Constructing Ontology for Planning Knowledge Management System

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ABSTRACT

In this research, a Planning Domain Ontology is constructed in the purpose of managing the knowledge complexity and semantic ambiguity which becomes serious nowadays. Ontology study has been raised in recent years and it’s believed to be a promising method of describing data and representing knowledge, in order to assist in problem identifying, decisions making, and knowledge management. This paper illustrates essential concepts and suggests a process to construct a Planning Domain Ontology within a specific scope of developing climate change adaptation plan in Taiwan. We find that replicate and shifting concept can be successfully represented using ontology. Two local cases are also demonstrated to show the usefulness of ontology in spatial planning.

1 INTRODUCTION

It’s an age of information explosion. Large amounts of published data and information are transmitted through the network quickly. It is gradually obvious that, in communication between people, information is much easier to access, while confusion and misunderstanding are increasing simultaneously. Part of reasons is that knowledge itself is also transforming, evolving, reflecting, reforming. Urban planning is not an exception to this situation. To deal with it, ontology has been employed by many researchers due to its capacity of knowledge organization, sharability, and interoperability (Hauda et al., 2010). And most of all, ontology can also act as a knowledge base for some knowledge domain which is continuing evolving.

This research proposes a special ontology by integrating planning theory and knowledge engineering for spatial governance and strategy-making concerning climate change adaptation. The objectives of this research are: 1) identifying special needs for knowledge manipulation in spatial planning process, 2) building a framework for planning ontology based on Taiwan’s experience, 3) proposing a construction process of Planning Domain Ontology including the several phases such as design, construction, adjustment, application.

In this paper, we illustrate a process of developing Planning Domain Ontology by the case of climate change adaptation planning in Taiwan. First we briefly review the ontology development and some applications in planning domain. In the methodology section, we point out some essential concepts and ideas for constructing the ontology which need to be clarified before starting the process. Then, we introduce the process step by step and the tools we used in each step. In the fourth section, the result of Planning Domain Ontology for climate change adaptation planning in Taiwan is shown, and two examples are compared to show how the ontology can help to make suggestion in planning. Finally, discussion and suggestions are made.

2 BACKGROUND

2.1 Ontology

"Ontology" is originally a term from philosophy. Computer scientists and information engineers then apply this idea into knowledge engineering, where ontology serves as a formal representation of concepts about their relationships (Zúñiga, 2001). The development of ontology has diverse directions. Most of them are related to information system such as knowledge engineering, knowledge representation, language engineering, database design, information modelling, information integration, information retrieval and extraction, knowledge management and organization (Guarino, 1998). These researches made computer more capable of reading and processing ontology.

In addition to information fields, ontology has been applied to various domains in recent year, because it provides promising technology for their domain knowledge which is rapidly expanding (McGuinness, 2001). In most applications, ontology can be employed as dictionary and/or lexical framework. The dictionary is a collection of terms and their commonly accepted definitions, while lexical framework is designed to share information between different communities (Smith, 2003).

Gruber (1993) defined the ontology as "a logical theory accounting for the intended meaning of a formal vocabulary, i.e. its ontological commitment to a particular conceptualization of the world." Guarino (1998) followed this definition and clarified the relationships between vocabulary, conceptualization, ontological commitment and ontology. Ontology indirectly reflects a set of ontological commitment by approximating as best as possible from its current model to the ideal model.

Therefore, in the initial process of creating domain ontology, domain experts and knowledge engineers should be involved to identify the key conceptualizations (Missikoff et al., 2002), which is divided into two levels. Top-level ontology describes general concepts. Domain ontology belongs to lower-level ontology, which shows the specific knowledge structure of a specific domain, sometimes for some specific purpose. Domain ontology is considered as a specialization of top ontology in a designated domain.

Though there are several methods for constructing domain ontology, selection of appropriate ontology not only depends on its purpose and requirement, but also strongly on the language it uses. Zúñiga (2001) described that the relation between philosophy and information systems was analogous to that between two distant countries with a distinct language and culture in each. As well as the relationship between conceptualization and the related language, the bridge should be particular for distinct language and culture. An ontology and underlying conceptualization is language-dependent (Guarino, 1998). For this reason, Huang et al. (2005a) led an ontology study for Chinese language, and come out with a general ontology based on SUMO. However, it is still lack of domain ontology developing in Chinese language.

2.2 Ontology in Planning Domain

Ontology development in planning domain is still at an initial stage. Most of them were designed for some special management purposes or tasks, such as government budget ontology (Brusa, 2006), health care project (Ali, 2010), public transportation ontology for user travel planning (Timpf, 2002; Houda et al, 2010), course of Action Planning Ontology (Darr et al., 2009), Disaster Recovery Scenarios ontology framework (Ramanathan et al., 2012). However, there’s still a lack of a method for planning ontology which is used to enhance the
capability of knowledge understanding, not only for knowledge querying, under a complex situations.

"Reaching commonly accepted definition" is one of major objectives of ontology building researches. Comprehensive process is usually needed to implement it (Brusa et al., 2006). However, “commonly accepted definition” may change or evolve due to outside environment transition. This argument is also in evidence in planning work. Planning is primarily a continuing process with integrating different ideas into alternatives for various scenarios. It indicates that Planning Domain Ontology should have some functions accommodating diverse, even contrary, ideas, information, and meanings. Furthermore, it is not only about the meanings of words, but also about knowledge structure behind words. This capability is particularly essential during communication process. In our experiences, it's better to explore cognitive differences among stakeholders before trying to obtain common consensus, agreement or conclusion. Planning is mainly about communication while misunderstandings exist between the common people as well as professional experts.

Climate change adaptation is a good example for such circumstance. The issue of climate change adaptation has been raised since IPCC proposed in 2007, and attracted many researchers, countries, and local governments to study. In Taiwan, the impact of climate change is also very serious. The Taiwan government completed the Adaptation Strategy to Climate Change in Taiwan in 2012, and is promoting local government to develop their own local climate change adaptation planning. At this stage, we encounter confusing expressions from different researchers, experts, journalists, government officials, and the common people. For example, the terms “climate change” and “land use” both have very broad meaning. Scientists, engineers, economists, sociologists, and planners stand in different fields and have different focuses, but speak in the same language even use the same term.

3 METHODOLOGY

Developing ontology could follow a systematic approach. In this section, we separate the methodology into two parts. Firstly we introduce some concepts and ideas, and then illustrate the constructing process.

3.1 Building Concepts for Planning Domain Ontology

To develop the Planning Domain Ontology in the case of climate change adaptation planning for local government, the followings are some important ideas to be understood and defined. Be aware that Planning Domain Ontology is a language-dependent and it may also be experience-based.

3.1.1 The Ontology Goal and Users

The goal of Planning Domain Ontology is set to represent a full concept of climate change adaptation planning in both national and local government in Taiwan. Climate change adaptation is a new issue which has been raised for recent years. In this initial stage, it’s important to educate the public as well as planning experts what is climate change adaptation. Two questions are set: 1) What is climate change adaptation? 2) How to develop climate change adaptation strategies or plans for local governments in Taiwan? Basing on these two concerns, we here focus on ontology for local governments and experts.

3.1.2 The Ontology Scope

Climate change adaptation is known as a very local issue according to local conditions. Council for Economic Planning and Development (CEPD) in Taiwan developed the
Adaptation Strategy to Climate Change in Taiwan in 2010. Local governments now are encouraged to develop their own climate change adaptation plans. The scope of ontology in this study will base on the experiences in Taiwan. Within this scope, the ontology emphasizes on how local governments promote climate change adaptation plan, what data and information should be collected, and what aspects should be considered.

3.1.3 Processes and classifications

It will be much easier to realize how a knowledge structure looks like by classifying key concepts and identifying processes first. For example, the Adaptation Strategy to Climate Change in Taiwan (CEPD, 2012c) illustrated eight sectors of adaptation issues including disaster, infrastructure, water resources, land use, coastal zones, energy supply and industry, agriculture production and biodiversity, and health. Fig.1 shows these eight sectors in national adaptation framework and each of them has ministry and/or council members. Each sector should promote its own adaptation strategies and action plans, following the processes which CEPD suggested in Fig.2.

Actually, classification and process are two different constructions in knowledge engineering, and they are described separately in some modeling language such as UML. Figs. 3 and 4 are corresponding structures of classification (Fig.1) and process (Fig.2).

![Figure1. National Climate Adaptation Framework](source: CEPD(2012))

![Figure2. Developing Process suggested by CEPD]
3.1.4 General Concepts Level and Specific Terms Level

In general, ontology is a structure with concepts (classes), instances and relationships among them (Zúñiga, 2001). The relationships under construction depend on domain concepts and intentional design. In many researches, concepts and instances are distinguished based on the technique of object-orientation. For example, Brusa et al. (2006) divided developing process into two phases: specification and conceptualization. Specification phase is to acquire knowledge of the domain, and the conceptualization phase is to represent the structure of knowledge, strongly depends on the language and environment. In our research, we follow the idea and make it more complicated. The Planning Domain Ontology divides the knowledge structure into two levels: General Concepts Level and Specific Terms Level.

Be careful to the purpose of this ontology system, which is set for communication, instead of querying or decision-making. Therefore, the complication is that we allow instances with a same term in Specific Terms Level can be mapped to different classes in the General Concepts Level. And mappings are determined according to the sentences or expressions in reports, materials, minutes or records we collected. For example, in communication, “adaptation” and “adaption plan” will possibly mix used, each has different concept structure. Experts frequently make classification in a specific way. For example, “We can classify the Land into Mountains, Hillsides and Plains according to the geographical terrain” or “We can classify the Hillsides into appropriate farming, appropriate foresting and enhanced conservation according to the land use management.” Continuing decomposition, “land, mountains, hillsides, plains, geographical terrain” and “hillsides, appropriate farming, appropriate foresting, enhanced conservation, land use management” are two groups of Specific Terms corresponding to the same General Concept by the rule of “classify A into B according to C.”
During the work of mapping concepts between general and specific levels, we find two phenomena, Replicate Concept and Concept Shifting. They often appear when people are speaking or writing, which planners should pay attention to.

3.1.5 Replicate Concept

Replicate Concept is common in communication which can be captured via mapping between the General Concept level and the Specific Terms level. Another benefit of adopting the mechanism of Replicate Concept is that it provides extendable space for the future ontology development.

“There are two concepts, adaptation and mitigation, associated with the impact of climate change. To enhance resilience, it’s important for government to develop an adaptation plan for leading the people to change their lifestyle and adapt to changing environment. But it lays on the premise that the people have the awareness of climate change and some collective consensus...."

In the speaking record above, a structure with three levels is easily identified as "climate change" in the first level, “adaptation” and “mitigation” in the second level, and “adaptation plan”, “environmental awareness”, “collective consensus” lie in the third level. But following the flow path of sentences is not always an efficient or practical method for constructing knowledge structure, especially when the scope of the knowledge domain is large. Because while the number of levels is unlimited extended, it possibly makes more confusion by homographs. If one term holds several unequal meanings may simultaneously exists in different locations, then the larger distance between levels is, the lower ability of awareness to each other will be. One of our purposes of Planning Domain Ontology is to handle the situation of heterogeneity in an effective way.

Therefore, the ontology carefully analyzes the knowledge correspondence between General Concepts Level and Specific Terms Level. Table 1 shows how different the structure can be represented with/without replicate concepts. Replication makes a 3-level structure be divided into two 2-level structures, mapping to the same General Concept 2-level structure. Two instances both called “adaptation” will be connected with another relationship. The advantage is that it will not be too complicated in the level of Specific Terms Level if the General Concepts Level has well defined and designed.

Table 1. Comparison between structure with and without replication

<table>
<thead>
<tr>
<th>Structure without replication</th>
<th>Structure with replication</th>
</tr>
</thead>
<tbody>
<tr>
<td>General Concepts Level :</td>
<td>General Concepts Level :</td>
</tr>
<tr>
<td><img src="#" alt="Climate change issue" /></td>
<td><img src="#" alt="Climate change issue" /></td>
</tr>
<tr>
<td><img src="#" alt="Response concepts" /></td>
<td><img src="#" alt="Response concepts" /></td>
</tr>
<tr>
<td><img src="#" alt="Tasks for concepts" /></td>
<td><img src="#" alt="Tasks for concepts" /></td>
</tr>
</tbody>
</table>
Specific Terms Level:

- Climate Change
  - (Climate change issue)
- Adaptation
  - (Response concepts)
- Mitigation
  - (Response concepts)
- Adaptation Plan
  - (Tasks for concepts)
- Environmental awareness
  - (Tasks for concepts)
- Collective consensus
  - (Tasks for concepts)

Specific Terms Level:

- Climate Change
  - (Climate change issue)
- Adaptation
  - (Response concepts)
- Mitigation
  - (Response concepts)
- Adaptation Plan
  - (Response concepts)
- Environmental awareness
  - (Response concepts)
- Collective consensus
  - (Response concepts)

3.1.6 Concept Shifting

The shifting of concepts is also a common phenomenon when people try to express knowledge by a "shortcut." Take an example as following:

“To do the vulnerability assessment, you need to consider the exposure, sensitivity, and adaptive capacity. Exposure is defined as degree of climate stress upon a particular unit of analysis. It usually includes factors such as magnitude and frequency of extreme events (IPCC, 2001). Sensitivity is the degree to which a system will be affected by, or responsive to climate stimuli (Smith et al., 2001). Adaptive capacity refers to the potential or capability of a system to adjust to climate change (Smit and Pilifosova, 2001). In the case of water resources vulnerability, we take the rainfall strength and frequency as exposure variables, the water usage as sensitivity variable, and the existing emergency measures are the adaptive capacity variable. Therefore, to analysis the vulnerability of water resources, we need to do comprehensive survey of current water usage. If the result shows high vulnerability, we need a well water usage management to enhance the resilience of water problem under the threats of torrential rain and drought.”

It is talking about a term, “water resources vulnerability,” but it related to at least two conceptual structures (classes structure) appeared in this paragraph. One is “vulnerability assessment” and another is “adaptation action plan.” It is talking about several concepts using the same term. It is an unconscious shifting from a structure to another structure during the presentation. Table 2 shows two different structures in both General Concepts and Specific Terms levels. The description of “vulnerability assessment” has shifted from one concept to another.

3.2 Constructing Process of Planning Domain Ontology of Climate Change Adaptation

The above showed conceptual structures of climate change adaptation policy, while this section is going to introduce the process of building a corresponding knowledge management system with Planning Domain Ontology. The steps are as follows. (1) A bunch of representative sentences is firstly collected from books, conference proceedings, and
meeting minutes concerning resilient community planning. (2) Key nouns and verbs, which described concepts and their relationships respectively, are extracted from collected sentences. (3) A prototypical ontology is built based on the extracted concepts (nouns) and relationships (verbs), which are further classified into synonym, hypernym, hyponym, part meronum, etc. (4) A web site system with the capability of editing and browsing the prototypical ontology will be developed. (5) The ontology will be continuously adjusted by inviting experts in spatial planning and other fields to review it. (6) A rule-based reasoning system will be built to explore knowledge embedded in the ontology. The first three steps take responsibility of building Planning Domain Ontology, and the last is working on the application phase of ontology, so called the knowledge management system.

Planning is a continuous process of considering a variety of factors and opinions from the professional and the non-professional. For this reason, planning ontology should place importance on the interface for planners and outside users such as experts from other fields, decision makers, or even local residents. For those who are not familiar with ontology, this system should provide an easy way to figure out and express terminologies in a precise way, in order to enhance the ability of interaction and communication with others.

Table 2. Comparison between two structures for the term “water resources vulnerability”

<table>
<thead>
<tr>
<th>Structure “vulnerability assessment”</th>
<th>Structure “adaptation action plan.”</th>
</tr>
</thead>
<tbody>
<tr>
<td>General Concepts Level:</td>
<td>General Concepts Level:</td>
</tr>
<tr>
<td>Vulnerability assessment</td>
<td>Adaptation action plan</td>
</tr>
<tr>
<td>Exposure</td>
<td>Plan goal</td>
</tr>
<tr>
<td>Sensitivity</td>
<td>Plan tasks</td>
</tr>
<tr>
<td>Adaptive capacity</td>
<td></td>
</tr>
<tr>
<td>Specific Terms Level:</td>
<td></td>
</tr>
<tr>
<td>Water resources vulnerability</td>
<td></td>
</tr>
<tr>
<td>(vulnerability assessment)</td>
<td></td>
</tr>
<tr>
<td>Rainfall (exposure)</td>
<td>current water usage survey</td>
</tr>
<tr>
<td>Agriculture water usage (sensitivity)</td>
<td>water usage management (plan tasks)</td>
</tr>
<tr>
<td>Industry water usage (sensitivity)</td>
<td>Enhance water resilience (plan goal)</td>
</tr>
<tr>
<td>livelihood water usage (sensitivity)</td>
<td></td>
</tr>
<tr>
<td>Rainfall strength (magnitude)</td>
<td></td>
</tr>
<tr>
<td>Rainfall frequency (frequency)</td>
<td></td>
</tr>
</tbody>
</table>

3.2.1 Sentences Collection

The starting step depends on lots of manual work to collect relevant sentences. Amount of planning sentences concerning resilient community are captured from textbooks, academic articles, newspaper, research project reports

3.2.2 Parsing sentences into terms
“Segmenter With Termlist” is a software developed by ICTI, Academia Sinica. Sentences are segmented into terms according to Chinese grammar structure and lexical category (Huang et al., 2005b) In this study, nouns and verbs were collected since they were considered as descriptions of concepts and relations. Fig.5 shows how it works to detect interested vocabularies excluding general terms and verbs. Stop words and proper nouns were identified and imported into the system as a set of refused terms or specialized combination of nouns. The extracted terms and verbs were classified into several domains, and kept the domain structure flexible for being challenged and adjusted in the future process.

3.2.3 Building prototypical ontology

Several tools and programming language were applied in this step, including yEd graph editor, Unified Modeling Language (UML), Protégé 4.2 software, Ontology Web Language (OWL), and the Webpage service tools for delivery.

3.2.4 Application phase of ontology

Currently, this research hasn’t proceeded into developing application phase, but we still can illustrate a conceptual framework for building an ontology-based knowledge management system by integrating several existing technique and tools. Fig. 6 describes the conceptual process. Graph editors software will be employed since it provides ontology developers a visual and intuitive interface. The extracted concepts (nouns) and relations (verbs) are represented as graphs by nodes and links respectively. The graphs will be transformed into UML, which is still widely used in constructing domain ontology. UML uses module-based approach which can describe the abstraction of reality and visualize the structure of knowledge (Wang et al., 2001).

Figure 5. Parsing sentences by “Segmenter with Termlist” system

Figure 6. Conceptual process of ontology-based knowledge management system

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By drawing the UML diagram, the knowledge base constructing by Protégé 4.2 will be very convenient. Protégé 4.2 is generally used in ontology building with a translation function from Protégé format to OWL language, which is the basic of semantic Web under W3C standard. Most of the ontology cases will be encoded according to some developed ontology description languages such as XML, RDF, and OWL. By implementing the ontology in a web version, it will be convenient for the end users to use.

While the number of concepts and relations of resilient community planning is growing by degrees, a Planning Web Dictionary should be developed for reviewing and editing by domain experts and planners. The dictionary should provide English translation, meanings, description of each term with searching interface.

4. RESULTS

4.1 General Concepts Level

The climate change adaptation planning in Planning Domain Ontology is shown below. Explanations of the symbols and notations are listed in Table 3. The whole picture of the structure in General Concepts level is shown in Fig.7, according to four main sources including Adaptation Strategy to Climate Change in Taiwan (CEPD, 2012c), Adaptation Plan to Climate Change in Pingtung County (CEPD, 2012a), Adaptation Plan to Climate Change in Taipei City (CEPD, 2012b), Chiayi City Climate Change Adaptation Working Reports. The first one is a national project and the rest are local projects.

<table>
<thead>
<tr>
<th>Notations</th>
<th>Definition / Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>concept_term</td>
<td>Concept terms in General Concept level.</td>
</tr>
<tr>
<td>A has* B</td>
<td>Has relation notation means A must has a property named B in General Concept level. The property can be clear defined in Specific Terms level. The * notation means in Specific Terms level, A can has more than one such as B {b1, b2, b3,….} with the same property.</td>
</tr>
<tr>
<td>A include* B</td>
<td>Include relation is similar to Has relation, but Include allow A has no such property named B. The * notation means in Specific Terms level, A can has any number of the property.</td>
</tr>
<tr>
<td>A procedure B</td>
<td>Procedure relation is used to describe a process. A is the previous step of B, in other words B cannot exist if there's no A.</td>
</tr>
<tr>
<td>A synonyms B</td>
<td>Synonyms relation means in some cases, A may have the similar meaning with B in Specific Terms level, even though A and B own different concept terms.</td>
</tr>
<tr>
<td>A equal B</td>
<td>Equal relation means A and B are definitely same thing in most all cases. Though they are belongs to different concept terms, one can regard them as two pointers pointing to a same object.</td>
</tr>
</tbody>
</table>
4.2 Specific Terms Level

Adaptation Plan to Climate Change in Pingtung County (CEPD, 2012a) and Chiayi City Climate Change Adaptation are two study case in this section. Pingtung County has finished their first period pilot project in 2012, and Chiayi City has being in progress since January, 2013. Both projects are supported by CEPD, and should be viewed and supervised in each step of the promoting period. This Planning Domain Ontology can help to view the projects and check if it follows the process guide made by CEPD, and then make suggestions to planning teams or local governments in a clear way. Simultaneously, projects content from other research teams make advantage to our ontology structure to become reasonable or suitable for use.

Adaptation Plan to Climate Change in Pingtung County took focus on four adaptation categories including disaster, land use, water resources, and coastal zone. Fig.8 shows just a part of the whole picture, in order to show the connections between each processes of developing adaptaiton plan.

The project of Chiayi City is still in progress. Fig.9 represents the present result which includes some vulnerability assessment, impact analysis, and some conceptual strategies for six adaptive sectors. Left part of the figure shows the impact and vulnerability analysis processes, and right part shows the adaptive stratagies developing process. Obviously, the gaps between these two processes is wide that means most the stratagies have not been produced yet, according to the analysis result in previous steps. In theory, the climate change adaptation plan should base on a continually developing process, in order to make the policy be comformity to the needs of the local city, and the present structure of Chiayi City’s project still has a great lack of this. Therefore, the suggesion will enrich the research work of the specific climate change factors effecting on the local place, and do more linkage from research study to the adaptation stratgies, which are much like collection of practical experiences in so far.
Figure 8. Pingtung County Climate Change Adaptation Plan
5. CONCLUSION

This study shows the importance of ontology for clarifying confusing and ambiguous terms in spatial planning by illustrating two cases of climate change adaptation policy making in local governments. The ontology has two levels: general concepts level and specific terms level. The general concepts level formally structures common terms which spatial planners use to describe climate change adaptation. Moreover, the specific terms level unfolds practical usages of terms in the same knowledge domain.

The process of constructing ontology is proposed in this article. The result showed here is a part of output from the first three steps, while the last three steps are still undergoing. So far, we developed formal ways to represent planning knowledge. For example, by trying to formally represent the knowledge structure of climate change adaptation, we found that replicate and shifting concepts, which are common in conversation and communication, can be captured by appropriate representations in general concepts level and specific terms level.

Ontology has been studied for a while, but spatial planners are still unfamiliar with it. Communication is an essential task for planners to complete their jobs. Nowadays, planners use verbal statements to clarify, argue, and communicate their terms, concepts and opinions. Due to the congenital defect of natural language, the course of communication may be very time-consuming and easily get lost. Ontology provides possible approach to help planners improve their communication work effectively.

In this article, we mostly represent planning domain ontology using graph. However, we also consider using the first order logic to represent a huge knowledge information system. More complicate planning issues will be able to be handled, detected, and resolved by adopting the technology of expert systems and artificial intelligent. Although there is still a lot of
research work to do, we believe that not only experienced planners but also beginners, students, journalists, experts in other knowledge domains, and the public will also be able to get benefit from the formal, clear, and rigid description of planning terms. A web version of planning domain ontology will spread the benefit even further and faster. Communication between human-machine and machine-machine is also possible.

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