Inconsistencies in Ontologies

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Abstract: Ontologies are the building blocks of semantic web. In recent year's further advancements in the area of semantic web has led to refinement and specialization of the existing frameworks for ontological development. These advancements include merging, alignment, unification, mapping etc. of ontologies usually belonging to similar domains. These operations are useful in their own respect but also bring along many inconsistencies in the ontological information. The removal of these inconsistencies is in itself an open horizon for researchers of semantic web and ontologies. In this paper, we review the different issues causing inconsistencies and some frameworks used for handling inconsistencies.

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1. Introduction

The World Wide Web is a system having a collection of documents, which are linked together and are accessed through Internet. These documents have different types of information about each and every domain of life. To understand that information, different techniques and methods are introduced which are collectively known as Semantic web. In fact it is the description of information or data that is available on web and provides convenience to computers and other machines to understand that.

One of the major domains of semantic web is ontologies. Different researchers and scientists have defined ontologies in different ways. That is why ontologies are taken in different ways for different scenarios. The most common and precise definition defined by Tom Gruber is *"An explicit specification of a conceptualization"* (Gruber, 1993) [1]**.** From philosophical point of view the ontology is defined as "theory of existence*"*(Marek Obitko, 2007) [2]. Different operations can be performed on ontologies like merging, mapping, matching, alignment, refinement, unification, integration and inheritance [2]. An application can use different ontologies and for different applications different operations are applied on ontologies.

On performing different operations on ontologies, they may cause the ontology inconsistency. Merging and alignment are the main operations that cause inconsistencies. These operations and their inconsistencies are discussed.

In the next section 2, main issues causing inconsistency are discussed. Section 3 describes the problems due to inconsistency. In section 4, different resolution frameworks against inconsistency causing issues are reviewed. And section 4 summarize the whole review paper and conclude it. And future directions are also given.

2. Operations on Ontologies

There are some operations of ontologies that are mostly discussed, i.e. merging and alignment. When ontology is merged with ontology, a new one is created. Ontologies to be merged have almost the same or some common domains [10].

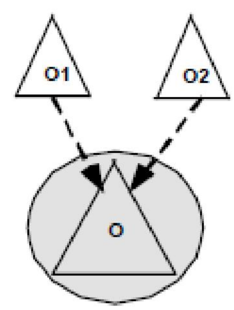

Fig. 1. Merging two ontologies O1 and O2

When two ontologies are aligned together, connected links are established between them. And ontologies, which are aligned, remain in the same conditions as they were before alignment. Ontologies to be aligned have domains that are different or complimentary to each other [10].

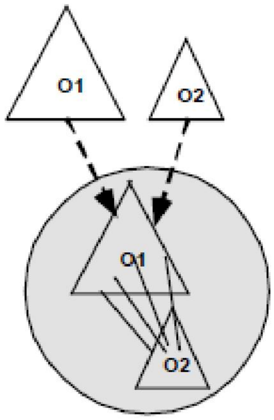

Fig. 2. Alignment of two ontologies

3. Issues Caused Inconsistency

In any operation if there is an unsatisfied condition occurs then it is called as an inconsistent state. Like In merging two or more ontologies to form the newer one may introduce the inconsistent data in the resultant ontology. The newly formed ontology may not have all the information of its parent ontologies. It shows that information is not fully transferred in merging different ontologies it means not fully consistent. This is the reason that causes the inconsistency in new ontology [2, 8].

For example: If ontologies have the facts that:

1. Bird ⟹ CanFly ⟹ CanFly ⟹ CanMove

2. Canary ⟹ Bird ⟹ Penguin ⟹ Bird
¬CanFly

In this Example, there are two ontologies. First ontology has the facts that bird can fly and anything that can fly means that can move. In the second ontology canary is a bird, and penguin is also a bird but it cannot fly. So now if we merge these two ontologies then the resultant ontology will become inconsistent. It is because facts of 1st ontology are not matching with the 2nd ontology.

Ontology alignment is achieved via two approaches [3].

Lexical Measures

Structural Measures

Lexical measures actually depend upon surface similarities. For example two entities can have the same title or name. On the other hand in structural measures taking into account the association among components and structures identifies similarity.

Following decisive factors (structural measures) has been used to decide that whether two entities are similar or not [4]:

Notation	Decisive factors
F1	Similar super-entities
F2	Similar sibling-entities
F3	Similar sub-entities
F4	Similar descendant-entities
F5	Similar leaf-entities
F6	Entities in paths from root to the entities in question are similar
F7	Relative entities to the entities in question are similar

In event of the ontology alignment inconsistency, which means that proper similarity has not been matched between components/entities of ontologies? Much work has been done to find out the structural similarities among these entities. Now in the following table some methods are identified which help to solve the ontology alignment problem [3].

Notation	Properties
ST	Structural Topological Dissimilarity on Hierarchies
UC	Upward Cotopic Similarity
SD	Similarity Distance
RS	Resnik Similarity
AP	Anchor Prompt
SF	Similarity Flooding
OL	OLA (OWL Lite Aligner)

Now the decisive factors and methods are compared in the following table [3]. Comparatively OL and SF are good enough because they comply all the decisive factors.

	F1	F2	F3	F4	F5	F6	F7
ST	√		√				
UC	√						
SD	√		√				
RS	√						
AP	√		√		√	√	
SF	√	√	√	√	√	√	√
OL	√	√	√	√	√	√	√

The following figure uses the above structural measures to assign weights to relationships between two entities of different ontologies.

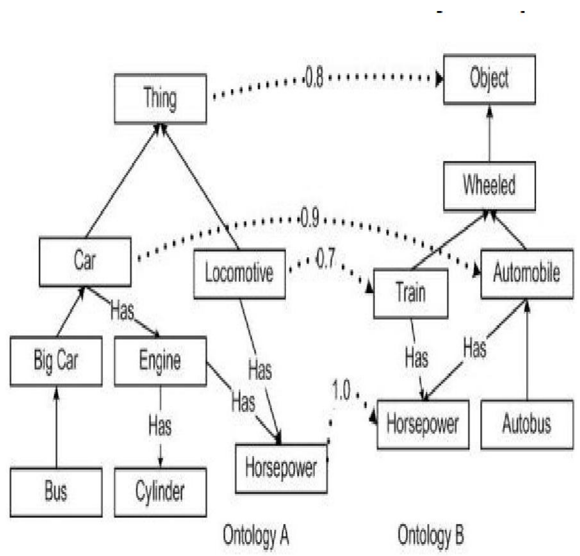

Fig. 3. Ontology Alignment

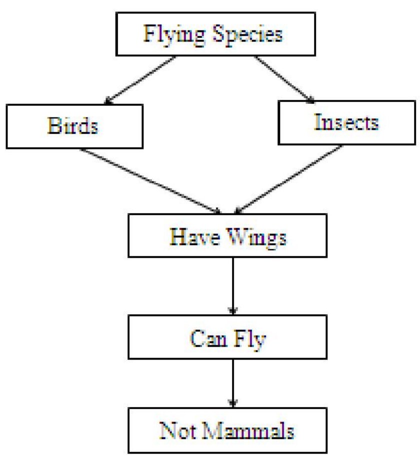

Fig. 4. Ontology 1

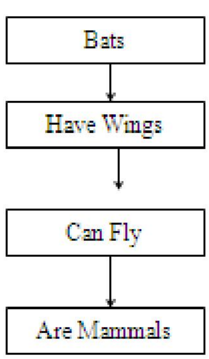

Figure 5. Ontology 2

If we merge these two ontologies, then we will get an inconsistent resultant ontology because there is a mismatch in their characteristics. In ontology 1, flying species (birds and insects) have wings, can fly but are not mammals. While in ontology 2, bats have the same characteristics except that they are mammals. So, we can't merge these two ontologies to avoid inconsistency in new resultant ontology. In order to solve this inconsistency we will re-organize these ontologies by keeping mammals as superclass.

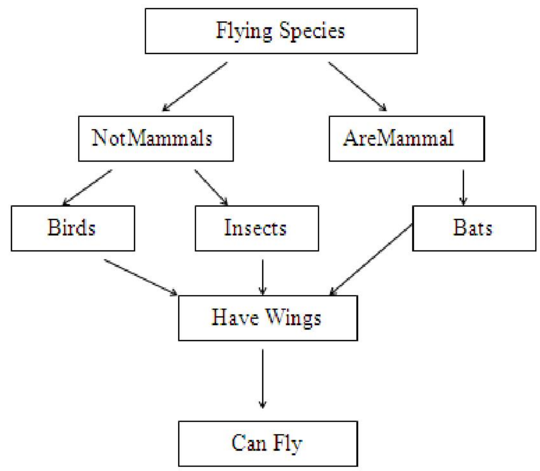

Fig. 6. Consistent merging of two ontologies

4. Some Framework Used to Resolve Ontology Inconsistency

Ontologies have the problem of inconsistencies when changes are applied to them. Different methods have been proposed for handling these inconsistencies. Peter Haase e.l had presented "A framework for handling Inconsistency in changing ontologies" [6].

In this paper [6] a framework is used to combine the inconsistency handling methods. The main components of this framework are:

Consistent ontology evolution (guarantees consistency even in the presence of changes).

Repairing inconsistencies (Repair the inconsistent ontologies).

Reasoning with inconsistent ontologies (when inconsistent ontologies are queried then meaningful results are obtained).

Multi Version Reasoning (There is a reasoning about the inconsistencies among the latest and previous versions of ontologies).

There is another paper "Screening for Inconsistencies and Changes in Semantic Web Ontologies: Experiments with Protégé" by Saumil Shah e.l, in which the basic inconsistency, incompleteness and redundancy errors are discussed. And the ontology evaluation tools are also mentioned. Inconsistency causing errors are of three type's i.e., [7].

Circulatory Errors (where a class is defined as a subclass/ superclass of itself)

Partition Errors (when there is no overlapping among subclasses then disjoint decomposition error occurs, and when one base class is partitioned into many subclasses then exhaustive decomposition error occurs.)

Semantic Inconsistency Errors (If a subclass is attached with a concept that does not belong to it.)

Ontologies have a variant nature, so after any change the resultant ontology can have many inconsistent data. When changes are applied to a consistent ontology then it is shifted to the inconsistent state. There are basic three forms in which ontology is consistent [9].

Structural consistency

Logical consistency

User-defined consistency

5. Conclusions and Future Directions

Blending of independently created ontologies/entities that represent somewhat similar concepts is taking pace as the semantic web is gaining more and more acceptance. Different models have come up in recent years to combine independent ontologies. Merging and Alignment are popular techniques to combine or relate different entities. These methods are pretty useful but at the same time bring along anomalies/inconsistencies because of dissimilar structures of ontologies. Different criteria, as explained above, have to be taken into consideration while entities are merged or aligned.

As semantic web is constantly growing, more and more ontologies are being created as time passes. There still isn't any completely automatic mechanism to unify or relate these growing and ever-changing ontologies without facing the irregularities and inconsistencies in the final result. So, more work needs to be done to automate this process to bring it closer and closer to perfection.

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