A Consensus-Building Support System based on Ontology Exploration

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Abstract. Consensus-building among various stakeholders from different fields is an important issue in order to facilitate policy and decision-making. For consensus-building stakeholders have to know what others are thinking about each other because differences of their viewpoints cause some conflicts. In this paper we propose a consensus-building support system based on ontology exploration. The key ideas consists two steps 1) developing an ontology to provide a base knowledge to be shared among the users (stakeholders), 2) each user explore the ontology according to his/her viewpoint and generate conceptual maps as the result of the exploration, and 3) they know differences of viewpoints through comparison of generated maps. This paper shows an overview of this tool, and discusses its usability and effectiveness through evaluation experiments by domain experts.

Keywords: ontology exploration, consensus-building, viewpoint

1 Introduction

One of the core questions for sustainability science is investigating how the dynamic interactions between nature and society can be better incorporated into emerging models and conceptualizations that integrate the Earth system, social system and human system[1, 2]. Since these interactions, by their nature, relate to various stakeholders and players from many different fields, the problem-solving process requires the collaboration and partnership of these players. Many efforts have been made to structure diverse and fragmented knowledge for facilitating their collaboration[3, 4]. Consensus-building among various stakeholders from different fields is one of key issues to solve for facilitating their collaboration. In order to build consensus, 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.

Ontology is defined as an "explicit specification of conceptualization" by Gruber[5]. A well-constructed ontology can present an explicit essential understand-

adfa, p. 1, 2011.

ing 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. In order to provide a base knowledge for consensus-building across various domains, the authors have developed a biofuel ontology on the basis of the sustainability science ontology [4], literature surveys and stakeholder analysis. And the authors have developed a divergent ontology exploration tool that can generate comprehensive conceptual maps from user's multiple arbitrary perspectives[6]. 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.

In this paper, we propose a consensus-building system based on the ontology exploration tool. The basic idea is to support stakeholders understanding differences of viewpoints through comparisons of conceptual maps generated by different users. For this objective, we (1) improve the ontology exploration tool so that it supports for consensus-building and (2) demonstrate how the system can facilitate integrated understanding and multi-stakeholder collaboration.

This paper is organized as follows. The next section overviews our collaborative approach between stakeholder analysis and ontology engineering. Section 3 explains the architecture of the consensus-building support system based on ontology exploration. In Section 4, we discuss usability and effectiveness of the proposed system through evaluation experiments by domain experts. Section 5 shows a comparison between this study and related works and, finally, we present concluding remarks together with future work.

2 Stakeholder Analysis and Ontology Engineering

In order to facilitate consensus-building among stakeholders, we take a collaborative approach between stakeholder analysis and ontology engineering. In this section, we discuss how we introduced stakeholder analysis into our ontology engineering approach.

It is important to consider stakeholder perspectives and multi-level governance for environmental problems. The purpose of stakeholder analysis is to indicate whose interests should be taken into account and why they should be taken into account during decision making process on a particular issue[7].This analysis also focuses on the quantity and types of resources those groups or actors can mobilize to affect outcomes regarding that issue. Stakeholder analysis encompasses a range of different methodologies and tools for analyzing stakeholder interests. This analysis should be generally conducted by an independent researcher/organization viewed as neutral to the issue in focus (Fig.1(a)).

On the other hand, ontology engineering aim at providing common concepts as a well-organized base knowledge and ontology exploration tool that can facilitate holistic framing and collaboration among various stakeholders in a particular issue. By using this system, users (stakeholders) can explore various conceptual linkages regarding their specific interests, and create conceptual maps which visualize relevant concepts with semantic links (nodes) around the focal concept (Fig.1(b)).

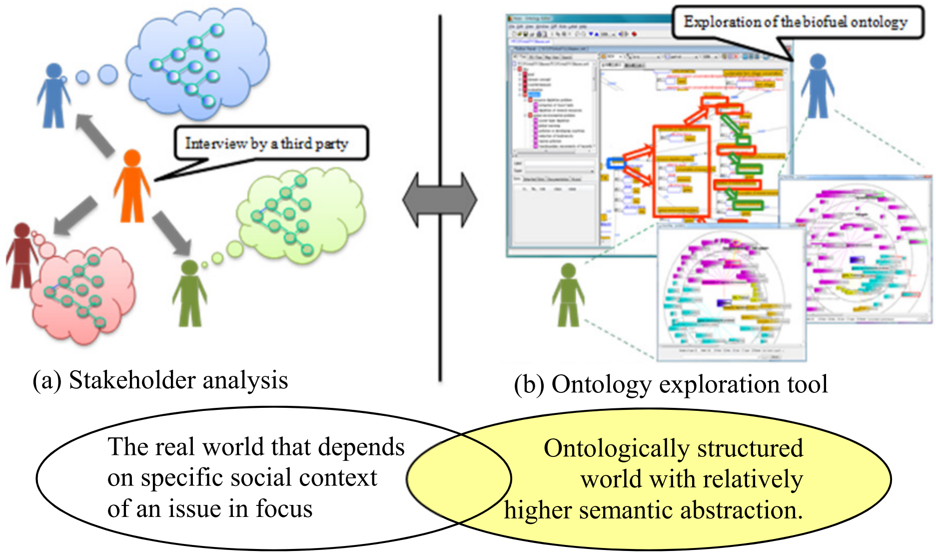

Fig.1 Collaboration between stakeholder analysis and ontology engineering

Through our research project on sustainable biofuel, we argued how to apply ontology engineering to stakeholder analysis, and enhance function of the existing ontology-based system to support stakeholder analysis. For this purpose, the gap between the two approaches was identified: stakeholder analysis treats the real world that depends on specific social context of an issue in focus, while ontology engineering emphasizes a structured world with relatively higher semantic abstraction. Then, modification and function enhancement were made to bridge the gap. For example, the existing biofuel ontology[6] was extensively upgraded on the basis of research outcomes by stakeholder analysis. That is, we extracted concepts and relationships related to stakeholder from them and added to the biofuel ontology. Here, we generalized each concept before we added it to the ontology in order to remove its context dependencies. Therefore, the research outcomes by stakeholder analysis are not represented in the extended ontology directly but they can be appeared as ontology explorations by users. This is why we did not develop a stakeholder analysis ontology separately. The system interface and functions were also improved to enable multiple users (stakeholders) to use of the system at the same time during the decision making process.

Based on the result of stakeholder analysis by collaborators in our research project [1] [8], we can identify four different dimensions for planning biofuel policy measures (Fig.2). First one is lifecycle of biofuel from land use change by energy crop cultivation, biofuel production, distribution, and endues of biofuel. Stakeholders are second dimension which often includes various players in both developed and developing countries. Types of policy measures as third dimension consider if a policy should or can be applied to global, regional or local scale, if it is long term or short

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[1] http://www.prime-pco.com/bforsd/

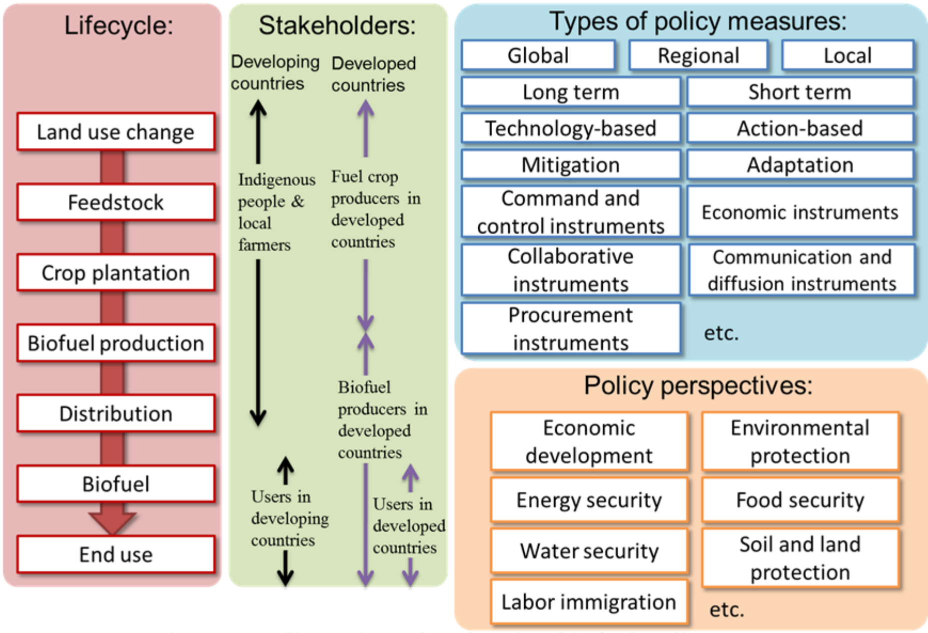

Fig.2 Four dimensions for planning biofuel policy measures

term, technology-based or action-based, and so on. Fourth dimension asks from which perspective or objective a policy is designed. Economic development, energy security, food security, or water security, for example, would be one of those perspectives. Implemented and proposed policy measures were sorted out to meet these dimensions, and integrated into the biofuel ontology.

3 Consensus Building Support based on Ontology Exploration

3.1 System Design

Fig. 3 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[6]. Collaborative work and/or discussion among them using the maps they generated is done in the second step. The interface of the system is designed to lighten the load of using its functions to enable users to easily generate maps. The interaction with the system is interactively exploiting the current user-friendly technology such as tablet PCs and multi touch tables. Conceptual map visualization after exploring the ontology is easily done as well as post-editing of the map to make it compact and informative enough. Especially, easy interpretation of maps is essential for our research. To achieve this, a couple of useful functions for highlighting focused items in the map are prepared. For example, the target items include kinds of relations and concepts, perspectives such as global/local and long-term/short-term.

“Change-view” function can redraw the map according to the specified item by the users to make the map more informative.

3.2 Divergent Exploration of ontologies

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 ontologies 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.

The divergent exploration of ontologies 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 (properties) among them, the aspect can be represented by a set of methods for extracting concepts according to its relationships[6].

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 man-

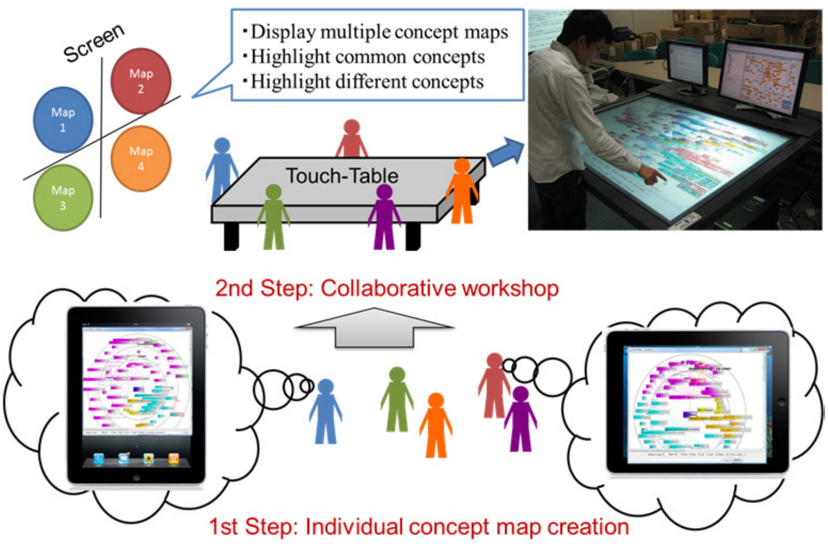

Fig.3 Steps of the planning and consensus building facilitation.

ual 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.

The multi-perspective conceptual chains are visualized in a user-friendly form, i.e., in a conceptual map. Fig. 4 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 want to generate maps from more detailed view points, he/she can specify kinds of concepts and relationships to follow.

When we want to know what countermeasures are appropriate for the focused problem, we can obtain another map using the system by selecting the problem as the starting point for an ontology exploration. This map suggests the utility of the system for facilitating policy making processes by stimulating policy makers with such maps demonstrating possible relations between problems and possible countermeasures against them.

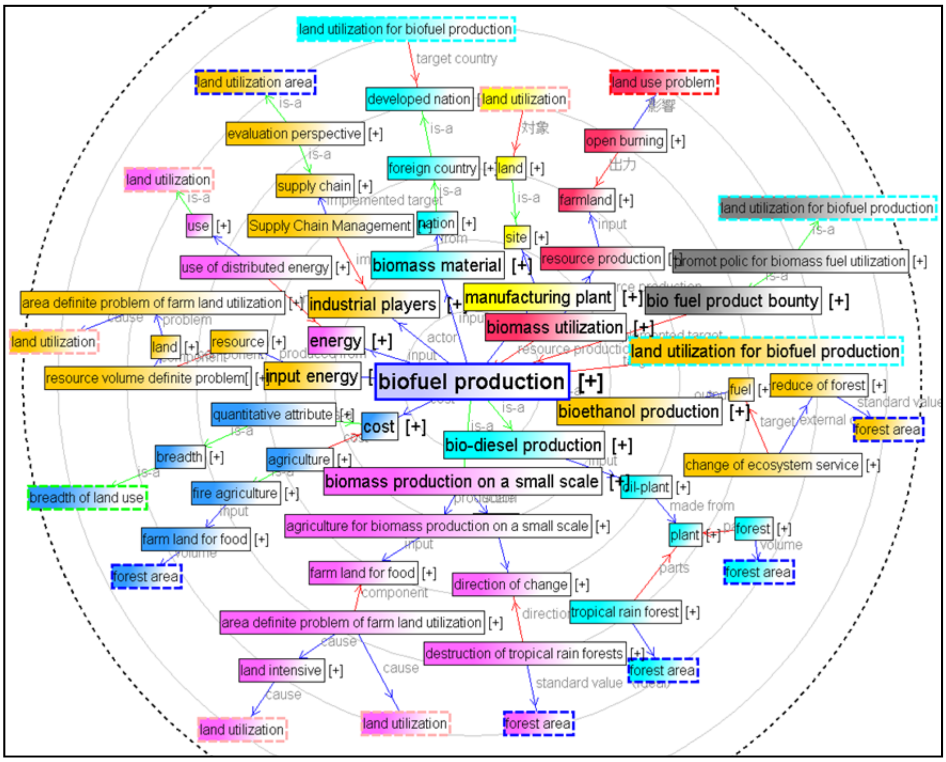

Fig. 4 An example of conceptual map generated from the point of view of an Environmental NGO

3.3 Comparison of conceptual maps

The goal of the second step is consensus building with the help of the system through discussion among stakeholders with 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. Furthermore, the system is equipped with a touch table display which is shared by all the stake holders as shown in Fig. 3. They stand around the table to observe and manipulate the integrated map through the user-friendly touch interface during the discussion.

4 Usability and Effectiveness of the System

4.1 Evaluation experiment by domain experts

To assess the effectiveness of the mapping tool, the authors asked four domain experts to use the tool and evaluate its practical performance. This experiment aims to evaluate whether the tool can generate maps which are meaningful for domain experts. 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; they explored and evaluated the paths with a four-level scale (4: very important or interesting; 3: important or interesting; 2: relevant, but neither important nor interesting; 1: wrong path). As a result, 30 paths (49 per cent) were graded as level 4, 22 paths (36 per cent) as level 3, 8 paths (13 per cent) as level 2 and 1 path (2 per cent) as level 1; thus 85 per cent of the selected paths were evaluated as level 3 or level 4. Although one should not exaggerate the tool's performance based on an experiment with such few samples, the experimental result suggests its practical applicability and effectiveness to some extent and provides useful feedback for its improvement[6].

4.2 An experiment of consensus building by role-play discussion

Overview of the experiment:

The goal of this experiment is to explore the feasibility of system. 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.

The subjects are composed of two junior students and two master course students in the department of Sustainable Energy and Environmental Engineering of the Faculty of Engineering (group A). In addition to them, we invited four researchers in the sustainability science domain (group B). Another researcher in the sustainability science domain joined in the discussion done among group A to coordinate the discussion.

Methods:

Table 1 shows the detail of the experiment with time table. Group A conducted two discussions: one without the system (Experiment 1) and the other with it (Experiment 2). Group B also did two discussions but neither used the system. After the experiments, we also discussed the utility and usability of the system.

Table.1 Processes of experiments with time table

<table>
<tr><th colspan="2">Time used in minute</th><th></th><th>Group A</th><th>Group B</th></tr>
<tr><td colspan="2">10</td><td></td><td colspan="2">Instruction of the experiment</td></tr>
<tr><td colspan="2">15</td><td rowspan="2">Experiment 1</td><td colspan="2">Preparation(1)[making a rough plan]</td></tr>
<tr><td colspan="2">20</td><td colspan="2">Group discussion(1)[without the system]</td></tr>
<tr><td rowspan="2">35</td><td>15</td><td rowspan="3">Experiment 2</td><td rowspan="2">Preparation(2)
[Each builds a map]</td><td>Preparation(2)
[rough planning]</td></tr>
<tr><td>20</td><td>Group discussion(2)
[without a map]</td></tr>
<tr><td colspan="2">20</td><td>Group discussion (2)
[Discussion with maps]</td><td>Participate in the discussion by group B</td></tr>
<tr><td colspan="2">20</td><td></td><td colspan="2">Answering inquiries with wrap-up discussion</td></tr>
</table>

The roles of stake holders used in the experiment are as follows:

a. Industry (Sugarcane farmers, investors, Sugar processing/brewery plants, etc.)
b. Government (President's, the relevant ministry, etc.)
c. Employees (Labors union, etc.)
d. Environmental NGO

In the experiment 1, in order to compare discussion using proposed tool with usual discussion, we ask the subjects to discuss about the same theme with the experiment 2 without maps. To make the experiment fruitful, we gave subjects instructions as follows: Each participant is requested to play the role to maximize his/her own benefits as the representative of the stakeholder. Concretely, we asked them to perform the discussion on the topics of production and use of biofuels from the role of the stakeholder with the following items in their mind:

- Negative opinions: problems to be solved and anything needs improvement, etc.
- Positive opinions: what you expect, what you utilize, etc.

We also asked them to summarize the discussion on the following items in a summary sheet:

- In what respects your opinion conflicts with others'
- Other stake holders with which you can collaborate on what respects

In the experiment 2 of group A with maps, each subject built a map after a brief instruction on how to use the system. The focal point from which exploration is done was set to "production of biofuels", and each subject built a map selecting a couple of keywords (3 to 5) from about 120 keywords prepared in advance. To minimize the deviation of the generated maps, we restrict the map generation command to "search path" which generates a map automatically according to the selected keywords. To make the maps compact and easy to interpret, we asked them to delete paths which they find not interesting and to extend such paths that they want to explore further. By doing this, they got maps including only interesting and meaningful paths from the perspective of the stake holder role they play.

The subjects performed the discuss using the integrated map presented on the touch table with appropriate enhancement of interested items to contrast differences and commonalities among maps they made based on their own perspectives (Fig.5). They thus exchange opinions with such a help provided by the system.

Fig.5 A snapshot of the discussion around the touch table.

Results and discussion

Table 2 shows the number of nodes included in each map built by each subject in group A and those of the overlapping nodes between them. The numbers of overlapping nodes indicate the how much the stake holders share common interests. Comparison between these numbers reveals that employees and environmental NGO share a lot of common interests. This interpretation is supported by the fact that both employees and environmental NGO are classified into the same category citizen in the result of stakeholder analysis[8]. We believe such a function that derives quantitative information between stake holders is one of the merits of the system. In addition to this, we found a couple of results which show particular relations between stake holders which we did not expect before.

The positive opinions we got from the subjects include:

- 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.

These show the feasibility and utility of the system to some extent.

Comparison between the discussion done by groups A and B shows something interesting. While there is no significant difference of the number of utterances between them in the first discussion, the number of utterances appearing the second discussion done by group A is significantly smaller than that of the second discussions done by group B. This was partly because the subjects in group A took much time to learn how to use the system so that they did not have enough time to perform discussion. In fact, we had quite a few requests on improvement of the mapping tool. Furthermore, we found the discussion done by group B includes quite a few concepts that are not covered by the current ontology. These facts suggest the system needs further improvement on its usability and extension of the ontology to cover wider and deeper topics. We plan to implement these modifications of the system to realize a useful and usable system for facilitating consensus making for consensus-building and policy making of biofuel production and utilization.

Table.2 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	16		12	5
c:Employees	187	21	12		49
d:Environmental NGO	115	10	5	49	

5 Related works

Although there are many researches on visualization of ontology, the main purpose of our research is not the visualization itself but exploration of an ontology. It is neither ontology browsing which are supported by most of ontology development tool nor ontology summarization. The divergent exploration of an ontology aims at integrated understanding of the ontology and its target world from multiple perspectives across domains according to the users' interests. We also focus on that our tool supports domain experts to obtain meaningful knowledge for themselves as conceptual chains through the divergent exploration.

Some researchers have developed tools for ontology exploration. Bosca develops a Protégé plug-in, called Ontosphere3D, which displays an ontology on a 3D space [9]. The feature of this tool is a user definable set of ontology entities (concepts and relations) called Logical View which is used for forming a hyper-surface in the multi-dimensional ontology space according to user's intensions. Although this approach for viewpoint management is similar to our tool, its purpose is different from that our tool focuses on. That is, Ontosphere3D aims to provide ontology designers with a flexible instrument for effective representation and modeling of an ontology while our tool aims to support domain experts to understand an ontology and its target world.

Noppens proposes rendering techniques which combines visual analytics with interactive exploration for large scale structured data on the web[10]. When users are exploring an ontology, this tool clusters related entities according to their class hierarchies and inheritance information and visualize the result as clusters. It supports to discover hidden connections between individuals. Popov proposes multi-pivot approach which enables the user to trace relationships among multiple concepts and support bidirectional navigation[11]. It extracts groups of instances from ontologies according to demands of the users and visualizes them. Although both of them focus on exploration for large ontology with its instances (individuals), our tool aims at exploration for ontologies without instances. One of strong points of our tool is that it could obtain unexpected knowledge from combinations of class-level knowledge defined in the target ontologies. The experiment by the domain users shows that it could include meaningful information for them.

6 Concluding remarks

In this paper, we proposed a consensus-building supporting system 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. In order to evaluate the system, we made an experiment of consensus building by role-play discussion in biofuel domain. The result shows an integrated map could well represent differences viewpoints of several stakeholders and could help their consensus-building through discussions using the map. It would contribute to consensus-building and policy making on interdisciplinary domains which consist various fields across multiple domains.

However, there are some rooms to improve the system because we had several comments about its user interfaces by the subjects. Other future work includes investigations on useful viewpoints to generate conceptual maps, application of our approach to ontology with instances and Linked Data.

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 its web service version, 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.

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References

1. Kates RW, Clark WC, et al. (2001) Environment and development: sustainability science. Science 292(5517):641–642.
2. Komiyama H, Takeuchi K (2006) Sustainability science: building a new discipline. Sustain Sci 1:1–6.
3. Choucri N, Mistree D, Haghseta F, Mezher T, Baker WR, Ortiz CI (eds) (2007) *Mapping sustainability: knowledge e-networking and the value chain*. Springer, New York.
4. Kumazawa T, Saito O, Kozaki K, Matsui T, Mizoguchi R (2009) Toward knowledge structuring of sustainability science based on ontology engineering, Sustain Sci 4: 99-116.
5. Gruber TR (1993) A translation approach to portable ontology specifications. Knowl Acquis 5(2):199–220. See also ''What is an ontology?'' available online at: http://www-ksl.stanford.edu/kst/what-is-an-ontology.htm.
6. Kozaki K, Hirota T and Mizoguchi R (2011) Understanding an Ontology through Divergent Exploration, Proc. of ESWC 2011, Part I, LNCS 6643:305-320.
7. Benjamin L. Crosby (1991) Stakeholder Analysis: A Vital Tool for Strategic Managers, Technical Notes: A publication of USAID's Implementing Policy Change Project,No.2,1-6.
8. Shiroyama H, et al. (2010) FY2009 Final Report for Hc-082 Biofuel Use Strategies for Sustainable Development (2) Formation of biofuel utilization strategies for sustainable development.
9. Bosca A and Bonino D (2007) Ontology Exploration through Logical Views in Protégé, In Proc. of the 18th International Conference on Database and Expert Systems Applications (DEXA 2007), Regensburg, Germany, 3-7 September 2007:465-469.
10. Noppens O, Liebig T (2008) Understanding Interlinked Data - Visualising, Exploring, and Analysing Ontologies, In Proc. of International Conferences on Knowledge Management and New Media Technology (I-KNOW '08), Graz, Austria:341-348.
11. Igor O. Popov, m.c. schraefel, Wendy Hall, Nigel Shadbolt (2011) Connecting the Dots: A Multi-pivot Approach to Data Exploration, In Proc. of ISWC2011, LNCS7031:553-568.