Updating and Re-establishment of Cadastral Control Points in Korea by Using GPS Observations

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Key words: GPS, cadastral control point, datum transformation, network adjustment

SUMMARY

Cadastral surveying in Korea is based on the cadastral triangulation points which are originated from the old surveying network established in early years of 20th century. The datum is different from New Korea Geodetic Datum 2000 (NKGD2000) which employs ITRF97 and GRS80 ellipsoid.

In order to improve quality of old cadastral surveying network, which will not be accurate enough to meet modern needs, the network is investigated by GPS measurements and trilateration adjustment is carried out. In this process, coordinate transformation between the old and NKGD2000 datum, and local geoid model is used to find out accurate control points. The adjustment computation by using the GPS observations on 32 triangulation points distributed over Gyunggi province (100km x 100km) has shown the control points employed in cadastral surveying has coordinate error up to one meter or more. The computation also has shown the estimated coordinate error of the adjusted points is within 5cm, highly accurate as well as highly consistent.

In Korea, more than 90% of cadastral surveying has been carried out by graphic method. And all the map sheets have been digitalized by the year 2003. Because the graphic map was digitalized independently of control points and of adjoining maps, several problems arise in surveying where the adjoining two maps are improperly connected. To solve the problem, we are going to update or re-establish the old control networks, and develop a method tying parcel boundary points to nearby control points.

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1. INTRODUCTION

In Korea, cadastral surveying is being carried out based on the cadastral triangulation points which are originated from the old surveying network established in early years of 20th century. The old network consists of 13 baselines, 189 first-order triangulation points, 1,102 second-order points, 3,045 third-order points, and 11,753 fourth-order points. The datum adopts Bessel ellipsoid as a reference with its origin fixed at Tokyo, Japan. Unfortunately, 80% of these triangulation points and original records of the old survey were lost during the 3-year Korean War in 1950-1953. So, we only have a set of coordinates of triangulation points.

Therefore, there had been several attempts to update the old network. In 1954, US Army Map Service Far East in cooperation with Geographical Survey Institute of Japan had resurveyed the network over Korean Strait in order to strengthen the connection between Korea and Japan. In 1975-1994, the re-establishment of Primary Precise Geodetic Network (PPGN) was carried out by National Geography Institute of Korea. PPGN consists of 1,155 points including 175(~15%) old first- and second-order triangulation points (Yun, 2001). The mean distance between the points is about 11km. PPGN was adjusted in the way that its coordinates are the same as the old ones. But there is controversy concerning the accuracy of PPGN.

Cadastral maps currently used are based not only on the old surveying network but also on some isolated surveying networks which were established independently before the old network was completed. Depending on the network, even physically the same monuments have significant coordinate differences, thus the need for the unified network with its point coordinate accurate enough for cadastral surveying is extremely large.

Using unique reference frame makes it easier to create boundaries in cadastral maps and to recognize their positions on the ground. GPS positioning is a desirable and adequate method for establishing and strengthening the national and regional geodetic networks. Therefore, in cadastral community of Korea, necessary preparations for employing NKGD2000 to be used easily for cadastral surveying has been underway for several years. In practice, since 2003, the Ministry of Government and Home Affairs (MOGAHA) in cooperation with Korea Cadastral Survey Corporation (KCSC) has been conducting GPS observations on the old triangulation points. By using these observations, in parallel with upgrading the old network establishing high density NKGD2000 network is being conducted.

In this study, by using GPS observations the coordinate difference of control points in cadastral surveying is examined, and an adjustment computation to upgrade the old control points is investigated.

2. CADASTRAL SURVEYING IN KOREA

The cadastre is an information system consisting of two parts: a series of maps or plans showing the size and location of all land parcels together with records that describe the attributes of the land. The cadastre include: geometric data (coordinates, maps), property address, land use and proprietary rights. It is distinguished from a land registration system in that the latter is exclusively concerned with ownership.

The land of Korea consists of 31,331,000 parcels of land and 3,420,000 parcels of forestry. The totals of 34,751,000 parcels are maintained in the forms of cadastral records and cadastral maps. Cadastral records are composed of land records, house records, and forest records in text format. Cadastral maps are composed of land maps and forest maps. The maps in straight line and polygon format had been written and drawn by hands and stored in the paper forms, then photocopied for public users until 1990. The land records and house records in text format had been typed to create a national database from 1982 to 1991 and began to be provided to the users through the nation-wide networks from 1991. The total number of map sheets to cover the whole land of Korea is about 750,000 which hold all of the parcels. The size of the border rectangle of a map sheet is about 30cm*40cm in 7 different scales of 1/500, 1/600, 1/1000, 1/1200, 1/2400, 1/3000 and 1/6000. All the map sheets have been digitalized by the year 2003.

Cadastral surveys are concerned with setting out and recording the turning-points or concerns along property boundaries. A variety of techniques may be used, each having its own inherent accuracy and cost. When the accuracy is defined, different methods of achieving it can be considered. In cities a precision of between 0.1 to 0.3 meters may be required while in rural areas 1 to 3 meters may be sufficient. However, digitalized maps require high and consistent accuracy because the area on the maps calculated by boundary coordinates must coincide with the statistics of the land by the records. This kind of discrepancy is caused by improper correction of the maps to compensate for the shrinkage-expansion of the map sheets, and integrated errors of surveying and mapping. Due to these problems, the digitalized map is used as isolated in cadastral surveying and mapping, and generating continuous map tied to control point is strongly required.

3. GPS NETWORK OF KOREA

GPS has gradually been replacing traditional procedures for conducting precise horizontal surveys. Post-processed GPS surveying with high accuracy and reliable result with a standard error of some millimeters has been well known and used quite a lot since many years. The observation time varies from minutes to hours or days depending on the baseline length and the conditions for the GPS observations. To reach this high accuracy, it is required to use relative carrier phase measurements, and ITRF coordinate of the reference station as accurate as possible. One of the objectives of the nationwide GPS network is to provide the reference data for geodetic surveys as a new type of geodetic control point.

In Korea, precise surveying by GPS has started with the establishment of the first continuously operating observation station in 1994. At the end of 2004, more than 80 permanent GPS stations were established throughout the country. The distances among the stations range from 30 km in urban areas to 60km in rural and mountainous areas. Figure 1 shows current status of the continuously operating GPS stations for geodetic and cadastral surveying established by Korean government. The stations marked with solid rectangle are operated by the Ministry of Government and Home Affairs, and the stations with circle are operated by the National Geography Institute.

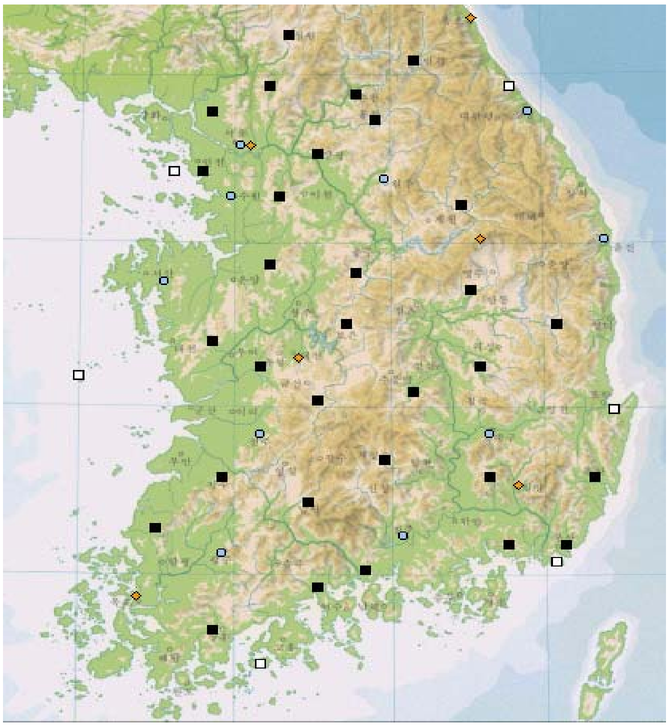

Figure 1: Permanent GPS stations operated by Korean government

The stations are equipped with the latest dual-frequency receiver. A receiver, a modem, a power supply and a tiltmeter are installed inside the pillar. The Ministry of Government and Home Affairs (MOGAHA), Ministry of Science and Technology, and National Geography Institute play cooperative roles in establishing and operating GPS networks. The purpose of the network is to (1) provide single- and dual-frequency data for relative measurements, (2) provide differential corrections for broadcasting to real-time users, (3) monitor the integrity of the GPS system, (4) act as high-precision control points for surveying and monitoring crust movements.

The collected data at each observation stations are transferred to the data center with the high-speed modem through public telephone lines. At the data center, the collected data are processed automatically using precise baseline analysis software to estimate 3 dimensional coordinates. Data processing is done repeatedly depending on ephemeris prepared. Calculations of baselines and positions are carried out using the broadcast ephemeris within 3 hours after the data acquisition. Alternative calculations are done to get final results using precise ephemeris prepared by IGS about 11 days later after the observations.

The data will be provided to users in the RINEX (Receiver Independent data Exchange) format via Internet for post-processing. In the near future, it is expected that some of the stations operated by MOGAHA will support RTK-GPS positioning. The network will be the backbone of the newly established precise geodetic network in conjunction with the conventional triangulation network.

4. DATUM TRANSFORMATION

The old national control points which are used in cadastral surveying have been measured on 461 triangulation points over South Korea. The tie of GPS surveys to existing triangulation monuments and vertical benchmarks enables the transformation of GPS datum to be resulted in the national datum. It has advantages in establishing minor control points and finding outlying points in local datum since they can be done with efforts much less than when the conventional method is used. This has led us to establish converting processes from a global datum to local ones.

To find the coordinate difference between the datums, 206 triangulation points are used to determine 7 conversion parameters between the Korean datum and NKGD2000. The seven parameters are three origin shifts (δX, δY, δZ), three rotations (ω_X, ω_Y, ω_Z) and a scale factor (δS). They were estimated by least squares methods. In this process, the geoid height referenced to the local ellipsoid has been calculated on the basis of the datum shift of Tokyo Datum with respect to WGS-84 (δX=146.43m, δY=-507.89m, δZ=-681.46m) reported by Geographical Survey Institute of Japan (Tsuchiya and Tsuji, 1996).

Table 1 shows the estimated seven parameters. The apparent differences between the old Korean Datum and NKGD2000 horizontal coordinates for the same point are approximately -11.5 to –10.2 seconds in latitude and 7.2 to 8.3 second in longitude (Yang et al., 1998). This corresponds to –360m to –310m in northward and 180m to 210m in eastward shift of Korean datum with respect to NKGD2000. The posterior RMS difference between them is 35cm. This accuracy will result in better than 1-PPM accuracy when relative GPS surveying is carried out from the control point with its NKGD20000 coordinate obtained by datum transformation. Figure 2 shows computed corrections in latitude (solid line) and longitude (broken line) between NKGD2000 and old Korean datum, and Figure 3 shows correction vector of the triangulation points.

Table 1: The estimated seven parameters to transform from the old Korean Datum to NKGD2000.

δX (m)	δY (m)	δZ (m)	ω_X (sec)	ω_Y (sec)	ω_Z (sec)	δS (PPM)
126.620	-481.002	-657.299	1.735	-1.958	-1.867	-6.466

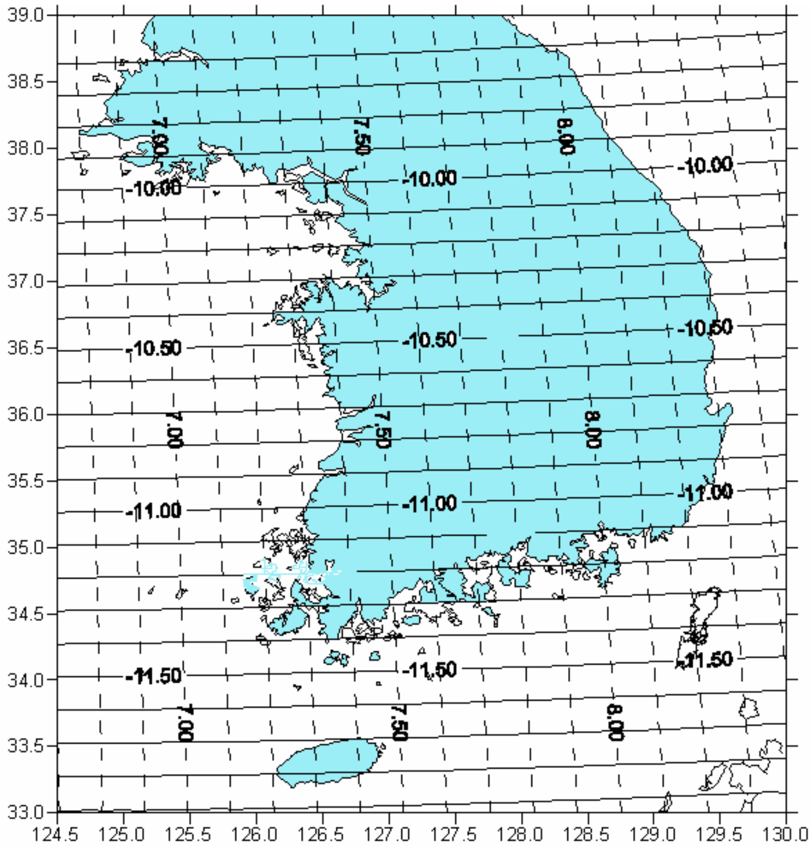

Figure 2: Contour lines of the corrections in latitude and longitude to transform from NKGD2000 to old Korean Datum (unit in seconds)

5. VERTICAL DATUM

Heights are related to the reference ellipsoid, whereas conventional leveling related heights to the geoid. No mathematical correspondence can be achieved as the geoid is an irregular surface defined by gravity. In usual, correlation must be established for a number of points in the area between GPS heights and orthometric leveling related to geoid. Interpolation is then carried out to deduce the orthometric heights of points measured by GPS. A greater density of vertical control points is required in an area of topographic irregularity where the geoid is likely to be irregular, as well.

Ellipsoidal heights are given from GPS measurements, and if they are combined with precise local geoid, orthometric heights are easily calculated. This can significantly reduce the efforts to measure the heights by leveling. The accuracy of the calculated orthometric heights depends on the accuracy of the local geoid, and that of the GPS ellipsoidal heights.

Throughout the southern half of the Korean peninsula, a local geoid model PNU95 is available (Choi et al., 1997). The model is calculated with over 5,000 well-distributed and well-controlled gravity measurements, sea surface heights from various altimeters, and a reference Earth gravity model of the OSU91A (Rapp et al., 1991). At 71 well-distributed points, the GPS/geoid heights are compared with orthometric heights from the national vertical datum. The RMS difference is about 12cm.

Although the result is not satisfactory, the differences of geoidal heights are useful in determining elevations in a small area where only one benchmark is available. The pseudoelevations for the area will be closer to the true values than if no geoid model were used and a single point were held fixed. The geoid is relatively smooth and elevations within 10km x 10km area can be determined 3cm or better in flat area.

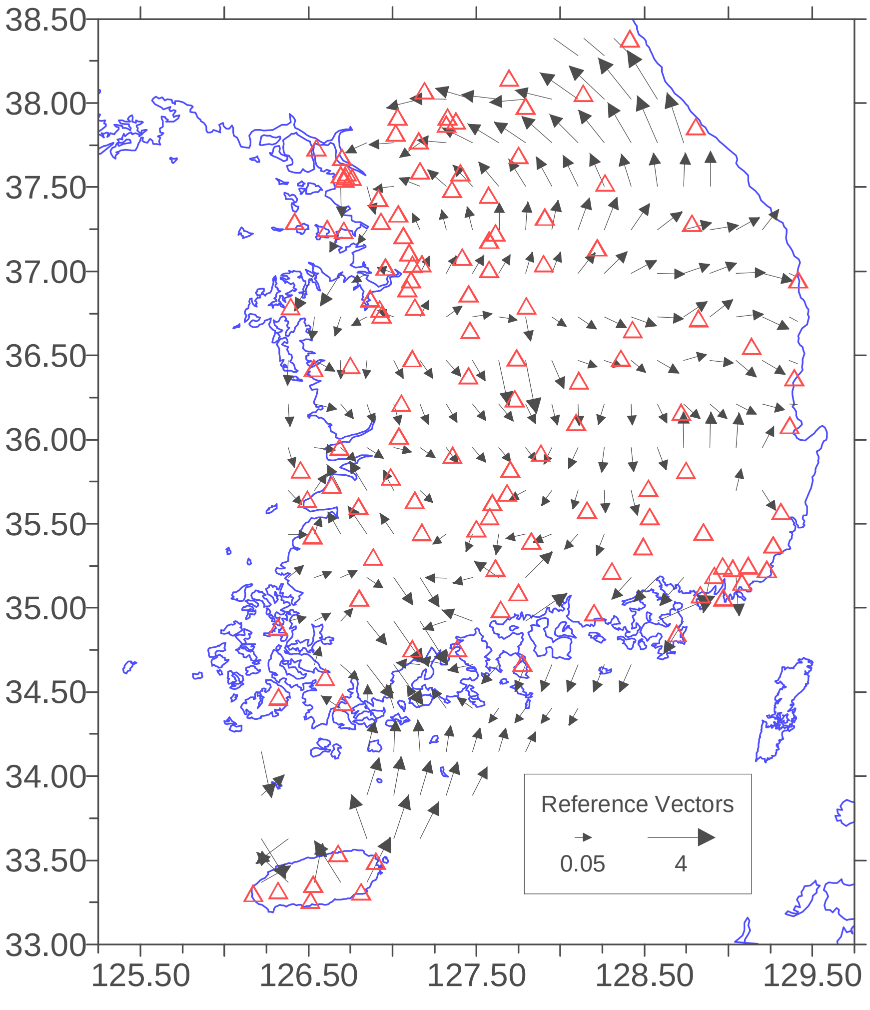

Figure 3: Correction Vector of the Triangulation Points Referenced to Datum Transformation from NKGD2000 to Old Korean Datum.

6. LOCAL ADJUSTMENT

Datum transformation from old Korean datum to NKGD2000 shows that apparent differences between the old Korean datum and NKGD2000 horizontal coordinates for the same point are approximately -11.5 to –10.2 seconds in latitude and 7.2 to 8.3 seconds in longitude. The posterior RMS difference between them is 35cm. The orthometric heights by GRS80 ellipsoidal height and local geoid model showed 12cm RMS differences from the national datum.

The transformed results have different residuals, depending on data distribution, their qualities and sizes of computation area. The results depend not only on the transformation formula but also on the inner accuracy of the coordinates of the common points which are used to compute transform parameters. When 7-transformation parameters are estimated for local areas, they are, especially with no constraint in parameters, significantly different from those for the national scale. This is largely due to the combination of outlying points, shrinkage-expansion, and distorted local surveying networks. In addition, it is difficult to estimate errors of transformed coordinates. Therefore, more efforts will be made to provide a standard for datum transformation and associated procedures that will result in adequate and consistent accuracy over the country.

Applying a transformation to precisely surveyed positions results in distortion of the accurate GPS measurements to make them fit a less precise control network. In determining point position in old Korean datum by GPS, network adjustment enables us to get more reliable result than datum transformation provided that we have at least three points with known coordinates. It is necessary that the points have precise coordinates in old Korean Datum, otherwise they may induce geometrical distortions of the network. The more control points we have the more reliable result will be. In finding out control points to employ as fixed points in the adjustment, the result obtained by datum transformation and orthometric height obtained by GPS/leveling is useful because we can easily check inner accuracy of the network.

This method is applied to local network consists of 32 triangulation points where GPS observations are conducted. The network encircles Gyunggido (100km x 100km) located northern west part of South Korea. Among the 32 triangulation points, 3 points are selected as the fixed in the adjustment. These points have coordinate differences less than 5cm between the registered coordinates and the transformed.

In computation, coordinates of the fixed points are assigned a standard deviation of zero. The fixed points will not be changed during adjustment. The baselines by GPS measurements are reduce on the surface of Bessel ellipsoid, and then plane projected distances are obtained. The distance are weighted according to the reciprocal of the square of distance times 1ppm. The adjustment forces all other points in a way that they will fit the fixed points. Thus, in this case, there are 26 unknown points to be determined. The unknown parameters are the coordinates of the unknown points.

Figure 4 shows the coordinate correction of the points obtained in this study. The coordinate correction is difference between the adjusted coordinate and the old registered coordinate of the corresponding point. This result shows that the control points employed in cadastral surveying has coordinate errors up to one meter or more. But the computation also has shown the estimated coordinate error of the adjusted points is less than 5cm, highly accurate as well as highly consistent.

It is remarkable that the result obtained by datum transformation is similar to the adjusted result. With the joint usage of the two methods, therefore, we can easily detect outlying points and select points to be fixed in adjustment. Provided that accurate control points are selected over wide range of several maps, we can easily compute unknown point coordinates by using baseline vectors and terrestrial measurements.

The digitalized cadastral map provides coordinates of boundary points. Although the map is originated from plane table surveying, there are measurements between the boundary points such as distances and angles. The unacceptable discrepancies of some decimeters or even metes between the points can be removed in adjustment. Then recalculation of the whole of the region including all the cadastral points can be conducted. In doing this computation, one of constraint that minimizes area difference of parcel polygon formed by the newly determined coordinates and by the old coordinates is necessary. This method will give consistent result of upgrading control point and boundary points altogether

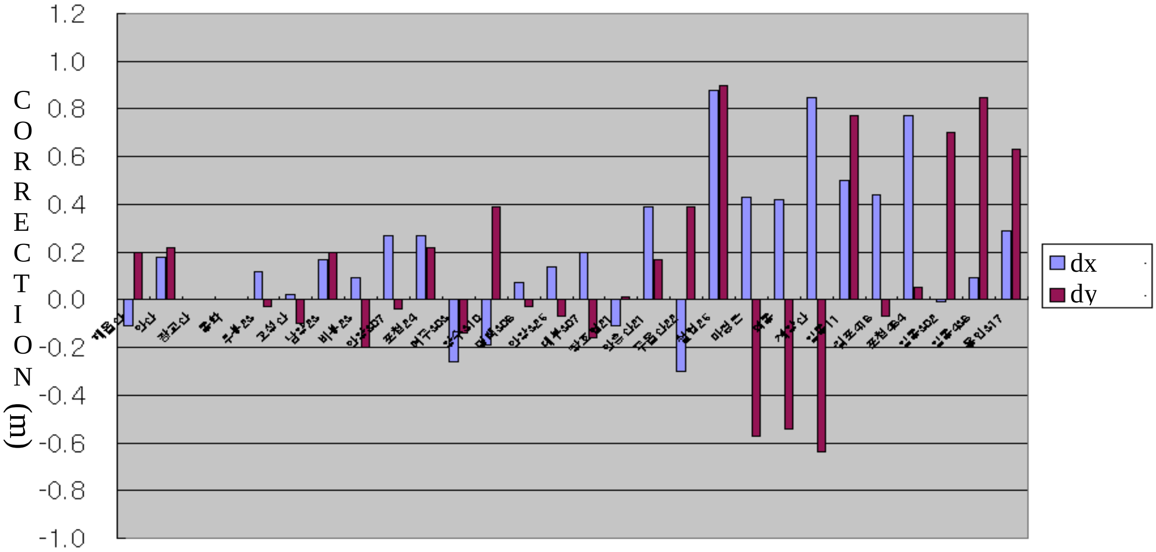

Figure 4: Coordinate difference (dx,dy) between the new coordinate from the adjustment and the old registered coordinate of the corresponding point.

7. CONCLUDING REMARKS

In Korea, more than 90% of cadastral surveying has been carried out by graphic method. Because the graphic map was digitalized independently of control points and of adjoining maps, several problems arise in surveying where the adjoining two maps are improperly connected. Therefore, producing accurate continuous map which can be used in cadastral surveying is one of the urgent task nowadays. To solve the problem, we are going to update or re-establish the old control networks, and develop a method tying parcel boundary points to nearby control points.

Through the use of baselines by GPS measurements and associated adjustment procedures, it is possible to combine GPS with conventional measurements. This will include establishing physical monuments sited in areas free from instability and any inconveniences to survey. Practically, physical monuments are still necessary as these can be seen and understood by land owners and ensure that cadastral surveys can still be undertaken even when GPS is not available. Of course, in final, we are going to connect the network to New Korea Geodetic Datum 2000 (NKGD2000).

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BIOGRAPHICAL NOTES

Yang Chul-soo is working for Korea Cadastral Survey Corporation in developing cadastral surveying techniques. He majored geophysics at Tokyo University and obtained PhD on physical geodesy in 1992. He is a member of Korean Society of Surveying, Geodesy, Photogrammetry and Cartography, Korean Society of Cadastre, and Japanese Society of Geodesy

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