Ontology - based GIS web service for increasing semantic interoperability among organizations involving drilling in city of Tehran

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Abstract

Organizations whose activities involve drilling in city of Tehran cause several damages to urban resources as well as wasting money and human resources, as a result of lack of information about underground facilities, not collaborating to share information with other organizations and inaccurate data. However, if these organization share a standardized set of geospatial data in a unified comprehensive network and develop methods to discover, access and use of this information, can prevent collision of drilling paths.

Local Spatial Data Infrastructure (LSDI) prepares a way for these organizations to share spatial data and have access to the recently updated information of other organizations. From the point of view of SDI, to achieve this level of collaboration, several activities should be considered; one of which is interoperability among geospatial information systems. This goal is attained when these systems have full structural, syntactic and semantic comprehension of each other. As long as syntactic and structural heterogeneity are already handled by different methods, semantic interoperability is considered as the most important factor in data sharing. Ontology, which is specification of a conceptualization, can lead to semantic communication among systems by gathering concepts and definitions from different organizations and finding relationship between them.

In this paper, the role of LSDI to facilitate data sharing was studied, the significance of ontology in semantic interoperability among organizations involving drilling in city of Tehran was investigated and finally an ontology-based GIS web service system was designed and a pilot was successfully applied in one region of Tehran.

Keywords: Local SDI, Interoperability, Semantic Web, Ontology

1. INTRODUCTION

City of Tehran with a population of more than ten million is the largest and the most populated city of Iran, which has increased in area and population in the recent years. Therefore planning and management of such big city, as Iran's capital have great importance and it needs to apply efficient policies by institutions and organizations which have a role in urban management.

The urban utilities such as water, sewage, electricity, gas etc. form cities artery, thus in the urban management system of Tehran, in which different organizations are responsible for develop and manage urban resources and services, management of underground utilities is quite important. Urban utility organizations perform several drillings in the city in order to develop urban resources and services. As a result of different problem, these activities lead to several accidents and damages; Such as breakage of water pipes, leakage of gas pipes, cutting optional fiber, burial of gas hatches and sewage manhole under asphalt etc. It is obvious that cutting high voltage electrical cable has danger of electrocuting worker or explosion; breaking water pipeline damages foundations, cutting optional fiber results in problem in communication and damaging gas pipeline causes a huge fire.

One of the most important problems of drilling in Tehran is the lack of centralized urban management. In order to collaboration in city's common activities, such as drilling, developing public passages, development and fixing buildings, annual plans of executive organizations in technical and service field etc. it is necessary that all urban utility organizations work under a centralized management, so that diversity in underground utilities management would not lead to uncoordinated urban development.

Moreover, by centralizing urban management, different organizations would not take any action without informing other ones, which could result in redundancy and consuming unnecessary financial and human resources, like drilling the same area several times, as a result of organizations unawareness about each other's activates. More over each one of urban utility organizations has its own underground facilities, but usually there are no appropriate spatial maps or data available of them. In other words, organizations do not have exact information about the location of their underground facilities.

Another of the main existing challenges is coordinating urban utility organizations in sharing their spatial data; because in order to prevent probable damages and life threat, it is necessary that all utility organizations act coordinated and be aware of location of each other's underground facilities; while currently, different organizations do not have access to maps and other spatial data of other organizations. So if one organization wants to perform drilling, first they will need to inquire from all other utility organizations. But this inquiry leads to sticking in complex official procedures, which is so time consuming and whereas the process is paper-based, that makes the process inaccurate and unreliable.

With these in mind, if these organization share a standardized set of geospatial data in a unified comprehensive network and develop methods to discover, access and use of this information, can prevent collision of drilling paths with urban facilities and decrease the scope of damages.

The growing need to organize data across different disciplines and organizations and also the need to create multi-participant, decision-supported environments has resulted in using of SDI. SDI is an initiative intended to create an environment that will enable a wide variety of users to access, retrieve and disseminate spatial data in an easy and secure way. In principle, SDIs allow the sharing of data, which is extremely useful, as it enables users to save resources, time and effort when trying to acquire new datasets by avoiding duplication of expenses associated with generation and maintenance of data and their integration with other datasets. SDI is also an integrated, multi-leveled hierarchy of interconnected SDIs based on collaboration and partnerships among different stakeholders (Mansourian et al, 2005).

In this paper, designing and implementing a GIS web services is proposed, which can resolve drilling problems in city of Tehran. This service should undoubtedly be constructed in an SDI environment in order to solve technical and non-technical problems of information exchanging.

In the field of underground facility management, local SDI can help utility organizations move in coordination towards permanent urban development by providing an environment for sharing spatial data. By using local SDI, each organization has access to spatial information of other organizations and can design drilling paths to have the least possible collision with other underground facilities.

One of the most important benefits of LSDI is saving time when inquire from other organizations. So that if a web-based systems is installed and all organizations share their information on the web, each organization can design its suggested drilling path on the web-based map; then inquire from them about suggested path by simply sending to other organizations through the web. As a result, all inquiries are done in the fastest possible way and no more time-consuming pare-based procedures are needed. Another benefit of LSDI is that all shared data is up-to-date, because every organization is obligated to keep the shared data up-to-date; hence other organizations always have access to the updated and most recent information and could make the best decision about drilling paths.

2. LOCAL SDI

Typically, more than 90% of information required for a city's administration has a spatial component, such as parcels of land, road networks, utility infrastructure, emergency services, garbage collection and recreational etc.(Bishop *et* al, 2000).

With development of spatial information technologies like Geospatial Information System (GIS), Remote Sensing (RS), global positioning systems (GPS) etc, everyday a large amount of spatial data in different domains is generated by organizations. In such situation inadequate information or lack of data sharing can increase parallel activities in organizations for data collection and decrease optimum use of current spatial data in execution and planning systems.

SDI by preparing a way for information-sharing and presenting appropriate methods for accessing data prevents duplication of expenses of generation and maintenance of spatial data and their integration with other datasets. SDI can be defined as initiative intent to create an environment in which all stakeholders can cooperate with each other and interact with technology to better achieve their objectives at different political/administrative levels (Chan *et* al. 2001). Such environment is achieved through design, implementation and maintenance of mechanisms that facilitate the sharing, access and utilizing of spatial data across different communities (Rajabifard et al, 2003).

Experiences of developed countries shows where geographical aspects are important for management, decision making and planning, these GISs and SDIs have helped to improve the efficiency of these urban management activities [Bishop *et* al, 2000]. It is obvious that by application of such mechanism in cities, the custodian organizations would function harmonically and cost, time and extra efforts will be saved. Local SDI (LSDI), aims to paving the way for exchange of information amongst city organizations by creating a series of standards and policies, developing technologies, training expert personnel, proper funding etc.

Rajabifard *et* al. (2002a), introduced five core components for SDI together with their relationships that can create an appropriate environment in which people including data producers, users and value-adders can cooperate with one another in a cost-effective and cost-efficient way to achieve their targets more efficiently through data sharing. These components consist of people, accessing network, policy, standard and data.

This paper focuses on standards. Standards define the technical characteristics of datasets. They facilitate data sharing and increase interoperability among automated spatial information systems (Shin, 2003). It is commonly accepted that standards are an essential requirement in the deployment, continuing support and development of a successful SDI (Davies, 2003). With respect to standards component, interoperability, metadata standards, data quality standards, and guides and specifications were identified as four important requirements. Interoperability which is an important subject that needs to be emphasized in the context of standard component is discussed in this paper.

3- INTEROPERABILITY

In order to achieve interoperability between GI Systems, the data from one system must be integrated into another system. However, this integration process is not always supported by the user's system. Therefore, tools are required to achieve interoperability of data sources, problems that might arise due to heterogeneity of the data are already well-known within the distributed databases systems community (kim et al,1991). In general these problems can be divided into three categories:

- Syntactic: Syntactic heterogeneity relates to difference in software, hardware, DBMS and data format which is used by data provider and analyzer.
- Schematic: Schematic heterogeneity relates to differences in data model, data coding and topology.
- Semantic: Semantic heterogeneity is relevant to differences in definition, primitives, structure and coordinate system of data layers. (Mansourian et al, 2005)

One method is designing methods and tools which translate structures, formats and concept of every organization into a common structure, format or concept so that interactions of different systems become possible. For instance, a central database which consists of a set of databases from different organizations is set up, and by equipping it with several integrators, different data are converted to a common form, interoperable among all present databases. However, these integrators con only solve differences in syntax and structure of formats in systems and conceptual problems would still remain unsolved, because each organization defines a feature according to how it perceives the concept of the feature and this concept might be not known to the other organization; or the same concept in two organizations refer to two different features. Therefore Semantic interoperability has been identified as a key issue concerning geographic data sharing between different geospatial information communities (GICs)(Pundt et al,2002) and it is necessary to develop a semantic translator (Visser et al, 2002) in which not only definitions of all common concepts in all organizations, but also the relations between these concepts are properly defined.

3.1. Semantic interoperability in urban organizations

Organizations perceive different urban features as they use or deal with it; therefore it is possible that different organizations have different expressions for the same concept or use the same expression for different concepts. Thus when combining these different terminologies automatically, we face a lot of challenges; because the machine, unlike human is unable to think, comprehend concepts and relate them; also cannot conform a specific expression from an organization's database to a concept used in another organization database unless a tool is designed which gives this ability to the machine. A solution to this problem is provided by the Semantic Web in the form of collection of information called ontologies (Alesso et al, 2005)

Ontology provides "an explicit formal specification of a shared conceptualization"(Gruber,1992), i.e. "it facilitates a formal notation interpretable by machines that enables an shared and common understanding of a domain"(Lacasta et al, 2007). Ontology of geographic kind is designed to yield a better understanding of the structure of the geographic world, and to support the development of geographic information systems that are conceptually sound. They play an essential role in the construction of GIS, since it allow the establishment of correspondences and interrelations among the different domains of spatial entities and relations (Smith et al, 1998). Using ontologies to build GIS applications can help data integration and avoid problems, such as inconsistency between ad hoc ontologies build into the system (Fonseca et al, 2000).

Ontologies can improve accuracy of search on the web. Search engines can look for pages related to an exact concept in an ontology instead of just simply looking for keywords (Berners-Lee et al, 2001). In addition, they can provide some questions to ask from the user in order to improve search results and may suggest more or less general questions considering user answers. For example when a user from gas organization intends to see the valves from water organization, s/he searches for "water valve" in the system; however in known items of water organization, there is no such thing defined as "valve" but instead, the existing items are: Network valve, Automatic control valve, End valve, Fire valve etc. so the system has to be designed to be able to understand the concept that the user is searching for and analyse what the user means on the basis of common expressions which are related to a feature.

Ontology defines the relationship between expressions by building a set of information about a concept, which when different systems need to interact, they can easily understand conceptual information of one another by connecting to relevant ontologies and exchange information. In general, participation in a unified ontology is a prerequisite to sharing information and to gain proper interaction, agreement upon expressions in a participating environment in a specific domain by declaring ontology is necessary.

4- DESIGN AND IMPLEMENTATION

4.1. Proposed System Architecture

The proposed system is an ontology-based GIS web service system in which municipality is considered as the moderator of the system which is sharing urban utility information. Figure1 illustrates architecture of proposed system.

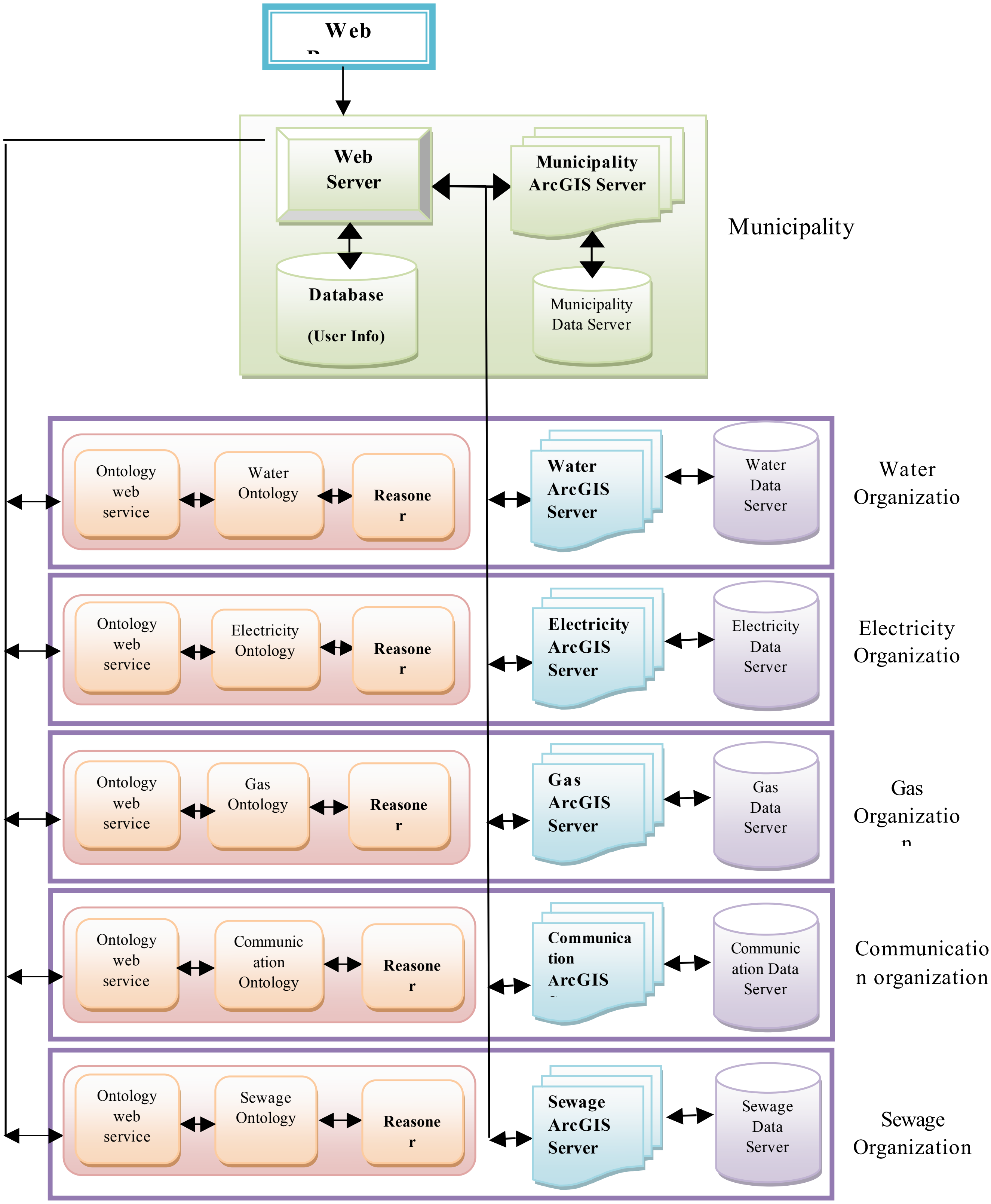
There are six servers, five of which are in organizations of water, electricity, gas, sewage and communication respectively, and the other one is located in municipality. The server of municipality consists of the following parts:

- Web Server: a web-based program which is the interface between users and the system, as well as being responsible for all sub-layer communications and data transfer between different servers.
- Data Server: consists of databases which stare Tehran's spatial information such as highways, streets, parks etc.
- Map Server: is a host for municipality spatial data and exposes them as a service to municipality and network users.

Each one of other five servers which are located in urban service organizations consist of the following parts:

- Ontology Server:
    - Ontology Web Service: receives user's request from municipality web server and forwards it to organization ontology and returns the results from analyser back.

Figure1. Architecture of the Proposed System

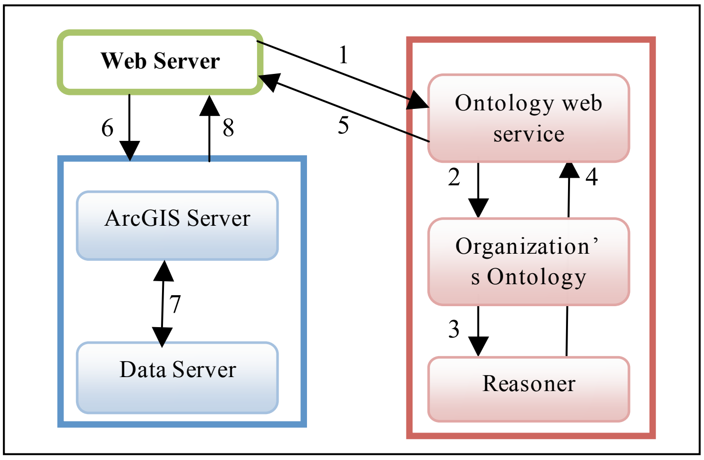


- Organization Ontology: consists of hierarchical descriptions about the items existing and defined in the organization which are stored in an ontology software.
- Reasoner: analyses user's request based on concepts and descriptions available in ontology software and returns the results to ontology web service.

- Data Server: consists of databases which store items of the organization.
- Map Server: is a host for the organization's spatial data and exposes them as a service to local and network users.

Users connect to the web server using a web browser. When the user requests some data from the web server, in the first step it connects to ontology web services of the organizations from which the user needs information. Second step would be forwarding the request by these web services to their organization ontology. In the third step, organization's ontology connects to the reasoner and the request is analyzed by defined concepts and logical restrictions. In the fourth step the results are sent back to the ontology web service which returns the result to the web server at the fifth step. At the sixth step, municipality web server displays the returned results from all requested organizations to the user where the user can select the available concepts from each organization. The web server then connects to ArcGIS Server of the selected organizations and requests the desired data. These ArcGIS Servers at the seventh step interconnect with the data server and send the spatial data to the web server where it is displayed to the user at the eighth step. Figure2 illustrates this procedure.

Figure2. Procedure of the system



5- CONCLUSION

In this paper it was discussed that in order to initiate a coordinated urban underground facilities management, it is necessary that all urban utility organizations, try to cooperate with each other. Since the majority of required information for urban management is geospatial, there should be a system, using which all organizations communicate and share their spatial information. When comprehensive and complete information from resources, services and facilities are accessible, the responsible organizations in urban utility management can make the best and most appropriate decisions in order to optimally allocate resources and develop the city cooperatively. More over semantic heterogeneity as one of the most important barriers against spatial data interoperability was discussed and Ontology was applied as the best solution to overcome these challenges.

Finally a prototype ontology-based GI Web Service system as a tool and an SDI framework to facilitate urban underground facilities management by providing a better way of spatial data sharing, access, usage and management was proposed.

In this system, spatial information of urban utility organization of region no.10 of Tehran was shared by a server machine in each organization through the internet. Using this system users could make the best decisions about drilling paths by having access to correct and updated spatial information of other organizations. Moreover, the results of the pilot project showed that spatial information systems of the organizations have achieved complete semantic interoperability, as if the user needs to view a feature from other organization's underground facilities, the system connects to organizations ontology by the ontology web services, then using of defined concepts and restrictions of each features, find the most appropriate feature and display to users. Finally users could in the shortest possible time inquire about the suggested drilling path from other organizations by sending it on the web-based map.

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