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A Study on Location-Based Services Based on Semantic Web

Jong-Woo Kim†, Ju-Yeon Kim††, Chang-Soo Kim†††

ABSTRACT

Location-based services are a recent concept that integrates a mobile device's location with other information in order to provide added value to a user. Although Location-based Services provide users with comfortable information, it is a complex task to manage and share heterogeneous and numerous data in decentralized environments. In this paper, we propose the Semantic LBS Model as one of the solution to resolve the problem. The Semantic LBS Model is a LBS middleware model that includes an ontology-based data model for LBS POI information and its processing mechanism based on Semantic Web technologies. Our model enables POI information to be described and retrieved over various domain-specific ontologies based on our proposed POIDL ontology. This mechanism provide rich expressiveness, interoperability, flexibility in describing and using information about POIs, and it can enhance POI retrieval services.

Keywords: Location-Based Services, Semantic Web, Ontology, Domain-Specific Information

1. INTRODUCTION

Location-based services (LBS) are a recent concept that integrates the location of mobile device with other information in order to provide added values to a user. The Location-based Services provide the context sensitive information based on the mobile user's location. The LBS includes the services such as local maps, local weather, traffic condition, tour guide, and shopping guides. For example, travelers can search not only the location of hotels and ATM machines near by user's current location but also the addition information using the LBS system when they visit a city first. Therefore, LBS provides different results as the users' position even though users request the same services [1].

Although Location-based Services provide users with much comfortable information, providing users with added value to mere location information is a complex task, and the basic requirements of the variety LBS applications are numerous [2]. To resolve these problems, most of the commercial LBS platforms have been implemented based on DBMS-based middleware. However, current LBS middleware has several challenges. First, it is difficult to manage LBS contents as a general data management in order to provide users with dynamic information frequently changed [3]. Second, it is difficult to share LBS information because the location-based services are operated in different processing methods, appropriative data exchange protocol, and various platforms [4]. Therefore, some approaches to overcome these challenges have been researched [5-7].

In this paper we propose a Semantic Web approach to overcome these challenges. Semantic Web [8] is a technology to add well-defined meaning to information on the Web to enable computer

※ Corresponding Author : Chang-Soo Kim, Address : PuKyong National University, Daeyoen-Dong, Nam-Gu, Busan, 608-737, Korea. TEL : +82-51-620-6394, FAX : +82-51-620-6390, E-mail : cskim@pknu.ac.kr

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† Dept. of Information Security, Pukyong National University
(E-mail : jwkim73@pknu.ac.kr)
†† Dept. of Information Security, Pukyong National University
(E-mail : jykim@pknu.ac.kr)
††† Division of Electronics, Computer and Telecommunication Engineering

as well as people to understand the meaning of the documents easily. The important standards of the Semantic Web are the Resource Description Framework (RDF), and the ontology. The RDF is an XML-based language to describe resources available via the Web. The RDF model is called as a triple because it has three parts, subject, predicate, and object. The subject and object means a resource, and the predicate defines their relation. The ontology defines the common words and concepts used to describe and represent an area of knowledge. The Semantic Web documents must be represented as the XML/RDF which defines common data of special domains based on the OWL(Web Ontology Language) which is an ontology language for the web. The contents on this structure can be searched, integrated, and inferred semantically [9-11].

In this paper, we propose the Semantic LBS Model that includes a data model for LBS POI information and its processing mechanism based on Semantic Web technologies. A distinguishing feature of Semantic LBS Model is to represent and retrieve the POIs with domain-specific information. It provides novel location-based services that provide not only LBS core services but also more enhanced POI(Point of Interest) retrieval service.

2. SEMANTIC WEB APPROACH IN LBS

The Directory Service is one of the main services provided by LBS platforms. The Directory Service provides a search capability for one or more points of interest (e.g., a place, product, or service with a fixed position) or area of interest (e.g., a polygon or a bounding box). The LBS middleware model is a set of POI retrieval services that facilitate the development and deployment of distributed applications in heterogeneous environments. This section presents our approach to enhance LBS middleware model.

Current LBS models based on database have some problems. First, it is difficult to describe various forms of data because of restricted expressiveness of database tables. For example, defining relations between tables and relations between properties is difficult, and designing table to store more than one data is not easy. Second, it is difficult to extend data model, and it is necessary to modify the middleware and application in case that the model is extended. Finally, it is efficient that LBS system is operated in decentralized environments because LBS data is heterogeneous and enormous. However it is a difficult problem to integrate different systems and databases.

Based on our analysis on the current LBS middleware models and their mechanisms, we present two key enhancements. First, we enhance POI Data Model. In order to expressively represent POI data, the following attributes are required: i) well understood matching semantics, and ii) sufficiently expressive to encode a wide range of LBS POI information over any domain-specific information model. Second, we enhance LBS Directory Service. The various LBS applications and mobile users expect that LBS middleware provides not only general POI information but also more specific information exactly.

In this paper, we propose Semantic LBS Model which is a LBS middleware model including a data model for LBS POI information and its processing mechanism based on Semantic Web technologies. The Semantic LBS Model is organized based on the three-tiered architecture shown in Fig. 1.

- Data Tier: This tier describes LBS POI information. Our approach enables LBS POI information to be described over domain-specific ontologies and to be retrieved in domain-specific contents on the decentralized system. For the purposes, we specify LBS ontologies describing POI information. More details of the LBS ontologies are described in Section 3.

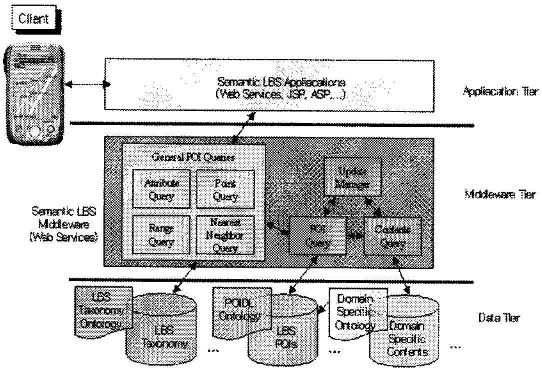


Fig. 1. Three-tiered Semantic LBS Model.

- Middleware Tier: This tier gives a connection between data tier and applications tier, and it takes charge of processing the POI information in place of applications. The middleware provides easy development environments to develop application regardless of data model and complicated processing methods. Moreover, middleware tier protects data from external access through preventing application from directly accessing the information. This tier provides primary queries for retrieving POI data based on Semantic Web. More details of the POI retrieval queries are described in Section 4.
- Application Tier: This tier provides application services by using primary queries in middleware. We presents an application of our approach in Section 5.

3. SEMANTIC REPRESENTATION FOR POIS

In this paper, we approach the enhancement of POI data model by specifying LBS ontologies. LBS ontologies support extensibility and information sharing due to its extensible structure and Semantic Web [8]. For the data model, we specify two fundamental LBS ontologies for describing POI information. POIDL ontology and LBSTaxonomy ontology. POIDL(POI Description Language) is a OWL-based description language that allows POI providers to describe their contents over domain-specific ontologies. The POIDL ontology provides more expressive and flexible description mechanism as well as information sharing. LBSTaxonomy is an ontology constructed as a hierarchical taxonomy of POI types, and it is used to index instances described by the POIDL as POI types. POIs are actually described by the LBS ontologies and various domain-specific ontologies. Domain ontologies are ontologies to specify domain-specific information, and are used so that each contents provider specifies pertinent POI information conforming with its characteristics.

POIDL is used to specify domain-specific information. In addition, POIDL allows the information for query used to search and update domain-specific information to be specified. This mechanism enables LBS to provide POI information changed frequently. POIDL includes three classes - POI, Content, ContentQuery. Fig. 2 shows an example of instances of POI ontology that describe the information of 'HotelA' including domain-specific information such as its grade and the number of empty rooms. In the example, 'poidl' is the prefix referring to the namespace of POIDL ontology.

POI class is used to describe general information about a POI and its domain-dependent information. Instances of POI class specify POI information using five properties below.

- poidl:name. This specifies a name of the POI specified in the instance of the POI class to identify the POI. In Fig. 2, this property specifies that the instance describe the POI that has name of 'HotelA'.
- poidl:isIncludedIn. : This property specifies a type of the POI instance. This associates LBSTaxonomy ontology which specifies hierarchical classification of POI types. In Fig. 2, this property specifies that the type of the POI instance is 'Hotel'.

```
//An instance of the POI class
<poidl:POI rdf:ID="POI_HotelA">
    <poidl:name>HotelA</poidl:name>
    <poidl:isIncludedIn rdf:resource="&lbstaxonomy;Hotel">
    <poidl:hasContent rdf:resource="#Grade_HotelA">
    <poidl:hasContent rdf:resource="#EmpteyRoom_HotelA">
    <poidl:rectLeft>210415</poidl:rectLeft>
    <poidl:rectRight>210415</poidl:rectRight>
    <poidl:rectTop>1270323</poidl:rectTop>
    <poidl:rectBottom>127323</poidl:rectBottom>
</poidl:POI>

//Two instances of Content class
<poidl:Content rdf:ID="Grade_HotelA">
    <poidl:typeofcontent rdf:resource="&onthotel;grade">
    <poidl:valueofcontent>Grade 1<poidl:valueofcontent>
    <poidl:query rdf:resource="#Query_Grade_HotelA">
</poidl:POI>
<poidl:Content rdf:ID="EmpteyRoom_HotelA">
    <poidl:query rdf:resource="#Query_EmptyRoom__HotelA">
</poidl:POI>

//An instance of ContentQuery class
<poidl:ContentQuery rdf:ID="Query_EmptyRoom__HotelA">
    <poidl:subject >hotela:HotelA</lbspoi:subject>
    <poidl:predicate>hotela:emptyRoom</lbspoi:predicate>
    <poidl:object>?num</lbspoi:object>
</poidl:POI>
```

Fig. 2. An example of instances of POIDL ontology.

- poidl:hasContent. This property is used to associate an instance of the Content class that specifies domain-specific information about the POI, and a POI can have more than one content. In Fig. 2, this property associates two contents, 'Grade_HotelA' and 'EmptRoom_HotelA', that are instances of Content class.
- The four location properties. poidl:rectLeft, poidl:rectRight, poidli:rectTop, and poidl:rectBottom describe the boundary of a POI.

Content class is used to describe a domain-specific information for a POI, and an instance of the Content class specifies the type and value of the POI. The Content class provides rich expressiveness and flexibility because instances of the class specify domain-specific information through referring domain-specific ontologies and their instances. Also the Content class associates an instance of the ContentQuery class that specifies a query for retrieving current value in its domain. The three properties for describing an instance of the Content class is as follows.

- poidl:typeofcontent. This property specifies a type of domain-specific information and associates a class of the domain-specific ontology of the POI. In Fig. 2, this property describes that an instance of the Content class, 'Grade_HotelA' specifies the grade of 'HotelA'.
- poidl:valueofconent. This specifies a value of domain-specific information of the POI. In example of Fig. 2, this property specifies that the grade of 'HotelA' is 'Grade 1'. And we can realize that the number of empty rooms has to be retrieved because it is dynamic information that changes frequently.
- poidl:query. This associates an instance of ConentQuery class for querying domain-specific information of the POI. For example, in order to retrieve the number of empty rooms for 'HotelA', 'Query_EmptyRoom_HotelA' that is an instance of ContentQuery class can be referred.

The ContentQuery class is used to describe a query for retrieving domain-specific information from its domain. This class enables domain-specific information to be retrieved and automatically updated. The query language to retrieve information from RDF documents such as RDQL is represented as a triple, same as RDF. The ContentQuery class specifies a triple for a query - lbspoi:subject, lbspoi:predicate, and lbspoi:object.

The LBSTaxonomy ontology is used to guide the taxonomy of POI entities in the LBS domain. An instance of the LBSTaxonomy ontology specifies the information about the POI used in Directory Service of Semantic LBS. An instance of the LBSTaxonomy ontology includes the basic information of the POI such as name, and location information to efficiently retrieve POIs as taxonomy.

It also specifies the information to refer the instance of the LBSPOI ontology that specifies domain-specific information of the POI and association information used to specify general retrieval patterns of user. In this work, the LBSTaxonomy ontology refers to the hierarchical classification code defined by National Geographic Information Institute (NGI) in Republic of Korea, and we extend it. For example, Hotel class is a subclass of ServiceFacility class, and ServiceFacility is a subclass of Structure.

The domain-specific ontologies define concepts for each domain and relationship between them. The domain-specific ontologies can be defined by contents provides or the Standard Organizations. Because LBS contents is different as their domain, the domain-specific ontologies help domain-specific information to be represented more exactly. The domain-specific ontologies is referred by the instances of POIDL ontology to specify the domain-specific information.

4. RETRIEVING POIS IN SEMANTIC LBS MODEL

In this paper we approach the enhancement of LBS Directory Service by building the middleware that provides retrieval services for Semantic LBS data model. Semantic LBS middleware provides not only general POI retrieval queries but also some advanced queries to retrieve more detailed and domain-specific information about a POI. These queries enable acquiring of the dynamic information which is changed frequently and automatically updating POI directories. Although the model and queries can provide more effective and automatic services by using first-order logic and reasoning, we consider only RDQL-based queries in this paper. RDQL(RDF Query Language) is a query language for RDF in Jena models [12].

4.1 General POI Queries

General POI queries of LBS search POI suited to subscribers requirements. The query types for retrieving POI can be divided into four type: (1) attribute queries, based on non-spatial attribute, and (2) proximity queries, based on spatial attributes [2]. A distinguishing feature of General POI queries in Semantic LBS is retrieving domain-specific information of POIs with users' complex conditions through POI Query. Fig. 3 shows RDQL templates for general POI queries.

The attribute POIs can be searched by the simple RDQL query as Fig. 3, because this is for searching information regardless of position. Here, unique attribute query and property are divided according to second condition existence of where- clause.

Proximity Queries are used in case of searching POIs related to specified location. Proximity Query, and Nearest Neighbor Query. Point Query

```
// The template for the Attribute Query
select ?poi, ?uri
where (?poi, rdf:type, <POIType>)
      (?poi, kb:name, <Name>)
      (?poi, kb:details, ?uri)
using kb for <http://slbs.pknu.ac.kr/lbstaxonomy.rdf#>,
   rdf for <http://www.w3.org/1999/02/22-rdf-syntax-ns>

// The template for the Point Query
select ?poi, ?poiname, ?x, ?y, ?uri
where (?poi, rdf:type, <POIType>)
      (?poi, kb:name, ?poiname)
      (?poi, kb:rectLeft, ?x)
      (?poi, kb:rectTop, ?x)
      (?poi, kb:details, ?uri)
and ?x = X, ?y = Y
using kb for <http://slbs.pknu.ac.kr/lbstaxonomy.rdf>,
   rdf for <http://www.w3.org/1999/02/22-rdf-syntax-ns>

//The template for the Range Query
select ?poi, ?poiname, ?x, ?y, ?uri
where (?poi, rdf:type, <POIType>)
      (?poi, kb:name, poiname)
      (?poi, kb:rectLeft, ?x)
      (?poi, kb:rectTop, ?x)
      (?poi, kb:details, ?uri)
and ?x >= X1, ?y >= Y1, ?x <=X2, ?y<=Y2
using kb for <http://slbs.pknu.ac.kr/lbstaxonomy.rdf>,
   rdf for <http://www.w3.org/1999/02/22-rdf-syntax-ns>
```

Fig. 3. Templates for general POI queries.

Queries include three queries - Point Query, Range (PQ) finds all spatial objects that contain a given query point P(X, Y). The RDQL Query for the Point Query is created by the template as Fig. 3. Range Query (RQ) finds all spatial objects which intersect a given query polygon P(X1, Y1, X2, Y2). The RDQL Query of the Range Query is created by the template as Fig. 3. Nearest Neighbor Query (NNQ) finds all spatial objects with the smallest distance to a given query point P(X, Y). Nearest Neighbor Query performs RDQL query which acquire (X, Y) coordinates of POI according to classification as the Range Query, and then it selects most near POI calculating distance of these coordinates.

4.2 Advanced Services

Semantic LBS middleware provides two queries for advanced services. First, it provides the POI Query that retrieves detailed POI information from instances described by POIDL. POI publishers can specify ontology for own information and describe POI information as RDF. This mechanism makes it possible not only to distribute and semantically search POI information, but also to provide more accurate information. The POI Query is made of three RDQL templates shown in Fig. 4. The next advanced service is the Contents Query which retrieves domain-specific information from each domain of POIs. The Contents Query utilizes a triple of query retrieved in POI Query as where-clause of the RDQL query. Update Manager also uses these queries to automatically update POI information for LBS Directory Service.

```
//Retrieving a list of contents for a POI
select ?poi, ?poicontent
where (?poi, rdf:ID, <POIID>)
      (?poi, kb:hasContent, ?poicontent)
using kb for <http://slbs.pknu.ac.kr/lbstaxonomy.rdf>,
     rdf for <http://www.w3.org/1999/02/22-rdf-syntax-ns>

//Retrieving a type of content and a value of content for a content
select ?type, ?value, ?query
where (?poicontent, rdf:ID, <ContentID>)
      (?poicontent, kb:typeofcontent, ?type)
      (?poicontent, kb:valueofcontent, ?value)
      (?poicontent, kb:query, ?query)
using kb for <http://slbs.pknu.ac.kr/lbstaxonomy.rdf>,
     rdf for <http://www.w3.org/1999/02/22-rdf-syntax-ns>

// A triple for a query to retrieve domain-specific information
select ?subject, ?predicate, ?object
where (?query, rdf:ID, <QueryID>)
      (?query, kb:subject, ?subject)
      (?query, kb:predicatet, ?predicate)
      (?query, kb:object, ?object)
using kb for <http://slbs.pknu.ac.kr/lbstaxonomy.rdf>,
     rdf for <http://www.w3.org/1999/02/22-rdf-syntax-ns>
```

Fig. 4. The templates for the POI Query.

5. REALIZING SEMANTIC LBS PLATFORM

Location-based Services (LBS) requires integrating various technologies and standards. In this section, we design and implement Semantic LBS Platform including Semantic LBS model and other primary technologies such as positioning and presentation. In addition, we design and implement a simple Tour Guide application to demonstrate our Semantic LBS Platform.

5.1 Positioning Service

The positioning function to determine location is necessary in LBS, because user's location is most important context in Location-based Services. There are two types of positioning systems commonly in use: cellular location-based system and GPS (Global Positioning System). For our solution, we used the GPS because of its global aspect and high accuracy.

The GPS receiver outputs GPS information using NMEA-0183 protocol which is defined by NMEA (National Marine Electronic Association). There are GGA, GSA, RMC and GSV messages provided within the NMEA-0183 protocol. The GGA and RMC messages include location information. In the positioning service, we get UTC Time, Latitude and Longitude from GPS information using GGA message format. However, the location information received in GPS cannot be used to show current location on digital map because GPS uses longitude/latitude coordinate system and digital map works on TM (in Korea)/UTM (in USA) coordinate system. The Positioning Service provides a conversion between the two coordinate systems using the principal of Gaus-Kriger Projection.

5.2 Directory Service

The directory service of location-based services provides a search capacity for one or more POIs. The directory service of Semantic LBS searches POI suited to subscribers requirements using the information represented by LBS ontologies described in Section 3. The directory service is implemented based on Semantic LBS middleware model described in Section 4.

In order to implement queries of Semantic LBS middleware, we use Jena toolkit and Joseki. RDF defines an information model that is best represented as a directed graph. HP Labs developed the Jena toolkit to make it easier to develop applications that use the Semantic Web information model and languages. Jena[12] is a Java application programming interface that is available as an open-source. Jena consists of RDF API, Stores, Inference, Query, and Network API. Joseki is a Java client and a server that implements the Jena network API over HTTP.

5.3 Presentation Service

Presentation service displays road maps and overlay routes, points of interest, object locations, and/or text information such as route descriptions on a road map. Currently, most presentation services are provided based on a visual interface framework [4].

For the Presentation Service, we expend our previous model developed for an efficient mobile GIS

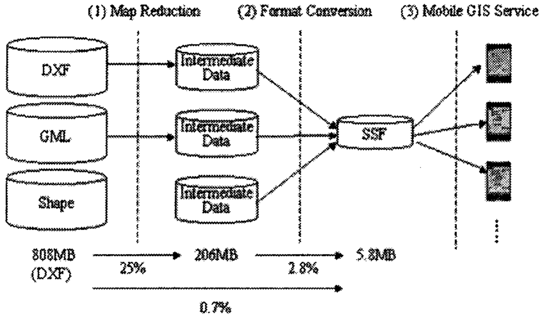


Fig. 5. The Mobile GIS Model.

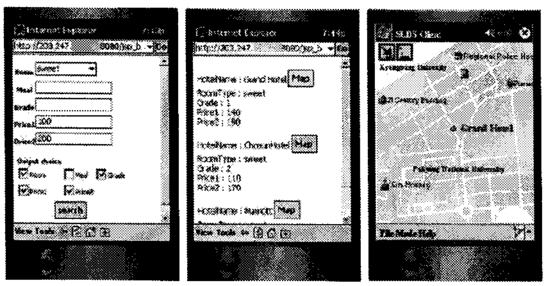
[13]. Our mobile GIS model was developed to present geographic information efficiently on mobile devices like PDA with limited environments. The objective of the mobile GIS model is to reduce the size of map data through map reduction and format conversion from DXF, GML, and Shape format to our proposed SSF(Simple Spatial data Format) as shown in Fig. 5. DXF(Drawing Exchange Format) is a CAD data file format developed by Autodesk for data interoperability between AutoCAD and other programs, and GML (Geography Markup Language) is the XML-based markup language defined by the Open Geospatial Consortium (OGC) to express geographical features. Using our Mobile GIS model, the size of DXF) was actually reduced as shown in Fig. 5. The reduced digital maps are to be stored on mobile devices such as PDA as well as on the GIS server. For more details of our mobile GIS model and SSF, readers can refer to our previous work [13].

5.4 An Application of Semantic LBS

Tour Guide has been recognized as a useful LBS application. Tour guide service is one of the most useful LBS services. Therefore, Tour Guide is mainly used to demonstrate studies on Location-based Services. Recent works [1,14,15] in the area of the tour guide services have focused on context-sensitive tour guide based on location-relevant contexts such as current location, surrounding entities and services, mobility constraints.

However, these systems have provided static information based on HTML-based contents. That is to say, they should store the information as the situation estimated in advance.

In contrast with other studies, our Semantic LBS platform can manage the various location-based information for tour guide dynamically and flexibly. In this paper, we implemented the tour guide application based on Semantic LBS as follow steps. First, we specify domain-specific ontologies for tour guide such as hotel and restaurant, and then represent domain-specific information based on each ontology. Next, we describe domain-specific information about each POI based on LBS ontologies described in Section 3. Finally, we implement tour guide application using Semantic LBS middleware as shown in Fig. 6. The tour guide services provides the tour information and map services for touring. Fig. 6 shows an example of tour guide application that retrieves nearby hotels with the specific information. The users input the search conditions including location, room type, meal type, and the range of the price through the Web browser and request tour guide information to the tour guide application (Fig. 6 (a)). Next, The tour guide application searches tour information from Semantic LBS Platform and shows the lists of hotels agreed with the condition (Fig. 6 (b)). The map service provides the location information of the hotel if they select a hotel item in the provided results (Fig. 6 (c)).



(a) (b) (c)

Fig. 6. User Interface of Tour Guide Application.

6. DISCUSSION

Semantic LBS is a platform that provides novel location-based services that provide not only LBS core services but also more enhanced POI(Point of Interest) retrieval service. The advanced services of Semantic LBS is provided by retrieving the POIs with domain-specific information. Some of the main contributions of our approach include:

- Expressiveness of POIs: Semantic LBS Model provides sufficient expressiveness. The POIDL in Semantic LBS Model provides more expressive and more flexible description mechanism for POI information that enables domain-specific information to be described.
- Information Sharing: Semantic LBS model supports information sharing in decentralized environments. Semantic LBS Model uses HTTP that is a standard data exchange protocol of Web, and shares LBS information through URI and ontologies.
- Benefits of POI retrieval: LBS Model provides not only basic queries for retrieving POIs but also some advanced mechanism that retrieves POI information: retrieving domain-specific information even if the information changes frequently and automatically updating domain-specific information of POIs for LBS directory service. The ontology-based data model enables Semantic LBS to provide the advanced functions.
- Flexibility: Semantic LBS allows the domain-specific ontologies to be extended without modifying the middleware and applications. Moreover because POIDL specifies templates for retrieving domain-specific information of each POI, Semantic LBS is able to append POI information easily.

7. CONCLUSION

Mobile users expect that Location-based Services provide more specific information exactly. For supporting users' requirement, our proposed Semantic LBS Model includes a data model for LBS POI information and its processing mechanism based on Semantic Web technologies in this paper.

For the data model, we specified two fundamental LBS ontologies for describing POI information: POIDL ontology and LBSTaxonomy ontology. POIDL is an ontology-based description language that allows POI providers to describe their contents over domain-specific ontologies. LBSTaxonomy is an ontology constructed as a hierarchical taxonomy of POI types. POIs are actually described by the LBS ontologies and various domain-specific ontologies. Based on the data model, Semantic LBS Model provides some queries to retrieve and update both POIs and their domain-specific information. In this paper, we also designed and realized Semantic LBS Platform based on our Semantic LBS Model and some core services including positioning service, directory service, and presentation service. The positioning service utilized GPS, and the directory service especially was realized based on our Semantic LBS model. the presentation service utilized our efficient Mobile GIS model developed in our previous work. In order to demonstrate our work, we developed a simple application, Location-based tour guide application.

Because Semantic LBS Model provides sufficient expressiveness and supports information sharing in decentralized environments, it can provides some advanced mechanisms that retrieve domain-specific information even if the information changes frequently and automatically update domain-specific information of POIs for LBS directory service.

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Jong-Woo Kim

He received a BS degree in Computer Science and a MS degree in Computer Science from Pukyong National University, Korea, in 1998 and 2003 respectively, He received a Ph.D. degree in Information Security from Pukyong National University, in 2006. His research interests are LBS, Personalization, Semantic Web, and Security Policy.

Ju-Yeon Kim

She received a BS degree in Computer Science from Korea National Open University in 2000, and a MS degree in Information Engineering from Kyungsung University in 2003. She received a Ph.D. Certification in Information Security from Pukyong National University in 2006. Her research interests are Personalization and Semantic Web.

Chang-Soo kim

He received a BS degree in Computer Science from Ulsan University, Korea, in 1979, and a MS degree in Computer Engineering and Ph.D degree in Computer Engineering from Chungang University, Korea, in 1984 and 1991 respectively. He has been a professor at the division of Electronics, Computer and Telecommunication, Pukyong National University, Korea, since 1992. His research interests are Operating System, GIS/LBS, USN/RFID, and Urban Disaster Prevention System.