Application of REAL TIME GIS using RTK-GPS for Local Government

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ABSTRACT:

Much local government has been using a large scale digital map with Information System (GIS). GIS will be able to work efficiently and to reduce the costs of mapping. However, the maintenance and renewal of a map database need much labor and time. The updating method of a map is not established yet, and there are very few successful examples. The purpose of this study is the application of REAL TIME GIS using RTK-GPS to the large scale digital map for local government. REAL TIME GIS is the system for real-time mapping and updating at the field site using Real-time Kinematic Global Positioning System (RTK-GPS), GIS and cellular phone. This system has the problem that RTK-GPS positioning data is Japanese Geodetic Datum 2000 (JGD2000) of WGS-84, but most of the digital maps of local government are still Tokyo Datum of old geodetic system. It is necessary to transform an old geodetic system to a new one. Several methods were used for this problem. The results of coordinates conversion were compared Affine Transformation with TKY2JGD. Moreover, the number and arrangement of control points were changed, coordinates were converted by Affine Transformation. In this paper, the parameters which were calculated by Affine Transformation were named “High-Accuracy Regional Parameter (HARP)”. As a result, TKY2JGD has a maximum 15cm error. Affine Transformation has 2cm errors using 4 control points at the corner of unit. In conclusion, the need of HARP with Affine Transformation was indicated. It is suggested that the process of REAL TIME GIS and HARP should be introduced to the work of local government.

1. INTRODUCTION

Much local government has been utilizing the Base Map (BM) in order to support for urban planning and management of facilities with GIS. GIS will be able to work efficiently and to reduce mapping costs. Furthermore, by sharing the data with their section in local government, it is possible to improve the service to a citizen. However, the maintenance and renewal of a map database need much labor and time. Map updating method was not established yet and, there are very few successful examples. The purpose of this research is establishment of the method of updating the large-scale map for a local government.

In order to solve this problem, Remote Sensing by the High Resolution Satellite Imageries (HRSI) and Global Positioning System (GPS) was utilized for GIS.

First, HRSI was introduced to GIS as a background map. It is a digital image having the position data about latitude and longitude. Resolution of HRSI is about 60cm to 100cm in each pixel. HRSI after the ortho graphic projection process can be corresponded with BM. It is able to distinguish each house, so it has been used in various fields, such as river management, disaster prevention, road management, environment and facility management. Change of the city is easily found by overlapping the HRSI to BM with GIS. HRSI might be expected to offer several advantages in renewal and cost of digital map. Especially, waterworks and wastewater facilities in urban area would frequently change at short interval, so the digital data for GIS needs updating the new information quickly.

The next is Real-Time Kinematic System (RTK-GPS) using GPS. RTK-GPS can be operated by one person. Accuracy of horizontal distance obtained by RTK-GPS has 1-3 cm at latitude and longitude. It is possible that digital map data update at real time using RTK-GPS which has high accuracy, simultaneity and cellular phone. In this study, it was defined as the REAL TIME GIS. RTK-GPS positioning data is Japanese Geodetic Datum 2000 (JGD2000) of WGS-84, but most of the digital map of local government is still Tokyo Datum of old geodetic system. In order to correspond with two kinds of data which have different geodetic system, it is necessary to transform coordinates.

2. CONCEPT AND SYSTEM OF REAL TIME GIS

“REAL TIME GIS” is the system for real time mapping and updating the Map at the field site using RTK-GPS and GIS. It can be connected with cellular phone or Internet through which the stored data can be transmitted to the host computer with GIS database. The positioning time per point by RTK-GPS survey needed only a few seconds, and it was possible to survey by one person. Renewal of the map can be completed very quickly. Figure 1 shows the concept of “REAL TIME GIS”.

The following step shows an example of gas pipe lines.

1. Position of gas pipe was measured by RTK-GPS when it was constructed.
2. Measured data sent to the map server by mobile phone and Internet.
3. Original map data is renewed at real time.

However, GPS data did not correspond the standard of Japan, because it had been adopted the BESSEL ellipsoid and Tokyo Datum as the general standard for a map geometry. Japan replaced the geometrical elements to GRS80 since April 1, 2002. While we can directly use GPS data to digital map data, modification of geodetic system causes the coordinates transformation between old system and new system.

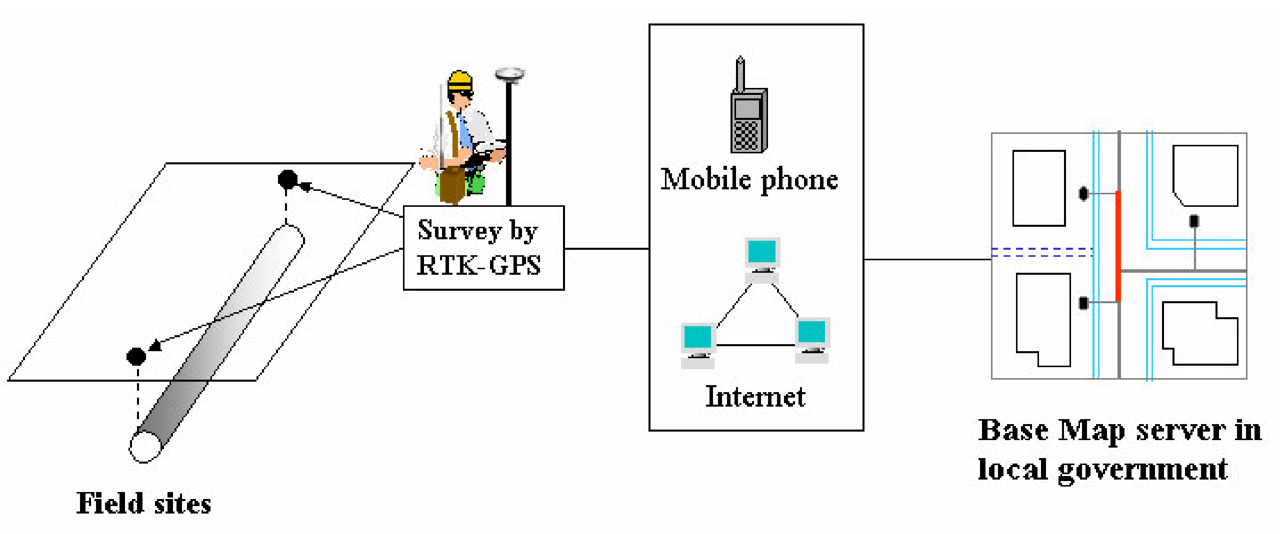

Figure1. The concept of the REAL TIME GIS

3. CONTROL POINT FOR CONVERSION

Geographic Survey Institute of Japan (GSI) adopted GRS80 instead of BESSEL ellipsoid since April 2002. Parameters of WGS-84 for GPS and ITRF94 are almost equal to GRS80. By modification of geodetic system, the data of the past survey which uses Tokyo Datum will need to be changed to JGD2000. GSI opened the website for the conversion parameters and programs (TKY2JGD). GPS data almost corresponded to digital BM data in small-scale map, however, the parameter could not adopt in large-scale map. It is necessary to make the parameter in narrow area, because it was too large for the range which made parameter by TKY2JGD.

In order to calculate parameters, the control point was made using GPS by us. In the research, control point means the point which shows both coordinates of Tokyo Datum and JGD2000. The verification area has the accurate data of Tokyo Datum (based on BESSEL ellipsoid and rectangular plane coordinate system) and was generated for town planning recently. There are 89 coordinate points in a map (about 400m square) for the group of town planning work, we chose 14 points suitable for GPS positioning. GPS positioning was carried out from August to October in 2003. Static positioning was performed over 2 hours using GPS at the point, and the coordinates JGD2000 was obtained. Table 1 shows the positioning point number, the coordinates of Tokyo Datum and GPS positioning data. GPS positioning area is shown in Figure 2.

The conditions which choose the positioning point are as follows.

- Clearly and confirmed point were used.
- The position need open sky and no high buildings.

In this way, these 14 points which had both geodetic systems were used for conversion to JGD2000.

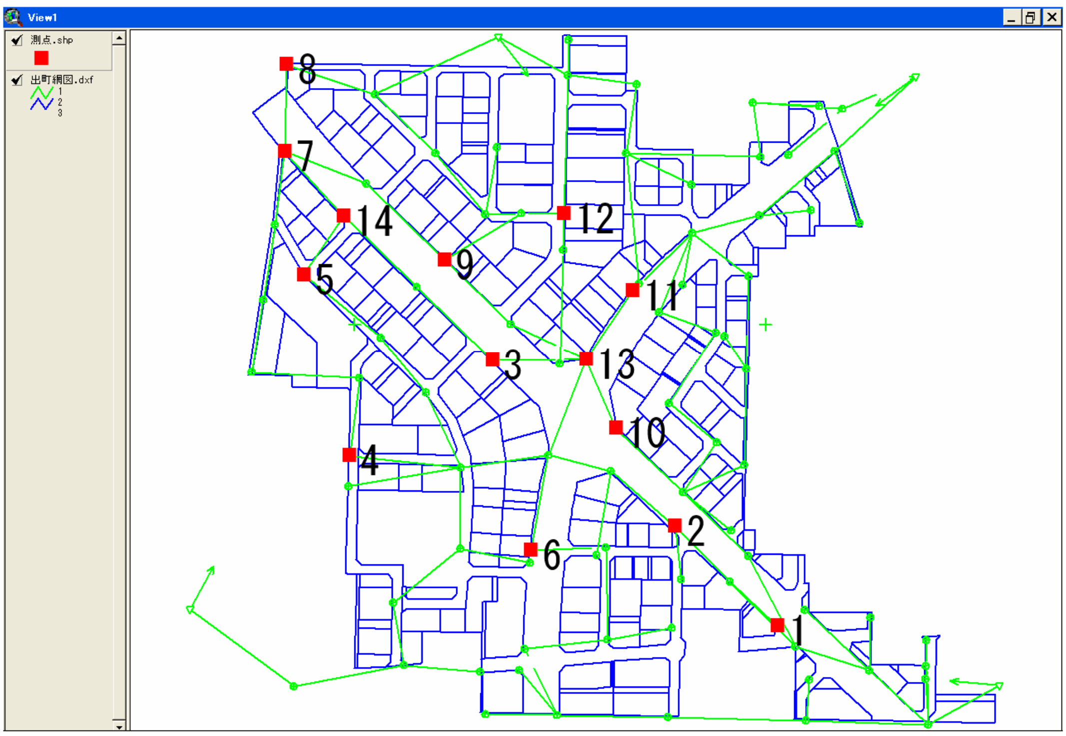

Figure 2. GPS positioning area

4. VERIFICATION OF THE CONVERSION

4.1 TKY2JGD

First, the accurate 14 coordinates of Tokyo Datum were transformed to new system from old system by using TKY2JGD. How long differences are there from the calculation results to GPS positioning data were verified. The result is shown in Table 1. The differences exceeded about 11.3cm on an average. Accuracy of level direction about facilities management is about 5cm, and the error is not allowed in large scale digital map. The results showed that it is necessary to verify the method of coordinate transformation in narrow area, because area of TKY2JGD was too large.

A, B, and C in Table 1 shows as follows

- A: Town planning work(Tokyo Datum): The coordinates of Tokyo Datum which was offered from the group of town planning work
- B: Town planning work (JGD2000): The coordinates of Tokyo Datum which was offered from the group of town planning work. It was transformed by TKY2JGD
- C: GPS positioning (WGS-84): The coordinates which was converted from GPS positioning data to rectangular plane coordinate system.

4.2 Affine Transformation

In the verification, Affine Transformation which the most general and simple method in various geometric conversions was used.

Affine Transformation makes the three parameters. There are rotation, scale and parallel transformation. These parameters transform the geodetic system (x, y) to (x', y'). The conversion formula is as follows.

Table 1. The control point of coordinates of Tokyo Datum and GPS positioning data

Unit: m

No		A Town planning work (Tokyo Datum)	B Town planning work (JGD2000)	C GPS (WGS-84)	Differences	Vector
1	x	61066.777	61413.870	61413.908	0.038	0.111
	y	-49492.594	-49761.114	-49761.010	0.104	
2	x	61127.327	61474.420	61474.453	0.033	0.104
	y	-49555.144	-49823.664	-49823.565	0.099	
3	x	61227.909	61575.004	61575.008	0.004	0.148
	y	-49666.002	-49934.521	-49934.373	0.148	
4	x	61170.181	61517.279	61517.261	-0.018	0.141
	y	-49753.116	-50021.634	-50021.494	0.140	
5	x	61280.154	61627.250	61627.229	-0.021	0.108
	y	-49780.701	-50049.219	-50049.113	0.106	
6	x	61112.771	61459.867	61459.873	0.006	0.121
	y	-49642.624	-49911.143	-49911.022	0.121	
7	x	61355.275	61702.371	61702.338	-0.033	0.122
	y	-49792.665	-50061.182	-50061.065	0.117	
8	x	61407.695	61754.790	61754.765	-0.025	0.102
	y	-49791.317	-50059.834	-50059.735	0.099	
9	x	61289.281	61636.376	61636.367	-0.009	0.125
	y	-49695.348	-49963.866	-49963.741	0.125	
10	x	61186.758	61533.852	61533.872	0.021	0.115
	y	-49591.219	-49859.7384	-49859.625	0.113	
11	x	61270.218	61617.3099	61617.316	0.006	0.107
	y	-49581.156	-49849.6748	-49849.568	0.107	
12	x	61317.370	61664.4620	61664.457	-0.005	0.043
	y	-49622.528	-49891.0463	-49891.004	0.042	
13	x	61228.627	61575.7204	61575.730	0.010	0.119
	y	-49609.195	-49877.7139	-49877.595	0.119	
14	x	61315.912	61663.0076	61662.986	-0.022	0.120
	y	-49756.810	-50025.3275	-50025.209	0.118	
					Average of Vector	0.113

$$x' = x_0 + k_x x - \theta_y y$$
$$y' = y_0 + \theta_x x + k_y y \quad (1)$$

where
(x, y): coordinates of Tokyo Datum
(x', y'): coordinates of JGD2000
(x_0, y_0): parallel transformation
k :scale, k_x : scale of X axis, k_y : scale of Y axis
θ : rotation, θ_x : rotation of X axis, θ_y : rotation of Y axis

In this paper, the parameters obtained by Affine Transformation was named "High-Accuracy Regional Parameter HARP (HARP)". HARP was calculated by using Affine Transformation equation (1) and three coordinates of A, B and C in Table 1. Point No.3 and No.12 did not use to the calculation, because of the accuracy was no good. Verification method shows in No.1 of Table2 and No.2 of Table3 respectively. Each results of conversion, parameters and standard deviation are shown in Table 2 and Table 3.

Table 2. The calculated result of the verification for No.1 Unit: m

No	Conversion result		GPS Positioning data		Differences	
	x	y	x	y	dx	dy
1	61413.909	-49761.004	61413.908	-49761.010	0.001	0.006
2	61474.445	-49823.552	61474.453	-49823.565	-0.008	0.013
3	61517.264	-50021.507	61517.261	-50021.494	0.003	-0.013
4	61627.227	-50049.098	61627.229	-50049.113	-0.002	0.015
5	61459.876	-49911.022	61459.873	-49911.022	0.003	0.000
6	61702.342	-50061.066	61702.338	-50061.065	0.004	-0.001
7	61754.759	-50059.723	61754.765	-50059.735	-0.006	0.012
8	61636.367	-49963.754	61636.367	-49963.741	0.000	-0.013
9	61533.867	-49859.628	61533.872	-49859.625	-0.005	-0.003
10	61617.324	-49849.573	61617.316	-49849.568	0.008	-0.005
11	61575.731	-49877.605	61575.730	-49877.595	0.001	-0.010
12	61662.987	-50025.212	61662.986	-50025.209	0.001	-0.003

HARP	
Parallel transfer to the x direction (m)	358.654076653
Parallel transfer to the y direction (m)	-268.674327282
Scale of the x axis	0.999945729
Scale of the y axis	0.999895301
Rotation of the x axis	-0.289866638
Rotation of the y axis	0.597025547

STD (m)	σx	σy
	0.00457	0.00980

Table 3. The calculated result of the verification for No.2 Unit: m

No	Conversion result		GPS Positioning data		Differences	
	x	y	x	y	dx	dy
1	61413.909	-49761.003	61413.908	-49761.010	0.001	0.007
2	61474.445	-49823.552	61474.453	-49823.565	-0.008	0.013
3	61517.264	-50021.507	61517.261	-50021.494	0.003	-0.013
4	61627.226	-50049.098	61627.229	-50049.113	-0.003	0.015
5	61459.876	-49911.022	61459.873	-49911.022	0.003	0.000
6	61702.342	-50061.066	61702.338	-50061.065	0.004	-0.001
7	61754.759	-50059.723	61754.765	-50059.735	-0.006	0.012
8	61636.367	-49963.754	61636.367	-49963.741	0.000	-0.013
9	61533.867	-49859.628	61533.872	-49859.625	-0.005	-0.003
10	61617.324	-49849.573	61617.316	-49849.568	0.008	-0.005
11	61575.731	-49877.605	61575.730	-49877.595	0.001	-0.010
12	61662.987	-50025.212	61662.986	-50025.209	0.001	-0.003

HARP	
Parallel transfer to the x direction (m)	11.912915697
Parallel transfer to the y direction (m)	0.439809339
Scale of the x axis	0.999960459
Scale of the y axis	0.999901826
Rotation of the x axis	-0.305657027
Rotation of the y axis	0.683326360

STD (m)	σx	σy
	0.00462	0.00986

1. Affine conversion is performed using 12 points of A and C, and HARP was calculated (Changed into JGD2000 from Tokyo Datum).
2. Affine conversion is performed using 12 points of B and C, and HARP was calculated (Changed into JGD2000 from JGD2000).

Which is more efficient between No.1 and No.2 was verified. Standard deviation was calculated from Affine Transformation results and GPS positioning data. Accuracy was verified by comparing the result of standard deviation.

As a result of verifying, there was almost no difference in standard deviation between No.1 and No.2. There is only about 0.1-0.2mm with coordinates x, y. The method of No.1 is simpler than No.2 , because of it does not need the time and labour in the process of conversion. Tokyo Datum was changed to JGD2000 directly by HARP. So, No.1 was adopted for coordinate transformation.

4.3 The Number and place of control points for Affine Transformation

Local government has over 1000 digital maps which are 1/500 scale (300×400m). It is better that the numbers of control points are few as much as possible, because of the maintenance, management and renewal of control points need much labor and money. In the research, we discussed what kind of method was appropriate as a coordinate transformation in the area.

HARP was calculated by 11 methods which was different of number and place of control points.

Figure 3, 4 shows the place of control points. All of 14 points were used for conversion. HARP was calculated by 12 points, however, No.3 and No.12 were excepted. Standard deviation was calculated between GPS positioning data and coordinates which was adopted HARP. The calculation result of standard deviation is shown in Table 4.

Table 4. Standard deviation

Number and place of control points	STD(m)	
	σx	σy
4 points at the corner of unit	0.0056	0.0199
4 points at the center of unit	0.0100	0.0222
6 points at the corner of unit	0.0056	0.0204
6 points at the center of unit	0.0064	0.0263
6 points with few errors	0.0063	0.0227
8 points at the corner of unit	0.0050	0.0202
8 points at the center of unit	0.0056	0.0226
8 points on the whole of unit	0.0054	0.0208
10 points at the corner of unit	0.0051	0.0203
10 points at the center of unit	0.0053	0.0216
Total points	0.0051	0.0209

As a result of verification, the smallest standard deviation in the x-coordinate is 0.5cm , and it was the case of "8 points at the corners". The largest standard deviation was 1cm , and it was the case of "4 points at the center". The smallest standard deviation with y-coordinate was about 2cm, and it was the case of "4 points at the corners". The largest standard deviation was about 2.6cm , and it is the case of "6 points at the center". Standard deviation was obtained less than 1cm in X and 3cm in Y at any case. This error is allowed in the level position accuracy about facilities management.

On the other hand, the standard deviations have variation by the calculation method of a parameter. But, it was proved that the methods of it place at the corner of unit as much as possible was accurate. If the number of point is equal, the corner position of the unit is the best way mentioned above.

5. CONCLUSION

This research suggested the conversion method of the large scale digital map for the local government using RTK-GPS. The new way will support the revise of BM at real time. The following conclusions were obtained:

(1) Control point for conversion.
  (a) The data of Tokyo Datum use the accurate data prepared by the town planning recently.
  (b) The data of JGD2000 use the GPS positioning data at each control point.

(2) Coordinate transformation.
  (a) The conversion uses Affine Transformation.
  (b) The control points for the conversion should be more than 4 points, and it has to place at the corner of unit as much as possible.
  (c) Desirable unit of conversion area is 1/500 scale map.

We recommend that local government introduce the system of "REAL TIME GIS" for their work. The simplification of mapping process, reduction of mapping and updating cost, and understanding of accurate urban conditions are connected with the improvement of the service to the citizens in the local government.

In this study, BM of local government is not actually converted yet. Actual experiment using RTK-GPS and BM after conversion has carried out in Kanazawa, Japan since April 2004. Probably, BM data and RTK-GPS data will be able to almost correspond with each other. The verification result may be reported at the conference.

6. REFERENCE

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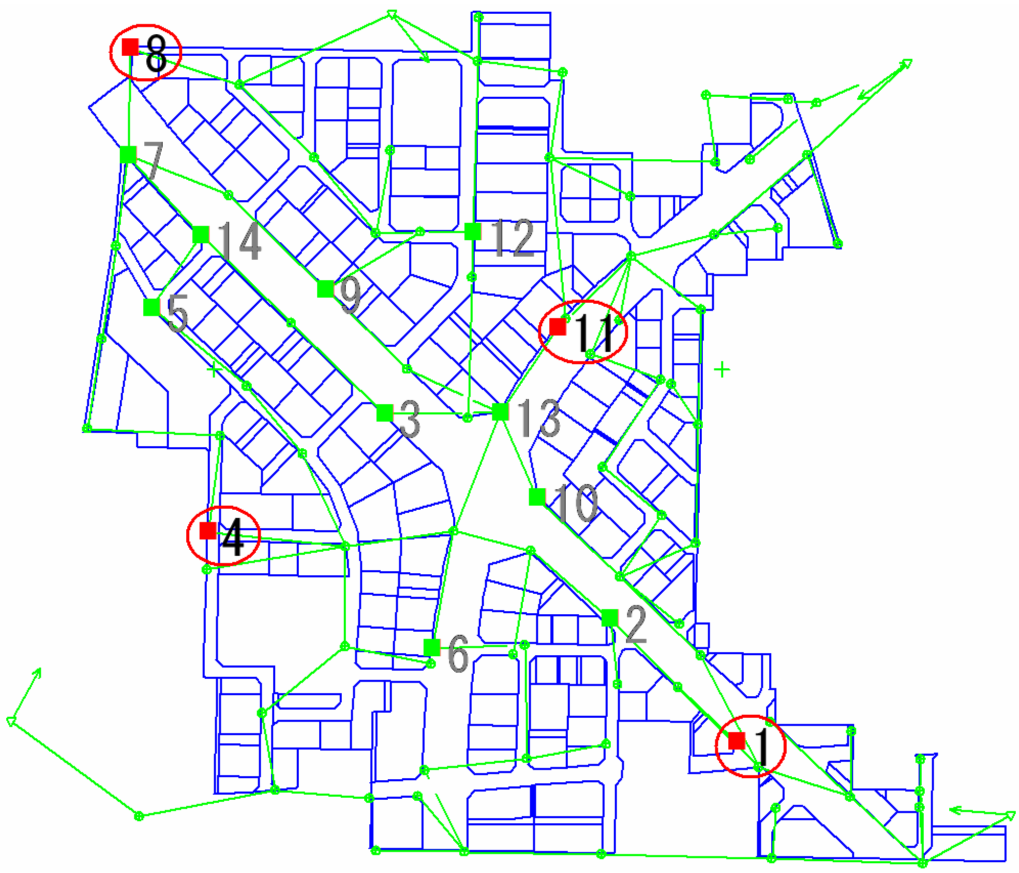

Figure 3. Position of control point (Corner of the unit)

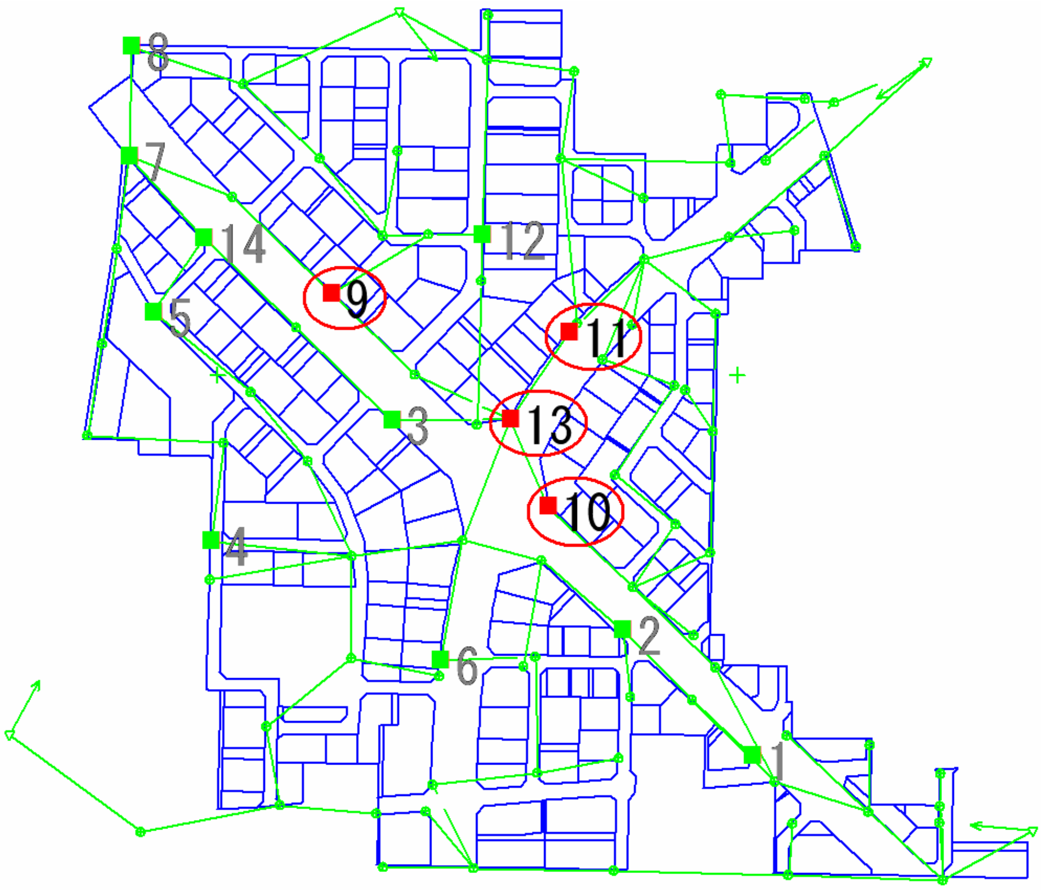

Figure 4. Position of control point (Center of the unit)