MyGeoOntology – An Information-Focused Geospatial Ontology for SDI towards Knowledge Interoperability

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Key words: Geo-ontology, knowledge interoperability, geo-knowledge

SUMMARY

In the context of spatial information management (SIM) for spatial data infrastructure (SDI), Semantic Technology can assist in geo-knowledge discovery in a data sharing environment by providing knowledge interoperability in the use of geospatial data. Knowledge interoperability is about enabling ready and correct use of the knowledge contained in spatial data, allowing enrichment of the spatial data with relevant information thus enhancing the knowledge that can be associated with the spatial data/features, as well as enabling the use of information which at the first glance seems not to be relevant spatially. This opens up multitude of information from various sources to be analyzed spatially. Geo-knowledge that can be conveyed through this knowledge interoperability can be described as knowledge of an issue from spatial perspective to explain the issue. Furthermore, spatial perspective can be explained as a viewpoint that addresses questions by employing information about location, circumstances of a place, connections and comparison among places, cognizant of an area as a unit, hierarchical relationships of areas, recognition of patterns across areas, and insights into processes that spread spatial patterns across areas. In this aspect, geo-ontology that is placed within SDI can be used to enhance the interoperability of spatial data and consequently enable interoperability of geo-knowledge contained in the data. Currently SDI facilitates the sharing of geospatial data through a catalogue of metadata coupled with connected systems for data producers to register their data and for users of data to access the information. Using geo-ontology, interoperability can be achieved by utilizing the capability of Semantic Technology and the knowledge model in a geo-ontology to mediate the possible different meanings of schemas employed by different data producers in their classification of the geospatial data. A Semantic application with a geo-ontology can use this catalogue to achieve steps in data exploration in similar ways that a user would, with further functionality that it simulates a situation where the user knew about the composition of the schemas used by the different data producers for the various geospatial data contained in the catalogue. Hence within SDI, a geo-ontology can be used to exchange geospatial information unambiguously, to bring out further knowledge related to the geospatial data, and to enable integration of the knowledge with other information from various sources to analyze them using geospatial context.

SUMMARY

Dalam konteks pengurusan maklumat spatial (SIM) untuk infrastruktur data spatial (SDI), Teknologi Semantik boleh membantu proses penemuan pengetahuan geospatial (*geo-knowledge*) dalam persekitaran perkongsian data dengan menyediakan kebolehan saling guna pengetahuan (*knowledge interoperability*) dalam penggunaan data geospatial. "Kebolehan saling guna pengetahuan" adalah mengenai kebolehan untuk menggunakan sesuatu pengetahuan yang terkandung di dalam data spatial secara tersedia dan betul, membolehkan pengayaan data spatial melalui imbuhan maklumat berkaitan lalu meningkatkan pengetahuan yang boleh dikaitkan dengan data spatial, serta membolehkan penggunaan maklumat yang pada sekali imbas tidak berkaitan untuk kegunaan spatial. Kebolehan ini membuka maklumat-maklumat dari pelbagai sumber untuk dianalisis secara spatial. Pemahaman geospatial yang boleh tercapai melalui saling guna pengetahuan ini boleh digambarkan sebagai pemahaman sesuatu isu dari perspektif spatial dalam menjelaskan isu tersebut. Seterusnya, perspektif spatial dapat dijelaskan sebagai pandangan yang menangani sesuatu soalan dengan menggunakan maklumat mengenai lokasi, keadaan sesuatu tempat, hubungan dan perbandingan antara tempat-tempat, menyedari sesuatu kawasan sebagai satu unit, hubungan hierarki antara kawasan, pengiktirafan corak spatial di sesuatu kawasan, dan pemahaman mengenai proses disebalik penyebaran sesuatu corak spatial di dalam kawasan. Dalam aspek ini, geo-ontologi yang ditempatkan di dalam SDI boleh digunakan untuk meningkatkan kebolehan saling guna data spatial dan seterusnya membolehkan saling guna pengetahuan geospatial (*geo-knowledge interoperability*) yang terkandung dalam data. Seperti sediada, SDI memudahkan perkongsian data geospatial melalui katalog metadata disamping penggunaan sistem bagi pengeluar data mendaftar data mereka dan bagi pihak pengguna data untuk mencapai maklumat yang dikongsi. Menggunakan geo-ontologi, kebolehan saling guna data dan pengetahuan geospatial boleh terhasil melalui keupayaan Teknologi Semantik dan model mengenai pengetahuan yang didirikan di dalam geo-ontologi. Dengan demikian, Teknologi Semantik dan geo-ontologi menjadi pengantara bagi makna-makna yang mungkin berbeza di dalam skema klasifikasi data geospatial yang dikongsi. Sistem aplikasi Semantik bersama geo-ontologi boleh menggunakan katalog dalam SDI untuk menjalankan langkah-langkah penerokaan data seperti seorang pengguna tetapi dengan penambahan kebolehan lanjut yang mana aplikasi Semantik tersebut menyerupai keadaan di mana pengguna tersebut berpengetahuan tentang pelbagai komposisi skema yang digunakan oleh pengeluar-pengeluar data geospatial mengenai data yang terkandung di dalam katalog tersebut. Oleh itu dalam SDI, geo-ontologi boleh digunakan untuk pertukaran maklumat geospatial dengan jelas, boleh menghasilkan pengetahuan lanjut berkaitan data geospatial, dan membolehkan integrasi pengetahuan dengan maklumat lain dari pelbagai sumber untuk menganalisis maklumat tersebut menggunakan konteks geospatial.

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1. INTRODUCTION

Spatial Data Infrastructure (SDI) can benefit from development in Semantic Technology since Semantic applications can provide solution to retrieve, share and analyze information and combine the information with the relevant geospatial aspects. Particularly for SDI, Semantic Technology can assist in geo-knowledge discovery in a data sharing environment.

Semantic Technology enables processing of information by providing contextual meaning of the information through its ability to organize the information using ontology and ways to process the information employing logic almost similar to human thought processes.

In the context of spatial information management (SIM) and SDI, Semantic Technology can provide interoperability in the use of geospatial data. As noted by Egenhofer (2002) geospatial "Semantic Web has a vision in which locations and location-based services (LBS) to be fully understood by machines" and that Semantic interoperability is a prerequisite to integrate information across domains.

Basically, MyGeoOntology will complement the Malaysian Gazeteer; which to a large extent will be similar to the efforts in semantic works by Ordnance Survey in Great Britain and by the Center of Excellence for Geospatial Information Science (CEGIS), USGS in their National Map project in the United States. However, the difference in MyGeoOntology will be about the focus on information (attributes, describing the places) and not so much on the geospatial features. Therefore, while others may emphasize the capturing of knowledge in topography map to make it usable by applications, we emphasize on the usage of spatial knowledge in processing of information.

This paper describes MyGeoOntology that forms part of a solution to enable the realization of spatial knowledge (geo-knowledge) contained in geospatial data. Geo-knowledge can be defined as knowledge of an issue in a spatial context or explanation of a phenomenon through spatial context.

The purpose to include geo-ontology in SDI is to facilitate interoperability of knowledge thus enabling the interchange and sharing of geospatial knowledge. Yang C., *et al.* (2010), quoting Raskin and Pan in their 2005 paper, noted that "geospatial knowledge refers to a shared understanding of geospatial terms and the collective, expert intelligence it makes available".

It can be added that spatial context can be explained as a viewpoint that addresses questions by employing information about location, circumstances of a place, connections and comparison among places, cognizant of an area as a unit, hierarchical relationships of areas, recognition of patterns across areas, and insights into processes that spread spatial patterns across areas.

Against this background, the objective of the paper is to give an overview on how this knowledge interoperability can be done.

2. KNOWLEDGE AMBIGUITY IN GEOSPATIAL DATA AND THE ROLE OF SDI

Geographic considerations such as spatial features, locations, place names, interrelationships, and attributes are often ambiguous and imprecise. People have different ways to describe a location according to their perceptions, different places may have the same name, and specification of spatial interrelationships such as distance and surroundings are influenced by one's experience.

In exchanging and sharing of geospatial data, although the data seem to be more precise than perceptions described above, the way a piece of data is catagorized, its attributes, and its assignment into classes and schema are subject to similar perception and understanding about the data and the intended use. In this aspect, geo-ontology can supplement SDI where it can be a central knowledge repository to provide comprehensive common sense knowledge about locations (Harvey F. *et al.* 2011).

2.1 Semantic Technology and Ontology

In contrast to conventional information processing where it often requires human to interpret the information, Semantic Technology enables machines (computer programs) to understand the piece of information being processed and to carry out the reasoning likened to human interpretation. Hence machine-to-machine communication can take place without ambiguity. Associated with this kind of application using Semantic Technology is ontology.

Ontology is an explicit specification of knowledge in a structure where concepts relevant to the knowledge that the ontology represents are organized unambiguously. Using semantic technology, information can be used (and shared) in its definitive term. This is important because much information has vague meaning including those that are conveyed through geospatial data.

Specifically for geospatial fields (and use of GIS data across various domains) Wang, Y., *et al*. (2007) noted that geo-ontology is the formalization of concept models of geographic information to enable the use of the information by both machine and human. The concept models, furthermore, is the abstract models generalized from cognition of geographic phenomenon and explicit restrictions applicable to the concepts (*ibid*.).

Thus an ontology for geospatial data will include geospatial entities, its associated properties and metadata, the geographical features, and topological relations between the features such as "part of" and "near" (Giunchiglia, F., *et al.* 2009).

2.2 Geo-Ontology and Spatial Data Infrastructure

In the context of geospatial data sharing, ontology (particularly geo-ontology) can enhance the current effort as undertaken through SDI. SDI or Geospatial Data Infrastructure (GDI) facilitates the sharing of geospatial data mainly through a catalogue of metadata coupled with connected systems for data providers to register their data and users of data to access the information.

In Malaysia, this geospatial data sharing facility is provided through Malaysian Geospatial Data Infrastructure (MyGDI), which is an initiative by the government and it includes among others, the policy, data and geospatial information, besides the enabling system for data sharing. Part of the system, MyGDI Catalogue Gateway enables on-line discovery of geospatial data that are published by the participating agencies. Through this system, the metadata can be linked to visualization of the geospatial data through map service.

Therefore if an agency is using a piece of spatial data that is obtained from external sources, through geo-ontology, the agency can be assured that the data fits the intended use. Of course this can be ensured through human inspection of the metadata but a geo-ontology can contribute towards its automation.

Beyond this possible automation, knowledge interoperability is also about enriching spatial data (features as well as the attributes) with relevant information thus enhancing the knowledge that can be associated with the spatial data/features.

The Malaysian geonames, for example, can have the information contained in the database to be further associated with other descriptive information about the places. This can include the region within which certain groups of localities are located, the characteristics of the place (economic, social, and demographic), and common unofficial names that are not included in the register of geonames (USJ and Taipan, for example, in addition to the official names of Subang Jaya Municipality or the District of Petaling that contains both USJ and Taipan).

This enrichment is possible due to the schema that is semantic-aware (meaningful according to context of use) where the domain of the features and attributes, the relations, and the range of the relations are structured according to the corresponding classes/concepts in a specified geo-ontology. As an example given by Maltese V. and Farazi F. (2013), if the domain of the attribute "population" is "populated place", which has been specified as the main class, it can be applied that the domain of the attribute "population" is also relevant for "city", "town" and "village", which are subclasses of "populated place".

Furthermore through a geo-ontology, knowledge interoperability also means enabling the use of information that is, at the first glance, not to be relevant spatially. This opens up multitude of information from various sources to be analyzed spatially; news about health information/disease outbreak, crime and other social situations, intelligence and emergency incidences, etc are possible to be digested through a spatial analysis.

3. MYGEOONTOLOGY

Using MyGeoOntology, a geo-ontology for Malaysia, geospatial knowledge about a place can be realized and usable in the right context by different users and applications seamlessly. In short the geospatial knowledge becomes interoperable. Hence the keyword here is knowledge interoperability where all this while much attention has been given on geospatial data interoperability.

Although data interoperability is important and often touches upon significant questions about data format, map projection, scale, and so forth, given the current situation where much progress for data interoperability has been achieved mainly through standards (OGC, etc.), the need to focus on knowledge interoperability must also be addressed.

Briefly, knowledge interoperability is about enabling ready and correct use of the knowledge contained in spatial data. The way in which information in geo-ontology is modeled makes it possible to achieve interoperability of geospatial knowledge for two reasons. Firstly, in general ontology itself addresses the ambiguity of information. In addition to this, the encoding of knowledge model contained in a geo-ontology is done independently from specific applications, consequently, enabling the use of the geo-ontology to convey the meaning of the information neutral from specific applications. This is in contrast to specification of relations in conventional database schema (database model) that meant to serve a specific application for the database.

3.1 Uses of MyGeoOntology

MyGeoOntology aims to enable interoperability of geospatial knowledge at three levels. At the first level, MyGeoOntology can be used to realize the possibility of exchanging geospatial information unambiguously. At the second level, through MyGeoOntology the geospatial data can be enriched to bring out further knowledge related to the data; while at the third level, MyGeoOntology can further be used to enable integration of the knowledge with other information using geospatial context. These are discussed in turn below.

3.1.1 Unambiguous Exchange of Geospatial Information

The first level of knowledge interoperability can be illustrated by the common approach in the use of semantic technology and the creation of geo-ontology that has been undertaken by mapping agencies such as CEGIS, USGS and the Ordnance Survey where the works include, among others, specifying the topographic feature semantics to create richer data models.

Many geospatial data in GIS are created and used by different agencies; many of these geospatial data refer to common features although the purpose they are created may differ according to the works undertaken by these agencies. Wang, Y., *et al.* (2007) refers to this as semantic heterogeneity where different experts from various domains have different emphases on the same dataset. This often results in different schemas of the geospatial data although the basic spatial elements are the same. Land use classification, building usage and road classes are some examples of schemas. While building footprints can be the basic geospatial features for both land use classes and building usage schemas, the grouping of the building footprints between these schemas may be different.

A geo-ontology enables exchanging of information about existing geospatial data that may have different connotations between the various agencies. The focus in this first level of interoperability is to enable the exchange of topographic information and to enrich the geospatial data in the topographic database with attributes in the correct context.

Using MyGeoOntology, this interoperability of geospatial data can be tackled at the catalogue level in SDI, rather than ontologizing the spatial features, to mediate the different meanings in the classification of the data. Arguably this is easier to achieve than the lengthy works involved in creating ontologies of the spatial features. The catalogue can describe the schema of data as it exists and provides the link to the actual data while enabling a Semantic application to use the catalogue together with MyGeoOntology. This approach, therefore, will achieve steps in data exploration by machine similar to using the catalogue by a user who has knowledge about the making up of the schemas of the various geospatial data contained in the catalogue.

Through the steps, assessment of the data for its fitness of usage is done at the schema level (that depended on the ontology of metadata) rather than at the individual spatial features.

3.1.2 Enriching Geospatial Data

The second level of knowledge interoperability facilitated by MyGeoOntology is about enabling further knowledge to be associated with geospatial data. As geo-ontology is structured to unambiguously represent geographic concepts (place names or geographical features, the descriptions, and the interrelationships, for example), it can become the base for other related concepts (about accessory information) to be linked to the geographic concepts thus deepen the knowledge that can be acquired through the structure the ontology provides.

Accessory information that can be associated with geospatial data is widely available. As an example, the work presented by Giunchiglia, F., *et al.* (2009) showed how Wordnet, a lexical database for English language that contains synonyms and relations between them can enrich geographical data using geo-ontology to create GeoWordnet. Other accessory information that can be included into a geo-ontology includes cultural information describing a place (e.g., east coast state) and other socioeconomic or geopolitical information.

Apart from introducing accessory information to MyGeoOntology, the knowledge about geospatial information it holds can be enhanced by adding further specification to the data. For example, specifying properties such as "located in" of the data will identify the hierarchical levels of the places in their relationships with each other. This information will help to carry out logical inference in querying of the data.

With enriched geospatial data, interoperability is enhanced since the meaning is clearer.

3.1.3 Enabling Integration of Knowledge

The third level how MyGeoOntology enables interoperability of geospatial knowledge is by enabling further integration with other sources of information, beyond the accessory information discussed in the above section. The works in literature about geospatial information retrieval (GIR) is relevant in this context where typical example would be the case where information retrieved from the web will be geo-tagged for its location. In the process, place names in the information is usually matched with location reference obtained through a geo-ontology.

This approach can be further expanded to include spatial keywords in addition to place names. For example, in parsing strings of words from a newspaper article, by using MyGeoOntology, a semantic application can assess spatial keywords such as "surrounding", "north", or "near" to assess whether these keywords are actually geographic keywords through the context of the article and the knowledge encoded in geo-ontology.

3.2 Example of Use and Further Application of MyGeoOntology

We have developed an exercise in a data sharing environment to illustrate machine-to-machine communication that integrates disparate pieces of information which requires knowledge interoperability supported by the use of geo-ontology. Putting this work within MyGDI is suitable as noted by Lacasta, J., *et al.* (2007, n. d.) that web ontology services can be utilized within an SDI environment to process information and bring out the knowledge that can be gained from the information.

MyGeoOntology in this proof of concept exercise is employed to provide an integrative approach in knowledge sharing in relation to biological conservation across agencies. This involves obtaining data from various agencies that deal with flora and fauna in their works (forestry, wild life, and marine life) where data from each agency need to be compiled to obtain the knowledge about biodiversity. The proof of concept is based on the needs identified by the Malaysian National Policy on Biological Diversity to create an integrative approach across sectors related to biological conservation. The solution presents a step towards building knowledgebase of biological issues that will enable the discovery of biodiversity information.

The National Policy on Biological Diversity also has the intention to have biological diversity considerations to be integrated into sectoral planning strategies, which activities are carried out by various agencies. Therefore, to have MyGeoOntology and the domain ontology for biodiversity located within the current MyGDI infrastructure is in line with this intention indentified in the policy as MyGDI can provide the data sharing environment for all relevant agencies to access the biodiversity information for their use. To facilitate this, MyGDI can include semantic capability in the use of MyGDI Catalogue Gateway and information from the Malaysian Gazetteer to enhance the interoperability of knowledge related to biodiversity considerations.

The following Figure 1 presents the conceptual configuration of the solution that involves the various agencies and the way in which the knowledge can be further shared through web-based applications and interfaces.

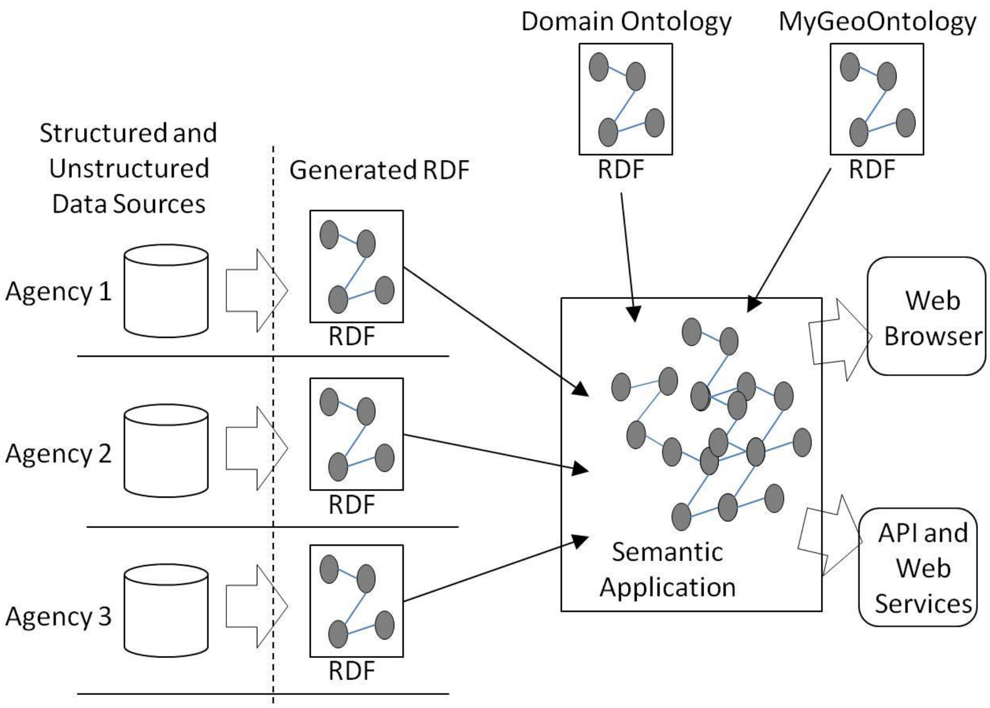

Figure 1. Use of Data from Multiple Agencies and Access to the Federated Data by Other Applications and Users through Semantic-based Solution

In the solution, MyGeoOntology helps in querying and interpreting geographical terminology while Semantic application helps to make sense of the available biodiversity information, relevant business workflows and processes which are carried out and managed by different people for different purposes.

Supported by MyGeoOntology, the solution attempts to identify areas with environmental concerns using information from the agencies that comes in various forms including from databases, spreadsheets, and textual reports. In processing of the information, MyGeoOntology is used to organize issues according to location including locality, characteristics of the areas such as urban, agriculture, forest reserves, and proximity of environmental-related issues to human activities. Besides the information that are obtained from the agencies, open public information such as news clippings can also be introduced into the analysis to add in current environmental issues, and organize them into categories that may include poaching, forest, fishing; development (hill side, for example), and the occurrence of this in terms of location and time.

It can be highlighted that in the exercise all three levels of interoperability of geospatial knowledge are applied, where:

- extraction of information from the agencies has to be done in the right context and unambiguously,
- identification of the areas with environmental concerns using information from the agencies requires enrichment of the data, supported by the model of knowledge in MyGeoOntology and domain ontology, therefore the semantic application can derive additional information to address the question, and
- pulling together all information from the various sources to be processed illustrates the capability to integrate knowledge from these sources to address the question.

Finally, note that MyGeoOntology is a re-useable repository of knowledge that can be used for other semantic applications. As discussed, making MyGeoOntology to be accessible in MyGDI for data sharing environment enables knowledge interoperability by allowing intelligible processing of geospatial information.

4. CONCLUSION

Given that geospatial data and information are naturally ambiguous, knowledge interoperability is important to make them to be used readily and correctly. This importance is further accentuated due to the fact that geospatial data, once created, are often reused and that the usage may be for different context or for different domain than the original context and domain when the data were first created. This paper highlights a solution Semantic Technology and geo-ontology can provide to mediate the possible different meanings that may be associated with geospatial data.

Development in technology across the decades has helped to ease problems in geospatial data management and usage. If previously users in geospatial industry relied on file base solutions, the advent of relational database has provided many advantages including having logical relationships and rules to be embedded in a database.

The idea forwarded in this paper leverages further on the advantages of this established technology in data management. Hence, rather than reworking on how elements of data are stored in a database, the focus is on how to intelligently search and access this wealth of geospatial data in databases. Currently in SDI environment, this search is provided through catalogues; the suggestion in this paper is to enable Semantic application to use the catalogue to mediate the different meanings in the data that result from different ways they are classified or categorized by data producers and data users.

Besides unambiguous sharing of geospatial data, additional knowledge that are locked in the data can be made explicit through knowledge model that can be encoded in geo-ontology. As described in this paper, this allows the discovery of geo-knowledge. Identification of areas with environmental concerns as shown in the proof of concept exercise discussed in this paper is an example of geo-knowledge discovery.

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BIOGRAPHICAL NOTES

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