# ONTOLOGY BASED SDI TO FACILITATE SPATIALLY ENABLED SOCIETY

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## Abstract

Spatial Data Infrastructure (SDI) development is moving more toward a user-centric platform to facilitate a decision-making in a spatially enabled society. A user-centric SDI pays more attention to user' preferences during data gathering and services (or/and infrastructure) designing. The first and second generations of SDI initiatives mainly are based on data-centric and process-based views. In the data-centric view, data are gathered and then services are designed based on data and finally the results are delivered to the users. But as this structure is not fully based on user's preferences, the user may not be happy using the services. In the user-centric view, users do necessarily need raw data but they need special data and services with respect to their preferences and needs. In order to facilitate this requirement ontologies are used to indicate a formally represented knowledge that is mainly used to improve data sharing and information retrieval in the user-centric SDI. Hence, the objective of this study is to develop an ontology based user-centric SDI using a route finding architecture as an example of spatial enablement to facilitate spatially enabled society. In this architecture, ontology facilitates SDI' services particularly the route finding analysis in a spatially enabled society.

Keyword: Route finding analysis; ontology; user-centric SDI; spatially enabled society

## 1. Introduction

Information societies are moving towards a user-centric information society. In the user-centric information society, governmental and private sections focus on severing general users. Their main policy is to use and apply various technologies and strategies to consider the preferences and requirements of general users to make users are satisfied. The user-centric information society facilitates the realization of spatially enabled society, where geospatial information (GI) are regarded as common goods made available to ordinary users and businesses to promote creativity and product development (Rajabifard 2009). The proliferation of ICT, the Internet and the Web have led to the evolution of Geospatial Information System (GIS) into the broader concept of Spatial Data Infrastructure (SDI) about two decades ago (Budhathoki and Nedovic-Budic 2008). According to GSDI (Global Spatial Data Infrastructure) Association Cookbook (Nebert 2004), “the term Spatial Data Infrastructure (SDI) is often used to denote the relevant base collection of technologies, policies and institutional arrangements that facilitate the availability and access of spatial data".

However, the existing sharing models, data transfer standard and clearinghouse architecture which are part of an SDI components are based on first generation of SDI initiatives. This generation is based on a data-centric view. In the data-centric view, data are gathered and then services (or/and infrastructure) are designed based on data and finally the results are delivered to the users. But as this structure is not based on user's preferences, the user may not be happy using the services. There is some dissatisfaction among SDI practitioners and data stakeholders regarding SDI and GIS functional capabilities. To alleviate this problem, in addition to the data-centric view, an SDI particularly GIS applications should also develop a user-centric view. In the user-centric view of SDI, users do necessarily need raw data but they need special data and services with respect to their preferences and interests. In the context of an SDI and GIS, ontologies are used to indicate a formally represented knowledge that is mainly used to improve data sharing and information retrieval. Ontology has a crucial role in SDI. Existing route finding analysis, as a significant application in a society and in the context of SDI and GIS, suffer from previous data-centric view. General users are not satisfied from the outcomes of such an applications due to inefficiency in accessing to datasets (particularly interoperable and integratable datasets).

The objective of this paper is to develop a user-centric ontology based route finding architecture using the user-centric view in SDI to facilitate the realization of spatially enabled society.

## 2. User-centric Spatial Data Infrastructure

Accessing to the information has always been as a great struggle for researchers, who cope with computational space representation (Davis et al. 2005). SDI can be used as a solution to decrease such difficulties (Maguire and Longley 2005). It provides an environment in which all sections deal with each other with proper technology to better achieve their goals at different administrative levels (Chan et al. 2001). (Rajabifard et al 2003) stated that such environment is achieved to facilitate the share, access and the use of spatial data across different communities via design, implementation and maintenance of mechanisms. In doing so, Rajabifard et al. (2002) addressed five main compents for SDI with their relationships as illustrated in Fig. 1 to facilitate data discovery, access, sharing .

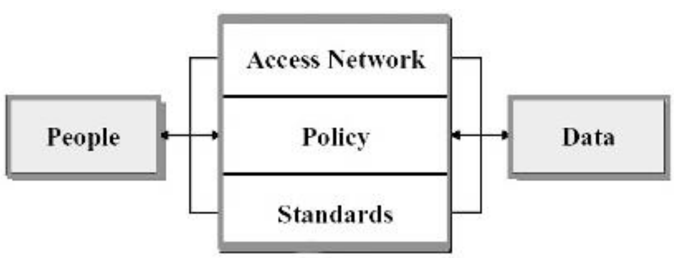


Figure 1. SDI components (Abbas Rajabifard (1997).

As Fig. 2 shows the SDI generation can be divided into three prominent steps (Rajabifard 2006; Budhathoki and Nedovic-Budic 2008) including data-centric SDI, process-centric SDI, and user-centric SDI. While in both data-centric and process-centric SDI users are the passive recipients of GI (Budhathoki and Nedovic-Budic 2008), in user-centric view users are the GI active receivers. Various processes were designed in process-centric SDI based on the data gathered in data-centric SDI generation. However, during designing of those processes, the end-user's preferences and interests have not been considered. User-centric SDI applies users requirements and preferences during or prior to designing SDI. Alternatively, in the data-centric SDI, government sections are the producers and suppliers of GI (Budhathoki and Nedovic-Budic 2008) and users have partial and full contribution in process-centric SDI and user-centric SDI, respectively.

In the data-centric view of SDI in the first generation, data are gathered by government agencies. In order to provide the key GI requirement of a society, various organizations have been supported to supply GI with certain mandates (Goodchild et al. 2007). After producing and gathering data in this type of SDIs, then are defined what the data has to look like. But as this structure is not based on user's preferences, the user may not be happy using the services. There is some dissatisfaction among SDI practitioners and data stakeholders regarding SDI and GIS functional capabilities. Process-centric SDI, as the second generation of SDIs, has been emerging after the rapid evolution of information and communication technologies (ICTs), the Web, and the Internet. Fig. 2 fully explains the difference between the first generation and the second generation of SDI. In summary, process-centric SDI has more attention to the user then data-centric SDI using new technologies such as Web. 2.0, Wikipedia, web service, and so on. However, even process-centric SDIs have not developed beyond the view of the user as an active recipient (Budhathoki and Nedovic-Budic 2008) and still do not fully consider the user's interests for services/infrastructure designing. In the user-centric SDI, the third SDI generation, there is a prominent shift from passive role of the user in the first and second generation (Budhathoki and Nedovic-Budic 2008) into an active role of the user. Fig. 2 shows that the transition from the first generation of SDIs to the second and third generation of SDIs occurred around 2000 and 2007, respectively. This figure specifically explains and compares the difference between various issues including data-centric, process-centric, and user-centric schemes one by one. It should be noted that conceptual apparatuses in SDIs such as metadata, standards, interoperability, policy, and organization have developed (Budhathoki and Nedovic-Budic 2007) over the first and second generations. These concepts could be applied to the third generation, perhaps with moderated compulsory elements.

## 3. Ontology based user-centric SDI for route finding architecture

A user-centric SDI based route finding architecture (USRFA) in GIS environments using ontology decision making approaches enables technology to present user behavior and context information to achieve user's satisfaction. The a prototype USRFA has four essential components, i.e. a user-centric SDI based impedance model (USIM), a geospatial component, a data repository component, and an ontology-based route finding analysis. The research also draws on the experience of implementing the USRFA in Seoul city road network.

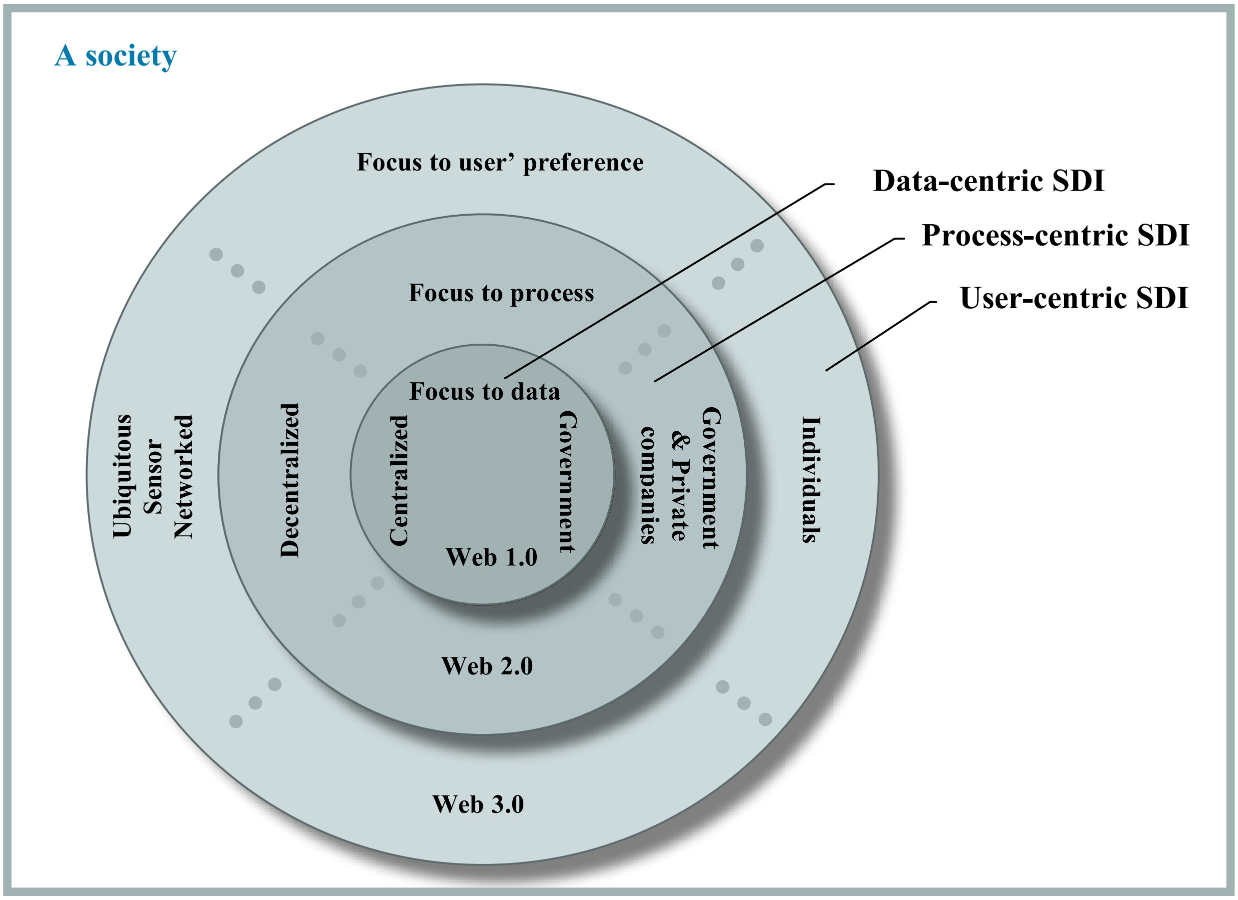


Figure 2. User-centric view acts as a key element of 3rd generation of SDI (Adapted from Rajabifard et al. 2006)

### 3.1. USIM development

The impedance model is the significant part of any route finding algorithm. Therefore, the prototype of USRFA requires the USIM development. To develop the USIM, determining all efficient criteria which is related to user's preferences and contextual situation is crucial. In this study, an ontology-based method using user-centric SDI concept was utilized to obtain these proper criteria. For this, ontology development was performed for USIM to derive the proper criteria of each road segment were determined. The ontology section of USIM includes to main ontology related parts, USIM ontology and task ontology. For the USIM ontology development, the set of intermediate representations proposed by METHONTOLOGY (Lopez et al. 1999) are utilized. Thus, the USIM ontology requires five parts for creation as follows: first, the USIM domain ontology part addresses the purpose of domain knowledge, and intended user for ontology. Second, the USIM ontology conceptualization part adapts an informally perceived view of a domain into a conceptual model represented in the form of graphs. Third, the USIM ontology formalization part alters a conceptual model into a formal computable model. Fourth, the USIM ontology implementation part codes computable models in the syntax of ontology languages, via ontology editors. Fifth, the maintenance part fixes and updates ontologies and their models.

### 3.1.1. USIM domain ontology

USIM domain ontology is a set of expressions in the model that are proposed to represent some aspects of the modeled object as well as to describe the domain knowledge for the evaluation of the USRFA. An USIM domain ontology is a conceptual structure of the problem domain where information which is collected and focused on more specific sets of systems. First, after confirming that there was no existing, appropriate ontology that could represent several criteria with respect to user's preferences and contextual situation, USIM domain ontology was built. Because the objective of this research is to develop an impedance model which can consider users' preferences and environmental condition around the user, thus multiple quantitative and qualitative criteria to create an impedance model are used. Fig. 3 shows the quantitative criteria include road, vehicle, POI (Point of Interest), user and climate. Road criteria designed in a way which covers all the effective quantitative criteria on impedance model such as road length, road traffics volume, road type and so on. POI criteria are one of the significant criteria in impedance model planning which should be considered in designing domain ontology. Police stations, post offices and gas station are some samples of POI as shown in Fig. 3. Quantitative user and climate criteria are two effective criteria in designing USIM ontology. Effective qualitative criteria in designing the impedance model domain ontology include the user and the road criteria as shown in Fig 3. Qualitative information of the user is examples of those criteria such as nationality, individual information, etc. Due to significance of designing domain ontology step, it is important to consider all the effective criteria in problem domain to reach the proper ontology.

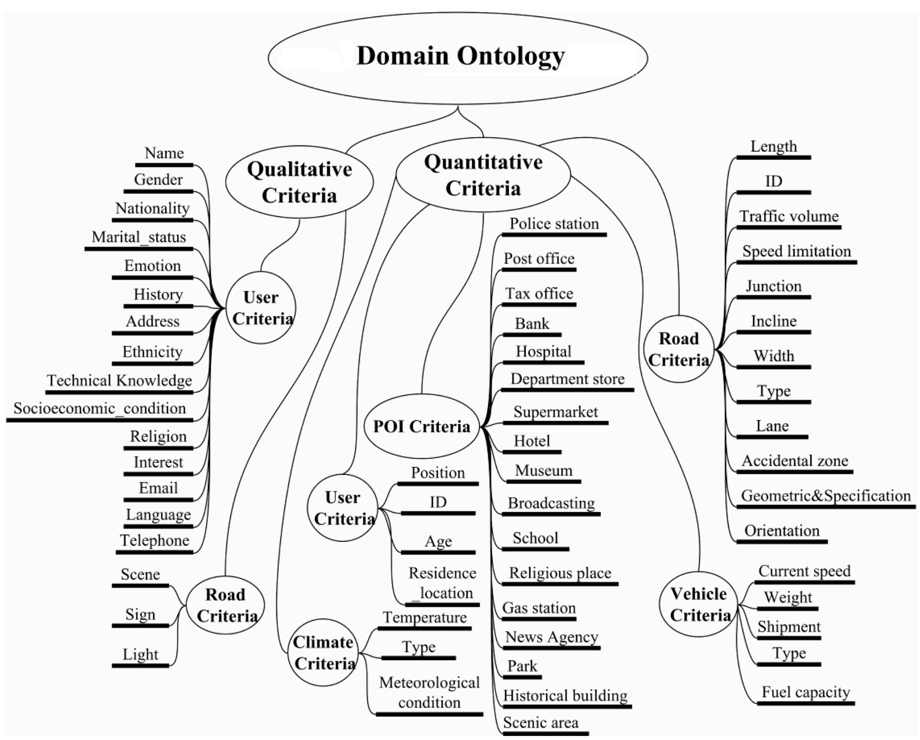


Figure 3. Impedance model domain ontology

After establishing the USIM domain ontology, the USIM ontology conceptualization activity was performed. The conceptualization activities were performed in several steps, such as identifying concepts, their instances, attributes and their values, classifying groups of concepts in hierarchical structure, describing constants and instances in tables, explaining route finding formulas used to infer numerical values of attributes and defining the inference rules. USIM ontology conceptualization includes all the classes which have an effective role in making that. The USIM ontology conceptualization shows the relations and effects of classes and different criteria. Thing class is the highest level class in designing impedance model conceptualization and location, location name, road network, and path classes are key criteria among other criteria such as road segment, POI, user, and vehicle.

Furthermore, USIM ontology formalization and implementation and maintenance activity were performed using a Protégé ontology editor. Finally, USIM ontology was constructed by the aforementioned steps. After creating the USIM ontology, final criteria related to user's preferences and contextual situation were derived (Table 1). The impedance model is built in next section after weighting and integrating these criteria in USIM task ontology section. In this research, some primitive assumptions in using criteria for creation of USIM ontology were used. The criteria which data for them was available were utilized in impedance modelling. In addition, the objective of modelling has significant role to choose proper criteria. For instance, the impedance modelling of this research was performed for within city road network for passenger car. In case of defining impedance model for inter-city road, some criteria will add or removed. Another example regarding the number of POI, there are more than POI used in this research. Due to two above mentioned reasons, the POI noted in Table 1 was used.

Table 1 Final criteria used in user-centric impedance model

| No. | Criteria |
|---|---|
| 1 | Gas stations |
| 2 | Schools |
| 3 | Police stations |
| 4 | Post offices |
| 5 | Religious place ( major Churches, Churches, and Temples) |
| 6 | Supermarkets |
| 7 | Department stores |
| 8 | Road type ( main roads and second roads) |
| 9 | Historical places ( parks, historical buildings, major museums, and museums) |
| 10 | Hospitals (major hospitals and hospitals) |
| 11 | Road traffic flow (high, low, and moderate) |
| 12 | Hotels (major hotels and motels ) |
| 13 | Road length |
| 14 | Tax offices |
| 15 | Banks |
| 16 | News agency (major news agency and news agency) |
| 17 | Broadcasting co. |
| 18 | Scenic area (high, low, and moderate) |

### 3.1.2. USIM task ontology using ANP method

After the USIM ontology creation, for weighting and integrating these criteria the impedance model task ontology using Analytical network process (ANP) technique was employed for the USIM task ontology. The ANP approach is capable of managing interdependence among criteria by obtaining the composite weights (Saaty 1988). In the task ontology, the proper criteria to create the impedance model will be selected using primary criteria and criteria pairwise comparison by the user and the expert knowledge. The ANP is comprised of two sections. The first consists of a network of clusters and criteria that control the interactions. The second is a network of influences among the criteria and clusters. After structuring the ANP based network, the clusters and criteria inside them are compared with one another to be weighted by specialist experts of ANP. Criteria are compared with one another the result is a relative weight granted to them in order to consider all judgments of the experts in one single result the geometric average of these weights is calculated. Finally, USIM is created from sum of weighted criteria.

## 3.2. Data repository component

The data repository component is developed to create ontology data which is necessary for ontology-based model from traditional text based database. The database information is converted to ontology data using mapping process. Ontology data describe a database and it is a specialization of ontology application. The mapping process creates the ontology data from ontology repository component and POI and road network database. This mapping process is performed by mapping between semantically similar schema components. These include the following steps: loading the route finding ontology to the road ontology, creating a road ontology data from road instances and road ontology, creating POI ontology data from POI instance.

## 3.3. Geospatial component

The geospatial component is the main GIS-based part of the architecture. The geospatial component has two critical components, the GIS engine and the interface. A unique feature of the user interface is that it is a GIS based system with an interactive map interface which offers travelers a map interface to select their origin and destination directly on the map. Some map rendering functions such as zoom and pan are also offered. Users can also enter their trip categories and scenarios on the map. Another important part of the geospatial component is the GIS engine. This part is designed to handle the geospatial data of GIS database. Since, the GIS engine is responsible to display map and the final result of route finding analysis in the user-centric ontology-based architecture, it has key role in the architecture.

## 3.4. Ontology-based route finding analysis

The ontology-based route finding analysis was developed including the route finding ontology and route finding task ontology. Like the cost model ontology, the route finding ontology development includes five steps for ontology building. The route finding domain ontology includes the cost model domain ontology in addition to node, link, geometric network and graph class. The domain ontology supplies a conceptual structure of the route finding problem domain that information is collected and focused on more specific sets of system. Route finding conceptualization activity converts an informally perceived view of the domain ontology into a conceptual model represented in the form of class and relationships.

It should be noted that the task ontology is a kind of dynamic knowledge and change based on different situations. The route finding task ontology includes two significant parts, inference engine and route finding algorithm. The type of route finding inference engine in this research is a rule based inference engine. One of the most commonly used in various ways to represent rules is in the form of if-Then rules. A rule-based inference engine use rules to represent other rules. A rule has the form: IF (conditions are satisfied) THEN (take an action or deduce new conclusions), for instance: If (trip type is tourist trip) THEN (find the path which has most attractive places in the vicinity of the path).

## 4. Conclusion

Ontology based SDI has a major role to facilitate a decision-making in a Spatially Enabled Society. A route finding analysis as an important application of ontology based SDI is one of decision-making tools for general users in the society during their travel. Therefore, the rote finding using ontology based user-centric SDI due to presenting user behavior and context information achieves user's satisfaction.

This paper described a user-centric view of SDI new generation called the user-centric SDI. The user-centric SDI facilitates the realization of a spatially enabled society using ontology concept. The user-centric SDI is defined as a SDI which is based on the users' preferences which will increase user's satisfaction in a spatially enabled society. In the user-centric SDI, users do necessarily need raw data but they need special data and services with respect to their interests. Furthermore, in the context of the user-centric SDI, ontologies were utilized to indicate a formally represented knowledge that is mainly used to improve data sharing and information retrieval.

In this research, a prototype ontology-based architecture was developed as a tool and a user-centric SDI framework to route finding analysis by providing a better way of spatial data sharing, access, reusing and management. This architecture will be in a way that any data with any format and structure can be connected to the proposed ontology-based service and after processing, the outputs are given to the user or any other machine-oriented service. The main areas that this study can assist are relevant to flexibility, reusability, accessibility and interoperability of spatial database for any route finding process. Using the user-centric SDI conceptual model using ontology concept as a framework facilitates partnership efforts among different environments and databases in which they can better resolve the current problems with route finding analysis considering user's preferences and contextual information. However, there are some drawbacks of the present research. For examples, using an ontology format database is slower than a text-based database due to the high volume of the ontology based data. Moreover, the route finding process including many middles points takes a long time in obtaining the results. Therefore, ontology based data loading and processing time is high and it creates some limitations in some devices. However, loading and processing time is trivial for the objectives of this research.

To sum up, one of crucial goal of a spatially enabled society is to pay attention to general users' preferences and interests which is one way of spatial enablement to facilitate spatially enabled society. Hence, general users of society are satisfied from the outcomes of any route finding analysis as a significant application in the society.


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