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A Semantic Web Service for Tourism Information over the Mobile Web*

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Abstract : To better publish geographical information on the Web, it is important to capture how Web technologies are changing. For a recent decade, Semantic Web has been developed by incorporating ontologies into the current Web, with an aim to make computers understand rather than simply display. Ontology, an explicit specification of a conceptualization, and the Semantic Web grounded on the ontology, have the potential for effective sharing and appropriate retrieval of geographical information. This paper describes a Semantic Web Service over the mobile Web that can offer pertinent tourism information according to user contexts. To do this, a tourism ontology was formalized in the PARA (Place-Attraction-Resource-Activity) ontology model by organizing tourist places, tourist attractions, tourism resources, and activities. Locational relationships between tourist places were also included in the PARA ontology model to take into account the movements of tourists on a railway network. The XML (Extensible Markup Language) Web Service in the middle tier manages the client-side request for information retrieval and the corresponding server-side response from the data provider. The PARA ontology was integrated into the XML Web Service for the concept-based discovery of tourism information. The applicability of the proposed system was tested through a simulation experiment for Tokyo tourism.
Key Words : mobile Web, ontology, Semantic Web, tourism infomation

요약 : 웹 기술의 변화발전 동향을 파악하는 것은 지리정보의 웹 공유에 있어서 우선적으로 고려되어야 할 사항 중의 하나이다. 시맨틱 웹은 컴퓨터가 정보를 보여주는 것에 그치지 않고 정보를 이해하도록 하는 방법론 및 기술로서, 기존의 웹과 온톨로지의 결합을 통해 이루어진다. 개념화의 명시적인 사양이라고 정의되는 온톨로지와 이에 기반한 시맨틱 웹은 지리정보의 효과적인 공유와 검색을 위해 활용될 수 있다. 이 논문에서는 모바일 웹 상에서 사용자의 행동맥락에 부합되는 관광정보를 제공하기 위한 시맨틱 웹 서비스에 대해 논의한다. 이를 위해 관광지, 관광자원, 관광객의 활동 등이 체계적으로 개념화 및 조직화된 PARA (Place-Attraction-Resource-Activity) 온톨로지 모형을 구축하고, 관광객의 이동을 고려하기 위하여 관광지와 연결된 전철 네트웍을 이 모형에 결합시킨다. XML (Extensible Markup Language) 웹 서비스는 클라이언트의 요청과 이에 따른 서버의 응답을 중개하는 역할을 하는데, PARA 온톨로지 모형과 연동되는 XML 웹 서비스를 통해 개념기반의 관광정보 발견이 가능하도록 한다. 이 연구에서 제안하는 시스템은 도쿄 관광정보의 검색 시뮬레이션을 통해 그 가용성이 테스트되었다.
주요어 : 관광정보, 모바일 웹, 시맨틱 웹, 온톨로지

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1. Introduction

To better publish geographical information on the Web, it is important to capture how Web technologies are changing. For a recent decade, the Semantic Web for machine-understandable information has been developed by incorporating ontologies into the current Web (Berners-Lee and Hendler, 2001). As an explicit specification of a conceptualization (Gruber, 1993), the ontology has drawn attention of various communities in information science including GIS (Geographic Information System). Geographical information is not straightforward, and many concepts in geography and related fields might be vague and ambiguous. Modeling an explicit specification of the concepts in geographical domains at an adequate level would be crucial to the advancement of Web GIS. The combination of ontologies with the Web can overcome the problems coming from the inexplicitness, and also facilitate geographical knowledge sharing and reuse.

An exhaustive ontology for geographical domains is not established yet. However, as a foundation for such goal, generic spatial and temporal entities are being converted to ontologies, using the standards of the ISO (International Organization for Standardization), the OGC (Open Geospatial Consortium), and the FGDC (Federal Geographic Data Committee). The GIS applications using ontologies have been constructed primarily in the fields of transportation (Lorenz *et al.*, 2005; Obitko and Marik, 2005), navigation (Schlenoff *et al.*, 2003; Hong, 2006; Tvarozek, 2006), cartography (Gandon *et al.*, 2003; Kulik *et al.*, 2005), tourism (Tomai *et al.*, 2005; Cardoso, 2006; Lam and Lee, 2006; Yueh *et al.*, 2007), and natural resource management (Yoon and Yoo, 2000; Bennett, 2001; Third *et al.*, 2007). Now, Semantic Web Services based on the geographical ontologies should be challenged by succeeding the existing theoretical and technological achievements and by building a pertinent domain-specific ontology to be accessed through the Internet.

This paper describes a Semantic Web Service for tourism information over the mobile Web. The author built an ontology model, named PARA (Place-Attraction-Resource-Activity), to formalize tourism information based on the concepts of "what," "where," and "when," as well as the locational contexts between tourist places. A case of Tokyo tourism was tested for the applicability of the proposed ontology model. To service the tourism information over the mobile Web, an XML (Extensible Markup Language) Web Service was built to manage the communication between mobile clients and a server-side data provider. Upon a request of a mobile client, the XML Web Service searches the PARA ontology to discover appropriate sets of recommendation. The information of recommended tourist attractions and the vicinity are represented in a map of SVG (Scalar Vector Graphics) on mobile devices. The Semantic Web Service with the PARA ontology model can answer to the question like "I have something in mind but I am not sure about where to go." or "She and I have a little different tastes but we want to go to some place together."

This paper is organized as follows (Figure 1). While the background and objective being briefly introduced in this section, the theoretical and technological issues as to ontologies, Semantic Web, and the geographical information are explored in section 2. Basics for building a tourism ontology and the principles for the PARA ontology model are described in section 3. In section 4, the Semantic Web Service with the PARA ontology model is examined, and a simulation experiment for Tokyo tourism information is demonstrated over the mobile Web. Section 5 concludes the paper with a

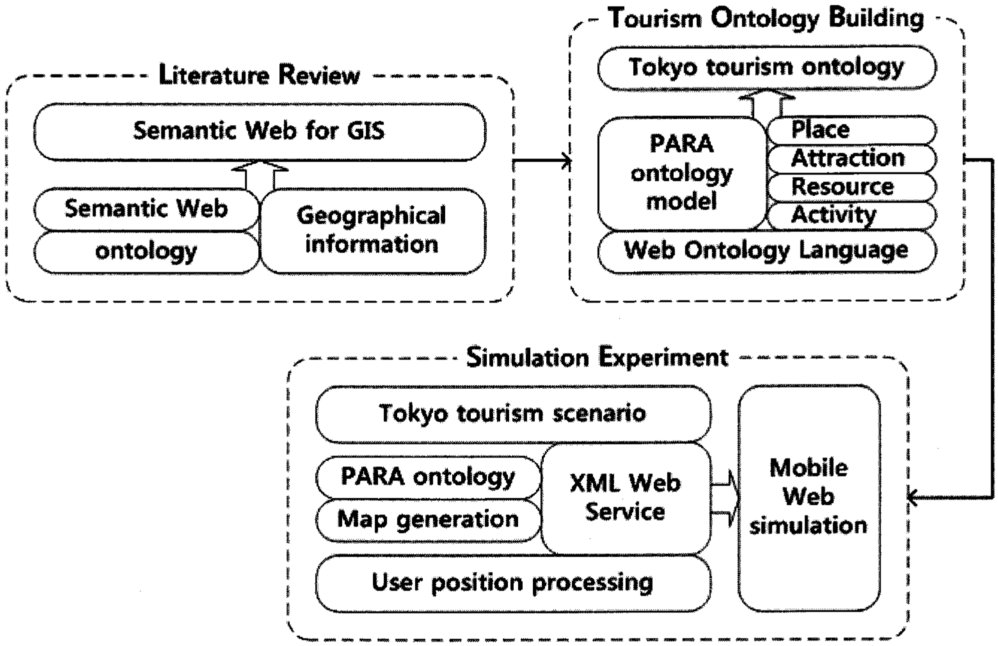

Figure 1. Organization of the study

summary and implications.

2. Ontologies, Semantic Web, and the Geographical Information

1) What is an ontology?

The ancient Greeks were concerned with the question "What is the essence of things?" Regarding the study of the essence of things, Aristotle distinguished different modes of being and established a system of categories that classifies anything in the world (Calero *et al.*, 2006). In philosophy, the term ontology relates to the subject of existence, namely, the study of the categories of things that exist or may exist in some domain (Sowa, 2000). The ontology of a certain domain is about its terminology (domain vocabulary), essential concepts in the domain, their classification, their taxonomy, their relationships (including hierarchies and constraints), and domain axioms (Gašević *et al.*, 2006).

The term ontology, which is borrowed from philosophy, has been adopted in the field of information engineering with a slightly different meaning. There can be a parallelism between the ways of perception by people and by computers (Gruber, 1993). Computers are better at handling well-defined data, but human beings can infer the meanings or implications of the information. To make computers "understand," domain knowledge should be codified in a machine-interpretable language (Gómez-Pérez *et al.*, 2003). Such codification of knowledge can be represented in the form of an ontology.

An ontology is an explicit, formal specification of a shared conceptualization (Gruber, 1993; Studer *et al.*, 1998; Kalfoglou, 2002). "Conceptualization" means an abstract, simplified view of the world. The world actually refers to some phenomenon, topic, or subject area in the world. Every representation of the knowledge in an area of interest is based on a conceptualization. Every conceptualization is grounded on the concepts, objects, and the relationships among them (Genesereth and Nilsson, 1987). "Explicit" means that the type of concepts and the constraints on using the concepts are explicitly defined in the data structure of an ontology. "Formal" indicates that the ontology should be machine-interpretable. "Specification" means a declarative representation of the knowledge. "Shared" implies that an ontology is not supposed to represent the subjective knowledge of some individual, but it captures consensual knowledge accepted by a group or a community. In short, an ontology is the manifestation of a shared understanding of a domain that acquired a consensus, and such consensus can facilitate effective communications. This, in turn, leads to other benefits such as interoperability, reuse, and sharing (Agarwal, 2005; Gašević *et al.*, 2006).

2) Main components of an ontology

An ontology defines basic terms and relations, as well as the rules for combining the terms and relations in a topic area (Neches *et al.*, 1991). Although different knowledge representation methods exist for the formalization of ontologies, the primary components of ontologies can be summarized as follows (Gruber, 1993; Uschold and Gruninger, 1996; Studer *et al.*, 1998; Chandrasekaran *et al.*, 1999; Arpirez *et al.* 2001; Agarwal, 2005).

- Class: A class defines a group of objects that belong together and share some properties. Classes can be organized in a hierarchy using subclasses. The word concept is sometimes used in place of class because a class is the concrete representation of a concept.
- Individual: Individuals refer to the objects of a domain in which we are interested. Individuals are the instances of classes.
- Property: Properties can be used to state relationships between individuals, or from individuals to data values. Properties are also known as roles in description logics, and as relations in object-oriented notions. Relations represent types of interactions among classes.
- Axiom: An axiom models the conditions that are always true for a domain. Restrictions and characteristics of properties are used to define axioms on classes.

3) Semantic Web with ontologies

Semantic Web is about making the Web more understandable by computers (Heflin and Hendler, 2001). Hence, ontologies form the backbone of the Semantic Web (Fensel, 2003) as a method for knowledge representation and sharing on the Web. The Semantic Web is an extension of the current Web, in which computers and people can better work in cooperation (Berners-Lee *et al.*, 2001) by allowing intelligent agents to retrieve and manipulate pertinent information (Hendler, 2001).

Principal technologies for the Semantic Web consist of a set of layered specifications. The RDF (Resource Description Framework), the RDFS (RDF Schema), and the OWL (Web Ontology Language) are the components for representing ontologies. The SPARQL is a query language for the ontologies represented in RDF/RDFS and OWL. All the building blocks for Semantic Web are based on the URI (Universal Resource Identifier), XML, and XML Namespaces. This is well expressed in the "Semantic Web layer cake" (World Wide Web Consortium, 2004) in Figure 2.

The XML is a general-purpose markup language that allows its users to define their own

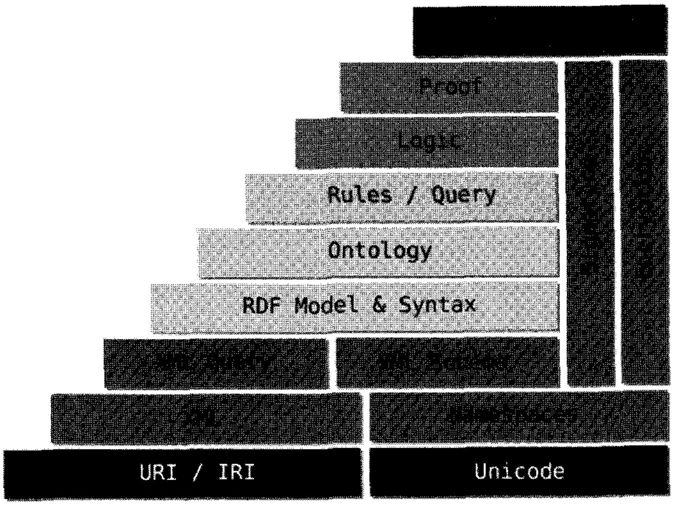

Figure 2. Semantic Web layer cake

Source: World Wide Web Consortium, 2004

tags within documents, but associates no semantics with the meaning of the content. The XML Schema provides a set of rules to which an XML document must conform. The RDF is a simple language for modeling information in the form of the triple patterns by use of subject-predicate-object expressions, commonly written as P(S, O). The triple patterns are also called graph patterns because subjects, predicates, and objects can be connected in a graph. An object of a triple can function as the subject of another triple, yielding a directed labeled graph, where resources (subjects and objects) correspond to nodes, and predicates correspond to edges (Fensel *et al.*, 2007). An RDF-based data model can be represented in XML syntax. The RDFS is a lightweight ontology language for defining vocabularies for RDF. It describes the classes and properties of RDF-based resources, with the generalized hierarchies of such classes and properties. The OWL adds more vocabulary for describing properties and classes, such as relations between classes, cardinality[1)], equality, richer typing of properties, characteristics of properties, and complex classes. The SPARQL, a standardized query language for the RDF, allows for joining distributed collections of ontology data. A SPARQL query processor searches for sets of triples that match the graph patterns by binding variables in a query statement to the corresponding parts of each triple. The queries of SPARQL can be conducted using various relations defined in properties.

4) Ontologies for geographical information

Task-oriented ontologies (Kuhn, 2001) emerge from the standpoint that the knowledge in a domain depends on the purpose of tasks in that domain. Hence, the ontology for geographical information requires the criteria for establishing the view to specific natures of geographical concepts and the semantic contents associated with them (Agarwal, 2005).

Geographical information is not straightforward, and many of geographical terms may be vague and ambiguous. For example, what is the difference between a hill and a mountain? A stream can refer to any channel with flowing water, or simply to a small channel such as brook. Such ambiguity is exacerbated by a wide range of human activities and physical phenomena in geographic space (Third *et al.*, 2007). Thus, modeling spatial and temporal entities and the relations between them at an adequate level is significant in the design of geographical ontologies.

Three foundational issues need to be resolved in the geographical domain (Mark *et al.*, 2006): (1) conceptual issues concerning what is required to establish geographical ontologies, (2) representational issues with respect to appropriate methods for formalizing the ontologies, and (3) issues of implementation regarding how to incorporate the ontologies into GIS applications.

An exhaustive geographical ontology is not accomplished yet. However, as to the first two issues (conceptualization and formalization), a few researchers are building OWL ontologies as follows[2)], using the standards of the ISO, the OGC, and the FGDC. The third issue about ontology-based GIS applications has been dealt with in the fields of transportation, navigation, cartography, tourism, natural resource management, and so on.

- ISO/TS 19103:2005 Geographical information – Conceptual schema language
- ISO 19107:2003 Geographical information – Spatial schema
- ISO 19108:2002 Geographical information – Temporal schema
- ISO 19109:2005 Geographical information – Rules for application schema
- ISO 19110:2005 Geographical information – Methodology for feature cataloguing
- ISO 19111:2007 Geographical information – Spatial referencing by coordinates
- ISO 19112:2003 Geographical information – Spatial referencing by geographic identifiers
- ISO 19115:2003 Geographical information – Metadata
- FGDC-STD-001-1998 Content standards for digital geospatial metadata
- OGC Ontology for Topic-2: Spatial referencing by coordinates
- OGC Ontology for Geography Markup Language (GML 3.0)

3. Building a Tourism Ontology

Practical steps in building an ontology include determining the scope of a domain, arranging classes and the class hierarchy, defining the properties and data values for the classes, and creating instances of the classes (Noy and McGuinness, 2001). Figure 3 shows a generic procedure for ontology building. Moreover, Gruber (1995) has proposed five principles for ontology design: (1) clarity for effective communication regarding the intended meaning of defined terms, (2) coherence for the inferences that are consistent with the definitions, (3) extendibility for the shared vocabulary as a conceptual foundation for a range of anticipated tasks, (4) minimal encoding bias for the knowledge sharing without depending on a particular notation, and (5) minimal ontological commitment for maintaining the consistent use of knowledge by defining only essential terms for communication.

1) Basics for ontology building

A tourism ontology can be built to answer three main questions as to what, where, and when (Cardoso, 2006).

- What: What can a tourist see, visit, and do at a tourist place?
- Where: Where are the interesting places to see

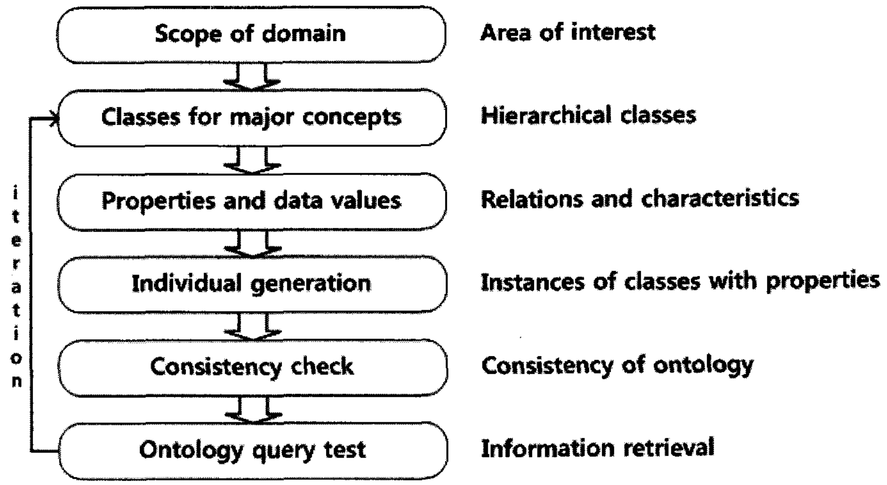

Figure 3. Procedure for building an ontology

and visit?

- When: When can the tourist visit a particular place?

The concepts of what, where, and when can be represented as classes. The class [What] refers to activities that tourists can carry out, such as strolling, shopping, and dining. The class [Where] indicates the places where tourists can do the activities, such as traditional streets, shopping malls, and restaurants. The class [When] relates to the time when a tourist can carry out an activity, such as opening hours.

A class hierarchy are defined by stating that a class is a subclass of another (owl:subClassOf). The classes [Strolling], [Shopping], and [Dining] can be the subclasses of [What]. Two classes can be made equivalent (owl:equivalentClass), for example, [What] can be stated to be equivalent to [Activity]. It is also possible to assert that two classes are disjoint (owl:disjointWith) from each other. For example, if the class [UrbanArea] is disjoint with the class [RuralArea], an instance of [UrbanArea] cannot be an instance of [RuralArea].

The OWL can define properties of classes to represent the relationships between instances, or from instances to data values. Examples of properties include [hasObservatory] and [hasEntranceFee]. The first one, called the object property, can be used to relate an instance of [Where] to another instance of [Where]. The second is referred to as the data type property, which relates an instance of [Where] to an instance of the data type "integer." Object properties can link an instance of a class with an instance from either the same or a different class. For example, the object property [hasActivity] relates the class [Where] to the class [What]. This means that a place may offer a kind of activity to its visitors. The first related class is called the domain while the second is called the range. Data type properties allow instances to have data values in specific data types. The OWL uses the data types borrowed from XML Schema, such as "xsd:string," "xsd:int," and "xsd:boolean."

Properties have several characteristics in representing the relations between classes. Properties can be stated to be symmetric (owl: SymmetricProperty). If the pair (x, y) is an instance of the symmetric property P, then the pair (y, x) is also an instance of P. For example, the friend relationship can be asserted to be a symmetric property. Properties may be stated to be transitive (owl:TransitiveProperty). If the pair (x, y) is an instance of the transitive property P, and the pair (y, z) is an instance of P, then the pair (x, z) is also an instance of P. For example, the ancestor relationship can be asserted to be a transitive property. Properties can be stated to have a unique value using the functional property (owl:FunctionalProperty) whose minimum cardinality is 0 and maximum cardinality is 1. For example, [hasWife] can be stated to be a functional property.

Properties also have restrictions so that an instance can satisfy a certain condition. The restrictions owl:allValuesFrom and owl: someValuesFrom limit which values can be used while the restrictions owl:minCardinality, owl:maxCardinality, and owl:cardinality limit how many values can be used. For example, the class [Person] may have a property called [hasDaughter] restricted to have allValuesFrom the class [Woman]. A property [hasChild] is restricted to have someValuesFrom the class [Woman] and the class [Man]. The minimum cardinality of a property [hasNationality] on [Person] is one. The maximum cardinality of the property [hasNationality] on [Korean] is one whereas that on [USCitizen] is at least one.

2) A case of Tokyo tourism

The author built a PARA ontology model to conceptualize tourist places, tourist attractions, tourism resources, and activities, using Protege (http://protege.stanford.edu/), an ontology editor. An example of the instances of the class [Place], [Attraction], [Resource], and [Activity] are shown in Figure 4. Each letter in the acronym PARA can be defined as follows.

- Definition 1: "Place" is an area for tourists. Tourist place corresponds to a geographic region in most cases.
- Definition 2: "Attraction" indicates a tourism object that is located in a tourist place. Tourist attraction is the concept of a complex with several resources (e.g., shopping street).
- Definition 3: "Resource" means a subset that consists of a tourist attraction. A tourist attraction is composed of several tourism resources that provide their own activities (e.g., a fashion store and a park at the shopping street).
- Definition 4: "Activity" refers to a primary function that a tourism resource offers. A fashion store can offer shopping while a park can provide a rest.

A tourist place has at least one tourist attraction. For a tourist attraction, there can be one or more tourism resources. Each tourism resource provides its own activity. The relationships among these four concepts (Figure 5) were expressed by the properties such as [hasAttraction], [isAttractionOf], [hasResource], [isResourceOf], [hasActivity], and [isActivityOf]. In

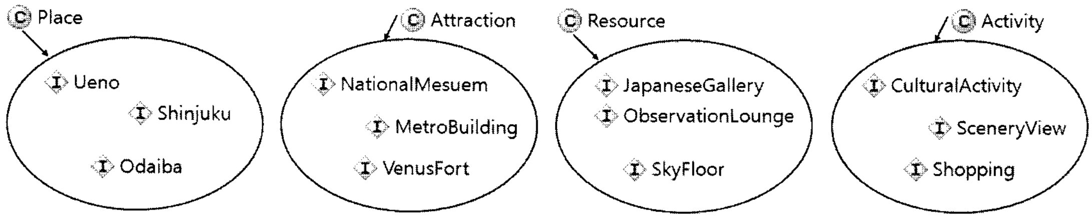

Figure 4. Instances of tourist place, tourist attraction, tourism resource, and activity

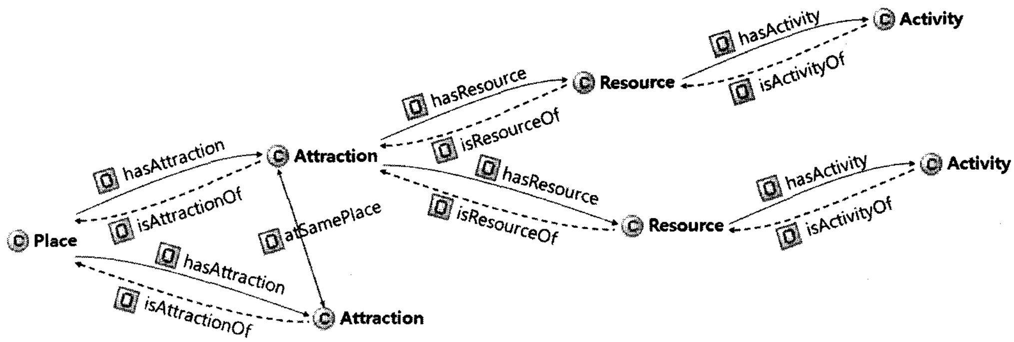

Figure 5. Relationships among primary classes

addition, we can relate an attraction to another at the same place, using a symmetric property [atSamePlace]. This property helps search for another recommendation close to a specific tourist attraction.

A tourist obtains an image for a tourist attraction, according to its tourism resources and the corresponding activities. Some tourists visit "Yebisu Garden Place" for fancy sightseeing while others go there for restful strolling. "Everland" can be thought of as an amusement park or as an automobile racing circuit. Although a tourist attraction provides multiple activities, tourists tend to visit there on their own purposes. Such diversity in tourist gazes comes from the fact that a tourist attraction can be interpreted by multiple tourism resources and their own activities. This notion is especially helpful when two or more people decide a destination together. If an attraction comprises the resources to meet their different needs, or if different activities in the attraction can be compromised by

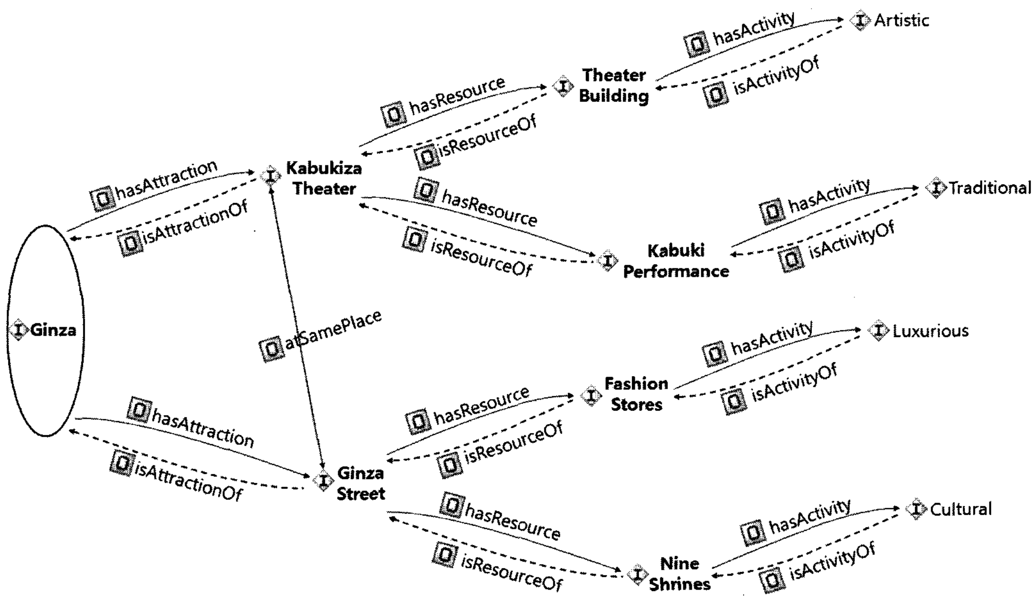

Figure 6. Multiple tourism resources and multiple tourist gazes: an example of Ginza

the tourists, the attraction would be chosen owing to the multiplicity of its resources and activities. The PARA ontology model handles such multiplicity, for more delicate retrieval of tourism information. Figure 6 shows an example of the multiple tourism resources and multiple tourist gazes.

In this paper, a tourist place in Tokyo was supposed to correspond to a geographic region whose area is covered by walk. Since a tourist place can be uniquely identified by the name of the region, the class [Place] was created without subclasses. The class [Attraction] has subclasses such as museum, park, shopping mall, beach, street, shrine, temple, etc., according to the type of tourist attractions. The class [Resource] can be divided into various subclasses for more elaborate conceptualization. The class [Attraction] is related to the class [Resource] by the property [hasResource]. Hence, the subclasses of [Attraction] inherit the property [hasResource], so that they can be also related to the subclasses of [Resource]. For example, garden, building, bench, streetlight, fountain, etc. can be created as the subclasses of [Resource], which can be linked with the class [Park] by the property [hasResource]. The class [Bench] and [Streetlight] can be also related to the class [Street] also by that property. In a natural language, it would be like “A park has the resources such as garden, building, bench, streetlight, and fountain.” and “Street has the resources like bench and streetlight.” Subclasses and the inheritance of properties may facilitate a pertinent retrieval of tourism information, for example, “Find the parks that have benches beside a fountain and a streetlight.” In addition, temporal factors of tourism information also need to be taken into account. In the PARA ontology model, opening hours of a tourism resource were attached to the class [Resource] as a data type property.

Suppose a tourist seeks some resource for

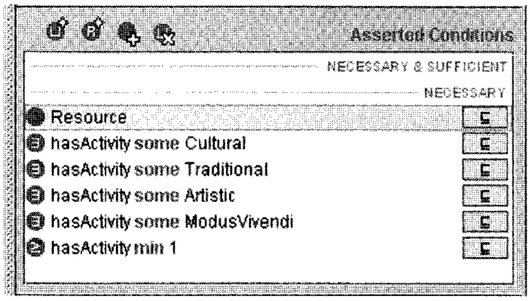

Figure 7. Axiom for cultural tourism

“cultural tourism.” Then a manifest definition of cultural tourism would be required in advance. Given that cultural tourism is based on the resources from traditions, cultures, arts, and Modus Vivendi, its definition can be expressed by using an axiom as in Figure 7.

Based on these classes and properties, the individuals for Tokyo tourism has been instantiated. Necessary data for the instantiation was gathered from the Web site of Tokyo Tourism Info (http://www.tourism.metro.tokyo.jp/) serviced by Tokyo Metropolitan Government. Tourist places, tourist attractions, tourism resources, and activities were analyzed to instantiate. The locations of tourist places have been georeferenced using a geocoding method (http://geocoding.jp/) that converts a place name (or address) to latitude and longitude. These locations were combined with the railway network information of Tokyo because most tourists in Tokyo take a railway for moving from a tourist place to another. A tourist place was supposed to have at least one railway station; hence, the property restriction “minCardinality” was set to 1. The railway stations within a 500-m radius were assigned to the corresponding tourist places. If no station is found within a 500-m radius, the closest one was assigned to the place. In addition, the properties [hasStation] and [isStationOf] were created to relate the class [Place] to the class [Station]. The individuals of [Station] were instantiated for the Tokyo railway

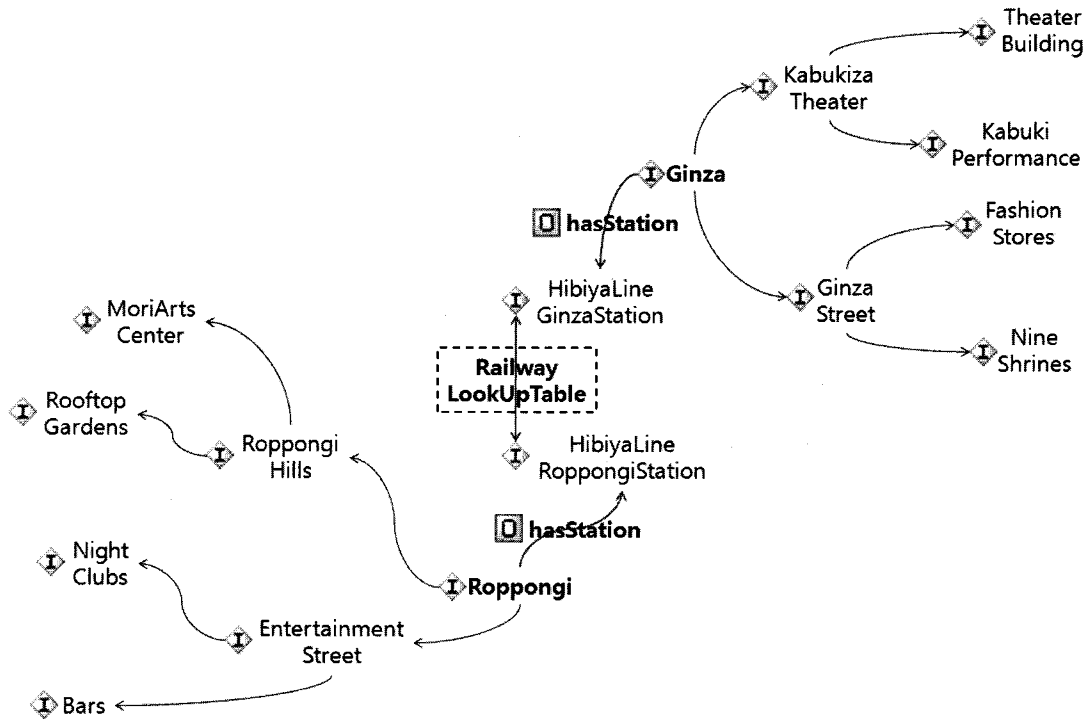

Figure 8. Use of the property [hasStation] and the link between stations

stations including JR (Japan Railway), Tokyo Metro, and several private railways. A railway lookup table was built to reference the transfer information and the time distance between arbitrary two stations, using the data collected from the Web site of Yahoo Japan-Transit Information (http://transit.yahoo.co.jp/). Figure 8 shows an example the use of [hasStation] and the link between the stations of tourist places.

An advantage of the PARA ontology model is to support the locational contexts to retrieve the tourist attractions around a place or between places (e.g., origin and destination). The concept of "around" can be formalized using the time distance from a place, such as 15 minutes by railway. Suppose a tourist, who is at Hijiribashi Bridge in Ochanomizu, searches for a Tenmangu (a shrine for the God of academy) around there. Such Tenmangu can be found by using the properties of [Place] and [Attraction], the railway lookup table, and the threshold value of 15 minutes, as in the following steps (Figure 9).

(1) The property [hasStation] returns three stations (A, B, and C) that are related to Ochanomizu.
(2) From the railway lookup table, the [Station] individuals within 15 minutes from any of the three stations are selected.
(3) The property [isStationOf] returns the [Place] individuals that are related to the stations selected in the step 2.
(4) For the places chosen in the step 3, the property [hasAttraction] returns the [Attraction] individuals.
(5) If the subclass of the attractions selected in the step 4 is [Tenmangu], the attractions are recommended to the tourist.

To formalize the concept of "between" on the railway network, we need origin and destination,

Figure 9. An example of "around" operation for finding tourist attractions

as well as the budget of time distance for a tourist. Suppose a tourist, who moves from Asakusa to Harajuku, wants to stop by somewhere, for example, a cozy strolling street. The tourist also wants a bench to sit and rest. He/she can spend 20 minutes for each movement, that is, from Asakusa to the place, and from the place to Harajuku. Such tourist attractions can be discovered by using the properties of [Place], [Attraction], [Resource], and [Activity], the railway lookup table, and the budget of time distance, as in the following steps.

(1) The property [hasStation] returns one station (Asakusa Station) that is related to Asakusa.
(2) From the railway lookup table, the [Station] individuals within 20 minutes from the Asakusa Station are selected.
(3) The property [hasStation] returns two stations (Harajuku Station and Meijijingumae Station) that are related to Harajuku.
(4) From the railway lookup table, the [Station] individuals within 20 minutes from the two stations are selected.
(5) The intersections of the result of the step 2 and that of the step 4 are determined.
(6) The property [isStationOf] returns the [Place] individuals that are related to the stations selected in the step 5.
(7) For the places chosen in the step 6, the property [hasAttraction] returns the [Attraction] individuals.
(8) If the subclass of the attractions selected in the step 7 is [StrollingStreet], the attractions can be candidates.
(9) If the attractions from the step 8 have a resource [Bench], and the resource has the activity [Rest], these attractions are recommended to the tourist.

4. Semantic Web Service for Tourism Information

Recommender systems can help tourists in discovering tourist attractions, especially when they are not sure about where to go. Unlike existing systems, the PARA ontology model can support the recommendation through a compromise to meet the diversity in tourist gazes. When two or more people travel together, their different needs can be satisfied in the PARA ontology model because a tourist attraction is interpreted as multiple tourism resources and the corresponding activities. As a test bed for the PARA ontology model, a Semantic Web Service for Tokyo tourism information was experimentally built using an XML Web Service on the mobile Web.

1) System composition

Figure 10 shows the overview of the Semantic Web Service based on the PARA ontology model. An XML Web Service in the middle tier manages the communication between mobile clients and a server-side data provider. Mobile clients can access to the Web Service through two types of protocol such as HTTP (Hypertext Transfer Protocol) and SOAP (Simple Object Access Protocol). On the server side, the PARA ontology that organizes tourist places, tourist attractions, tourism resources, and activities can be retrieved by a query engine for SPARQL. Recommended tourist attractions and the vicinity are represented in a mobile SVG map.

2) XML Web Service architecture

The XML Web Service is a software application identified by a URI, whose interfaces and binding are defined, described, and discovered by XML (World Wide Web Consortium, 2002). Through XML-based messages, an XML Web Service supports direct interactions with multiple applications distributed in different network

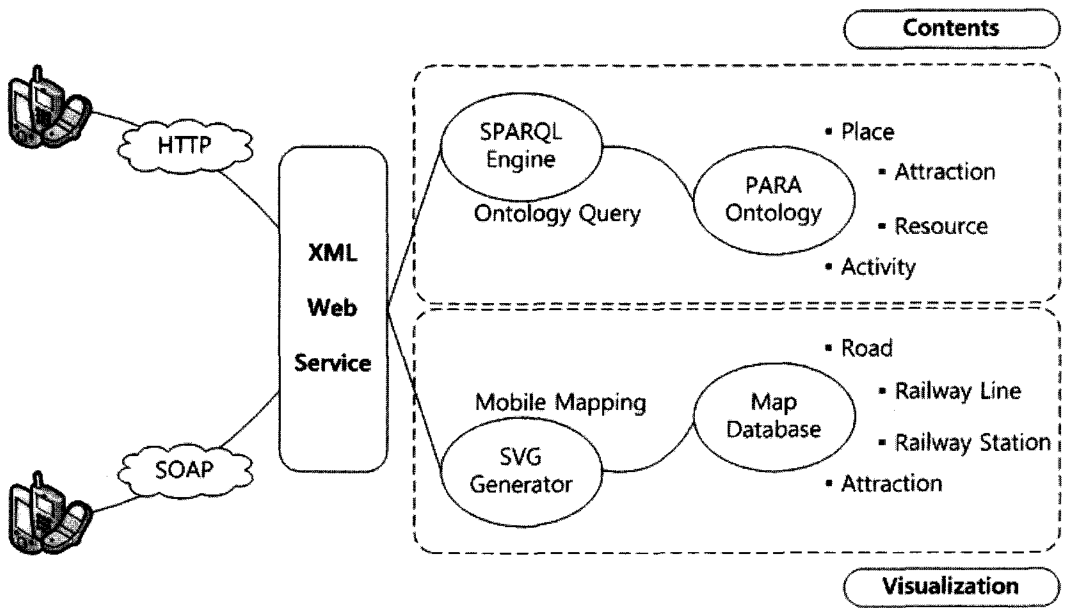

Figure 10. System composition of a Semantic Web Service for tourism information

locations. An advantage of the XML Web Service is an integrated interface that can be consumed by any type of XML-based client. Common features of the XML Web Service are as follows.

- XML Web Service exposes its functionalities to Web clients through a standard protocol such as HTTP and SOAP.
- XML Web Service provides the interfaces for client applications in an XML format called WSDL (Web Services Description Language) document.
- XML Web Service is registered to the Internet so that Web clients can find the service by UDDI (Universal Discovery Description and Integration).

  The XML Web Service supports HTTP/GET, HTTP/POST, and SOAP for the request/response on the Internet, and the characteristics of each method are as follows.
- HTTP/GET: Simple, unstructured information is bundled in the page, as a sequence of name-value pairs. These pairings are a simple way to combine all the values into a single string.
- HTTP/POST: While HTTP/GET uses the end of the URL to pass its information from resource, HTTP/POST uses the body of the transmission to carry the same name-value pairs.
- SOAP: It provides an object-based method to call remote functions, in the form of XML.

The SOAP is a protocol for exchanging XML-based messages through HTTP, and the XML-formatted SOAP messages are independent of the platforms such as hardware, software, and programming language. It allows for defining an extensible messaging framework that includes simple objects written in the standard data types of XML Schema.

The SVG is an XML specification for describing two-dimensional vector graphics, both static and animated. As an XML formatted data, an SVG map can be incorporated into the SOAP messages, and thus can provide a mobile client with a simplified view around the recommended tourist attractions. In the database server, spatial data for roads, railway lines, railway stations, and tourist attractions have been stored. A server-side procedure for converting spatial objects to an SVG map is called by the XML Web Service, upon a client request.

3) User position processing

The position of mobile users with a GPS (Global Positioning System) receiver can be optionally used for the "around" and "between" operations in the PARA ontology model. Because GPS positioning accuracies tend to be degraded by obstacles like buildings (Lee *et al.*, 2006; 2007), a calculated GPS position may deviate from the actual user location. Thus, several tourist attractions within a certain radius from the GPS position (for example, within a 1-km radius) can be shown in a drop-down list on the screen, so that a mobile user can choose the current location for the "around" operation or the origin for the "between" operation.

If a GPS receiver is connected with a mobile device, the user position can be obtained by reading from the serial port of the mobile device at interval of n seconds. Through the serial communication, 6 types of NMEA-0183 sentences[3] such as GPGGA (Global Positioning System Fixed Data), GPGLL (Geographic Position – Latitude/Longitude), GPGSA (GNSS[4] DOP[5] and Active Satellites), GPGSV (GNSS Satellites in View), GPRMC (Recommended Minimum Specific GNSS Data), and GPVTG (Course over Ground and Ground Speed) are analyzed. Each sentence starts with "$" character, and ends with CR+LF character[6]. Between the "$" and CR+LF character, there is an actual sentence starting with a sentence ID and ending with a checksum[7]. A

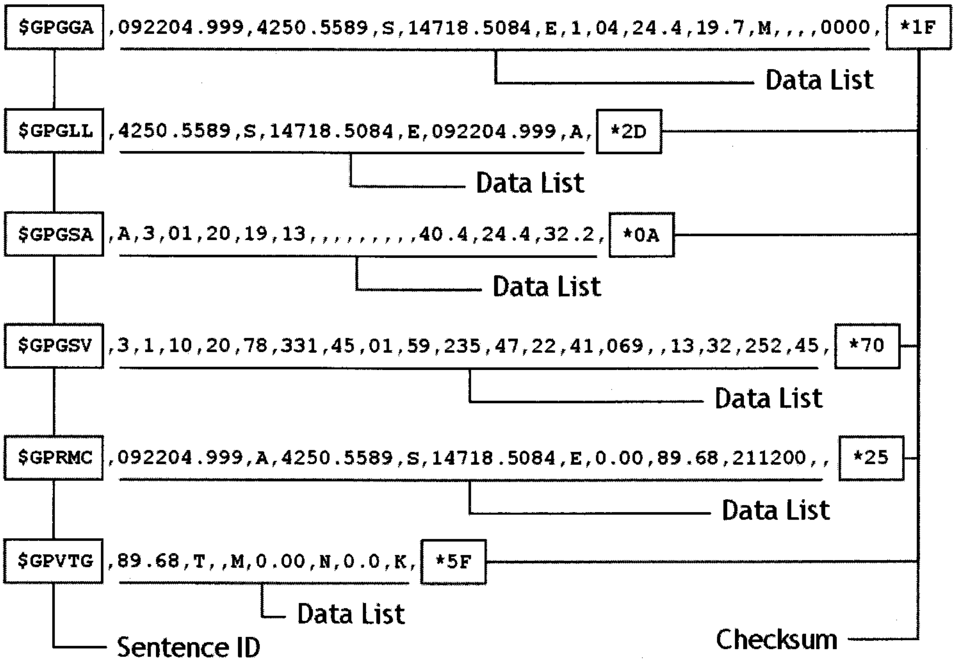

Figure 11. Structure of NMEA-0183 common sentences for GPS receiver

Table 1. Interpretation of GPGGA sentence

"$GPGGA,092204.999,4250.5589,S,14718.5084,E,1,04,8.4,19.7,M,,,,0000*1F"			
No.	Field	Example	Comments
1	Sentence ID	GPGGA	Global Positioning System Fixed Data
2	Time	092204.999	hhmmss.sss
3	Latitude	4250.5589	ddmm.mmmm
4	N/S Indicator	S	N = North, S = South
5	Longitude	14718.5084	dddmm.mmmm
6	E/W Indicator	E	E = East, W = West
7	Position Fix Indicator	1	0 = Invalid, 1 = Valid SPS[8)], 2 = Valid DGPS[9)], 3 = Valid PPS[10)]
8	Satellite Used	04	Number of satellites used (range: 0 to 12)
9	HDOP	24.4	Horizontal dilution of precision
10	Altitude	19.7	Altitude in meters according to WGS84[11)] ellipsoid
11	Altitude Units	M	M = Meters
12	Geoid Separation		Geoid separation in meters according to WGS84 ellipsoid
13	Separation Units		M = Meters
14	DGPS Age		Age of DGPS data in seconds
15	DGPS Station ID	0000	
16	Checksum	1F	Result of XOR[12)] operation of all the characters between $ and *

sentence has comma delimiters that divide each token such as latitude, longitude, and time in GMT (Greenwich Mean Time). The structure of NEMA-0183 is described in Figure 11, and the interpretation of an example for the GPGGA sentence is shown in Table 1.

4) Simulation experiment

To test this Semantic Web Service, a simulation experiment was conducted on a scenario basis. In the following scenario, two tourists search for some place to visit. They are going together, but the place they want seems somewhat different.

Peyton and Brooke are friends. Peyton majors in architecture and Brooke majors in fashion design. After visiting Yoyogi Park to see the scenery of maples with a fountain, they decided to move to another place but they are not sure about where to go. Peyton wants to visit an art gallery for cultural experience while Brooke thinks of window-shopping for fancy clothes. Both of them like strolling along street trees. It is 2 PM, and they cannot go quite far away because they have a dinner appointment at Shinjuku Kabukicho, 6 PM. They searched the Internet using the keywords "Yoyogi Park," "Shinjuku," "art," "architecture," "fashion," "shopping," and "strolling." A number of information came out, but it was not easy to find out what both of them want.

Viewing from the PARA ontology model, the needs of Peyton and Brooke can be expressed using the classification of activity, as well as the locational contexts between Yoyogi Park, Shinjuku, and somewhere they are looking for. Art, architecture, fashion, shopping, and strolling can be chosen for the category of activity. Their origin is set to Yoyogi Park, and the destination is assigned to Shinjuku Kabukicho. Suppose each 15 minutes is reasonable for the movements by railway, that is, from Yoyogi Park to somewhere, and from somewhere to Shinjuku Kabukicho. Yoyogikoen Station is related to Yoyogi Park, the origin; Shinjuku Station is linked with Shinjuku Kabukicho, the destination. Those stations that are within 15 minutes from both Yoyogikoen Station and Shinjuku Station can be expressed as {S}. The tourist places that are related to {S} can be

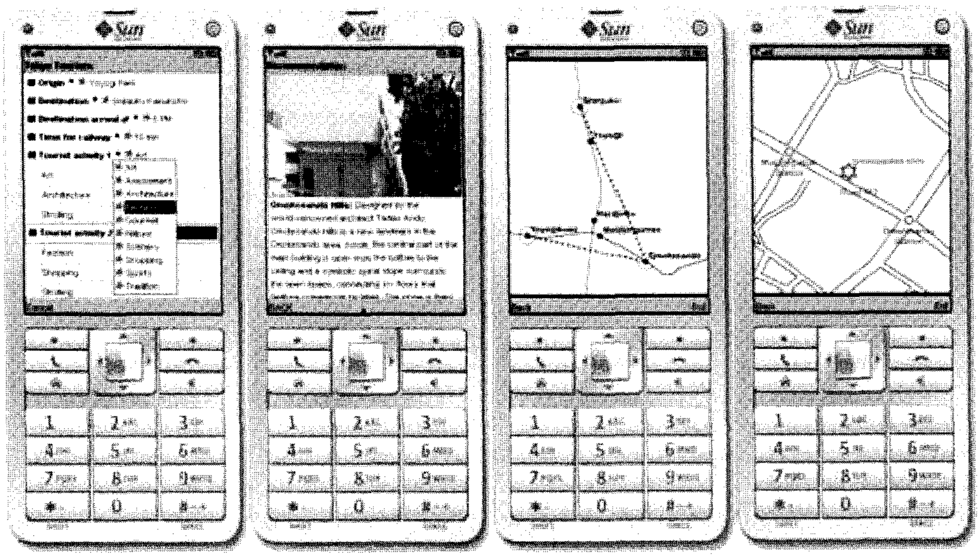

Figure 12. User input and the recommendation by PARA ontology model

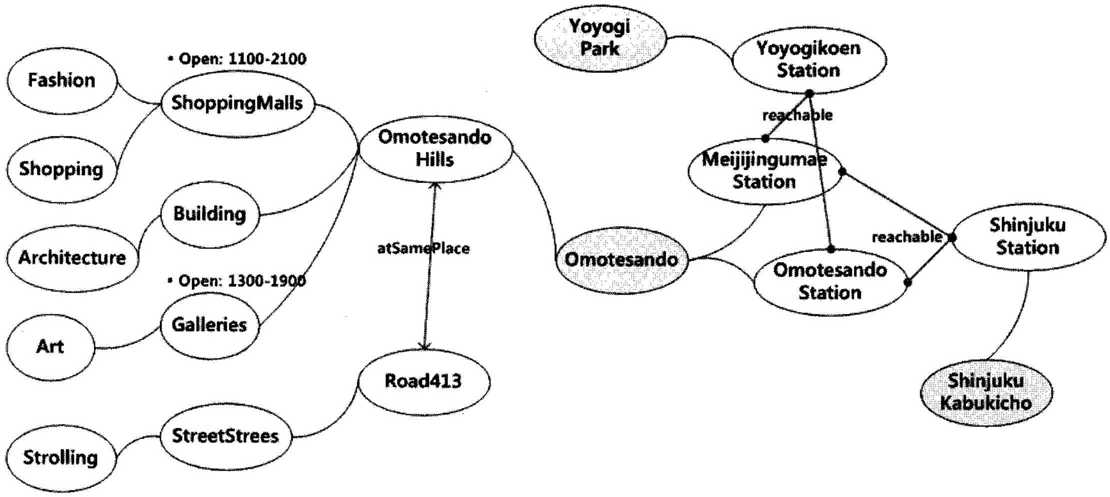

Figure 13. Retrieval procedure using the relations among places, attractions, resources, and activities

denoted as {P}. All the tourist attractions of {P} are referred to as {A}, and their resources are expressed as {R}. For each element of {R}, their activities are examined to see if they satisfy the conditions from user input. In addition, the closing time of a tourist resource is compared to the arrival time at the destination. As a result, Omotesando Hills and Road 413 were recommended, and Figure 12 shows the user input, the recommendation, the railway map, and the vicinity map of the recommended attractions. The procedure for this retrieval is represented in Figure 13.

Omotesando Hills (Figure 14), which was designed by a world-renowned architect Tadao Ando, shows a unique building structure. The central part of the main building is open from the bottom to the ceiling, and a symbolic spiral slope

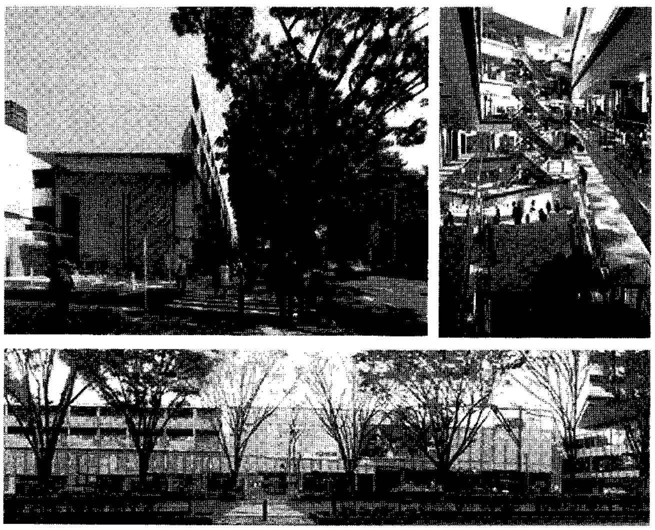

Figure 14. Omotesando Hills

surrounds the open space, connecting six floors. Omotesando Hills is thought of as a Japan's center of international fashion with a number of splendid boutiques. Several art galleries offer various exhibitions for painting, drawing, prints, sculpture, and photography. The Road 413, which is contiguous to the Omotesando Hills, provides walkers with a cozy strolling along street trees.

5. Concluding Remarks

This paper aimed at building a Semantic Web Service over the mobile Web that can offer more appropriate tourism information according to user contexts. To do this, a tourism ontology was formalized in the PARA ontology model by organizing tourist places, tourist attractions, tourism resources, and activities, as well as the locational relationships among the railway stations linked with tourist places. The PARA ontology was incorporated into the XML Web Service in the middle tier that manages the client-side request for information retrieval and the corresponding server-side response from the data provider. The PARA-based XML Web Service allows for the concept-based discovery of tourism information and supports the recommendation through a compromise to meet the diversity in tourist gazes. However, this study has limitations, in that the ontology for Tokyo tourism was manually built. An automated method for building the PARA ontology would be necessary as a future work.

The significance of the ontology and the Semantic Web has been stressed by a number of studies so that geographical concepts may be systematically organized and effectively shared. In addition to these foundational efforts for standardized interoperability, the specific knowledge for various domains of spatial phenomena such as population, real estate, transportation, industry, tourism, election, vegetation, weather, soil, geology, water resource, pollution, etc. should be adequately formalized in an ontology and serviced through Internet, for a context-based retrieval of pertinent geographical information.

Notes

1) Cardinality refers to the relationship of the number of elements, such as one-to-one and one-to-many.
2) http://loki.cae.drexel.edu/~wbs/ontology/list.htm
3) NMEA is the acronym for National Marine Electronics Association. NMEA-0183 interface standard defines electrical signal requirements, data transmission protocol, and specific sentence formats for serial communication (http://www.nmea.org/pub/0183).
4) Global Navigation Satellite System
5) Dilution of Precision
6) Carriage Return + Line Feed
7) A checksum is used for checking if the values in a data list are valid.
8) Standard Positioning Service
9) Differential GPS
10) Precise Positioning Service
11) World Geodetic System 1984
12) Exclusive or

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