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A rule-based semantic approach for automated regulatory compliance in the construction sector

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ABSTRACT

A key concern for professionals in any industry is ensuring regulatory compliance. Regulations are often complex and require in depth technical knowledge of the domain in which they operate. The level of technical detail and complexity in regulations is a barrier to their automation due to extensive software development time and costs that are involved. In this paper we present a rule-based semantic approach formulated as a methodology to overcome these issues by allowing domain experts to specify their own regulatory compliance systems without the need for extensive software development. Our methodology is based on the key idea that three semantic contexts are needed to fully understand the regulations being automated: the semantics of the target domain, the specific semantics of regulations being considered, and the semantics of the data format that is to be checked for compliance. This approach allows domain experts to create and maintain their own regulatory compliance systems, within a semantic domain that is familiar to them. At the same time, our approach allows for the often diverse nature of semantics within a particular domain by decoupling the specific semantics of regulations from the semantics of the domain itself. This paper demonstrates how our methodology has been validated using a series of regulations automated by professionals within the construction domain. The regulations that have been developed are then in turn validated on real building data stored in an industry specific format (the IFCs). The adoption of this methodology has greatly advanced the process of automating these complex sets of construction regulations, allowing the full automation of the regulation scheme within 18 months. We believe that these positive results show that, by adopting our methodology, the barriers to the building of regulatory compliance systems will be greatly lowered and the adoption of three semantic domains proposed by our methodology provides tangible benefits.

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1. Introduction

One of the major concerns for professionals in any industry is ensuring compliance of their work against the plethora of statutory, contractual and performance based requirements that govern their disciplines (Cheng, Lau, & Law, 2007; Nikhil et al., 2008; El Kharbili, 2012). While the use of computer systems to support regulatory compliance has become increasingly common (Law & lau, 2012), the effective conversion of often complex and non-binary (True/False) textual regulations, designed to be readable by humans, into computer executable code remains a difficult challenge (Kerrigan & Law, 2003). Performing this task often requires close co-operation between domain experts with building regulation expertise and software developers (Law & lau, 2012; Liu, Muller, & Xu, 2007).

This paper addresses key limitations to the development of IT solutions for regulatory compliance problems; the complex nature of regulations that necessitates a lengthy software development process, more specifically, the complexities involved in communicating the requirements of often industry specific regulations to software developers and, conversely, validating the developed software by domain experts. The output of this process leads to regulatory compliance systems that are often closed and can only be maintained by dedicated software developers (Solibri Model Checker, 2015). This process is simply not viable in the complex and continuously changing regulatory landscape.

Moreover, existing commercial and academic approaches fall short in addressing effectively the accuracy, scalability, maintainability (including, domain experts ease of use) requirements. We argue that a suitable compliance checking system should provide an end-to-end methodology that (a) understands the semantics

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of both the regulations, the domain in which they operate, and the data formats related to the domain, (b) allows seamless extraction of regulations from textual documents, (c) provides the ability for integration with industry standard software, and (d) maintains strong links between the extracted regulations and the original text from which they have been generated. Above all our methodology separates the domain expertise from the computing expertise.

This paper focusses on the construction sector which forms a prime candidate for the implementation of our compliance checking methodology. This industry has a complex structure and is facing the major challenge of meeting the need to reduce greenhouse gas emissions from existing and new buildings. This increasing complexity and new government targets have led to a huge appetite within the construction industry for intelligent solutions (Irani & Kamal, 2014). A prime example of this, is the need for the impact of existing, often continuously evolving, regulations (in areas such as environmental, energy, waste, and water) to be assessed by specialists to satisfy regulatory compliance, statutory requirements, planning consents, and various public concerns (Rezgui & Miles, 2011).

Additionally, these regulatory and statutory requirements vary between countries and even sometimes between local authorities which renders the compliance checking process ever more complex. In addition, the construction sector presents additional unique challenges (Rezgui & Miles, 2011):

- Traditional industry practices need continuous adaptation and integration to suit local conditions, new materials and frequently changing stakeholder relationships.
- Concerns for quality, timely, and to budget delivery against the threat of financial penalties are causing the major industry players to reduce their circle of specialists and sub-contractors.
- Project data management and coordination often follows ad hoc approaches (Rezgui, Beach, & Rana, 2013). Data within the construction sector is still often stored in a series of incompatible proprietary data formats for application such as AutoDesk Revit (Autodesk Revit Architecture, 2013) and Bentley Systems Micro-station (Bentley Systems, 2013). Currently only one open data standard exists - The IFCs (Industry Foundation Classes, 2005), and the implementation of this standard varies (Rezgui et al., 2013).
- Semantics within the target domain are not standardised and many regulations utilise different semantics. For example one regulation standard refers to the area in which a building is being developed as a "Development Site" (Global, 2011), and another refers to it simply as "site" (U.G.D. for Communities, 2010), these regulations are described in more detail in Section 4.

The aim of the paper is to develop, test and validate a generic rule-based semantic regulatory compliance checking methodology, with an application in the construction sector. We foresee two key emerging advantages as a result of the adoption of our methodology: (a) the ability of domain experts to understand and update the regulations within an open software architecture. This vastly improves the maintainability of the system, and (b) the increased understanding of what the regulatory compliance system is actually checking. This allows validation of the system to be conducted with a far higher level of certainty.

Following this introduction, the related work section summarizes existing work in the field of regulatory compliance. The architecture of our system and its components are then elaborated in Section 3. Next, the case study section provides a detailed description of our case study in the construction sector and its results. The final section (Section 5) discusses our results and provides concluding remarks as well as directions for future research.

2. Related work

There has been considerable efforts in the past towards performing automated regulation checking, with various approaches being adopted (Cheng et al., 2007; El Kharbili, 2012; Giblin, Liu, Müller, Pfitzmann, & Zhou, 2005; Liu et al., 2007).

Giblin et al. (2005) describe their developments in the use of regulations expressed as logical models, with a focus on the regulation of business activities. This work importantly identifies the key requirements of a conceptual model, that describes the domain in which the regulations lie. This work is expanded further by Cheng et al. (2007), who perform regulatory compliance checking by explicitly mapping the terminology of regulations onto an industry specific taxonomy, recognising, importantly, that the semantics of a particular regulation do not always map onto the general semantics of the domain in which it operates. Other related work includes the REGNET system developed by Law and lau (2012). The REGNET system aims to develop an infrastructure to facilitate access and analysis of government regulations. Their approach requires the addition of meta-data to requirements documents, while maintaining strong links between the logical structure generated from the process of adding metadata to the requirements. The limits of this REGNET system are that, mainly due to the nature of the legislation that it targets, there is no scope for targeting industry specific data file formats. Within their current work, the authors instead focus on an approach that largely guides the users through the regulations using a web-based system.

Several authors have attempted to tackle the problem of extracting regulatory information from textual documents. Nikhil et al.'s (2008) work focuses on designing a logical representation of legislative regulations which they named ReFL logic. One of the most interesting aspects of their work is their focus on handling the referencing between laws in the complex, and often interlinked legal structures that exist today. Hassan and Logrippo (2009) also adopt an approach in which their UML Governance extraction Model to extract legal and enterprise requirements. The work by El Kharbili (2012) surveys approaches related to the compliance checking of business processes, and the formalising of the regulations put upon business processes so they can be compared against the already formalised business process modelling language. Liu et al. (2007) conducted similar work utilising a business process specification language that captures regulatory compliance of business processes. This language is then translated to linear temporal logic. An automated approach in a related domain is taken by Yeung, Cheung, Wang, and Tsui (2014), this work, while not focused on compliance checking, outlines an approach for extracting semantic information from narratives in the construction sector, using natural language processing techniques. This is important work as their approach attempts to automate the process of extracting domain semantics from text.

Specifically, within the construction sector, there has been several examples of the utilising of intelligent systems to aid decision making (Hajdasz, 2014). Recent work by Hajdasz focuses on building decision support systems to aid with repetitive tasks within the construction site. In the domain of compliance checking Liebich, Wix, and Forester (2002) provide one of the earliest successful examples of the implementation of a compliance checking system. This particular work was targeted at Singapore's Building Regulations. However, their system focusses mainly on the processing of rules in relation to industry standard data formats, namely IFCs, rather than the critical aspect of rules extraction from

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