Towards an Ontology-enabled Approach for Modeling the Process of Conformity Checking in Construction

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Abstract. This paper presents an ontological method aimed at semi-automatic checking the conformity of a construction project represented by RDF graph against a set of construction norms formalized as SPARQL queries. The reasoning is modeled by the matching of RDF representations of construction projects to SPARQL conformity queries. We integrate meta-knowledge relative to the checking process by annotating the conformity queries themselves and organize them according to their annotations. The queries annotations also help to guide the information/knowledge extraction and reasoning process and explain the results of the validation process, especially in case of failure.

Keywords: Conformity checking, knowledge extraction in construction, organization of the base of conformity queries, Semantic Web in Construction.

1 Introduction

The execution of construction products is nowadays characterised by complex rules and regulations. However, their current representations are still mostly paper-based (e.g. texts with diagrams, tables) and require a human interpretation [7].

Construction projects (e.g. public buildings) are commonly represented by the Industry Foundation Classes (IFC) model, an object oriented data model for Building Information Modelling. There is a standard XML representation for the IFC model (ifcXML[1]), which is, however, insufficient to describe the complexity of the building information flow: the IFC model is semantically richer than any XML language.

Our research aims at the development of a conformity-checking model based on semi-formal representations of technical norms: we study how to represent and organise them for the specific task of effective conformity checking. Our checking model is based on the matching of norm representations with those of construction projects. Its efficiency is explained by the *ontological representation* of regulation

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[1] http://www.iai-international.org/IFCXML/

knowledge and the conformity-oriented *annotation of norms* with meta-knowledge improving the checking process and the explaination of its results.

2 Knowledge Representation Oriented Conformity Checking

The first phase of our knowledge acquisition method aims at *acquiring formal representations of technical construction norms* relative to the accessibility of disabled persons. We use the CD REEF, the electronic encyclopaedia of construction texts and regulations, to extract a base of accessibility constraints, which we formalise as SPARQL queries in terms of the IFC model. This is a manual process (the knowledge extraction from texts is out of the scope of our research) conducted in collaboration with construction experts (mainly from CSTB) who help to explicit the domain knowledge. As a result, we are provided with a base of SPARQL queries expressing *non conformity* constraints: e.g. "*The minimum width of a door is 90 cm*" is formalized by:

```
select ?door display xml where
{ ?door rdf:type ifc:IfcDoor
OPTIONAL { ?door ifc:overallWidth ?width
FILTER ( xsd:integer(?width) >= 90)}
FILTER (! bound( ?width) )}
```

The second phase aims at the *semi-automatic acquisition of an ontology oriented conformity checking.* This conformity-checking ontology is developed on the basis of the concepts occurring in the acquired conformity queries. *Primitive* IFC concepts are extracted from the ifcXML schema - solely those occurring in the conformity queries; they are organized into an OWL Lite ontology based on the schema structure. The conformity queries also make use of some non-IFC concepts. To integrate them in the ontology, the intervention of a domain expert is necessary whose task is to define these concepts with primitive IFC concepts. These definitions are represented by RDF graphs (e.g. GroundFloor is a subclass of IfcBuildingStorey defined as an IfcBuildingStorey situated on the level of entering into a building: the value of property pset_BuildingStoreyCommon_EntranceLevel is TRUE).

The third phase of our method consists in *the annotation of the conformity queries themselves for effective checking.* We associate them supplementary information, which is helpful in the conformity checking process: e.g. information on the regulation corpus from which queries are extracted. We automatically extract RDF annotations of conformity queries from the CD REEF, which contains information relative to regulations (in addition to the regulation itself): (i) characteristics of the regulation: type of regulation text (e.g. Construction Code), level of application (e.g. national); (ii) application domain (e.g. accessibility); (iii) destination of a building (e.g. public administration building). The acquired RDF annotations are later manually enriched by *domain* knowledge: (i) subject (e.g. entrance door); (ii) construction common knowledge (*obvious* for domain experts: e.g. a hotel is a public building, not a private house), etc.

The last phase is dedicated to the *acquisition of a construction project representation oriented conformity checking*. Such representations are developed on the basis of the initial IFC representation and guided by the acquired conformity-checking ontology. First, we develop an XSLT stylesheet that filters the ifcXML description of a construction project, transforms only the data relative to the conformity checking ontology and finally builds an RDF graph representing the project. This RDF representation may be further enriched with some non-IFC concepts defined in the conformity-checking ontology (in second phase of our method) in case their definitions appear as subgraph as the RDF graph representing the project.

4 Conformity Checking Model

We adopt an ontological approach and the semantic web technologies [2] to develop our reasoning model [7]. It is based on graph-based formalisms for knowledge representation, which have declarative semantics, are logically founded, allow the structured representation of knowledge and describe it at the different levels (e.g. ontological and asserted knowledge). The basic reasoning operation for a query-answer system is graph projection, formally defined as a labelled homomorphism between graphs [3]. The *reasoning thus consists in graph homomorphisms* [1] [5] and modelling of the checking process is close to the process of validation of knowledge bases [6]. The elementary reasoning mechanism of our model is the matching of a construction project representation with representations of conformity queries. We check the *negative* constraint (e.g. "*the width of the door is less than 90cm*"): if such matching is found for some elements, these elements cause the *non-conformity* of the project.

Conformity queries are automatically classified and organized into a query base by parsing their RDF annotations. The classification is done according to (i) external information characterizing the query (e.g. regulation text); (ii) specialization-generalization relations, which could be found in the graph patterns of queries.

By organizing the queries, we define the optimal scheduling of matching procedures as *a set of explicit expert rules*. The expert reasoning is represented by the *query scheduling*: (i) according to priorities holding between *classes* of queries (e.g. queries extracted from *acts* are prior to *circular* ones); (ii) according to knowledge specification: inside the same query class, queries representing more specialised knowledge are treated in priority (e.g. an *entrance door* query is prior to a *door* query, because if a construction project is non conform to the first one, it will be automatically non conform to the second one); (iii) according to query annotations: priority is given to the queries with most specific annotations.

The *results of the checking process* (validation/non-validation, explanation of non-validation, no answer) are *analysed* to generate *a structured conformity report* grouping conformity queries by classes. It is automatically generated on the basis of annotations of classified queries. The conformity report lists queries that have failed (i) because of non-matching; ii) queries which graph pattern is more general in comparison to the ones previously that failed, (iii) queries which annotation representing the condition of its application is more general in comparison to the annotation of another failing query. Another possible reason of failure of the project validation is that the representation of the construction project does not contain sufficient information for matching. In case of such incomplete representations, it is useful to precise the lacking elements (the sub patterns of the query which can not be matched), so that a user could know the reason of non-verifiability and/or complete the representation of the project.

5 Conclusion and Perspectives

We have presented the ontology-enabled model for the conformity checking process of a construction project against conformity norms, based on matching of an RDF representation of a project to a SPARQL conformity query. Conformity queries are annotated and organized to improve the checking process and help in the interpretation of checking results in terms of conformity in construction.

For validation of our conformity-checking approach, we develop the C3R[2] system, which relies on the CORESE [4] semantic engine that answers SPARQL queries asked against an RDF/OWL Lite knowledge base.

Ongoing works focus on the incremental development of the C3R prototype and its evaluation by domain experts.

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