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TOWARDS AN ONTOLOGY-BASED APPROACH FOR CONFORMANCE CHECKING MODELING IN CONSTRUCTION

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ABSTRACT: This paper gives an overview of a formal ontological approach of conformance models for regulations in Construction aiming at answering the research question: "is an IFC-represented building project compliant to a set of construction rules?" The study analyses three key subtasks: (i) transformation of the IFC of the construction project; (ii) regulations formalisation; (iii) conformance checking reasoning. While analysing the IFC model redundancy and/or insufficiency for conformance checking reasoning, we suggest an intermediate RDF-based model, semantically enriched and regulation-oriented. The regulation formalisation is studied under two viewpoints: the formalisation of paper-based regulation texts to be automatically used in reasoning and the development of the representation of ontology-based regulations. The construction rules are represented as a set of rules which premise and conclusion are RDF graphs. The conformance checking starts from the alignment of the construction project ontologies to the premise/conclusion ontologies of the construction rule. Then, the checking in construction is seen as reasoning in terms of the corresponding RDF graphs. The paper concludes with a preliminary conceptual framework based on Semantic Web technologies modeling the conformance checking problem, as well as the technical solutions for its implementation. The respective architecture and future challenges of the work are also discussed.

KEYWORDS: conformance checking, ontologies in construction, e-regulations, construction project conformance to regulations, semantic web in construction.

1 INTRODUCTION

Today, the construction industry is a major user of increasingly complex rules and regulations affecting products, components and project execution which play an important role in the security and quality guarantee of a building, its exploitation characteristics and environmental compatibility features.

Current representations of regulations are mostly paper-based (texts with diagrams, tables and plans) and require a total human interpretation in order to make them (i) accessible electronically; (ii) structured and understandable by machines; (iii) represented in a standard format and interoperable (Lima et al. 2006). Therefore, it reveals clear that an expert's knowledge turns out to be a necessary component to apply them on practice, as well as to use them in other automated elaboration and validation operations. Under the initiative of eGovernments, multiple studies on implementing electronic regulation services are conducted: OntoGov, INTELCITIES, TERREGOV project, QUALEG 2005, e-POWER, ISTforCE, to mention but a few.

The construction products (e.g. public buildings, roads, private houses) can be represented using the IFC[1] format. The IFC data model is an object oriented file format with a data model developed by the IAI[2] to facilitate interoperability in the building industry, and is a commonly used format for Building Information Modeling (BIM)[3] that captures information about all aspects of a building throughout its lifecycle. Because of its focus on ease of interoperability between different software platforms the use of IFC format is compulsory for publicly aided building projects. In the regard of the conformance checking in construction, there are two different but complementary perspectives to be taken into account. Firstly, only the necessary information for conformance checking process should be extracted from the IFC and added to a simplified intermediary format. From the other viewpoint, the complexity of the conformance checking problem requires semantically rich data concerning a construction project. We argue the role of Semantic Web mechanisms facilitating the integration of the "extern" related construction information into the IFC-based intermediary model used for reasoning.

The main objective of this research is the development of the conformance-checking model answering the question: "How compliant is the IFC-based project to a set of construction rules?" In this paper, we discuss our contribution

[1] The Industry Foundation Classes

[2] International Alliance for Interoperability, http://www.iai-international.org/

[3] http://www.iai-international.org/Model/IFC(ifcXML)Specs.html

to an innovative work to continue progress in this direction and propose our solution of modelling of the checking process. In order to do this, we introduce a formal ontological approach to model the conformance checking of a construction project to construction regulations which are represented through RDF-based ontologies and the reasoning in terms of conceptual graphs.

The paper is organised as follows. The analysis of the conformance-checking problem in construction is provided in the section 2. The section 3 introduces the knowledge representation of the construction project and the construction rules. The development of the ontological representation of the construction project which is aligned to the regulation ontology is discussed in the section 4. The section 5 makes parallel between the conformance checking in construction and the reasoning in terms of graphs by the homomorphism of two conceptual graphs. The section 6 discusses the implementation of our research and provides the general framework of conformance-checking system. In conclusion, we present the ongoing works and the challenges of the research.

2 ANALYSIS OF THE CONFORMANCE-CHECKING PROBLEM IN CONSTRUCTION

Nowadays, the importance of conformance checking problem in construction is proved by multiple studies throughout the world:

- The *Singapore ePlanChecking* system, a major application of expert systems technology that automates the checking of many hundreds of building, fire, civil defence, disability access, water use, food hygiene and other regulations for government agencies through the integration of expert knowledge in conformance checking and computer-aided design (CAD);
- The *Norwegian Byggsok* system aiming publishing the information required to prepare zoning plan or building applications. That provides a basis for communication between developers and local Government and registers applications for development and construction;

The vision moving these works inspires our research on the conformance checking modelling in construction. We analyse it from three main viewpoints: (i) Can we use the existing IFC model for reasoning? (ii) How the construction regulations can be integrated to the conformance checking process? (iii) Which reasoning formalisms can be implemented (graphs, FOL[4], DLP[5], etc.)? The answers to these questions point to three main research problems: (i) the transformation of the IFC model to the intermediary model that is semantically richer and regulation-oriented; (ii) the ontological representation of the construction rules; (iii) the reasoning if this intermediary model is compliant to a set of ontologically represented construction rules. The development of the efficient reasoning algorithms depends on the computational completeness and expressiveness of the regulation knowledge base, as well as on the characteristics of the IFC-based intermediary model of the construction project. We take these criteria into consideration while analysing the reasoning formalisms, as they could turn out contradictory (good decidability corresponds to poor expressiveness and vice versa).

Our work therefore comes within the scope of this double trend: we intend to develop a checking system manipulating the semantics of non-formalised construction knowledge and make it available on the web. The development of the corresponding system is based on the ontological approach of the knowledge representation and the reasoning in terms of the RDF model implemented thanks to the Semantic Web standards (XML/S, RDF/S, OWL).

Aiming at answering three key problems of the conformance checking in construction, a checking reasoning system should project the regulatory environment into simple Web-based applications facilitating the process of conformance checking. It enables the end users to check their IFC-represented construction project to a set of construction rules (environmental, accessibility regulations, etc.). Constantly developed and modified by national and international regulation bodies, the construction regulations are available in the Internet. However, because of their complexity, they cannot be formalised directly without human interpretation. Therefore, the semantic enrichment of regulations is a necessary step before adding them into a rule-based regulation system. The results of the process are to be communicated in a verification report, listing non-verified rules together with offending items in the project. Moreover, during the checking process, the premise and conclusion parts of checked rules are validated by a domain expert, so they could be added to the conformance checking rule ontology that enriches the regulation knowledge base. This base should be accessible for a user so that s/he can easily interrogate it via web-based services and define a set of construction rules to check. In this user-oriented architecture, the complexity of the system is hidden due to Web-based services and applications giving access only to the interface, but not to the structure of reasoning algorithms.

3 KNOWLEDGE REPRESENTATION

3.1 *Model-based representation of construction projects*

The construction projects are represented and exchanged in IFC, the open object-oriented international standard for building information interoperability. The IFC model is intended to support interoperability across the individual, discipline-specific applications that are used to design, construct, and operate buildings by capturing information about all aspects of a building throughout its lifecycle[6].

We should note that in architectural practices, the use of IFC format is still rare in the early stages of design. The architects prefer to work with various documents, schemas and plans and to transform them into the IFC format later, if necessary. However, the IFC model is now supported by most of the major CAD vendors as well as by

[4] FOL: First Order Logics
[5] DLP: Description Logic Programming

[6] http://www.aecbytes.com/feature/2004/IFCmodel.html

many downstream analysis applications which possess necessary plug-ins for IFC generation (e.g. ArchiCAD).

Generally speaking, the IFC model allows the XML representation or can be automatically generated from an EXPRESS schema via BLIS-XML[7], a methodology for encoding EXPRESS-based information in XML format. That's why; we suppose that each construction project has its representation in the IFC model in the XML format (ifcXML[8]): that is well defined and efficient for information exchange.

However, the complexity of the building information flow sometimes leads to failure of the IFC model to describe a construction project that is semantically richer than XML could provide. Multiple researches aiming the standardisation of construction project representation and exchange are recently held under the ontological viewpoint:

- the International Framework for Dictionaries, (Bell & Bjorkhaug 2006), a standardised library of semantic descriptions of the IFC terms. It is the base for the construction of the global buildingSMART ontology that can be detailed to a particular project;
- the analysis of the evolution of the IFC standard guided by the needs of the ifcXML interoperability and the ontology representation (Aranda-Mena & Wakefield 2006);
- the bcXML[9] initiative of the development of the XML vocabulary for construction needs.

Guided by the needs to increase the semantics of the representation of a construction project, we suggest representing the construction project in RDF, the standard language of the Web above XML which graph model is rather expressive to apply the reasoning formalisms. A powerful knowledge representation tool, RDF is also a powerful visual formalism, so it does not require am additional interface. It allows representing different types of knowledge (e.g. ontological and factual) in graph reasoning which is based on graph homomorphism.

In a formal way, the RDF-structured document is a set of triples {subject, object, predicate} where each element is identified. The RDF representation structures the non-structured documents as nodes and organises them in graphs by annotating them and proposing the graph representation interface. The subject of each triple is URI or an anonym node, the predicate is URI and the object can be URI, a literal or an anonym node. A triple itself corresponds to the oriented arc, which label is the predicate, the source node is the subject and the end node is the object. According to this representation, a RDF document corresponds to a labelled oriented multi graph. By choosing the RDF formalism for modelling the construction project, we thus obtain the hierarchical structure for the representation while keeping the expressiveness for the reasoning.

The RDF-representation of the project can be achieved semi-automatically from its ifcXML by extracting the RDF triples from the class diagrams corresponding to the IFC entities. This extraction is based on the hierarchy of IFC classes, IFC objects (the instances of IfcObject and its sub classes), IFC properties (the instances of IfcProperty and its sub classes) and the relations between these classes. The classes and their instances could be interpreted as subject and object of RDF triples, and the relations between them could be seen as properties of RDF triples. Such extraction is achieved by the XSLT transformation of the ifcXML representation of the construction project into RDF. This RDF description is then analysed by a domain expert who validates the representation. An expert can also enrich the project description with the additional knowledge from his own experience (e.g. calculating the "passing width" concept from the parameters of the door and adding this concept to the construction project description).

3.2 *Representation of construction rules*

The code dissemination by administrations or organisations of regulation is still mostly paper-based (texts, diagrams and tables), even if the electronic form becomes more frequent nowadays, thanks to the Internet (Lima et al. 2006). Even if the special tools are used for the dissemination of regulations, there is no real assistance for the usage of these documents. Besides, they are sometimes not so easy to be found and understood with their correct meaning. In order to become operable, the regulations need a human interpretation of some background knowledge implicit in the annotations according to the knowledge base of a construction practitioner. The problem of 'digitalising' the regulations consists of two aspects: the text conversion (from PDF- et HTML-format into XML) and semantic enrichment of converted documents (which also includes the information 'lost' during the text conversion).

The transformation of the 'text' regulations into XML is based on the knowledge extraction methods: (i) by analysing the hierarchical structure of the documents and by adding new tags (Kerrigan 2005); (ii) natural language analysis (Nédellec and Nazarenko 2005); (iii) linguistic extractions (Amardeilh & al. 2006), etc. These transformations are characterised by the significant lost of information. The expert support is thus necessary before machines could use the regulations. The next phase consists in the semantic enrichment of the XML data by "meta" tags (Kerrigan 2005) in order to integrate tacit knowledge into the regulations.

It is important to note that nowadays the dissemination of e-regulations becomes more frequent thanks to the implementation of eGovernment strategies, which simplify the access to, and the automatic treatment of the regulations.

The ongoing research in the sphere is concentrated on the semantic enrichment of the regulations by modelling them by more expressive formalisms. As example, we can name the following projects:

- Methodologies and tools to support enabling Local Governments to manage their policies in a transparent and trusted way, carried out by the QUALEG project (*QUALEG 2005*);
- The development of a knowledge management solution via methods/tools that help to improve the quality of legislation, conducted by the *e-POWER* (European Program for an Ontology based Working Environment

[7] http://www.blis-project.org/BLIS_XML/
[8] http://www.iai-international.org/IFCXML/
[9] http://www.econstruct.org/

for Regulations and Legislation) project. Of particular relevance to this work is their method for converting legislation/regulation into formal models (Van Engers et al. 2000);

- *MetaLex*[10], an open format and a generic and extensible framework for the XML and RDF encoding of the structure and contents of legal documents. It is based on the XSLT-based transformation into RDF and OWL.
- Another research on creating standards for the electronic exchange of legal data is carried out by the collaborative work of *LegalXML.org*[11] and OASIS project that form a global consortium driving the development, convergence and adoption of e-business standards. OASIS also manages XML.org focusing on XML developments for eGovernment. The particular interest represents the collaboration partners of The OASIS LegalXML: ebXML (Electronic Business XML), e-Gov, and OASIS's Universal Business Language (UBL) and Digital Signature Services (DSS).
- The CONNIE project under eContent initiative which aims at regulation knowledge base development by OWL-modelling of regulations (Cerovsek & al 2006).

Inspired by these works of the semantic enrichment of the XML-represented regulations, we suggest representing them as ontologies and to use RDF formalism for modelling. This helps to transform all regulations into common format that is independent from the initial representation (paper, XML or RDF/OWL). We can then consider that all regulations have the ontology representation and are modelled by a set of rules which premise and conclusion are RDF graphs linked by a causal rule 'if-then' (see Figure 1).

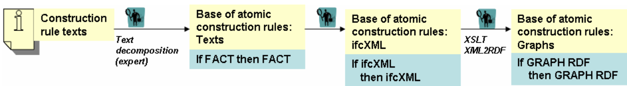

Figure 1. Scheme of the Construction Rules Modelling.

The first sub graph describes the premise of the rule 'if A', the second – the conclusion 'then B'. The rule explains how the knowledge B can be added to the system containing A (Baget, Mugnier 2002), (Corby et al. 2006).

To illustrate this idea, let's take the definition of the minimum door in French construction regulation base (Arrêté du 24 décembre 1980 modifié, article 2)
A = graph describing « La largeur minimum des portes est de 0,90 mètre » ;
B = graph defining « Porte Conforme »

The definition of the door is given in a standard causal form 'if A, then B'

We underline that the linguistic extraction and lexical analysis of the rules semantics are not the key points of our research. Therefore, in the context of this work, we describe only the main aspects of this extraction and rule formalisation, in order to show how the RDF representations of the construction rules could be achieved.

First, the domain expert analyses the texts of construction rules and decomposes them into simple atomic rules, which are represented in the "premise-conclusion" (if-then) form. Each part of the atomic rule is formalized separately. In order to do that, the expert uses the IFC library for the description of the knowledge of the rule. This phase mainly relies on the identification and syntactic comparison of the concepts in the text of the rule to their IFC equivalents. As the result, the expert reformulates the construction rule in the terms of the IFC-based tag dictionary that allows representing it in the ifcXML format. The RDF graph of each part of the rule is then achieved by XSLT transformation of its ifcXML representation.

The construction rule is therefore formalised by two RDF graphs: the premise and conclusion graphs of the regulation.

4 DEVELOPMENT OF THE CONSTRUCTION PROJECT REPRESENTATION "ALIGNED" TO THE REGULATION ONTOLOGY

We have chosen the RDF model as the common representation of both types of construction data: the construction project and the construction rule. The research problem is now concentrated on the ontology alignment of the corresponding models: the concepts of the construction project could be different and non comparable to those of the construction rule.

It is important to underline the fact that the "development of the representation aligned to" is not used in its classic meaning of ontology alignment. We don't align two existing ontologies, as the ontology corresponding to the construction project is not developed yet. So, we also need to construct in the way that it is aligned to the regulation ontology – the alignment of the ontologies is done at the same time one of them is created. It means that the ontology alignment problem is substituted by the development of the ontology on the base of IFC representation transformed to the RDF model of the construction project. In order to reduce the problem complexity, we extract an intermediary RDF-based model which is oriented conformance checking.

The development of the aligned ontology is based on the "classic" alignment algorithms, which estimate the similarity value between the entities of the compared ontologies (concepts, properties, instances, etc.). The similarity values are calculated between the entities of the nodes of the RDF graphs representing the construction project and the rule. In order to deduce the similarity between the entities of two RDF/S representations, the RDF(S) characteristics are analysed (see Figure 2). The similarity value is calculated in two parts: the linguistic one (e.g. the name, the label, the description of the entity) and the structural one (e.g. the "place" of the entity in the RDF graph, the relations between entities). In the paper, we do not discuss the technical details of the modified similarity value algorithms: they are explained in (Bach 2006). Only the nodes with high similarity value could be added to the construction project ontology.

[10] http://www.metalex.nl
[11] http://legalxml.org/about/index.shtm

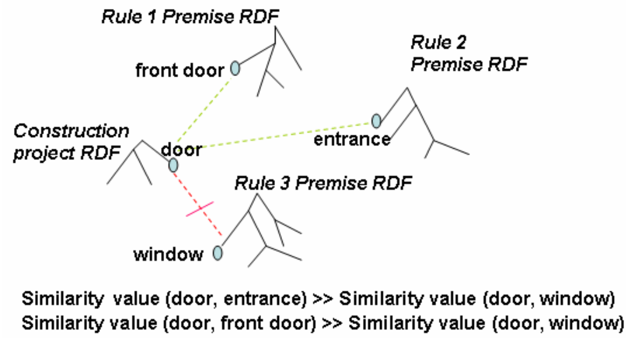

Figure 2. Similarity value between entities of RDF/S graphs.

In the context of conformance checking reasoning, we are more interested in the scenarios of their implementation. The algorithms are applied to the concepts of the regulation rules and to the concepts of the construction project. The similarity value is deduced by analysing the hierarchical structure of classes and the properties between them. If the similarity value between the corresponding RDF is rather high, it means that these classes can be compared in the context of conformance checking. We can also note that they are semantically aligned to the concepts of the regulation ontology.

In a case of low similarity value (insufficient or non formalised information in the initial models, transformation lost, impossibility to treat automatically some tacit knowledge), the system informs the user that the rules are 'not applicable': there are no nodes in the construction project graph that are *semantically* equivalent to the regulation nodes. The user should enter the missing information: (i) to add the information on the construction project; (ii) to precise the semantics (e.g. the quantity dimensions of the 'accessible route'); (iii) to delete this node from the regulation ontology if it is not really used for conformance checking (e.g. in the case when the rule operates indicates the information which it never uses *in practice* for the conformance checking).

The results of this iterative process are as follows: (i) aligned concepts (of the construction project and those corresponding to the premise and the conclusion of the rule); (ii) identification of the construction rule that is *not applicable* because of the *information insufficiency* even after the expert interpretation; (iii) identification of the construction rule that is *not applicable* because of the *impossibility to align the ontologies* by the implemented algorithms.

5 CONFORMANCE CHECKING REASONING

The process of conformance checking in construction can be seen as the reasoning in terms of the graphs of construction project compared to the graphs of premise of the rule and its conclusion.

To start, we must underline that the majority of rules cannot be checked. This conclusion is based on the estimation of the 'checkable' rules, one of the results of the ISTforCE[12] project held by the CSTB. In the scope of this project, an on-line Web based service offering an automated checking tool for projects was developed. The tool has two types of entering data: a construction project (given by a client) and current accessibility regulation knowledge base (that is in free access and dynamically uploaded). According to this estimation, the checking of the construction rules could be:

- *Full checking* 21%: the rule can be checked entirely
  - full checking corresponds to geometrical checking of the building entities (comparison of the corresponding parameters)
    Ex: La largeur minimum des portes est de 0,90 mètre. (Arrêté du 24 septembre 1980 modifié, art.2).
    IFC data: Type of the door: IfcDoor (Generic Type); Width is calculated by using: IfcDoor (TypeDefinitions), IfcPropertyTypeDef (SharedProperties), etc.
  - relatively simple calculating of accessibility ways. The information is provided by the IFC model, the CAD tools and is formalised to be treated by machines
    Ex: Les paliers de repos doivent être horizontaux (Arrêté du 24 septembre 1980 modifié, art.2).
    IFC data: Type of the room: IfcSpace (Generic Type). The corresponding dimensions can be calculated by using: IfcSpace (ProductShape), IfcProductShape (ShapeRepresentations), etc.
- *Partial checking* 6%: the rule can be checked only partially
- The lack of information in the IFC model
  - The lack of information in the IFC model
  - The lost of information or impossibility to formalise some tacit knowledge by the CAD tools
    Ex: Le cheminement horizontal (ou par rampe) est obligatoire de l'ascenseur aux logements dans les étages des bâtiments avec ascenseur (Circulaire n° 82-81 du 4 octobre 1982, art.1.1.1).
    This rule could be checked only if other rules of this article are full checked, so that we can take into consideration the results of the checking.
- Not checkable 72%
  - The IFC model does not provide the necessary information
    Ex: Bord d'évier : hauteur maximale 85 cm (NF P 91-201, juillet 1978, art. 4.2.2).
    This rule is to be applied to a kitchen ('cuisine') of a special type 'locaux de service'. How can a kitchen be classified in a standard way?
  - There is no standardised solutions of the classification or interpretation of the information
    Ex: Le cabinet d'aisances et le lavabo accessibles aux personnes handicapées doivent être desservis par un cheminement praticable (Arrêté du 27 juin 1994, art.6).
    Semantic poverty: How make the term 'cheminement praticable' understandable by machines? This rule also speaks on the equipment absent in the IFC

The objective and principles of realisation of the ISTforCE project perfectly correspond to those of our research. However, the ISTforCE project aims at checking

[12] IST-1999-11508 ISTforCE: Intelligent Services and Tools for Concurrent Engineering

only one type of conformance: accessibility –, therefore, the corresponding RDF model is extracted according to *predefined* accessibility characteristics of the building. Besides, the accessibility checking is largely defined by geometrical checking of building entities or by calculating the routes (Han 2000), (Lau et al. 2006), that are also defined by physical parameters of the construction project. Being a partial case of the whole problem domain, the accessibility checking results cannot be generalised to conformance checking results. The *predefinition* of the entities to be included to the RDF model significantly decreases the complexity of reasoning. In general case, the IFC parameters to be included are not defined before identifying the set of construction rules, which is chosen by the user.

We use this classification to study different cases of reasoning in terms of RDF graphs representing the construction project as well as the premise and the conclusion of the rule. Our reasoning is based on the conclusion of (Berners-Lee 2001) concerning the similarity between the graphs RDF and the conceptual graphs for the problem of conformance checking in construction.

The conceptual graphs represent a logic system based on the existential graphs and semantic networks and take advantages of both formalisms: the graphic representation and the expressiveness and decidability characteristics of the logics (Sowa 1999). The implementation of the conceptual graphs to the conformance checking in construction also makes possible the application of the theoretical results of this theory to this applied research problem.

The RDF graph of the construction project forms the basis of its conceptual graph. The construction rule, as we have already shown, consists of two parts: the premise and the conclusion. It means that it is modelled by a triple: two conceptual sub graphs and a causal rule "if-then".

The reasoning results with the homomorphism of the graphs (projection) which semantics is given in terms of the positive, conjunctive and existential First Order Logics (Baget, Mugnier 2002). In the context of knowledge acquisition, the existence of the projection from the conceptual graph Q to the conceptual graph G means that the knowledge represented by Q could be deduced from the knowledge represented by G.

The compliance checking in construction is held in terms of conceptual graphs projection:

A construction rule can be applied to a project if there is a projection from the graph of its premise to the graph of a construction project.

A construction project is compliant to the rule if the conclusion graph could be projected to the graph of a construction project.

Actually, in some cases, the projection could be partial (while taking into account the semantic closeness of the concepts), and so the system should explain the reasons of these results. The further reasoning is done with regards of the partial projection.

It is important to note that we do not need to analyze the projection from the conclusion graph to the graph of the construction project if this rule is not applied (the premise-graph of the corresponding rule is not projected). Therefore, we can reduce the number of projections to study. The compliancy is checked for those rules, which are applied.

The correspondence between the conformance-checking problem and the homomorphism of the graphs (Baget 2005) is also important for the estimation of the complexity of the conformance-checking problem (as the complexity of the RDF implication is NP-complete). In order to reduce the complexity, we can study particular cases of the representation graphs, which correspond to the polynomial complexity of the RDF implication (e.g. when the corresponding graphs are trees (Mugnier, Chein 1993)).

The ongoing research is devoted to the analysis of the complexity of the defined problems, as well as on the interpretation of the theoretical results in the context of the conformance-checking problem in construction.

6 IMPLEMENTATION: GENERAL FRAMEWORK OF THE CONFORMANCE CHECKING SYSTEM

The conformance checking process is supposed to be supported as much automatically as possible. It means that three key processes: (i) the transformation of the IFC model to the intermediary semantically rich model; (ii) the ontological representation of the construction rules; (iii) the reasoning if this intermediary model is compliant to a set of ontologically represented construction rules – are taken into account in the system functionalities. The process is schematically described in the Figure 3.

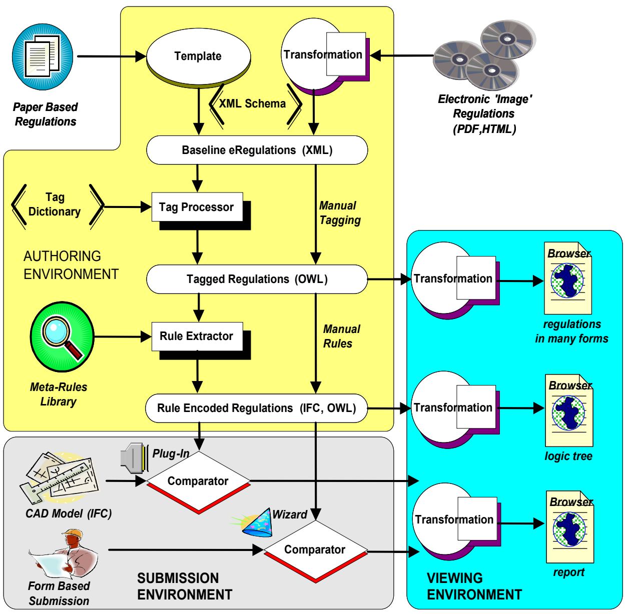

Figure 3. Scheme of the Conformance Checking process.

In its *Authoring Environment,* the system enables users to access "digital" regulations concerning the regulation subject they choose. In order to be presented in the structured format and to make a basis for a regulation environment to reason in, the regulations are extracted from the regulation documents (text-to-XML conversion, language processing), represented as RDF graphs and fed into a rule-based ontological system. The regulation formalisation and the meta annotation of the construction rules (e.g. by "meta" tags) is also made in the *Authoring Environment*.

Conformance checking reasoning makes the heart of the *Submission Environment* that operates different RDF/S representations: those of construction regulations, the construction rules, and the construction project. The conformance checking mechanisms are applied to the RDF graphs of premise and conclusion of the rule and the RDF of the construction project aligned to this rule. The validation of the construction rule is held in terms of graph projection. The existence of the projection means the applicability of the rule to the project (projection from the premise graph to the project graph) or the conformity (projection from the conclusion graph to the project graph). In the case of non-projection, the system analyses the non-projection reasons (non applicability or non conformity, impossibility to project because of the absence of construction project information).

The results (compliancy or "projection failure" report) received at the *Submission Environment* are sent to the *Viewing Environment* that provides the necessary tools in order to facilitate the use of the system. The report details the source of the problem and the rule to which the project is not compliant. Therefore, the user could easily (1) find the corresponding regulation thanks to the meta-annotation of the rule base, (2) identify the problem of non-conformity and/or (3) add the missing information that makes the projection impossible and restart the checking process. This is supposed to be done through a set of Web-based services and interfaces that allow the user to use a set of construction rules to check his/her construction project while hiding the complexity of the system. Some of the functionalities – multilingual support, indexing, search and helping wizard – that could be realised thanks to the ontological approach of the system are also provided here.

7 CONCLUSION

In this paper, we have presented the conformance-checking problem in construction and the modelling of it by a formal ontological approach that allows reasoning while taking into consideration the semantics of the construction data. Our research is focused on the generating of graph representation of the construction information (project and rules) and on the conformity reasoning in terms of graph projection. The analysis of these problems is based on a state of the art in corresponding domains and their results are interpreted in the context of the conformance checking in construction.

The research problem is decomposed into two sub tasks: the development of the representation aligned to the regulation ontology and the reasoning in terms of the aligned ontologies. The development of the project representation aligned to the regulation ontology is based on the modified alignment algorithms that calculate the similarity value between the concepts and properties.

The main contribution of the research is threefold. First, we propose the method to formalize the regulation text in terms of the application domain. Second, the representation of the construction project is represented in a richer RDF format and its entities are aligned to the ones of the selected construction rule. Third, the checking reasoning is substituted by the projection of graphs, so the theoretical results could be directly applied to the construction domain. The graph projection approach also helps to "visualize" the reasons of non-projection, and consequently of non-verifiability or non-conformity. The method is semi-automated, so each phase of it allows human intervention for data modifications or validations.

The ongoing works on our research are now concentrated on the detailed development of the proposed approach up to the validation of its results: the definition of the XSLT transformation of the construction project into the RDF model; the implementation of the modified similarity value algorithms to the construction of the aligned ontology representation and the reasoning in terms of the conceptual graphs.

The evaluation is planned soon. It will cover the application domain aspects: rule formalisation, semantic correspondences and expert validation of reformulations, and the knowledge engineering aspects: the graph representation of construction knowledge and the projections corresponding to the conformance reasoning.

Our research is intended to contribute to the variety of works aiming the conformance checking in construction, while developing the theoretical background for such type of modelling. In general, due to the novelty of the Semantic Web approach and the development of the underlying technologies, we especially focus on the research axis of their industry application, addressing the specific needs of the construction industry. The rational behind this work, the general interest to the automated reasoning and ongoing works throughout the world open promising perspectives to the research in this domain and ensure the possibility of efficient implication of theoretical results in practice with regard of their performance and trustworthiness.

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