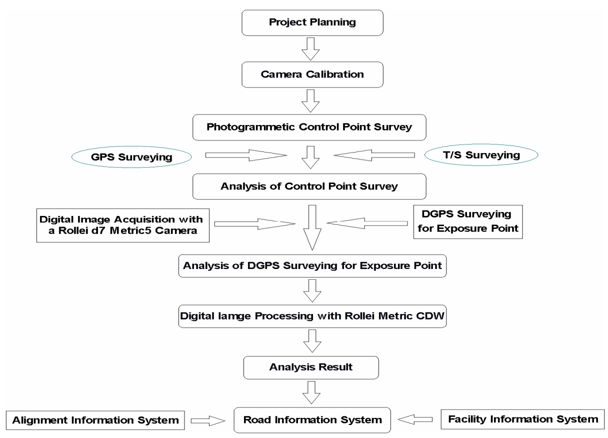

Figure 1**. The flow chart of study**

2. Theory of Multi Image Orientation of Digital Photogrammetry

Orientation of multi image rectification refers to calculating on both camera position(X_c, Y_c, Z_c) and spinning elements(ω, φ, κ) of various photos and objects, that is to calculate the coordinates of object over orientation point. It is divided into inner and outer orientation (pollefeys et al., 2000).

In multi image rectification, both space intersection and space resection are used at the same time for orientation. And, the following is used: photo coordinate of orientation point, approximate outer orientation elements inputted from sketch, inner orientation elements of camera from self validation, exact outer orientation of photo, and determination of coordinate system of object for calculation of coordinate of the object on orientation point (Wolf, 1999).

Space intersection is a photogrammetric calculation method based on the cross of light in 3-dimensional space, which calculates the common orientation point of object from outer orientation and coordinates of the two sheets of photos and then determines exact outer orientation. It is like Fig. 2. Space resection is to determine a spacial position by crossing toward at least 3 direction at the point equal to one already known. It determines the outer orientation of a photo from both the object coordinate on the base and the photo coordinate on at least 3 orientation points. It is shown in Fig. 3.

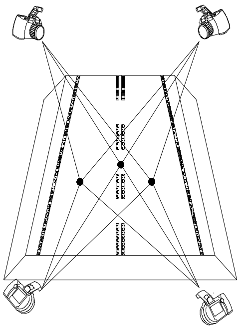

Fig. 2. Space intersection

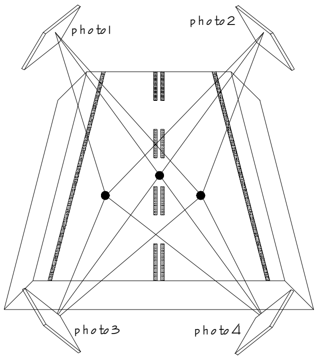

Fig. 3. Space resection

3. Survey of Road Center Line using Digital Photogrammetry

3.1 Survey and analysis of ground baseline measurement

For precise positioning of ground control point in the target area, two trigonometric points in the environs, □309 and □422 were surveyed using GPS static positioning method for every 10 seconds over 1 hour, of which GPSs are shown in Fig. 4. The receiver used in the survey of control point and shooting point was a GPS receiver of JAVAD co., which is able to receive L1/L2 C/A code and P code, and carrier phase and has the specification in Table 1. Fig. 5 shows the trigonometric network. When observing two points(B43, B47) in the target area with two trigonometric points fixed, satellites more than 5 were observed, and PDOP was 2 ~ 4, indicating stable observation. The observation error was σx= 20.1mm, σy= 16.1mm, σz= 42.8mm for the control point of B43, and σx= 24.6mm, σy= 19.0mm, σz= 50.5mm for the control point of B47. The Korean cartesian coordinate of this is like table 2.

Fig. 4. The type of triangulation Station

Table 1. Speification of GPS Receiver

Receiver	Legacy - H
Channel	20 Channel, GPS L1,L2 , GPS L1/L2
Signal	GPS L1/L2(L1-CA and L1/L2- Full Cycle Carrier Phase, P1/P2)
Accuracy	Vertical 3mm+ 1ppm, Horizontal 5mm+1ppm

Table 2. Adjusted Coordinates of TM(Grid , Zone Korea)

Point Name	Coordinates (m)			Sigmas (m)		
	North	East	Orto H	s(X)	s(Y)	s(Z)
B43	179364.4965	209349.7402	69.9206	0.0201	0.0161	0.0428
B47	179302.7072	209400.5448	70.9263	0.0246	0.0190	0.0505
□422	184236.8118	207407.7793	427.6300	0.0	0.0	0.0
□309	179821.0928	211051.9423	224.6000	0.0	0.0	0.0

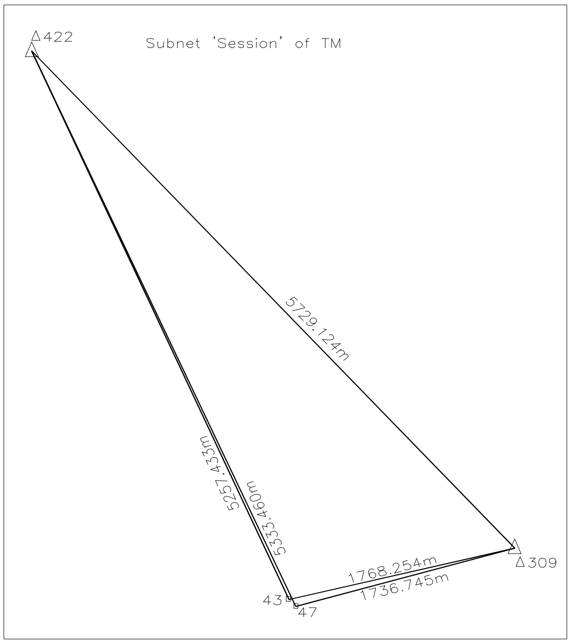

Fig. 5. The shape of Session

In the study, for a precise measurement of ground control point in the target area, the two control points, B43 and B47 rectified after triangulation using GPS were marked around the target road, and then measured using Total Station, a recently developed equipment. 78 points at 5m interval on the road center line, which were used as the control points, were measured with Total Station, and their 3-d coordinates were determined with Total Station as the first overlapped photo needed at least 7 orientations for multi image orientation .

3.2 Obtaining and analysis digital image

A road near Youngdang-dong, Nam-gu, Pusancity, in Korea was selected as the observation area to educe road plane alignment information using digital image. The observation area was to be such a place that traffic volume is comparatively heavy and both curve and straight line exist for smooth alignment information. The area in the study is shown in Fig. 6. Equipment used in obtaining the 3-d image of the area was a tripod as in table 3, which is able to extend to 3m in height for shooting the road surface. To shoot along with the road center line, a self-manufactured mobile vehicle was used to facilitate movement. These observing equipments are in Fig. 7. The road was shoot using digital image to get the plane information. As general roads are long to longitudinal direction, the road in the study was divided into 14 zones at 15m intervals as in Fig. 8, and shoot at the 4 corners. To secure the continuity of the road, each zone was shoot in a way that it is somewhat overlapped. Not attaching targets to the road, 139 natural points were used as orientation points.

Digital images of 56 images and 139 orientation points were taken and then processed with RolleiMetric CDW, a digital photogrammetry software program. The results from bundle adjustment are in table 4, which shows the RMSE of 3-d coordinate to zone. Its schema is like Fig. 9. Why Zone-11 and Zone-12 have large error to Y axis is thought that shooting was done at curve area of the road.

To analyze the accuracy of 3-d coordinates determined with multi image orientation and bundle adjustment, 20 check poits were used in comparative analysis. The results are as in table 5. Average error of the 20 examination points was 0.0203m to X axis, 0.0209m to Y axis, 0.0513m to Z axis, of which schema is like Fig. 10.

Table 3. Speification of Rollei d7 metric[5] Camera

Classification	Rollei d7 metric[5]
Recording mode	CCD recode
Shutter	1/8,000 sec
Focal Length	7mm
Dimensions	151×102×106 mm
Weight	650g (without batteries)
Pixel in X	2,552
Pixel in Y	1,920


Fig. 6. Observation Area


Fig. 7. Observation Equipment

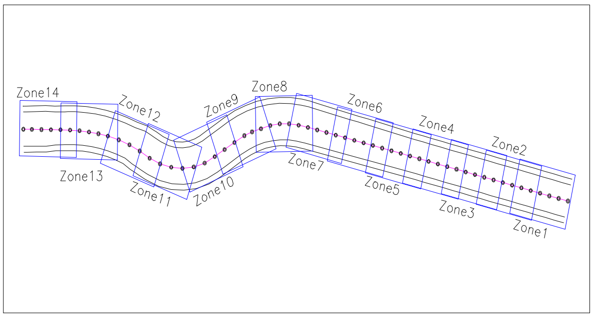

Fig. 8. Zone of Observation Area

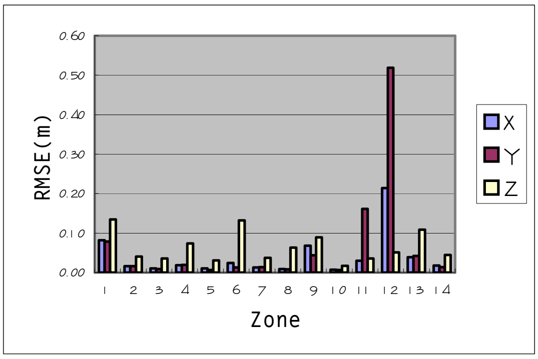

Fig. 9. RMSE of bundle adjustment

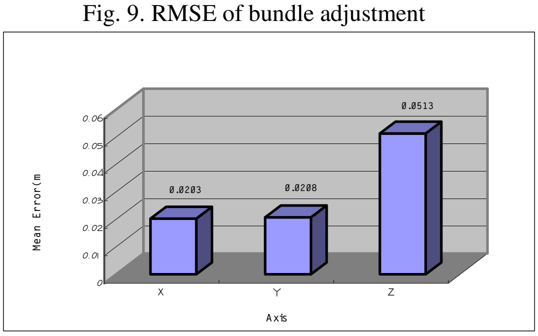

Fig. 10. Mean error of check points

Table 4. RMSE of bundle adjustment

Zone	RMSE		
	X	Y	Z
1	0.0815	0.0790	0.1348
2	0.0162	0.0165	0.0408
3	0.0104	0.0092	0.0355
4	0.0183	0.0191	0.0738
5	0.0105	0.0067	0.0305
6	0.0244	0.0133	0.1324
7	0.0132	0.0134	0.0377
8	0.0091	0.0083	0.0629
9	0.0685	0.0440	0.0888
10	0.0072	0.0065	0.0172
11	0.0304	0.1613	0.0357
12	0.2141	0.5190	0.0507
13	0.0388	0.0421	0.1084
14	0.0177	0.0136	0.0449
Average	0.0400	0.0680	0.0639

Table 5. the residuals of check point

No.	Total Station			Rollei d7metric[5]			v_x(m)	v_y(m)	v_z(m)
	X(m)	Y(m)	Z(m)	X(m)	Y(m)	Z(m)			
1	178943.403	209463.129	75.366	178943.403	209463.130	75.487	0.000	0.001	0.121
2	178940.523	209462.546	75.448	178940.548	209462.642	75.556	0.025	0.096	0.108
3	178937.515	209461.947	75.522	178937.545	209462.014	75.582	0.030	0.067	0.060
4	178896.318	209454.182	75.604	178896.473	209454.204	75.682	0.155	0.022	0.078
5	178893.487	209453.612	75.554	178893.641	209453.642	75.693	0.154	0.030	0.139
6	178881.827	209451.349	75.274	178881.743	209451.333	75.352	-0.084	-0.016	0.078
7	178822.556	209440.311	72.435	178822.630	209440.267	72.625	0.074	-0.044	0.190
8	178947.988	209456.084	75.322	178947.8504	209456.1929	75.317	-0.138	0.109	-0.005
9	178944.815	209455.412	75.416	178944.8207	209455.5418	75.487	0.006	0.130	0.071
10	178938.915	209454.383	75.563	178938.8207	209454.4087	75.488	-0.094	0.026	-0.075
11	178930.302	209452.675	75.655	178930.3075	209452.676	75.735	0.005	0.001	0.080
12	178924.314	209451.578	75.815	178924.3347	209451.561	75.721	0.021	-0.017	-0.094
13	178912.461	209449.251	75.816	178912.6045	209449.2794	75.824	0.143	0.028	0.008
14	178897.470	209446.318	75.624	178897.4698	209446.318	75.682	0.000	0.000	0.058
15	178894.628	209445.757	75.557	178894.7396	209445.6318	75.707	0.112	-0.125	0.150
16	178782.780	209439.946	70.400	178782.6096	209440.0484	70.551	-0.170	0.102	0.151
17	178766.098	209448.535	69.726	178766.0932	209448.5366	69.788	-0.005	0.002	0.062
18	178763.163	209449.223	69.617	178763.1594	209449.2177	69.788	-0.004	-0.005	0.171
19	178695.049	209431.026	70.831	178695.0859	209431.0279	70.695	0.037	0.002	-0.136
20	178676.992	209430.263	71.795	178677.1307	209430.2688	71.606	0.139	0.006	-0.189
Average							0.0203	0.0208	0.0513

4. Development of Road Information System

4.1 Creation of road information materials

It is creation of road information materials that is first required for development of road information system using digital photogrammetry. In the study, road information materials obtained through digital photogrammetry were treated according to the flowchart of Fig. 11. In the flow chart, firstly, road information materials are read from digital files, with which variables are initialized. This is executed twice from the beginning to the end of the file, and then each record is saved to an array. Each is cut to a given order and then saved as the value of variable. The number of records is automatically counted, and execution is repeatedly performed as many times as the number of records. Repeatedly processed values are saved to each variable, and finally to the file Roadf. Next is exit.

The screen views the number and the coordinate of the data, as well as image. This view is like Fig. 12.

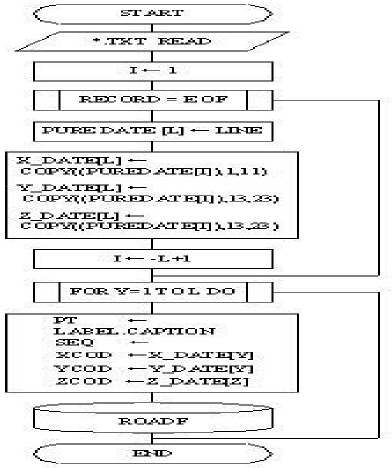

Fig. 9. Developed system of flowchart

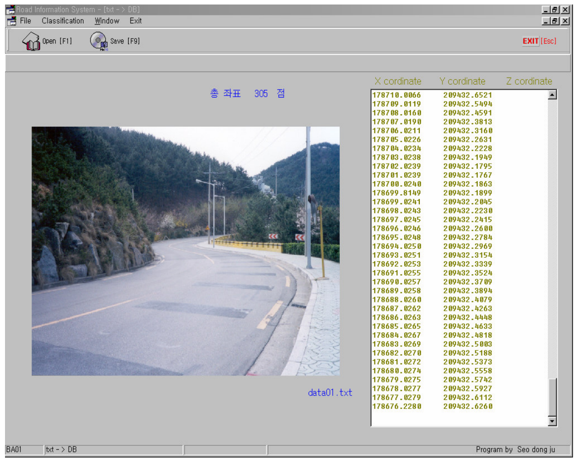

Fig. 10. Developed system of data formation

4.2 Development of road alignment information system

Road alignment information system is composed of plane and longitudinal alignment information. First, plane alignment information was retrieved. Data for the plane alignment was the figures from digital photogrammetry. The developed plane alignment information system is like Fig. 13. BC, EC, IP, R calculated through observation is in Fig. 15. Execution result of the program is in Fig. 14, in which the position of IP coordinate is blinking in the top left of the screen.

Development of longitudinal alignment information system used 3-d values from digital photogrammetry. The road longitudinal alignment information system developed in the study is like Fig. 16. The program views data selection in the left, alignment diagram in the top left, and longitudinal information in the top right. Calculation button moves CANVAS to the DB coordinate to express the alignment diagram, and click of the ground level on a specific point of the grid views the data and the alignment of the 18 points after selected point.

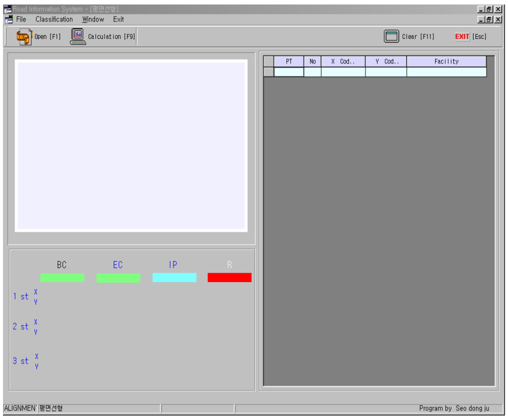

Fig. 11. Horizontal alignment information system of initial screen

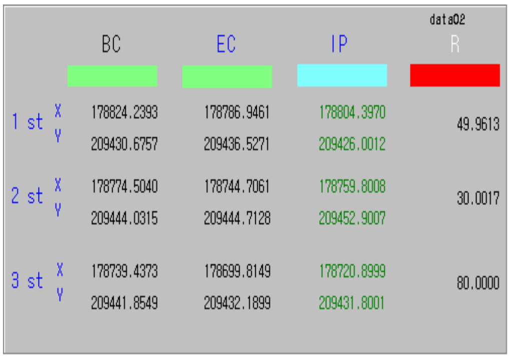

Fig. 12. Result of BC, EC, IP, R

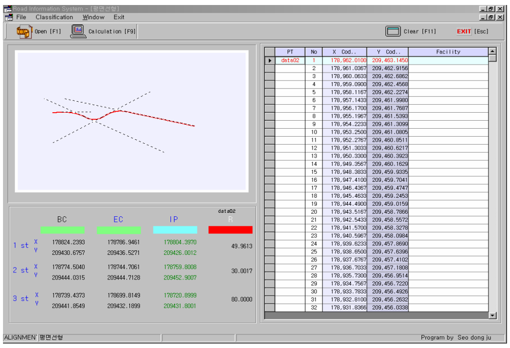

Fig. 13. Horizontal alignment information system

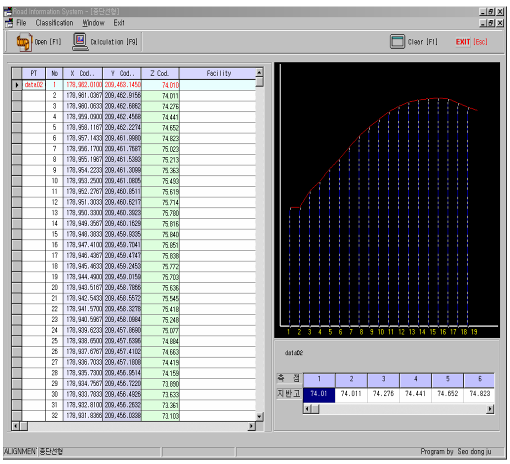

Fig. 14. Vertical alignment information system

4.3 Development of Road Facilities Information System

A facilities information system was developed to maximize visual effect on the facilities installed on a road. In the data input of the facilities information system developed in the study as in Fig. 17, OPEN button pops up a dialog box to select a data in DB. View is composed of 4 sections; top left, bottom left, top right, and bottom right.

Top left views the real local photo of the data in DB, and top right views. the digital topography of the target area. Bottom left expresses the scattering of data onto grid in which each point records and saves the attributes of facilities on it. Bottom right views the close-up of a point on the photo in top left when clicked with mouse. Addition of the study is that road manager takes the motion picture of the present status of the road and makes it available so that users can grasp the present status of the road. Also, road managers take the road pictures over time and save them as motion picture. This motion picture module is in Fig. 18.

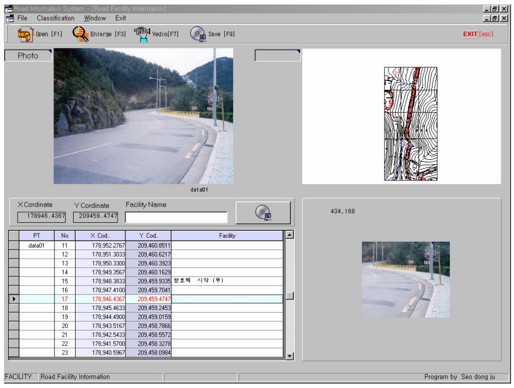

Fig. 15. Road facilities information system

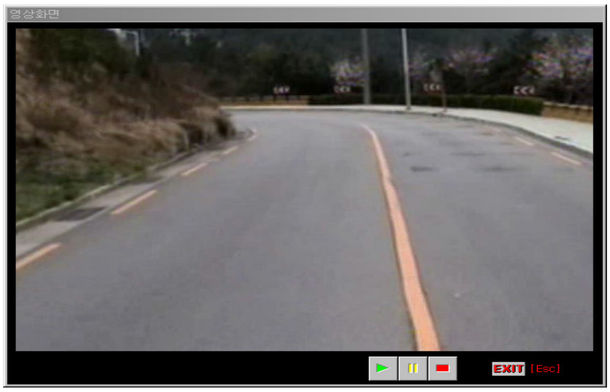

Fig. 16. Screen of moving image data

5. Conclusion

A more exact and economical road information system was developed using digital photogrammetry. The conclusions are as follows.

First, to obtain road information using digital photogrammetry, a road was shoot in the 4 corners in each zone along road extension and proceeded to bundle adjustment. RMSE was 4~7cm, indicating that it was within the allowable error of reduced scale of 1:12,000.

Second, in digital photogrammetry, it was possible to obtain 3-d coordinates of road center line and facilities through orientation with natural points, when the error was 2~5cm, a practical range. It was thought that control score could be much reduced.

Third, a software program using Delphi, an object-oriented language, was developed to construct road alignment information(IP, BC, EC, R) and facilities information from digital photogrammetry. The program can provide the users with motion pictures, giving better visual effect than old method.

Forth, when future road information system is connected with such studies that combine the digital motion picture data from digital photogrammetry with data from GPS and IMU, this study output would be applied to MMS(Mobile Mapping System).

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