Chapter 12
Application of Ontology for Developing Strategy Options

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12.1 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 (Kates et al. 2001; Komiyama and Takeuchi 2006). 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 (Choucri et al. 2007; Kumazawa et al. 2009).

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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.

Gruber (1993) defined ontology as an “explicit specification of conceptualization.” 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. 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 (Kumazawa et al. 2009), 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 (Kozaki et al. 2011). 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.

This section describes detail design and functions of ontology-based application system which supports consensus-building system based on the ontology exploration and effectiveness of ontology system for developing for biofuel strategy options.

12.2 System Architecture and Process

Chapter 3 introduces stakeholder perspectives and emphasizes the importance of multilevel governance. 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 (Crosby 1991). 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. 12.1).

On the other hand, this chapter explains the ontology-based knowledge structuring and visualizing (mapping) system 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.12.1).

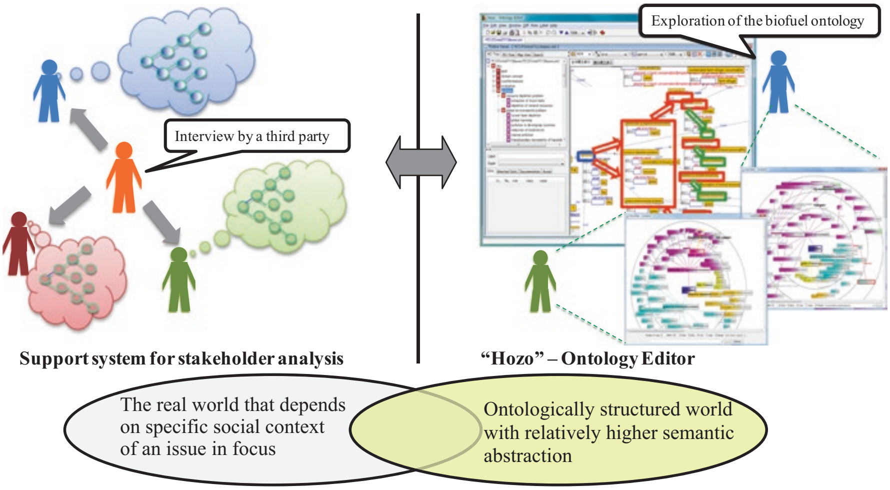

Fig. 12.1 Collaboration between stakeholder analysis and ontology engineering

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 concrete world that depends on specific social context of an issue in focus, while ontology engineering emphasizes structured world with relatively higher semantic abstraction. Then, modification and function enhancement were made to bridge the gap. For example, the existing biofuel ontology was extensively upgraded on the basis of research outcomes by stakeholder analysis. The system interface and functions were also improved to enable multiple users (stakeholders) to use the system at the same time during the decision-making process.

Based on the stakeholder analysis in Chaps. 3 and 9, we can identify four different dimensions for planning biofuel policy measures (Fig. 12.2). The first one is the life cycle 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 and if it is long term or short term, technology-based or action-based, and so forth. 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.

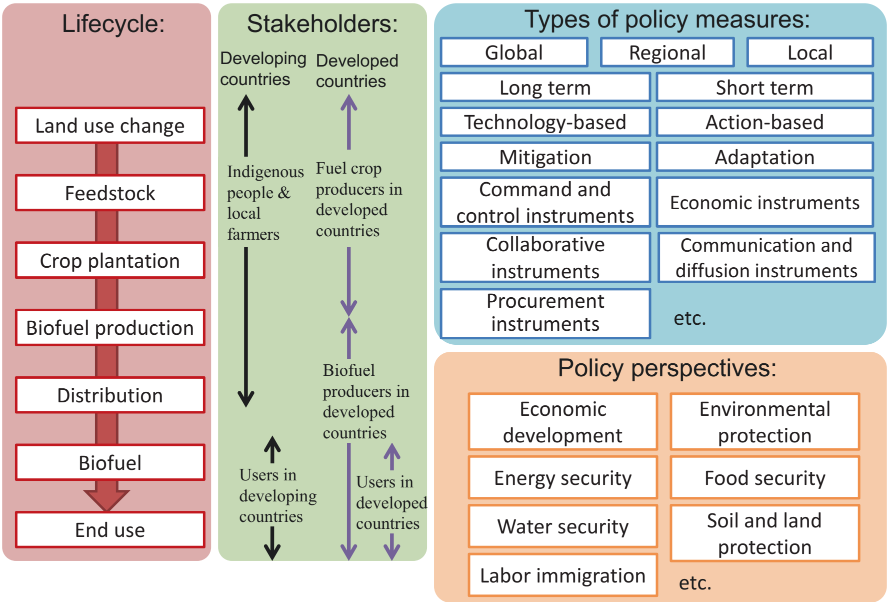

Fig. 12.2 Four dimensions for planning biofuel policy measures

12.3 Facilitation of Planning and Collaboration

Figure 12.3 shows the block diagram of the system for facilitating planning ad consensus building. The system behavior is composed of two steps. In the first step, each user (stakeholder) is asked to build a map based on his/her own interest. 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 use of its functions to enable users to easily generate maps. The interaction with the system is interactive exploiting the current user-friendly technology such as tablet PCs and multitouch tables. 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 and 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.

Figure 12.4 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 takes account of all relationships related to not only the selected concepts but also subclasses of them, we can see many concepts related to them such as "forest area," "open burning," "area definition problem of farm land uti-

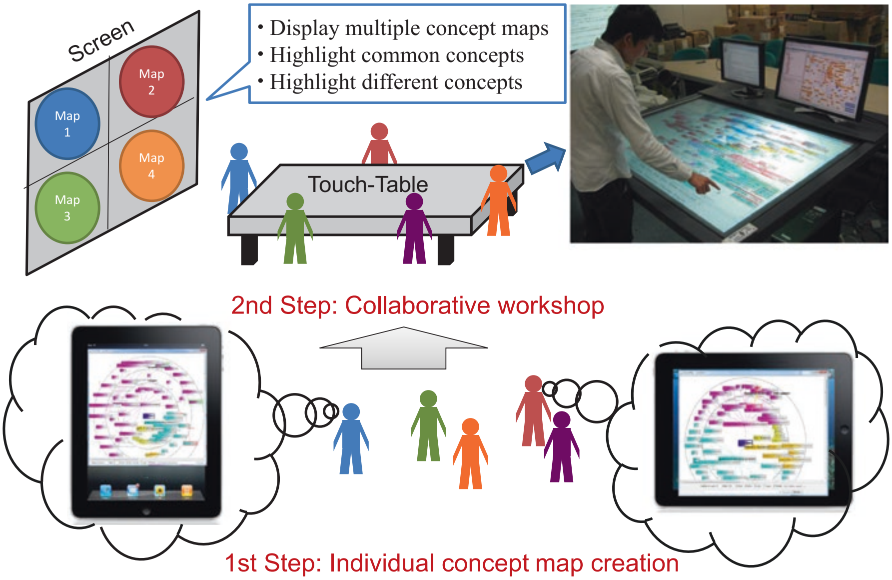

Fig. 12.3 System design of the planning and consensus building facilitation

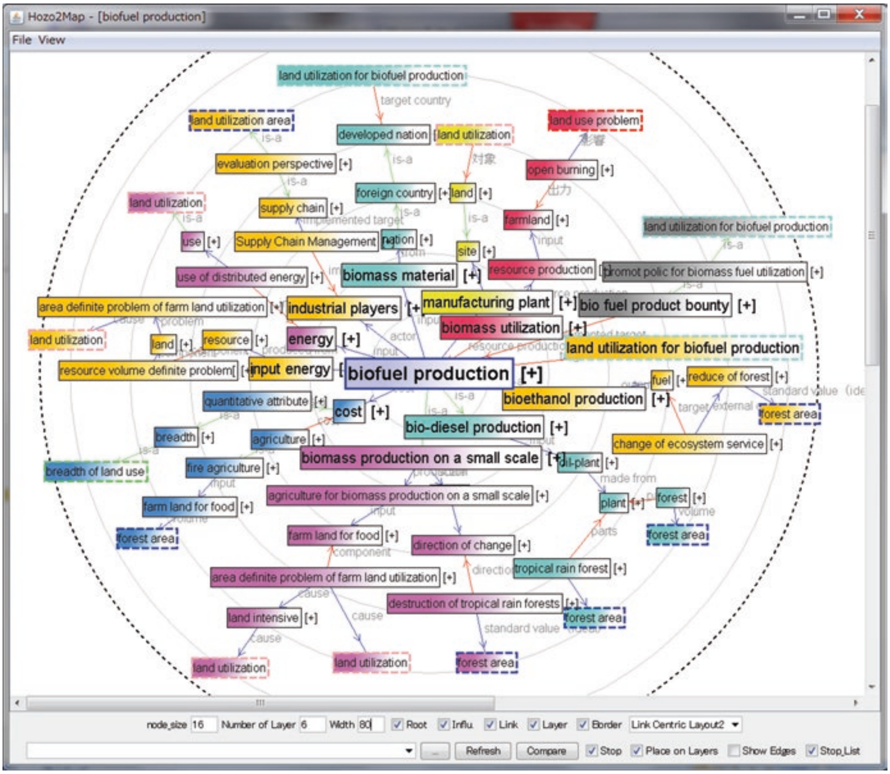

Fig. 12.4 An example of conceptual map generated from the point of view of an environmental NGO

lization," etc. from this map. When the user wants to generate maps from more detailed viewpoints, 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.

The goal of the second step is consensus making 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 thus helps them reach a consensus. Furthermore, the system is equipped with a touch table display which is shared by all the stakeholders as shown in Fig. 12.3. They stand around the table to observe and manipulate the integrated map through the user-friendly touch interface during the discussion.

12.4 Usability and Effectiveness of the System

12.4.1 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 (Fig. 12.5). After basic instruction regarding its use, they created 13 conceptual maps (3 or 4 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%) were graded as level 4, 22 paths (36%) as level 3, 8 paths (13%) as level 2, and 1 path (2%) as level 1; thus 85% 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 (Kozaki et al. 2011).

12.4.2 An Experiment of Consensus Making by Role-Play Discussion

12.4.2.1 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 stakeholders related to biofuel production and policy making for it and ask them to discuss the related topics by role-playing

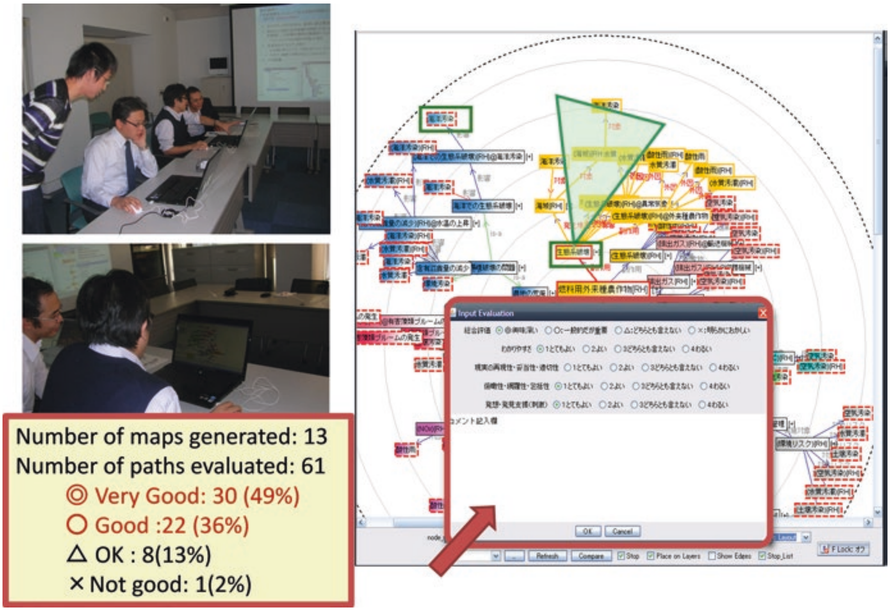

Fig. 12.5 Experimental expert workshop for application and evaluation of the tool

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 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.

12.4.2.2 Methods

Table 12.1 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.

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, the relevant ministry, etc.)
(c) Employees (labor unions, etc.)
(d) Environmental NGO

Table 12.1 Processes of experiments with time table

Time used in minute			Group A	Group B
10			Instruction of the experiment	
15		Experiment 1	Preparation (1) [making a rough plan]	
20			Group discussion (1) [without the system]	
35	15	Experiment 2	Preparation (2) [each builds a map]	Preparation (2) [rough planning]
	20			Group discussion (2) [without a map]
20			Group discussion (2) [discussion with maps]	Participate in the discussion by group B
20			Answering inquiries with wrap-up discussion	

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 stakeholders 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 (3–5) 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 stakeholder 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. 12.6). They thus exchange opinions with such a help provided by the system.

Fig. 12.6 A snapshot of the discussion around the touch table

Table 12.2 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	–

12.4.2.3 Results and Discussion

Table 12.2 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 stakeholders share common interests (Fig. 12.7). 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 (Shiroyama et al. 2010). We believe such a function that derives quantitative information between stakeholders is one of the merits of the system. In addition to this, we found a couple of results which show particular relations between stakeholders which we did not expected before.

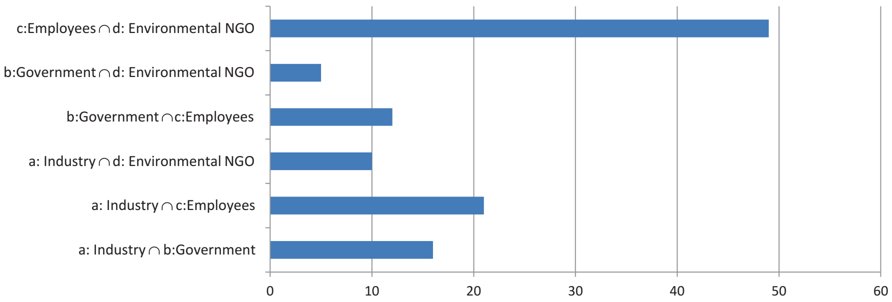

Fig. 12.7 Number of overlapping nodes between maps of stakeholders

The positive opinions we got from the subjects include:

- Visualization of conceptual maps is helpful to understand in 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 differences of number of utterances between them, 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 which 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 policy making of biofuel production and utilization.

12.5 Conclusion

In this section, 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 different 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.

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://env-ss.hozo.jp/.

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