Journal of the Korean Geographical Society, Vol.47, No.4, 2012(592~605)

GIScience Studies and Policies in Korea: Focus on Web GIS and National GIS

Cha Yong Ku* · Chulsue Hwang** · Jinmu Choi***

한국의 지리정보학과 지리정보 정책: Web GIS와 국가 GIS를 중심으로

구자용* · 황철수** · 최진무***

Abstract : This article reviewed issues in Korean geographical journals: web GIS and National GIS. Web GIS in Korea is now evolving to mobile GIS, which requires portable hardware, wireless Internet, and GPS receiver. The new trend of mobile GIS is using a smart phone. Recently, a variety of studies for the mobile App and mobile Web in Korea has been developed. With explosive information on the Web 2.0, the Korean government has built the Human-Oriented Geographic Information System (HOGIS) in which Ontology was implemented for semantic query on the Web. On the government side, Korean government has produced various nationwide data through 4-phase NGIS project. Current NGIS (4^{th} phase: 2011-2015) moves toward a Korean Green Geospatial Society using geospatial information as a new growth engine for the future.

Key Words : Web GIS, Mobile GIS, Web 2.0, GeoOntology, NGIS, NSDI

요약 : 본고에서는 한국의 지리학 관련 논문들에 대해 가장 급속하게 발전하고 있는 웹 GIS와 국가 GIS 서비스라는 두 분야에 대한 연구동향 및 방향을 논의하였다. 한국의 웹 GIS는 현재 모바일 GIS로 진화하고 있는데, 휴대용 하드웨어, 무선 인터넷, GIS 수신기를 통합적으로 필요로 한다. 따라서 모바일 GIS의 새로운 방향은 스마트 폰을 이용하는 것으로 최근 다양한 모바일 엡과 웹이 개발되고 있다. 웹 2.0 기술과 함께 폭발적으로 증가한 정보를 관리할 수 있도록 한국 정보는 인문지리정보시스템(HOGIS)을 개발하고 있으며, 여기서 온톨로지를 이용해 국토공간에 대한 시멘틱 검색이 가능하도록 개발하고 있다. 다른 한편으로 정부 차원에서 1995년부터 5년간 4차에 걸쳐 국가 GIS 프로젝트를 수행하고 있다. 현재 4차 국가 GIS를 수행하고 있으며, 공간정보를 미래의 성장 동력으로 선정하여, 국가 녹색 공간정보 사회를 향해 프로젝트를 진행하고 있다.

주요어 : 웹 GIS, 모바일 GIS, 웹 2.0, GeoOntology, 국가 GIS, 국가 공간 데이터 기반

1. Introduction

The development of computer network including Internet has been a great influence on the development of GIS technology. While GIS functions were allowed only for the GIS specialists in the past, now everyone would be able to access the GIS functionality

* Professor, Department of Geography, Sangmyung University
** Professor, Department of Geography, Kyung Hee University
*** Associate Professor, Department of Geography, Kyung Hee University, cjm89@khu.ac.kr

over the Internet. Web GIS is a technology that a user can access GIS functionality and data just with a Web browser. With the advances in Web GIS technology, a GIS server could provide a variety of GIS functionality so that the client hardware would be smaller. Recent advances in information and communication technology, wireless internet leads a tendency to transfer a traditional Web GIS technology into mobile GIS.

On the other hand, Linking Open Data (LOD) is a technology to access a lot of linked information on the Web. Ontology is the basis of LOD. While Ontology has a philosophical background, it has narrow meaning in computer based information management (Hong, 2006). In terms of information management, the narrow meaning of Ontology is a collection of terms, concepts, and relationships between concepts. Linkage of concepts based on the defined relationships between them makes a variety of query possible. This query method is called a Ontology-based query of a semantic query in Web GIS.

In Korea, studies on Ontology have been done in both academia and industry. In the Academia, Information technology in both Computer Science and Geography is the main part of Ontology study. In computer science, there are several directions on Ontology study including automatic Ontology building method, Web device coordination using Ontology, expending Ontology using Web resources, and so on (Kim *et al*, 2008; Huang *et al*, 2008; Song *et al*, 2009). In Geography, the main issue related to Ontology is how to implement geographic information into Ontology, so called GeoOntology (Hong, 2010; Lee *et al*, 2010; Hong, 2012). In the industry Saltlux is the major company that builds ontology in both Information technology and Geospatial areas (Saltlux, 2010).

Although private areas including academy and industry use and produce spatial information, government agencies play a major role to produce nationwide information, especially spatial information. During last two decades Korean government has produced various nationwide data including national digital topographic map, soil map, land cover map, and so on. Several local governments, public institutions and private companies also began to digitalize their paper maps partially for business purposes. Specifically, the explosion of the city gas supply base in Seoul in 1994 and the gas pipe explosion in the Daegu subway construction site in 1995 became decisive moments for the emergence of the National Geographic Information System (NGIS) project in Korea. After these tragic accidents, GIS systems became spot-lighted to manage underground facilities effectively and to be an powerful tool to support the public polices. The nation-wide plan for the Korean NGIS project started in 1995 and has been renewed by the central government every five years. However, GIS projects performed by multiple agencies for the early 10 years have given rise to data duplications, the lack of compatibility, and the poor sharing.

The main objective of this paper was a review on Web GIS study in Korea because the Web GIS is the most developing and quickly changing area in GIS. Articles in two areas including Web GIS and national GIS were reviewed. On the Web GIS, the major two topics were mobile GIS with the advances in smart phone technology for communication and Ontology for semantic query on the Web information. For the first topic, the mobile GIS and its development trends in Korea were discussed. For the second topic Ontology and GeoOntology for semantic query on the Web were discussed. Since most geospatial information on the Web were provided by the governmental spatial data infrastructure, the final topic was on the national GIS projects to establish national GIS and geospatial data infrastructure. Future GIS direction in both Web GIS and national GIS in Korea was discussed in Summary.

2. Mobile GIS with Smart phone

1) Renovation from Desktop Web GIS to Mobile GIS

The development of information and communication technologies leads to change the environment of Web GIS. Computer hardware is more compact, and free wireless Internet connection has been widely used. In a changing environment of Web GIS, one can directly access to geographic information during the field work with mobile GIS.

Mobile GIS means the integrated technology of geographic information service through handheld devices to use GIS, GPS, remote sensing and other related technology (Tsou, 2004). For mobile GIS, GPS, Internet, and wireless technology are required (Pundt, 2002). Because of portability of devices, mobile GIS has the advantage to store data directly in the field and easy to manipulate. With the use of wireless internet, we can connect it to the Web GIS server and utilize GIS functionality and data.

Mobile GIS largely consists of six components. They are location service system, mobile GIS receiver, mobile GIS software, wireless networks, geographic data, and GIS server. Figure 1 shows the structure of Mobile GIS components.

Mobile GIS and related research can be divided into two major categories. The first is the implementation of GIS functionality in a smaller mobile platform in order to improve processing speed and manipulate a huge geographic information (Lee and Park, 2004; Youn *et al.*, 2008). The second is developing mobile GIS system to store locational and attribute data directly in the outdoor field using mobile devices, especially for the archeological site (Jang, 2006) and agricultural crop research (Mun and Lee, 2008).

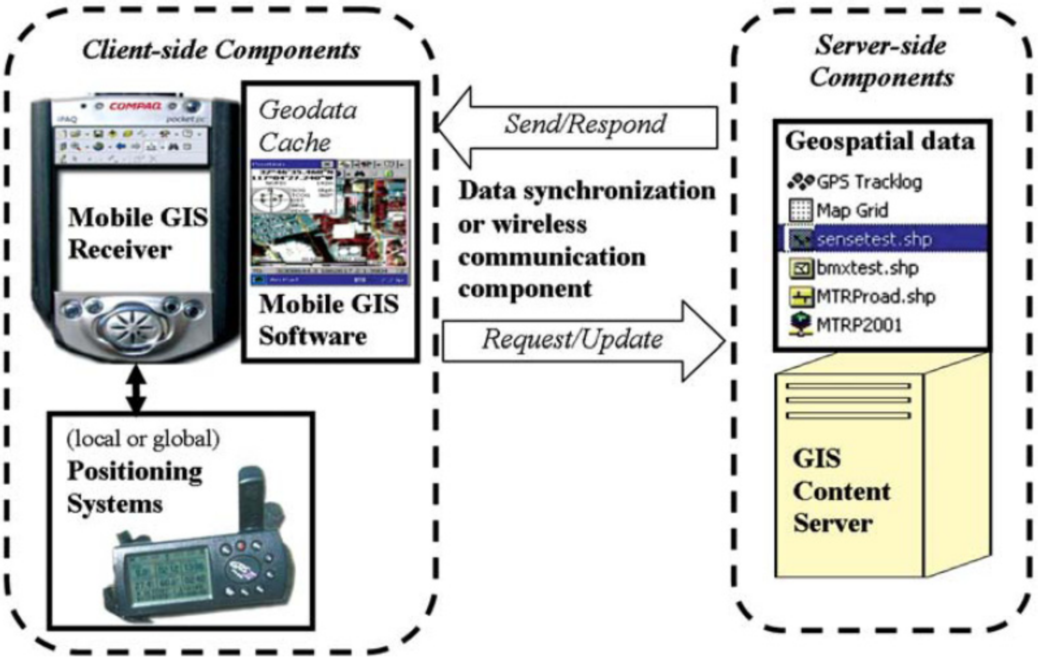

Figure 1. Structure of Mobile GIS

Source: Tsou, 2004

2) Evolution from Mobile GIS to smart phone Based GIS

Recently, smart phones replace the existing mobile communication devices, and showing an explosive increase, for example about 2 million users at the end of October 2011 in Korea (Seoul Economy, 2011). In particular, smart phones are well suited for implementing a mobile GIS.

With the growth of Web 2.0, Internet portal companies such as Google, Naver, and Daum have provided an online map service. Through the API (Application Programming Interface)-based mashups, online map service can be provided without a special map server. In other words, the online map API can be used to implement mobile GIS for a map service without GIS engine or GIS database. In order to utilize online map service and Web GIS functionality from the server to the client, it is just needed to install a mobile program to smart phone, which is called mobile app. The implemented structure for mobile GIS app on smart phone using online map services and Web GIS functionality is shown in Figure 2. Smart phone handset has existing GIS capabilities and GPS receiver, and an online map service provided by portal vendor has the capability of the map database.

The studies using a mobile app for smart phone to collect and analyze geographic information were relatively recent. Kang and Lee (2010) developed an user interface for smart phone to process the satellite image. Park and Ku (2011) developed the flood warning system for smart phone. Lee and Lee (2010) developed a mobile GIS app to serve a personal schedule with online map service. Ku (2012) also developed the field reference data gathering system by smart phone. In near future, the number of smart phone users will increase continuously so that researches on mobile GIS services using a smart phone will continue to grow.

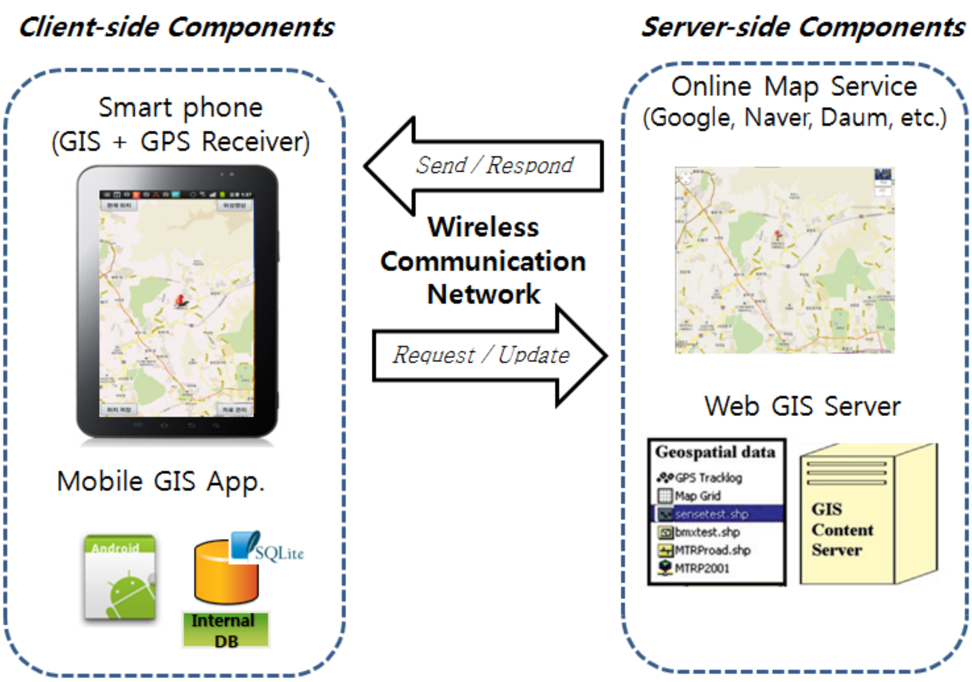

Figure 2. Structure of Mobile GIS app and online map service

Source: Revised from Ku, 2012

3) New Appearance of HTML5, the Mobile Web GIS

Although the technology of a mobile app for smart phone has been advanced, the application service for mobile app depends on the mobile platform including smart phone operating system such as iOS and Android. To overcome the limitation of platform-dependency, alternative technology with a common platform for mobile GIS services is a mobile Web. If GIS services are provided through the mobile Web, map representation and analysis would be implemented in mobile devices regardless of the type of platform such as smart phone or tablet PC.

The environment of mobile Web GIS has limitations on the processing speed and data storage space on mobile devices. A solution being promoted as the next-generation Web standards by W3C (World Wide Web Consortium) is HTML5. This is the next version of HTML and the current standard-setting work is in progress. Compared to the traditional HTML, HTML5 supports for semantic markup and provides a variety of API which provides two-dimensional graphics and geographic location for the Web GIS functionality.

The mobile Web GIS model using HTML5 is shown in Figure 3. In the figure, the Web GIS server provides a GIS functionality and spatial data just like a former desktop based Web GIS. HTML5 uses the API functions for implementing a variety of GIS software. It supports an online map services. Large amounts of geographic data are processed on the server side based on the request, and then the result data are sent to the client side using local storage and local cache.

In Korea, a variety of studies for mobile Web GIS using HTML5 canvas have been actively imple-

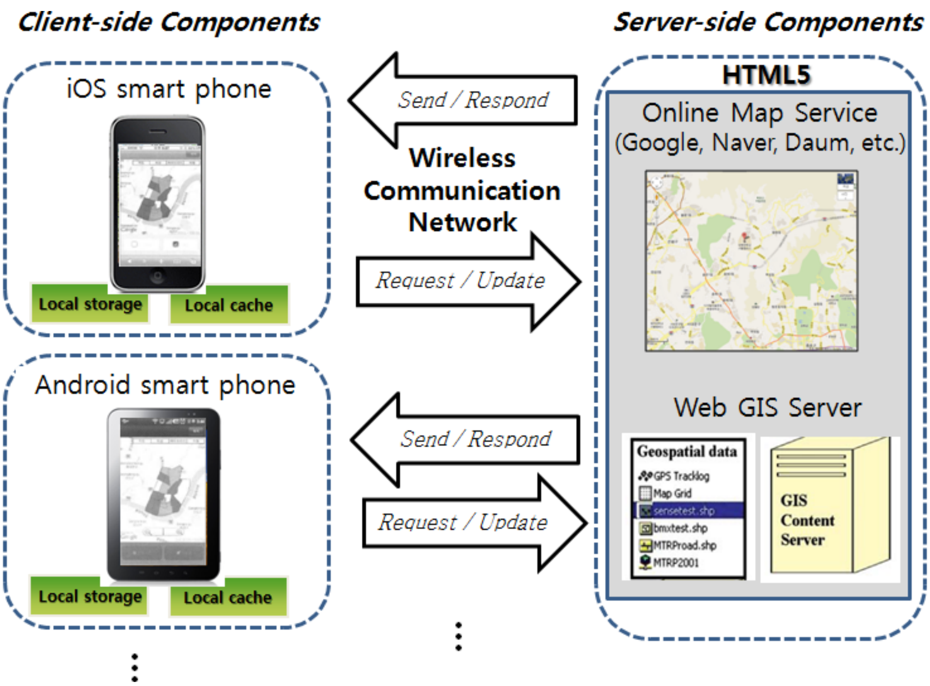

Figure 3. Structure of Mobile Web GIS and online map service

Source: Revised from Ahn and Kim, 2010

mented. Ahn and Kim (2010) developed a geo-Web service that runs independently on any mobile devices by using HTML5. In addition, Kim and Lee (2011) implemented a prototype for searching a meta-data of the satellite image by HTML5. Ahn (2011) developed a dynamic animated map services using the HTML5 canvas. Park *et al*. (2011) used the HTML5 services to support the geovisual analysis for geographic data.

HTML5 is still a developing service and does not support all mobile devices yet. If HTML5 is adopted as Web standard, it is expected that platform independent powerful mobile GIS functionality is possible.

3. Ontology in Geography

1) Building Ontology

In information engineering, Ontology created in Philosophy is to define concepts as the form that a computer can understand (Lee *et al*, 2010). In other words, Ontology defines domain concepts explicitly for computers to interpret. In addition, Ontology defines relationships between domain concepts for enabling computer-based logical reasoning through the linkage of domain concepts. Therefore, Ontology can be used to represent the relationships between various objects based on their semantics (Kim *et al*., 2008).

Building an Ontology from the knowledgebase of specific field can be classified into following four types (Huang *et al*., 2008). The first method is to convert a knowledgebase into the form of RDF ow OWL Ontology format (Assem *et al*., 2006). The second method is extracting specific information (eg, constraints, etc.) and converting it into Ontology (Golbeck *et al*., 2003). The third is to build Ontology using the concepts defined in a thesaurus and their relationships (Soergel *et al*., 2004). The final method is to build Ontology based on the classified semantic relationships from broad concepts, narrow concepts, and relationship terms in a thesaurus by defined rule or pattern (Kawtrakul *et al*., 2005). Thesaurus is a glossary classifying vocabularies in a specific domain by meaning and presenting synonyms, related words by subordination, and so on (Han, 2004). Each of these four methods for building Ontology includes both concept classification and definition of relationships of concepts.

Establishing concept classification typically constructs high-level concepts as Ontology first, then

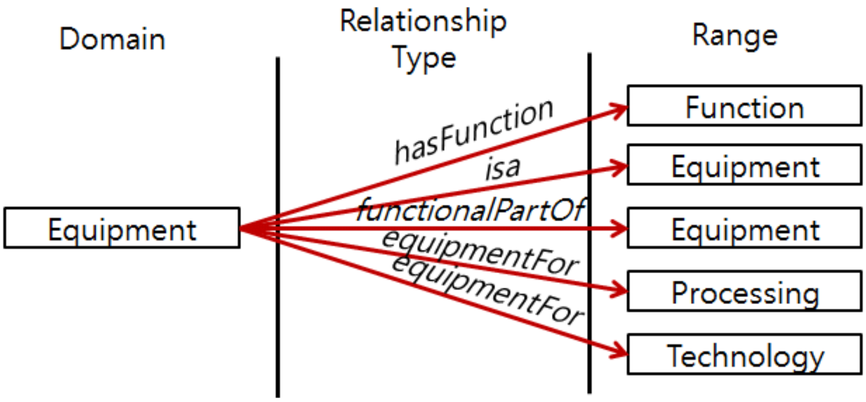

Figure 4. Relationships between domain and ranges

Source: Huang *et al*., 2008

constructs domain Ontology. Both high-level concepts and domain concepts can be extracted from a thesaurus or glossary based on the frequency (Huang *et al*., 2008). For the relationships between concepts, hierarchical structure and synonyms can be also extracted from a thesaurus. Huang *et al*. (2008) defined a domain and ranges and extracted their relationships with patterns. Relationships mainly divided into 'is-a' relationship for synonyms and inclusion and 'non_is_a' for other relationships. 'Non_is_a' relationship represents functional, PartOf, purpose, and containment relationships (Figure 4).

2) Ontology Applications

Afore mentioned, explosive information is on the Web. Web 1.0 has be based on one directional communication between users and online information. People were merely users who downloaded and used those web information. Government agencies or companies who have web servers are only information providers. On the Web 2.0, bi-directional information exchange is possible. Now, users can be producers. For example, you can acquire locational information through Google Map, and also create your maps using Google My Maps functionality that let you create and share personalized, annotated maps of your world (Google, 2012). Web 2.0 accelerates the amount of information on the Web.

Explosive information on the Web 2.0 makes web search more difficult and complex. Semantic query based on the relationships is necessary for efficient web search on certain online information (Lee, 2007). Since Ontology is a formal specification of concepts and their relationships, Ontology is the key technique for semantic query on the web (Berners-Lee *et al*., 2001). Song *et al*. (2009) developed a prototype of web application that can expand the properties of Ontology class through web search by key words. The process includes, first, building domain Ontology classes and relationships, second, extracting properties of defined Ontology classes on the Web through key word search, Finally, mapping Ontology classes and searched properties of those classes (Figure 5). This study showed an

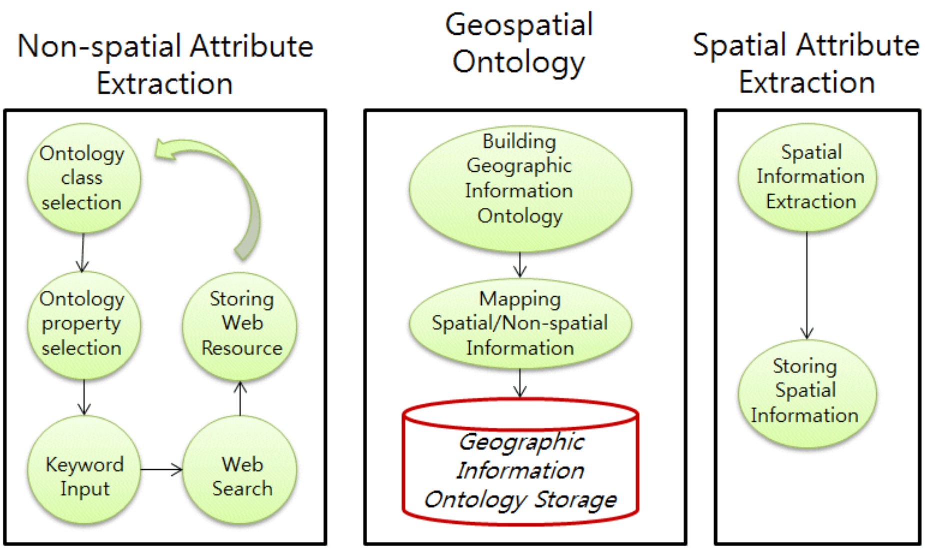

Figure 5. Mapping Process of Spatial and Non-spatial Information with Ontology

Source: Song *et al*., 2009

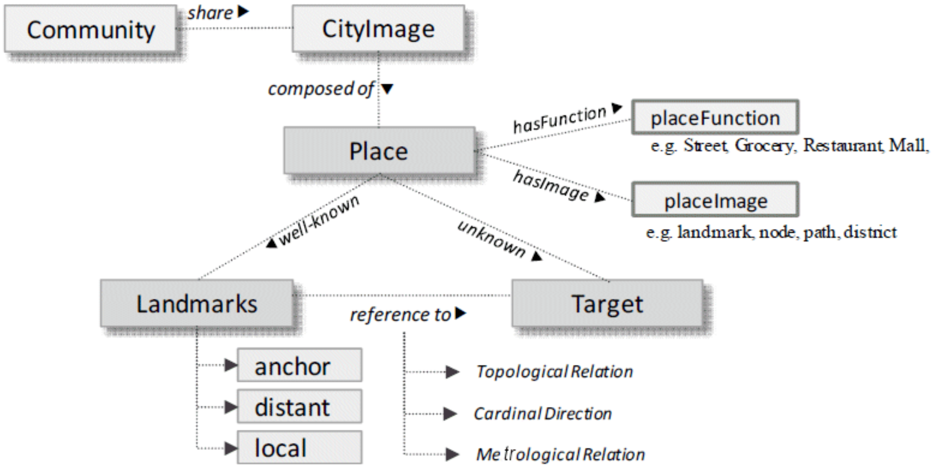

Figure 6. Conceptual Model of City Image with Place and Landmarks

Source: Hong, 2010

efficient method how Ontology information could be expanded with rich web resources.

The other area of Ontology applications is geography in which the main information for query is spatial location. Hong (2010) used Ontology modeling approach to represent City image. He modeled city image for local and regional navigation and implemented the Ontology model in protege program. City image for a community is composed of places (Figure 6). While well-know places are landmarks, unknown places would be destination (or target). Places have functionality and own image. Navigation utilizes the relationships between landmarks and connected targets, which includes topological, directional, and metrological relationships.

3) GeoOntology

Many efforts for developing international standards of GeoOntology has been done. As a result, ISO 19103 provides the conceptual schema of Geospatial Ontology (Di *et al.*, 2008). Geospatial Ontology is a collection of the obvious meaning, phenomena, relationships for integration, sharing, and reuse of geographic information with other information in various knowledge domains (Saltlux, 2010). Geospatial Ontology reference model contains Metadata for geospatial information, Data Source for geospatial data gathering system, and semantic and Ontology services including Ontology development history, annotation scheme for geospatial data, Ontology browsing and search method, geospatial information search method, semantic search method, and semantic linking information (Table 1). Especially, relationships connecting geospatial entities in Geospatial Ontology are based on direction, distance, and topology.

A few examples of GeoOntology are currently available worldwide. DERI digital library used GeoTagging to provide historical information with related location (Dabrowski and Kruk, 2006). A Belgian company, Iknow, provides travel information using GeoOntology by combining routing information and POI (point-of-interest) (Brackman and Brands, 2009). The Korean government has been built the Human-Oriented Geographic Information System (HOGIS)[1] in which Ontology was implemented for semantic query on geographic information (Hong and Oh, 2010). Figure 4 shows the result of semantic query on top of image

Table 1. Geospatial Ontology Reference Model

Contents		Description
Metadata		Various Metadata definitions for geospatial information
Data Source		Data acquisition methods and systems for geospatial information
Semantic and Ontology Service	Ontology development and Versioning	History of Ontology development and its version story
	Annotation Scheme	Annotation handling scheme for geospational information
	Ontology Browsing and Search	Methodology for Ontology browsing and search
	Information Search	Tools for information search
	Semantic Search	Support for semantic search
	Semantic Linking	Providing information fo semantic relationship fo linking

Source: Saltlux, 2010

map. The query term '한라산 (Hallasan)' was in the middle and the queried items were placed hierarchically around the '한라산 (Hallasan)' based on the level of relationship with the query term. The background image map showed the place of the query term '한라산 (Hallasan)' automatically during the query since HOGIS implemented Geo-Tagging technique, which is the basic level of GeoOntology. In near future, GeoOntology with full geospatial relationship will be implemented.

4. National GIS Policies: NGIS and NSDI

1) History of Korean National GIS Policies: NGIS and NSDI

The first-phase of the National GIS implementation plan was initiated just after the two gas explosions.

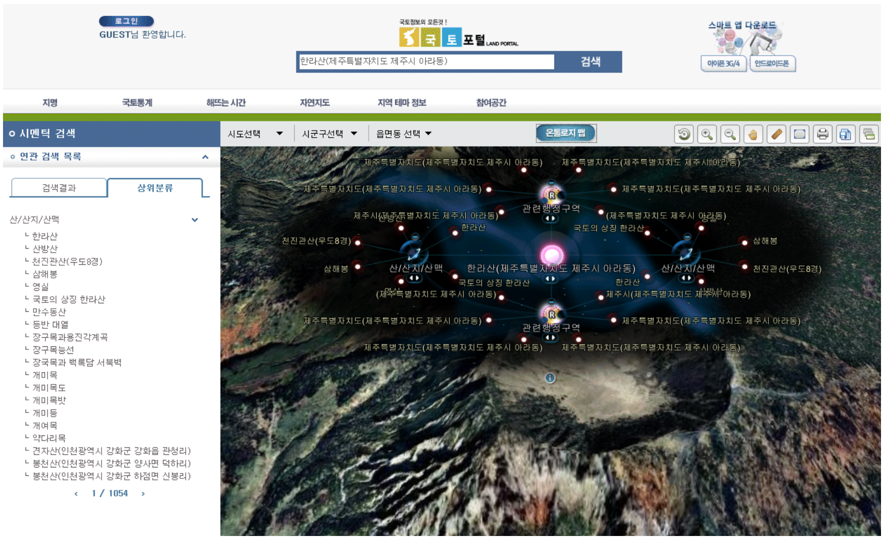

Figure 7. Semantic Query with Ontology

Source: Land Portal by NGII

To prevent similar accidents, GIS technology was proposed by the national assembly. Huge budget was allocated (see table 2). So far, the four phases of comprehensive National GIS implementation plans leaded by the Ministry of Land, Transport and Maritime (MLTM) have undertaken with the cooperation of many local governments, GIS academies, and industries. The descriptions of each phase of the NGIS are as follows.

(1) 1st phase (1995-2000): Digitalization of Spatial Data

The 1st phase of NGIS was primarily concerned with a creation of a digital topographic map base for the whole country at scales ranging from 1:1,000 in urban areas to 1:25,000 in rural areas. At the same time, several nation-wide thematic maps, parcel-address maps, land use maps, and urban planning maps were digitalized. Special attention was also given to digital mapping of underground facilities containing water pipeline, sewage, gas, electricity, communication, oil pipeline and heating information in conjunction with municipal governments and government-invested organizations in this phase.

(2) 2nd phase (2001-2005): Implementation of Korean Digital Land

In the 2nd phase, establishing framework data and building application systems as well as enhancing the digital maps of the 1st phase were important issues. The maps were revised and updated according to the basic plan of the 2nd phase. Entire country was divided into 5 regions, and one region was surveyed each year and then maps for this region were updated accordingly. These updated digital maps are called digital maps version 2 developed by the national mapping agency, NGII.

(3) 3rd phase (2006-2010): For Korean Ubiquitous Land

The substantial usage and synergic effect by linking and integrating digital data and systems to support spatial decision making were continuously focused in the 3rd phase. The second focus was on improving and enhancing the NGIS in accordance with public agencies, private companies, and individuals. Finally, the government would recognize the NGIS as a key in the 21st century's ubiquitous society in cooperating with related ITs, GPS, and sensor technologies.

(4) 4th phase (2011-2015 in progress): Korean Green Geospatial Society

The vision of the master plan for the 4th phase of NGIS (2011-2015) is GREEN. GREEN is the combination of acronyms for GR (Green growth), EE (Everywhere and Everybody) and N (New deal). GREEN

Table 2. Investment for Korean NGIS Project

(unit: billion won)

	1st NGIS (1995~2000)	2nd NGIS (2001~2005)	3rd NGIS (2006~2010)
Framework data	116.6(41.8%)	147.6(32.4%)	150.6(33.9%)
Application	128.7(46.2%)	268.9(59.1%)	234.2(52.8%)
Technology	20.4(7.3%)	22.6(5.0%)	53.1(12%)
Standard	1.4(0.5%)	4.0(0.9%)	1.3(0.3%)
Law/Institution/Policy	11.6(4.2%)	11.9(2.6%)	4.6(1%)
Sum	278.7(100%)	455.0(100%)	443.8(100%)

※ Central government budget only (MLTM, 2010)

Geospatial Society aims for the national economic development through creating green industries and using geospatial information in open, linked and integrated ways as a new growth engine for the future.

2) Korean NSDI and 4th NGIS

To prevent wasting the budget on redundant investments to build the geographic information, the need for National Spatial Data Infrastructure (NSDI) was brought up. The demand of geographic information use for the e-government is another reason why the government established the NSDI. Through the starting e-government projects (2002-2003) and the following 31 e-government road map projects (2003-2007), the Korean e-government has shown innovative performances. The integration of spatial data and administrative data for the Korean e-government has been the most important and critical work in the next generation plan of e-government established in 2007.

The NSDI plan has a 4-step road map that consists of preparing the information strategy planning step (2006-2007), the pilot project step (2008-2009), the expanding project(main project) step (2010-2012), and the enhancing project step (2013-) (MLTM, 2012b). By 2012, NSDI project plans to support the system that links 23 agencies and 76 geographic information systems to use in 246 local governments. Land use, policy statistics and other services are performed with spatial information such as terrain, cadastre, and land use in the government sector. And the NSDI homepage (http://www.nsdi.go.kr) provides the open API codes that can produce personal maps and the spatial cafe service to provide map creation tools.

The 4th NGIS master plan reflecting strategic scheme of the government and related-organizations coincides with visions of NSDI for Korea. It has five detailed implementation strategies to describe the 4th NSDI: the governance for mutual cooperation, an easy and convenient approach to spatial information, the interoperability of spatial information, the integration of spatial information infrastructure, and the intelligent spatial information technology.

First, in the governance for mutual cooperation sector, the goal is building a spatial information system to lead the actual cooperations among spatial information producers, users, and service providers. Second, the purpose of easy and convenient approach to spatial information is to freely transfer the huge data. Third, the interoperability of the spatial information sector aims to develop the standards and sustainable strategic development of the international standards that can be used in practice. Fourth, ten detail projects are running under the integration of the spatial information infrastructure sector. Data integration capabilities that enhance the use of spatial information is very important. Thus, each project presents the production of the spatial data standards and the guidelines to ensure the

Table 3. Budget for 4th NGIS 2010 to 2012

(unit: billion won)

	2010	2011	2012
Governance for mutual cooperation	97,666	83,772	90,790
Easy and convenient approach to spatial information	1,087	3,518	3,691
Interoperability of spatial information	1,150	2,850	2,748
Integration of spatial information infrastructure	92,611	93,822	106,840
Intelligent spatial information technology	24,000	12,029	3,000
Sum	216,514	195,991	207,069

※ Central government budget only (MLTM, 2012a) integration of basic spatial data. Lastly, the intelligent spatial information technology sector aims to develop the technologies relevant to ubiquitous spatial information.

For the 4th phase of NGIS (2011-2015), much more budgets (4,406 billion won) are expected to be invested. Table 3 shows the change of 4th NGIS sector's budget from 2010 to 2012. In the central government, a total of 50 projects from 10 institutions, approximately 2,071 billion won will be allocated.

5. Summary and Future Direction

In this paper, two recent research topics in Web GIS in Korean Geography were discussed: mobile GIS and GeoOntology. As the source of Web geospatial information, National GIS project was also reviewed. On the Web GIS, the GIS technology is moved to a mobile environment, and various service applications has emerged. The direction of these technologies are heading to the mobile Web GIS. If the mobile GIS technology is standardized to a mobile Web GIS, we should focus on the contents of mobile GIS rather than service methods in the future. It is not a simple location-based services, but a wide range of geographic information contents in a mobile environment.

GeoOntology is a method to build the contents of Web and mobile GIS based on geographic information and their relationships, since Ontology is the key technique for semantic query on the web. ISO 19103 provides the conceptual schema of Geospatial Ontology, which is a collection of the obvious meaning, phenomena, relationships of geographic information. The key issue of GeoOntology model is how to grab relationships connecting geospatial entities. Therefore, research studies on the spatio-temporal relationships including direction, distance, topology, change, and history are necessary to build GeoOntology in near future.

Finally, the main source information for Web GIS processing and query is the NSDI. With the increase of GIS data necessities on the Web, the need for standardizing, organizing, storing, managing and sharing them is getting better. The NSDI is an important national infrastructure required even for the continuous development of the nation's economic activity, for the development of a safe and convenient living environment, and for the efficient and productive administration. At the early stage of NGIS and NSDI in Korea, the focus was on the GIS establishment of the public sector by the central and local governments. Now NGIS and NSDI have become the basis of most administrative systems and the resource of various business sectors. Future NGIS will utilize geographical information through Web GIS to manage land effectively and develop new industries for national economy. For example, mobile GIS technology can be utilized for cadastral survey, which is next NGIS project for effective land management. GeoOntology can also contribute to NGIS through semantic query on land information for both public and government agencies.

Endnotes

1) http://www.land.go.kr/portal/main.do

References

Ahn, J.-S. and Kim, H.-T., 2010, A Study on the Implementation Method for GeoWeb Service based on Mobile Web with HTML5, *The Geographical Journal of the Korea*, 44(3), 375-381 (in Korean).

Ahn, J.-S., 2011, Design and Implementation of a Mobile Web Based Animated Map Service Using HTML5 Canvas and WMS Time Dimension, *Journal of the Korean Cartographic Association*, 11(3), 17-25 (in Korean).

Assem, M.V., Malaise, V., Miles, A., and Shreiber, G., 2006, A Method to Convert Thesauri to SKOS, *In Proceedings in the 3rd European Semantic Weg Conference*. Oct. 2006.

Berners-Lee, T., Hendlers, J., and Lassila, O., 2001, the Semantic Web, *journal of Communications* & *Strategies*, 65(1), 17-37.

Brackman, P. and Brands, M., 2009, Ontological Routing & POI linking, *Geospatial* & *LBS Innovation Community*, Community Forum, Sophia Antipolis, July 2, 2009.

Dabrowski, M. and Kruk, S.R., 2006, Geo-annotations in Semantic Digital Libraries, *Geospatial Knowledge Infrastructures Workshop*, Digital Enverprise Research Institute.

Di, L., Zhao, P., and Yu, G., 2008, Development and application of A Geospatial Service Ontology Based on ISO 19119, *ISO/TC211*.

Golbeck, J., Fragoso, G., Hartel, F., Hendler, J., Oberthaler, J., and Parsia, B., 2003, The National Cancer Institute's Thesaurus and Ontology, *Journal of Web Semantics*, 1(1), 75-80.

Google, 2012, Creating custom maps, available onilne at http://support.google.com/maps/bin/answer.py?hl=en&answer=62843.

Han, Y.S., 2004, *Koran Thesaurus Study*, Hangook culture co., Korea, P. 226.

Hong, I., 2006, Communal ontology of landmarks for urban regional navigation, *Journal of the Korean Geographical Society*, 41(5), 582-599.

Hong, I., 2010, Representing City Image as Regional Geographic Knowledge: Ontology Modeling Approach, *Journal of the Korean Association of Geographic Information Studies*, 13(2), 74-93 (in Korean).

Hong, I. and Oh, C., 2010, Ontology research for Developing Integrating System of Human-Oriented Geographic Information, *Journal of the Korean Cartographic Association*, 10(2), 139-148 (in Korean).

Hong, I., 2012, A Study on Developing Linked Data Application for Geographic Information, *Journal of the Korean Cartographic Association*, 12(1), 141-150.

Huang, J.X., Shin, J.A., and Choi, K.S., 2008, Building Domain Ontology through Concept and Relation Classification, *Journal of KIISE: Software and Applications*, 35(9), 562-571.

Jang, Y.-G., 2006, Development of Surface Survey System for Archaeological Site using Mobile GPS and GIS Technique, *Journal of The Korean Association of Geographic Information Studies*, 9(2), 91-101 (in Korean).

Kawtrakul, A., Imsombut, A., Thunkijjanukit, A., Soergel, D., Liang, A., Sini, M., Johannsen, G., and Keizer, J., 2005, Automatic Term Relationship Cleaning and Refinement for AGROVOC, *Workshop on the 6th Agricultural Ontology Service*, Jul 2005.

Kang, S. and Lee, K., 2010, Development of Android Smart Phone App for Analysis of Remote Sensing Images, *Korean Journal of Remote Sensing*, 26(5), 561-570 (in Korean).

Kim, H.W., Nam, J.Y., Lee, H., and Shin, D.M., 2008, A Device Coordination Mechanism with Context Ontology for a Ubiquitous Web Application Environment, *Journal of Engineering* & *Technology*, 17, 39-48.

Kim, K. and Lee, K., 2011, Design and Prototype Implementation of Hybrid App for Geo-Metadata Searching of Satellite Images, *Korean Journal of Remote Sensing*, 27(2), 203-211 (in Korean).

Ku, C.Y., 2012, Generating the Field Reference Data for the Process of the Satellite Image Using Smart Phone, *The Geographical Journal of the Korea*, 46(1), 39-52 (in Korean).

Lee, H.-J. and Lee, Y.-W., 2010, An Android Application for combining Personal Schedules with Map Services, *Journal of the Korean Cartographic Association*, 10(2), 103-111 (in Korean).

Lee, Y.-W., 2007, A Semantic Web Service for Tourism Information over the Mobile Web, *Journal of the Korean Geographical Society*, 42(5), 788-807.

Lee, Y.-W., Ku, C.Y., and Choi, J., 2010, Data Modeling and Ontology Building for an Integrated GIS Database, *Journal of the Korean Cartographic Association*, 10(2), 129-137 (in Korean).

Lee, Y.-W. and Park, K.-H., 2004, Design and Implementation of a Mapping Middleware for Wireless Internet Map Service, *The Journal of Geographic Information System Association of Korea*, 12(2), 165-179 (in Korean).

Ministry of Land, Transport and Maritime Affairs, 2010, *4th National GIS Master Plan(2010~2015)*, Ministry of Land, Transport and Maritime Affairs.

Ministry of Land, Transport and Maritime Affairs, 2012a, *National Spatial Information Policy Action Plan 2012*, Ministry of Land, Transport and Maritime Affairs.

Ministry of Land, Transport and Maritime Affairs, 2012b, Online document dated on 24 May 2012, http://www.mltm.go.kr/USR/NEWS/m_71/dtl.jsp?lcmspage=23&id=95070291

Mun, Y.-C. and Lee, H.-R., 2008, Development of Mobile System for Crop Situation Investigation using GPS based on GIS, *Journal of The Korean Association of Geographic Information Studies*, 11(4), 22-31 (in Korean).

Park, J.D. and Ku, C.Y., 2011, Implementation of Flood Warning Service with Mobile GIS, *Journal of the Korean Geographical Society*, 46(6), 738-750 (in Korean).

Park, M.-R., Park, K.-H., and Ahn, J.-S., 2011, Design and Implementation of a Computing Environment of Geovisual Analytic using HTML5 Canvas, *Journal of The Korean Association of Geographic Information Studies*, 14(4), 44-53 (in Korean).

Pundt, H., 2002, Field data collection with mobile GIS: Dependencies between semantics and data quality, *GeoInformatica*, 6(4), 363-380.

Saltlux, 2010, *Geospatial Ontology*, White paper, Saltlux Inc., Seoul.

Seoul Economy, 2011, Online document dated on 30 Oct 2011, http://economy.hankooki.com/ArticleView/ArticleView.php?url=industry/201110/e20111030173153120180.htm&ver=v002

Soergel, D., Lauser, B., Liang, A., Fisseha, F., Keizer, J., and Katz, S., 2004, Reengineering Thesauri for New Application: The AGROVOC Example, *Journal of Digital Information*, 4(4), available online at http://journals.tdl.org/jodi/article/view/112/111.

Song, W., Baik, D.K., and Jeong, D., 2009, Populating Geo-ontology with Web resources, *Journal of KIISE: Computing Practices and Letters*, 15(10), 740-751.

Tsou, M.-H., 2004, Integrated Mobile GIS and wireless internet map servers for environmental monitoring and management, *Cartography and Geographic Information Science*, 31(3), 153-165.

Youn, G., Kim, H., and Jun, C., 2008, The Optimization of Vector Data for Mobile GIS, *The Journal of Geographic Information System Association of Korea*, 16(2), 207-218 (in Korean).

Correspondence: Jinmu Choi, Department of Geography, Kyung Hee University, 26 Kyunghee-daero, Dongdaemun-gu, Seoul, Korea 130-701 (e-mail: cjm89@khu.ac.kr; phone: +82-2-961-0188; fax: +82-2-964-0250)
교신: 최진무, 130-701, 서울시 동대문구 경희대로 26, 경희대학교 이과대학 지리학과 (이메일: cjm89@khu.ac.kr; 전화: 02-961-0188; 팩스: 02-964-0250)

Recieved August 1, 2012
Revised August 10, 2012
Accepted August 13, 2012