Evaluation of Ontology Quality based on Analysis of Relations in Concept Lattices

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Abstract. The paper presents an approach to evaluation of the quality of domain ontology. The approach is based on construction of concept lattice based on ontology relations. The approach allows to evaluate the completeness of the ontology relations. The result of this analysis helps to draw conclusions about the overall quality of the ontology.

Keywords: ontology, domain, ontology analysis, concept lattice, relation, evaluating, completeness of the ontology relations

1 Introduction

In computer science, the term "ontology" means the formal representation of knowledge. It is used as a form of knowledge representation of the real world, or part of it [1].

Currently, many intelligent systems use ontology as a knowledge base. The effectiveness of this system depends on the effectiveness of knowledge represented in the ontology. Regardless of the type of ontology its creation is a laborious and expensive task. At the same time there is a possibility to receive of ineffective product as a result in accordance with the obsolescence of developed knowledge, priorities change with time or just give incorrect or contradictory knowledge a part of the ontology. To avoid it is necessary to evaluate the quality of ontology at every stage of its production. In the existing ontology analysis methods are based on the expert evaluation. Experts in this case often act domain experts or knowledge engineers. The main problem here is the amount of time required for checking the quality of the ontology. Modern methods provide a variety of tools for ontology analysis, but most of them are only effective in ontologies with a certain structure. Therefore, a search for new approaches to the analysis of the quality of ontology of various structures is needed.

One such approach could be the approach to ontology evaluation, based on an analysis of the relations between the terms of concept lattice. This approach analyzes the various inconsistencies that are detected by comparing the basic structure of the relations of ontology and concept lattices constructed on the basis of the same relations. Thus, the approach makes it possible to calculate the completeness of the ontology relations.

We introduce some definitions of key terms used in paper on the basis of [10].

The term is a sign of a special semiotic system, which is the minimum carrier of scientific knowledge, and it is the short name of an established concept of having a definition.

Concept is knowledge, which is expressed by this term at the conceptual modeling domain.

According to [1] conceptual objects are divided as follows:

- entities (tangible and intangible objects);
- properties (quantitative, qualitative, relative);
- actions (operations, processes, state);
- dimensions (time, position, space).

Conceptual relations are divided as follows:

- quantitative relations (relations of identity, inclusion, exclusion, intersection, union);
- qualitative relations (hierarchical and functional relations).

2 Domain ontology

In [2] the history of the sign in semiotics and logic was analyzed. Categories and their design of signs representing them were defined on the basis of a pentagon of Nikitina S.E., described in [11], and the concept structure and classification of conceptual objects of Dahlberg.

This approach of building structures of signs of conceptual objects of Dahlberg as the main categories of abstraction allows you to create a common conceptualization of the domain, which will be able to understand the different systems.

On the basis of this approach the basic design of structure of the terms of the domain ontology, proposed in [2], was created. Therefore the object of the analysis the studied approach is the ontology built on the basis of this ontology. The ontology is represented in this case in the form of groups of related terms, divided into categories: concept, action, state, event, property, quantity. Each term is a vector structure, a certain term category. The structure contains a full description of the term, including its name, relations to other terms meta-signed representation, etc.

Each term in this case is represented by a specific set of names, definitions and relations. **Categorical sign** is a sign that represents the general structure of the term of a certain category. Construction of categorical sign is represented as a vector of sets of definitions and relations represented by the term. Each categorical sign corresponds to one category of ontology terms.

This representation of domain ontology introduces sematic differences between terms of different categories, making this ontology structure semantically active.

Consider some of the categorical construction signs and the possible relations between the ontology terms.

"Concept" and "Action" categories have most semantic meaning in the ontological structure than others.

The design "Concept" sign is eight:

$$Concept = < t, D, P, A, C, S, T, M > \quad (1)$$

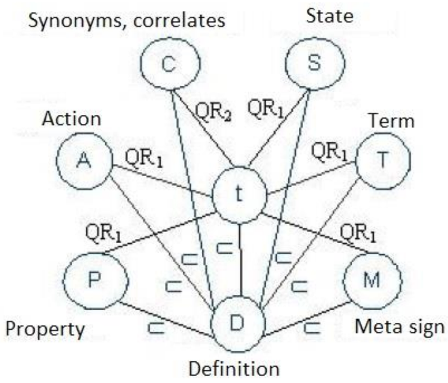

Fig. 1. Graphic representation of "concept" sign

The design of the "Action" sign is nine:

$$Action = < a, D, P, SO, C, I, A, E, M > \quad (2)$$

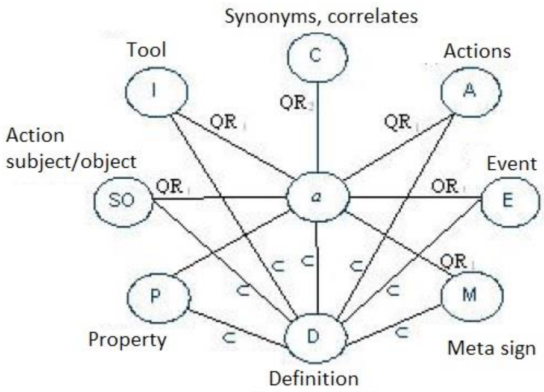

Fig. 2. Graphic representation of "action" sign

Here the elements of *t* and *a* - the term name, the type of object and the conceptual view of nature: material or immaterial. Most of the other data elements of the vectors represent the relations between the terms. Set of substantial definitions (D) and methods metalinguistic representation (M) in this case are not considered. Detailed design of categorical signs presented in [1].

Concerning types of conceptual relationships qualitative relations between ontology terms can be classified as follows:

- hierarchy (abstract-concrete area)
  - Concept-Concept (*T*)
  - Action-Action (*A*)
  - Property-Quantity (*Q*)
- aggregation (attachment area)
  - Concept-Concept (*T*)
  - Action-Action (*A*)
  - Concept-State (*S*)
  - State-Event (*E*)
  - <term>-Property (*P*)
- functional (processuality area)
  - Concept-Action (*A*, *I*)
  - Concept-Action \ Action-Concept (*SO*)
  - Action-Event (*E*)
  - Event-State (*S*)
  - Property-Quantity (*Q*)
- semiotic relations (area of content and form) relate to methods of metalinguistic representation (M)

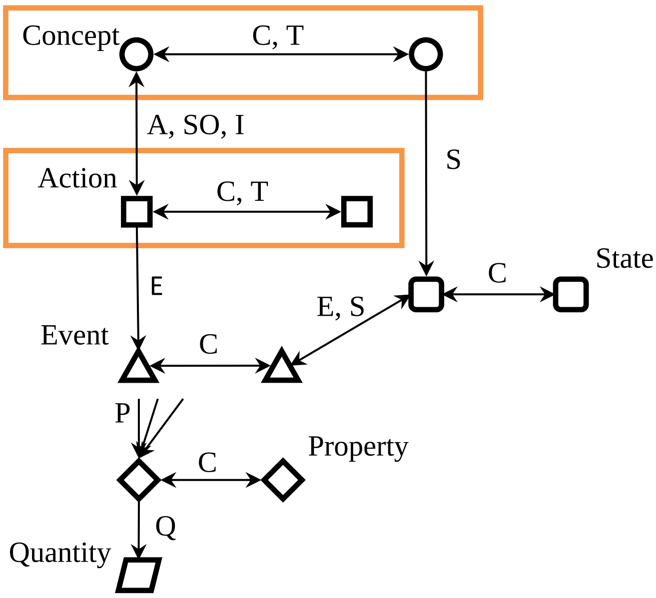

Fig. 3. Diagram of the relations between the terms of categorical signs

Also present quantitative relations in the ontology (the identity of the scope and correlation, C). Analysis of these relations will determine the consistency of concepts and relations of the ontology.

Domain ontology contains a structured open data, which makes it possible to assess the application of certain properties of formal concept analysis methods. Our study is to analyze the relations within these structures through the use of concept lattices.

3 The approach to ontology evaluation

3.1 The purpose of the analysis

The purpose of the analysis of this approach is **the completeness of the ontology relations**. This property shows the extent to which knowledge about the relations between domain terms displayed in the ontology.

To evaluate this property is necessary to determine whether the ontology relations complete and consistent. In this paper, we consider only the qualitative relations.

3.2 Description of the approach

The basis of the analysis is to find inconsistencies between the grid concepts, built on a certain relation, and ontology relations.

Analysis in accordance with the approach consists of several sequential steps (figure 4):

1. Select the type of term relation that you want to analyze. Every relation type has its semantic meaning, so the result of the analysis is interpreted according to the selected type.
2. Construction of concept lattices. On certain relations between the concepts of the lattice constructed ontology terms where terms are considered categories are taken as objects and attributes. The theme of constructing a formal context and concept lattice is mentioned in a large number of works devoted to the FCA, such as [10-13] and etc. This theme has been well studied. Depending on the relation type it is possible to use different methods of constructing a formal context to maximize the effectiveness of analysis.
3. Search lattice inconsistencies and the structure of the ontology relations. Here are compared with corresponding lattice of concepts relating to the structure of the ontology. A search of all relations, which are absent in the resulting lattice or structure of ontology relations. When constructing lattices on the basis of terms between the different categories of objects and attributes are taken in such a lattice terms of different categories.
4. Analysis of the inconsistencies. This analysis is performed by an expert, however, can be made automatically concluded terms with the greatest discrepancy coefficient, ie, terms which are associated with greater inconsistencies.

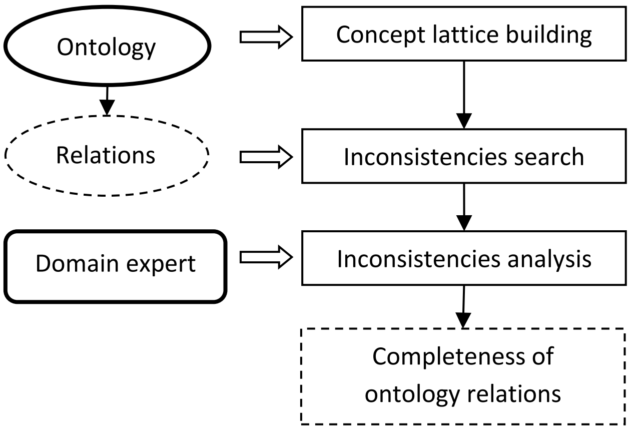

Fig. 4. Sequence of analysis steps

By the terms of categorical signs exist qualitative relations that define some hierarchy of terms relative to each other. However, only the terms of "Concept" and "Action" categories are qualitative relations with the terms of its category.

The relations between the terms of these categories can be divided into two types: relations of one category (Concept-Concept, Action-Action) and relations between categories (Concept- Action, Action-Concept). When looking for inconsistencies using both types of relations, and they have different effects on the result of the analysis.

3.3 Relations of one category

"Concept-Concept" and "Action-Action" relations have different semantics. However, they are similar to the structure, so the relations are equivalent to the analysis of terms.

Consider the example of such relations "Class-Kind" between the terms of the "Concept" category of ontology. Table 1 provides a formal context received on the relation.

In the construction of the formal context the known methods of its constructing can be used. In this example, we use a simple method: all terms that do not take the role of "Class" in any relations are formal objects, and other terms are formal attributes.

Table 1. Example of formal context

G\M	hoofed	herbivorous	overland	predator
Cow	X	X	X	
Rabbit		X	X	
Wolf			X	X
Piranha				X

Figure 3 shows a lattice of concepts on the formal context.

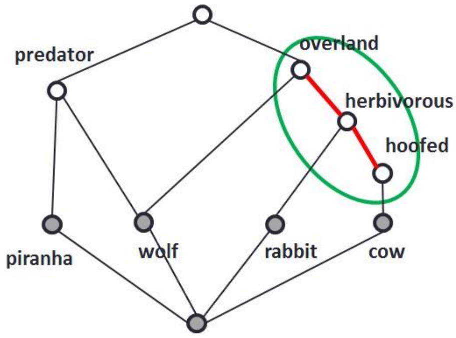

Fig. 5. Example of concept lattice

For example, in this example, fragment structure of " Class-Kind " relations of ontology is as follows:

- overland. Connected with:
  - cow
  - rabbit
  - wolf
- herbivorous. Connected with:
  - rabbit
  - cow
- hoofed. Connected with:
  - cow

From this it follows that the relation between the terms "overland" and "herbivorous" and the relation between the terms "herbivorous" and "hoofed" obtained during the construction of the lattice are absent in the source ontology (relations are marked in Figure 3). Thus, we can infer the probability that the set of relations of the ontology is incomplete. Found relations probably must be included in the ontology.

Let the set of relations of a particular type of source ontology is T_O, and the set of relations derived from a concept lattice of relations of the same type is T_R. Then the set of inconsistencies relations of one category is defined as

$$N_T : T_O \setminus T_R \cup T_R \setminus T_O. \tag{3}$$

However, it should be separated by a set of lattice inconsistencies ($N_{TR} : T_R \setminus T_O$) and ontology inconsistencies as they may have a different weight in determining the completeness of the ontology relations.

As a result, we get a lot of incredible inconsistencies. Such inconsistencies can be a great multitude, which may confuse the expert. Therefore, relations between categories should be considered.

3.4 Relations between categories

"Concept-Action" and "Action-Concept" relations have different semantics. However, they are similar to the structure, so the relations are equivalent to the analysis of terms.

Consider the example of such "Concept-Action" relation of ontology. Table 2 presents a formal context received on the relation. Unlike the previous example, where the objects and attributes are terms of the same category, in this case the objects are all terms of "Concept" category, and attributes are terms of "Action" category.

Table 2. Example of formal context

G\M	moos	jumps	eats meat	floats
Cow	X	X		
Rabbit		X		
Wolf		X	X	
Piranha			X	X
overland	X	X	X	
herbivorous	X	X		
Hoofed	X	X		
predator		X	X	X

Figure 4 shows concept lattice of the formal context.

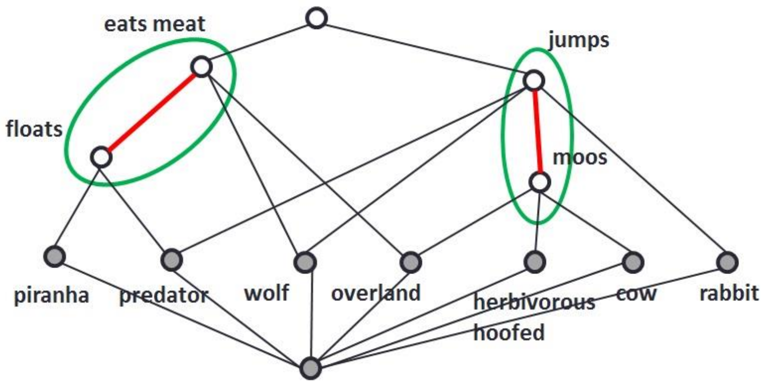

Fig. 6. Example of concept lattice

Assume in this example in the initial ontology actions "moos", "jumps", "eats meat" and "floats" are not connected qualitative relations between each other.

It follows from this relation between the terms "eats meat" and "floats" and the relation between the terms "jumps" and "moos" are absent in the source ontology and may be included therein (the relation of marked in Figure 4).

Let the union of qualitative relations of one category of original ontology is $\cup T_{Oi}$, and the set of relations derived from the concept lattice of relations of the same type is A_R.

Then the set of inconsistencies of the relation is defined as

$$N_A : (\cup T_{Oi})\backslash A_R \cup A_R\backslash(\cup T_{Oi}). \quad (4)$$

However, it should be separated by a sets of lattice inconsistencies ($N_{AR} : (\cup T_{Oi})\backslash A_R$) and ontology inconsistencies ($N_{TO} : A_R\backslash(\cup T_{Oi})$) as they may have a different weight in determining the completeness of the ontology relations.

Unlike lattices of relations of one category in this case is not specified the type of relations based on the qualitative, which searches for inconsistencies. On the basis of the terms of relations with the other categories of construction abstract terms this category hierarchy.

Because of lack of a particular type of relations such inconsistencies have little weight in the analysis, however, together with the inconsistencies obtained by relations of one category define a more detailed analysis of the completeness of the ontology relations.

Thus, inconsistencies, which are available to the expert for consideration, determined by

$$N : N_T \cap N_A. \quad (5)$$

As a result, the expert receives the set is not appropriate for the two parameters of relations. This allows it to draw a conclusion about the completeness of the ontology relations.

4 Conclusion

Formal Concept Analysis provides additional opportunities for analysis of the ontology of the model. Formal context and concept lattice allows sharing the concepts of the ontology of individual relations, which provides a more detailed analysis of ontological knowledge.

The presented approach allows us to evaluate the coherence of concepts and relations of ontology based concept lattice. Lattice allows you to identify the logical dependencies based on the relations of one category or hidden depending based relations with the terms of different categories.

To develop an accurate and effective method for the analysis of completeness of ontology relations requires further research relations and properties of the ontology. In this paper, we considered only the basic relations on the terms of the "Concept" and "Action" categories. For complete analysis there is needed for further study of the relations and the inclusion in the analysis of the terms of other categories.

At the moment, the approach is still under development. For further development of the approach required to examine all possible relations between the terms of ontology. It is necessary to determine the exact relations between the types of relations for a full analysis of inconsistencies in the ontology and the completeness of the ontology relations.

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