The Journal of GIS Association of Korea, Vol. 16, No. 4, pp. 401-410, December 2008

Invited Papers

Renovation of Korean Geodetic Control Points

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ABSTRACT

In this contribution, the renovation of the Korean geodetic control points is introduced. The renovation is described in terms of structure and accuracy. Mainly the establishment of the three-dimensional control points is the renovation on structure which leads many changes in accuracy, contents and hierarchy of the control points. The accuracy of the information is being improved based on the satellite positioning technology and precision geoid being developed. Diverse spatial information such as gravity and environmental elements are considered to be measured at the position of the control points so that the related research is enhanced through the analysis of combined information. In addition, an access to the information of control points and service to the public with spatial information will be faster and more efficient through RFID and CDMA communication. With all these efforts being made currently, the Korean geodetic network will provide the most accurate and diverse spatial information in an efficient way. We hope that these activities lead the trends, roles, and future direction of the geodetic control points.

Keywords : Geodetic Control Point, Precision Geoid, Urban Control Point

요 약

본 연구에서는 우리나라의 측지기준점의 개선에 대하여 소개하였다. 개선의 내용은 기준점의 구조와 정확도에 중점을 두어 설명하였으며, 구조의 경우 3차원 기준점으로 변화하면서 정확도, 포함 정보, 그리고 기준점의 위계에 대하여 서술하였다. 정확도의 개선은 위성측지 기술의 발달과 정밀지오이드를 기반을 주 내용으로 하고 있으며, 기준점의 개념은 위치뿐 만 아니라 중력, 환경정보와 같은 다양한 공간정보를 포함하여 전반적인 정보의 분석이 가능한 점이 강조되었다. 또한 RFID와 CDMA 기술을 이용한 공간정보의 효율성과 신속성을 소개하였다. 이러한 모든 노력으로 한국의 측지망은 보다 정확하고 다양한 공간정보를 효율적으로 전달할

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수 있을 것이라 판단되며 이러한 개선이 측지 기준점의 역할과 미래의 방향에 큰 영향을 미칠 것으로 기대된다.

주요어 : 측지기준점, 정밀지오이드, 도시기준점

1. Introduction

The network of geodetic control points are the fundamental framework of a country since this is a basis where all spatial applications refer to. A geodetic network provides accurate positional information with its changes with respect to time. This information is the basis on the analysis of many scientific research fields such as geodesy, geophysics, astronomy, geodynamics, and so on. Some typical examples on the geodetic network application could be found in tectonics (Halicioglu and Ozener, 2008), volcanology (Yu et al., 2001), and crustal motion (Capra et al., 2002).

Historically, the geodetic network has been established and maintained in terms of two categories, namely the horizontal and vertical network. The main reason for this separate structure is the reference surface of the horizontal position and vertical position. That is, the natural reference surface for the vertical datum would be the mean sea surface from which the height is quantified in terms of potential number (Heiskanen and Moritz, 1967) while the reference of the horizontal position is ellipsoid. Recently, this separate structure is re-examined and some disadvantages are discussed. Basically, the old 2D+1D structure is not a consistent network. While the vertical datum contains physics by definition, the horizontal network is purely geometric. To accommodate the state-of-art technology, it was necessary to define a consistent network which provides purely geometric location of a point. This became possible by the satellite technology GNSS (Global Navigation Satellite System). In GNSS, the geodetic coordinate namely geodetic latitude, longitude, and ellipsoidal height are used so that all the satellite based applications are easily analyzed three dimensionally. Therefore, it is a natural trend to renovate the old geodetic network to new three dimensional system based on CORS (Continuously Operated Reference Station).

To keep pace with international trends, fully utilize the recent satellite technology and construct the spatial data infrastructure which is compatible worldwide, the geodetic datum of Korea is superseded by the new Korean Geodetic Datum 2002 (KGD2002) from January 1, 2007. According to this datum change, the datum origin is recalculated based on the VLBI (Very Long Baseline Interferometry) observations; the 1st order control stations consist of 14 GPS CORS stations is readjusted for precise positions; two hundred 2nd order control stations which were previous 1st order triangulation control points and 8,744 3rd order control points are re-established by GPS surveying. The reference epoch of the new datum is on the year of 2002.0, and the baseline lengths of the 2^{nd} and 3^{rd} order control points are 20~30 km and 5km, respectively (NGII, 2006). From this framework of the network, Korea will densify, stabilize, and modernize the network until the year of 2010. Related to this renovation of the network, the Korean government initiated a gigantic project called Land Spatialization in Sep. 2007. The project is composed of five core-project; Geospatial Information Infrastructure, Land Monitoring, Intelligent Urban Facility Management, U-GIS Informative Construction Technology Innovation, and U-GIS Core SW Technology. Under the first core-project, the development of the next generation national ubiquitous control point and precise geoid are included (Figure 1). The successful achievement on these challenging topics is expected to upgrade the current geodetic network in terms of the structure, precision, and service.

In this paper, the effort on the renovation of the Korean geodetic network is reviewed and the future development is described. To understand the renovation, the current status of the network is described first, the renovation is investigated in detail, and some summarized conclusions are drawn from next sections. It is expected that this renovation on the fundamental framework of the national control network has tremendous and significant improvements on related spatial information areas.

2. Current Status

The first geodetic network in Korea is established in 1910 by the Bureau of Land Survey with the cooperation of the Japanese Military Land Survey. After that the geodetic network was re-established and updated a couple of times after Korean War as KTN1957 and KTN1987. The adjustment conducted for the current network is mainly done in 2006 by National Geographical Information Institute (NGII). In the followings, summary of the 2006 network adjustment is presented thus readers are re-

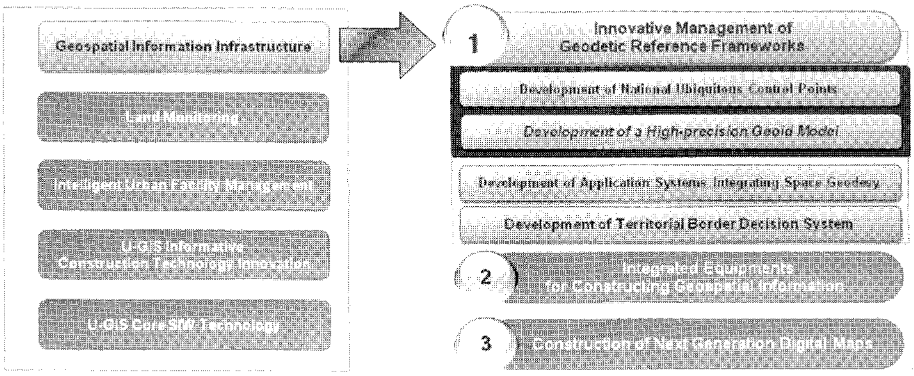

Figure 1. Structure of Land Spatialization.

commended to refer to NGII (2006) for more details.

2.1 Vertical Network

The origin of the Korean vertical datum has been determined from MSL by observing the tide of Incheon Bay in 1963 and is located in the campus of Inha Technical College, Incheon city. In KGD2002, the normal orthometric height system is used because Korea has not the official nationwide precise geoid model. Korean 1st order vertical network consists of 1,127 BMs and 36 routes, with total length of 3,342 km. The 2nd order vertical network consists of sixteen leveling loops with total length of 7,863 km; ten loops are encircled by 1st order leveling routes and six loops are bordered by a 1st order leveling routes (Figure 2). In 2006, 1090 1st order, and 3988 2nd order data are re-processed generating the accuracy of 20.36 mm. Total 26 loops which corresponds to 11,609 km in distance were processed.

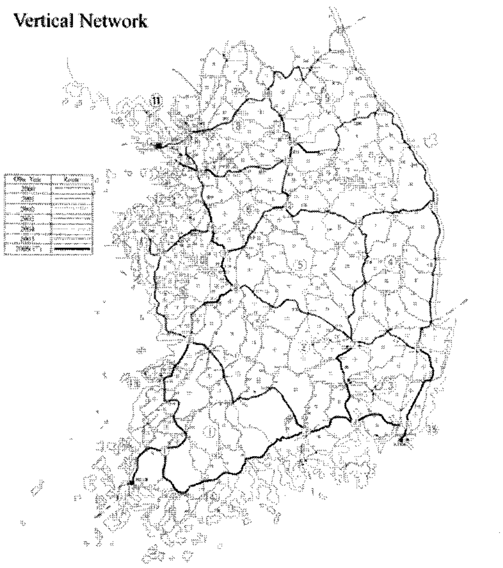

Figure 2. Overview of Korean 1st and 2nd vertical network.

The results of vertical network adjustment show the drastic improvement compare with existing leveling data set. In case of 1st order network adjustment, posteriori variance under the condition of one fixed point was 1.8 mm/$\sqrt{km}$ while 4.3 mm/$\sqrt{km}$ in previous adjustment in 1987. Moreover, In case of 2nd order network adjustment, posteriori variance under the condition of one fixed point was 2.2 mm/$\sqrt{km}$ while 9.1 mm/$\sqrt{km}$ in 1988.

2.2 Horizontal Network

The origin of the new Korean datum KGD2002 is determined from the baseline determination between the VLBI observation point and the datum origin point. The VLBI observation conducted through Joint Geodetic Project of Korea and Japan in 1995, and the measurement was sent to NASA to connect to the IVS network on November 14, 2000. The adjusted coordinates from this work is based on ITRF 2000 with reference epoch of 1997.0. From January 17 to 26 in 2002, GPS baseline survey (3 sessions; each observation period is 7 hours) and five geodimeter observations were carried out from the VLBI stations to the datum origin marker. Through these observations, the coordinates of origin of KGD 2002 is determined with the reference epoch of 2002.0. That is, the origin coordinates are updated by including the vector of the crustal motion from 1997.0 to 2002.0

(Table 1). The datum origin of KGD 2002 is located at NGII and the coordinates are shown in Table 2.

Currently, more than 90 GPS CORS are being operated by various institutes/centers in Korea. Among them, 44 stations are operated by NGII whose mission is to provide the coordinates of the national control points. Now, the GPS CORS of NGII is served as the first order control points in KGD 2002. The NGII, with cooperation of a number of surveying contractors, has held GPS observation campaign over the national geodetic control points since 1996. During these campaigns, about 10,000 points were observed until the end of 2005. Table 3 shows a summary of GPS data observed at the 2nd and 3rd order horizontal control points (i.e., triangulation points).

The main differences between the two types of observations are baseline length and GPS receiver occupation time. While the baseline lengths of the 2nd order network range from 20km to 40km (Figure 3), those of the 3rd order network do not exceed 5km. GPS occupation times were eight hours for the 2nd and four hours for the 3rd order networks, respectively. Through the re-adjustment in 2006, the coordinates of the 2nd order network were estimated

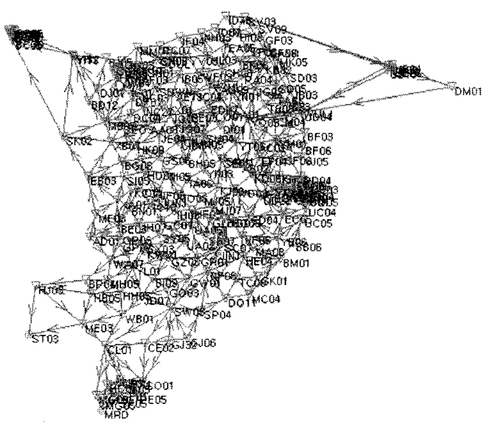

Figure 3. Reprocessed 2nd order GPS network.

Table 1. The VLBI Results.

ITRF 2000 (epoch 1997.0)	Crustal motion (1997.0~2002.0)	ITRF 2000 (epoch 2002.0)	ITRF 2000 (epoch 2002.0), GRS80
X=-3062024.021m	ΔX=-0.145m	X=-3062024.166m	37-16-31.53193
Y=4055453.834m	ΔY=-0.038m	Y=4055453.796m	127-03-15.16770
Z=3841809.998m	ΔZ=-0.051m	Z=3841809.947m	81.521 m

Table 2. The origin of KGD2002.

Latitude (deg)	Longitude (deg)	Height (m)
37-16-33.3659	127-03-14.8913	91.253

Table 3. Summary of GPS observations at the 2nd and 3rd order horizontal control points.

Type	Baseline Length	Recoding Time	Num. of Stations	Num. of Campaigns
2nd order Net.	20~40km (mostly)	8 hours	200	8
3rd order Net.	2~5km	4 hours	9,296	66

with the average accuracy of better than 3cm and 6cm in horizontal and vertical component, respectively. On the other hand, that of the 3rd order network adjustment was better than 1cm and 2cm in horizontal and vertical component, respectively.

2.3 Geoid

An essential prerequisite of utilizing GPS for the determination of the orthometric height is the precise geoid. Furthermore, geoid plays an important role in the analysis of geodynamics related to the gravity field. The study on the geoid in Korea has been continued for the last ten years. Among them, Yun et al. (1999) determined the geoid in and around the Korean peninsula using spherical FFT technique, Lee et al. (2004) determines the geometric geoid using GPS/Leveling data, and Choi and Suh (2005) determines the precision geoid using recently observed ground and ship-borne gravity data. In spite of all the efforts on the more than last ten years, the accuracy of those geoid is known to be about 15~25cm. The main reason for this relatively poor accuracy comes from the data distribution and accuracy. In other words, the distribution and quality of the basic elements on the geoid determination namely gravity and terrain data was not enough for high precision geoid. As can be seen Figure 4, the clear lack of the north-eastern area of Korea caused aliasing effect coupled by the rough terrain. Furthermore, some of the gravity data was preserved not in the form of raw data but free-air anomaly. This means those data was not

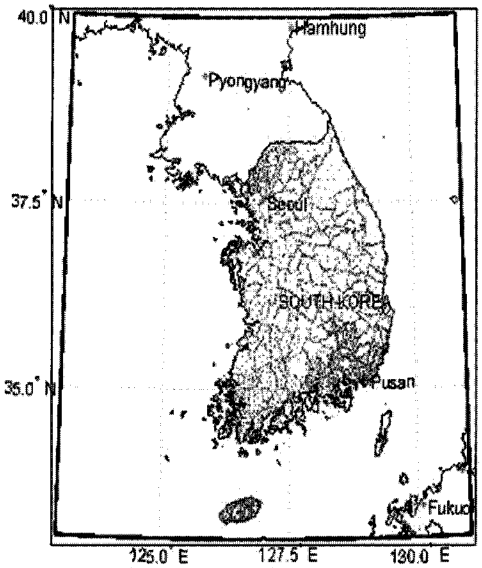

Figure 4. The distribution of the gravity data used in previous studies.

preprocessed in a consistent way which might generates some systematic biases among the measurements.

On top of the problems in gravity data, the topographic data used in the geoid determination did not have enough accuracy and data interval either. Some of topographic data is digitized from topographic map and the digital elevation model of GTOPO was not enough in mountainous area in terms of interval and accuracy for precision geoid.

3. Renovation

In this section, the current activities and plans for the Korean network renovation are presented. The renovation here means the changes in structure as well as in accuracy. These changes are being progressed under a couple of projects such as Land Spatialization by Ministry of Land, Transport and Marine Affairs (MLTM) and Establishment of Unified Control Station by NGII. In the following sections, those renovations with current status with directions for near future are described.

Figure 5. Distribution of the gravity data used in previous studies.

3.1 Dimensional Control Point

One of the dominant changes in Korean geodetic network is the activities on the establishment of three-dimensional control point. In other words, the control points are observed, processed and maintained in three-dimensional way. On this control point, the geodetic coordinates, orthometric height, and the gravity value. The main reason for this is to fully utilize the satellite positioning technology and to establish the complete compatibility in worldwide coordinate system. On top of that, scientific and engineering data being provided at the same point with accurate spatial information is expected to enhance the research quality so that more detailed analysis on physical phenomena could be performed. Figure 5 shows a unified control point established by NGII at Suwon City Hall. The dimension of the marker at the base plate is 2m × 2m and the diameter and the diameter of the central marker is 40cm. After this installation, NGII now decided to make the base plate smaller as 1.5m × 1.5m and about 1200 points will be installed in next three years.

As mentioned above, the coordinates of the unified control points are given in KGD2002 with gravity values and orthometric height. The level of the unified control point will be assessed as the 1st grade control point in horizontal as well as vertical. In addition, further spatial information such as environmental information would be measured and maintained at the same point based on necessities. It should be noted that the unified control point would make easier operation and maintenance on the control points as well. Starting from the adjustment up to the service, every procedure would be follow three dimensionally. This basically leads to more consistent and efficient maintenance in terms as time and labor.

3.2 Urban Control Point

The other ambitious project underway is to establish the urban control point. As a matter of fact, a couple of studies already are conducted on the ubiquitous control points which focused on design (Kim et al., 2007) and remote control access on the national control point (Park et al., 2007). At this time, the functionality with whole system structure is defied in detail so that an

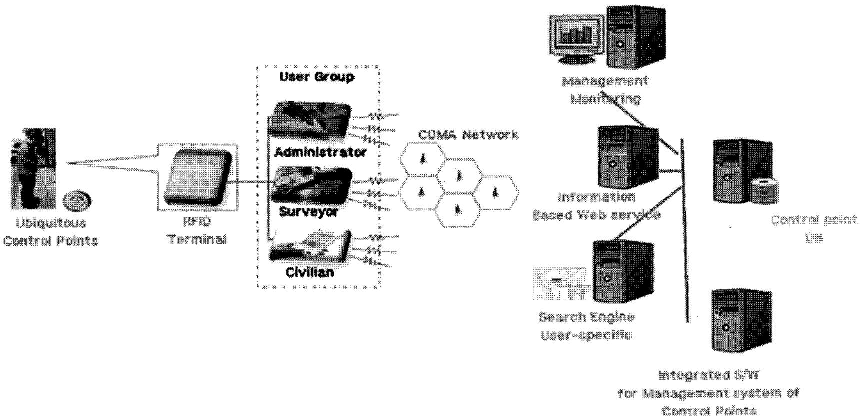

Figure 6. Scheme of the urban control point.

efficient management and operation on the control points are possible.

As seen in Figure 6, the user obtains the positional and some additional spatial information from the urban control point using RFID and CDMA network. The information related to the control point is centrally managed in which the database, web service, search, and related software are integrated. By combining the unified control point described in previous section with this urban control point, the control point in Korea will play an active role to provide the basic information for all kinds of spatial information fields.

3.3 Precision Geoid

One of the challenging topics under the Land Spatialization is to develop the precise geoid model. The target resolution and accuracy is 5km and 5cm, respectively. As mentioned previously, the biggest problem in the development of Korean precision geoid is the density and quality of gravity data. Since the recently published SRTM (Shuttle Radar Topography Mission) is considered to be enough for the determination of precision geoid, the only concern resides on the gravity data. To assure the quality of the gravity data, the only data with raw measurements are re-processed to calculate the free-air anomalies (Lee et al., 2008) and the accuracy of 0.48mGal is obtained. In addition, the effect of gravity data quality and spacing is investigated by Lee et al. (2008) to identify the area needs more data. Based on the study, the supplementary gravity surveying with GPS/Leveling will be conducted mainly in the east-north area of the Korea in this year.

A consistent gravity data is to be constructed by airborne gravity survey in this year. As seen in Figure 7, the airborne gravity survey covers whole south Korea including Jeju Island. The survey will be carried out mainly in NS direction and several EW profiles are planned for cross-over adjustment with total flight length about 17,000 km. Currently, the survey is prepared and planned to start in early December and will

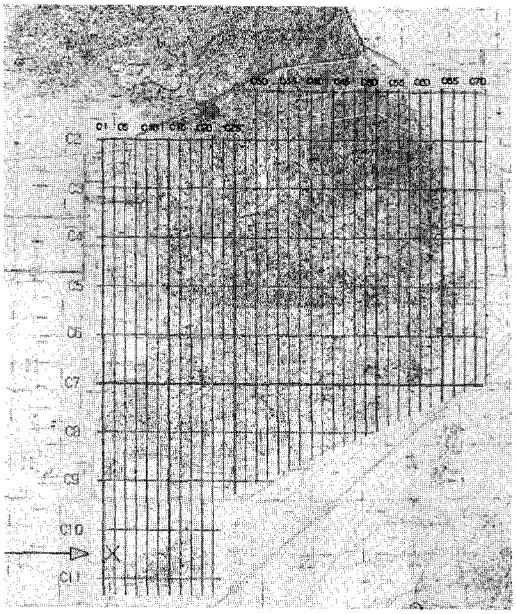

Figure 7. Trajectories of the airborne gravity survey.

be completed in two months. After successful achievement of this rather ambitious project, the geoid from airborne survey will be calculated with accuracy about 2mGal. After that, an optimal combination of all the available gravity data will be integrated so that the goal of 5cm is achieved. Once the precision geoid is constructed, more efficient height determination would be possible in many spatial related fields based on the satellite positioning technique. Of course, the accuracy of 5cm is not enough for certain applications like national control point, so the geoid should be continuously updated with more data and better processing techniques.

4. Summary and Conclusion

In this paper, current status and on-going activities with future prospect on Korean geodetic network is described. The main changes could be defined as a 'renovation' and are summarized as below.

First, the three dimensional control networks are to be established so the measurement, processing and management of the control point will be done in three-dimensional way.

Second, the control points will include some useful spatial information such as gravity and environment information. This will enhance the role of the control point and accelerate the research in scientific and engineering fields which use spatial information.

Third, ubiquitous control points are to be established in urban area for more efficient and rapid service and applications.

Fourth, the precision geoid with resolution of 5km and accuracy of 5cm will be constructed in next few years. This will make the determination of orthometric height much faster and easier due to the satellite positioning technique.

In sum, the Korean geodetic network will be renovated in terms of the structure and accuracy in next few years. Thanks to a couple of projects by the government, a three-dimensional network with diverse spatial information with enough accuracy will be constructed. Especially, the accommodation of spatial information on geodetic network is the first trial in the field of geodesy and survey which will affect future development of the control point significantly. Based on all these efforts we are making now, the Korean geodetic network will provide the most accurate and diverse spatial information and hope to lead the trends and future direction on this field.

Acknowledgement

This research was supported by a grant (07 KLSGC02) from Cutting-edge Urban Development - Korean Land Spatialization Research Project funded by Ministry of Land, Transport and Maritime Affairs.

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Received (September 12, 2008)
Revised (December 15, 2008)
Accepted (December 15, 2008)