

Method for Concept Labeling Based on Mapping between Ontology and Thesaurus

Kazuki Sonoda and Masahiro Hori

Abstract—When designing information systems that deal with large amount of domain knowledge, system designers need to consider ambiguities of labeling terms in domain vocabulary for navigating users in the information space. The goal of this study is to develop a methodology for system designers to label navigation items, taking account of ambiguities stems from synonyms or polysemes of labeling terms. In this paper, we propose a method for concept labeling based on mappings between domain ontology and thesaurus, and report results of an empirical evaluation.

Keywords—Concept Labeling, Ontology, Thesaurus, Vocabulary Problem

I. INTRODUCTION

DUE to the rapid growth of information society, the amount of information people can access from web sites and information systems is exponentially increasing. To make it easier for users to reach information they need, it is important to provide navigation labels such as headings and menus that facilitate users' understanding of what labels means [1]. In such a situation, system designers need to consider ambiguities stems from synonyms or polysemes of labeling terms. Users may not understand an intended meaning of a polysemous label when they are not well acquainted with the domain knowledge. In such situations, users may fail to forecast contents indicated by item labels, and expect information different from the one intended by the system designer [2].

To help system designers to label navigation items with appropriated domain vocabulary, we propose a method for concept labeling based on mappings between ontology [3] and thesaurus [1]. In our method, on the basis of an ontological engineering method [3], domain ontology is constructed to deal with in-depth semantics of domain concepts for a target information system. In addition, thesaurus is prepared to provide a collection of terms familiar to users. Items in these two constructs are then mapped each other to clarify relationships between terms and concepts. These mapping relations are exploited for assisting system designers to select appropriate domain terms for users when labeling concepts for navigating information items.

II. AMBIGUITY OF VOCABULARY

In general, the terms have various features in representations and meanings like synonym and polyseme [4]. Polyseme means a term that expresses two or more concepts. Synonym means two or more terms that express common concept. Relations between terms and concepts would not be so straightforward since they depend on various contexts. Explicit contexts include academic, technical and special domain, while implicit contexts include individual experience, property, or region. For example, an information system that deals with disaster-prevention knowledge for general users has a domain term *flood*, which entails two meanings: rise of river and overflow of river (Fig. 1).

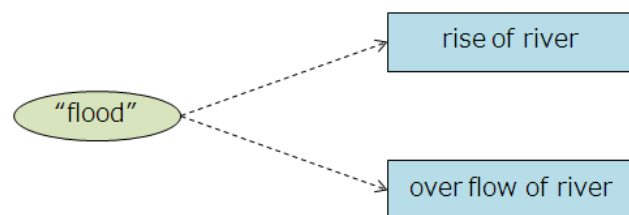


Fig. 1 Polysemous word *flood*

In an information system, when a polysemous word *flood* is used in the sense of rise of river, there might be a possibility of providing misleading information if a user takes the meaning as overflow of river (Fig. 2). This is the reason why system designers need to select an appropriate label for navigation design taking account of the variations and ambiguities in the domain.

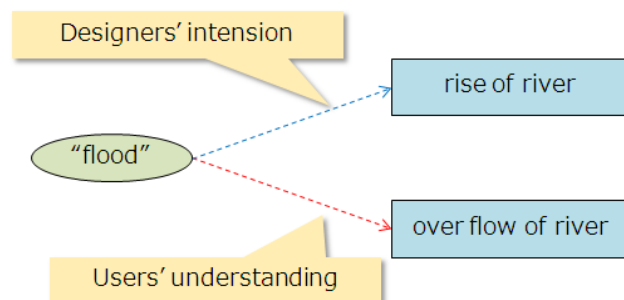


Fig. 2 Semantic mismatching between designers and users

III. APPROACH

We propose a method for concept labeling based on a mapping between ontology and thesaurus (Fig. 3). By means of

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an ontological engineering method, fundamental concepts are elicited from domain knowledge, and concepts and relationships of those concepts are defined without regard to lexical labels[3]. Although the terms expressing concepts are diverse, concepts behind terms are canonical since they are prescribed as domain ontology. Domain ontology is organized here with an upper ontology that consists of general concepts that are not specific to the domain at hand[3]. In addition to the domain ontology, to deal with domain-specific terms, we construct thesaurus that is a systematization of terms organized by means of relations between terms such as narrower, broader, synonymous, and polysemous[1] (Fig.4). Thesaurus is a collection of domain term, and is concerned with neither concept definitions nor semantic relations between concepts behind terms. Each domain term in the thesaurus is mapped to a corresponding concept in the domain ontology, so that the terms can be given with semantic definition. In particular, synonymous terms are mapped to a common concept, and a polysemous term is mapped to more than one concept. According to this mapping, relationships between terms and concepts are made explicit. It is then expected that the mapping allows system designers to remind ways users understand or confuse meaning behind the terms, and help the designers to select more adequate navigation labels.

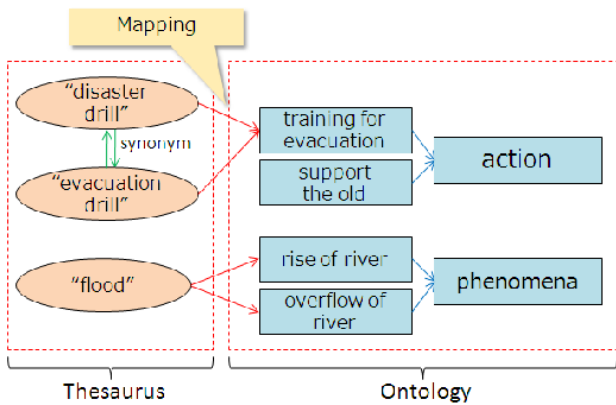


Fig.3 Overview of the mapping approach

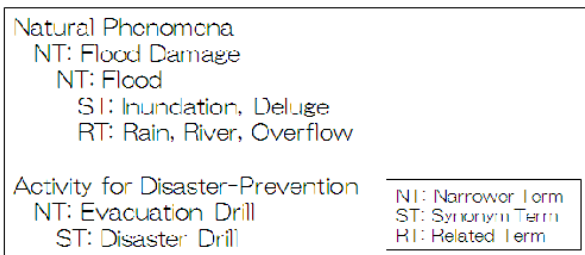


Fig. 4 Example of thesaurus

Relations between terms and concepts are diverse. However, concepts corresponding to polysemous terms are specialized in individual situations, and their meanings can be clarified in relation to context-dependent concepts (called *role concepts*[5]). The role concept, therefore, is a key to cope with

the multiple, potentially ambiguous relations between the terms and concepts. Taking account of the role concept and *is-a* relation in the representation of ontology, we extracted essential relationships between terms and concepts as possible configurations, and classified them into 8 patterns (Figs.5 and 6). In our method, an ontology developer establishes the ontology-thesaurus mapping by using these mapping patterns.

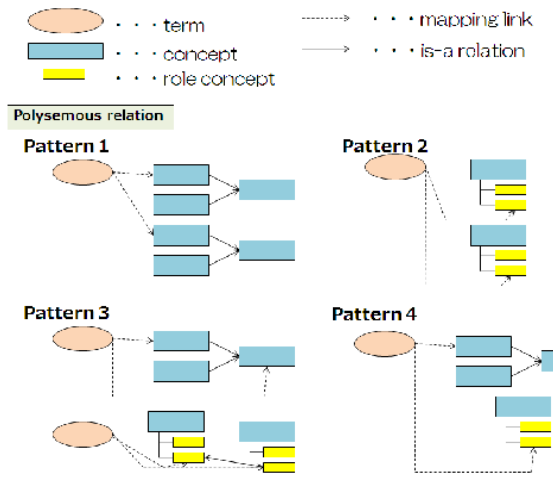


Fig.5 Mapping patterns for polysemous relation

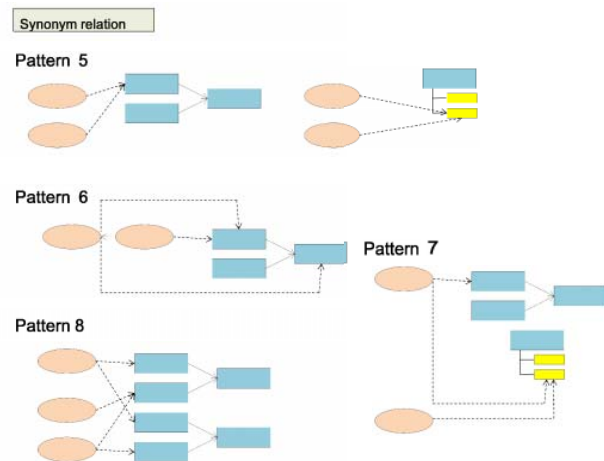


Fig. 6 Mapping patterns for synonymous relation

Fig.7 shows an example in disaster prevention domain. That is mapping between a term *flood* and concepts 'flood' and 'inundation.' 'Flood' whose meaning is rise of river is a role concept that depends on a 'prevent flood' task. This role concept is specialized in the sense that a general phenomenon 'rise' occurred particularly at river and becomes a subject of prevention task. 'Rise' is defined as a process that a certain substance increases in a certain space. 'Inundation' whose meaning is overflow of river is also a role concept that depends on 'flood' concept. This role concept is specialized in the sense that a general 'overflow' phenomenon is occurred at river, which is different from 'flood'. 'Overflow'

is defined that certain amount of substance goes out of a space when the amount of substance exceeds the capacity of the space. In the thesaurus side, term *flood* has multiple meanings, which are rise of river and overflow of river. A term *inundation* also has the same meanings. Furthermore, another meaning of the term *inundation* is simply 'overflow'. Therefore, they are both mapped to 'flood' and 'inundation' concepts and term *inundation* is also mapped to the concept of 'overflow' in ontology. These mapping relations fall into the patterns 2 and 4 depicted in Fig. 5. In this way, the term *flood* leads to both rise of river and overflow of river, and the meaning of the latter is expressed by the term *inundation* as the synonym of term *flood*. It is important to note here that the mapping patterns allow system designers to pay more attention to ambiguity of terms, and provide opportunities of clarifying the relations between terms and concepts.

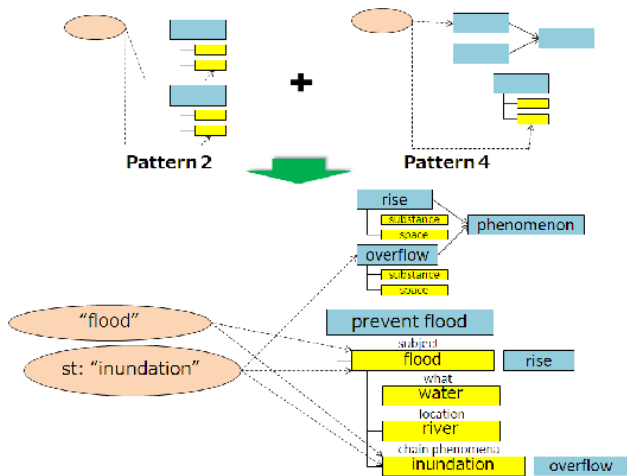


Fig.7 Mapping example

IV. EVALUATION

We conducted empirical evaluation as a user study to investigate the two points: (1) designers' prerequisite knowledge and understanding on ontology engineering required to use the proposed method, and (2) usefulness of the proposed concept-labeling method.

A. Participants

Evaluation was conducted with 9 participants belonging to Japan Advanced Institute of Science and Technology (JAIST). As depicted in Fig. 8, we considered two situations where system designers are given with a domain ontology in different manners: ontology with mapping to thesaurus (task condition A), and ontology without mapping to thesaurus (task condition B). As an evaluation method, think-aloud protocol method [6] was used.

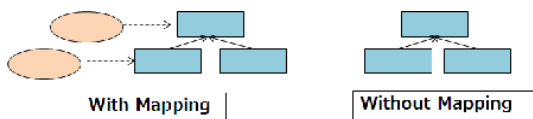


Fig. 8 Situations considered in the evaluation

In order to avoid order effect, we divided participants into two groups: one group begins with the condition A, and another begins with B. To balance the experience period of ontological engineering, the participants are allocated to different experimental conditions considering their period of experience (TABLE I).

TABLE I
ALLOCATION OF PARTICIPANTS

| Participant No. | Experience period of ontological engineering | Task execution order |
|-----------------|---|----------------------|
| 1 | Short (less than 2 months) | AB |
| 2 | | |
| 3 | | BA |
| 4 | | |
| 5 | Medium (more than 3 months, and less than one year) | AB |
| 6 | | |
| 7 | | BA |
| 8 | | |
| 9 | Long(6 years) | AB |

B. Materials

We used flood damage measures in disaster prevention as a domain of ontology and thesaurus for this evaluation. The domain ontology was constructed with the upper ontology YAMATO [7] which is modeled based on the principle of role concept and Activity First Method (AFM) [8]. The domain ontology here includes task concepts for the flood damage measures, as well as ways of taking measures relevant to the task concepts, flood damage phenomena, and general phenomena. Examples of the task concept hierarchy and task concept definition are shown respectively in Figs. 9 and 10.

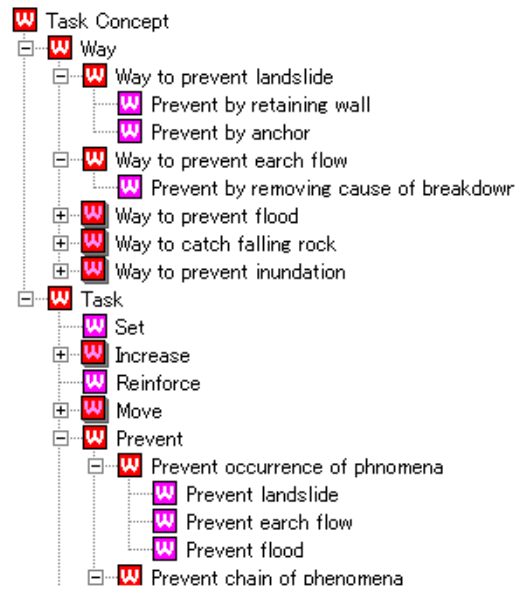


Fig. 9 Task concept hierarchy

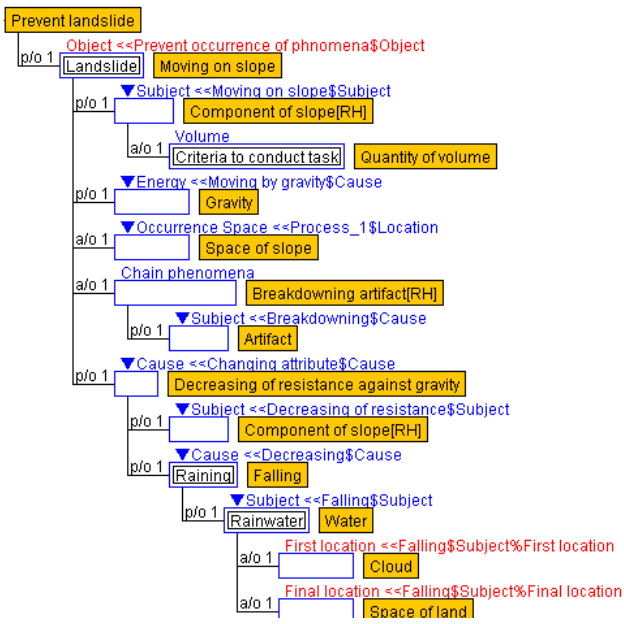


Fig. 10 Example of task concept definition

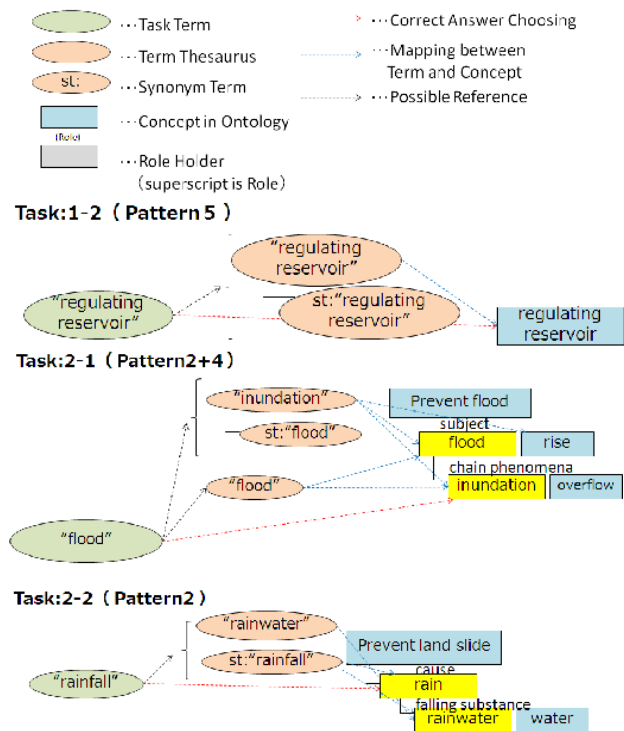


Fig. 11 Associations between task terms and concepts

A thesaurus was constructed following the construction guidelines [9]. Fig. 11 shows associations between terms in the thesaurus and concepts in the ontology, which are created based on the mapping patterns in Figs. 5 and 6. Meanings of task terms are handed out as printed glossary and participants are allowed to see the glossary whenever they want.

C. Tasks

In evaluation tasks, participants are given task terms (TABLE II) chosen from the thesaurus, and asked to find concepts semantically correspond to those terms from the ontology.

TABLE II
TASK TERMS AND CONCEPT LABELS WHICH SEMANTICALLY CORRESPOND TO TASK TERMS

| Task No. | Task term | Concept label |
|----------|----------------------|----------------------|
| 1-1 | land slide | land slide |
| 1-2 | regulating reservoir | regulating reservoir |
| 1-3 | overflow of river | inundation |
| 1-4 | super bank | high-grade bank |
| 2-1 | flood | inundation |
| 2-2 | rainfall | rainwater |
| 2-3 | overflow | brim over |
| 2-4 | rain cloud | rain cloud |

D. Equipment

We developed a viewer that runs on a web browser (Figs. 12 and 13), and made it available for all the participants. The viewer consists of an ontology viewer and a thesaurus viewer.

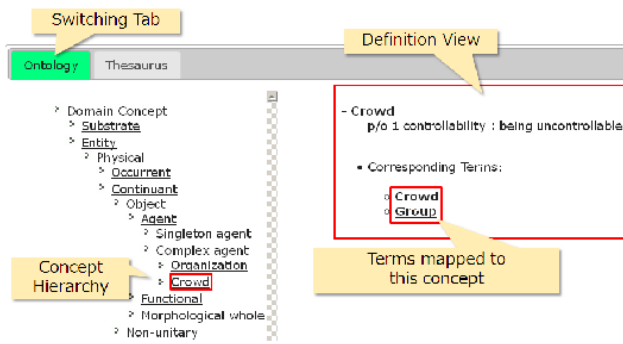


Fig. 12 Screen copy of Ontology viewer

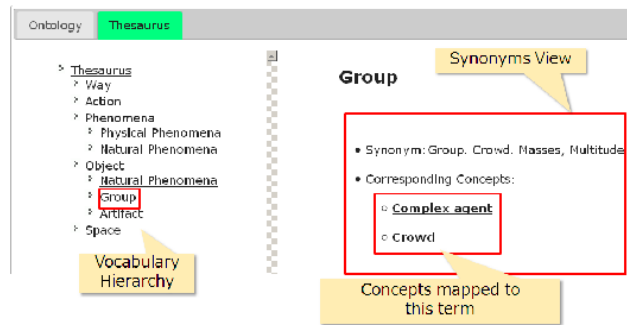


Fig. 13 Screen copy of Thesaurus viewer

These two view panes can be switched alternatively over by a switching tab. This viewer provides functions and user interface similar to existing ontology editors such as Hozo[10]. All the evaluation sessions were videotaped with permission from the behind. Participants' utterances and behavior during the task execution were recorded, and used for protocol analyses following the think-aloud evaluation method.

E. Evaluation Procedure

Evaluation tasks were performed individually. After the explanations on the task execution procedure, we asked participants to think aloud, especially the points as follows.

- Meanings that reminded from task terms
- Reasons to narrow down target concepts
- Reasons to select a concept

We then instructed participants to practice thinking aloud using a shopping web site. A sample task was to look for items. Actual evaluation tasks consist of 8 tasks, and the four tasks are provided thesaurus while remaining four tasks are done without thesaurus. Finally, we asked participants for their comments on the mapping method and difficulty/ease of selecting target concepts in the interview session.

V. RESULTS

It took 96 minutes for one participant to complete all the eight tasks in an average (evaluation tasks: 56 minutes, explanation and interview: 40 minutes). We analyzed the recorded utterance and behavior interacting with the viewer. Since the four participants did not look up the thesaurus at all during the evaluation sessions, the following analyses were made for the other five participants who referred to both the thesaurus and ontology.

A. Data Analysis

First, we transcribed utterances and extracted access log data of items and concepts manipulated by participants on the viewer screen. After the data collection, we classified types of utterances. The classification of utterances was made with regard to the types of interaction steps in the extended model of HCI [11]. The results are shown in showed in TABLE III.

TABLE III
CORRESPONDENCE OF UTTERANCES CONTENTS CATEGORY
TO AN EXTENDED MODEL OF HCI

| Steps in Extended HCI model | Category of utterances | Explanation |
|-----------------------------|------------------------|--------------------------------------|
| Interpret the object | Reason | reason to select objects |
| | Choice | selected objects |
| Interpret the outcome | Forecast | forecast meaning of task term |
| | Interpretation | interpretation of the result at hand |
| Evaluate the outcome | Evaluation | evaluation of the entire results |

B. Results of Analysis

Relations between experience period of ontological engineering and the number of correct answers are given in TABLE IV. There were few differences in the number of correct answers. TABLE V shows the relations between experience period and the number of utterance types classified into the interpretation and evaluation.

TABLE IV
THE NUMBER OF CORRECT ANSWERS

| Experience period of ontological engineering | Thesaurus | |
|--|--------------|-----------------|
| | with mapping | without mapping |
| short (n=3) | 2.7 | 1.3 |
| medium (n=1) | 3 | 2 |
| long (n=1) | 2 | 0 |

TABLE V
THE NUMBER OF UTTERANCES TYPES CLASSIFIED
INTO INTERPRETATION AND EVALUATION

| Experience period of ontological engineering | Thesaurus | |
|--|--------------|-----------------|
| | with mapping | without mapping |
| short (n=3) | 0.3 | 0.7 |
| medium (n=1) | 0 | 3 |
| long (n=1) | 4 | 3 |

The shorter experience period of ontological engineering participants have, the fewer utterances the participants made for the interpretation and evaluation. The participants with less experiences only talked about shallow reasons such that "a term with the label same as given task term was found," even if they made utterances about evaluation. Further, in the interview session, we got comments about criteria of similarity between task terms and concept labels, and realized ways of selecting answers from thesaurus without looking up and grasping concepts in the ontology. From these results, it is supposed that as the participants with less experiences judge relying merely on superficial similarities between terms and labels. One participant with medium experience made utterances about interpretation and evaluation only in the cases where the mapping was given. In cases without thesaurus mapping, it was not clear if the participant understood the meanings of concepts and evaluated the similarity appropriately.

On the other hand, the participant with the longest experiences made utterances about interpretation and evaluation. For example, a task term *regulating reservoir* in the task 1-2 matches the mapping pattern 5 (Fig. 6), and is contained in the thesaurus as a synonym of a term *balancing reservoir*. This term semantically corresponds to a concept 'regulating reservoir' which is mapped to the term *balancing reservoir* in the thesaurus. All the participants chose the correct answer for this task. The participant with the longest experience was inspired by a concept label as well as the lexical similarity of the task term, and then judged that the concept 'regulating reservoir' semantically corresponds to the task term *regulating reservoir*. In contrast, all the other participants with less experience judged merely considering the lexical similarity.

A task term *overflow of river* in the task 1-3 matches the mapping patterns 2 and 4 (Fig. 5), and semantically corresponds to a concept 'inundation' which is mapped to the term *inundation* in the thesaurus. This is a role concept and specified

depending on the other role concept 'flood'. The participant with the longest experiences came up with a term *inundation* from the task term and looked up the concept definition of 'inundation' mapped to the term *inundation* in the thesaurus. However, the experienced participant only looked up the concept definition of 'flood' depended by the concept 'inundation' and did not regard it as over flow of river. Finally, the participant selected a similar concept 'overflow' that is also mapped to *inundation* in the thesaurus. All the other participants with less experiences selected a concept either 'inundation' or 'flood', but they made that decision merely on the basis of the lexical similarity between a term *inundation* or *flood* came up with the task term and concept labels. In this task, the concept 'flood' had only the meaning of rise of river. A task term *rainfall* in the task 2-2 matches the mapping patterns 2 and 8 (Figs. 5 and 6), and semantically corresponds to a concept 'rainwater'. In general, the term *rainfall* entails the meanings of both rain phenomena and water of rain. In the task 2-2, *rainfall* means the latter which corresponds to concept 'rainwater'. However, in cases of the task condition without thesaurus mapping, the participants with short experience as well as the participant with the longest experience came up with the former meanings and selected the concept 'fall' and 'water'. The participants with short experience made that decision merely on the basis of the lexical similarity. The participant with the longest experience selected the concept based on the semantic similarity.

VI. DISCUSSION

To use the proposed method, it is necessary for system designers to have prerequisite knowledge and understanding on domain ontology. The shorter experienced period of ontological engineering the participants have, the fewer concept interpretation and semantic term-similarity evaluation the participants made. It was observed that participants with less experience relied merely on superficial lexical similarity between task terms and concept labels. Therefore, it is probable that inexperienced designers cannot find out semantic difference between terms that has semantic similarity. Therefore, it would be beneficial for such designers to be provided with assistance of reminding semantically similar concepts and terms with tool support by means of the mapping patterns presented in this paper.

It was found that the proposed method made it possible for the participant with the longest experience to pay attention to multiple meanings or representations of terms, and that allowed the participant to come up with the reasonable selection in the case of terms with multiple meanings. In the task condition without thesaurus mapping, it was observed that participants could not notice another meaning of terms. In the interview session, the participant with the longest experience said that he could understand that similar terms were semantically different due to the thesaurus mapping. However, in complex cases such that role concepts are specified in relation to the other role concepts, the participant overlooked subsequent role concepts and only looked up immediate role.

VII. CONCLUSION

In order to help system designers to select appropriate domain terms for users when labeling concepts for navigating information items, we proposed a method for concept labeling based on mapping between ontology and thesaurus. As results of the empirical evaluation, it was confirmed that the proposed method should be provided with system designers acquainted with ontological engineering to some extent. In addition, we found that the proposed method would facilitate system designers to notice multiple meanings or representations of terms. Since this evaluation was made only the small number of participant, further investigation is needed to make sure the above points, collecting more empirical data from a number of participants. Moreover it is necessary to conduct evaluation with different domains.

REFERENCES

- [1] L. Rosenfeld, and P. Morville, "Information architecture for the world wide web", Third Edition, O'Reilly Media, Inc. 2006
- [2] G. W. Furnas, T. K. Landauer, L. M. Gomez, and S. T. Dumais, "The vocabulary problem in human-system communication", *Comm. ACM*, Vol.30, No.11, 1987, pp.964-971
- [3] R. Mizoguchi, "Tutorial on an ontological engineering - part 1: introduction to an ontological engineering", *New Generation Computing*, OhmSha & Springer, Vol.21, No.4, 2003, pp.365-384
- [4] J. Sowa, "Knowledge representation: logical, philosophical, and computational foundations", *Course Technology*, 1999
- [5] R. Mizoguchi, "Tutorial on an ontological engineering - part 3: advanced course of an ontological engineering", *New Generation Computing*, OhmSha & Springer, Vol.22, No.2, 2003, pp.198-220
- [6] K. A. Ericsson, and H. A. Simon, "protocol analysis: verbal reports as data", revised ed. Cambridge, MA: MIT Press, 1993
- [7] R. Mizoguchi, "YAMATO: Yet Another More Advanced Top-level Ontology", http://www.ei.sanken.osaka-u.ac.jp/hozo/onto_library/YAMATO101216.pdf, 2010
- [8] R. Mizoguchi, M. Ikeda, K. Seta and J. Vanwelkenhuysen, "Ontology for modeling the world from problem solving perspectives", *Proc. of IJCAI-95 Workshop on Basic Ontological Issues in Knowledge Sharing*, 1995, pp.1-12
- [9] J. Aitchison, A. Gilchrist, D. Bawden, "Thesaurus construction and use: a practical manual", Routledge; 4 edition, 2002
- [10] K. Kozaki, Y. Kitamura, M. Ikeda, and R. Mizoguchi, "Hozo: an environment for building/using ontologies based on a fundamental consideration of 'role' and 'relationship'", *Proc. of the 13th International Conference Knowledge Engineering and Knowledge Management (EKAW2002)*, 2002, pp.213-218
- [11] M. Hori, and T. Kato, "Mobile web and accessibility", In S. Harper and Y. Yesilada Eds, *Web Accessibility: A Foundation for Research*, Springer-Verlag London Limited, 2008, pp. 301-313