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Mappings for the Semantic Web

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Mappings usually relate two similar knowledge aware resources. Mapping examples abound in thesauri, databases, and ontologies. Additionally, mapping systems can relate two different knowledge resources, such as databases and ontologies. All these mappings are operationally different and are sometimes named differently— for example, correspondences, semantic bridges, transformations, semantic relations, functions, conversions, and domain-method relations.

We've analyzed some of the existing mapping definitions and representations in the ontology world and its semantic neighborhood, and we propose a new definition and model to address the Semantic Web and its needs for format, access, and resource heterogeneity.

Knowledge-Representation Definitions

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Drawing on the idea of mappings as a structured representation, Semantic Web researches have focused mapping definitions on ontologies. For example, in 2002, Xiaomeng Su gave this definition:[1]

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Given two ontologies A and B, mapping one ontology with another means that for each concept (node) in ontology A, we try to find a corresponding concept (node), which has the same or similar semantics in ontology B and vice versa.

In Su's definition, the mapping elements are ontology concepts. Because mapping involves only two ontologies, the relation between elements is bidirectional and the semantic of the relation is of similarity or identity. Su's definition includes no idea of a conversion or transformation of elements.

In that same year, Alexandre Maedche and colleagues, proposed a definition that picked up on the transformation idea. They also extended the process vocabulary by introducing the term "semantic bridge" for mappings in which the transformation was not equivalent:[2]

An ontology mapping process is the set of activities required to transform instance of a source ontology into instances of a target ontology…. [T]he mapping must define the two ontologies being mapped. Additionally, one may specify top-level semantic bridges which serve as entry points for the translation even if they are not mandatory. In this case the translation engine starts executing the Individual-Individual bridge.

In 2003, Monica Crubézy and Mark Musen introduced yet another new dimension— namely, mapping between a domain and a problem-solving method (PSM) ontology:[3]

Our mapping ontology provides the basis for expressing the adaptation knowledge needed to configure a PSM for a certain application. In that sense, our mapping ontology extends the notion of domain-PSM bridges in the UPML [Unified Problemsolving Method description Language] framework by providing a structured and operational set of possible mapping axioms that bridge the ontologies of both components.

This definition isn't classified into mappings or semantic bridges according to the complexity of functions. Mappings focus on configuring a PSM that will execute on concrete domain elements. The transformation idea is missing.

In 2004, a specification deliverable, led by Jerome Euzenat and Pavel Shvaiko, for the EU's KnowledgeWeb project provided a new definition of mapping between ontologies:[4]

A formal expression that states the semantic relation between two entities belonging to different ontologies. When this relation is oriented, this corresponds to a restriction of the usual mathematical meaning of mapping: a function (whose domain is a singleton).

Again, mapping is defined here as an expression, without an explicit transformation objective. This definition upgrades the set of ontology components by extending Su's restricted mappings (only between concepts), and covers all complexity levels of expressions. Additionally, a new element appears—direction associated to the mapping when the relation is a function. This direction contradicts Su's bidirectional definition (because it covers only similarity and identity relations).

In their 2005 survey, Yannis Kalfoglou and Marco Schorlemmer defined ontology mapping as follows:[5]

A morphism, which usually will consist of a collection of functions assigning the symbols used in one vocabulary to the symbols of the other.

They distinguished two mapping types: one oriented to correspondence between representation languages and the other oriented to correspondence between vocabularies. Such mappings have functions that assign the terms of one ontology to the terms of another. Therefore, their definition covers the mappings between PSM and domain ontologies, although it's restricted to only two ontologies.

Semantic Web Mappings

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All these definitions between ontologies apply within the Semantic Web area. Although ontologies are the main knowledge representation of the Semantic Web, they aren't the only one. Integrated in the Semantic Web are systems and applications that work with other formats such as databases, natural language documents, annotated documents, Web pages, semantic networks, graphs, and navigation models. These knowledge aware resources can be mapped with ontologies or between them.

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Additionally, the Semantic Web includes systems that execute PSMs to obtain different results with different domain ontologies. So, Semantic Web mappings need to cover directional and not-predefined functions.

Figure 1. Mapping model proposal. Mappings define relations between knowledge representations and their associate information (such as certainty, reference, and metadata).

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The Ontology Engineering Group at Universidad Politécnica de Madrid (UPM) has developed a mapping definition that covers the Semantic Web resources and functions:

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A mapping is a formal explicitation of a relation between elements, or a set of elements, of different knowledge resources (models and data).

In this definition, "explicitation" refers to a relation that's both explicit and formal, as in "machine-readable."; and "element" refers to all components of a resource (concepts, nodes, columns of a table, value of an attribute in an instance, etc.). This definition doesn't limit the relation to a reciprocal function or declarative transformations, as shown in model at figure 1. However, it supports mappings between all knowledge-representations elements in any type of resource, without restriction to the number of elements or resources. Moreover, it encompasses all mappings that are part of Semantic Web processes, such as ontology alignment, heterogeneous resources integration, and annotation.

Mapping Models

The literature offers several mapping models. For example, the Common Warehouse Model (CWM) represents mappings that are both generic and expressive,[6] but this model is also complex. It's composed of classes—Transformation, TransformationMap, Classifier-Map, FeatureMap, ClassifierFeatureMap, TypeMapping—and their properties and characteristics.

The RDF Transformation (RDFT) metaontology is based on the CWM. The RDFT specifies a small language for DTD mappings of XML to RDF-Schema and viceversa.[7] Its main class is Bridge, although it also includes Map, EventMap, Interface, Roles, Event2Event, DocumentMap, XMLBridge, VocabularyMap, and RDFBridge.

OWL defines equivalentClass and equivalentProperty as primitives, both of which can be considered mapping explicitations.[8]

C-OWL is a mapping-language proposal that can express relatively simple alignments between ontologies. The constructs in C-OWL are called bridge rules, and they can express a family of semantic relations between concepts/roles and individuals. C-OWL mappings provide eight semantic relations: equivalence, containments (contains and is contained in), overlap, and their negations.[9]

The SEKT (Semantically Enabled Knowledge Technologies) mapping language provides a set of constructs to express mappings between ontology classes, attributes, relations, and instances.[10] Several other languages express mappings, though we focus here on the language that is the most similar to our mapping concept, that is, the INRIA's alignment format.[11]

Mapping Model Proposal

Starting from common elements of these models and taking into account that mapping could exist between elements of different type of resources, we designed a simple model for covering mappings and their uses in the Semantic Web. Figure 1 shows this model.

This model is independent of the knowledge resource; we can therefore use it to represent mappings between ontologies, between relational databases and ontologies, between some thesauri, and so on. Furthermore, mapping managers can define the relations they need because mapping relations are not limited. The model includes component metadata such as LastModificationDate and Reference, mainly for tracing information flow.

For making this representation usable, we present it as an XML Schema Definition (http://www.oeg-upm.es/Alighment/Schema.xsd).

Evaluation

The UPM has a bilateral agreement with the Spanish National Geographic Institute (IGN) to integrate current heterogeneous databases using the definition and representation proposals presented here. IGN has four databases with geographic information in different scales. This information is classified into phenomena that have tremendously different granularity—for example, one catalog has 22 phenomena and another has 560. UPM and IGN have jointly developed an ontology of phenomena, called PhenomenOntology, and they are developing an automatic mapping discoverer between the ontology and the relational databases. Such mappings are represented using the model presented in figure 1.

Additionally, the Ontology Engineering Group is working on extracting mappings of concept classification from textual semantic annotations. Such mappings could be used in ontology-learning or ontology alignment applications and we are representing them following our model above showed.

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