A Parthood approach for modeling Tangible Objects' Composition TOC - an application on Cultural Heritage

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Abstract. Several semantic web approaches tackle the problem of integrating multidisciplinary rich content using Linked Open Data. Cultural heritage (CH) is a multidisciplinary domain that contains a massive heterogeneous content that varies distinctly by types and properties. Various semantic web approaches have been proposed in the context of CH, and at multiple integration levels (local, national, international). These approaches focus on metadata schemata integration but give no significant importance to the representation of a tangible cultural heritage object, as a whole entity, and the different parts that compose it. Targeting the goal of the preservation and restoration of CH artifacts, we aim at modeling the CH content focusing on the composition of a CH object. We thus illustrate here an approach of using a part-whole and spatial relations to model the composition of a tangible object in general, and a CH object in particular. To do this, we introduce parthood concepts and properties for representing the composition mechanism, and 7 cases of parthood/spatial relations in tangible objects, with their corresponding logical/ontological relation(s). We implement our approach using OWL2 as the ontological language for our linked open data approach.
Keywords: Conceptual modeling · Composition relations · Part-Whole relations · Spatial relations · Cultural Heritage.

1 Introduction

Cultural heritage: CH gives high importance for studies on the restoration and preservation of the physical pieces of evidence of the past i.e. CH artifacts. Despite the distinct variation of the CH content, it is semantically richly interlinked. Several semantic web approaches have been proposed, built and implemented to model this content, and at multiple integration levels (local, national, and international). Examples include the Europeana data model [1] (aiming at greater flexibility and expressiveness for designing a metadata schemata), the CIDOC CRM [2] (focusing on objects' types and 3 main composition relations: consists of, is composed of, and defines typical parts of), FRBRoo [3] (establishing a formal ontology for bibliographic information), cultural heritage integrated into the framework of INSPIRE [4] [5] (creating an abstract model of 3 main parts, and representing a cultural material/non-material entity), ABC Ontology [6] (to research models that describe the variety of content -including CH content- that is increasingly populating the web), CultureSampo [7] (a prototype

system for integrating the context of the national Finnish culture).
However, most approaches have tackled the problem of schema integration focusing on modeling a metadata schemata. But, they do not consider a CH object itself, its composition, and its different parts.
Our approach: Hence, we address the goal of preservation and restoration of CH artifacts by building a complete representation of a tangible CH object, and studying its evolution with time and space constraints. For the former part, the representation of a tangible object is illustrated through modeling the composition of it using part-whole relations between entities. The idea is to offer rich top-level semantic contextualization for the composition of tangible objects in general, with the application to cultural heritage objects in particular, using part-whole concepts and properties and spatial relations. This will enable complex semantic and spatial inferences on these objects.
Part-whole relations: The study of part-whole relations between entities has been an active area of research in several domains [14]: conceptual and object-oriented modeling [9] [10], knowledge representation and reasoning about objects, spatial representations [11] [12], cognitive sciences, linguistics, and philosophy [13]. Here in our proposed approach, we plan to use a combination of part-whole relations based on Winston's part-whole relations taxonomy and properties [13], Bittner's and Donnelly's ontological/spatial aspect [11] along with RCC8, the qualitative spatial aspect [12]. The choice is based on the context's needs and the part-whole relations that would best represent it.

2 TOC Ontology

The TOC ontology is a conceptual ontology for the representation of tangible object's composition. It allows the modeling of the composition of any type of valuable entity according to the TOC automaton, that uses parthood concepts and properties. Furthermore, the parthood relations specialize the parthood properties according to the type of the domain and range entities.

2.1 Ontology Formalization in OWL2

As OWL does not provide any built-in primitives for part-whole relations [15], we aim at filling this gap through the TOC ontology. An initial implementation of the ontology is built using OWL2 in Protégé. An OWLdoc documentation is available at the following URI `http://lig-tdcge.imag.fr/steamer/patrimalp/TOC-ontology`.

2.2 TOC components

The TOC ontology introduces two main parent-concepts, *ParthoodConcept* and *ValuableEntity*, and two main parent-properties, *ParthoodProperty* and *ParthoodRelation*. Together, they form the main components of the TOC ontology that are used as the elements of the *TOC automaton*. Due to the limitation of space, for further explanation of concept in this section, refer to the online documentation `http://lig-tdcge.imag.fr/steamer/patrimalp/TOC-ontology`.

ParthoodConcept: It is the parent-concept of the part-whole concepts of the TOC ontology. It encompasses the two primitive classes *Whole* and *Part*, and their subclasses *PartWhole*, *AbsolutePart*, and *AbsoluteWhole*. As the fact of being a part or not being a part is a matter of the perspective upon which an entity is viewed, we base our approach on relativeness. That is an entity A can be viewed as a part with respect some entity B ($\exists isPartOf.B$), and as a whole with respect to another entity C ($\exists hasPart.C$). Thus, an entity is referred to be one of the parthood concepts based on its role in the composition mechanism (compositional function), rather than its nature as an entity. Moreover, one can say that an entity can always be part of a bigger entity, and thus it will be always both; a whole and a part. However, the composition mechanism that we model is based on the closed-world-assumption. That is, for an entity to be a *Whole* or/and a *Part*, it should be explicitly expressed that it has the relation *hasPart* or/and *PartOf* respectively.

ParthoodProperty: It is the parent-property of the part-whole properties of the TOC ontology. It encompasses the two primitive properties *hasPart* and *isPartOf* which are inverse properties. More specifically, depending on the domain's and range's types as roles in the composition mechanism, the subproperties are *hasAbsolutePart*, *hasRelativePart*, *isAbsolutePartOf*, and *isRelativePartOf*.

ValuableEntity: It is the parent-concept of the entity types in the TOC ontology. We refer to the hierarchy of valuable entities built in CHARM [17], the Cultural Heritage Abstract Reference Model. We extend it by generalizing some terms and presenting it as an infrastructure ontology of entity types in TOC.

ParthoodRelation: It is the parent-property of the part-whole relations of the TOC ontology expressing not only relations between whole and part entities, but also the spatial position of the part with respect to whole. It specializes 7 cases of part-whole and spatial relations depending on the domain's and range's entity-types. Out of which, 5 relations are based on Winston's linguistic taxonomy of part-whole relations (1, 4, 5, 6, & 7) and reused, and 2 proposed ones (2 & 3).
1- Area-Place: is the meronymic relation between two spatial entities. RCC8, the qualitative spatial representation and reasoning calculus, is used as the ontological family of relations to represent the area-place parthood relation.
2- Place-Object: is the relation between a spatial entity and a material or methodological entity. In our model, 4 ontological relations are used to it: contained-in, located-in, located-on, and includes-stratigraphy.
3- Sequence-Unit: is the relation between a group of entities having order (functional spatial/temporal relation) and an entity of this group. Two ontological relations are used to represent it: object-stratum-of and deposit-stratum-of.
4- Mass-Portion: is the relation between portions and masses, extensive objects, or physical dimensions. In our model, we choose two ontological relations to represent it: sample-of and fragment-of.
5- Integral Object-Component: is the meronymic relation between components and the object to which they belong. In our model, the ontological relation sub-object-of is used to represent it.
6- Object-Stuff: is the meronymic relation representing what an object is made of. The ontological relation has-material-composition is used to represent it.
7- Collection-Member: is the relation between an abstract group of entities and an entity of this group i.e. membership. In our model, the ontological relation member-of is used to represent it.

TOC automaton: A graph representation of the composition mechanism using nodes and arcs to represent the parthood concepts and properties respectively.

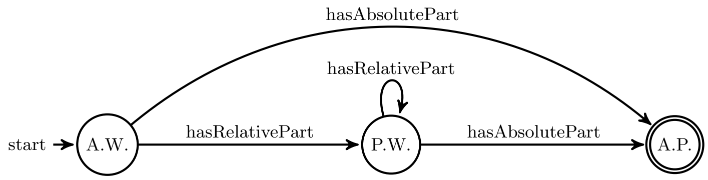

Fig. 1. The TOC automaton

2.3 Discussion of the model's application

For the overall structure of the application of the model, our approach is a "Global as View" approach [16] presenting a global ontology, the TOC ontology. TOC uses generic and domain-independent vocabularies that make it applicable in more than one domain. It can be used as a language representing objects' composition, and to which local ontologies -of different domains- can be linked. This link can be seen as an instantiation of local models from the global one. An example of a local model is an archaeological CH model representing the composition of a CH site in general, and Rocher du Chateau site in particular. For the usage of the model's components, figure 2.3 illustrates an example of the composition of an entity X. On the one side, each entity is classified, according to its nature, to a valuable entity type upon which the corresponding part-whole relation is used. On the other side, according to the occurrences of the *isPartOf* and *hasPart* properties of each entity, it will be classified into a parthood concept representing its function in the composition mechanism.

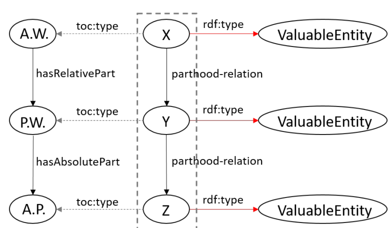

Fig. 2. An example of the usage of TOC's main components

2.4 Evaluating ontological decisions using OntoClean

For evaluating the correctness and consistency of the ontology's taxonomy, we use the OntoClean methodology [18]. OntoClean is used in Protégé with OWL and its reasoner based on the OntOWLClean approach [19]. According to the tutorial of applying OntoClean in Protégé [20], three tasks were performed: punning the TOC ontology, assigning meta-properties to classes of the TOC ontology, and running the reasoner to discover the inconsistencies. This resulted in no inconsistencies which validates the correctness of our taxonomy. The built TOC-with-OntoClean ontology is available at the URI `http://lig-tdcge.imag.fr/steamer/patrimalp/TOC-with-OntoClean`.

3 Conclusion and future work

In this paper, we illustrated the work done in the CH context and highlighted the gap of focusing on the preservation and restoration of a CH entity. Then, we proposed the approach of modeling the composition of tangible entities using part-whole and spatial relations. After that, we presented the TOC ontology and provided an OWL2 based implementation. We also discussed the model's application using an example from the CH domain. For the ontological evaluation of the model, we showed the validity of its taxonomy using Ontoclean.

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