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Construction of Management System of Road Position Information Using GPS Surveying Data

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Abstract

This study aims to construct a management system of road position information as part of the build-up to a maintenance and management system of highways. First, information on the positions of the roads were obtained by a real-time kinematic satellite surveying, and then the degree of accuracy was analyzed in comparison with the data of the existing design drawings. The linear coordinates of road center line obtained by using RTK GPS showed about 7.6~13.2cm errors in X and Y directions in the case of the national road No.2 section, and about 8.4~9.2cm errors in the case of local road No.1045 section. These errors were within the tolerance scope regulated by the TS survey, and could be practically used. In the case of vertical alignment, there were about 6.2cm errors in the Z direction in local road No.1045 section. Aerial photographs are normally used in producing numerical maps, and it can be practically used because the tolerance scope of the elevation control point is 10cm when the scale of aerial photographs is 1/1000. The management system of road position information, utilizing Object-Oriented Programming(OOP), was built having the data acquired in this way as the attribute data. The system developed in this way can enable us to spot the positions of road facilities, the target of management with ease, to easily update the data in case of changes in the positions of roads and road facilities, and to manage the positions of roads and road facilities more effectively.

Keywords : *Road position information, Maintenance and management system, Alignment, Real-time kinematic satellite surveying, Object-Oriented Programming(OOP)*

1. Introduction

Roads have been developed throughout the history of mankind, and play a significant role among many traffic facilities for the economy, politics and cultures of our lives. However, the management of roads has not been fully scientific due to governmental policies focused on construction, resulting in damages, and the loss of drawings of existing roads. In this case, it is difficult to rearrange roads using normal cadastre due to its time consuming work.

There has been an effort to solve these problems and to manage road alignment and road facilities using RTK(Real-Time Kinematic) GPS(Stathas *et al.*, 2001; Hubiao, 1996), a kind of satellite survey (Brougton, 2000), to obtain 3-dimensional coordinates of center lines of roads(Lee, J.C., 2001).

In this research, an efficient and economic method was sought to recover drawing data, and to examine the alignment elements of roads where accidents happen frequently due to the deficient geometric structures of roads(Savvaidi *et al.*, 2000). For this purpose, the alignment elements of roads were extracted using RTK GPS, and then compared to existing drawings when they were available.

The new construction and management of roads are equally important. The results of this research will be used as a management system of road position information within a Highway Management System (HMS)(Stathas *et al.*, 2001)to renew and manage the alignment data of roads for the purpose of managing alignment data, and road facilities effectively. For managers of roads to find easily facilities to be managed and to communicate easily among the

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managers. For system mangers of roads, it will be easily and precisely done to renew data when the alignments are changed or extended, or positions of facilities to be managed are changed.

2. Extracting Road Alignment Using the Method of Least Squares

To find a sample regression line, it is necessary to define what the most appro-priate straight line is to avoid personal subjectivity. Normally, the straight line of the minimum residuals is the most appro-priate straight line. The problem in using this method is that always the sum of residuals is zero, even though no residual may be zero as some are negative and the others are positive. To solve this problem, the most appropriate straight line is defined as having the least sum of squares of all residuals. This is the so called method of least squares. It is a method to find the straight line, which has the least sum calculated by squaring each distance from an observed value to the line.

Center lines are calculated from some functional formulas. When joining coordinates of center lines, it becomes a straight line, circular curve, and transition curve. When there is no drawing for a road, the alignment can be extracted by observing coordinate values (X_i, Y_i), which is a position of the center line, and by using the method of least squares.

Coordinate value (X_i, Y_i), which is a position of the center line can be obtained by using GPS, and data of (X_i, Y_i) is always the more the better. When lane markings are not available, coordinate value (X_i, Y_i) can be obtained by measuring the width of a road to obtain its center line. In this research, the center lines and width of the target roads were obtained along with many other data in a short period using RTK GPS, which is rather good in its accuracy.

3. Management System of Road Position Information

3.1 Summary of the Management System of Road Positioning Information

The basic purpose of the management system of road positioning information is to manage and use the positions of roads and their facilities. For road managers, it is easy to find facilities to be managed, and to communicate with each other. For drivers, it is easy to find their own positions on roads, and to inform others of their positions. For administrators of systems related to roads, it will be easy and precise to renew data when their alignment are changed or extended, or the positions of road facilities to be managed are changed.

The methods used in the management system of road position information are classified into the space partitioning method and linearization. Fig. 1 shows those methods.

Because the object roads of this research were not roads of which alignments and structures are almost not changed, but national roads or local roads which are under ever changing conditions due to their improve-ments and of which there were no drawings, the space partitioning method was used as a method using a 3-dimensional coordinate system using longitudes, latitudes and altitudes obtained from GPS.

Because the space partitioning method of GPS uses coordinate values, it is easy to relate to the Geographic Information System (GIS), and to change the values

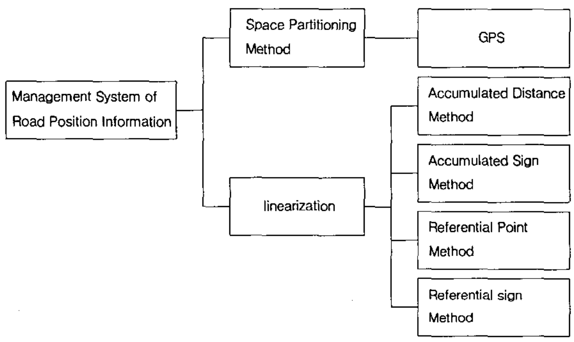

Fig. 1. Classification of the Management System of Road Position Information.

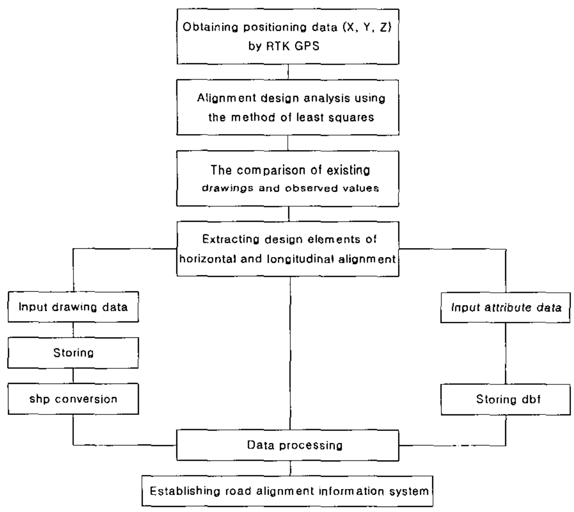

Fig. 2. Road Alignment Information.

obtained to the shape of a map. The alignment information of roads was established as a part of the management system of road positioning information. Fig. 2. shows this process.

3.2 The Design Concept of the System

Attribute data is basic data to be analyzed with space data, which were classified and made as DBF files. Existing data also were maintained as a part of database, and any article changed or newly inserted is easy to modify, or inputted into the tool itself. Fig. 3 shows items inputted as attributes.

Figure data were inputted by using an AutoCAD program in different layers. The alignment of roads were inputted as horizontal and vertical alignment, and the scope of inputting was about a 4km section of the local road No. 1045. Table 1 shows the classification of layers.

The structure and frameworks of ArcInfo data generate coverage using DXFArc command for space data to be read in ArcInfo, and make topology using build command on the generated coverage.

Table 1. The Classification of Each Layer

Layer name	Contents	Layer name	Contents
L001	Center line	A055	Text
L055	IP line	L002	End of lane
L056	boundary	L053	Shoulders

The purpose of the alignment information system of roads is to express information quickly, which users want by connecting figure data generated using AutoCAD, and attribute data in the database. To connect the figure data and the attribute data, there are two methods available. One is a conversational method with which users select object figures on a screen which displays figure tables and attribute tables, and then input the values of relevant attributes. The other is a batch method in which code values are provided to figure data when inputting attribute values. In the conversational method, it is easy to modify data and to find errors, and in the batch method, the attribute information already inputted in the database can be available.

4. The Result of Measurement and Analysis

4.1 The Object Road and Equipment for Measurement

The object roads of this research are parts of the national road No.2 section, and the local road No.1045 section, which has a rather good alignment. The equipment used for measurement was a Trimble 4600LS, and accuracy was horizontally 1cm+1ppm, and vertically 2cm+1ppm in RTK Survey Mode.

4.2 Obtaining the Data

A reference receiver was installed at the survey fields, and a remote receiver did the role of obtaining

Horizontal alignment

Item	Remarks
IP	
I	
R	
B.C	
E.C	

Vertical alignment

Item	Remarks
VIP	
BVC	
EVC	
i_1	
i_2	

Cross section composition

Item	Remarks

Section of Road

Item	Remarks
Road classification	
Design	
Length	
Start point	
Ending point	

Picture information

Item	Remarks
Field space	

Fig. 3. Attribute Data.

Fig. 4. View of Reference Receiver.

Fig. 5. Measurement Field.

3-dimensional coordinates at each measuring point for the alignment of the center line of an existing road. Even though surveying with a car equipped with GPS Receivers is efficient in surveying the linear of the center line of a road with GPS, it is dangerous to drive along the center line on public roads, and surveyed values can be changed dramatically by different driving patterns. Therefore, in this research, GPS Receivers were fixed on the center of a pallet (Stathas *et al.*, 2001), and the pallet was pulled by manually along the center line and the lane markings. Fig. 4 shows a view of reference receiver and Fig. 5 shows a measurement field.

4.3 The Results and Analysis

Firstly, errors in the measurement using RTK GPS for extracting plane linear of existing roads on the section of the national road No.2 were analyzed. The points on drawings were assumed to be most probable value, errors of X direction and Y direction were calculated with coordinates of measuring points obtained from RTK GPS. Table 2 shows the results for 21 measurement points.

As shown in Table 2, the average errors of the 21 survey points are 13.2cm and 7.6cm for X and Y direction, respectively. As these errors were within 30cm, which is the deviation of coordinate difference of roads regulated by TS surveying, it could be practically used. The reasons for these surveying errors might come from construction errors, lane making errors, or mismatching courses of remote receiver, and center lines or roads. Fig. 6 and Fig. 7 show the linear map obtained by overlapping observed coordinates and coordinates in drawings for some of curves of this road. As shown in the figures, there is almost no difference.

Table 3 and 4 show the comparison between the values extracted by using the method of least squares on position data (X, Y, Z) surveyed using RTK GPS

Table 2. X and Y direction error

The national road No.2 section						
Survey Point	X direction error			Y direction error		
	Observed Coordinate	Drawing Coordinate	Error	Observed Coordinate	Drawing Coordinate	Error
1+700	178781.8035	178781.9008	-0.0973	176501.9221	176501.9424	-0.0203
1+800	178761.2545	178761.4977	-0.2432	176599.7881	176599.8388	-0.0507
1+900	178741.3335	178741.4421	-0.1086	176697.7851	176697.8062	-0.0210
⋮	⋮	⋮	⋮	⋮	⋮	⋮
3+500	179422.7512	179422.9616	-0.2104	178051.8788	178051.7866	0.0922
3+600	179456.7067	179456.9013	-0.1946	178145.8294	178145.7731	0.0563
3+700	179481.0297	179481.1031	-0.0734	178242.8027	178242.7858	0.0169
Average error	0.1315 (m)			0.0759 (m)		

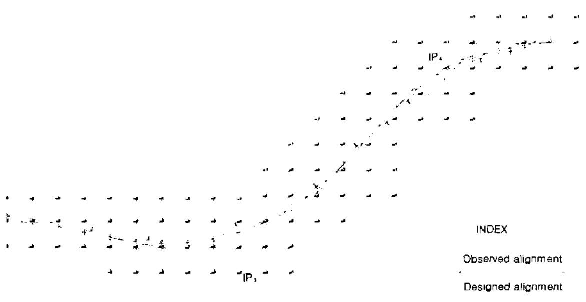

Fig. 6. The linear drawing overlapped with the observed coordinates and the drawing's coordinates.

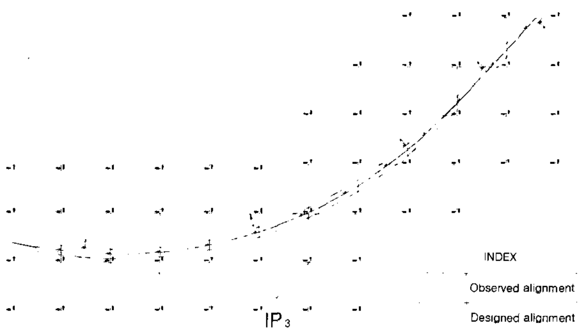

Fig. 7. The linear drawing overlapped with the observed coordinates and the drawing's coordinates (magnified a section).

Table 3. A comparison of drawings values of IP3

	Observation Values	Drawing Values	Remarks
IP	X=178630.6649 Y=177234.7424	X=178628.7757 Y=177236.6555	X=1.8892 Y=1.9131
R	902.9946	900	2.9946
A	449.2949	450	-0.7051
I	58 ° 49 ′ 16.32 ″	59 ° 17 ′ 41.15 ″	-0 ° 28 ′ 24.83 ″
⊿R	2.306	2.342	-0.036
L	223.5516	225	-1.4484

Table 4. A comparison of drawings values of IP4

	Observation Values	Drawing Values	Remarks
IP	X=179413.3271 Y=177956.1379	X=179415.5000 Y=177957.0000	X=-2.1729 Y=-0.8621
R	752.5014	750	2.5014
A	298.0833	300	-1.9167
I	34 ° 31 ′ 42.47 ″	34 ° 35 ′ 36.71 ″	-0 ° 3 ′ 54.24 ″
⊿R	0.772	0.800	-0.028
L	118.0777	120	-1.9223

and values of the drawing, and differences between the surveyed values and the values in the drawings.

As errors in the drawings were verified to be in the tolerance scope of TS regulations when analyzing horizontal alignment of some districts on the national road No.2, the local road No.1045 was also analyzed and verified in the same manner for its horizontal and vertical alignment, and then linear was extracted using RP (S/W Road Project 2.1), a road design program, based on the values in these drawings.

Table 5 shows errors for X and Y directions. The average error for X direction was 8.41 cm using 9

Table 5. X and Y direction error

The local road No.1045 section						
Survey Point	X direction error			Y direction error		
	Observed Coordinate	Drawing Coordinate	Error	Observed Coordinate	Drawing Coordinate	Error
1+000	195754.1020	195753.9147	0.1873	164039.6750	164039.5760	0.0990
1+100	195824.7228	195824.9471	-0.2243	164109.8096	164109.9635	-0.1539
1+200	195895.9333	195895.9795	-0.0462	164180.3966	164180.3810	0.0156
1+300	195967.0852	195967.0130	0.0722	164250.8594	164250.7373	0.1221
1+400	196040.5003	196040.4381	0.0622	164318.6673	164318.5979	0.0694
1+500	196118.2331	196118.2208	0.0123	164381.2364	164381.4163	-0.1799
1+600	196200.0203	196200.0155	0.0048	164438.9188	164438.9135	0.0053
1+700	196284.9225	196284.7913	0.1312	164492.6809	164492.5847	0.0962
1+800	196368.8339	196368.8507	-0.0168	164546.2117	164546.1254	0.0863
Average error	0.0842 (m)			0.0920 (m)		

survey points, and the average error for Y direction was 9.2cm using 9 survey points.

As these errors are within 30cm, the deviation of coordinate difference of roads regulated by TS surveying, it has practical uses.

Table 6 show the comparison between the values extracted by using the method of least squares on position data (X, Y, Z) surveyed using RTK GPS and values in the drawings. The remarks show differences between the observed values and values in the drawings.

Next is an analysis for vertical alignment. Survey points were obtained by using position data (X, Y, Z) of RTK GPS. Table 7 shows the errors of the two directions, and the average error for the Z direction for the 9 survey points was 6.2cm, as shown in Table 7.

The causes of these errors might be construction errors, lane marking errors or elevation errors due to the geoid model when converting the coordinates in GPS post-processing work.

Table 8 shows the comparison between the values extracted by using the method of least squares on position data (X, Y, Z) observed using RTK GPS and values in the drawings. The remarks show differences between the observed values and values in the drawings.

Table 6. A comparison of drawings values of IP3

	Observed Values	Drawing Values	Remarks
IP	X=196080.9005 Y=164363.5771	X=196080.8848 Y=164363.5775	X= 0.0157 Y=-0.0004
R	1499.4892	1500	-0.5108
I	12 ° 21 ′ 56.88 ″	12 ° 22 ′ 1.93 ″	-0 ° 0 ′ 5.05 ″

Table 7. Z direction errors

The local road No.1045 section				
Survey Point	Observed Coordinate	Drawing Coordinate	Error	Average error
1+000	66.39	66.30	0.09	0.062 (m)
1+100	71.91	71.80	0.11	
1+200	77.12	77.05	0.07	
1+300	81.57	81.51	0.06	
1+400	85.51	85.44	0.07	
1+500	89.43	89.35	0.08	
1+600	93.28	93.26	0.02	
1+700	97.20	97.18	0.02	
1+800	101.13	101.09	0.04	

Table 8. A comparison of drawings values of VPI3

	Observed Value	Drawing Value	Remarks
VPI	STA=1219.339 Z=78.437	STA=1220.000 Z=78.400	STA=-0.661 Z=0.037
i_1	5.51%	5.50%	0.01%
i_2	3.91%	3.91%	0%
BVC	STA=1119.996 Z=72.963	STA=1120.000 Z=72.900	STA=-0.004 Z=0.063
EVC	STA=1319.892 Z=82.360	STA=1320.000 Z=82.310	STA=-0.108 Z=0.037
L	199.896	200	-0.104

5. Establishing Data for the Alignment Information System of Road

The results of extracting design elements of horizontal and vertical alignment by applying the method of least square to position information (X, Y, Z) obtained from RTK GPS, and applying the results to the two object areas was analyzed and verified to be credible. It means that this method can be applied to other areas to extract alignment design elements more rapidly than normal survey methods.

In this research, the alignment information system of road was established as a part of the management system of road position information based on position information and attribute information extracted by using RP(S/W Road project 2.1), a program for road linear design, on linear design elements extracted by the same method for about 4km interval in interval of the local road No.1045.

5.1 Establishment of the System

Firstly, coordinates (X, Y, Z) obtained by using RTK GPS on the object road was used as position information, and then alignment design elements based on these data were verified and compared to those in existing drawings. When these data were in its tolerance scope, alignment design of road was done using RP(S/W Road Project 2.1), a special purpose program for road design, based on these extracted data. The design was inserted to into the system by Map Object.

5.2 Searching in the System

Fig. 8 shows the loading screen of the alignment information system of road, and Fig. 9 shows the main screen. As shown in Fig. 9~Fig. 11, it is easy to select the road alignment, and the requested attribute data are displayed on the screen when inputting IP number of attribute information to be searched. The searched alignment drawings and attribute data can be printed.

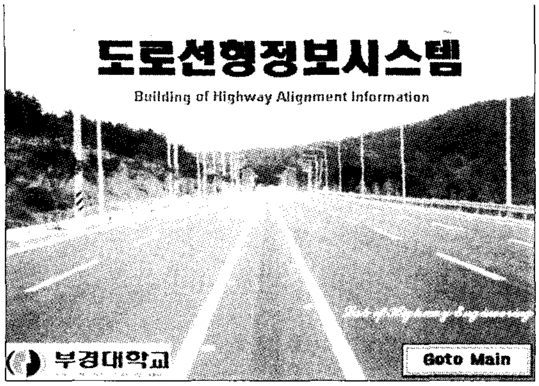

Fig. 8. The Loading Screen.

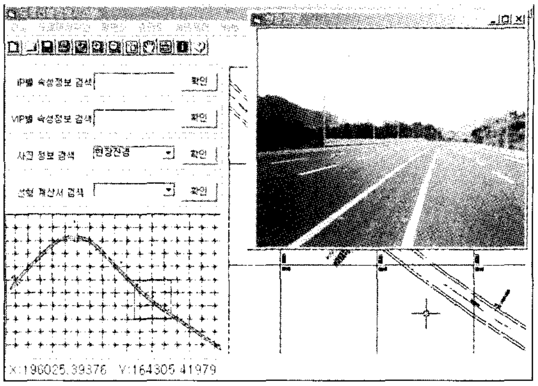

Fig. 11. Search for the Field.

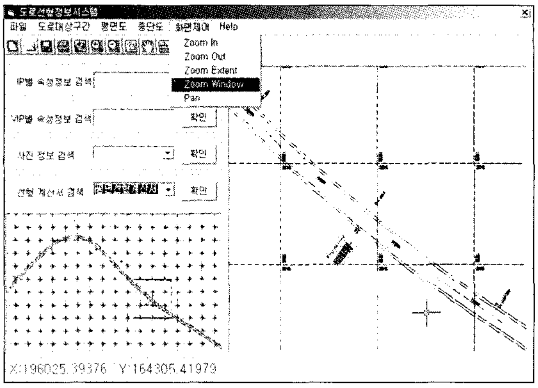

Fig. 9. The Main Screen.

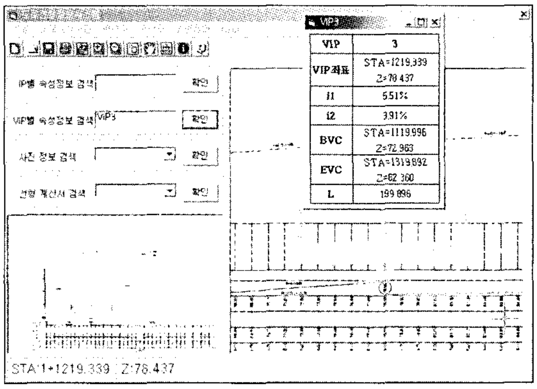

Fig. 12. The Vertical Alignment Searching Screen.

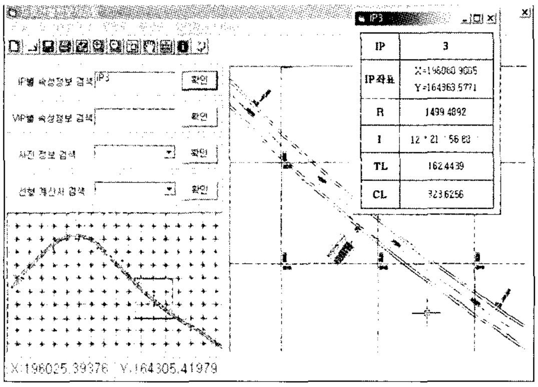

Fig. 10. Search for the Horizontal Alignment.

Information for the field scope and specification of object roads are also included, and the vertical alignment searching screen is displayed as Main is changed to the vertical alignment searching screen when selecting "vertical alignment-vertical alignment drawing" from the menu.

Fig. 12 shows the vertical alignment searching screen. When the VPI number is inputted, attribute data of vertical alignment requested are displayed, and the linear drawings and attribute data searched can be printed. The vertical alignment calculation sheet can also be printed.

By this establishment, the efficient management and usage of roads and their facilities can be possible. For road managers, it is easy to find the positions of road facilities to be managed, and to communicate each other. For the system administrator who manages systems related to roads he or she can easily and precisely renew data when the positions of road facilities are changed, or the linear of roads is changed or extended.

6. Conclusion

In this research, alignment design elements of roads were extracted by obtaining position information (X, Y, Z) by using RTK GPS for efficient and scientific management of road position information, and the alignment information system of road was established based on these data. The results of this research are outlined below.

1. The linear coordinates of road center line obtained

by using RTK GPS showed about 7.6～13.2cm errors in X and Y directions in the case of the national road No.2 section, and about 8.4～9.2cm errors in the case of local road No.1045 section. These errors were within the tolerance scope regulated by the TS survey, and could be practically used. In the case of vertical alignment, there were about 6.2cm errors in the Z direction in local road No.1045 section. Aerial photographs are normally used in producing numerical maps, and it can be practically used because the tolerance scope of the elevation control point is 10cm when the scale of aerial photographs is 1/1000.

2. It was proved that it is possible to recover or renew relevant data by using RTK GPS when there are no drawings or alignment of national roads, or local roads are improved.

3. Without visiting fields, efficient manage- ment and use of roads and their facilities can be possible. For road managers, it is easy to find the positions of road facilities to be managed, and to communicate each other.

4. The Highway Management System(HMS) will be used extensively to renew and manage road data based on these alignment data for wide areas.

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