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Survey on Techniques for Ontology Interoperability in Semantic Web

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Abstract- Ontology is a shared conceptualization of knowledge representation of particular domain. These are used for the enhancement of semantic information explicitly. It is considered as a key element in semantic web development. Creation of global web data sources is impossible because of the dynamic nature of the web. Ontology Interoperability provides the reusability of ontologies. Different domain experts and ontology engineers create different ontologies for the same or similar domain depending on their data modeling requirements. These cause ontology heterogeneity and inconsistency problems. For more better and precise results ontology mapping is the solution. As their use has increased, providing means of resolving semantic differences has also become very important. Papers on ontology interoperability report the results on different frameworks and this makes their comparison almost impossible. Therefore, the main focus of this paper will be on providing some basics of ontology interoperability and briefly introducing its different approaches. In this paper we survey the approaches that have been proposed for providing interoperability among domain ontologies and its related techniques and tools.

Keywords: ontology mapping; ontology alignment; ontology merging; semantic heterogeneity; semantic web.

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Survey on Techniques for Ontology Interoperability in Semantic Web

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Abstract- Ontology is a shared conceptualization of knowledge representation of particular domain. These are used for the enhancement of semantic information explicitly. It is considered as a key element in semantic web development. Creation of global web data sources is impossible because of the dynamic nature of the web. Ontology Interoperability provides the reusability of ontologies. Different domain experts and ontology engineers create different ontologies for the same or similar domain depending on their data modeling requirements. These cause ontology heterogeneity and inconsistency problems. For more better and precise results ontology mapping is the solution. As their use has increased, providing means of resolving semantic differences has also become very important. Papers on ontology interoperability report the results on different frameworks and this makes their comparison almost impossible. Therefore, the main focus of this paper will be on providing some basics of ontology interoperability and briefly introducing its different approaches. In this paper we survey the approaches that have been proposed for providing interoperability among domain ontologies and its related techniques and tools.

Keyterms: ontology mapping; ontology alignment; ontology merging; semantic heterogeneity; semantic web.

I. Introduction

The WWW has become a vast resource of information. It is growing rapidly from last few decades. The problem is that finding the information, and the individual desires are often quite difficult, because of complexity in organization and quantity of the information stored. In traditional search engines, Information Retrieval (IR) is keyword based or with a natural language. Query entered by the users is not understandable, so it retrieves the large number of documents in the ranked order which have poor semantic relationships among the documents. This keyword based approach results poor precision - List of retrieved documents contain a high percentage of irrelevant documents, and poor recall- List of relevant retrieved among possible relevant. To avoid the above problems semantic search engines are required.

Ontology is used to model knowledge representation of a particular domain (E-learning, sports, medical, etc). Ontologies are explicit specifications of the conceptualization and corresponding vocabulary and (Gruber 1993). Ontology is the fundamental factor for semantic web. We can perform different techniques for ontology reusability called ontology interoperability techniques. Different interoperability techniques like Transformation & translation, merging, Integration, Alignment, mapping have their own significance.

Translation and transformation are the basic operations on ontology. Ontology alignment process takes two or more input ontologies and produces a set of relationships between concepts that match semantically with each other. These matches are also called mappings. Ontology merging, as its name implies merges two ontologies of same or similar domain in to one based on semantic similarity of concepts and produces unique ontology. Ontology integration is the one which creates new ontology by merging two different domains.

Ontology mapping is one of the interoperability techniques to avoid heterogeneity and inconsistency problems caused by ontology engineers of similar or same domain. Ontology mapping operation interprets the sets of correspondences between similar concepts and among two or more ontologies of same or similar domains. This is prominent research area in the field of AI (Artificial Intelligence). These mappings support two other related operations ontology alignment and ontology merging.

Three important mismatches may exist between ontologies syntactic, semantic and lexical mismatches. Our recent researchers developed several methods and techniques to identify these mismatches.

The rest of the paper organized as follows. Section II discusses about different types of ontology interoperability, Section III discusses about types of ontology mapping. Section IV discusses about challenges in ontology mapping. Section V discusses about types of mismatches. Section VI discusses about tools and techniques used for ontology interoperability.

II. Ontology Interoperability

This section describes several operations on ontologies like Transformation and translation, merging, mapping, Integration. These can be considered as an ontology reuse process. [16, 21]

a) Ontology Transformation and Translation

Ontology Transformation [2, 4] is the process used to develop a new ontology to cope with new

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requirements made by an existing one for a new purpose, by using a transformation function't'. Many changes are possible in this operation, including changes in the semantics of the ontology and changes in the representation formalism. Ontology Translation is the function of translating the representation formalism of ontology while keeping the same semantic. In other words, it is the process of change or modification of the structure of ontology in order to make it suitable for purposes other than the original one. There are two types of translation. The first is translation from one formal language to another, for example from RDFS to OWL, called syntactic translation. The second is translation of vocabularies, called semantic translation [2]. The translation problem arises when two Web-based agents attempt to exchange information, describing it using different ontologies.

b) Ontology Merging

Ontology merging [17, 6, 4] is the process of creating a new single coherent ontology from two or more existing source ontologies related to the same domain. The new ontology will replace the source ontologies.

c) Ontology Integration

Integration [17, 6] is the process of creating a new ontology from two or more source ontologies from different domains.

d) Ontology Alignment

Ontology alignment [20,7, 15,30] is the process or method of creating a consistent and coherent link between two or more ontologies by bringing them into mutual agreement. This method is near to artificial intelligence methods: being a logical relation, ontology alignments are used to clearly describe how the concepts in the different ontologies are logically related. This means that additional axioms describe the relationship between the concepts in different ontologies without changing the meaning in the original ontologies. In fact the ontology alignment uses as a pre process for ontology merging and ontology integration. There are many different definitions for ontology alignment depending upon its applications and its intended outcome.

Sample definitions include the following :-

- Ontology alignment is used to establish correspondences among the source ontologies, and to determine the set of overlapping concepts, concepts that are similar in meaning but have different names or structure, and concepts that are unique to each of the sources [4].
- Ontology alignment is the process of bringing two or more ontologies into mutual agreement, making them consistent and coherent.
- Given two ontologies O1 and O2, mapping of one ontology in to another means that each entity (concept c, relation R, Instance I) in ontology is trying to find a corresponding entity which has the same intended meaning in ontology O2.

Formally, an ontology alignment function is defined as follows:

- An ontology alignment function, align based on the set E of all entities e € E and based on the set of possible ontologies O, is a partial function.

Align: O1 ^ O2

Align (eO1) = fO2
if Sim (eO1, fO2) > threshold. Where Oi: ontology, eOi, fOj: entities of (Oi, Oj,)
Sim (eO1, fO2): Similarities function between two entities eO1 and fO2.

The ontology alignment function is based on different similarity measures.
A similarity measure is a real valued function Sim(ei, fj): OxO ^[0, 1] measuring the degree of similarity between x and y.

Ontology heterogeneity is shown in Fig 1.

e) Ontology Mapping

Ontology mapping [30, 12, 2, 14, 28] is a formal expression or process that defines the semantic relationships between entities from different ontologies. In other words, it is an important operator in many ontology application domains, such as the Semantic Web and e-commerce, which are used to describe how to connect and from correspondences between entities across different ontologies. Ontology matching is the process of discovering similarities between two ontologies. An entity 'e' is understood in an ontology O denoted by eIO is concept C, relation R, or instance I, i.e. eIO € C U R U I. Mapping the two ontologies, O1 onto O2, means that each entity in ontology O1 is trying to find a corresponding entity which has the same intended meaning in ontology O2.

The Ontology mapping function "map" is defined based on the vocabulary, E, of all terms e € E and based on the set of possible ontologies, O as a partial function: map: E x O x O ^E, with e € O1(3 f €O2 : map(e,O1,O2) = f v map(e,O1,O2) = ^).
An entity is mapped to another entity or none.

III. Types of Ontology Mapping

Based on the method of ontology mapping and how ontologies are created and maintained, it is divided in to three categories.

a) Ontology mapping between an integrated global ontology and local ontologies.[5,23]

In this case, ontology mapping is used to map a concept of one ontology into a view, or a query over other ontologies.

b) Ontology mapping between local ontologies [19]

In this case, ontology mapping is the process that transforms the source ontology entities into the target ontology entities based on semantic relation. The source and target are semantically related at a conceptual level.

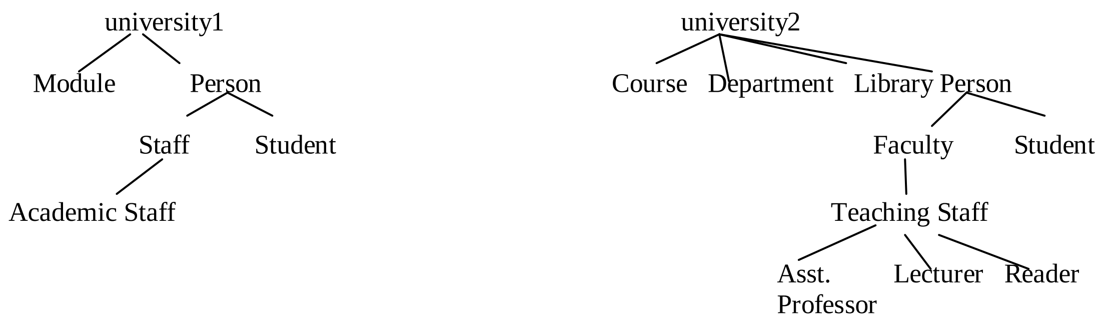

Figure 1 : Ontology heterogeneity among ontologies of same domain

c) Ontology mapping in ontology merge and alignment[4]

In this case, ontology mapping establishes correspondence among source (local) ontologies to be merged or aligned, and determines the set of overlapping concepts, synonyms, or unique concepts to that sources [4]. This mapping identifies similarities and conflicts between the various source (local) ontologies to be merged or aligned.

IV. Challenges of Ontology Mapping

In this section, we discuss challenges of ontology mapping

1. Large-scale evaluation
2. Performance of ontology-matching techniques
3. Discovering missing background knowledge
4. Uncertainty in ontology matching
5. Matcher selection and self-configuration
6. User involvement
7. Explanation of matching results
8. Social and collaborative ontology matching
9. Alignment management: infrastructure and support
10. Reasoning with alignments

V. Types of Mismatches

Different types of mismatches may occur between different ontologies. Indeed different ontology designers opt for different representation languages and use different ontology editors to represent knowledge at different levels of granularity (detail). This explains the emergence of different forms of ontology mismatches. The identification of these types of mismatches is essential in order to solve them during the mapping, alignment or merging process.

a) Syntactic mismatches

Two ontologies are syntactically heterogeneous if they are represented by different representation languages, such as OWL, KIF etc. To resolve this type of mismatches, simply transform the representation language of one ontology to the representation language of the other ontology. Herein, we state that sometimes the translation is difficult and even impossible.

b) Lexical mismatches

Describe the heterogeneities among the names of entities, instances, properties, or relations. In this type of mismatches, we may find four forms of heterogeneities: Synonyms, Homonyms, Same name in different languages, and same entities with the same name but with different syntactic variations.

c) Semantic mismatches

These kind of mismatches describe words belong to same synonym set. For example, ontology A has price and ontology B has cost. Then both are said to be semantically equivalent or match, otherwise it is a mismatched pair.

VI. Tools and Techniques for Ontology Mapping

LSD [15] (Learning Source Description): LSD semi automatically creates semantic mappings with a multi strategy learning approach. This approach employs multiple learner modules with base learners and the meta-learner where each module exploits a different type of information in the source schemas or data. LSD uses the following base learners: 1) The Name Learner: it matches an XML element using its tag name, 2) The Content Learner: it matches an XML element using its data value and works well on textual elements, 3) Naive Bayes Learner: it examines the data value of the instance, and doesn't work for short or numeric fields, and 4) The XML Learner: it handles the hierarchical structure of input instances. Multi-strategy learning has two phases: training and matching. In the training phase, a small set of data sources has been manually mapped to the mediated schema and is utilized to train the base learners and the Meta learner. In the matching phase, the trained learners predict mappings for new sources and match the schema of the new input source to the mediated schema. MOMIS [23] (Mediator Environment for Multiple Information Sources): MOMIS creates a global virtual view (GVV) of information sources, independent of their location or their data's heterogeneity. MOMIS builds an ontology through five phases as follows:

1. Extraction of local schema
2. Local source annotation using Word Net (online dictionary)
3. Common thesaurus generation: relationships of inter schema and intra-schema knowledge about classes and attributes of the source schemas
4. Generation of GVV: A global schema and mappings between the global attributes of the global schema and source schema are generated.
5. GVV annotation is generated by exploiting annotated local schemas and mappings between local schemas and a global schema.

A Framework for OIS [24] (Ontology Integration System): Mappings between an integrated global ontology and local ontologies are expressed as queries and ontology as Description Logic. Two approaches for mappings are proposed as follows: 1) concepts of the global ontology are mapped into queries over the local ontologies (global-centric approach), and 2) concepts of the local ontologies are mapped to queries over the global ontology (local centric approach).

GLUE [18]:

It semi-automatically creates ontology mapping using machine learning techniques. It consists of Distribution Estimator, Similarity Estimator, and Relaxation Labeler. It finds the most similar concepts between two ontologies and by using a multi-strategy learning approach calculates the joint probability distribution of the concept for similarity measurement. It has Content Learner, Name Learner, and Meta Learner. Content and Name Learners are two base learners, while Meta Learner combines the two base learners' prediction. The Content Learner exploits the frequencies of words in content of an instance and uses the Naive Bayes' theorem. The Name Learner uses the full name of the input instance. The Meta-Learner combines the predictions of base learners and assigns weights to base learners based on how much it trusts that learner's predictions.

ONION [25] (ONtology compositION system):

It resolves terminological heterogeneity in ontologies and produces articulation rules for mappings. The linguistic matcher identifies all possible pairs of terms in ontologies and assigns a similarity score to each pair. If the similarity score is above the threshold, then the match is accepted and an articulation rule is generated. After the matches generated by a linguistic matcher are available, a structure-based matcher looks for further matches. An inference-based matcher generates matches based on rules available with ontologies or any seed rules provided by experts. Multiple iterations are required for generating semantic matches between ontologies. A human expert chooses, deletes, or modifies suggested matches using a GUI tool.

LOM [22] (Lexicon-based Ontology Mapping):

LOM finds the morphism between vocabularies in order to reduce human labor in ontology mapping using four methods: whole term, word constituent, synset, and type matching. LOM does not guarantee accuracy or correctness in mappings and has limitations in dealing with abstract symbols or codes in chemistry, mathematics, or medicine.

QOM [11] (Quick Ontology Mapping):

QOM is an efficient method for identifying mappings between two ontologies because it has lower run-time complexity. In order to lower run-time complexity, light weight ontologies QOM uses a dynamic programming approach. A dynamic programming approach has data structures which investigate the candidate mappings, classify the candidate mappings into promising and less promising pairs, and discard some of them entirely to gain efficiency. It allows for the ad-hoc mapping of large size, light-weight ontologies.

PROMPT [25]:

PROMPT is a semi-automatic ontology merging and alignment tool. It begins with the linguistic- similarity matches for the initial comparison, but generates a list of suggestions for the user based on linguistic and structural knowledge and then points the user to possible effects of these changes.

Onto Morph [13]:

Onto Morph provides a powerful rule language for specifying mappings, and facilitates ontology merging and the rapid generation of knowledge-base translators. It combines two powerful mechanisms for knowledge-base transformations such as syntactic rewriting and semantic rewriting. Syntactic rewriting is done through pattern-directed rewrite rules for sentence-level transformation based on pattern matching. Semantic rewriting is done through semantic models and logical inference.

Anchor-PROMPT [19]:

Anchor-PROMPT takes a set of anchors (pairs of related terms) from the source ontologies and traverses the paths between the anchors in the source ontologies. It compares the terms along these paths to identify similar terms and generates a set of new pairs of semantically similar terms.

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CMS [8] (CROSI Mapping System):

CMS is an ontology alignment system. It is a structure matching system on the rich semantics of the OWL constructs. Its modular architecture allows the system to consult external linguistic resources and consists of feature generation, feature selection, multi-strategy similarity aggregator, and similarity evaluator.

FCA-Merge [9]:

FCA-Merge is a method for ontology merging based on Ganter and Wille's formal concept analysis [28], lattice exploration, and instances of ontologies to be merged. The overall process of ontology merging consists of three steps: 1) instance extraction and generation of the formal context for each ontology, 2) the computation of the pruned concept lattice by algorithm TITANIC29, and 3) the nonautomatic generation of the merged ontology with human interaction based on the concept lattice.

CHIMAERA [26]:

CHIMAERA is an interactive ontology merging tool based on the Ontolingual ontology editor. It makes users affect merging process at any point during merge process, analyzes ontologies to be merged, and if linguistic matches are found, the merge is processed automatically, otherwise, further action can be made by the user. It uses subclass and super class relationship.

ConcepTool [1]:

This is an interactive and analysis tool that aims to facilitate knowledge sharing. It supports ontology alignment process where the ontologies are represented in Entity Relationship model resulting from reasoning based on description logic. ConcepTool is based on heuristic and linguistic inferences to compare attributes of two entities belonging to the input ontologies. The analyst is then charged of identifying relevant information to resolve conflicts between overlapping entities. Overlapping entities are related to each other through semantic bridges. Each bridge provides a semantic transformation rule to solve the semantic mismatches between these entities. Summarizing, ConcepTool begins by analyzing the input models to derive taxonomic links and overlapping entities. Then, the analyst matches the common entities. The articulation ontology entities are automatically generated and the analyst defines mappings between the attributes of the matched entities. Finally, the articulation ontology is analyzed.

VII. Conclusion

The ontology Interoperability is a prominent issue in many application domains such as semantic query processing, data integration, data-warehousing, E-Commerce and E-Business. Issues of heterogeneity and inconsistency among the ontologies of same or similar domains will be resolved using ontology mapping. Definitions of ontology matching, ontology merging, ontology Integration are given. We have presented a general framework situating ontology Mapping. Kinds of ontology mapping are proposed. Ten challenges which we face while mapping ontologies are presented. We have located three forms of mismatches that are usually studied in these processes, namely, lexical, syntactic and semantic mismatches.

Because of the wide usage of ontology Interoperability techniques there is a need to consolidate different techniques and tools have been proposed to handle ontology Alignment, ontology Mapping and Merging processes. In this paper, we have surveyed the literature of these techniques and described the different criteria and approaches adopted by algorithms.

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