Journal of the Korean Geographical Society, Vol. 40, No. 2, 2005(153~171)

An Integrated Approach to the GIS Data Reengineering for the New Korea Geodetic Datum

Yang-Won Lee* · Key-Ho Park**

세계측지계 도입에 따른 공간데이터 재정비를 위한 통합모델 연구

이양원* · 박기호**

Abstract : The newly adopted Korea Geodetic Datum (a.k.a. KGD2002) calls for massive reengineering work on geospatial dataset. The main focus of our study is placed on the strategy and system implementations of the required data reengineering with a keen attention to integrated approaches to interoperability, standardization, and database utilization. Our reengineering strategy includes file-to-file, file-to-DB, DB-to-file, and DB-to-DB conversion for the coordinate transformation of KGD2002. In addition to the map formats of existing standards such as DXF and Shapefile, the newly recommended standards such as GML and SVG are also accommodated in our reengineering environment. These four types of standard format may be imported into and exported from spatial database via KGD2002 transformation component. The DB-to-DB conversion, in particular, includes not only intra-database conversion but also inter-database conversion between SDE/Oracle and Oracle Spatial. All these implementations were carried out in multiple computing environments: desktop and the Web. The feasibility test of our system shows that the coordinate differences between Bessel and GRS80 ellipsoid agree with the criteria presented in the existing researches.
Key Words : KGD2002, ITRF2000, interoperability, standardization, spatial database

요약 : 세계측지계의 도입에 따라 광범위한 공간데이터의 재정비가 필요하게 되었다. 이 연구에서는 이를 위한 통합모델로서 상호운용성과 표준화 및 공간DB 활용에 기반한 구체적인 전략과 시범시스템을 제시한다. 세계측지계를 위한 지도데이터 변환은 파일변환과 공간DB 변환, 그리고 파일-공간DB 상호간 변환의 형태로 이루어질 수 있다. 이 연구에서 개발한 통합모델은 기존의 파일형식(예컨대, DXF와 Shapefile)은 물론 새로운 표준으로 권장되는 파일형식 (예컨대, GML과 SVG)의 세계측지계 변환이 파일형식 상호간에 이루어지도록 한다. 이러한 지도파일들은 세계측지계 변환모듈을 거쳐 공간DB로 임포트되거나 공간DB로부터 익스포트될 수 있다. 또한, 공간DB의 세계측지계 변환은 단일 DB 내부변환과 함께 이질적인 DB간의 변환 (예컨대, SDE/Oracle과 Oracle Spatial)을 포함한다. 이 연구의 세계측지계 변환시스템은 다중컴퓨팅 환경을 고려하여 데스크탑과 인터넷 기반에서 동시에 운영되도록 구현되었다. 시험운영과 평가를 통해 본 연구에서 제안한 통합모델의 상호운용성과 타당성이 검증되었으며 또한 좌표변환의 결과도 기존 연구의 결과물과 일치함을 확인하였다.
주요어 : 세계측지계, 상호운용성, 표준화, 공간데이터베이스

* Postdoctoral Researcher, Center for Spatial Information Science, The University of Tokyo, jwlee@iis.u-tokyo.ac.jp
** Associate Professor, Department of Geography, College of Social Sciences, Seoul National University, khp@snu.ac.kr

1. Introduction

Being conformant to an international standard of high-precision coordinate system, ITRF2000 (International Terrestrial Reference Frames 2000) has been adopted in approximately 50 countries including United Kingdom, Australia, New Zealand, and Japan.[1] In Korea, KGD2002 (Korea Geodetic Datum 2002), the local version of ITRF2000, has also been established by a variety of researches on coordinate transformation and the nationwide public surveying based on more advanced positioning solutions. The shift to KGD2002 not only ensures more accurate coordinate system when compared to the Tokyo Datum built in 1910s, but also influences every concerned people and organizations that use maps. The entire current digital maps based on the legacy Tokyo Datum would be subject to modifications. This is because there is approximately 370-meter's difference between old and new coordinate system. According to the revised surveying law[2], the use of KGD2002 will be mandatory from 2007.

Even though the research on the appropriate transformation model for KGD2002 has been accumulated recently, few addresses the issue of conversion strategies involving a vast range of geographic information in accordance with KGD2002 (Lee and Cho, 2004). National and municipal GIS datasets are of particular importance since they constitute the core source of entire geographic information systems. As such, the interoperability and standardization should be a requisite for national and municipal GIS data (Jung et al., 2004). From the viewpoint of GIS data, the interoperability is for mediating heterogeneous data formats, and the standardization is for providing criteria of data format so that the interoperability could be achieved. In the initial stage of National GIS Project in 1990s, there had been numerous trials and errors due to the lack of interoperability and standardization: for instance, the non-unification of geometry and attribute in GIS data. As the project makes progress, however, several guidelines for the interoperability and standardization have been established.

Now, in another important era of national and municipal GIS for a wide range of massive data rearrangement for KGD2002, the notion of interoperability and standardization should be revisited and thus taken into consideration in the actual process of GIS data reengineering. In addition, the active utilization of spatial database is necessary, because it ensures the efficient maintenance, share, and circulation of GIS data. Although many researches have brought about stabilized transformation model, there are no significant results when it comes to the concrete strategies for GIS data reengineering of KGD2002.

This study attempts at proposing an integrated approach to the interoperability, standardization, and database utilization for the GIS data reengineering of KGD2002. Our strategy and implementations include the aspects of GIS data format, data storage, and computing environment based on the notion of de facto integration. First, as for the GIS data format, newly recommended standard map format such as GML (Geography Markup Language) and SVG (Scalable Vector Graphics) are handled in addition to the existing standard map format such as DXF (Drawing eXchange Format) and Shapefile. Secondly, with regard to the GIS data storage, four types of map conversion including file-to-file, file-to-DB, DB-to-file, and DB-to-DB are developed for the coordinate transformation of KGD2002. Thirdly, these reengineering processes are performed in multiple GIS computing environments: desktop and the Web.

GML proposed by OGC(Open Geospatial Consortium)[3] is an XML(eXtensible Markup Language) encoding for the transport and storage of geographic information, including both the spatial and non-spatial properties of geographic features (OGC, 2001). SVG proposed by W3C (World Wide Web Consortium)[4] is a language for describing two-dimensional graphics in XML. SVG allows for three types of graphic objects: vector graphic shapes, images, and text (W3C, 2001). GML plays an important role of GIS data standardization, because it is extensible to all types of geographic information that may not be covered by a single DXF or Shapefile. In addition, SVG contributes to activating mobile GIS and LBS (Location-Based Services), because it is portable to any XML-enabled devices such as PDA and cellular phone. In order to make KGD2002-converted maps suitable for standardization and ubiquitous computing, GML and SVG could be the alternative approaches.

While the background and objectives of this study being briefly described in this section, we explore in more detail the issues on the shift to KGD2002 in section 2 of the paper. The components for the GIS data reengineering such as mathematical model, data format, data storage, and computing environment are examined in section 3. As to the strategy for the GIS data reengineering, section 4 describes the design of our reengineering environment for KGD2002. Section 5 illustrates and demonstrates our prototype system for file-to-file, file-to-DB, DB-to-file, and DB-to-DB conversion and the feasibility test on a few cities. Section 6 concludes the paper with a summary and implications of our work.

2. Shift to the New Korea Geodetic Datum

ITRF may be considered as one of the most considerable progresses in recent years for establishing global standard of coordinate reference system[5]. ITRF is the realization of ITRS (International Terrestrial Reference System), the standard geocentric coordinate system proposed by IERS (International Earth Rotation and Reference Systems Service)[6]. ITRF2000, the latest version of ITRF set by several times revision[7] is based on the advanced space geodetic solutions such as SLR (Satellite Laser Ranging) and VLBI (Very Long Baseline Interferometry) for more accurate positioning (Altamimi *et al.*, 2002).

ITRS is a spatial reference system co-rotating with the Earth in its diurnal motion in space. In such a system, positions of points attached to the solid surface of the Earth have coordinates that undergo only small variations with time, due to geophysical effects such as tectonic or tidal deformations. ITRF is a set of physical points with precisely determined coordinates in the ITRS (McCarthy and Petit, 2003). The coordinates in ITRF is represented by a set of digit X, Y, and Z, where the origin point is the mass center of the Earth; X-axis is the direction of the intersection point between Greenwich meridian and the Equator; Y-axis is the direction of the 90° E; and the Z-axis is the direction of the north pole (Lee and Cho, 2004).

The existing coordinate system of Korea is dependent on the surveying base points constructed almost 100 years ago. Between the

Bessel ellipsoid for the existing coordinate system of Korea and the GRS80 (Geodetic Reference System 1980) ellipsoid for ITRF2000, there is approximately 740-meter's difference in semi-major axis and 673-meter's difference in semi-minor axis, respectively. Thus, the origin point of the existing coordinate system of Korea has an offset of approximately 370 meter southeast from that of ITRF2000 (Lee *et al.*, 1999; Yoon *et al.*, 2003).

Recently, Korea conducted nationwide public surveying based on VLBI and GPS (Global Positioning System) in order to reconstruct high-precision national surveying base points for KGD2002, the local version of ITRF2000. In addition, various researches on the new coordinate system have been conducted: for example, appropriate transformation model (Lee, 2002; Yoon *et al.*, 2003), analysis of the coordinate difference between the existing and new coordinate system (Lee *et al.*, 1999), and development of coordinate transformation tool (Yoon *et al.*, 2004). Owing to the public surveying and the efforts to develop appropriate transformation model, a standard method for the transformation between the existing and new coordinate system has been established. The similarity transformation by Molodensky-Badekas model with seven parameters is a primary transformation method, and it is supported by distortion modeling for detailed correction (National Geographic Information Institute, Korea, 2003).

KGD2002 not only provides more accurate coordinate system but also accelerates the practical use of GIS and GPS.[8] In order to maximize these advantages, some challenging issues still remain. With regard to the accuracy improvement, the modification of transformation method and parameter is suggested for large-scale map such as 1/1,000 (Lee and Cho, 2004) and for marine areas (Choi, 2004). In addition, spatial database conversion is also considered for framework and common GIS data. However, the issues on interoperability and standardization or the issues on utilization of mobile GIS and LBS, for the shift to KGD2002 has not been addressed to in the literature we reviewed.

3. Components for GIS Data Reengineering

The reason we use the term 'reengineering' is because we deal with not only coordinate transformation but also data format, data storage, and computing environment for the GIS data rearrangement of KGD2002 conformance. Mathematical models for coordinate transformation are the basis of this reengineering work. The mathematical models are applied to the map conversion of different data formats in different data storages. The entire process of coordinate transformation and map conversion has to be performed in multiple computing environments.

1) Mathematical Models for Coordinate Transformation

A typical method of the coordinate transformation between two different coordinate systems may be either analytical or map-to-map transformation. The analytical transformation is composed of a series of strict procedures, and it is more appropriate for the transformation that includes datum transformation between two ellipsoids (Lee *et al.*, 1999). For the KGD2002, the transformation from TM[9] with Bessel ellipsoid to TM with GRS80 ellipsoid is necessary. This transformation procedure has five steps: each step corresponds to each arrow of Figure 1 and Figure 2. The semi-major axis and flattering of Bessel and GRS80 ellipsoid used in this transformation process are as Table 1.

(1) TM to Lat/Lon with Bessel

$\{x,y\}$, the TM-projected coordinate can be transformed to $\{\phi,\lambda\}$, the latitude/longitude with Bessel ellipsoid using the following equations (Snyder, 1987).

$$\phi=\phi_1-(N_1\tan\phi_1/R_1)[D^2/2-(5+3T_1+10C_1-4C_1^2-9e'^2)D^4/24+(61+90T_1+298C_1+45T_1^2-252e'^2-3C_1^2)D^6/720] \quad (1\text{-}1)$$

$$\lambda=\lambda_0+[D-(1+2T_1+C_1)D^3/6+(5-2C_1+28T_1-3C_1^2+8e'^2+24T_1^2)D^5/120]/\cos\phi_1 \quad (1\text{-}2)$$

where ϕ_1 is the footpoint latitude or the latitude at the central meridian which has the same y coordinate as that of the point $\{\phi,\lambda\}$.

$$\phi_1=\mu+(3e_1/2-27e_1^3/32+\ldots)\sin2\mu+(21e_1^2/16-55e_1^4/32+\ldots)\sin4\mu+(151e_1^3/96-\ldots)\sin6\mu+(1097e_1^4/512-\ldots)\sin8\mu+\ldots \quad (1\text{-}3)$$

$$e_1=[1-(1-e^2)^{1/2}]/[1+(1-e^2)^{1/2}] \quad (1\text{-}4)$$

$$\mu=M/[a(1-e^2/4-3e^4/64-5e^6/256-\ldots)] \quad (1\text{-}5)$$

$$M=M_0+y/k_0 \quad (1\text{-}6)$$

$$M_0=a[(1-e^2/4-3e^4/64-5e^6/256-\ldots)\phi_0-(3e^2/8+3e^4/32+45e^6/1024+\ldots)\sin2\phi_0+(15e^4/256+45e^6/1024+\ldots)\sin4\phi_0-(35e^6/3072+\ldots)\sin6\phi_0+\ldots] \quad (1\text{-}7)$$

where e is the eccentricity of ellipsoid; M_0 is the true distance along the central meridian from the Equator to ϕ_0, the latitude crossing the central meridian λ_0 at the origin of the $\{x,y\}$; k_0 is the scale on central meridian; and a is the semi-major axis of ellipsoid.

$$e'^2=e^2/(1-e^2) \quad (1\text{-}8)$$

$$C_1=e'^2\cos^2\phi_1 \quad (1\text{-}9)$$

$$T_1=\tan^2\phi_1 \quad (1\text{-}10)$$

$$N_1=a/(1-e^2\sin^2\phi_1)^{1/2} \quad (1\text{-}11)$$

$$R_1=a(1-e^2)/(1-e^2\sin^2\phi_1)^{3/2} \quad (1\text{-}12)$$

$$D=x/(N_1k_0) \quad (1\text{-}13)$$

datum transformation

$$\{x_1,y_1\}\rightarrow\{\phi_1,\lambda_1\}\rightarrow\{X_1,Y_1,Z_1\}\rightarrow\{X_2,Y_2,Z_2\}\rightarrow\{\phi_2,\lambda_2\}\rightarrow\{x_2,y_2\}$$

Figure 1. Procedure of Analytical Transformation between Two Different Coordinate Systems

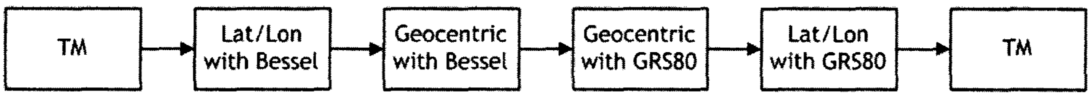

Figure 2. Procedure of Analytical Transformation for KGD2002

Table 1. Semi-major Axis and Flattening of Bessel and GRS80 Ellipsoid

Ellipsoid	Semi-major axis	Flattening
Bessel	6,377,397.155 meter	1/299.1528128
GRS80	6,378,137 meter	1/298.257222101

(2) Lat/Lon with Bessel to Geocentric Coordinate with Bessell

$\{\phi,\lambda\}$, the latitude/longitude with Bessel ellipsoid can be transformed to $\{X,Y,Z\}$, the geocentric coordinate with Bessel ellipsoid using the following equations, where ν is the radius of curvature at ϕ and h is the ellipsoidal height[10].

$$\nu=a/(1-e^2\sin^2\phi)^{1/2} \quad (2\text{-}1)$$
$$X=(\nu+h)\cos\phi\cos\lambda \quad (2\text{-}2)$$
$$Y=(\nu+h)\cos\phi\sin\lambda \quad (2\text{-}3)$$
$$Z=[\nu(1-e^2)+h)]\sin\phi \quad (2\text{-}4)$$

(3) Geocentric Coordinate with Bessel to Geocentric Coordinate with GRS80

$\{X_1, Y_1, Z_1\}$, the geocentric coordinate with Bessel ellipsoid can be transformed to $\{X_2, Y_2, Z_2\}$, the geocentric coordinate with GRS80 ellipsoid using the following equation of Molodensky-Badekas model, where origin point X_0=-3159521.31, Y_0=4068151.32, Z_0=3748113.85; displacement (in meter) ΔX= -145.907, ΔY=505.034, ΔZ=685.756; rotation (in second) R_x=-1.162, R_y=2.347, R_z=1.592; and scale change (in millimeter) λ=6.342 (National Geographic Information Institute, Korea, 2003).

$$\begin{bmatrix} X_2 \\ Y_2 \\ Z_2 \end{bmatrix} = \begin{bmatrix} X_0 \\ Y_0 \\ Z_0 \end{bmatrix} + \begin{bmatrix} \Delta X \\ \Delta Y \\ \Delta Z \end{bmatrix} + (1+\lambda) \begin{bmatrix} 1 & R_z & -R_y \\ -R_z & 1 & R_x \\ R_y & -R_x & 1 \end{bmatrix} \begin{bmatrix} X_1-X_0 \\ Y_1-Y_0 \\ Z_1-Z_0 \end{bmatrix} \quad (3\text{-}1)$$

(4) Geocentric Coordinate with GRS80 to Lat/Lon with GRS80

$\{X, Y, Z\}$, the geocentric coordinate with GRS80 ellipsoid can be transformed to $\{\phi, \lambda\}$, the latitude/longitude with GRS80 ellipsoid using the following equations.[11]

$$\phi=\tan^{-1}[(Z+e^2\nu\sin\phi/(X^2+Y^2)^{1/2}] \quad (4\text{-}1)$$
$$\lambda=\tan^{-1}(Y/X) \quad (4\text{-}2)$$

(5) Lat/Lon with GRS80 to TM

$\{\phi, \lambda\}$, the latitude/longitude with GRS80 ellipsoid can be transformed to $\{x, y\}$, the TM-projected coordinate using the following equations, where $A=(\lambda-\lambda_0)\cos\phi$ (Snyder, 1987).

$$x=k_0N[A+(1-T+C)A^3/6+(5\text{-}18T+T^2+72C-58e'^2)A^5/120] \quad (5\text{-}1)$$
$$y=k_0\{M-M_0+N\tan\phi[A^2/2+(5-T+9C+4C^2)A^4/24+(61-58T+T^2+600C-330e'^2)A^6/720]\} \quad (5\text{-}2)$$

2) GIS Data Formats

The current major GIS data format of national and municipal GIS in Korea is DXF and Shapefile. The initially constructed digital maps are in the form of DXF, and some of them have been converted to Shapefile for the integration of geometry and attribute. Shapefile is also used for loading GIS data into spatial database system.

In addition to the typical map format such as DXF and Shapefile, our reengineering environment handles the new standard map format such as GML and SVG. In fact, GML does not specify a concrete representation method, since the GML itself is a way of structurizing geographic information including spatial and non-spatial properties. The model is independent of the view, i.e., a model may be combined with any one of the available views. Thus, the visualization of GML is typically achieved by linking with a style-sheet that defines the visual style of each object. Usually, GML is converted to SVG for visualization since the SVG includes styling information in addition to spatial properties. SVG is portable to any XML-enabled environment including Web browsers and mobile devices. Table 2 shows the comparison of DXF, Shapefile, GML, and SVG in the aspect of geographic content and representation.

The Ordnance Survey[12] of United Kingdom provides unified geographic information in the form of GML. In Japan, G-XML (Geospatial

Table 2. Comparison of DXF, Shapefile, GML, and SVG

Format	Spatial information	Attribute information	Styling information
DXF	●		●
Shapefile	●	●	
GML	●	●	Linkable
SVG	●	Linkable	●

XML)[13], the XML-based geographic information encoding, is adopted as one of the standard GIS data formats. In Korea, the Standardization Committee of National GIS Project has also allowed the GML included in the National GIS Service Framework (Si *et al.*, 2002) for the reciprocal interchange of geographic information among conventional GIS's (Chung and Bae, 2003). GML is extensible to all types of geographic information that may not be covered by a single DXF or Shapefile, so that the reciprocal interchange can be realized. Considering the wide effect of KGD2002, this interchange or interoperability is significant.

3) GIS Data Storages

The GIS data formats such as DXF, Shapefile, GML, and SVG are physically stored in the form of file. Like any other kinds of data, GIS data is managed by both file system and database system. The usefulness of spatial database is well known, because a database system provides efficient management of a large volume of data for common use. As in the case of Seoul Metropolitan GIS, spatial database supports the efficient share and circulation of data among concerned organizations (Park, 1999).

Since most data in spatial database system is generated by loading GIS data file, well-arranged GIS data files are the key to stable spatial database. However, considering the amount of spatial data to be converted in accordance with KGD2002, an alternative to the bulk loading is necessary. The data conversion inside a database system could be realized by two kinds of method. One is to compose a series of database query in PL/SQL (Procedural Language/Standard Query Language) for handling coordinate transformation. The other is to compose a program that works on coordinate transformation with direct connection to database system.

The former approach has a merit in performance because the entire processes are handled internally in server-side database, but it is confined to DB-to-DB conversion. The latter approach has a merit in extensibility, because the objects for geometry and coordinate transformation can be reused for other kinds of map conversion such as file-to-file, file-to-DB, and DB-to-file, in addition to DB-to-DB conversion (Figure 3). In fact, the DB-to-DB conversion includes intra-database and inter-database conversion. The intra-database conversion works in a single database environment. The inter-database conversion works between two different database environments, for example, between SDE/Oracle[14] and Oracle Spatial[15].

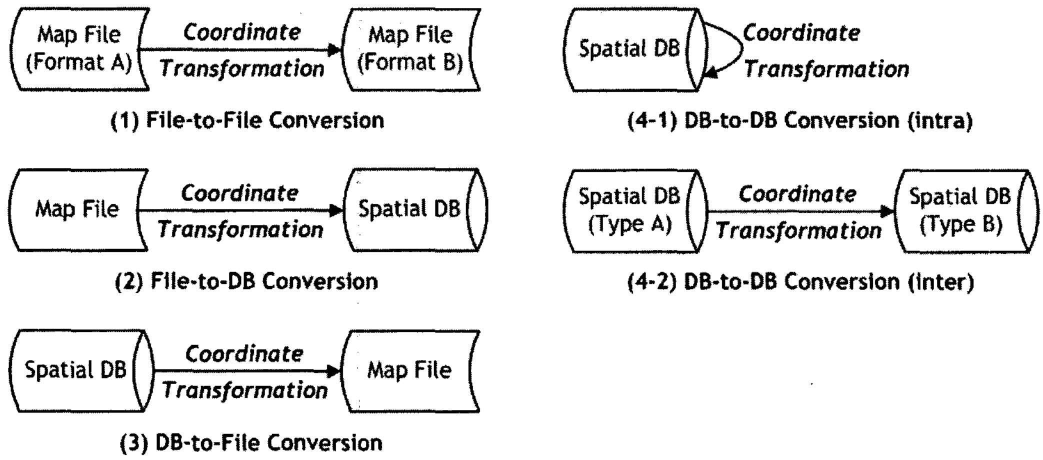

Figure 3. Types of Map Conversion for KGD2002

4) GIS Computing Environments

Typical GIS of today is operated in three different kinds of computing environments: desktop, Web, and mobile. The desktop GIS is preferred in complex spatial analysis; the Web-based GIS in information service; and the mobile GIS in field data collection. For the GIS data reengineering of KGD2002, desktop and Web-based computing environments are appropriate, because the process of coordinate transformation and map conversion for a large amount of GIS data may require a lot of resource of computer and network. Anyhow, the results of reengineering are utilized also in the mobile computing environment.

The desktop environment includes standalone system working without server-side database, and conventional client/server system working with server-side database. While the standalone system processes file-to-file conversion, the client/server system processes file-to-file, file-to-DB, DB-to-file, and DB-to-DB conversion. The Web-based system has the same functionality as conventional client/server system, but it can be accessed by users anywhere only with Web browser.

4. Design of Integrated Reengineering Model

1) Overall Architecture

The overall schema of GIS data reengineering for KGD2002 is illustrated in Figure 4. It is composed of three major parts, i.e., GIS data, user interface, and data processing. In the GIS data part, the source and result data of coordinate transformation are stored in the form of map file (DXF, Shapefile, GML, and SVG) or in a spatial database (SDE/Oracle and Oracle Spatial). According to the user's choice in the user interface part, a series of processes for coordinate transformation and map conversion are performed in either desktop or Web-based environment. The data processing part includes map file handler for DXF, Shapefile, GML, and

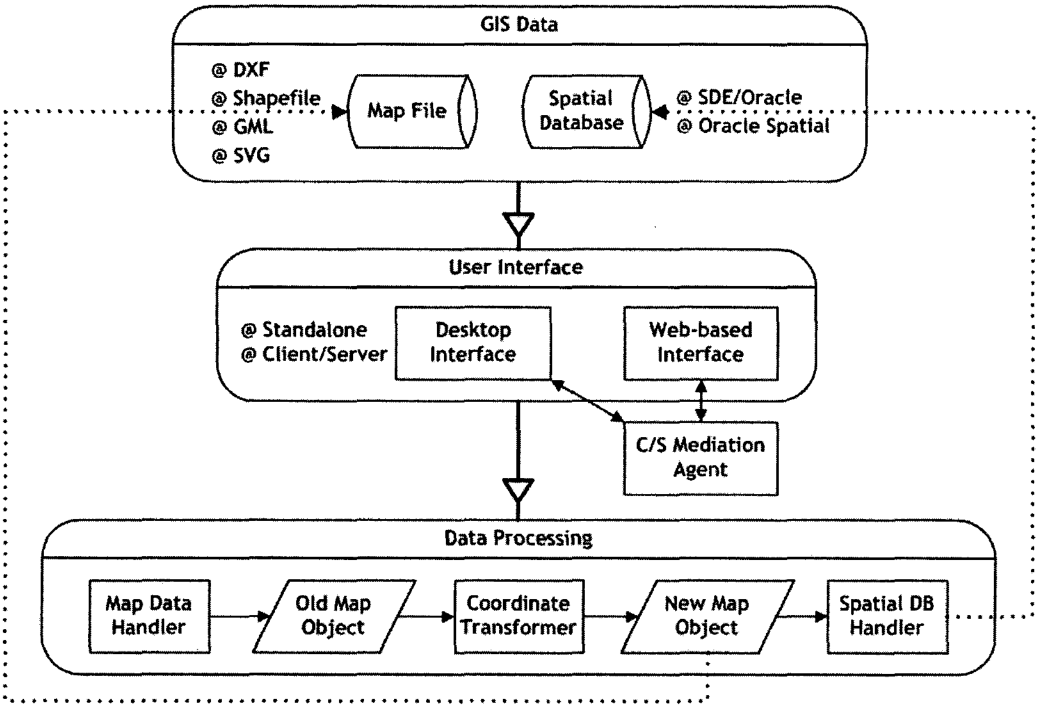

Figure 4. Overall Architecture of GIS Data Reengineering for KGD2002

SVG; coordinate transformer for KGD2002; and spatial DB handler for SDE/Oracle and Oracle Spatial.

2) Coordinate Transformation

The 5-step analytical process for KGD2002 is implemented in the component of coordinate transformer. For each step, intermediate value of coordinate information is passed to the next step in the form of parameter, as shown in the sequence diagram (Figure 5). The coordinate values extracted from any types of map data are converted in this component. For the transformation from Bessel to GRS80 ellipsoid, Molodensky-Badekas model with seven parameters of National Geographic Information Institute, Korea is provided by default. Users can choose the type of model and modify the parameters, if necessary.

3) Map File Management

Object modeling is especially important for this map file handler, because the unique properties and common properties of each file format should be arranged for efficient class structure. The four types of map file such as DXF, Shapefile, GML, and SVG have their own internal structure for representing geographic information. Thus, each subclass such as DXFHandler, ShapefileHandler, GMLHandler, and SVGHandler is constructed for parsing and generating each format of map file. They inherit MapFileHandler, the superclass (Figure 6).

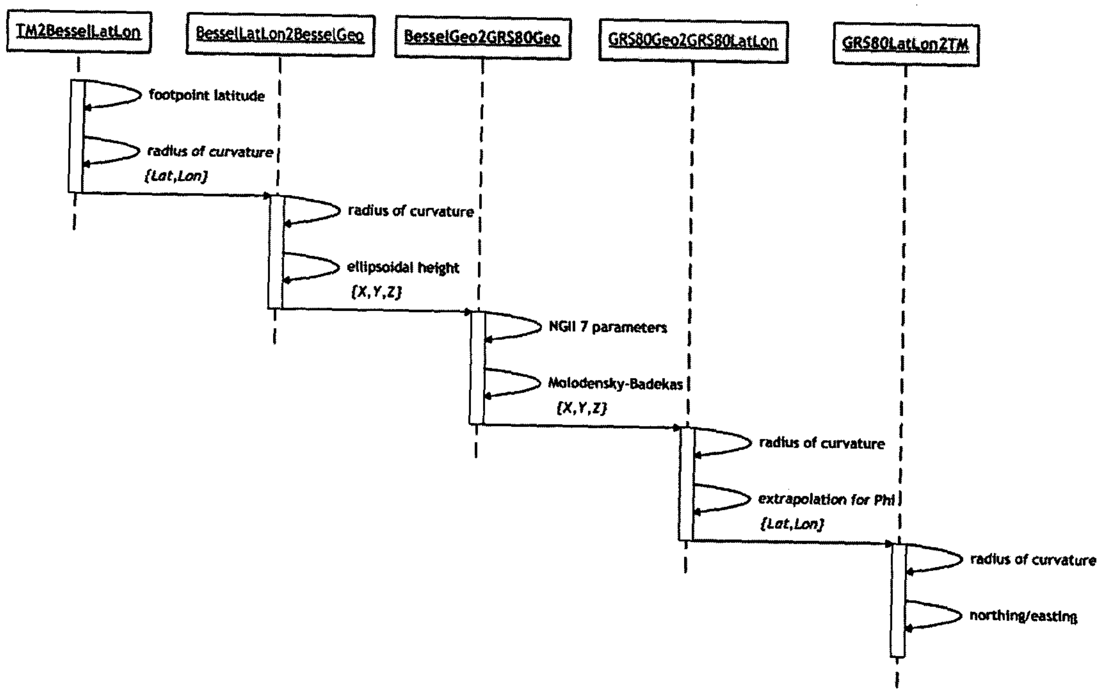

Figure 5. Sequence of Coordinate Transformation for KGD2002

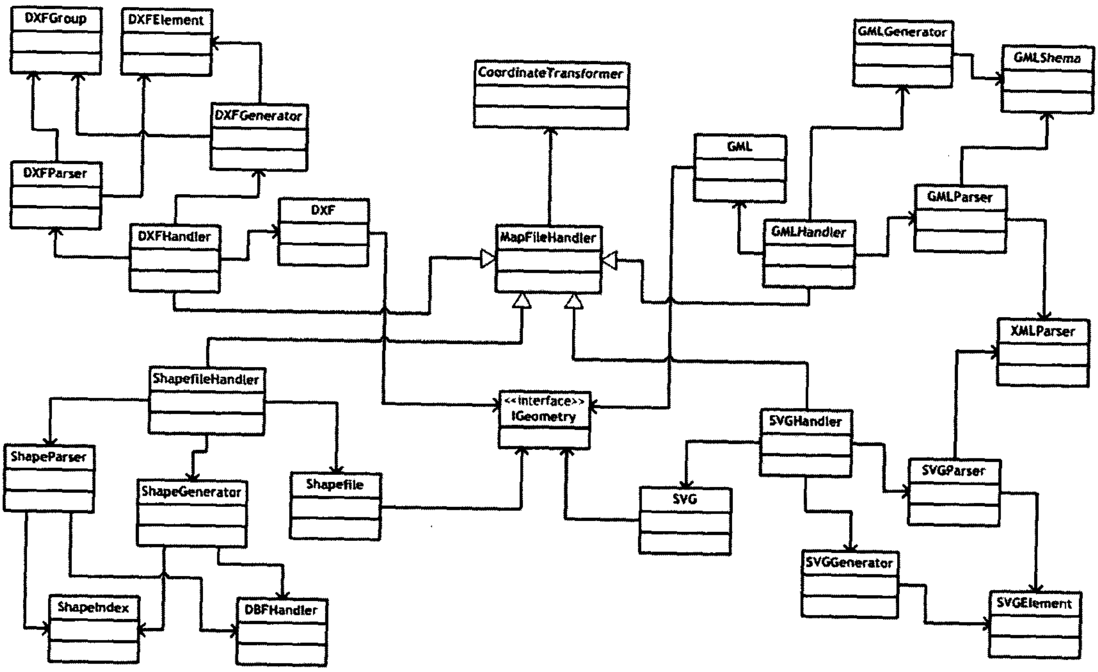

Figure 6. Class Structure of Map File Handler for KGD2002

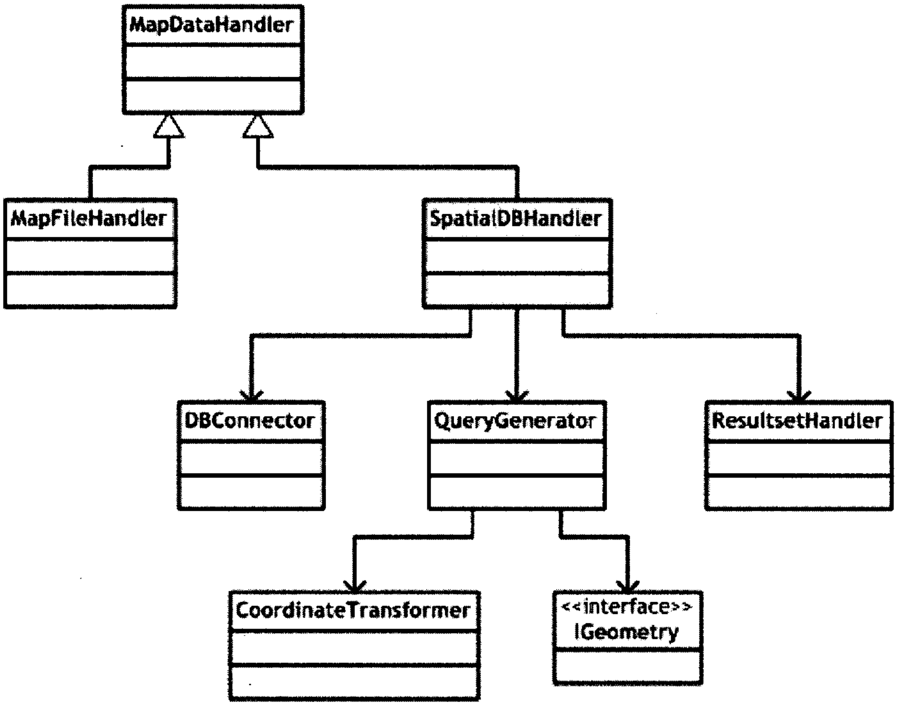

Figure 7. Class Structure of Spatial DB Handler for KGD2002

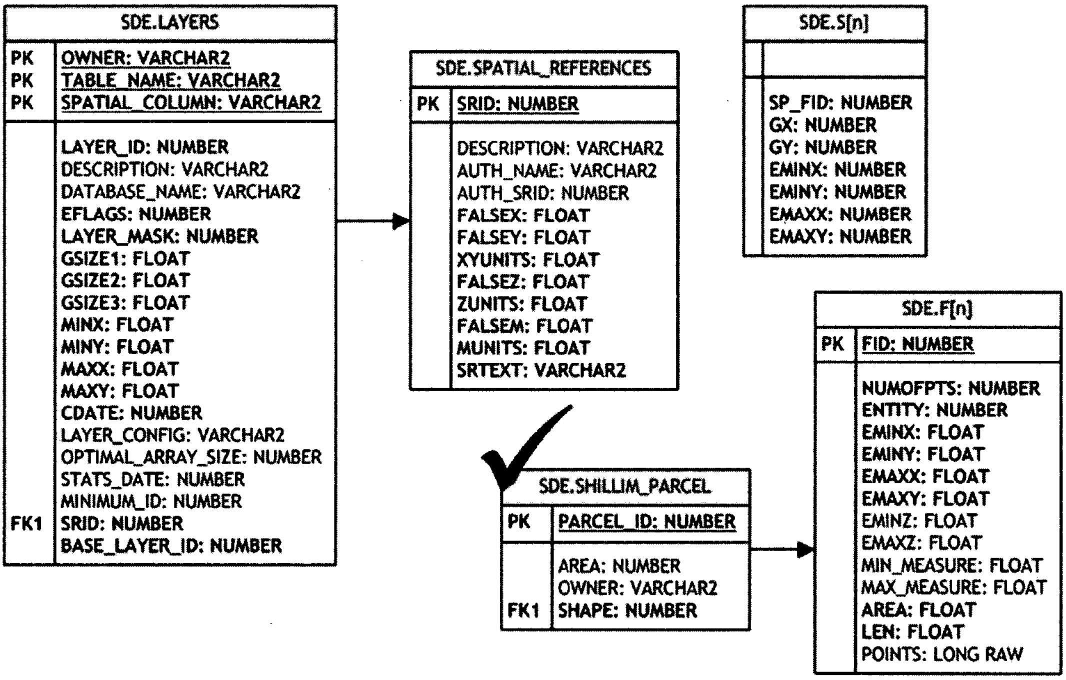

Figure 8. Relational Data Model for GIS Data in SDE/Oracle

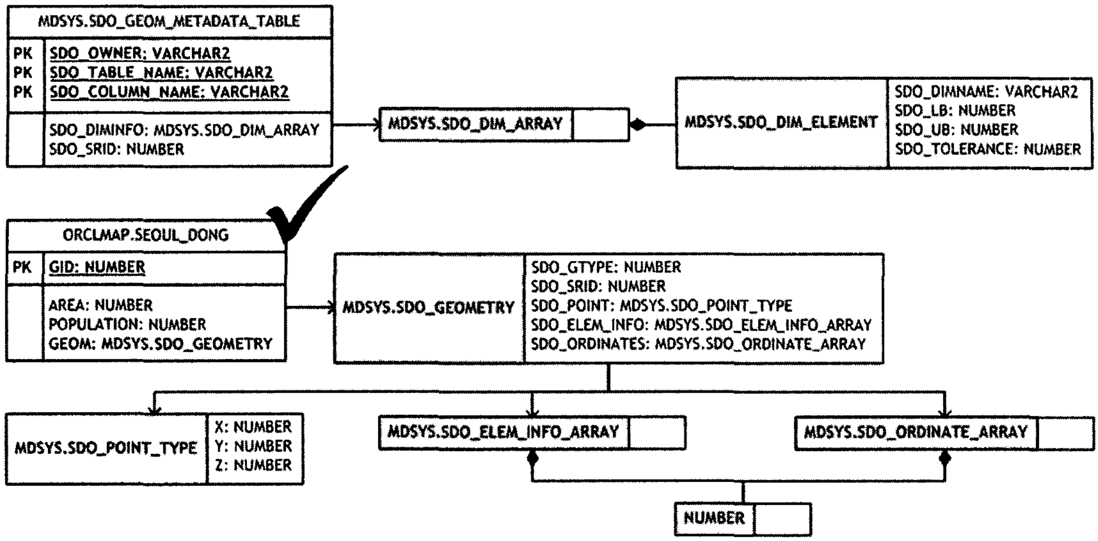

Figure 9. Object Relational Data Model for GIS Data in Oracle Spatial

4) Spatial Database Management

This study deals with SDE/Oracle and Oracle Spatial that are most commonly used database system for GIS. The coordinate transformation and map conversion using spatial database could be performed in two ways as mentioned previously. We chose composing a program that works on coordinate transformation with direct connection to database system, because the functionality of DB-to-DB conversion should be reused for file-to-DB and DB-to-file conversion.

As shown in Figure 7, QueryGenerator class extracts coordinate values from spatial database using SQL; generates new values using CoordinateTransformer class, and sends the new coordinate values to spatial database using SQL. The DML (Data Manipulation Language) operation of 'SELECT' and 'INSERT' of the QueryGenerator class is based on the analysis of the spatial database structure. Figure 8 and Figure 9 show the ERD (Entity Relation Diagram) of SDE/Oracle and the ORD (Object Relation Diagram) of Oracle Spatial. These diagrams include the tables for user's map data (SDE.SHILLIM_PARCEL in SDE/Oracle and ORCLMAP.SEOUL_DONG in Oracle Spatial, respectively) and the tables and objects of internal system that allow the user's map data spatially enabled.

5) Client/Server Mediation Agent

The four types of map conversion including file-to-file, file-to-DB, DB-to-file, and DB-to-DB are processed in the typical client/server and Web-based environments. A client/server mediation agent is necessary to bridge client (using functionality) and server (providing functionality). We adopt XML Web Services under the .NET Framework for building a mediation agent. XML Web Services is a programming method for distributed computing on the Internet that supports HTTP/GET, HTTP/POST, and SOAP (Simple Object Access Protocol) for the request and response between

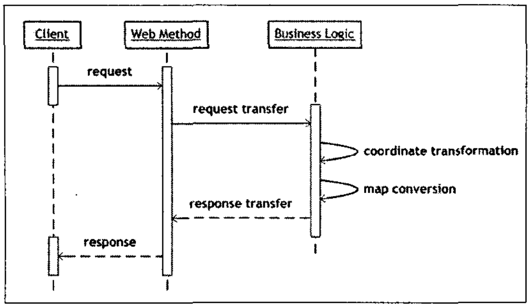

Figure 10. Client/Server Mediation Agent for KGD2002

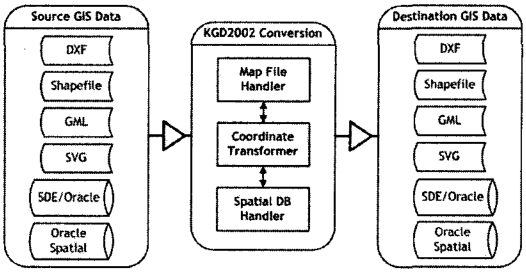

Figure 11. Combination of Input and Output GIS Data for KGD2002

client and server. This client/server mediation agent is composed of Web Method for client/server brokerage and Business Logic for KGD2002 (Figure 10).

5. Prototype System Development

Based on the system design presented in the previous chapter, we implemented prototype applications of integrated reengineering for KGD20002 in multiple computing environments: desktop and the Web. The desktop application works on file-to-file conversion in the standalone environment; and works on file-to-DB, DB-to-file, and DB-to-DB conversion in the client/server environment. The Web-based application works on file-to-file, file-to-DB, DB-to-file, and DB-to-DB conversion.

The file-to-file conversion handles coordinate transformation in accordance with KGD2002 and file format conversion among DXF, Shapefile, GML, and SVG. The file-to-DB conversion handles coordinate transformation for these files and imports the transformed data into SDE/Oracle and Oracle Spatial. The DB-to-file conversion handles coordinate transformation for the server-side map data in these database systems and exports the transformed data in the form of DXF, Shapefile, GML, and SVG. The DB-to-DB conversion handles intra-database and inter-database conversion for KGD2002. The combination of input and output data is illustrated in Figure 11.

1) Desktop Application Development

The desktop application was developed using C# .NET. In the standalone environment for file-to-file conversion, the entire process occurs in local computer. On the other hand, in the client/server environment for file-to-DB, DB-to-file, and DB-to-DB conversion, almost all the process occurs in server-side, allowing a client to choose the necessary options for processing. The core parts are composed of (i) mathematical model for KGD2002 transformation, (ii) map file handler and geometry object for DXF, Shapefile, GML, and SVG, and (iii) spatial DB handler for SDE/Oracle and Oracle Spatial. These three parts can be rebuilt in the form of XML Web Services so that they can be plugged-in to Web-based application by the extensibility of object-oriented programming.

Figure 12 shows the execution screenshots of this desktop application that performs a Shapefile conversion to Oracle Spatial in accordance with

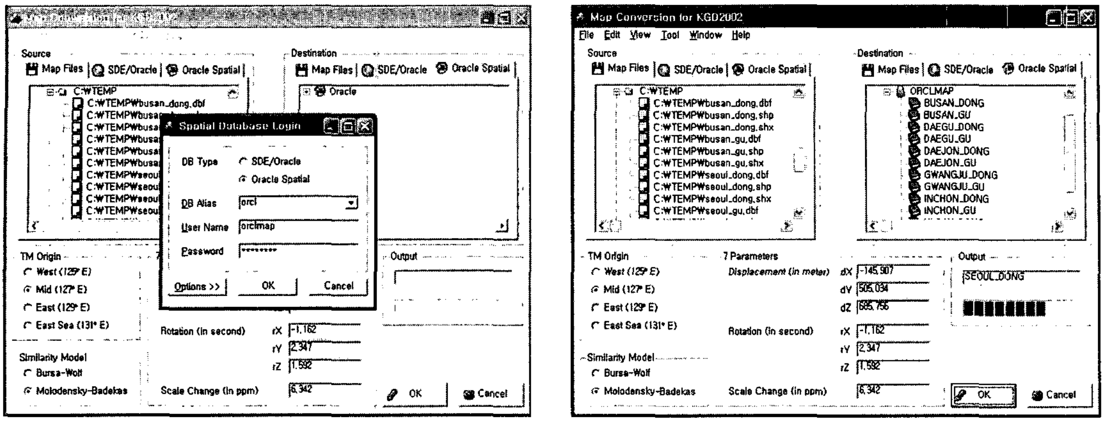

Figure 12. Execution Screenshots of Desktop Application for KGD2002

KGD2002. In this example, user chooses a source map file in local computer; configures Oracle settings for DB connection and table creation; and optionally adjusts the coordinate transformation methods for TM origin, similarity model, and transformation parameters[16].

2) Web Application Development

The Web application was developed using ASP. NET with C# .NET. One of the advantages of Web application is providing necessary functionality to a variety of users location-wide. In order to serve remote Web clients, the XML Web Services built for KGD2002 transformation was referenced by Web pages. The Web Method of the XML Web Services accepts the request of Web client and returns the response of server as the result of coordinate transformation and map conversion.

In the Web pages of Figure 13, the request and response of coordinate transformation and map conversion are illustrated. The request of a Web client includes user's choice on the source data to convert (①); destination of conversion result (②); and options for coordinate transfor-mation such as TM origin, similarity model, and seven parameters (③). The response from the server-side process provides an overlaid map of before/after transformation (④). If user's request for conversion result is file format, a downloadable map file is additionally provided.

3) Feasibility Test

The KGD2002 transformation from Bessel to GRS80 ellipsoid brings digital map approximately 300 to 350 meter's difference in north direction and -210 to -165 meter's difference in east direction, though there are some regional variations. This corresponds to approximately 340 to 410 meter's difference in Euclidean distance (Lee *et al.*, 1999; Yoon *et al.*, 2003). The zoomed-in overlay of original and converted SVG of Seoul illustrated in Figure 14 also shows this offset.

To verify the reliability of our system, we extracted the coordinate values of the entire points for each polygon from the original and

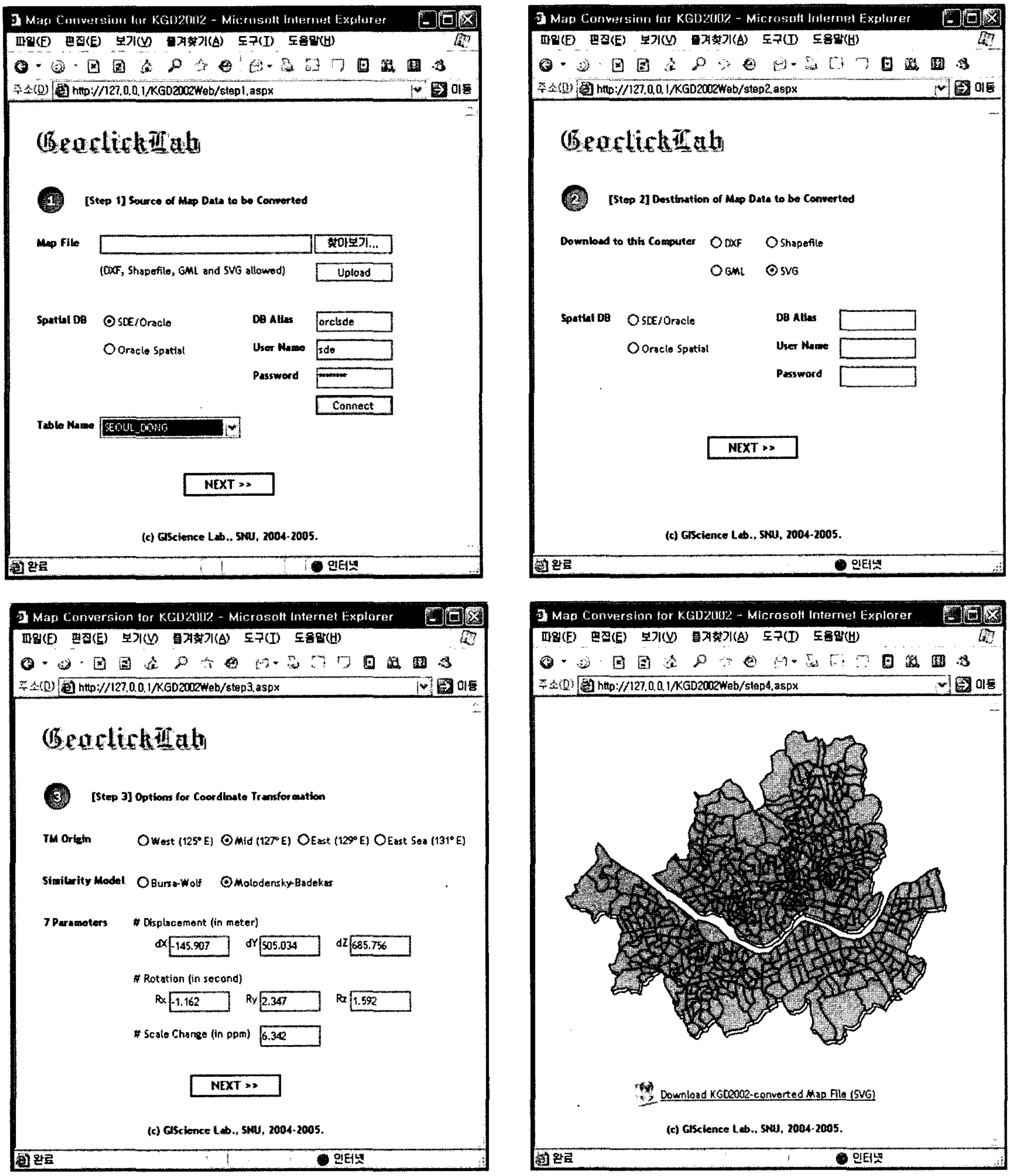

Figure 13. Execution Screenshots of Web-based Application for KGD2002

converted maps, and calculated the average difference in north and east direction. As shown in Table 3, the average coordinate differences of Seoul, Busan, and Gwangju selected as an example of each TM origin (West/Mid/East)[17] agree with the criteria presented in the existing researches. The result of Busan has somewhat bigger differences, partly because it is a coastal area.

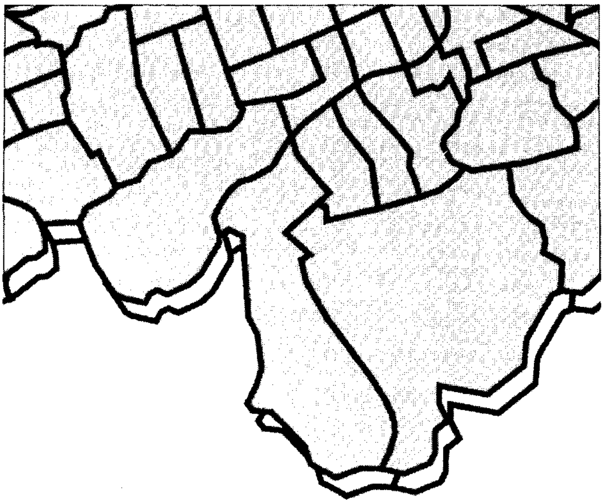

Figure 14. Zoomed-in Overlay of Original and Converted SVG

Table 3. Coordinate Difference between Bessel and GRS80 Ellipsoid

City	TM origin	Difference in north	Difference in east	Difference in distance
Seoul	MID	305.24 meter	-185.73 meter	357.31 meter
Busan	EAST	305.85 meter	-206.41 meter	368.98 meter
Gwangju	WEST	306.33 meter	-173.49 meter	352.04 meter

6. Conclusion

We discussed the GIS data reengineering for KGD2002, focusing on the strategy and system implementations based on the integrated approach to interoperability, standardization, and database utilization. Our reengineering strategy includes file-to-file, file-to-DB, DB-to-file, and DB-to-DB conversion for the coordinate transformation of KGD2002. In addition to the existing standard map format such as DXF and Shapefile, the newly recommended standard map format such as GML and SVG are also accommodated in our reengineering environment. These four types of standard format may well be imported into and exported from spatial database via KGD2002 transformation component. Besides, DB-to-DB conversion includes not only intra-database conversion but also inter-database conversion between SDE/Oracle and Oracle Spatial. All these implementations were carried out in multiple computing environments: desktop and the Web.

With regard to the algorithm of KGD2002 transformation, the distortion modeling for detailed correction was not included in this study, because the mathematical models of coordinate transformation are enough to verify the validity and necessity of our strategy and implementations for GIS data reengineering of KGD2002. The feasibility test of our system shows that the coordinate differences between Bessel and GRS80 ellipsoid agree with the criteria presented in the existing researches. The result of Busan has somewhat bigger differences, partly because it is a coastal area. As Choi (2004) addresses, the transformation parameters for marine areas should be established differently from land areas.

The implications of this study are as follows:

First, our strategy and implementations for the GIS data reengineering of KGD2002 reemphasized the significance of interoperability and standardization. For recent decade, the National GIS Projects have established several guidelines for the interoperability and standardization, but the actual utilization has not been very active (Jung *et al.*, 2004). Considering the inactive utilization in the meantime is due to the burden of cost, this era of new coordinate system should be a second chance of revitalizing the interoperable and standardized GIS data.

The GML ensures the efficient share and integration of geographic information in a variety of system environments, because it is extensible to all types of geographic information that may not be covered by a single DXF or Shapefile. One of the emphasized advantages of KGD2002 is the compatibility with GPS indispensable to mobile GIS and LBS. The SVG will encourage mobile GIS and LBS, because it also provides mobile-dedicated data format such as SVG Basic and SVG Tiny. Therefore, the conversion of the existing GIS data for KGD2002 should take GML and SVG into consideration.

Secondly, we presented a strategy for the utilization of spatial database for the GIS data reengineering of KGD2002. As the importance of efficient maintenance, share, and circulation of GIS data increases, the role of spatial database becomes more crucial. Thus, the spatial database conversion is as important as file conversion (Lee and Cho, 2004). Our reengineering environment covers four types of map conversion including file-to-file, file-to-DB, DB-to-file, and DB-to-DB for the coordinate transformation of KGD2002.

Thirdly, the multiple computing environments of our prototype system support various cases of the GIS data reengineering for KGD2002. Standalone environment is enough for the file-to-file conversion. However, the file-to-DB, DB-to-file, and DB-to-DB conversions are processed by the connection with server-side database, and thus requires client/server environment. In addition, Web-based environment has the advantage of supporting location-wide multi-users, because there is no need of troublesome deployment of programs. In this sense, we implemented the four types of map conversion functionality in multiple computing environments: desktop and the Web. Necessary functional modules can be transplanted even between different computing environments owing to the object-oriented structure of our system.

Interoperability and standardization have been considered a very important issue in geographic information science. This study presented a methodology for the interoperability and standardization in the GIS data reengineering of KGD2002. The new coordinate system will influence all the people and organizations that use maps, including government, industry, and academy. In order to minimize confusions and to maximize benefits, the efforts for not only accuracy improvement but also interoperability, standardization, and database utilization will be necessary.

Notes

1) National Geographic Information Institute, Korea, "Q&A

on the Shift to the New Korea Geodetic Datum" (http://www.ngii.go.kr)

2) Revision on July 1st, 2002; enforcement from January 1st, 2003

3) OGC is a non-profit, international, voluntary consensus standards organization that is leading the development of standards for geospatial and location based services (http://www.opengeospatial.org).

4) W3C is an international consortium where member organizations, full-time staffs, and the public work together to develop Web standards (http://www.w3c.org).

5) The terms 'coordinate system' and 'reference system' are used as an abbreviation for 'coordinate reference system.'

6) IERS was established as the International Earth Rotation Service in 1987 by the International Astronomical Union and the International Union of Geodesy and Geophysics, and it began operation on January 1st, 1988. In 2003, it was renamed to International Earth Rotation and Reference Systems Service (http://www.iers.org).

7) In 1992, 1993, 1994, 1996, 1997, and 2000

8) KGD2002 is compatible with WGS84 (World Geodetic System 1984), the coordinate system of GPS. Although there is 0.1-millimeter's difference in the length of semi-minor axis between GRS80 and WGS84 ellipsoid, this tiny difference does not need to be considered for the practical use of GPS.

9) As a conformal projection suitable to the representation of tabular rectangular coordinate, TM (Transverse Mercator) projection is adopted for the national coordinate system in most countries (Cho, 1996).

10) The ellipsoidal height is replaced by zero, because it is unknown here.

11) ϕ is found by extrapolation process where the deviation converges on zero.

12) http://www.ordsvy.gov.uk

13) http://gisclh.dpc.or.jp/gxml

14) ESRI SDE (Spatial Database Engine), the middleware for spatial data management, runs on a physical database system such as Oracle, SQL Server, Informix, and DB2 (http://esri.com/software/arcgis/arcsde).

15) A subset of Oracle for spatial functionality (http://www.oracle.com/technology/products/spatial)

16) Default value of transformation parameters follows the notification no. 2003-497 of National Geographic Information, Korea.

17) The region of East Sea origin was not included in this test.

References

Altamimi, Z., Sillard, P., and Boucher, C., 2002, ITRF2000: A New Release of the International Terrestrial Reference Frame for Earth Science Applications, *Journal of Geophysical Research*, 107(B10), ETG2/1-ETG2/19.

Cho, K. J., 1996, A Study on the Transformation of Coordinate on TM Projection, *Journal of the Korean Society of Surveying, Geodesy, Photogrammetry, and Cartography*, 14(2), 119-126.

Choi, Y. S., 2004, *A Datum Transformation in Island and Sea around Korea*, Ministry of Construction and Transportation, Korea.

Chung, W. I. and Bae, H. Y., 2003, Efficient Publishing Spatial Information as GML for Interoperability of Heterogeneous Spatial Database Systems, *Journal of Korea Multimedia Society*, 7(1), 12-26.

Jung, M. S., Park, J. T., and Kim, J. H., 2004, *Vision and Policy Issues for National Geographic Information System in Korea*, Korea Research Institute for Human Settlements.

Lee, Y. J., Cha, D. K., and Kim, S. Y., 1999, Analyses of Coordinates Differences in GRS80 Transformation, *Journal of the Korean Society of Surveying, Geodesy, Photogrammetry, and Cartography*, 17(3), 265-272.

Lee, Y. J., 2002, *Guidelines on the Transformation and Utilization of the New Korea Geodetic Datum*, National Geographic Information Institute, Korea.

Lee, S. M. and Cho, S. H., 2004, *An Implementation Plan to Convert GIS Data under ITRF System*, Seoul Development Institute.

McCarthy, D. and Petit, G., 2003, *IERS Technical Note*

No. 32: IERS Conventions (2003), International Earth Rotation and Reference Systems Service.

National Geographic Information Institute, Korea, 2003, *The Notification of National Coordinate Transformation Parameters*, National Geographic Information Institute, Korea, Notification No. 2003-497.

Open Geospatial Consortium, 2001, *Geography Markup Language (GML) 2.0,* available at http://www.opengis.org/docs/01-029.pdf.

Park, S. H., 1999, A New Implementation Strategy and Conceptual System Architecture for the Seoul Metropolitan Government's GIS, *The Journal of GIS Association of Korea*, 7(2), 237-253.

Si, J. I., Lee, H. J., and Ha, S. W., 2002, *A Study on Service Models Standardization for the National Geographic Information System (NGIS)*, National Computerization Agency, Korea.

Snyder, J. P., 1987, *Map Projections - A Working Manual*, U. S. Geological Survey Professional Paper 1395, United States Government Printing Office.

World Wide Web Consortium, 2001, *Scalable Vector Graphics (SVG) 1.0 Specification*, available at http://www.w3.org/TR/2001/REC-SVG-20010904/REC-SVG-20010904.pdf.

Yoon, H. S., Cho, J. M., and Song, D. S., 2003, *A Study on the Coordinate Transformation for Digital Maps (II)*, National Geographic Information Institute, Korea.

Yoon, H. S., Cho, J. M., Song, D. S., Kim, M. H., and Cho, H. M., 2004, Development of Coordinate Transformation Tool for Existing Digital Maps, *Journal of the Korean Society of Surveying, Geodesy, Photogrammetry, and Cartography*, 22(1), 29-36.

Correspondence: Key-Ho Park, Department of Geography, College of Social Sciences, Seoul National University, Seoul 151-742 Korea (khp@snu.ac.kr)

교신 : 박기호, 151-742, 서울시 관악구 서울대학교 사회과학대학 지리학과 (이메일: khp@snu.ac.kr)

Received May 10, 2005
Accepted June 7, 2005