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A Study on Facility Information System using GIS and Semantic Web in Underground Space

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ABSTRACT

The utilization of underground space has recently increased with the complication of road, the rise of the land price, and the development of green technology. Underground space ranges from classical excavations to subway, underground cities, and shopping malls where there are crowds of people. At this time, government has spent a lot of money in installing various types of safety facilities for preparations of increasing potential disasters. Therefore, an effective facility management system is required. In this paper, we propose an information retrieval process to effectively extract the facilities' information based on the ontology and spatial analysis in underground space. The ontology-based searching supports hierarchical and associated results as well as knowledge sharing with hierarchy concepts. The spatial analysis based searching has "Buffer" and "Near" functions to operate on a map without understanding any property of the facility information.

Key words: Facility Management System, Underground Space, Retrieval System, Ontology, Spatial Analysis

1. INTRODUCTION

Underground spaces are increasingly becoming important for a wide diversity of uses by society. They range from classical excavations to subway constructions, underground sport halls, power stations, waste repositories, underground cities, and many others. This phenomenon, which is started in countries subjected to extreme climates is now becoming more widespread. At this time various types of facilities and users have rapidly grown and an effective management of facilities in underground space is required for preparations of increasing potential disasters[1,2]. We know the obvious characteristic in underground space is darkness, so searching locations of some facilities like emergency lamps and fire extinguishers to refuge from disasters or control disasters are very important works for reducing possibly and seriously occurring dangerous accidents, and these works can save people' lives.

New ages of searching methods have been recently approached toward a semantic Web. Nowadays, semantic searches based on the ontology are widely applied in many fields related to search works as described in [3-7]. The Geographic Information Systems(GIS) has experienced an astonishing growth in recent decades and such development is, in many ways, closely related to the spatial analytic capabilities. As the technology of semantic Web and GIS are recently spreading, we use these technologies to support an effective

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management of the facilities in a variety of disasters through searching some valuable information and visualizing locations of the facilities. Such a system maybe makes significant contribution to reduce injured people or save people's life. In addition, the system can educate children about refuge manual and using help of the facilities in disasters. However, data retrieval and spatial analysis are not considered by researchers and a system which is integrated many powerful functions is necessary to provide improved management and more safe use and manuals of the facilities in underground spaces.

In this paper, we propose a facility information system based on the ontology and spatial analysis. Our proposed system focuses on hierarchy and association searching through the ontology and simple and easy searching through spatial analysis. This paper is organized as follows. In the next section, we introduce our related works, and in section 3, we design the proposed system for searching facility information of underground space. In the section 4, we describe contents of implementation of the proposed system using a scenario, next, the section 5 takes analysis on our proposed system. Finally, in the section 6, we summarize this paper.

2. RELATED WORKS

2.1 Underground Space Facility

Underground space development may be one of the most significant to contend with urban predicaments such as congestion, lack of open space, and aging infrastructures. Therefore, building underground space is becoming more common. Meanwhile, the dangerous factors in underground space have increased since the underground space became complicated and large-sized[8,9]. In order to prepare various kinds of disasters, many kinds of facilities have been installed in underground space. They can be divided into 6 major categories as table 1.

The management of these facilities is a significant work for administrators. In a facility management system, an effective retrieval engine can support user's convenience in attaining related information.

2.2 Facility Information System

We can search some underground space information through linking related Web site like transit corporations. We can get just little information about underground space facilities, but there is plenteous information about helping information like how to use subway, how to buy a ticket, surrounding environment information, and so on.

2.2.1 Seoul Metro

The Seoul Metro[10] serves surrounding environment information of subway stations, location and usage information of the facilities, safety guide information, and so forth. The figure 1 shows the guide map image in Seoul Metro homepage. We

Table 1. Facility Categories in Underground Space

Categories	Facilities
Refuge Facility	Emergency elevator, emergency exit, emergency lamp, escape ladder, escape stair, leading light, leading mark, respirator, ventilator, warning facilities, and so on
Extinguishing Facility	Fire extinguisher, inside fire hydrant, sprinkler, and so on
Fire Prevention Facility	Automatic fire protection shutter, fire door, fire wall, and so on
Electricity Facility	Leakage alarm, leakage circuit breaker, and so on
Gas Facility	Inflammable gas detector, toxic gas detector, and so on
Telecommunication	Broadcasting, wireless devices, and so on

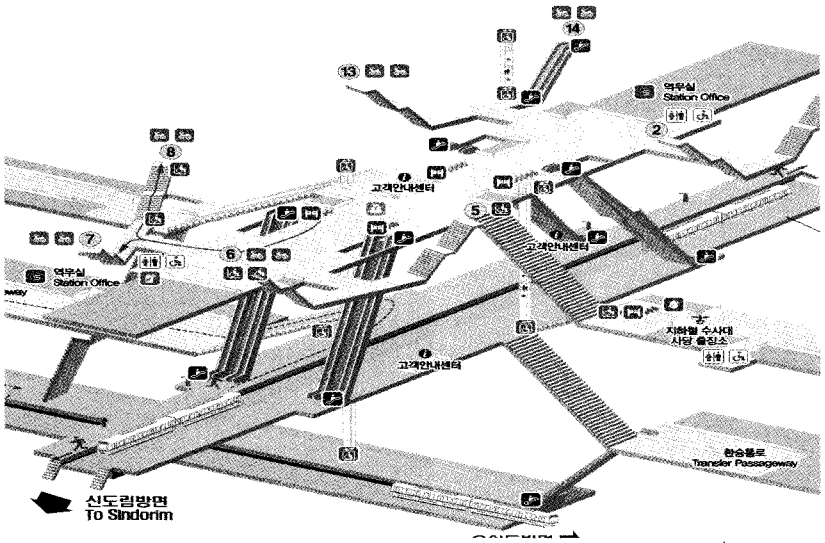

Fig. 1. Seoul Station Image in Seoul Metro Homepage.

can see from the guide map, it shows some symbols of different facilities and probable locations of those facilities, but there are not any other refuge facilities like respirators and emergency lamps except for fire extinguishers. The introduction of safe guarding equipment like fire extinguisher, indoor fire hydrant, spring cooler, and other objects can be found in the menu. Also, there is safety guide information like safety rules in the vehicles and subway and how to use an escalator and elevator.

2.2.2 Seoul Metropolitan Rapid Transit Corporation

The Seoul Metropolitan Rapid Transit Corporation[11] serves more plentiful contents with station information, time schedule of subway, inside guide map, traffic and tour information of surrounding environment, and so forth. The guide map is expressed by the 2D flash file like Seoul Metro's guide map. The resolution of image is too low for people to clearly recognize it, and the refuge facilities and their location information are not provided. Moreover, they do not support the usage information of the facilities.

2.2.3 Busan Transportation Corporation

The Busan Transportation Corporation[12] serves like some usual information system as early mentioned and uses 2D flash file to display inside of environment. As a new and useful way, they provide Video files about usage of information about how to buy a ticket, how to use an automatic charge machine, and so on.

2.3 Semantic Web and GIS

The semantic Web was initially proposed by Tim Berners-Lee as an evolution of the current World Wide Web(www), in which Web resources and services can be understood and can be used by both people and machines[13]. Ontologies play an important role in the semantic Web because they can provide a more flexible way of introducing semantics into the semantic Web[14]. An ontology is defined as a formal and explicit representation of a set of concepts within a domain and the relationships between those concepts to share common understanding of the structure of information among people or software agents[15,16]. Ontology can be used to improve the accuracy of information retrieval[17,18]. The most popular ontology languages are Resource Description Framework (RDF) and Web Ontology Language(OWL).

A Geographic Information System(GIS) is a computer system capable of capturing, storing, analyzing, and displaying geographically referenced information which is widely used for scientific investigations, resource management, asset management, and other purposes[19,20]. The power of a GIS comes from spatial analysis. The spatial analysis can model the real world using maps and attribute information in databases and can forecast some results of problems which are happened in the real world through various analysis methods. Therefore, it can be used to make some refuge plans in emergence[21].

3. DESIGN OF THE PROPOSED SYSTEM

This section presents a design of a facility information system in underground space based on the ontology and spatial analysis. Users can use the proposed system to search related facilities' information with some attribute information based on ontology and also search on the map with spatial analysis function. Moreover, the proposed system provides map layer control function for users[22].

3.1 System Overview

The proposed system has three layers like figure 2: user interface, retrieval engine, and DBMS. There are four main modules in the system such as map control module, DB retrieval module, ontology-based retrieval module, and spatial analysis module.

The user interface has user condition input, map control module, toolbar, and map layer controller. In the user condition input part, user inputs some attribute conditions to DB search and ontology search and defines some interested location on the map and gives some distance value to take spatial analysis.

The retrieval engine divides into three parts to provide different searching methods. The DB retrieval module is an retrieval engine which is widely used in many other information systems. When users do not want some related information, they can search with DB retrieval module. The ontology-based retrieval module can reduce users' searching works by hierarchical searching for providing intelligent and simple searching works. Also, we propose a flexible procedure that deals with both RDF type of data and general data in the databases to support an effective retrieval. The retrieval process has two steps to extract information. The first step is extracting some major resources from "Facility Ontology Information"

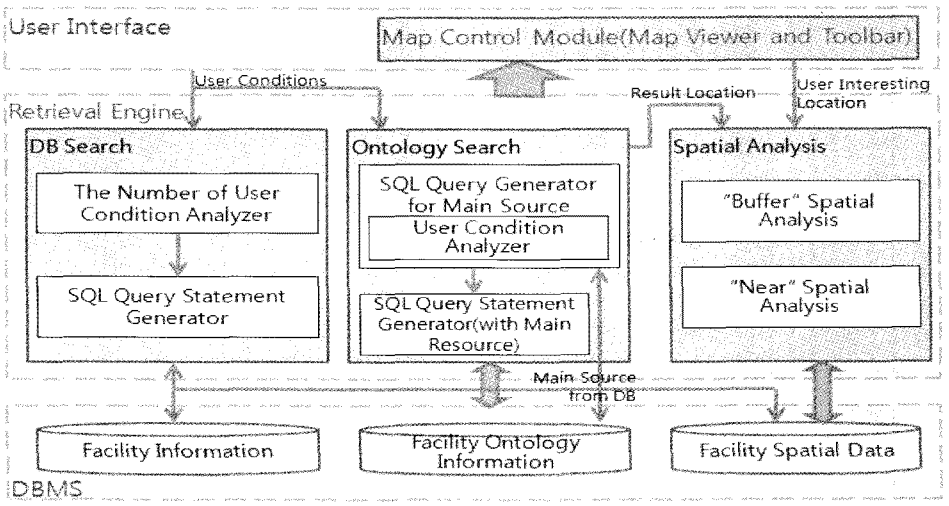

Fig. 2. System Architecture of the Proposed System

according to the result analysis information of user's conditions. The second step is searching results from "Facility Information" according to the major resources. After that, the results will be shown to users. The spatial analysis provides "Buffer" and "Near" functions. Before performing the spatial analysis, users have to select a reference point. Users can get the reference point from results of the ontology-based search or click on the map where users want to take spatial analysis. When users execute the "Buffer" spatial analysis, a buffer region will be shown on the map.

Our proposed system construct databases using Oracle 11g which supports for semantic technologies including storage, inference, and query capabilities for data and ontologies based on Resource Description Framework(RDF), RDF Schema(RDFS), and Web Ontology Language (OWL). There are three parts with "Facility Information", "Facility Ontology Information", and "Facility Spatial Data" in our database. "Facility Information" stores all attribute information of facilities, staffers, and business data. "Facility Ontology Information" stores facility ontology information and "Facility Spatial Data" stores location information of facilities like x and y coordinate figures.

3.2 User Interface

The user interface with map control functions and ontology-based search is shown in figure 3 and the user interface of spatial analysis is shown in figure 4.

The "Toolbar"① contains some useful tools like "Full Extent", "Pan", "Zoom In", "Zoom out", "Fixed Zoom In", "Fixed Zoom Out", "Go Back To Previous Extent", "Go To Next Extent", "Zoom Control", "Select Features", and "Measure". The "Map layer controller"② displays different symbols of the facilities and supports for layer selection function to users. The "Coordinate figure"③ shows the x and y coordinate figure where the pointer points on the map. The "Map viewer"④ shows the map of "Kyungsung Univ. Pukyong Nat'l Univ." subway station in Busan. The "Ontology-based search"⑤ allows users to input some values according to different types of attributes. When users input one value, the condition will be added in the conditions list box. The check box of "Search Within Results" means searching more valuable information from previous results, that is, it can be used instead of filter function. The "Result"⑥

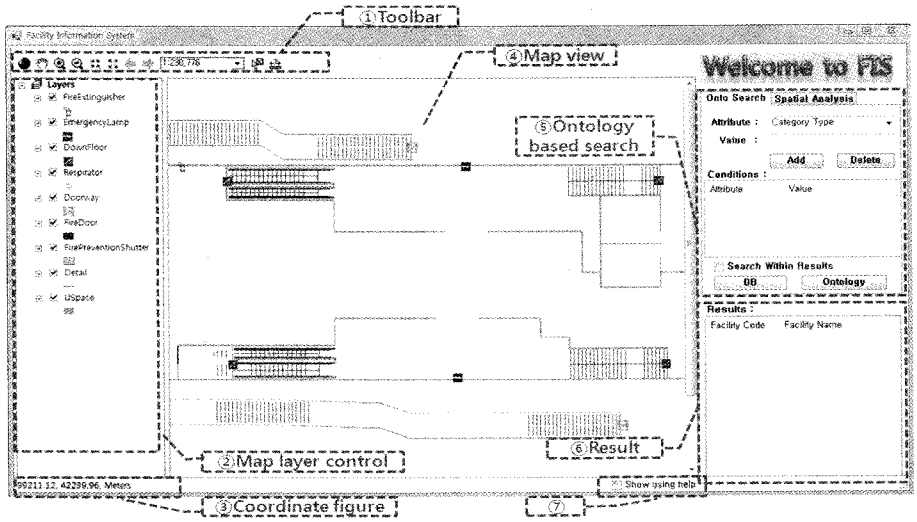

Fig. 3. User Interface with Ontology-based Search.

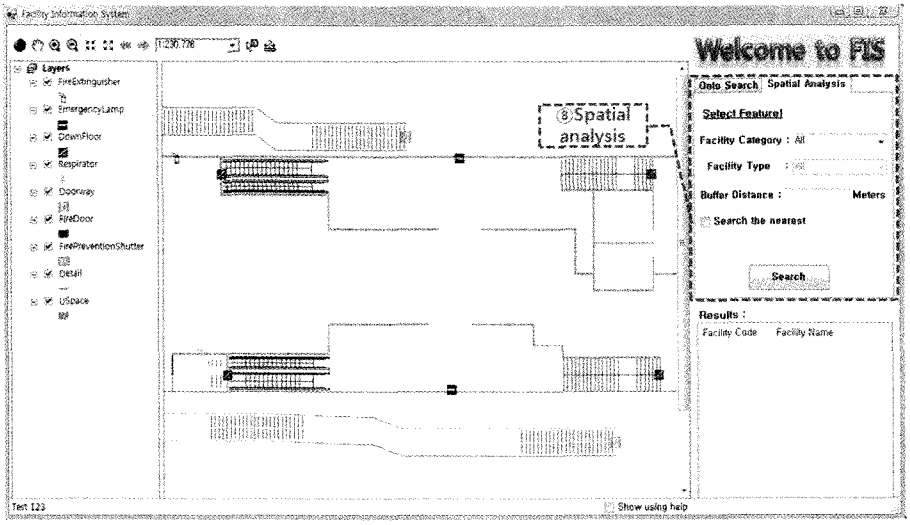

Fig. 4. User Interface with Spatial Analysis.

part shows results with facility code, facility name, and other information. If users want to know some using information of facilities, they can check this "Show using help"⑦ check box. To take a spatial analysis, users can get a reference point from results of ontology-based search or click on the map where users want to take "Spatial analysis"⑧[22].

4. IMPLEMENTATION OF THE PROPOSED SYSTEM

In this section, we represent the facility ontology modeling and the database schema for implementing and take a facility retrieval scenario to show each procedure. We use Visual Studio .Net 2005 development tool and Oracle 11g Database. To express obvious and clear results, we edit the original shape format map to add more helpful information using ArcGIS desktop tool. The ontology was constructed in Protégé-OWL tool which is the most popular tool, as well as free, open source ontology editor.

4.1 Ontology Modeling and DB Schema

An ontology contains some classes and properties that are hierarchically related to different classes one another, some axioms, and some constraints. We defined four superclasses of underground space facility ontology such as "Business", "Facility", "UndergroundSpace", and "User". The figure 5 shows a fragment of the underground space facility ontology. The "Business" class means some business works about managing facilities. The "Facility" class includes all types of facilities, and the "UndergroundSpace" class shows different kinds of underground spaces with subways, parking places, underground passage, and underground shopping centers. The "User" class includes user types like administrator, checker, and public user.

We also defined objects properties and data type properties to describe the relationship between classes and data values like table 2.

Because the ontology has hierarchical structure, subclasses can inherit properties from their superclass. From table 2 and figure 5, "Checker" class is one of the subclass of "Staffer" class, and "Staffer" class is one of the subclass of "User" class. The "User" class has object property of "search", and "Staffer" class has object property of "manage" and data type property of "sid", so the "Checker" class has the object properties of

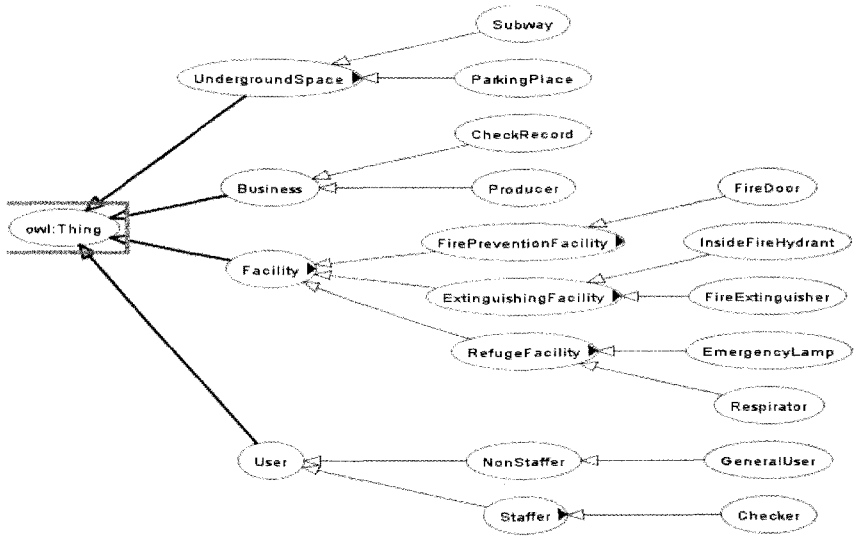

Fig. 5. A Fragment of the Underground Space Facility Ontology.

Table 2. Properties of Facility Ontology

Classes	Constraints	
	Object Property	Data Type Property
Facility	isLocatedIn : single, "UndergroundSpace" isMadeBy : single, "Producer"	fname : string fcode : string
User	search : multiple, "Facility" or "UndergroundSpace"	
Producer	produce : multiple, "Facility"	produceCode : string
Staffer	manage : multiple, "Facility" or "UndergroundSpace"	sid : string
Checker	check : multiple, "Facility" register : multiple, "CheckRecord"	
UndergroudSpace		locationName : string

"search", "manage", "check", and "register", and has the data type property of "sid".

In this paper, we design a database schema like figure 6 to implement the proposed system. The "FacilityInfo" table includes all attribute information of facilities with five reference tables "LocationInfo", "UsageInfo", "FacilityCategory", "Producer", and "GeoFacility". The "Producer" table stores some manufactories' information which made facilities in underground space. The "GeoFacility" table stores x and y coordinate figures of facilities. The "CheckRecord" table is used facility management business. The "Facility-OntoInfo" stores N-Triple file of the facility ontology information. The figure 7 presents command statement of loading ontology information to Oracle 11g database using "oracle.spatial.rdf.client.BatchLoader" class.

4.2 Retrieval Scenario

In this part, we intend to address a scenario to represent retrieval procedures in each module through showing N-Triple file, related ontology structure, retrieval of main resource, and buffer

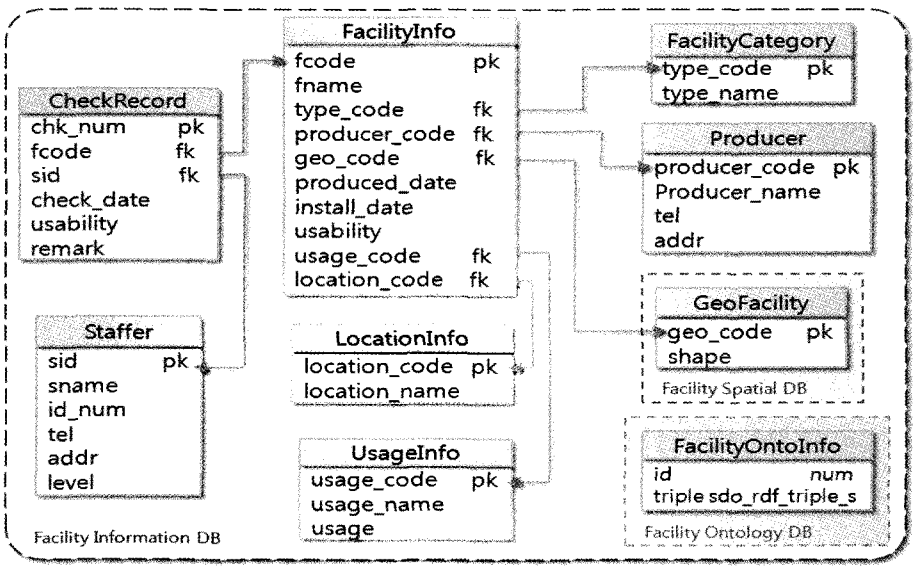

Fig. 6. Database Schema in Oracle 11g

```
java -Ddb.user=facility -Ddb.password=facility
-Ddb.host=203.247.166.110 -Ddb.port=1521 -Ddb.sid=oracle -classpath
D:\oracle\ora11\product\11.1.0\db_1\md\jlib\sdordf.jar;D:\oracle\ora11\product\
11.1.0\db_1\jdbc\lib\ojdbc5.jar oracle.spatial.rdf.client.BatchLoader
D:\MasterThesis\OntologyConstruction\ntriples\FacilityOntology
FacilityOntoInfo rdf_tblspace FacilityOnto
```

Fig. 7. Ontology Loading Command.

zone and results.

Suppose that an administrator wants to search facility information in "Kyongsung Univ. Pukyong Nat'l Univ." subway station that category type was "Refuge Facility" which was available to use and was produced at "2007/11/12". After taking some results information, the user wants to carry out spatial analysis with a result facility.

For the query statement, a normal retrieval just based on the database executes join works of "FacilityCategory", "FaclityInfo", and "LocationInfo" tables for searching information. To depict an obvious different results in this paper, we did not create related information which satisfy conditions, so the DB search can not return any results. In this case, ontology-based data retrieval can return some information of related facility code through hierarchical feature and some properties of ontology. The ontology-based retrieval has two steps. Firstly, retrieve the main resources after analyzed user's conditions. In this scenario, because there is no result with DB search, so, the engine analyzes user's queries and selects the superclass of "CheckedDate" to access the related properties for generating SQL query statement to retrieve main resources.

When the proposed system carries out above query statement to retrieve main resources, users can not get the main resources from the user interface. To show the intermediate process, we will use the "SQL Plus" to display the main resources. The figure 8 expresses DB search results and ontology-based search results with related main resource information.

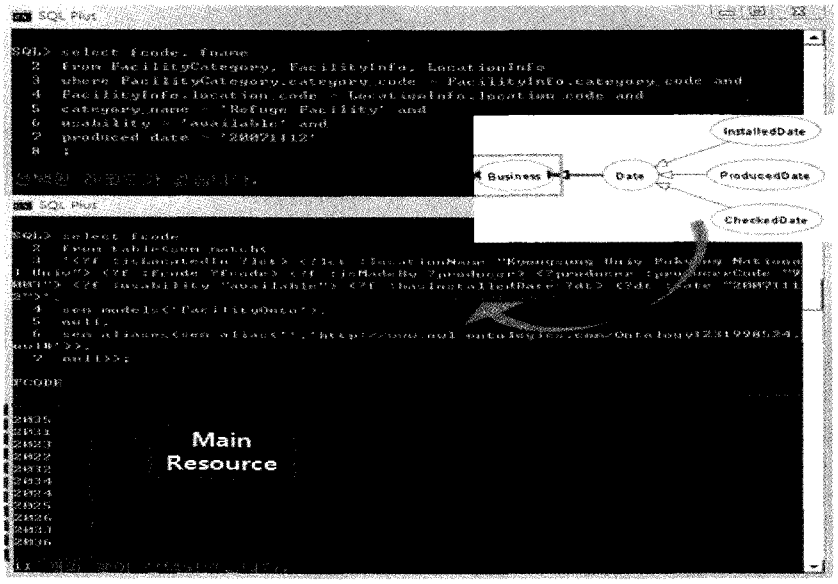

Fig. 8. Main resource retrieval

The retrieve engine searches superclass of individuals of the last user's condition, that is "Produced Date". It belongs to "ProducedDate" class, so retrieve engine finds its superclass "Date" class to search related individuals. The figure 11 shows some related individuals in the "InstalledDate" class and returned 11 main resources. After retrieving main resource, the proposed system uses the main resources to get facilities' other information from "FacilityInfo" table to display results information in the result list box like figure 9.

In the results list box, users can double-click their interested facility to take spatial analysis. When users double-click an emergency lamp as a reference point, the user interface will turn to spatial analysis tab, and the location selected by users will be shown in the middle of the map at the same time. After click "Search" button, buffer polygon will be seen in the map viewer, and "Results" part will show facility information which in the buffer polygon like figure 10[22].

5. SYSTEM ANALYSIS

Our proposed system focuses on more usage and valuable information of subway and facilities for providing some safety and refuge information to users. From the service scenario, the proposed system shows easy search work with designed user interface. Especially general users who are not familiar with using technical information of the facilities can utilize spatial analysis to retrieve information.

The ontology-based retrieval module in our proposed system uses a new mechanism with Oracle 11g through two retrieval steps to provide more flexible procedure that can deal with both the RDF type of data and general data in databases. This kind of the retrieval mechanism can avoid inconvenient and complicated works in programming with Java Server Page(JSP). Moreover, it can take power function to staffers. Usually, they search facility information with facility attribute values. In a classical retrieval system like searching based on database, users complicated queries often get no results and have to input or modify query many times to retrieve some information. The ontology hierarchical structure deals with above problem through defining different query categories as classes and presenting object properties.

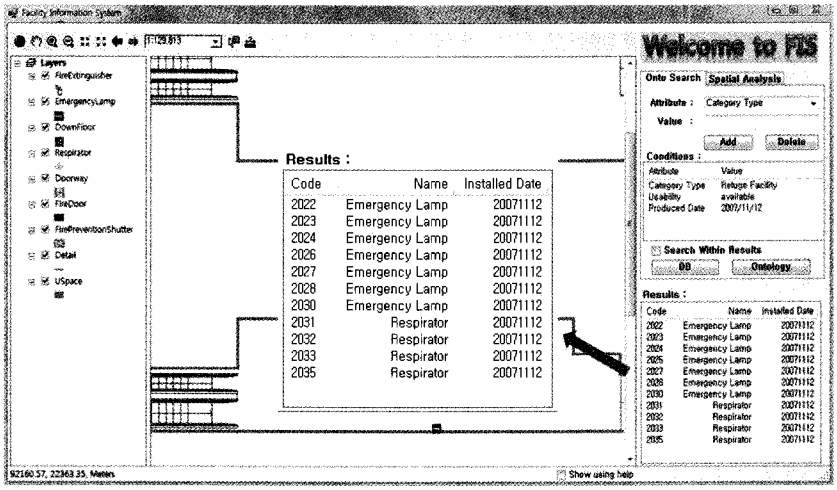

Fig. 9. Results of Ontology-based Retrieval

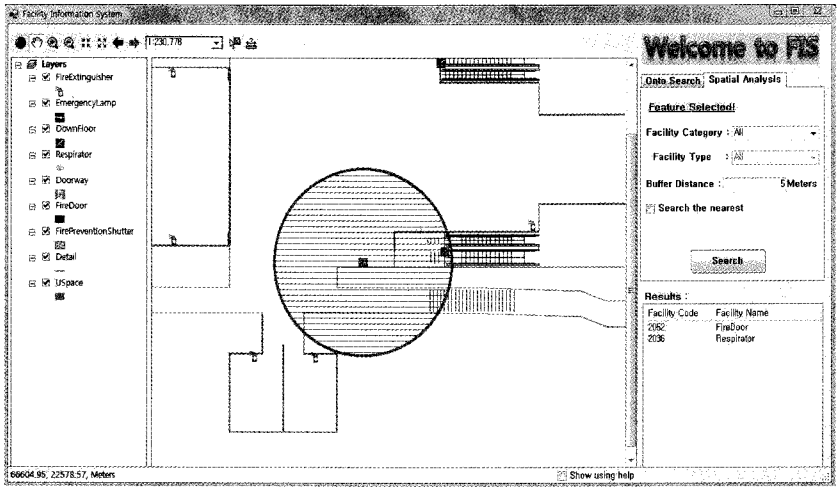

Fig. 10. Results of "Buffer" Spatial Analysis

The retrieval module based on spatial analysis gets facility information by operating on the map with "Buffer" and "Near" functions without understanding any property information of the facilities. Especially, the general users use spatial analysis to get facility usage information, the nearest safety facility location, and distance between two facilities and so forth[22].

6. CONCLUSION

How to take an effective management on a disaster situation is becoming the most concerned issue in our society with the development of building in underground space. Subway stations, underground shopping malls, and underground entertainment places become larger in scale and more complicated. Meanwhile, government has spent a lot of money in installing safety facilities. Hence, effective retrieval of valuable facility information becomes an important work.

New ages of searching methods have recently been approached toward a semantic Web that is a technology to make Web resources more acces-

sible by intelligent semantic agents with ontologies. The Geographic Information System is becoming more and more common with its spatial analysis to capture, analyze, manage, and present data that are linked to location.

This paper discussed the design and implementation of a facility information system in underground space based on semantic Web and GIS technologies. The proposed system is integrated with ontology and spatial analysis to provide users with hierarchy and association searching and simple and easy searching. No matter staffers or general users who do not understand any attribute information of facilities, everyone can use the system easily. The attribute-based category searching with filter function will take more convenience and effective business to staffers. The most important thing in the proposed system can give a contribution to disaster prevention systems.

However, the proposed system is hard to show some safety facilities like sprinklers and guide light which are on the ceiling, and the spatial analysis can not available for the above equipments because it is confined to 2D map. Also, there are not any coordinate systems in underground space to apply on the map. Finally, the proposed system needs to research the effective methods how can apply our system to the popular smart phones. We also consider the our system to be able to display underground spaces with 3D graphics and to provide more effective ontology-based searching and the effectiveness of the searching.

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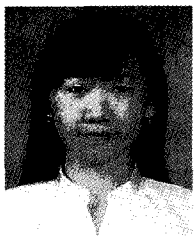

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