Thesis for the Degree of Master of Engineering

# Design and Implementation of a Facility Information System Based on GIS and Semantic Web in Underground Space

by

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Department of Interdisciplinary Program of Information Security

The Graduate School

Pukyong National University

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# GIS 및 시맨틱 웹 기반 지하공간 시설물 정보 시스템 설계 및 구현

Advisor: Prof. Chang Soo Kim


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A thesis submitted in partial fulfillment of the requirements for the degree of

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# 요 약

도시의 고도화 및 과밀화 현상은 지상 도로의 복잡화, 대도시 토지 가격 상승을 초래하였고, 이에 따라 토지의 이용률을 높이고, 효율적인 공간 활용을 위하여 지하공간의 다중 이용시설의 개발은 점차 증대되고 있다. 대표적인 지하공간의 다중이용시설로 지하철 역사를 들 수 있으며, 지하철 역사는 역사 본래의 기능과 함께, 주변 상가, 만남의 장소, 지하 건널목, 교차로 등의 부가적인 기능을 수행한다. 이러한 지하공간의 다중이용시설은 그 공간적인 특성상 많은 위험에 노출되어 있으며, 이러한 위험을 방지하기 위한 각종 시설물 및 재난 안전도구들이 곳곳에 배치되어 있다. 그러나 현재 지하공간을 위한 방재 시설물을 체계적으로 관리하고, 재난 발생 시 적재적소에 활용할 수 있는 정보 시스템의 개발은 미흡한 실정이다.

본 논문에서는 지하공간의 배치되어 있는 시설물의 위치와 상세 정보를 온톨로지와 공간분석을 이용하여 효율적으로 검색하는 시스템을 설계 및 구현한다. 시스템 구현을 위하여 ArcGIS 기반의 샘플 데이터를 사용하여 기본적인 지리정보를 구축하고, 지능화된 검색 구조의 설계를 위한 OWL 형태의 온톨로지를 설계하고 적용하였다. 그리고 검색 시나리오를 통하여 제안 시스템을 평가하였다.

본 논문에서 제안한 시설물 정보 시스템은 온톨로지 계층구조 검색을 통한 사용자의 반복적인 검색을 줄임으로써 보다 지능화된 검색 서비스를 지원한다. 또한 사용자 인터페이스는 카테고리 형식의 검색으로 사용자의 복잡한 질의를 처리할 수 있다. 제안한 온톨로지 검색엔진에서는 시설물 온톨로지 정보를 저장하기 위한 방법으로 Java API로 데이터베이스와 연동한다. 저장된 데이터베이스의 내용은 사용자의 질의를 통하여 결과를 가져올 수 있다. 기존의 온톨로지 검색방법과 비교할 때, 제안 방식은 RDF 파일의 구조와 RDF 핸들러가 통합된 형태로 데이터베이스에 저장되어 있어 사용자는 간단한 쿼리만으로 결과를 도출할 수 있다. 제안한 공간분석기반 시설물 검색은 구체적인 사전 정보 없이도 주변 시설물을 쉽게 검색할 수 있다는 장점이 있다. 사용자는 지도상에서 임의의 한 점 혹은 시설물을 선택하여 기준점을 정하고 일정한 거리내의 시설물을 검색할 수 있다. 또한 설정된 기준점으로부터 가장 가까운 시설물을 종류별로 검색할 수 있다. 그리고 또, 지도 파일의 모든 레이어들을 선택함으로써 지도상에서 사용자가 관심이 있는 시설물을 종류별로 편리하게 디스플레이 할 수 있다.

# Chapter Ⅰ. Introduction

## 1.1 Background

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. It is believed that population growth and demand for better accommodation and leisure places, which are combined with a desire to improve the landscape, will result in the need to develop more underground spaces. 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].

The disaster for the accident of fire in the Dae-gu subway station was recorded as a big man-made disaster and related to careless of management[3]. 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, these works can save people' lives.

New ages of searching methods have been recently approached toward a semantic Web, which is a technology to make Web resources more accessible by intelligent semantic agents, one of the intelligent systems that can distinguish homonymous or synonymous words considering users' information and can infer some rules automatically. Hence, the computer can understand the useful information based on the key-words and automatically process users' queries with defined ontologies. Nowadays, semantic searches based on the ontology are widely applied in many fields related to search works as described in [4][5][6][7][8].

Geographic Information Systems(GIS) are the computer systems capable of capturing, storing, analyzing, and displaying geographically referenced information which is widely used for scientific investigations, resource management, asset management, and other purposes[9]. The power of a GIS which coming from the ability to relate with different information in a spatial context and to reach a conclusion about this relationship, is spatial analysis.

As the technology of semantic Web and GIS are recently spreading, we use these technologies to support an effective 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.

Many researchers come to realize this viewpoint, so Woohyun Hwang[10], R. Bernstein[11], K.Cypas[12] studied on visualization of underground space and other objects with the basic map control functions. However, these systems have some drawbacks that just provide single function and neglect additional useful and necessary functions like searching and spatial analysis. Data retrieval is an essential function in an information management system and intelligent retrieval services have been considered as a measure to improve user's convenience and effective business, especially in disasters[13]. The spatial analysis on a map is effective, simple and convenient function particularly to the public users, but both works 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.

## 1.2 Main Contributions and Organization of the Thesis

This thesis addresses ontology−based retrieval and spatial analysis based retrieval in the facility management of underground space. We design and implement an facility management system through constructing a facility ontology, as designing an effective DB schema, utilizing the spatial analysis tools, and representing service scenario with the ontology and the spatial analysis cases. This thesis integrates the ontology and the spatial analysis technologies and focuses on following advantages.

① Hierarchy Searching.

When users input several incorrect conditions, the ontology−based retrieval engine can extract the most similar results by hierarchical searching of the facility ontology structure. With the hierarchical searching, users can reduce repeated queries to improve work efficiency in the case of different emergencies.

② Association Searching.

The ontology−based retrieval engine can understand the relationship between classes and individuals according to the object and data type properties to automatically search useful information.

③ Simple and Easy Searching.

The retrieval engine based on spatial analysis has "Buffer" and "Near" functions to operate on a map without understanding any property of the facility information for retrieving locations and property information. Therefore, it can be easily used by public users.

We describe related researches and our works in the rest of this thesis. This thesis is organized as follows. In the next chapter, we introduce works related to facility categories in underground space, the ontology technology, and the spatial analysis. In the chapter 3, we design the proposed system for searching facility information of underground space and give details about each proposed modules. In the chapter 4, we describe contents of implementation of the proposed system with development environment, ontology modeling, DB schema, and a service scenario. Next, the chapter 5 shows the results of our proposed system compared with other systems and contains analysis of experimental results. Finally, in the chapter 6, we summarize this thesis.

# Chapter Ⅱ. Related Works

## 2.1 Underground Space Facility and Facility Information System

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. Even though building underground is not something new for mankind, it is referred to as one of the last frontiers. In different meanings, the underground space has been utilized according to the needs of the era. It has served as a shelter, storage place, subway, underground cities, and many other subjects.

### 2.1.1 Underground Space Facility

The dangerous factors in underground space have increased since the underground space became complicated and large-sized[14][15]. In order to prepare various kinds of disasters, varieties of the facilities have been installed in underground space. They can be divided into 6 major categories as follows[3]:

① Refuge facility : It includes emergency elevator, emergency exit, emergency lamp, escape ladder, escape stair, leading light, leading mark, respirator, ventilator, warning facilities, and so on.

② Extinguishing facility : It includes fire extinguisher, inside fire hydrant, sprinkler, and so on.

③ Fire prevention facility : It includes automatic fire protection shutter, fire door, fire wall, and so on.

④ Electricity facility : It includes leakage alarm, leakage circuit breaker, and so on.

⑤ Gas facility : It includes inflammable gas detector, toxic gas detector, and so on.

⑥ Telecommunication : It includes broadcasting, wireless devices, and so on.

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.

### 2.1.2 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.

#### (1) Seoul Metro

The Seoul Metro[16] serves surrounding environment information of subway stations, location and usage information of the facilities, safety guide information, and so forth.


Figure 2.1 Map Service of Seoul Metro

The figure 2.1 shows map services with a graphic file which is provided by the Seoul Metro. Users can link to station information on the map to search train timetable, first and last train, and station guide map like figure 2.2.

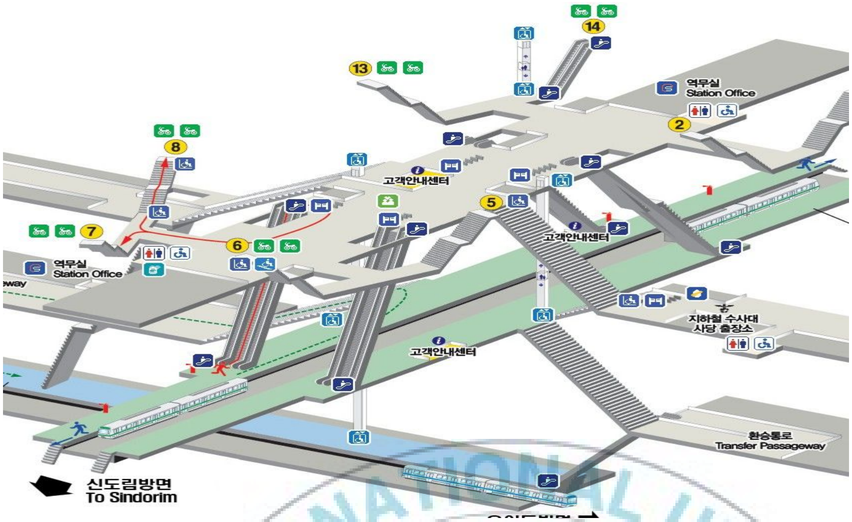


Figure 2.2 Seoul Station Image in Seoul Metro Homepage

The guide map 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 "Safety Management" of "Environment". Also, there is safety guide information like safety rules in the vehicles and subway and how to use an escalator and elevator.

⑵ Seoul Metropolitan Rapid Transit Corporation

The Seoul Metropolitan Rapid Transit Corporation[17] 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.

⑶ Busan Transportation Corporation

The Busan Transportation Corporation[18] 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.

## 2.2 Semantic Web

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[19]. The main advantages of semantic Web can be summarized into several aspects as follows[20]:

① Allows the description and spread of the current Web and resources, adding it to a concept layer
② Allows machine-readable, interpretable, and editable Web content
③ Offers a way to enable semantic annotations that could be easily organized and found
④ Enhances search mechanisms with the use of ontologies
⑤ Enables software agents to carry automatically sophisticated tasks - through the use of smart data
⑥ Allows better communication between platform-independent software agents
⑦ Enables the use of levels of trust for information

The development of the semantic Web proceeds in steps, each step building a layer on top of another. The Figure 2.3 shows the "layercake" of the semantic Web, which describes the main layers of the semantic Web design and vision[21].

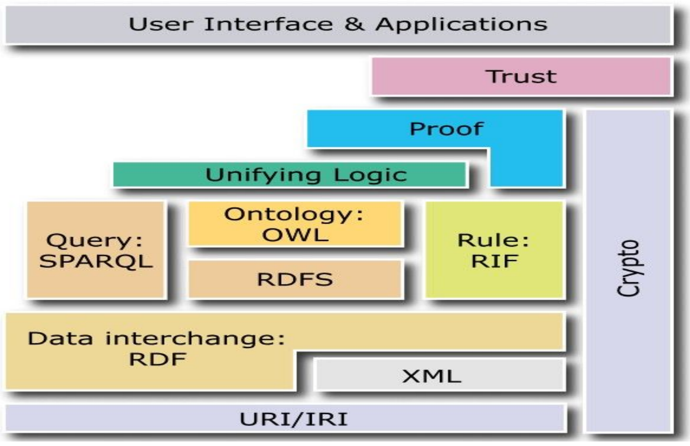


Figure 2.3 A "LayerCake" of Semantic Web

From the "LayerCake", at the bottom we find XML, a language that lets one write structured Web documents with a user-defined vocabulary. XML is particularly suitable for sending documents across the Web.

RDF(Resource Description Framework) is a basic data model, like the entity-relationship model, for writing simple statements about Web objects. The RDF data model does not rely on XML, but RDF has an XML-based syntax. Therefore, in Figure 2.3, it is located on top of the XML layer.

RDF Schema provides modeling primitives for organizing Web objects into hierarchies. Key primitives are classes and properties, subclass and subproperty relationships, and domain and range restrictions. RDF Schema is based on RDF.

RDF Schema can be viewed as a primitive language for writing ontologies. There is a need for more powerful ontology languages that expand RDF Schema and allow the representations of more complex relationships between Web objects.

The logic layer is used to enhance the ontology language further and to allow the writing of application-specific declarative knowledge.

The proof layer involves the actual deductive process as well as the representation of proofs in Web languages and proof validation.

Finally, the trust layer will emerge through the use of digital signatures and other kinds of knowledge based on recommendations by trusted agents or on rating and certification agencies and consumer bodies. Sometimes "Web of Trust" is used to indicate that trust will be organized in the same distributed and chaotic way as the WWW itself. Being located at the top of the pyramid, the trust is a high-level and crucial concept: the Web will only achieve its full of potentiality when users have trust in its operations and in the quality of information provided.

Ontologies play an important role in the semantic Web because they can provide a more flexible way of introducing semantics into the semantic Web[22]. In this thesis, ontology will be used in retrieval engine to enhance search mechanisms.

### 2.2.1 Ontology

Ontology in philosophy is the study of the nature of being, existence or reality in general as well as of the basic categories of being and their relations[23][24]. In computer science and information science, an ontology is a formal representation of a set of concepts within a domain and the relationships between those concepts[25].

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[26][27][28]. Ontology can be used to improve the accuracy of information retrieval[29][30]. In other words, the traditional retrieval program can look for the information matched to key-words instead of discovering related and inferred information using the categorized concept.

Ontologies as the essential technology of semantic Web are used in artificial intelligence, software engineering, biomedical informatics, library science, and so forth. Nowadays, it is widely studied in many fields like database design and integration[31][32], information extraction and retrieval[33][34][35], and so forth, expecially in information technology.

### 2.2.2 Ontology Language

In computer science and artificial intelligency, ontology languages are formal languages used to construct ontologies. They allow the encoding of knowledge about specific domains and can include reasoning rules that support the processing of the knowledge. Ontology languages are usually declarative languages, almost generalizations of frame languages and are commonly based on either first-order logic or on description logic. The most popular languages are Resource Description Framework(RDF) and Web Ontology Language(OWL).

The Resource Description Framework(RDF), which is a method of modeling information through a variety of syntax formats, includes a powerful function for making statements and for connecting those statements[23]. Also it provides the means of recording data in a machine-understandable format, allowing more efficient and sophisticated data interchange, retrieval, cataloging, and so on. RDF has a graph-based data model. Its key concepts are resource, property, and statement. A statement is a resource-property-value triple.

RDF Schema is a primitive ontology language. It offers certain modelling primitives with fixed meaning. Key concepts of RDF Schema are class, subclass relations, property, subproperty relations, and domain and range restrictions. RDF is domain-independent. RDF Schema provides a mechanism for describing specific domains.

The Web Ontology Language(OWL) is an ontology language to describe the semantics of knowledge in a machine accessible way[36]. It builds upon RDF and RDF Schema in Protégé-OWL which is a free, open source ontology editor and knowledge-based framework developed by Stanford Center for Biomedical Informatics Research at the Stanford University School of Medicine[37]. An OWL ontology interprets a set of "classes" and a set of "property assertions" which are related each other and consists of a set of axioms which provide semantics by allowing systems to infer additional information based on the constraints.

RDF is limited to binary ground predicates, and RDF Schema is limited to a subclass hierarchy and a property hierarchy, with domain and range definitions of these properties. OWL builds upon RDF and RDF Schema: (XML-based) RDF syntax is used; instances are defined using RDF descriptions; and most RDFS modeling primitives are used.

### 2.2.3 Semantic Technology Tools

The Protégé-OWL editor[37] is an extension of Protégé that supports the OWL which is the most recent development in standard ontology languages. The Protégé-OWL editor enables users to :

① Load and save OWL and RDF ontologies.

② Edit and visualize classes, properties, and SWRL rules.

③ Define logical class characteristics as OWL expressions.

④ Execute reasoners such as description logic classifiers.

⑤ Edit OWL individuals for semantic Web markup.

The Oracle Database 11g[38] supports for semantic Web 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). To load semantic data, it uses SEM_APIS.BULK_LOAD_FROM_STAGING_TABEL procedure and uses the SEM_RELATED operator to perform ontology-assisted queries.

## 2.3 Geographic Information System

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[39][40][41].

GIS technology has experienced an astonishing growth in recent decades and such development is, in many ways, closely related to the spatial analytic capabilities of GIS. The power of a GIS comes from the ability to relate different information in a spatial context and to reach a conclusion about this relationship, and that is spatial analysis.

Spatial analysis is one of the most important functions of GIS. It 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[42].

ESRI[1] is a software development and services company providing Geographic Information System software and geodatabase management applications. It uses a tool of the named ArcGIS to refer its suite of GIS software products, which operate on desktop, server, and mobile platforms. ArcGIS also includes developer products and Web services.

1) http://www.esri.com

ArcGIS Desktop software products allow users to author, analyze, map, manage, share, and publish geographic information. With the ArcInfo license which is the most complete desktop GIS, system can include all the functionality of ArcEditor and ArcView and add advanced spatial analysis, extensive data manipulation, and high-end cartography tool.

ArcGIS spatial analyst provides powerful tools for comprehensive, raster-based spatial modeling and analysis. Using ArcGIS spatial analyst tool, you can derive new information from your existing data, analyze spatial relationships, build spatial models, and perform complex raster operations.

With ArcGIS spatial analyst tools, you can

① Find suitable locations,

② Calculate the accumulated cost of traveling from one point to another,

③ Perform land use analysis,

④ Predict fire risk,

⑤ Analyze transportation corridors,

⑥ Determine pollution levels,

⑦ Perform crop yield analysis,

⑧ Determine erosion potential,

⑨ Perform demographic analysis,

⑩ Conduct risk assessments,

⑪ Model and visualize crime patterns.

# Chapter Ⅲ. Design of the Proposed System

This chapter 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.

## 3.1 System Overview

The proposed system has three layers: 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. Each module can carry out independently, as well as work with one another. The Figure 3.1 shows the architecture of the proposed system.

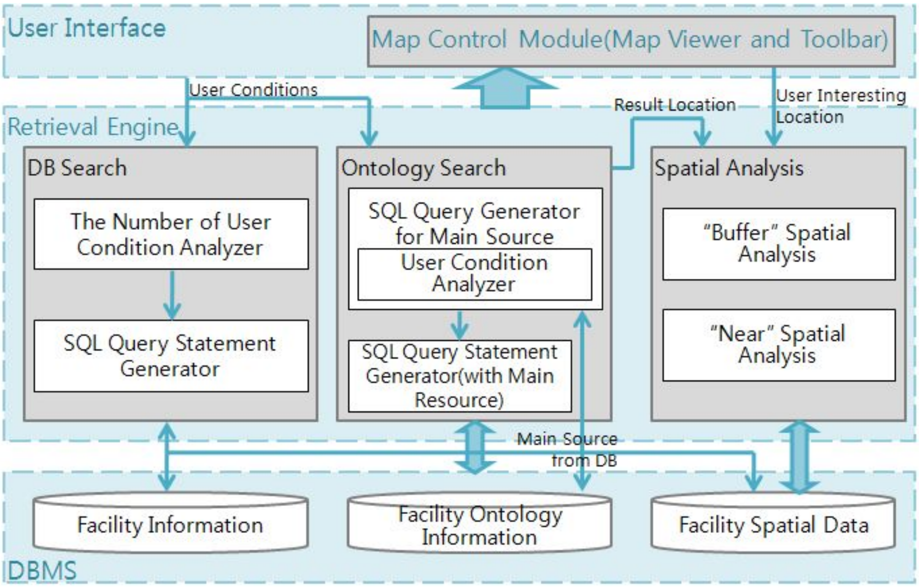


Figure 3.1 System Architecture of the Proposed System

(1) User Interface Layer

User interface has user condition input, map control module with map viewer, 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 map control module is mainly responsible for the display of maps and provision of some basic map operation tools. It divided into three parts: toolbar, map layer controller, and map viewer part. The toolbar consists of several usual tools such as "Full Extent", "Pan", "Zoom In", and "Zoom Out" and so on. The map layer controller part displays all different facility layers in the map document file to show layers which user interested in. The map viewer part shows map and can move to the facility location and zoom in which user selected.

(2) Retrieval Engine Layer

Retrieval engine divides into three parts to provide different searching methods. Each part has relations with "Search Within Results" and "Go to Spatial Analysis" functions.

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. After DB retrieval module received user conditions, the first step is analyse the number of user's conditions to get related tables for generating SQL query statement.

The ontology-based retrieval module is the main part of the proposed system to reduce users' searching works by hierarchical searching for providing intelligent and simple searching works. This module analyses the user's inputted conditions, and generates SQL query statements according to analyzed result to extracts some major resources from "Facility Ontology Information" database. After that, it generates SQL query statement to search results from the "Facility Information" database with the extracted major resources.

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.

(3) DBMS Layer

In this thesis, we construct databases using Oracle 11g which is the new version that 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 which created in Protégé-OWL tool in triple format and it constructed through loading N-Triple file using Java API. "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 3.2 and the user interface of spatial analysis is shown in Figure 3.3.

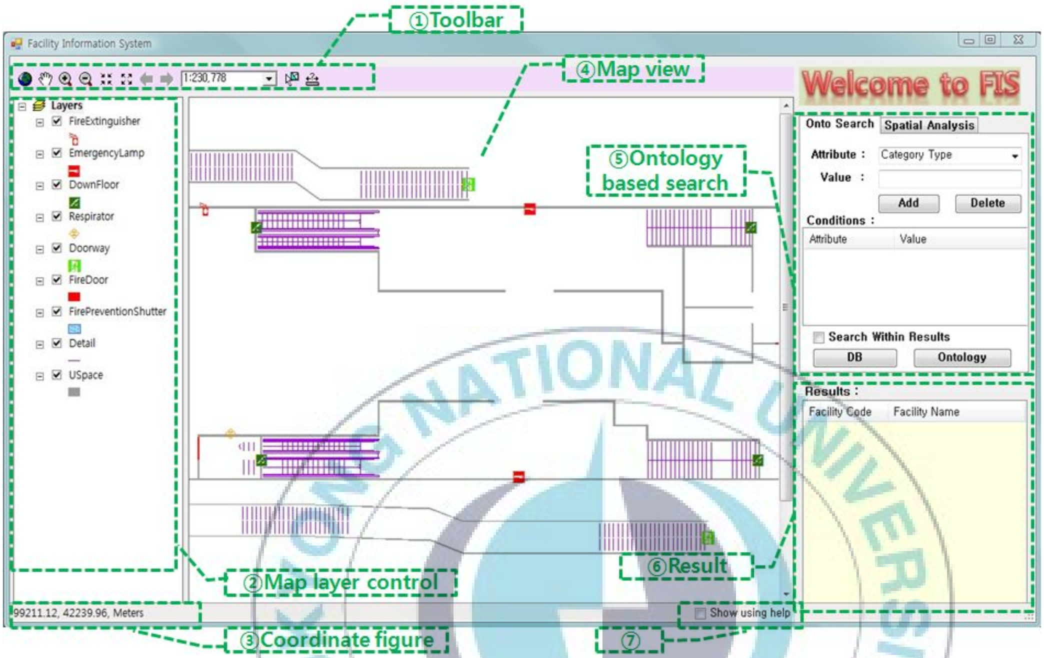


Figure 3.2 User Interface with Ontology−based Search

① Toolbar

It 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".

② Map layer controller

This part shows different symbols of the facilities and supports for layer selection function to users for displaying users interested layers on the map. When the check box is checked, some related layers will be shown on the map.

③ Coordinate figure

This status strip shows the x and y coordinate figure where the pointer points on the map.

④ Map viewer

In this thesis, we take the map of "Kyungsung Univ. Pukyong Nat'l Univ." subway station in Busan as our studied domain. Map viewer part shows the map of station.

⑤ Ontology-based search

Users can input some values according to different types of attributes in this part. 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.

In ontology based search, this system provides several usual attribute types to users. They are "Category Type", "Usability", "Producer Code", "Produced Date", "Installed Date", "Checked Date", "Checker Code", and "Checker Name".

⑥ Result

This part shows results with facility code, facility name, and other information.

⑦ Show using help

If users want to know some using information of facilities, they can check this "Show using help" check box. When the check box is checked, a message box will be shown beside of the pointed facility.

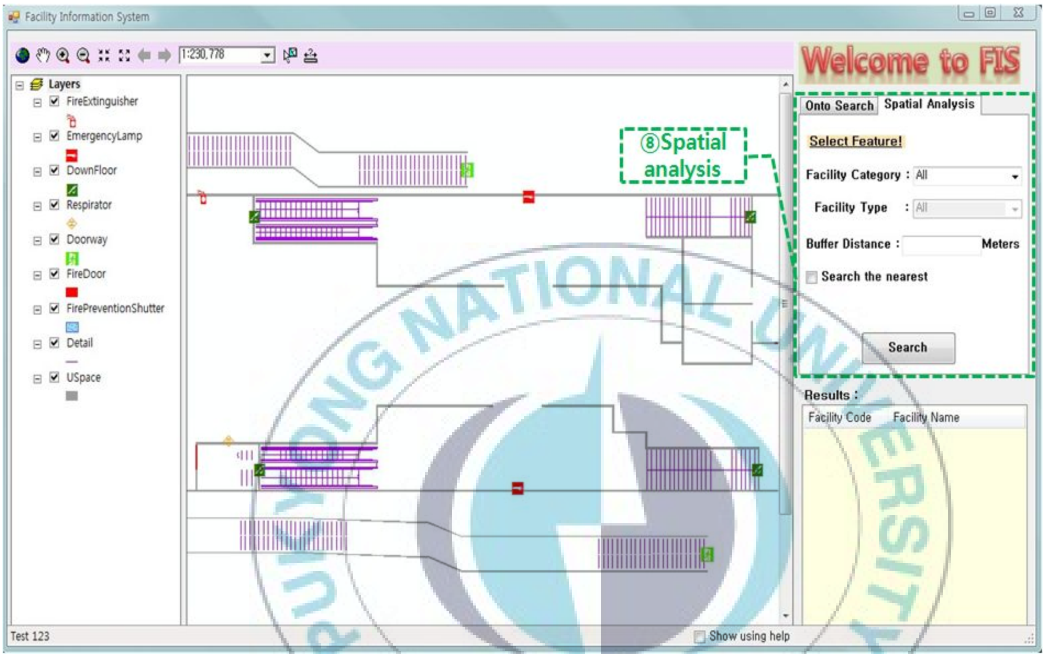


Figure 3.3 User Interface with Spatial Analysis

⑧ 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. Before executing spatial analysis, there will be a massage with "Select Feature!" to ask user for selecting a feature if users have not selected any feature, The "Facility Category" and "Facility Type" options are used to select result categories and types of spatial analysis. They are defined as follows:

a. "Extinguishing Facility" consists of "Fire Extinguisher", "Inside Fire Hydrant", and "Sprinkler".

b. "Fire Prevention Facility" consists of "Shutter", "Fire Door", and "Fire Wall".

c. "Refuge Facility" consists of "Emergency Elevator", "Emergency Exit", "Emergency Lamp", "Escape Ladder", "Escape Stair", "Leading Light", "Respirator", "Ventilator", and "Warning Facility".

d. "Electricity Facility" consists of "Leakage Alarm", and "Leakage Circuit Breaker".

e. "Gas Facility" consists of "Inflammable Gas Detector", and "Toxic Gas Detector".

f. "Telecommunication" consists of "Broadcasting", and "Wireless Device".

## 3.3 Retrieval Engine Based on Ontology

In our proposed facility information system, the retrieval engine based on ontology has advantages in providing intelligent and simple searching works by hierarchical and association searching for reducing the works of users' repeated queries. 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.

In the past, we always use Java Server Page(JSP) to connect and deal with RDF files and RDF query. Because process has several times data exchange, it is an inconvenient and complicated work in programming to carry out that process.

To avoid above shortcoming, in this thesis, we try to use a new flexible method through Oracle 11g Database version for carrying out all retrieval process in the database using SQL query statement with just two retrieval steps.

3.3.1 Ontology-based Retrieval Process

The figure 3.4 shows the ontology-based retrieval process of the proposed system.

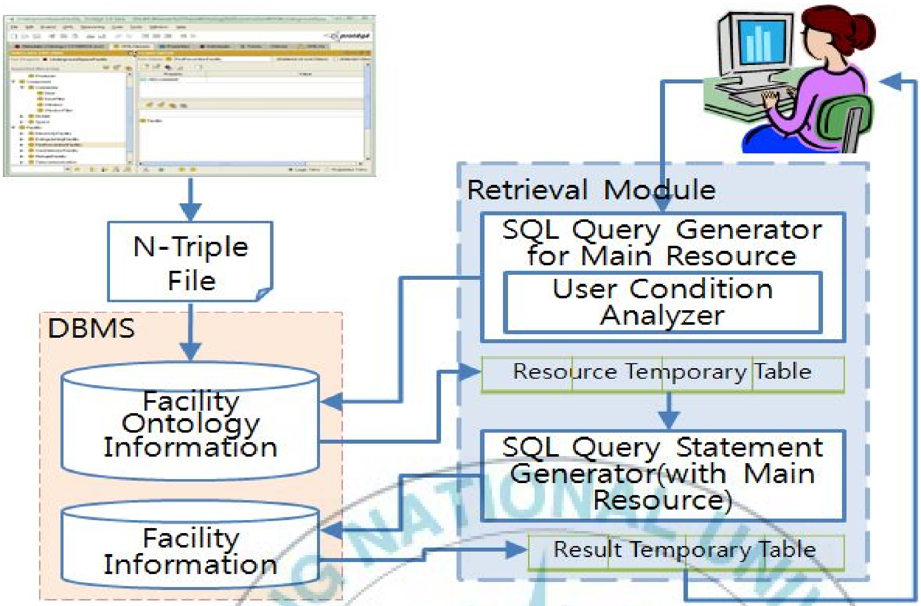


Figure 3.4 Ontology-based Retrieval Process

DBMS is the most important part in every information systems. In our proposed system, the DBMS concludes all data including facility ontology information.

The facility ontology was constructed using Protégé-OWL tool, then be exported to a N-Triple file which is a line-based, plain text serialization format for becoming a practicable file format to be loaded to Oracle 11g Database. After that, using a Java API to import all facility ontology information to "Facility Ontology Information" database.

We have mentioned that the retrieval process has two steps to extract information. When users search information using categorized structure, the first step is extracting some major resources from "Facility Ontology Information" table according to the result analysis information of user's conditions and store these resources in "Resource Temporary Table". The second step is searching results from "Facility Information" table according to the major resources and then store the results in "Results Temporary Table". After that, the results will be shown to users.

### 3.3.2 Main Parts of Ontology-based Retrieval Module

If the proposed retrieval engine based on ontology can not find searching results with user's complicated query, it tries to retrieve results from the superclass of defined ontology as the hierarchical characteristic of the ontology structure and properties. In other words, the hierarchical searching can be executed because an individual of a subclass is also an individual of its superclass as to the relationship among superclasses and subclasses have already defined in the ontology.

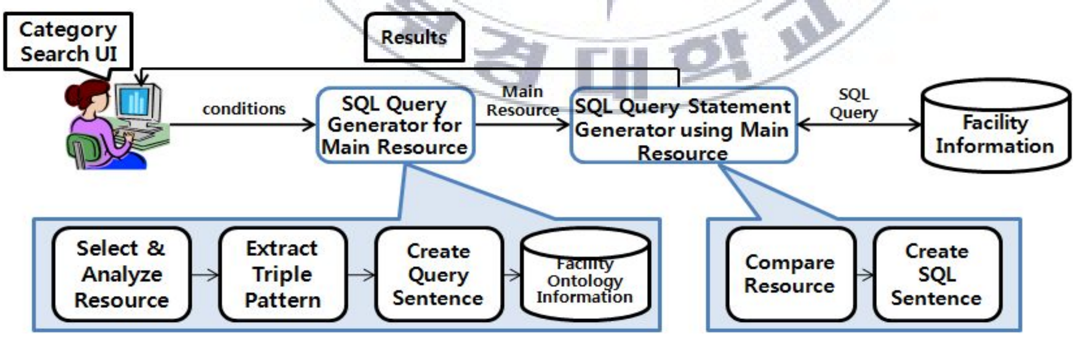


Figure 3.5 Detailed Procedures in Two Retrieval Steps

The figure 3.5 represents detailed procedures in each retrieval steps of "SQL Query Generator for Main Resource" and "SQL Query Statement Generator with Main Resource".

① SQL Query Generator for Main Resource

The "select & analyze resource" part decides the main resource type in order to reduce the join work of tables when a resource mapping with tables to access results from the database.

The "extract triple pattern" module recognize each object in users' conditions and decide resource to find related object properties and data type properties that can connect all different objects together.

The "create query sentence" part takes charge of writing query sentences in every different cases with users' conditions.

The last procedure is extracting main resources from "Facility Ontology Information".

⑵ SQL Query Statement Generator using Main Resource

This part is simple in respect that the previous step filtered some search conditions.

The "compare resource" part compares the main resources with tables to confirm related tables, and the "create SQL sentence" part has the same function like "create query sentence" part. Finally, the module returns results to users from "Facility Information" database.

## 3.4 Retrieval Engine Based on Spatial Analysis

The proposed system has "Buffer" and "Near" spatial analysis functions. "Buffer" creates buffer polygons to a specified distance around the user selected feature layer or user defined point. "Near" determines the distance from each feature in the input features to the nearest features in the near features, or within the search radius. Also, the "Near" function performs based on "Buffer" function. The Figure 3.6 shows spatial analysis process in proposed system.

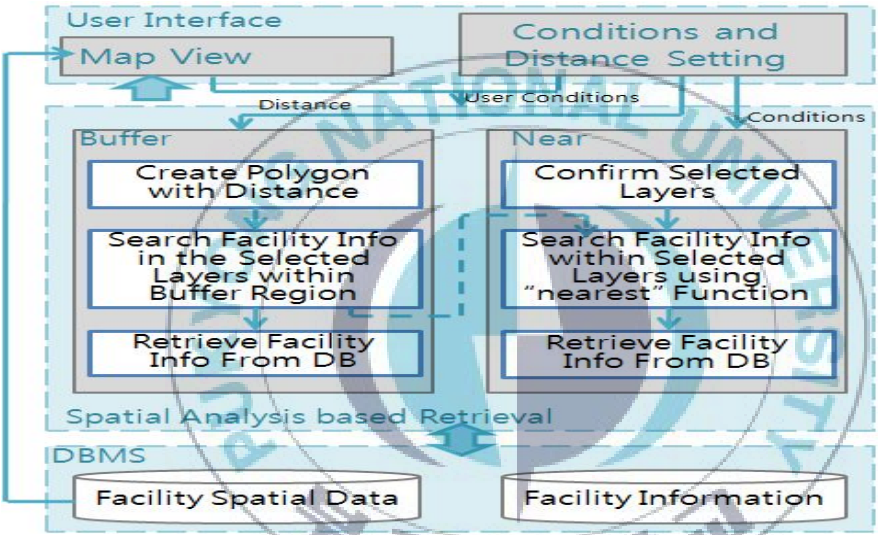


Figure 3.6 Spatial Analysis Process

3.4.1 "Buffer" Spatial Analysis

Users input some conditions like result types and distance values using the user interface. These conditions are input and output features. The distance is used to create buffer zones around input features.

The "Create Polygon with Distance" part takes charge of drawing buffer zone on the map and create a new buffer zone feature class for next procedure. The "Search Facility Info in the Selected Layers within Buffer Region" search related facility coordinate figure from "Facility Spatial Data" within buffer zone feature class. At the last procedure, the results information like facility code and facility name are retrieved from the "Facility Information" database according to the facility coordinate figures.

In the second procedure, the results can be used by "Near" function if the users want to search some facility information which is the nearest from users confirmed location with the distance value.

### 3.4.2 "Near" Spatial Analysis

This function also needs some of users' inputted conditions like a reference point. A reference point is can be a new created point on the map or a facility location.

The "Confirm Selected Layers" determines output feature layers according to user's selection. In the next procedure, there are two cases that one with defined distance around zone and one without limit. In the case one, the second procedure that "Search Facility Info within Selected Layers using 'nearest' Function" will search related facility coordinate figure information in the buffer zone which is created from "Buffer" spatial analysis. In the second case, the procedure searches useful information from the users' inputted feature layers.

The last procedure is the same with "Buffer" spatial analysis that the results information are retrieved from "Facility Information" database according to the facility coordinate figures.

# Chapter Ⅳ. Implementation of the Proposed System

In this chapter, we represent the facility ontology modeling and the database schema for implementing and take a facility retrieval scenario to show each procedure.

## 4.1 Development Environment

For implementing the proposed system, this thesis uses real map of "Kyungsung Univ. Pukyong Nal'l Univ." station of subway line 2. The table 4.1 shows detailed system development environment.

Table 4.1 System Development Environment

| Variable | Specification |
|---|---|
| Development tool | Visual Studio .Net 2005 |
| DBMS | Oracle 11g |
| Ontology Modeling | Protégé-OWL |
| Map Editor and Operation | ArcGIS Desktop 9.3(ESRI) |
| Map | Kyongsung Univ. Pukyong Nal'l Univ. Station |
| Map Format | ESRI shapefile |

To express obvious and clear results, we edit the original shape format map to add more helpful information using ArcGIS desktop tool which is developed by ESRI. We gather shape files into map document file(.mxd) format for easy displaying on the map viewer.

The ontology was constructed in Protégé-OWL tool which is the most popular tool, as well as free, open source ontology editor and knowledge-based framework developed by Stanford Center for Biomedical Informatics Research at the Stanford University School of Medicine.

## 4.2 Ontology Modeling and DB Schema

### 4.2.1 Ontology Modeling

An ontology contains some classes and properties that are hierarchically related to different classes one another, some axioms, and some constraints. In our proposed ontology, we tried to describe underground space facility as possible as detailed.

We defined four superclasses of underground space facility ontology such as "Business", "Facility", "UndergroundSpace", and "User". Figure 4.1 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 introduced in the related works. The "Underground Space" class shows different kinds

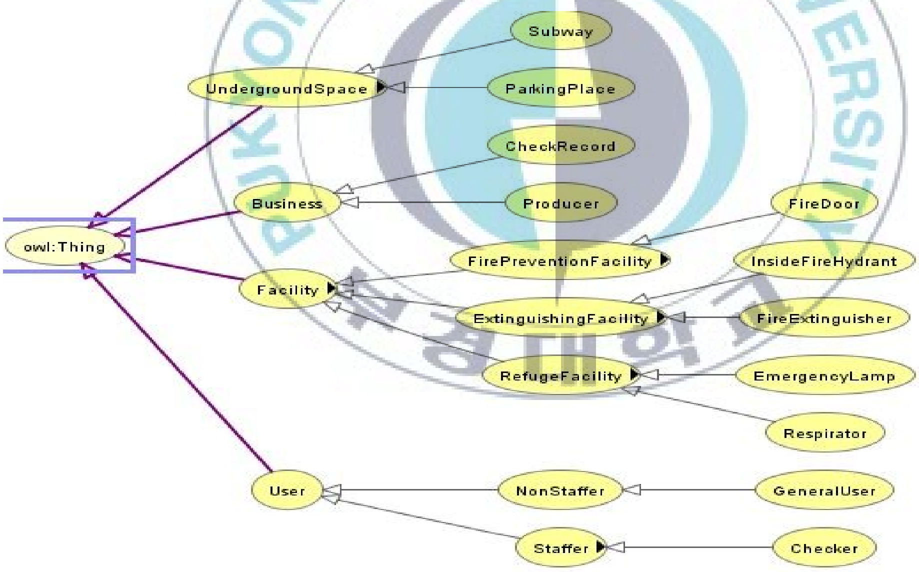


Figure 4.1 A Fragment of the Underground Space Facility Ontology

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 defined objects properties and data type properties to describe the relationship between classes and data values. Table 4.2 shows a part of the constraints with object properties and data properties in the underground space facility ontology.

Table 4.2 Properties of Facility Ontology

| Classes | Constraints | |
|---|---|---|
| | Object Property | Data Type Property |
| Facility | isLocatedIn : single "UndergroundSpace"<br>isMadeBy : single "Producer" | fname : string<br>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"<br>register : multiple "CheckRecord" | |
| UndergroudSpace | | locationName : string |

Because the ontology has hierarchical structure, subclasses can inherit properties from their superclass. From Table 4.2 and Figure 4.1, "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 "search", "manage", "check", and "register", and has the data type property of "sid".

The Figure 4.2 expresses a part of relationships between objects.

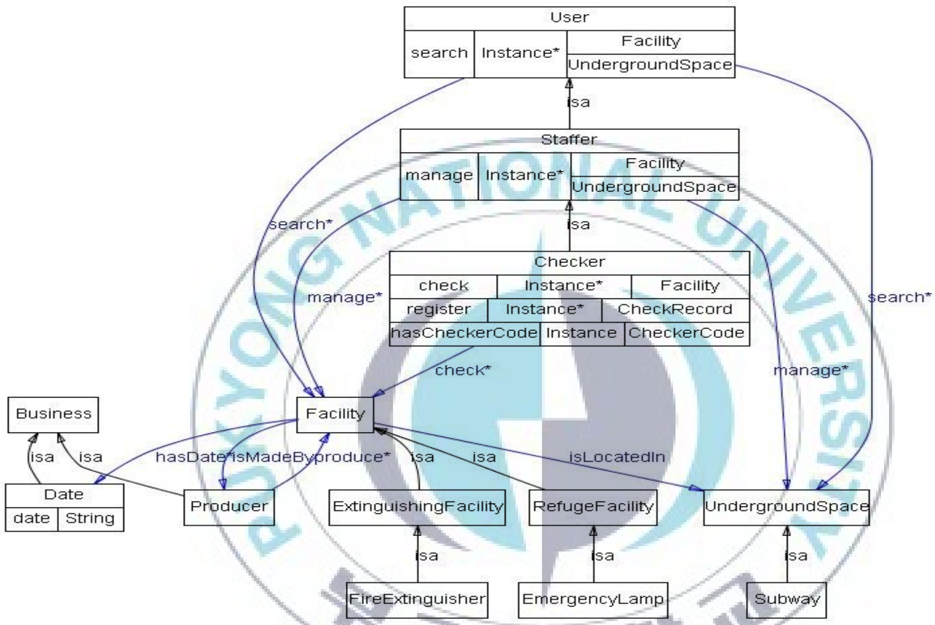


Figure 4.2 A Part of Relationships Between Objects

4.2.2 Design DB Schema

In this thesis, we use following database schema like figure 4.3 to implement the proposed system.

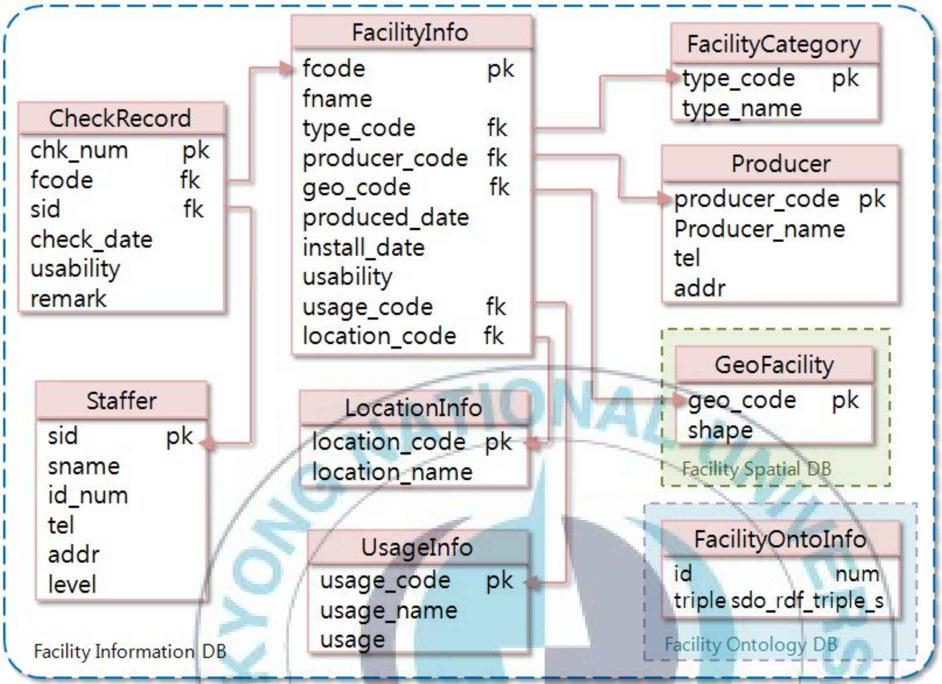


Figure 4.3 Database Schema in Oracle 11g

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.

After staffers checked some facilities, they register checked information to this table as records.

The "FacilityOntoInfo" stores N-Triple file of the facility ontology information with triple format. In Oracle 11g, new version supports for semantic Web technologies including ontologies based on Resource Description Framework(RDF), RDF Schema(RDFS), and Web Ontology Language(OWL). Using this method, the proposed system can deal with ontology in the database and retrieve results just with SQL query statements. The Figure 4.4 presents command statement of loading ontology information to Oracle 11g database using oracle.spatial.rdf.client.BatchLoader class.

```
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\pr
oduct\11.1.0\db_1\jdbc\lib\ojdbc5.jar oracle.spatial.rdf.client.BatchLoader
D:\MasterThesis\OntologyConstruction\ntriples\FacilityOntology
FacilityOntoInfo rdf_tblspace FacilityOnto
```

Figure 4.4 Ontology Loading Command

## 4.3 Retrieval Scenario

In this chapter, 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 zone and results.

For an example scenario, 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. The user's inputted conditions are like the Figure 4.5.

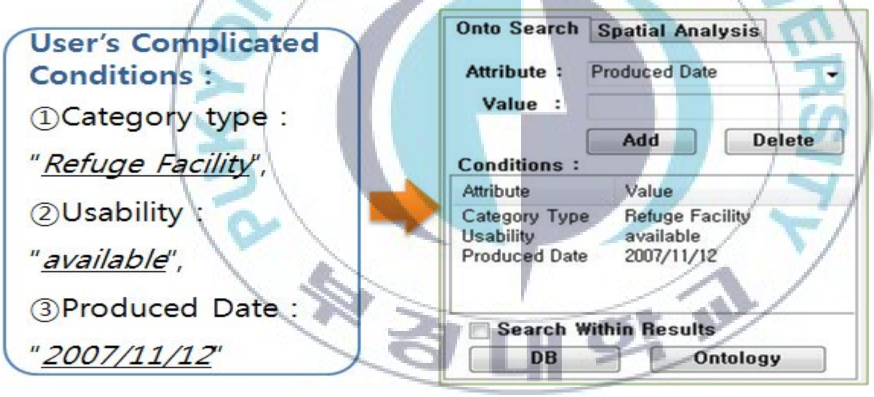


Figure 4.5 User's Complicated Conditions in the Scenario

For the query statement, a normal retrieval just based on the database executes join works of "FacilityCategory", "FacilityInfo", and "LocationInfo" tables for searching information. To depict an obvious different results in this thesis, we did not create related information which satisfy above 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 "SQL Query Generator for Main Resource" part analyzes user's queries and selects the superclass of "CheckedDate" to access the related properties for generating SQL query statement to retrieve main resources. The figure 4.6 shows the created SQL query statement.

```
select fcode
from table(sem_match(
   '(?f :isLocatedIn ?lct)
   (?lct :locationName "Kyongsung Univ Pukyong National Univ Station")
   (?f :fcode ?fcode)
   (?f :isMadeBy ?producer)
   (?producer :producerCode "9003")
   (?f :usability "available")
   (?f :hasInstalledDate ?idt)
   (?idt :date "20071112")',
 sem_models('FacilityOnto'),
 null,
sem_aliases(sem_alias('','http://www.owl-ontologies.com/Ontology1231998524.owl#')),
 null));
```

Figure 4.6 SQL Query Statement of the Example

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 4.7 expresses DB search results and ontology-based search results with related main resource information.

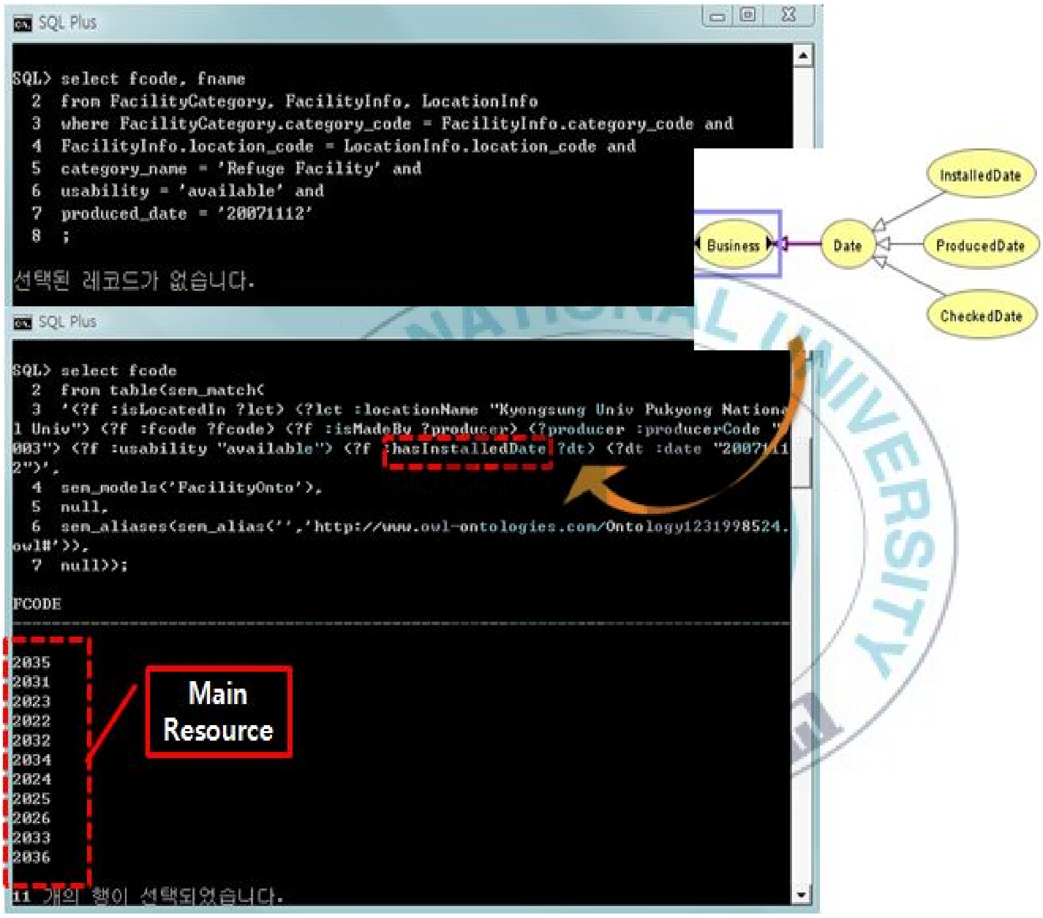


Figure 4.7 Main resource retrieval

The "User Condition Analyzer" module searches superclass of individuals of the last user's condition, that is "Produced Date". It belongs to "ProducedDate" class, so the "User Condition Analyzer" finds its superclass "Date" class to search related individuals. The Figure 4.7 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 in the result list box like Figure 4.8.

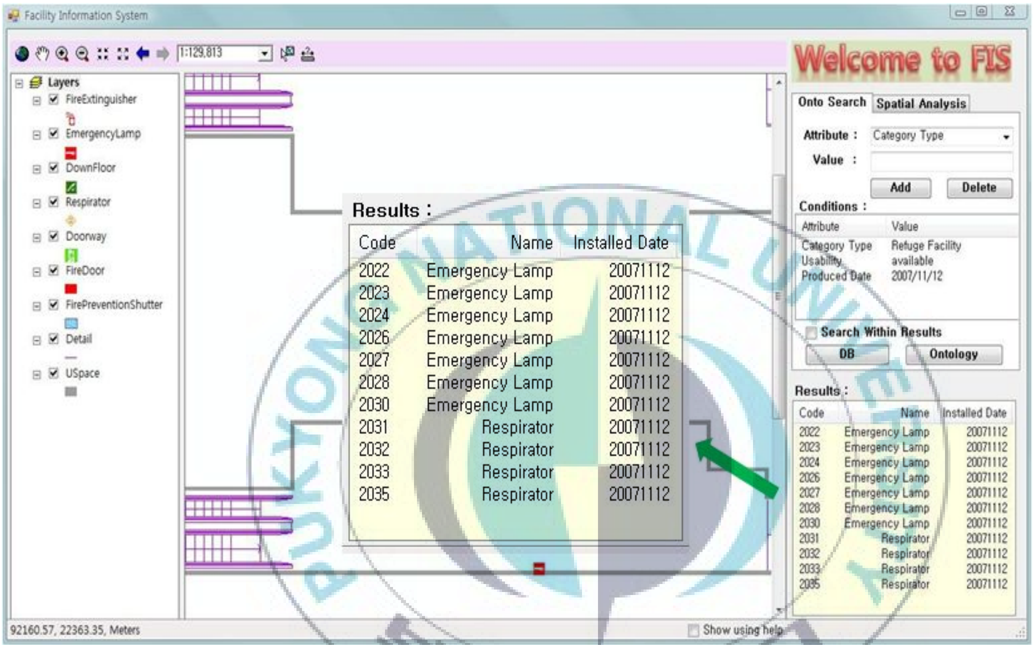


Figure 4.8 Results of Ontology-based Retrieval

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 4.9.

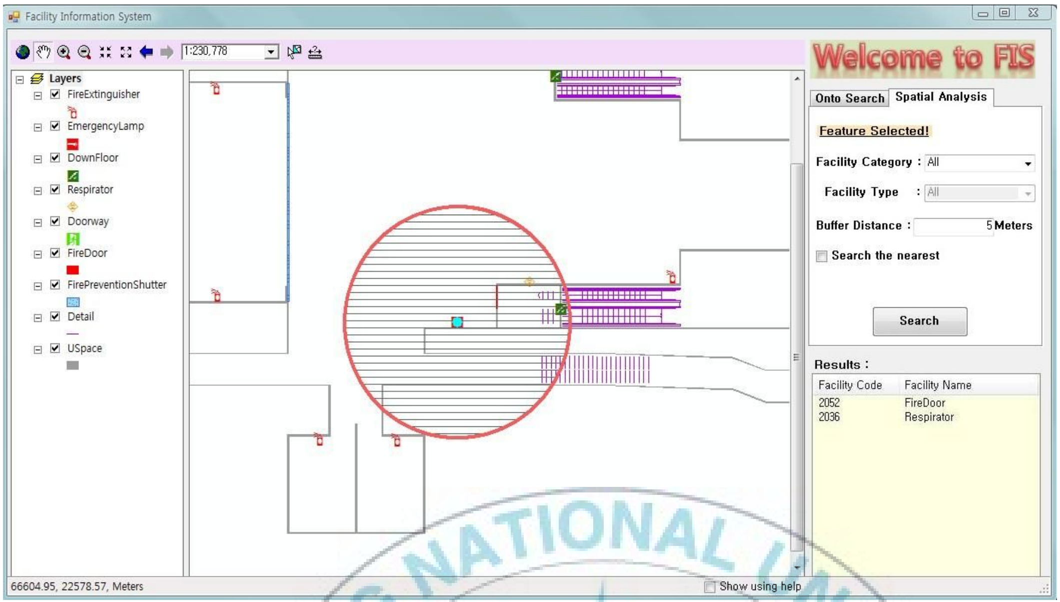


Figure 4.9 Results of "Buffer" Spatial Analysis

# Chapter Ⅴ. Comparison and Analysis

## 5.1 Comparison with Other Systems

Our proposed system focuses on more usage and valuable information of subway and facilities for providing some safety and refuge information to users. We tried to compare our proposed system with existed other facility systems which were introduced in related works. We want to compare four systems in several aspects like "station guide map", "map resolution", "safety facility location", "facility information retrieval", "spatial analysis function", and "surrounding environment information". The comparison is shown as Table 5.1.

Like we can see from the table, the system [16] and [17] uses 2D flash map files with zoom in and zoom out functions and the system [18] has no services on station guide map. Conversely, our proposed system uses 2D map file with more usual functions like zoom in, zoom out, pan, distance measure, selecting features, and so on. Our system has higher map resolution than other maps. The system [16] shows probable locations of facilities on the map, and the system [17] and [18] do not offer any facility locations. In our proposed system, the station guide map shows the exact facility location with coordinate figures. The facility information retrieval and the spatial analysis function are the most important parts in our system. The facility information retrieval is offered through category retrieval with attributes and the spatial analysis function is offered by "Buffer" and "Near" functions. Though, the other three systems do not offer these functions. The three related systems offer surrounding environment information of subway stations, but our proposed system does not offer.

Table 5.1 The Comparison of Facility Systems

| Systems / Variable | Seoul Metro [16] | Seoul Metropolitan Rapid Transit Corporation [17] | Busan Transportation Corporation [18] | Our System |
|---|---|---|---|---|
| Station Guide Map | 2D Flash File | 2D Flash File | No offering | 2D Map File |
| Map Resolution | Low | Low | Low | High |
| Safety Facility Location | Probable Location | No offering | No offering | Exact Location with Coordinate |
| Facility Information Retrieval | No offering | No offering | No offering | Category Attribute Retrieval |
| Spatial Analysis Function | No offering | No offering | No offering | "Buffer" and "Near" |
| Surrounding Environment Information | Offer | Offer | Offer | No offering |

## 5.2 Analysis of the Proposed System

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.

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.

# Chapter Ⅵ. 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 more larges of scales and more complicated. Meanwhile, government has spent a lot of money in installing safety facilities. Hence, effective retrieval of valuable facility information becomes to 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 accessible 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 thesis designs and implements 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 without understanding 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.

Most important thing of 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. The limitations in our system remains our future works. We will enhance 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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