ESTABLISHMENT OF MAP RENEWAL TECHNIQUE FOR LOCAL GOVERNMENT BY USING REAL TIME GIS

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KEY WORDS: Mobile Mapping System, Database Updating, GPS-Assisted Photogrammetry, GPS/IMS Integration, Digital Mapping,, Matching

ABSTRACT:

Much local government has been utilizing a large-scale digital map using Geographic Information System (GIS). However, the maintenance and renewal of a map database need much labor and time. Moreover, the updating method of a map has not been established yet and there have been almost no successful examples. The purpose of the study is to establish a method of updating the large-scale map for local government using Real-Time GIS. The Real-Time GIS is a technique for updating a digital map instantly using the Real-Time Kinematic Global Positioning System (RTK-GPS) and mobile phones.Absolute position of a GPS is extremely precise, and the ellipsoid of Japanese is Geodetic Datum 2000 (JGD2000) of GRS-80. However, most of the digital maps of local government are still Tokyo Datum of an old geodetic system. To match two kinds of data having different geodetic systems, it is necessary to transform coordinates. Several methods were used for this problem. This study used TKY2JGD and Affine Transformation. In this paper, parameters which were calculated by Affine Transformation were named “High-Accuracy Regional Parameter (HARP).” As a result, parameters using TKY2JGD could not be applied to a large-scale map. Standard deviation of Affine Transformation had only 3cm errors. These results showed that HARP can transform Tokyo Datum to JGD2000. The paper suggested that Real Time GIS and HARP will help to revise the map of local government.

1. INTRODUCTION

The Japanese Government executed a new law for a Spatial Information Society on May 30, 2007. In this law, a Basic Map (BM) of the Spatial Information Society was established. For the establishment of BM a large-scale map of local government is used. Much local government has been utilizing a large-scale digital map using Geographic Information System (GIS). GIS will be capable of efficiently working and reducing mapping costs. Furthermore, it is possible to improve service to local citizens by the information in local government. However, the maintenance and renewal of a map database need much labor and time. Further, no updating methods of a map have been established yet and there have been almost no successful examples.

“The map should be fresh” is a concept of our laboratory. The purpose of this study is to establish a method for updating a large-scale map for local government using a Real-Time GIS. The Real-Time GIS which was defined by our laboratory can be used to renew the BM. The Real-Time GIS is a technique that updates the BM instantly by the Real-Time Kinematic Global Positioning System (RTK-GPS), GIS, and mobile phones (Figure1). These techniques have been called “Geoinfomatics” that is a new field of survey.

Japan has adopted a new general standard for map geometry since April 1, 2002. Ellipsoid of a new geodetic system in Japan is almost equal to WGS-84 of GPS. However, most of the digital maps of local government are still Tokyo Datum of an old geodetic system. To cope with two kinds of data which have different geodetic systems, it is necessary to transform coordinates.

In the master's thesis of Ms. Aki Okuno who graduated from Kanazawa Institute of Technology (KIT), she tried to solve the problem between the old and new geodetic systems by TKY2JGD and Affine Transformation. The result is listed below (Okuno, 2006).

1. The control point of transformation has to be located at four corners in the map. The exact point (national control point and public control point) of the control point could not be found in the field of survey.
2. A 1/500 scale area is desirably converted.
3. The precision is improved further by offset adjustments.

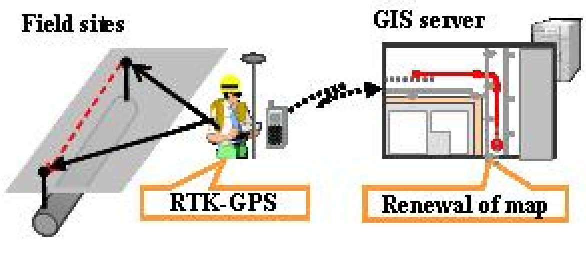


Figure 1. Concept of “Real Time GIS”

However, the method of making control points was not adopted because it is difficult to obtain the coordinates on a map and to find the points at the field. Therefore, the control points of town planning group data and cadastral data were used for coordinate transformation. Many control points are in a narrow area.

As a result, the old transformed geodetic map will be allowed to overlap to a new map measured by RTK-GPS.

2. CONTROL POINT FOR TRANSFORMATION

To transform the BM, the control point was used at the field. In the research, the control point means a point for showing both exact coordinates of Tokyo Datum and JGD2000. A verification area has accurate data of Tokyo Datum (based on BESSEL ellipsoid and rectangular plane coordinate system), and the data are managed by the Town Planning Group and the Cadastral Section in Kanazawa City. Experiment areas are “Area A,” “Area B,” “Area C,” “Area D,” and “Area E” (they are marked as A, B, C ,D, and E hereafter).

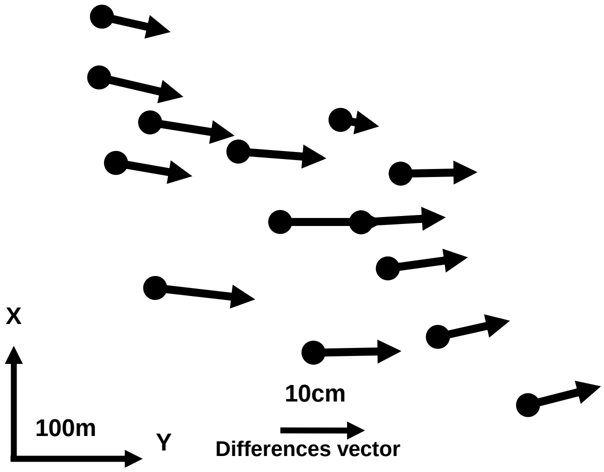
To obtain the coordinates of JGD2000, this study used static positioning of GPS and VRS-GPS at test fields (Figure 2). A and B were measured over 2 hours using static positioning of GPS. C, D and E were measured for one minute using VRS-GPS. The measurement time is decided by the law of Japan.

The control points of the Town Planning Group data and Cadastral Section data were installed simply. Especially, the control point number could be discerned on a road. Therefore, everyone can easily confirm the control point at the field. However, in the future, marking ink of the control point number will disappear. A better method for maintaining and managing the control point for coordinate transformation is to adopt the control point of town blocks and an IC tag.

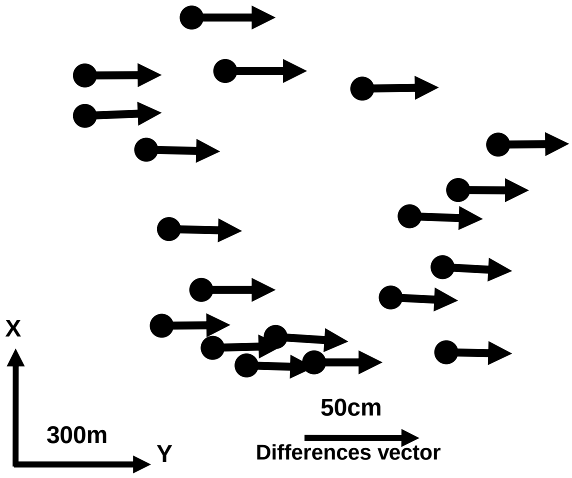
Figure 2. GPS measuring at the field point

3. VERIFICATION OF TKY2JGD FOR JAPANESE STANDRAD CONVERSION

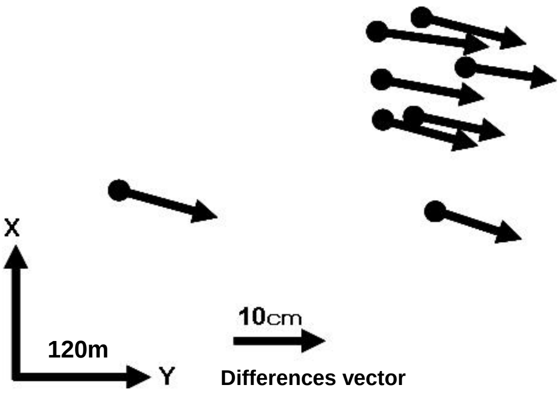
Geographical Survey Institute of Japan (GSI) opened a website for conversion parameters and programs (TKY2JGD). First, the coordinates of Tokyo Datum of the old geodetic system were transformed to new ones by TKY2JGD. The differences between calculation results and GPS measurement data were verified. The results are shown in Figure 3. A circle point means a point subjected to coordinate transformation by TKY2JGD and the top of an arrow means GPS data.



(a) Differences of vector at Field A

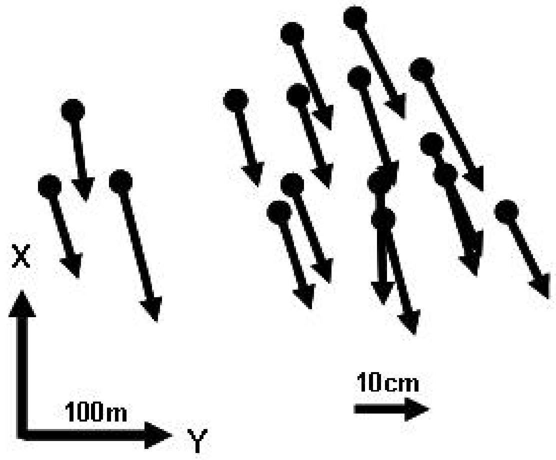


(b) Differences of vector at Field B

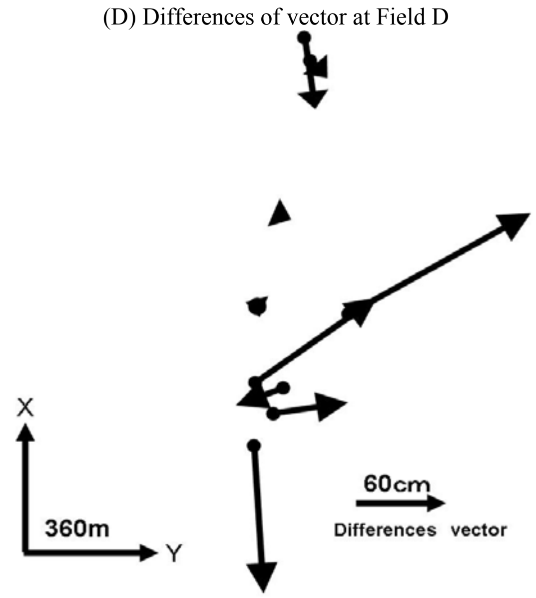


(c) Differences of vector at Field C

Figure 3. Differences of vector



(D) Differences of vector at Field D



(E) Differences of vector at Field E

Figure 3. Differences of vector

The average differences at A, B, C, and D and E were about 11.3, 31. 9, 11, 14 and 108 cm respectively. In addition, A, B, C, D, and E were rotary, parallel, south-east, south-southeast, and irregular patterns, respectively.

The areas A, B, and C have a regular accident error, but the area D did not have any accident errors because many kinds of control points existed in the area D (Figure 4). Therefore the control point could not be measured accurately. Converted data almost all corresponded to digital BM data in a small-scale map. However, the parameter could not be adopted in a large-scale map. Because the parameter area of TKY2JGD is too large, it is necessary to make the parameter in a narrow area.

Figure 4. Many kind of control point in Area D

4. VERIFICATION OF HIGH-ACCURACY REGIONAL PARAMETER USING AFFIN TRANSFORMATION IN NARROW AREA

On the verification, Affine Transformation which is the most general and simple method in various geometric conversions Affine Transformation makes the three parameters. Elements were rotation, scale and parallel. These parameters transform the geodetic system (x, y) of old geodetic system to (x', y') of new one. The conversion formula is as follows.

$$
\begin{aligned}
x' &= x_0 + k_x x - \theta_y y \\
y' &= y_0 + \theta_x x + k_y y
\end{aligned}
\tag{1}
$$

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

Parameters obtained by Affine Transformation are called "High-Accuracy Regional Parameter (HARP)". HARP was calculated by the coordinates of Tokyo Datum and GPS data. In this paper, the data of area E are not used. In the master's thesis of Ms. Aki Okuno who graduated from Kanazawa Institute of Technology (KIT), she performed calculation by 11 methods having a different number of control points and different places of control points, and standard deviation of Affine Transformation had only 3cm errors when using control points at four corners. In this paper, four control points were located at four corners of the area. In addition, calculated parameters by the coordinates of A B, C and D were named parameter A, parameter B, parameter C, and parameter D respectively.

Transformation methods are as follows.

- Areas A, B, C, D were transformed by using parameters A, B, C, D.
- Areas B, C, D were transformed by using parameters A.

Table I shows that result of adapting the parameter of the same area. As a result of verification, the error was not more than 4cm in X and Y.

Parameters	Error(m)	
	σx	σy
Area A (parameter A)	0.0062	0.0037
Area B (parameter B)	0.0038	0.0091
Area C (parameter C)	0.0056	0.0036
Area D (parameter D)	0.0079	0.0154

Table Ⅰ. Error calculated by the same parameter

Parameters	Error(m)	
	σx	σy
Area B (parameter A)	0.1003	0.9661
Area C (parameter A)	0.0315	0.0158
Area D (parameter A)	0.1325	0.8936

Table Ⅱ. Error calculated by different parameter

Table II shows that result of adapting the parameter of a different area. The error was large in areas B and D. However, the error of area C was not more than 4cm in X and Y since A and C are close. Therefore it is possible to transform a 5km× 5km area by one parameter. In addition, the overlaying of GPS data and transformed should be verified. Then, the accuracy of coordinate transformation will become clear.
Therefore it is possible to transform 5km×5km area by using the one parameter. In addition, it has to confirm that GPS data and transformed BM be able to overlay. Then, the accuracy of coordinate transformation will become clear.

5. OVERLY OF GPSDATA AND TRANSFORMED BM INTO JGD2000 SYSTEM

The large-scale BM used in local government was transformed by the parameter. The parameter was calculated in area A. The transformed BM was overlapped with GPS data. GPS data was acquired by Virtual Reference Station - GPS (VRS-GPS). An original program for transformation was made by our laboratory. Transformation parameters were inputted to the program, and the result of the overlapped map is shown in Figure5. In Figure 5, a circle symbol means VRS-GPS.

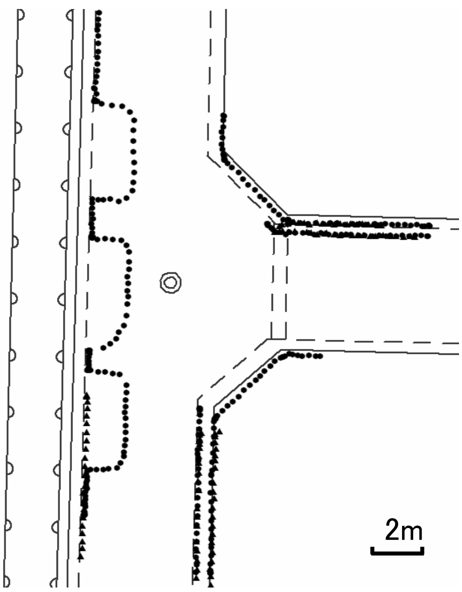


Figure 5. Overlapped BM and GPS data

The curve shown at the left side is a parked car on the road. The difference between both data is 5~10cm and 30cm in longitude and latitude, respectively.

In the case of field A, the centre area of the transformed map was coincided with GPS data. However, in the corner of the map, GPS data and the map did not coincide in a latitude direction due to parameters including rotational elements.

Additionally, the accuracy can be improved by an offset adjustment. The verification is necessary also in other areas.

6. CONCLUSION

If the local government introduces high-resolution satellite imageries as a background of BM, the government and general users can easily recognize the urban conditions. We recommend that the local government introduce the system of "REAL TIME GIS" and Remote Sensing imageries for their work. The simplification of the mapping process, reduction of mapping and updating costs, and understanding of accurate urban conditions are connected with the improvement of improved service to the citizens. In the experiment, the coordinate transformation of the large-scale map for local government was successfully conducted at a part of test site areas. And, VRS-GPS was measured without any trouble. However, all BMs were not accurately transformed to the new geodetic system.

It is suggested to use the town block control point for geometrical transform. The town block control point was made by GSI on" Basic Survey of Town Block for Renewal of Urban Areas." The town block control points maintain accurate data because of they are managed by the nation, and they were set up at a short interval (every 200m). Therefore, accurate reference point data can be acquired. If the town block control point is used for geometrical transform, the characteristic of the difference between the old geodetic system and the new one will be understood easily and, coordinate transformation will be performed more efficiently.

In addition, an IC tag is installed at the town block control point. Position coordinates are recorded on the IC tag. The IC tag will become a useful tool for the maintenance and management of control points.

Collaboration of Remote Sensing, GPS, and GIS will help local government renew a large-scale map.

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ACKNOWLEDGEMENTS

The authors wish to special thank to Ms.Aki Okuno of KOKUSAI KOUGYO Co., LTD. We wish to express our gratitude to Kanazawa Water and Energy Center , the town planning group of Kanazawa City , Hitachi, Ltd., CENTRAL Aero.Survey, KokudoKaihatu Center, Ltd., and Nihonkai consultant, Ltd, that offered data. Moreover, we would like to express our heartfelt gratitude to the cooperation of Leica Geosystems, Ltd. for VRS-GPS experiment.