Ontology Exploration Tool for Social, Economic and Environmental Development

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***Abstract*—In the SEED (Social, Economic and Environmental Development) framework, semantic knowledge management is one of key technologies which refine the framework. In order to facilitate collaborative sustainable development, it is important to know what others are thinking about each other accrues different domains. This paper overviews an ontology exploration tool which facilitates collaborative sustainable development. Its features are divergent exploration according to the user's viewpoints and consensus building support through comparisons among conceptual maps which are results of the explorations.**

Keywords—ontology exploration; sustainable development; viewpoint; consensus building

I. Introduction

The SEED (Social, Economic and Environmental Development) framework, developed by iFOSSF (International Free and Open Source Solutions Foundation), is an ICT (Information, Communications and Technologies) enabled digital ecosystem blueprint. It aims to facilitate collaborative sustainable development through locally-led innovation. The framework defines six (6) locally-led innovation lifecycle phases; *needs*, *strategy*, *incubation*, *localization*, *evaluation*, and *creation*. It is refined via four (4) technology enablers; *Semantic Knowledge Management*, *Value-based Partnership Modeling*, *Ecosystem Governance & Operation*, *Benchmarks and Metrics*[1]. This paper focuses on semantic knowledge management for the SEED framework.

In order to facilitate collaborative sustainable development, it is important to know what others are thinking about each other because differences of their viewpoints cause some conflicts. However, it is difficult to understand different views in particular when they come from different fields. To overcome this problem, we took an ontology-based approach and developed knowledge-structuring tool based on ontology engineering. It is based on a reference model composed of five layers for knowledge structuring in sustainability science[2].

Fig.1 shows an overview of the knowledge structuring tool. Ontology is defined as an "explicit specification of conceptualization" by Gruber[3]. A well-constructed ontology can present an explicit essential understanding of the target world. Based on ontology engineering, a wide range of knowledge can be organized in terms of general, highly versatile concepts and relationships. Annotating metadata using terms defined in ontologies enable users to search data across domains (*Layer 0-1*). A divergent ontology exploration tool can generate comprehensive conceptual maps from user's multiple arbitrary perspectives[4]. The exploration tool allows the user to explore ontologies interactively according to their interests. The results of their explorations are visualized as conceptual maps. That is, the conceptual maps represent viewpoints of the users (*Layer 2*). The ontology exploration tool also supports comparisons and convergences of multiple maps. It can help consensus-building among stakeholders in domains and facilitate multi-stakeholder collaboration which is an important technique for context based convergence of knowledge (*Layer 3*)[5]. We believe that the ontology exploration tool can provide semantic knowledge management techniques for the SEED framework.

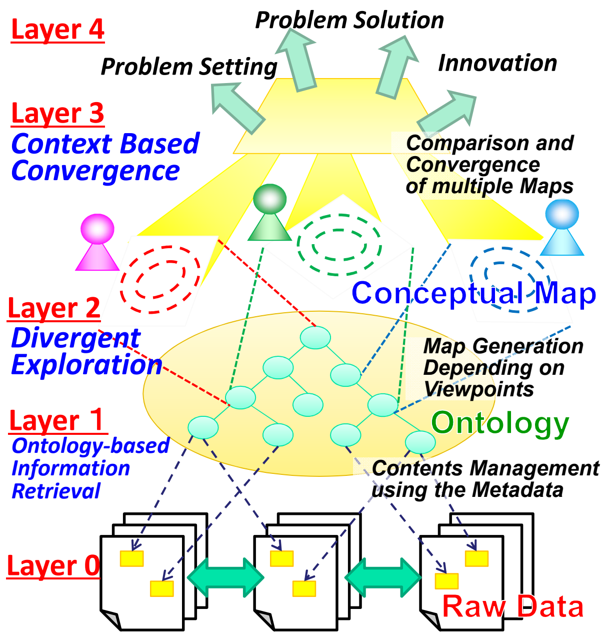

Fig. 1. An overview of t the knowledge structuring tool.

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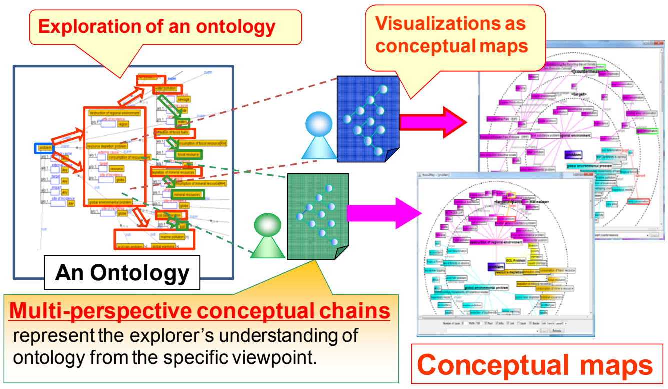

Fig. 3. Divergent exploration of ontology.

This paper is organized as follows. The next section overviews the ontology exploration tool. Section 3 explains the architecture of the consensus-building support based on ontology exploration. In Section 4, we present concluding remarks together with future work.

II. Divergent Exploration of Ontologies

A. Divergent exploration of an ontology

Most of semantic web applications use ontologies as vocabularies to describe metadata and are aimed at semantic processing of them. By contrast, we regard ontology as the target for divergent exploration of the ontology itself. The divergent exploration of an ontology enables users to explore a sea of concepts in the ontology freely from a variety of perspectives according to their own motive. The exploration stimulates their way of thinking and contributes to deeper understanding of the ontology and hence its target world. As a result, the users can find out what they take interest. Some of them could include new findings for them because they could obtain unexpected conceptual chains which they have never thought through the ontology exploration.

Fig.2 outlines the framework of ontology exploration. The divergent exploration of an ontology can be performed by choosing arbitrary concepts from which, according to the explorer's intention, they trace what we call *multi-perspective conceptual chains*. We define the viewpoint for exploring an ontology and obtaining the multi-perspective conceptual chains as the combination of a *focal point* and *aspects*. The focal point indicates a concept to which the user pays attention as a starting point of the exploration. The aspect is the manner in which the user explores the ontology. Because an ontology consists of concepts and the relationships among them, the aspect can be represented by a set of methods for extracting concepts according to its relationships. The multi-perspective conceptual chains are visualized in a user-friendly form, i.e., in a conceptual map.

B. Definition of view points

We implement the divergent exploration of an ontology as an additional function of Hozo which is our ontology development tool [6]. Fig.3 shows an example of ontology defined using Hozo. Ontologies are represented by nodes, slots and links. The nodes represent concepts (classes), *is-a* links represent *is-a* (subclass-of) relations, and slots represents *part-of* (denoted by "p/o") or *attribute-of* (denoted by "a/o") relations. A slot consists of its kind ("p/o" or "a/o"), *role concept*, *class restriction*, *cardinality*. Roughly speaking, a slot corresponds to *property* in OWL and its role name represent name of property. Its class restriction and cardinality correspond *owl:allValuesFrom* and *owl:cardinality* respectively.

As described above, viewpoints are defined as a combination of a focal point and aspects, and an aspect is represented according to relationships defined in an ontology. We classify these relationships into four kinds and define two aspects of ontology exploration for each relationship according to the direction to follow (upward or downward) (see Table. I). The user can control kinds of relationships to follow by specifying kinds of role concept (properties) in the aspects type (B) to (D). We call the control "role limitation of aspect". Similarly, users can constrain the types of concepts to reach through aspects by specifying types of concepts. We call the constraint "class type limitation of aspect"

Fig.4 shows an example of an ontology exploration. The user set *Destruction of regional environment* as the focal point and select (1) Extraction of sub concepts as an aspect. Then, following *is-a* relations, seven concepts such as *Air pollution*, *Land contamination*, etc. are extracted. Next, if the user focus

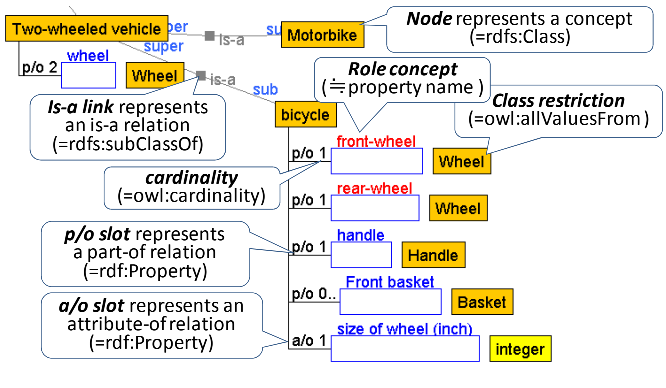

Fig. 1. An example ontology representation in Hozo and its correspondence with OWL.

TABLE I. The Aspects of Ontology Exploration

	Related relationships: Hozo	Related relationships: OWL	Kinds of extraction
(A)	*is-a* relationship	rdfs:subClassOf	(1) Extraction of sub concepts
			(2) Extraction of super concepts
(B)	*part-of / attribute-of* relationship	rdf:properties which are referred in	(3) Extraction of concepts referring to other concepts via relationships
			(4) Extraction of concepts to be referred to by some relationship
(C)	*depending-on* relationship		(5) Extraction of contexts
			(6) Extraction of role concepts
(D)	*play (playing)* relationship		(7) Extraction of players
			(8) Extraction of role concepts

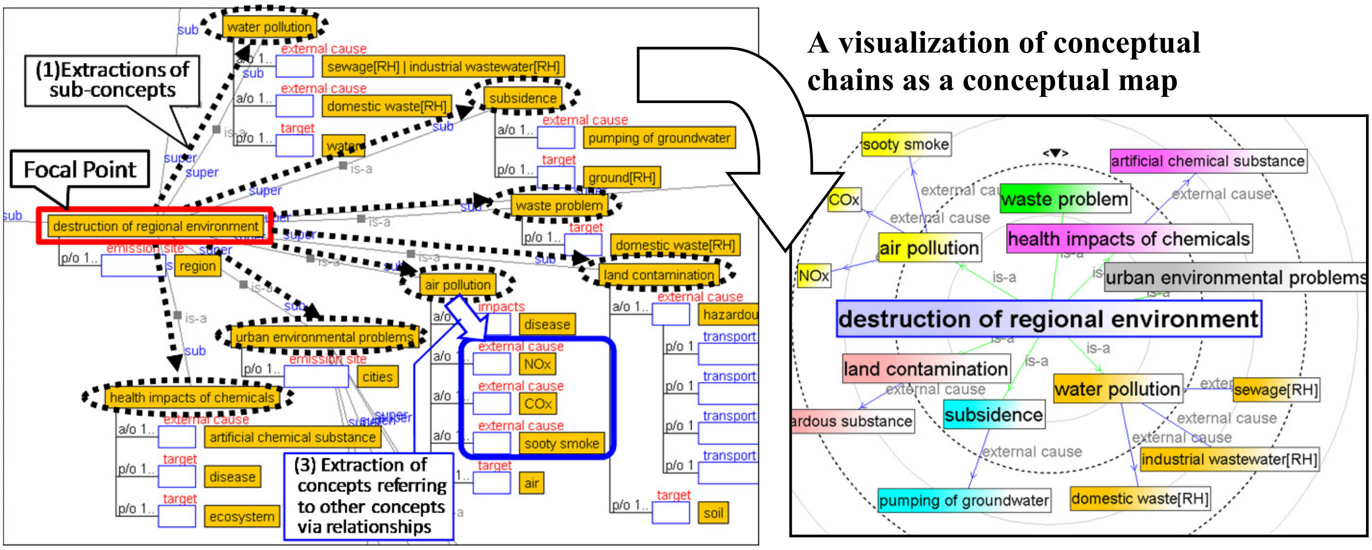

Fig. 4. An example of divergent exploration of an ontology.

on Air pollution and selects (3) Extraction of concepts referring to other concepts via relationships as an aspect, *Disease*, *NOx*, *COx*, *Sooty smoke* and *Air* are extracted following attribute-of relations of *Air pollution*. On the other hand, if the user applies external cause as role limitation of aspects, only *NOx*, *COx* and *Sooty smoke*, which are related to external cause, are extracted (Fig. 4 left). As a result of this concept extraction, the system generates conceptual chains that match the user's interest and visualizes them as a conceptual map. In the conceptual map, extracted concepts and followed relationships are represented as nodes and links respectively, and the nodes are located on concentric circles in which the focal point is located at the center. As a result, the conceptual chains are represented as a divergent network (Fig.4 right). In this way, the user can explore an ontology from various viewpoints by choosing combinations of focal points and aspects, and the results are visualized as conceptual maps.

III. Consensus Building Support based on Ontology Exploration

Fig.5 shows a way of facilitating planning and consensus building based on ontology exploration. It is composed of two steps. In the first step, each user (stakeholder) is asked to build a conceptual map through divergent ontology exploration based on his/her own interest. Collaborative work and/or discussion among them using the maps they generated is done in the second step.

A. Individual Concept MapCcreation

The interface of the system is designed to lighten the load of using its functions to enable users to easily generate maps. The user can control kinds of relationships to follow by specifying names of relationships. Similarly, users can constrain the types of concepts to reach through aspects by specifying types of concepts. The ontology exploration tool support not only manual exploration but also machine exploration called search path. When the user chose search path to explore the ontology, the system can search all combination of aspects to generate conceptual chains from a concept selected as starting point to those specified by the user. As a result, the system shows all conceptual chains between the selected concepts and visualizes them in a conceptual map.

For example, Fig. 6 shows the map generated intended to extract the influence of the increase of biofuel production on the land use from the point of view of an Environmental NGO. This map was generated by search path from "biofuel production" to "land use". Because the system take account of all relationships related to not only the selected concepts but also sub-classes of them, we can see many concepts related to them such as "forest area", "open burning", "area definition problem of farm land utilization", etc., from this map. When the user wants to generate maps from more detailed view points, he/she can specify kinds of concepts and relationships to follow.

B. Comparison of conceptual maps

The goal of the second step is consensus building with the help of the system through discussion among stakeholders with

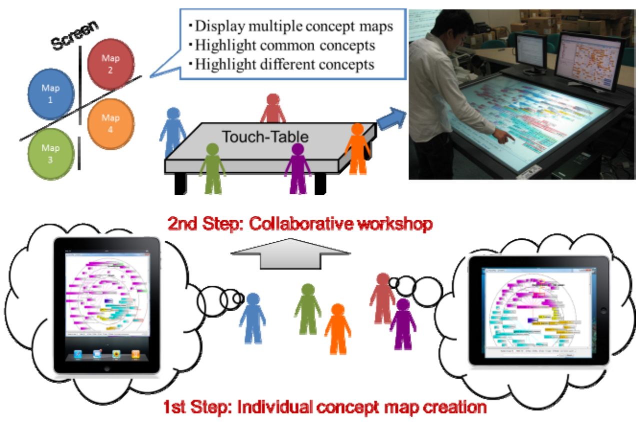

Fig.5. Steps of the planning and consensus building facilitation.

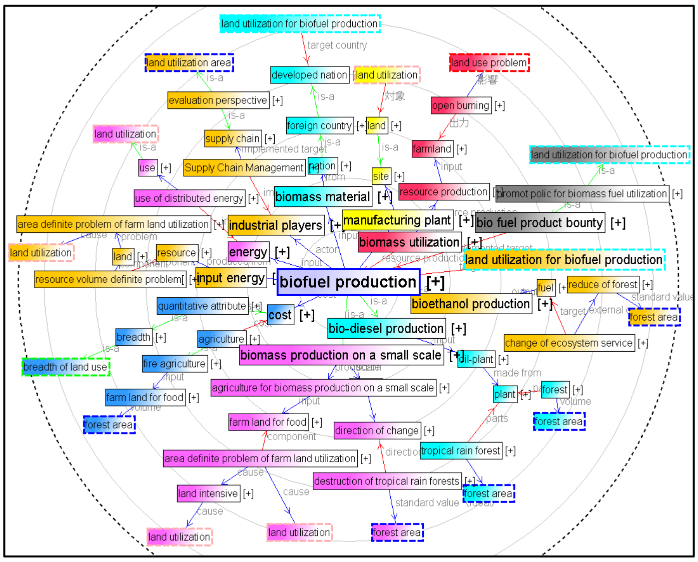

Fig. 6. An example of conceptual map generated from the point of view of an Environmental NGO

the maps they generated. The system integrates all the maps generated by them to enhance differences and commonalities among those maps which facilitate mutual understanding among participants. The integrated map consists of all paths appeared in the maps generated by the stakeholders. In the generated map, each path is shown in different color according to stakeholders. When the same paths appeared in maps by different stakeholders, they are shown in graduations of colors corresponds to them. The system also allows the user to specify paths shown in the integrated map according to stakeholders. The integrated map thus helps them reach a consensus.

IV. Preliminary Evaluations of the System

We conducted preliminary evaluations of the system using to consider its usability and effectiveness in our previous works.

In an evaluation experiment of ontology exploration, the authors asked four domain experts of sustainable science to use the tool and evaluate its practical performance. After basic instruction regarding its use, they created 13 conceptual maps (three or four maps per expert) within an hour in accordance with their specific interests. Then they chose 61 conceptual paths (linkages between concepts in a map) from the 13 maps and evaluated the paths. As the result, 85% of the selected paths were evaluated as important or interesting for the domain experts. That is, we could make sure that domain experts could obtain meaningful knowledge for themselves as conceptual chains through the divergent exploration of ontology using the tool. Furthermore, the conceptual chains generated in the experiment included about 75% paths which were not supposed when the ontology was constructed. That is, we can say that the tool stimulated their way of thinking and contributed to obtaining unexpected conceptual chains which they have never thought[4].

For an evaluation of consensus-building support, the author made an experiment by role-play discussion[5]. In the experiment we assigned a couple of subjects roles of stake holders related to biofuel production and policy making for it and ask them to discuss the related topics by role-playing and to explore the possibility to come to a better mutual understanding which would help them reach a reasonable consensus. Table II shows the number of nodes included in each map built by each subject and those of the overlapping nodes between them. The numbers of overlap-ping nodes indicate that how much the stake holders share common interests. We believe such a function that derives quantitative information between stake holders is one of the merits of the system.

TABLE II. Number of Nodes and Overlapping Nodes

	Number of nodes in the map	Number of overlapping nodes			
		a: Industry	b:Government	c:Employees	d: Environmental NGO
a:Industry	110		16	21	10
b:Government	88	-		12	5
c:Employees	187	-	-		49
d:Environmental NGO	115	-	-	-	

In addition to this, we got some positive opinions from the subjects as follows:

- Visualization of conceptual maps is helpful to understand what respects we are different by identifying what concepts we share and don't from the map.
- It sometimes helps us to realize the issues better by explicating unexpected relations or dependencies between concepts.
- It is useful for organizing my opinion to enable smooth discussion.
- It is useful to reveal overlap and distinction between us objectively.

However, there are some rooms to improve the system because we had several comments about its user interfaces by the subjects.

V. Concluding Remarks

In this paper, we overview ontology exploration tool and consensus-building based on ontology exploration. The system generates conceptual maps through ontology exploration by the users. Because the generated maps represent the users' viewpoints to understand the target domains of the ontology, it could show differences of viewpoints through comparisons of them. It would contribute to consensus-building and facilitation of sustainable development on interdisciplinary domains which consists various fields across multiple domains. We think that the ontology exploration tool can provide a semantic knowledge management technique for the SEED framework.

The client application version of ontology exploration tool is implemented as an extended function of Hozo which is published as free software at http://www.hozo.jp. The prototype of web service for ontology exploration, which only supports search path function, is also available at http://hozoviewer.ei.sanken.osaka-u.ac.jp/HozoWebXML/. Both of them supports not only ontologies developed using Hozo but also OWL ontologies through its import function.

Future work includes investigations on useful viewpoints to generate conceptual maps, application of our approach to ontology with instances and Linked Data. Improvement of user interface for more user friendly operation is another important future work.

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