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Communal Ontology of Landmarks for Urban Regional Navigation

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도시 지역 이동을 위한 랜드마크의 공유 온톨로지 연구

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Abstract : Due to the growing popularity of mobile information technology, more people, especially in the general public, have access to computerized geospatial information systems for wayfinding tasks or urban navigation. One of the problems with the current services is that, whether the users are exploring or navigating, whether they are travelers who are totally new to a region or long-term residents who have a fair amount of regional knowledge, the same method is applied and the direction are given in the same way. However, spatial knowledge for a given urban region expands in proportion to residency. Urban navigation is highly dependent on cognitive mental images, which is developed through spatial experience and social communication. Thus, the wayfinding service for a regional community can be highly supported, using well-known regional places. This research is to develop the framework for urban navigation within a regional community. The concept of communal ontology is proposed to aid in urban regional navigation. The experimental work was implemented with case study to collect regional landmarks, develop the ontological model and represent it with formal structure. The final product of this study will provide the geographical information of a region to the other agent and be the fundamental information structure for cognitive urban regional navigation.

Key Words : landmarks, urban navigation, cognitive maps, ontology modeling, semantic web

요약 : 최근 정보기술의 발달과 대중화로 인해, 일반인들에게 지리정보의 보급이 확대되었고, 길찾기를 위한 인터넷 지도서비스나 혹은 차량항법장치 등은 공간의사결정에 지리정보시스템을 활용하는 좋은 사례라고 할 수 있다. 기존의 시스템이 제공하는 서비스에서 발견할 수 있는 문제점 중 하나는, 사용자가 그 지역에 처음 방문한 여행자이든 혹은 사용자가 그 지역에 지리를 어느 정도 알고 있는 거주자이든, 동일한 방식의 길찾기 방식이 적용된다는 점이다. 주어진 도시지역에 대한 공간지식은 거주기간에 따라 발달하게 되고, 도시이동은 공간에 대한 경험 속에서 발달된 인지지도에 많은 영향을 받게 되며, 이들의 공간적 지식의 발달은 그들이 속한 사회적 관계에 밀접한 영향을 받게 된다. 따라서 보다 인지적인 길찾기를 위한 서비스를 위해서는, 주어진 지역 내에서 사람들에게 잘 알려진 장소들, 다시 말해, 랜드마크를 통한 위치 인식이 중요한 역할을 하게 된다. 본 연구는 사회적 관계를 공유하는 한 지역 내 커뮤니티의 지역이동에 있어서 발달하는 인지지도를 하나의 공유된 지식으로 보고 이를 활용하는 도시공간이동에 대한 개념적 모델을 제시하였다. 이와 함께, 개념적 모델에 지식공학의 접근방식 중 하나인 온톨로지 방법론의 응용가능성을 살펴보았다. 지역 내 잘 알려진 공유된 랜드마크 지식을 지식모델링 기법의 하나인 온톨로지 방법으로 모델링하여 재사용가능한 지역지식으로 구조화하여 이를 공유 온톨로지라 정의하였다. 사례연구에서는 설문조사와 웹 내용분석의 방식을 통해 랜드마크의 추출하고, 온톨로지 방법론을 통해 사례지역 내 랜드마크 정보를 데이터베이스로 구성하여 활용하는 방안에 대하여 고찰하였다. 본 연구는 기계적 알고리듬으로만 제한된 현재의 GIS 기능을 인지적 모델과 접목을 도모하는데 큰 의미를 갖는다.

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1. Introduction

In the age of rapidly increasing information, the World Wide Web is a critical medium to distribute, disseminate, and share geographic data. Data sharing via a network requires a common understanding between different communities and the idea of an ontology is suggested to overcome semantic barriers (Bishr, 1998). The concept of interoperability introduces the critical role of an ontology which includes classifying domain knowledge, categorizing the hierarchical structure of classes, and constructing meta information about the specified domain. This enables us to query information not only using keywords but also through the semantic relationships present among the resources. In short, an ontology has two kinds of roles. The first is data integration and the second is semantic queries about resources. In this study, a communal ontology is concerned with geospatial queries about geographical resources for urban navigation.

Actual implementations of ontology are easily found in web navigation. For example, Yahoo! is one of the search engines that provide a category-based service. Yahoo's categories are descriptors of web page content. These simple ontologies are used to browse this content, and their conceptual hierarchies are built on the basis of users' navigation patterns or behaviors. Browsing is usually done by clicking through a hierarchy of concepts, or an ontology, until the area of interest has been reached. As for urban navigation, we may think of cases similar to web navigation. We can think about two different methods to give directions to the destination: give the shortest directions composed only of paths and nodes from the starting point to the destination, or give the directions using relations to the closest and most familiar landmark, which is categorized and classified according to regional function and familiarity. This method enables us to recognize destinations quickly and helps users make their own directions.

The current Internet mapping systems also provide categorized places such as city names, counties, or road names as labels on maps to facilitate easier understanding. One of the problems with this type of categorization is that whether users are explorers or navigators, whether they are the travelers who are totally new to a region or long-term residents who have a fair amount of regional knowledge for that place, the same classification is applied. Additionally, one resident may consider a certain place to be higher-level, while a different person might consider the same place to be low-level, according to their familiarity with that place or their level of acquired spatial experience. An inadequate categorization of place names makes non-experts face information overload with unfamiliar place names or unrecognizable scaled areas. It makes them spend more time and effort to understand the given symbolized two-dimensional maps. Within the geographic domain, a semantic query to find a place (Jones *et al.*, 2001) and categorized place names which are called a digital gazetteer (Hill *et al.*, 2001) are the rapidly growing area of research. Category-based solutions for non-experts help them to recognize places more easily, using semantically related places based on their familiarity and preferences.

The traditional behavioral geographer's methodology provides the way to collect regional preferences and familiar places using surveys. In addition, with the help of web content mining, the preference and familiarity of regional landmarks can be measured from the community web site. The regional geographical knowledge is not just the mental image of an individual but of the collective interest of the community that individual is a member of as well. In this study, the term communal ontology is defined as the collective geographical preferences and familiarity of a given regional community. If we apply the concept of ontology to regional navigation, each community has an agent that communicates with other regional agents that provide the familiar landmarks and characterize the locations within a community. This study tries to solve the issues of complexity in machine-generated route instructions given by current GIS, by using an ontology-based knowledge representation.

In general, ontology is regarded as the specification of a conceptualization (Gruber, 1993), and this specification enables formal definitions of objects to be stated using categories and relationships among the members of these categories. The places of a community have their own terminology. They are categorized and classified according to their familiarity, and are related to each other. The structured relationships among landmarks are considered to be indicators of reference points for urban navigation. A method for ontological modeling is introduced to organize the collected places and their relationships as reusable information. The purpose of this research is to propose a regional geographical ontology that provides more cognitive means of urban navigation.

The remainder of the paper is organized as follows. Section 2 is the related works which cover the overview of the researches in geospatial ontology. Section 3 deals with the conceptual framework for the ontology-based urban navigation. Section 4 is the experimental work with case study and section 5 is conclusion.

2. Related Works: Spatial Knowledge Representation with Ontology

The study of geospatial ontology is one of the research streams in GIScience and has a significant theoretical contribution. The recent increases in publications indicate the importance of geospatial ontology. Winter (2001) classified the research trends of ontology into two kinds: the ontology design and the ontology application development. Smith and Mark (2001) are one of the researches of ontology design and they have conducted a foundational study in geospatial ontology. Through human subject testing, they attempted to reveal the first concepts in the geographical domain with ontological approach. The application development study in ontology was conducted by Raubal (2001), Kuhn (2001) and Timpf (2002). In these studies, the domain ontology for each application area was developed and specified to facilitate the further communication with the related agents.

On the other hand, the study of ontology crosses multiple disciplines and it covers theoretical studies in philosophy and application researches in knowledge representation. In this context, Mark *et al.* (2000) suggested three kinds of subjects of ontology researches in GIScience. First, the formal ontology in philosophy has developed a formal axiom (Bittner and Smith, 2002; Smith, 2003). The cognitive and psychological subject in ontology forms the second type, which extracts the conceptual agreement in theoretical approach (Mark *et al.*, 1999; Sorrows *et al.*, 1999; Agarwal, 2004). The third is the practical and applicable research area in ontology. The database integration and data modeling such as UML, semantic web are good examples for this area (Jones *et al.*, 2001; Hiramatsu and Reitsma, 2004). However, these areas are not exclusive but complementary to each other. In short, geospatial ontology in GIScience covers the formal ontology in philosophy, the conceptual and linguistic approach in cognitive science and the data modeling and knowledge representation in ontology engineering.

At present, we do not take into account the syntax or format in the data conversion or sharing, with the help of the various standard formats. However, the major concern of GIS is how to overcome the semantic difference in concepts or definition of geographic objects that come from the different social cultural history (Bishr, 1998; Fonseca *et al.*, 2000). When we define the semantic as the meaning of the data, a meaning of words and understanding of concepts may differ from one community to another, because people have different conceptual definition and interpretations of data. For example, the concept of a major road is differently represented with the shape of geometry. Some community defines it as a single line and others define it as a polygon according to their cultural setting. The meaning of attributes can also be different to each community, in spite of the same attribute name.

The aim of semantic interoperability in GIS is to improve the understanding of the meanings people associate with geographic information and to develop the interoperable solutions in the future (Harvey *et al.*, 1999). Semantics of geo-data could be explicitly represented in the metadata, such as RDF/RDFs. It can be used during integration, using spatial data from different sources. The basic interoperability issues might be solved with the help of emerging technical development. However, interoperability not only has to overcome complexity of sharing data but also overcome semantic heterogeneity that comes from different conceptualizations (Hakimpour and Timpf, 2001).

Ontology is a vocabulary of engineering and it is defined as explicit and formalized specifications of conceptualizations. It plays an important role to extract and formalize semantics. Ontology consists of logical axioms that convey the meaning of terms within a community. The logical axioms represent hierarchies of concepts and the relations among concepts. With the help of ontology, there have been two kinds of researches of GIS. The first is the data integration research, which tries to overcome the semantic difference between communities for data sharing and integration (Pundt and Bishr, 1999; Harvey *et al.*, 1999; Shanzhen *et al.*, 2001). The second is research related to semantic search, which tries to perform semantic spatial search within spatial dataset, based on the taxonomy or category of geographical concepts (Jones *et al.*, 2001; Egenhofer, 2002).

While semantic web attempts to cope with the large complex data set on Internet resources, it is important to understand how GIS can effectively manage a large spatial data set (Flewelling and Egenhofer, 1999). The study of semantic web in the area of spatial information is called semantic geospatial web (Egenhofer, 2002), where it is defined as a spatial search system that have the capability of processing the request with various degrees of geospatial contents that users obtain results to match their tasks. The Internet user might want to implement the geospatial semantics that have fuzzy locations and to make it possible to do a geospatial query, such as "Where are the Rocky Mountains?" or "Find the lake in Maine". The search results can be the geo-data set that satisfies the constraints, or the place name. However, the research issues are still broad and the standardized forms of research do not exist, yet. On the other hand, geospatial semantics is also useful research for spatial decision support in spatial navigation. The semantic web and Location Based Service (LBS) can work together to provide useful navigation guidance or wayfinding tasks (Casey and Austin, 2002). LBS is typically related to spatial problem solving such as identifying self location, searching location for services and how to reach to destination. Geographic references that include geographic relations to well-known locations might be useful for explaining these requests (Hiramatsu and Reitsma, 2004). The software agents will find the meanings of terms and the geospatial ontology are the repositories of these machine-interpretable meanings.

3. Communal Ontology for Urban Regional Navigation

This study tries to solve the issues of complexity in machine-generated route instructions given by current GIS by using an ontology-based knowledge representation. The idea of communal ontology-based navigation is depicted in Figure 1. The navigation agent facilitates effective navigation by providing communal information for the domain of the community in which the semantic structures of

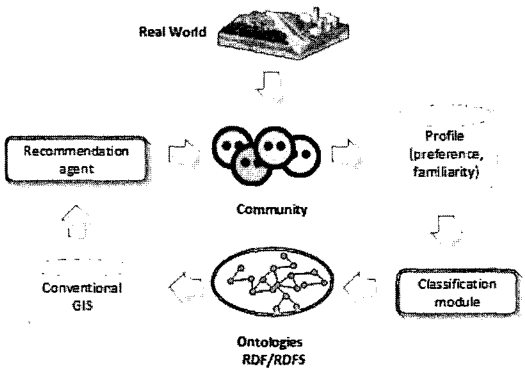

Figure 1. Communal ontology-based navigation

place names are clearly defined. The place names of a community are categorized according to familiarity and referential relationships and are classified as semantic structures with geographical features. This classification constitutes ontology of informational structure. It provides the needed information for the agent to identify semantic content and relations present among the places, as well as to grasp users' intentions for navigating in an urban region. Place names are fetched by a look-ahead search from the ontology of regional places for a community and those that match the user's search criteria are selected as reference points to generate recommended directions. Thus, conventional GIS can generate directions using these reference points to the destination. The conceptualized geographical terms and vocabulary for a community can be regarded as a communal ontology that supports navigation in an urban environment. Agents can utilize this structure to support spatial requests in giving directions to a certain location.

1) Ontological modeling process

An ontological approach is used to encode place names, allowing a community to share and reuse their knowledge, capture the semantics implicit in the place names, and allow computational manipulation of the acquired knowledge from the surveys. This manipulation of the geographical places would allow semantic directions to be given. Here, this study presents such an approach to representing knowledge of a geographical resource that allows sharing, reusing, and automatic reasoning by capturing its semantic content.

In practical aspects, developing an ontology includes defining classes, arranging the classes in a taxonomic hierarchy, defining properties or values for the classes, and initiating instances for each class (Noy and Mcguinness, 2001). Building a well-designed ontology represents a significant challenge and there is great diversity in the way that ontologies are designed as well as in the way they try to represent the world. A range of methods and techniques have been reported in the literature regarding ontology building methodologies (Uschold, 1996; Lopez, 1998; Noy *et al.*, 2001) and there is still an ongoing debate within ontology research about what the best method is to build them. Though various ontologies have their own procedures by which they were developed, they are generally modified or scaled down to fit a specific purpose. Figure 2 represents the development process which is adopted and modified for this study.

The first step is to identify the purpose, scope and users. The purpose of this study is to create the communal ontology to support the urban regional navigation. The next step is domain analysis and knowledge acquisition. To analyze regional familiarity of places and acquire geographical preferences, the behavioral

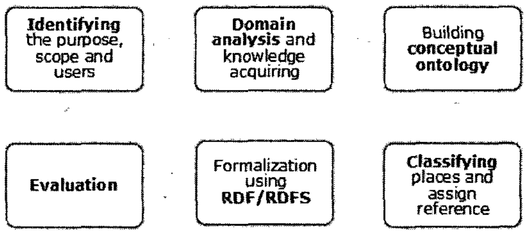

Figure 2. Ontology development steps

geographer's methodology and the web content mining methodology are applied. The more detail about these methodologies will be discussed in section 4. Shared common geographical terms and locations are extracted from the collected experiential data and their familiarity and prominence measures are acquired. A semantic network of place names can be organized based on these measures, which are important geographical meta-information that explains the preferences, interests, and familiarity with the geographical region of a community.

Stage 3 is building the conceptual ontology. The conceptual framework will be presented in section 3.2. An ontology of the places modeled in this study will be presented in the case study, section 4. Following this conceptual ontology, a classification module that classifies places according to conceptual structure is employed. At this stage, an ontology is constructed as a list of the classifications of places. The next step is to instantiate the developed ontology as a conceptual model. After a review of available ontology development environments, semantic web method is selected. After the ontological model is implemented, the final step is to evaluate the whole structure and reorganize it according to the results and/or inconsistencies found from testing and evaluating the model. While creating and implementing the ontology, it is necessary to make general assertions about fundamental concepts, and be able to later test these assertions and ensure that they hold across the entire knowledge base.

2) Ontology of Places for Regional Navigation

An important characteristic of the proposed ontological model is its capability to represent the referential relationships among places. This is of particular importance for geographical data, since the concepts and relations among them enable users to easily recognize or reach destinations. Figure 3 presents the proposed ontology of the places modeled in this study, from the perspective of regional navigation for a community. Any location in a community can be categorized as a well-known location (landmark) or an unknown location (target place). The landmarks of a community have are sub-classed according to spatial familiarity and provide an important geographical reference frame. A landmark is categorized as anchor, distant, or local. Firstly, anchor refers to a place of commuting, which involves frequent interaction and is specialized and socialized according to similar interests or social interaction. Secondly, distant and local refer to well known places and they are categorized according to level of familiarity within the regional community. There exist spatial relationships that function as reference frames between landmarks and other locations. Thus, places can be related to other places recursively, like a family tree.

An ontology is defined as a specification of conceptualization, and is comprised of objects and their relationships (Gruber, 1995). Also, an ontology is an axiomatic characterization of the meaning of a logical vocabulary. Hence, an ontology consists of a representative vocabulary for objects and relations that define the interrelationships between objects. In this study, ontology is used as a conceptual hierarchy of places, which are classified and categorized according to familiarity and function. As shown in Figure 4, the ontology is represented as a hierarchy of nodes, where each node denotes a place and each edge denotes a relation, in order to facilitate the description and classification of the hierarchical conceptual structure of place.

The assistant agent programs can convert place names to the corresponding set of concepts using this structure. An advantage of concept mapping is that an agent can provide information about the place not by its coordinate information

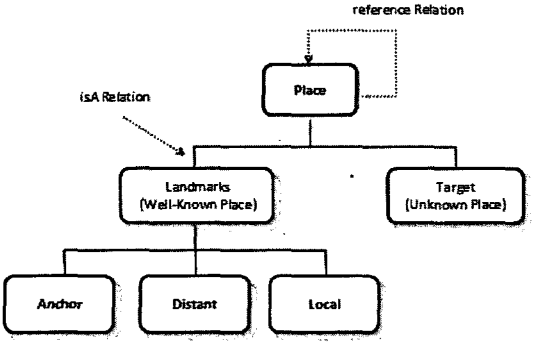

Figure 3. Ontology of place for regional navigation

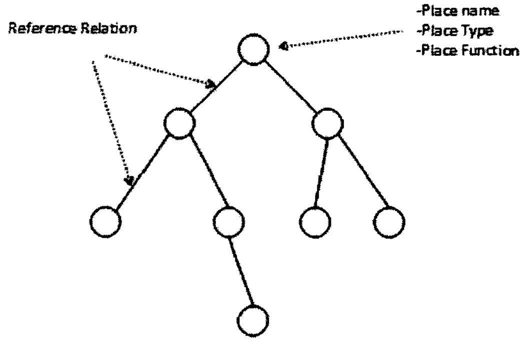

Figure 4. Building the concept hierarchy

but by a hierarchy of concepts, so that the agent can recognize the most effective reference points and what the function and role of each place is in the specified regional community.

The communal ontology for a community is composed of landmarks. To build the structure, the starting root node is the one that has the highest value of the centrality and familiarity, which is calculated from landmarks analysis. The domain ontology is composed of those landmarks regarded as most well-known to a regional community. Thus, this structure can bring a common understanding to the agents. The connections among the landmarks are not decided arbitrarily. In general, less familiar locations are placed lower in the hierarchy, and are not used as references to describe more familiar locations, which occur higher in the hierarchy. The ontology allows connections among equal levels, which represents connections of one type of landmark to another of the same type, such as anchor to anchor or distant to distant, to be connected. To avoid the creation of orphan clusters, manual insertion of landmarks is allowed. The formulation of the connections focuses on constructing the ontology for the classification of places according to level of familiarity. In this way, each community can have a different order or list of places to describe or represent the same geographical region.

3) Classifying and Connecting Places

In this study, the weighted concept hierarchy is adapted to represent the hierarchical structure of geographical place names for urban regional navigation. Each different community in a region may have a different conceptualized hierarchy of the same places according to their different interests. The following Figure 5 explains how places can be classified by a community and shows the connections among them. First, well-known places were collected from a survey and the landmarks are classified by type according to the measures that are acquired from landmark analysis. Second, the connections among the places were created based on rules that find the closest and most familiar places from the current place. In the case of the connections between landmarks, a manual connection is possible, because the number of places is manageable. However, an automated procedure is needed to connect unknown places to the landmarks.

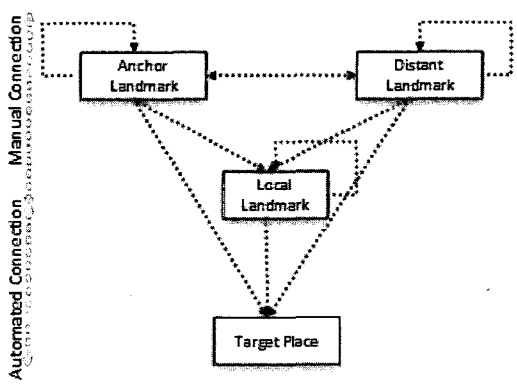

Figure 5. The classified places in community and their connection

For automated connections, the measures are needed to create the connections between landmarks and other destinations. It is assumed that the best reference point for a destination is the one with the highest familiarity and the least distance from the target. There needs to be two kinds of weighted measures to create connections between landmarks and other places. One is the measures of each node, which is called the spatial prominence, and the other is the measures of each edge, which is called the reference score in this study.

The classification of place names is a task consisting of mapping a well-known location to a suitable node in the conceptual hierarchy. Places are mapped to the most relevant landmarks which are conceptually categorized into three types (anchor, distant, and local). The places collected from the field survey are classified according to the spatial prominence measure. The spatial prominence is calculated on the basis of the field survey with residents and web content mining to local community web sites. Spatial prominence (SP) is measured as follows,

$$SP(p)=LF(p)\cdot DF(p)\cdots\cdots\cdots\cdots\cdots\cdots (1)$$

In this equation, $LF(p)$ is the landmark familiarity that is measures from the survey subjects, $DF(p)$ is the document frequency of each landmark which is measured from web content mining. Thus, landmarks are classified using the collected survey data and the measures calculated from the landmarks analysis.

To recommend a reference point, the reference score (RS) is calculated and assigned to each candidate points. Equation (2) shows how to measure the reference score for a given location. This equation considers three factors: the first is the spatial familiarity-based factor that normalizes the value of familiarity for each node. The second is the location-based factor that considers the distances between places. The last is the conceptual factor that gives different weighted values to places based on the category that the places belong to.

$$RS(p)=Max_i\left(\frac{SF(p)_i}{MaxFamiliarity_i}\,\frac{1}{Edist(p,p_i)}\,\frac{1}{Cdist(p_i)}\right)\cdots(2)$$

In this equation, $Edist(p, p_i)$ is the Euclidean distance that is calculated from the current place

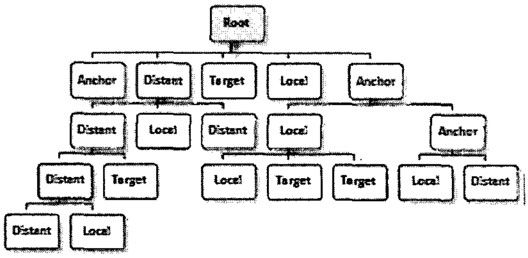

Figure 6. The hierarchical network of landmarks

to the candidate place $Cdist(p_i)$in the given attachment area. is a conceptual distance that is a weighted value, depending on the type of the landmark (anchor, distant, local). It is assumed that the nearest reference points with the highest spatial familiarity are the most relevant reference points and the relationship from the current node to the reference is assigned based on this assumption. A strategic advantage of using this ontological hierarchy is that the navigation assistant is able to find a concept in the upper level of the hierarchy. In consequence, the user gets a reference that is regarded as the most relevant, based on the RS scores.

As a result, we are able to represent a concept hierarchy, using a small number of nodes, and give more sophisticated recommendations using this hierarchical classification. Figure 6 shows the concept hierarchy of places. It is structured as a tree and spreads over the space as a network. Using this concept hierarchy composed of weighted values, urban navigation is assisted using the classification and its linked reference points.

4. Experimental Work: Case Study

As the object of the case study, UB community was selected. To explain how UB (University at

Buffalo) students conceptualize the Buffalo-Amherst region, the landmark analysis examined the mental images of geographic places and the Semantic Web methodology (RDF/RDFs) is adopted to represent the ontological structure of places for regional navigation.

1) Data Collection

The quantifiable works of behavioral geographers are selectively adopted to explore the symbolic value of study area. Two kinds of experiments are performed to acquire the proposed measures of landmark significance. As the first experiment, we asked subjects to write down a set of place names which are considered to be landmarks in study area. As the second method, the web content mining is implemented, using the web documents which are located at buffalo.edu domain.

Subjects consisted of undergraduate students. 47 students were recruited from GEO 120, Maps and Mapping class, which was an introductory level of course for cartography and GIS. The majority of students were American students. A survey instrument was created to ascertain which elements in Buffalo-Amherst are regarded as best known to UB community. The goal was to obtain responses from a representative sample place names from UB undergraduate students. Data collection occurred with the fill-out survey forms. To measure and quantify the geographical familiarity of the Buffalo-Amherst area, the 64 locations were selected at the pilot study. The pilot study was conducted with a group of individuals who have long-term knowledge of Buffalo-Amherst. Place names were tersely worded, giving either the title of a landmark such as city hall or a brief description of place. To measure the familiarity, it is generally used to mark the ranked number to the list of places which is given at survey questionnaire (Gould and white, 1974; Golledge, 1982). In stead, this study used 5 familiar indexes, following Gale's four dimensions of familiarity (Gale *et al*, 1990). Table 1 show the familiar index that was used for survey questions.

These five indexes were used to measure the spatial familiarity of the places. Each place will have 1-5 degree by subjects. Subjects were instructed to give these a score according to the familiar index. With the weighted matrix, the familiarity is scaled from 1 (low level) to 5 (high level) and the average of spatial familiarity of each place is calculated. Table 1 is the results of the survey and shows the list of top 10

Table 1. Familiar Index

DO you know this place(landmarks)?	Degree
No, I don't and have never heard about it.	1
No, I don't but I have heard about that place name.	2
Well, I know where it is but I cann't drive there by myself.	3
Yes, I know where it is but I did not use it/go there often.	4
Yes, I know where it is and I've been/used that very often.	5

Table 2. TOP 10 list of landmarks in UB community, collected from subjects

Place Name	Shape	Familiarity
01 UB North Campus	District	4.93
02 UB Sorth Campus	District	4.74
03 Wegmans	District	4.70
04 Maple Rd & Niagara Falls Blvd	Intersection	4.52
05 Boulevard Mall	District	4.48
06 Bailey Ave & Main St	Intersection	4.48
07 I-90 & I-290	Intersection	4.48
08 Bailey Ave & Maple Rd	Intersection	4.44
09 I-290 & Niagara Falls Blvd	Intersection	4.37
10 Buffalo Niagara International Airport	District	4.33

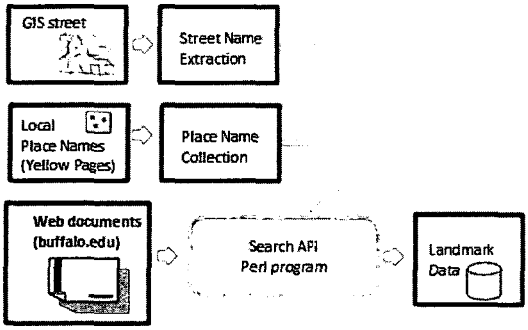

Figure 7. Landmark extraction process, using web content mining

landmarks and their average of familiarity. Tables 2 reveals that the district type of landmarks and intersections are the places that show the significant familiarity measures.

Through the human subject survey, the familiar landmarks can be extracted directly. However, the demerit of this method is the survey results might be subjective to the investigator's personal experience and the time and cost limits the number of participation. To compensate this issue, the web content mining method gives the chance to acquire the objective results from web documents (Tezuka and Tanaka, 2005). The regional information is indirectly reflected in local news paper or web pages and the document frequency of the geographical names gives a chance to grasp the familiarity of each places.

For web content mining, two kinds of GIS layers are utilized. Firstly, the street network that covers the case study area is adopted to extract the well-known intersections. Total 4038 street names are collected from street network layer in study area and the document frequency of each street name is measured. Secondly, the firm table which includes the address and business names in study area is acquired from yellow pages. Total 20100 business names are collected and

Table 3. Procedure for computing the document frequency for landmarks

Input: a set of place names, $P = \{P_i\}$ **Output**: a set of frequency for places, $F = \{F_i\}$
Initialize: $C_i \leftarrow P_i$, for $1 \le i \le P$, and $C = \{C_i\}$
loop
if (C_i is valid landmarks)
$F_i \leftarrow CountAvailableDocument(C_i)$
else
exit
end
for each $c_i \in c$, create frequency output F_i;

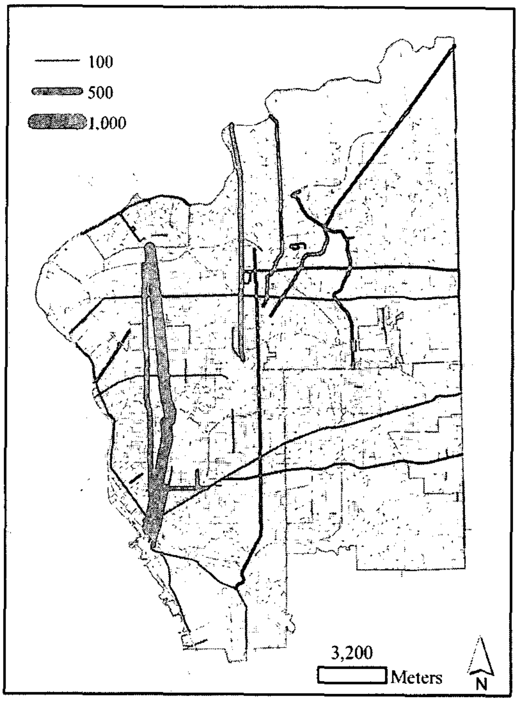

Figure 8. The document frequency of street names in study area

they are converted as firm layer, using geo-coding. The document frequency of each point is acquired from the analysis. Figure 7 explains the landmark extraction process, using web content mining. For the analysis of the document frequency, the Web search API which is provided by search engine is used. The program is developed by Perl language, which generate the number of pages of each input places at the given domain corpus. Table 3 shows the structure of the computation. The corpus for

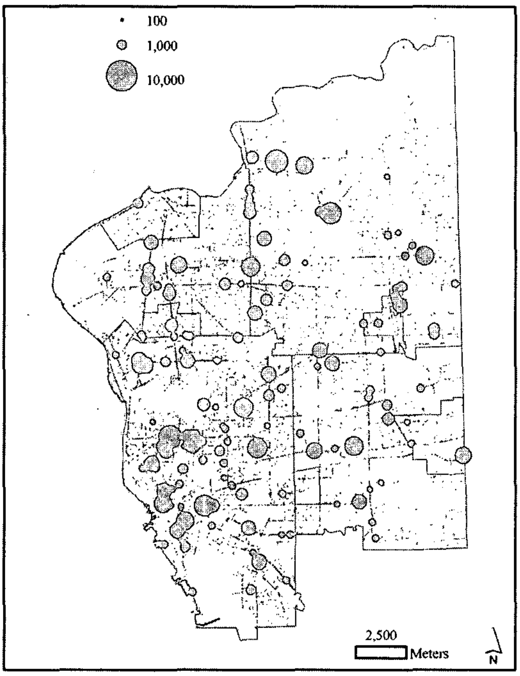

Figure 9. The document frequency of business names in study area

landmarks analysis is restricted to the web documents which are located at buffalo.edu domain.

Figure 8 show the document frequency of each street in study area. In this analysis, Delaware Ave, Elmwood Ave, Niagara Falls BLVD, and Sheridan Dr are the street names that ranked in top list. Using these results, the intersections which are generated by the high ranked streets are extracted. Secondly, Figure 9 displays the document frequency of point type business names. In this figure, the business points which are located at buffalo downtown and the points which are located at the close to Niagara Falls BLVD & Maple Rd shows the high ranks of frequency.

In the case of document frequency analysis for the firm layer, as the names of business is used for searching keyword, this measure is insufficient in terms of measuring an object's significance in spatial context, for several reasons. Firstly, the names of business often have ambiguities in the context. For example, "Target" is not only the business name which is located at Niagara Falls BLVD but also is the generic term. Secondly, where two different objects have a common name, a single geographic object may have more than one name, such as the official name and popular alternative names. The place names which are acquired from yellow pages were valuable to catch the objective results. However, there might be inaccuracy, because of the ambiguity. Thus, the contribution of the spatial prominence should be less than the case of survey results.

Using the measures that are acquired from field survey and web content mining, top 30 list of places is extracted and their spatial prominence and reference scores are calculated. On the basis of these measures, the hierarchical networks of landmarks are structured and presented in Figure 10. This is constructed according to the following steps. Firstly, the central and starting location is decided according to the results of landmark analysis that shows the highest familiarity measures. The intersection Niagara Falls blvd & Maple Rd is the central places. Secondly, the anchor and distant type of landmarks are classified, according to their functional characteristic and familiarity. The list of landmarks that have high spatial familiarity measures are regarded as distant landmarks. The anchor type landmarks are reselected from distant landmarks, which are the places that invoke periodic interactions the UB community. The reference relationship between selected landmarks is constructed according to the reference score. In addition, the network has the

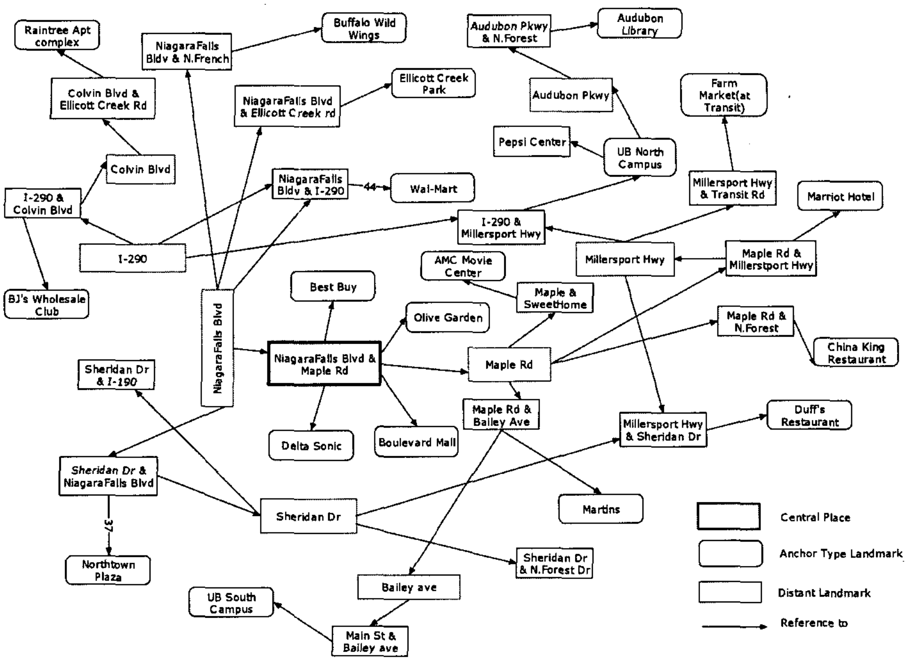

Figure 10. The hierarchical structure of landmarks in study area

hierarchical order according to their class. In short, the place name that structured the figure is network that has links between nodes hierarchically. The network links imply what node can be reference to the others and the hierarchy means what the effective node as a reference in this structure is.

2) Ontology Implementation with RDF/ RDFs

In this section, the conceptual model which is discussed at previous section is implemented. For implementation, the Semantic Web method is applied to represent the hierarchical structure of landmarks as a formal format. We are going to discuss how the domain knowledge places is represented with RDF/RDFs. In addition, the way of the querying is shown, using RQL syntax.

The Semantic Web initiative is to enable the automated reasoning to web-based resource (Berners-Lee 1999; Berners-Lee et al. 2001). The inference rules make it possible to implement the content based information retrieval. RDF (Resource Description Framework) has the most important position in Semantic Web layers. RDF is to represent the logical facts that are the kind of the semantically structured knowledge (W3C, 2002). RDF statement is composed of three triples, which are composed of subject, predicate

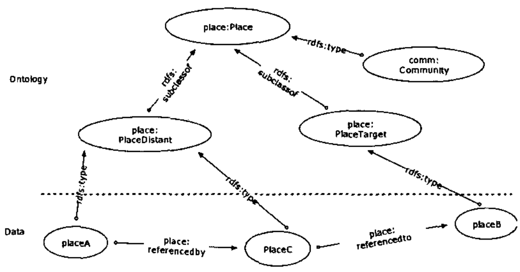

Figure 11. RDF and RDFs structure of landmarks

(property), and object. For example, in the statement, "A place is referenced by a landmark", a place is subject and a landmark is object and 'is referenced by' is predicate. Any kinds of geographic entities can be resources, which take the part of subject or object in triples. In addition, literal or numeric values can be object as a property value for entity. Figure 11 shows the role of RDF and RDFs (RDF Schema) to represent the semantic relationships between places. In here, RDF is the graph data structure which presents the triple relationship and RDFs is to define the class relationship and its property of places.

For the urban regional navigation, the communal ontology of landmarks might be formalized with RDF/RDFs in the three perspectives. Firstly, the geographical place names which are the common interests of a community can be thought as the subject and object as a reference point. Secondly, their spatial relationship with the others as a reference point is matched as the role of predicate. Lastly, the places are organized as the hierarchical class structure, according to their functional characteristics and their spatial familiarity. In this context, the role of Semantic Web in regional navigation is to clarify the community's geographical understanding. This knowledge enables us to access the cognitive solutions for wayfinding task.

In regional navigation, analytical application of Semantic Web is typically able to extract the name of unknown places and its reference point. The details on its components are such as coordinates, name, function, the level of familiarity, shape, and possibly some information about the community that they belong to. Destination is associated with well-known

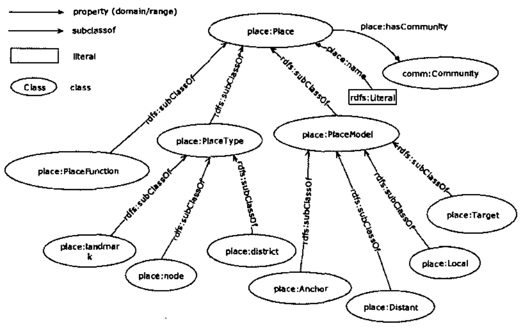

Figure 12. RDF Schema with class and key concept for regional navigation

Table 4. RQL example for structured level

Question: find the landmark which is referenced to target place "Marriot Hotel"
Select X @P
From {X} @P {Y}
Where Y like "Marriot Hotel"

Table 5. RQL example for semantic level

Question: find the landmark which is type of distant and referenced to target place "Marriot Hotel"
Select X,
From {X : place: Distant } place:refereneTo {Y}
Where Y like "Marriot Hotel"

landmarks. Examples of information 'triples' are "Place X is referenced by landmark Y.", "Landmark Y has name Boulevard Malls.", "Landmark Y has the function of Z.", "Function Z has name shopping mall.", "The kinds of Y is anchor type." Figure 11 shows the RDF schema which is defined at the conceptual model. The central point of the schema is the concept of Place. Place is super-class of all landmarks and its function, type, and model is defined as subclass.

The cognitive maps are the community's meta information for wayfinding and navigation. The place recognition and description of destination is on the basis of the geographic meta data. RDF is the programming language to store and manage these meta data. To query and search the structure of RDF storage, the query language is developed and it is called RQL (RDF Query

Language) (Karvounarakis *et al*, 2003). Unlike standard SQL, these languages only serve for querying and not for data manipulation. The building blocks of RQL are functions and path expressions. RDF is composed of a set of triples and basically it is structured on the basis of graph model. Thus, in structural level, the model allows us to find out which subject is connected to which object in terms of relationship of predicate. In this application, an RQL would allow us to query which landmarks are connected to target places in structural level. For example,

The clear advantage of this query is that it directly addresses the RDF data model, and that it is independent of the specific syntax that has been chosen to represent the data. In addition, RQL allows querying a special semantics in RDFs that is defined as a class relationship and property.

5. Conclusion

This research focused on finding an alternative way to provide a semantic solution for wayfinding requests in the mobile age. This approach differs from the usual computational approach which currently dominates in GIS routing services. The list of places that is well-known and familiar to a community is the strategic location that extends their spatial knowledge and guides the other locations. The wayfinding or navigation in the local region might be differentiated with the exploration at the new environment. The study of domain ontology is to organize and formalize the specific tasks and knowledge and it enables us to reuse. The community who has the similar geographical interests of involves a similar social network owns their shared geographical meta information about their urban environment. It might be called as cognitive maps or image of city. The mental geographical terms of place names can be regarded as the domain interests on their geographical perspective and it can be formalized as the ontological model.

To classify places to the concept in ontology and assign referential places, the spatial *prominence measure* and *referential score* is calculated. Using these measures, the semantic network of community's places is organized. The organized hierarchical network is represented by RDF/RDFs formalization. It is called as simple ontology that makes it possible to create the semantic query on the basis of conceptual schema and relationships between instances by RQL. Lastly, the ontology model is the semantic guide that can help the current GIS to get the semantically related places.

In this study, the communal ontology-based navigation is discussed as an assistant that helps a user with the navigation by using ontology. The navigation assistant represents the semantic relationship between place names by conceptual structure, and classifies them using the ontology that consists of the concepts. The navigation assistant based on the ontology identifies the community's geographical information need more efficiently and correctly. The use of ontology is to improve the effectiveness of information retrieval. Communal ontology can indeed enhance the subjective performance of retrieval for each community and a desirably feature in many situations. However, it can easily be perceived as erratic and obtrusive, if not handled adequately.

The contributions of this research are

represented in the following ways. First of all, the conceptual framework proposed in this research can extend the capabilities of current navigation services. Specifically, it enables GIS to communicate with the geographical common understanding of a community, which is to georeference the destination using familiar landmarks. Secondly, this research contributes to the study of communal ontology by constructing a Semantic Web application. Methodologically, the use of RDF/RDFs for modeling and representation can generally be coordinated with other agents for navigation support. The advantage of this research is that it can provide reusable knowledge for navigation.

In this study, the following facts are lefts as the limitation and future work. The hierarchical structure of places is structured with the limited number of places from case study. To handle the entire dataset, the automated procedure is needed to generate the links between the target places to reference points. The second is to develop the application system that provides the reference points. At this time, there are many web-based Semantic Web systems such as Jena, Sesame and RDF suite. The linking these systems to the current Internet Map Services will be another challengeable future work to enhance GIS service. Lastly, it will be a further research subject to examine how much the ontological approah suggested in this study is efficent for regional navigation, comparing with the current systems.

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