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Original article

Prototyping of Community Mapping for Enabling Response to Urban Flood

Koo, Jee Hee[1] · Jeon, Min Cheol[2] · Kim, Sun Woong[3]

Abstract

Recently, there has been growing interest in public participation GIS (Geographic Information System) technology that enables spontaneous public response to increasingly frequent flood and drought events. Accordingly, social and economic demands are increasing on portal services that are designed to help cope with natural hazards such as earthquakes. By focusing on a specific hazard, urban flood, this study designed a prototype of a disaster response portal and its service system. The community map developed in this study is focused on prevention and mitigation of the urban flood damage by analyzing the vulnerable areas, and providing effective means to inspect the roads and sewer systems. By considering the compatibility with VGI (Volunteered Geographic Information) portals, the study created a system environment by employing universally used open-source software programs such as Apache Tomcat, GeoServer, GeoNetwork, and PostgreSQL/PostGIS.

Keywords: VGI Portal, Urban Flood, GIS, Public Participation GIS

1. Introduction

Climate change-related natural hazards and disasters have been frequent in recent decades. The impacts have rendered it necessary to promptly gather, disseminate, and update related information. As a practical solution to the problem, interested parties may consider obtaining the information expeditiously through web-based VGI (Volunteered Geographic Information) portals. As companies and the public sector are considering increasing citizen participation, such participation is gaining more momentum along with the expansion of social networks and collective intelligence.

Some researchers have developed public participation GIS (Geographic Information System) and management system for natural hazard and disaster response. Kim *et al*. (2008) developed web GIS based natural hazard damage information system that delivers GIS data and damage information to the users fast and effectively. The system also serves the high resolution satellite images to provide visual aid to the damaged area and the nearby infra structures and facilities. Ban *et al*. (2008) used the GIS and VGI in selecting the optimal location of the sanitary landfill. Bugs *et al*. (2010) developed Web 2.0 PPGIS application prototype utilizing the user-generated content and the local knowledge of the people to enhance the open communication among the decision makers, focusing on the urban housing policy. Jeong *et al*. (2011) implemented 'U-disaster prevention urban management system' us-ing smartphone, which delivers disaster monitoring information. The system uses the input from the public with smartphones. The first responders analyze the inputs make the decision through web portal and feed those information back to the public within the same framework. The uploaded images are automatically masked to protect the privacy and personal information. Lee *at al*. (2012) suggested a

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1) Division of Interdisciplinary Studies, Social Eco-Tech Institute, Konkuk University (E-mail: koojeehee@gmail.com)
2) Dept. of Advanced Technology Fusion, Konkuk University (E-mail: mcblue@konkuk.ac.kr)
3) Corresponding Author, Member, Dept. of Advanced Technology Fusion, Konkuk University (E-mail: geomon@konkuk.ac.kr)

prototype system which integrates a number of different disaster information sources to increase the efficiency of the system. Several Government agencies are running independent disaster response systems and these systems are not interoperable, decreasing the efficiency of the disaster response. By integrating multiple data source, more systematic response can be accomplished. Lee *et al*. (2014) developed a GIS based steep slope integrated management system for prevention and mitigation of landslide during urban storm surge. Horita *et al*. (2015) proposed AGORA-DS, which is the SDSS (Spatial Decision Support System) in flood management, by integrating the WSN (Wireless Sensor Network) in the river and VGI. AGORA-DS proved that VGI is quite useful in supplementing the data from the sensor network. Furthermore, public participation smartphone applications have enabled citizens and laypeople to participate in disaster prevention processes, offering them a tool with which they can aid the setting up of realistic, reasonable, and comprehensive prevention plans (Ki, 2012).

Plans established in this manner can be more practical if the information providers have resided for a substantial period or are spending substantial amount of time in the area. With assistance from specialists or civil servants, the citizens and laypeople could participate more assertively in the process of planning and implementation. Currently, the government is endeavoring to build an integrated urban disaster prevention database and web tool platform, which is based on coordination and combination of data from a number of related systems. Furthermore, the administration is implementing a participatory geographic information portal through community mapping where citizens are engaged in the process (NGII, 2015).

This study designed a prototype of a public participation spatial information portal for urban flood response, i.e., a VGI portal. The citizens can use this system to participate and communicate, so that the hazard source can be predetermined, inspected and managed. By utilizing standard web technologies as well as GIS open standard services and interfaces, the study designed and realized four types of functions: GIS common, community mapping, map style management, and data sharing and management.

2. Trends in Community Mapping

Since the 2000s, advancements in Web GIS and mobile devices have allowed a migration of the core user of spatial data from expert groups to laypeople or ordinary citizens. As a result, there have been systems wherein the spontaneous participation of citizens is resulting in the creation, update, and maintenance of spatial data. Nevertheless, questions are being continuously raised about the positional and logical accuracy of such spatial data created by non-experts. This problem has also been subjected to many strategies proposed by organizations and agencies that provide VGI mapping services (Goodchild and Li, 2012; Van Exel *et al*., 2010). Despite the efforts, VGI maps are markedly expanding their presence in markets in recent years because of their cost competitiveness, freedom in data use and speed, and the greater variety of themes being addressed when compared to the existing data produced by government agencies and commercial spatial-data providers.

Community mapping is a form of PPGIS (Public Participation Geographic Information System). PPGIS involves the use of the Internet and GIS in the citizen participation process, which allows laypeople to partake in spatial data decision-making processes through mapping and GIS analysis. The number 2.0, denoting later version, refers to the grating of the Web 2.0 concept into spatial information services, thus allowing users to add information to the maps or access other types of services they require. Similar developments have enabled real-time voicing of opinions of citizens as they are based on spatial information, UCC (User Created Content), and other multimedia inputs. Furthermore, Goodchild (2007) proposed a concept called "VG (Volunteered Geography)", wherein individuals have the opportunity to participate as active geographic information creators, and combined VG with GIS and named it VGI.

The term "community mapping" is a combination of the words "community" and "mapping." Community refers to a community or local community, i.e., a spatial and localized unit within the social organization. The term also refers to the emotional bonds or sense of belonging. Mapping, on the other hand, refers to the process of creating maps, wherein the information about geography and space is expressed

visually such that the information is linked to places (Choi, 2015). In other words, community mapping is a process of employing collective intelligence for specific purposes such as collecting information and involves registering such information on a real-time basis and solving problems of the community by utilizing location-based services. As part of the global community's efforts to overcome the most recent incidents of large-scale natural hazards, case studies of social media outlets such as Twitter and Facebook are being introduced to a significant extent. In July 2011, localized heavy rains struck Seoul, South Korea causing significant damages. A few citizens posted the location and status of the flood-stricken areas in Seoul to their individual SNS (Social Networking Service) pages for dissemination. The combined reports led to a compilation of online maps and the completion of citizens-initiated, SNS-based flood maps. The maps provided the citizens in the affected areas with the information that they can employ to prevent flooding. The informed citizens were able to further mitigate the damages by bypassing or evacuating the flooded areas (Jang and Kang, 2012).

As to disaster response, open-source disaster management platforms such as Ushahidi are available against natural hazard, building collapse, crime, and disease. As part of their agreement, the city of Seoul and internet portal Daum presented Agora, a portal that offers a flood damage community map service wherein citizens can directly report flood sites along with their locational information. When citizens shoot and send the images of blocked gutters and drains (a direct cause of flooding) as well as flood-stricken sites, such images are registered in maps on a real-time basis, and they have actually been utilized by the city for providing and implementing safety measures against floods (Hwang and Ahn, 2015).

3. Development of Public Participation Spatial Information Portal

3.1 System design considerations

Advancements in Web GIS and mobile devices have allowed a migration of the core user of spatial data from expert groups to laypeople or ordinary citizens. As a result, there have been systems wherein the spontaneous participation of citizens is leading to the creation, update, and maintenance of spatial data (Hong, 2012). Nevertheless, questions are being continuously raised about the positional and logical accuracy of similar spatial data created by non-experts. This problem has also been subjected to numerous strategies proposed by organizations and agencies that provide VGI mapping services. Despite the efforts, VGI maps are markedly expanding their presence in markets in recent years because of their cost competitiveness, freedom in data use and speed, and the greater variety of themes being addressed when compared to the existing data produced by government agencies and commercial spatial-data providers.

Open-source GIS have recently started to reinforce their structure such that they can replace the system of GIS product groups of commercial GIS providers, while the commercial GIS companies themselves have started to adopt open-source GIS models by modifying their own products to be open source (Jang *et al*., 2016). The previously prevalent issues with respect to quality verification and maintenance and repair are being addressed by the arrival of commercial open-source GIS providers and their implementation of continued upgrades and maintenance and repair. Hence, it is necessary for public participation spatial information portals to actively incorporate the user VGI, open source platforms, and open standards that are part of the latest technologies set forth by the UN-GGIM (United Nations Committee of Experts on Global Geospatial Information Management).

The OGC (Open Geospatial Consortium) is presently defining spatial data standards for offering GIS services. WMS (Web Map Service) is a standard specification that converts maps into images and is the interface standard defined by the OGC for offering map image. WFS (Web Feature Service), on the other hand, is a standard specification that converts spatial data to GML (Geography Markup Language) and is the interface standard for geographic configurations (vectors). WCS (Web Coverage Service) is a geographic coverage interface standard that returns the requested coverage in a file format such as GeoTIFF. CSW (Catalog Service for Web) refers to the service interface standard that enables users in web environments to employ simple interfaces to search, access, and create metadata

regarding spatial information. The establishment of public participation spatial information portals is to be in a manner as to support and utilize OGC-specified geospatial open standards such as WMS, WFS, WCS, and CSW.

3.2 Creating public participation spatial information portals

The software that was employed to create public participation spatial information portals was various open source programs with verified stability and universality (Fig. 1). GeoServer was employed for GIS software that can process geographic spatial data. For DBMS (Data Base Management System) server, PostgreSQL was adopted as it is employed widely in open source DBMS. PostGIS, which adds support for geographic objects to PostgreSQL, was applied to create the system. GeoNetwork was employed for the catalog engine that manages spatial metadata storage and CSW services.

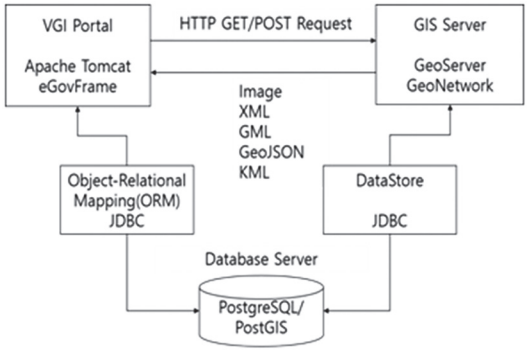

Fig. 1. Portal system diagram of volunteered geographic information

3.2.1 Public participation VGI portals

(1) Apache Tomcat

Apache Tomcat is a container with Servlet and JSP (Java Server Page) technologies realized. Tomcat is embedded with its own HTTP server and thus is able to play the role of web server and provide Java environments that can be coordinated with the web server for implementation. Therefore, Tomcat offers an environment wherein JSP and Java servlet can operate. The key features thereof include (a) verified stability that supports universality, load balancing, and session clustering and (b) high levels of security that supports security protocols such as HTTPs and SSL as well as JMX -based proxy.

(2) eGovernment Standard Framework

The Republic of Korea's eGovernment Standard Framework, which is standardized for each platform in its public sector informatization projects, provides the application architecture, basic functions, and common components that are required when creating web-based informatization systems. eGovernment Standard Framework consists of implementation environments, development environments, operating environments, management environments, and common components. The eGovFrame (the standard framework provided by the Ministry of the Interior) has been employed as the basic framework, while user management, file transfer, database query, and other features have been realized by utilizing the major components and interfaces of eGovFrame.

3.2.2 Construct for GeoSpatial data processing system

(1) GeoServer

GeoServer is an open source GIS software server capable of sharing and editing GeoSpatial data that are developed in Java. The software program is the realization referenced for WMS of the OGC, which complies with high-performance certification, and standards for WFS and WCS. GeoServer is the core component of GeoSpatial web services.

Key features of GeoServer include (a) visualization of data (e.g., dynamic visualization of WMS-based vectors, rasters, etc.); (b) realization of various support functions that are certified (e.g., OGC web services such as WMS, WFS, and WCS standards); (c) provision of extension support for WPS (Web Processing Service); (d) offering support for various data sources, e.g., open sources (PostGIS, Shapefile, ArcSDE, DB2, Oracle, MySQL, etc.) as well as commercial RDBMS; (e) Native Java-based support for raster formats (GeoTIFF, GTOPO30, ArcGrid, World Images, Image Mosaics, Image Pyramids, etc.); (f) ability to utilize all raster formats that are supported by GDAL using GDAL ImageIO Extension (e.g., MrSID, ECW, JPEG2000, DTED, Erdas Imagine, NITF, etc.); (g) support for on the fly reprojection; and (h) support

for web map outputs (JPEG, GIF, PNG, PDF, SVG, etc.).

(2) GeoNetwork

GeoNetwork is a management catalog application for spatially referenced resources. The application offers metadata editor and search functions as well as interactive web map viewer. The major functions of GeoNetwork include: (a) multilingual metadata editor; (b) multilingual verification system support; (c) support for OGC standard service CSW; and (d) support for ISO19115-1/ISO19115-3 plugins.

3.2.3 Creating data server for GeoSpatial systems

(1) PostgreSQL / PostGIS

PostgreSQL is a highly effective open-source object-relation database system that complies with the ANSI SQL standard and is equipped with high levels of security and reliability. The database system offers (a) various indexing techniques; (b) flexible full-text search; (c) MVCC (MultiVersion Concurrency Control), which increases concurrency; (d) various flexible copy method support; (e) support for various procedures (PL/pgSQL, Perl, Python, Ruby, TCL, etc.); (f) support for various interface languages (JDBC, ODBC, C/C++, .Net, Perl, Python, etc.); (g) support for various functions and types; (h) key-value store extension; (i) GIS add-on support (PostGIS); and (j) DB links.

PostGIS is the spatial extension of PostgreSQL, which complies with the OGC standard (SF-SQL). It offers spatial data types and operators and indexes as well as approximately 800 functions that are employed for efficient spatial operation. PostGIS also supports smooth coordinate system transformation such that efficient utilization of spatial data is ensured. Specifically, functions offered by PostGIS include (a) support for various spatial data types and efficient spatial operation by employing GEOS; (b) support for various coordinate systems and coordinate system transformation by employing PROJ4; (c) support for GML-type data format and XML communication by employing LibXML2; (d) support for GeoJSON and JSON-type communication by employing JSON-C; (e) compliance with OGC standards; (f) connection to various applications (uDig, QGIS, etc.); (g) support for approximately 800 spatial functions; and (f) support for spatial indexing, which enables fast spatial query.

3.3 Major functions of public participation spatial information portals

The community map developed in this study is focused on prevention and mitigation of the urban flood damage by analyzing the vulnerable areas, and providing effective means to inspect the roads and sewer systems. With respect to the major functions of the public participation spatial information prototype, development was undertaken in each area such as (a) GIS common, (b) community mapping, (c) map style management, and (d) data sharing and management. First, GIS common involves map control, map layer management, and calculation functions (a line, plane, distance, and area on the maps). Community mapping offers functions such as viewing attributes of a feature appearing on the maps; creation, modification, and deletion of spatial data geometry (point, arc, polygon); and storage of the created maps and other registries as metadata in compliance with ISO19115-1 standard. In terms of map style management, the prototype classifies data by utilizing the attributes of spatial data, and sets up vector and raster data symbols. Last, in data sharing and management, newly developed functions are CSW server registry and effectiveness test and server-registered record search.

4. Realization of VGI Portal Prototype

4.1 Realization of GIS common and community mapping functions

To ensure flexible services employing community mapping techniques, map maneuvering by users was rendered convenient with the realization of basic GIS functions such as map control, layer management, distance/area measurement, and full-screen view (Fig. 2). Furthermore, editor functions were added to allow the addition, modification, and deletion of user-created spatial information and data (points, lines, polygons) (Fig. 3). When realizing these editor functions, WFS transaction service (an OGC standard service) was utilized to enable data storage.

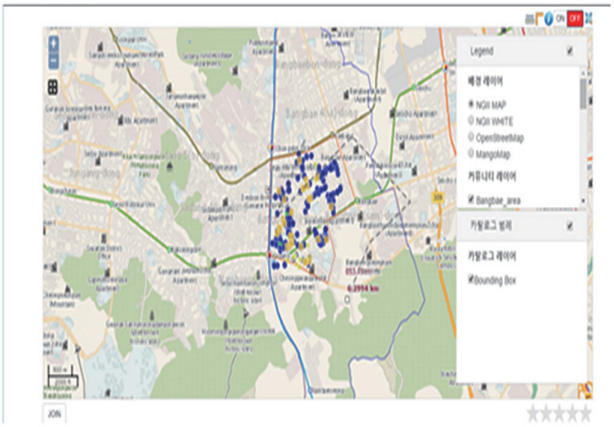

Fig. 2. Image of portal map

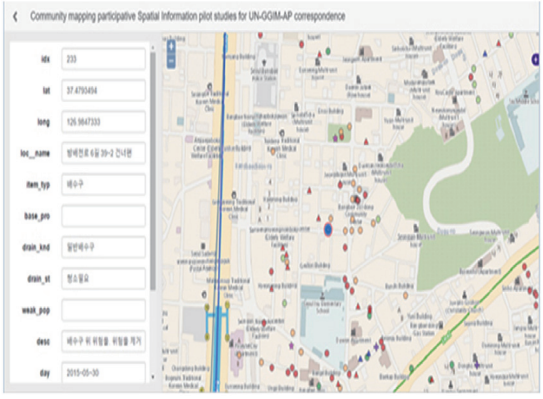

Fig. 3. Image of editor

Furthermore, general file upload and download functions were developed such that they are more user-friendly, while a function was realized wherein a file transfer progressbar is displayed during upload. Additionally, a system was built such that ISO19115-1/ISO19115-3, i.e., the latest international standard for spatial information metadata, can be stored and the metadata so stored can be disseminated. Moreover, a platform was provided to store and manage the flagship metadata of NGII, including unified control point, orthoimage, and aerial image. To enable the sharing of the stored metadata with external agencies through CSW services and downloading of files, documents, etc., such functions as those of spatial data interface information (URL, WMS, WFS, etc.) and offering of metadata information that is based on ISO19115-1 (Fig. 4), were realized.

Fig. 4. CSW-based sharing of metadata and information

4.2 Map style management and data sharing and management functions

For wide ranges of visualization of community mapping data, a stylizing tool was realized by utilizing the OGC standard-based symbol SLD (Styled Layer Descriptor). Fig. 5 illustrates the realization of various classification methods that are aligned to the data characteristics. In Fig. 5 the filter, rule, polygon symbolizer, line symbolizer, and point symbolizer functions are also illustrated. Furthermore, the prototype offers classification methods that were realized to classify spatial data by using various inputs values. The prototype also facilitated the application of various color classifications of the spatial data by utilizing ColorBrewer (a color table offering various degrees of spatial data color schemes) (Fig. 6).

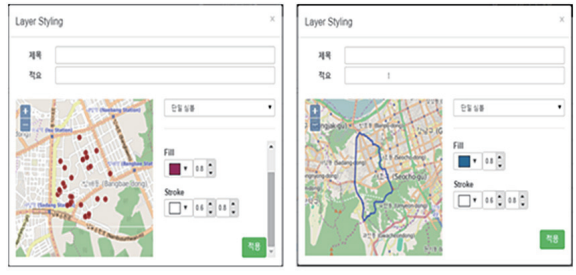

Fig. 5. Tool for creating spatial data SLD

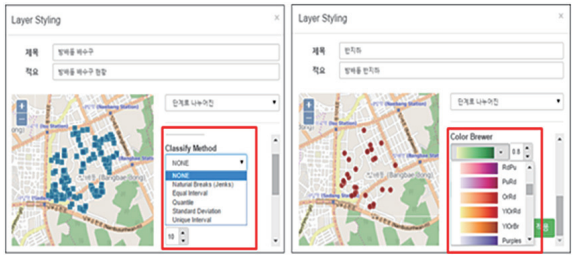

Fig. 6. Classification method and ColorBrewer

The NGII's four flagship metadata types, i.e., unified control point, orthoimage, aerial image, and digital topographic map, are capable of examining and confirming the stored metadata through the Catalog Service function, which has been realized by GeoNetwork. Furthermore, the metadata are created and registered as per the ISO19115-1 standard in order to offer a metadata-disclosing function through the CSW service for external users.

The data that has been created by both communities and experts are subjected to (a) CSW Server System that can be accessed through CSW; and (b) CSW Client that can obtain specialized data from external sources. Fig. 7 illustrates the whole construct of CSW that provides the services.

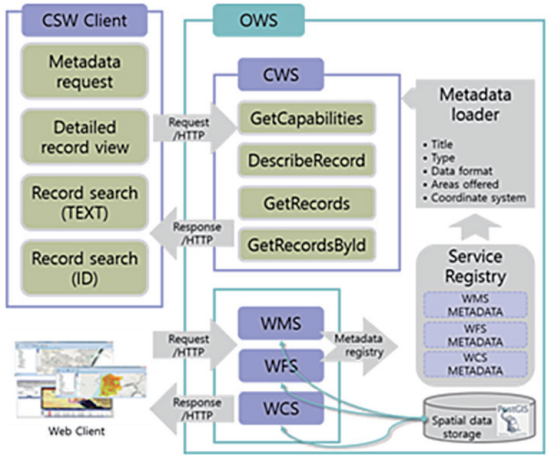

Fig. 7. CSW construct schematic

5. Differentiating factor from existing portal system

General Portal Service "Daum" is providing the flood information system for the public. They serve the location of flooded area and the damage status information. The service is only useful when there is a flooding event. The system designed in this study is focused on participation based interactive system for relatively small community.

Main steps in utilizing the Community Map is as follows:

1. Register the people who want to participate in the system via VGI portal.
2. Allocate the participants based on the age, address and skill set.
3. Participants are gathering information by taking the photo and upload to the system.
4. Information collected and uploaded by smartphones and tablets are mapped using spatial editing tool.
5. Share and distribute the mapped information and implement preventive measure.

Existing portal systems collects all different kinds of disaster information. This research is focused on 'urban flooding' and providing more professional service with public participation portal system. 'Urban flooding' can occur not only by typhoon and storm surge, but also by broken sewage pipe or clogged drain. Underground spaces are increasing as the city grows. These areas are quite susceptible for 'urban flooding'. The system developed in this research has very simple and intuitive user interface, so the beginners can use the system without intensive training. Menu items, icons configuration and multiple layer control can be easily accessible. Active public participation is the key to the success of this system. The citizens can report the clogged drain and broken sewage pipe with photo and text upload, and they can get the information on evacuation route and other disaster mitigation related information from this portal. The first responders can get the real information from the field, analyze the situation and efficiently allocate their resources. The system is very useful in preventing and mitigating the urban flooding.

6. Conclusion

Along with global warming and the resulting climate-related incidents, there has been a sharp increase in the occurrence of natural hazards and disasters, which in turn

has increased urban residents' requirement for securing safety and convenience of their lives. VGI based Community Map can be a very effective tool in preventing and mitigating urban flooding through active participation of the citizens and information sharing. The system can be further enhanced by integrating with the big data system, and help the decision makers making the right decision at the right time by providing dynamic and interactive visualization and analysis.

Depending on the purpose of such utilization, the re-produced data can be employed for disaster analysis, disaster prevention for specific areas, public policy decision-making, etc. This study focused on urban flooding, but it can be easily expanded to other areas such as wild fire management and landslide response.

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