ONTOLOGICAL APPROACH FOR THE CONFORMITY CHECKING MODELING IN CONSTRUCTION

Catherine Faron-Zucker, Nhan Le Thanh
I3S, Université de Nice Sophia-Antipolis, CNRS, 930 route des Colles, BP 145, 06903 Sophia Antipolis, France

Anastasiya Yurchyshyna*, Alain Zarli
CSTB, Centre Scientifique et Technique du Bâtiment, 290 route des Lucioles, BP 209, 06904 Sophia Antipolis, France
** I3S, Université de Nice Sophia-Antipolis, CNRS*

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Abstract: This paper presents an ontological method and a corresponding system C3R aimed to semi-automatically check the conformity of a construction project represented by RDF graph against a set of construction norms formalized as SPARQL queries. Our conformity-checking model has a two-level structure: the reasoning relies on matching of these queries and graphs and on expert rules guiding the checking process itself by optimal scheduling of matching procedures, according to semantic annotations of conformity queries, which integrate the meta-knowledge on the checking process (formalized with the help of CSTB experts). The reasoning results with a detailed (non)conformity report in terms of the Construction domain.

1 INTRODUCTION

The Construction industry is a major user of increasingly complex technical regulations defining the execution of construction projects (e.g. public buildings). To reply the increasing demand of the implementation of electronic regulation services, multiple researches are recently conducted: e.g. the ePOWER and the ISTforCE project, where CSTB has participated (IST eGovernment projects, 2007), aimed at the (semi)automation of the conformity checking process of a construction project against a set of technical norms. Our research work answers this initiative and focuses on the development of the ontology-enabled, construction-oriented conformity-checking model.

Today, construction projects are usually represented in the Industry Foundation Classes (IFC) model, an object oriented file format that becomes a standard for Building Information Modelling. The IFC model captures information about all aspects of a building throughout its lifecycle and its use is compulsory for publicly aided building projects. The IFC model allows an XML representation of a construction project (ifcXML) that can be automatically generated by architecture-oriented CAD tools (e.g. AutoCAD). The IFC model (and the ifcXML representation) fails, however, to represent the whole semantic complexity of construction data used for conformity checking (Yang, Zhang, 2006). It is not particularly oriented towards the checking problem either.

For this reason, we propose our knowledge acquisition method (Faron-Zucker et al, 2008) to model all the knowledge of the conformity-checking process in construction. First, we develop an ontology based on the classes of the IFC model, dedicated to and oriented by the problem of conformity checking. Second, in collaboration with domain experts, we develop a base of semi-formal representations of conformity queries and propose a special query annotation of these queries to integrate meta-knowledge on the checking process. Guided by the conformity-checking ontology, we then extract a construction project representation from its initial ifcXML data that is oriented conformity checking.

Our conformity-checking model is based on the matching of the norm representations with representations of construction projects. Its efficiency relies on two keystones: the ontological

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representation of construction regulation knowledge and the knowledge extraction process guided by the acquired ontological knowledge. To control the construction process itself, the model also integrates meta-knowledge formalized with the help of CSTB experts: we propose a special annotation of construction queries and organize them according to these annotations to schedule matching procedures. Such semantic annotations are also used to generate a conformity report and to explain the user the *non-conformity* results of the validation process.

2 ACQUISITION OF USEFUL REPRESENTATION OF CONSTRUCTION PROJECT

We adopt the ontological approach and the semantic web technologies (Berners-Lee, 2001) to acquire a representation of a construction project oriented the specific task of conformity checking. The success of the checking process relies on the ability to develop mechanisms of ontological reasoning: this representation should be semantically richer than its initial ifcXML description. Our research is based on the works of (Bell, Bjorkhaus, 2006) aiming at the development of a construction ontology buildingSMART and the projects aiming at the development of the IFC-to-OWL conversion tool (Schevers, Drogemuller, 2005).

2.1 Acquisition of a Conformity Query Base

The first phase of our knowledge acquisition method aims to explicit formal representations of technical norms. We use the CD REEF, the electronic encyclopaedia of construction texts and regulations, to extract a base of accessibility *non-conformity* constraints, which we formalise as SPARQL queries in terms of the IFC model: 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 ?w
FILTER ( xsd:integer(?w) >= 90)}
FILTER (! bound( ?w) )}
```

This is a manual process (the knowledge extraction from texts is out of the scope of our research) conducted in collaboration with CSTB experts who help to explicit the domain knowledge.

However, these queries contain only conformity constraints, but have no information useful for the *process* of conformity checking: e.g. the information of the regulation corpus from which the queries are extracted, etc. To integrate this information into our checking model, and thus to make it more “intelligent”, we propose a special RDF annotation of conformity queries, which contains all the information related to the checking process not represented by the query itself. It can be:

- Characteristics of the *regulation text* from which a query was extracted: (i) regulation type (e.g. circular); (ii) thematic (e.g. accessibility); (iii) title, publication date, references; (iv) level of application (e.g. national), (v) destination of a building (e.g. private house); (vi) characteristics of extraction process: article and paragraph from which a query was extracted (e.g. 1st paragraph of *Door* article).
- *Formalised expert knowledge*: tacit « common knowledge » on the process of conformity-checking that is commonly applied by domain experts: (i) knowledge on (sub)domain of the application of a query (e.g. Stairs); (ii) knowledge on checking practice (e.g. if a room is *adapted,* it is *accessible*)
- *Application context of a query*: the aspects of query application for certain use cases. For example, the requirements on the maximal height of stairs handrail vary from 96 cm (for adults) to 76 cm (for kids). In this case, it is important to know the destination of a building (e.g. school).

Characteristics and possible values of the first two groups are automatically extracted from the CD REEF. The knowledge described by the last two groups is defined partially and/or has to be explicitly formalised by domain experts.

2.2 Acquisition of Conformity Checking Ontology

The second phase is dedicated to the development of a conformity-checking ontology based on the IFC model. Guided by the goal of conformity checking, this ontology includes only the *primitive* IFC concepts (extracted from the ifcXML schema) occurring in the acquired conformity queries. These concepts are organized as hierarchies and described in the OWL Lite ontology. If conformity queries make use of some non-IFC concepts, we integrate them into the ontology. The intervention of domain experts is required in this case to define these concepts with primitive IFC concepts. These definitions are represented by RDF graphs (e.g. GroundFloor is a subclass of IfcBuildingStorey situated on the level of entering into a building).

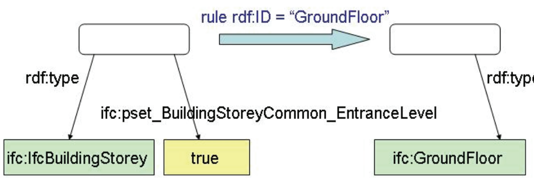

Figure 1: *GroundFloor* definition by a rule of RDF graphs.

2.3 Acquisition of the RDF Representation of a Project

The extraction of the RDF representation of a construction project is conducted by a XSL transformation of its initial ifcXML representation. Such transformation is guided by the acquired conformity-checking ontology. The acquired RDF is then enriched with non-IFC concepts extracted from conformity queries (e.g. a project representation is enriched by GroundFloor concept defined by its initial IFC-based data: IfcDoor, IfcStair, etc.).

3 CONFORMITY CHECKING MODEL

Our conformity-checking model is based on the matching of norm representations to construction project representations. Such modelling corresponds to the research on validation of knowledge bases (Dibie-Barthélemy et al, 2004), constructed according to the model of conceptual graphs (Sowa, 1984), (Baget, 2005). The results of matching and the non-validation reasons are interpreted in terms of conformity checking. To optimise expert reasoning, we organise the base of conformity queries, according to their semantic annotations, and define the optimal scheduling of matching procedures.

3.1 Validation by Projection

The elementary reasoning mechanism of our conformity-checking model is the matching of a construction project representation with representations of conformity queries. In practice, we interest on the *non-conformity* condition and the elements of the project causing its non-conformity against a query: a construction project is *conform* to a query, if there is no projection of the SPARQL representation of this query into the RDF of the project. If such projection is found for some elements, these elements are *non-conform*. If the RDF of the project does not contain enough information "asked" by the query, the projection cannot be established: *no answer on the conformity*.

3.2 Organisation of the Base of Conformity Queries

The organisation of the base of annotated conformity queries allows defining optimal scheduling of matching procedures. First, we classify them according to the *regulation texts* regrouping the queries: (i) thematic (e.g. acoustics), (ii) regulation type (e.g. NF norm); (iii) complex title, publication date, etc.; (iv) level of application (e.g. European), (v) destination of a building (e.g. public building). This classification is generated automatically by parsing the RDF semantic annotations of conformity queries. Second, we classify conformity queries on the basis of *specialisation/generalisation* relations, which can be found in their graph patterns. For example, queries concerning a building (e.g. public building, three-floor house, school) are in the class defined by a primitive concept IfcBuilding.

3.3 Formalisation of Expert Reasoning

By organizing the queries, we define the optimal scheduling of matching procedures as *a set of explicit expert rules,* which are defined by priorities holding between whole *classes* of queries.

For conformity queries classified according to *regulation texts* from which they were extracted, the scheduling of these queries corresponds to the order/hierarchy of their classes: e.g. queries extracted from *decrees* are prior to *circular* ones.

For queries classified according to *specialisation/generalisation relations* between their graph patterns, queries representing more specialised knowledge are treated in priority: e.g. an *entrance door* query is prior to a *door* query (*entrance door* is a specialisation of *door*): the non-conformity of a project to the first one implies its non-conformity to the second one.

For queries classified according to their semantic annotations, priority is given to the queries with most specific annotations: e.g. to check the accessibility of a *school*, we should start by queries applied to *public building receiving sitting public* and continue by more general queries applied to *public building receiving public.*

3.4 Analysis of the Results of Conformity Checking Process

The results of the validation process (validation/non-validation, elements causing the non-validation and its possible reasons) are used to generate a conformity report, which interprets them in the terms of conformity checking: "what's and why's of non-conformity". It lists thus the *failed* queries: (i) because of non-matching; (ii) which graph pattern is more general in comparison to the ones previously failed; (iii) which annotation is more general in comparison to the annotation of a failed query.

Moreover, the other possible reason of validation failure is the case when the representation of the construction project does not contain enough information for matching. For such incomplete representations, it is useful to define the lacking elements (the pattern sub graphs of the query which can not be matched) for necessary modifications.

4 C3R SYSTEM

The conformity-checking model we propose is called C3R that stands for Conformity Checking in Construction with the help of Reasoning (Fig. 2).

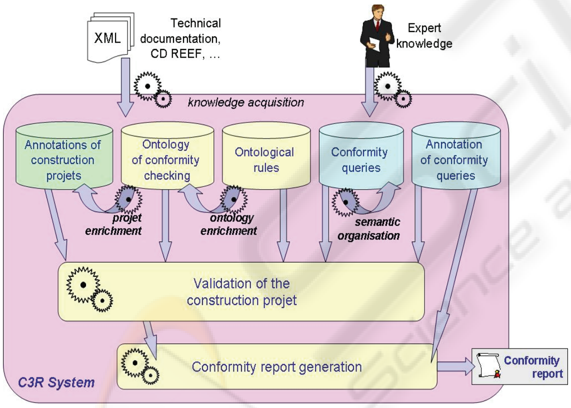

Figure 2: C3R in a nutshell.

The main phases of the C3R approach are as follows: (1) Acquisition of conformity queries; (2) Semantic annotation of queries and hierarchical organisation in query base; (3) Acquisition of conformity-checking ontology; (4) Acquisition of a useful annotation of a construction project; (5) Application of expert rules; (6) Validation by matching; (7) Generation of the conformity report.

For the checking operation itself, C3R relies on the semantic search engine CORESE (Corby, Faron-Zucker, 2007), which answers SPARQL queries asked against an RDF/OWL Lite knowledge base.

5 CONCLUSIONS

We have presented an ontological approach for the conformity-checking model in construction. Our checking model is based on matching of an RDF representation of a project to a SPARQL conformity query. We developed a special semantic annotation of conformity queries that integrates the meta-knowledge on the checking process. The queries are organized according to these annotations. This allows formalising expert rules guiding the checking process and interpreting the results of checking in terms of conformity in construction. Ongoing works focus on the incremental development of the C3R prototype and its validation by construction experts.

REFERENCES

Baget J-F. RDF Entailment as a Graph Homomorphism, in *Proc. of the 4th international semantic web conference (ISWC'2005), Galway (EI),* LNCS 3729, Springer Verlag, pp 82-96, 2005

Bell H., Bjorkhaug L., A buildingSMART Ontology. In *Proc. of the European Conference on Product and Process Modeling (ECPPM-2006)*, Valencia, Spain, 2006, pp. 185-190

Berners-Lee T. (2001). Reflections on Web Architecture. Conceptual Graphs and the Semantic Web. Available at http://www.w3.org/DesignIssues/CG.html

Corby O., Faron-Zucker C., Implementation of SPARQL Query Language based on Graph Homomorphism, in *Proc. of the 15th International Conference on Conceptual Structures (ICCS'2007)*, Sheffield, UK, LNCS, Springer Verlag

Faron-Zucker C., Yurchyshyna A., Le Thanh N. & Lima C Une approche ontologique pour automatiser le contrôle de conformité dans le domaine du bâtiment. *In Actes des 8èmes journées Extraction et Gestion des Connaissances, EGC'2008*, RNTI-E11, Cépaduès, p. 115-120. Sophia Antipolis, France (2008)

IST eGovernment projects, available at http://ec.europa.eu/information_society/activities/egovernment_research/doc/pdf/wkshop05.05.04_rep.pdf

Schevers, H. & Drogemuller, R. Converting IFC data to the web ontology language, in Proc. of the 1st International Conference on Semantics, Knowledge and Grid (SKG2005), Beijing, China

Sowa J.F. Conceptual Structures: Information Processing in Mind and Machine, *Addison-Wesley,* 1984

Yang, Q., Zhang, Y. Semantic interoperability in building design: Methods and tools, *Computer-Aided Design* 38(10): 1099-1112 (2006)