Computers in Industry 83 (2016) 28–45

Contents lists available at ScienceDirect

Computers in Industry

journal homepage: www.elsevier.com/locate/compind

A framework for integrating syntax, semantics and pragmatics for computer-aided professional practice: With application of costing in construction industry

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ARTICLE INFO

Article history:
Received 30 September 2015
Received in revised form 11 August 2016
Accepted 30 August 2016
Available online xxx

Keywords:
Rule-based
Semantic
Ontology
IFC
BIM
Cost estimation
Computer-aided professional practice
Expert system

ABSTRACT

Producing a bill of quantity is a knowledge-based, dynamic and collaborative process, and evolves with variances and current evidence. However, within the context of information system practice in BIM, knowledge of cost estimation has not been represented, nor has it been integrated into the processes based on BIM.

This paper intends to establish an innovative means of taking data from the BIM linked to a project, and using it to create the necessary items for a bill of quantity that will enable cost estimation to be undertaken for the project. Our framework is founded upon the belief that three components are necessary to gain a full awareness of the domain which is being computerised; the information type which is to be assessed for compatibility (syntax), the definition for the pricing domain (semantics), and the precise implementation environment for the standards being taken into account (pragmatics). In order to achieve this, a prototype is created that allows a cost item for the bill of quantity to be spontaneously generated, by means of the semantic web ontology and a forward chain algorithm. Within this paper, 'cost items' signify the elements included in a bill of quantity, including details of their description, quantity and price. As a means of authenticating the process being developed, the authors of this work effectively implemented it in the production of cost items. In addition, the items created were contrasted with those produced by specialists. For this reason, this innovative framework introduces the possibility of a new means of applying semantic web ontology and forward chain algorithm to construction professional practice resulting in automatic cost estimation. These key outcomes demonstrate that, decoupling the professional practice into three key components of syntax, semantics and pragmatics can provide tangible benefits to domain user.

1. Introduction

The ability to produce a standardised bill of quantities is a key issue for those undertaking cost estimation activities. Although the recent introduction of BIM can assist the process of cost estimation, difficulties remain where specialist knowledge, for instance measuring quantities that comply with standards and apply subjective unit price from expert experiences, is required to input the original quantities. Cheng et al. [1] state that this is also greatly impacted by the subjective decision making practices of estimators. While the use and accessibility of previous data is of great value, it is again subjective and regardless of the complexity of the tool, basic spreadsheet or cost modelling software, being used a degree of specialist input is needed. In fact, this process is used extensively as a means of overcoming the issues surrounding successful cost estimation [2,3].

This paper will focus on the key limitations relating to the production of BIM models created for cost estimation purposes. It is necessary to employ a broad and open-minded point of view as many factors must be acknowledged including current standards of practice, issues surrounding compatibility and those affecting subjective decisions. The detailed elements relating to standards of

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http://dx.doi.org/10.1016/j.compind.2016.08.004
0166-3615/

practice and expert knowledge lead to the necessity for an elaborate software development process. Specifically, this is required in order to tackle the complexities of sharing the requirements of meeting industry standards with software developers, in addition to confirming the functionality of the software created. The resulting outcome of this particular model is that it does not generally tackle details of pricing systems.

The overall aim of this study is to construct, review and confirm a common rule-based semantic specialist cost estimating process. Those undertaking the work believe two key outcomes will emerge from its development, specifically: the ability of domain experts to understand and improve the standards of practice and degree of awareness incorporated within open software architecture; the growth in understanding that methodical cost estimating closely corresponds with rule-based analysis and the framework to incorporate expert reasoning into information system. The outcome of this is the ability to substantiate the approach with increased levels of precision.

Subsequent to this introductory section, the background of cost estimation will be explored, reviewing the issues existing in this area as well as the previous work into potential intelligent solutions that has been carried out. Following this, section three will focus on the foundation of the framework and its associated method, while the next section will present the proposed framework and its elements. Then a case study detailing the results generated will be presented. Finally, the results will be examined and future developments suggested.

2. Backgrounds

The process of cost estimation incorporates a great deal of subjectivity and specialist input is generally required whether a basic spreadsheet or intricate cost modelling system is used. An estimate is a specialist's view of an expected future cost. While expert problem solving is not a specific cost estimation procedure, it is well understood and often used [2,3]. Specialists in the field generally reach estimated figures through the use of analogies and comparisons [4–10]. Studies undertaken by Sinclair et al. [11] reached the conclusion that existing methods of reasoned application were overly simplified throughout the construction industry. These methods regularly use existing items (with known specifics) to draw comparisons with new items (with unknown specifics). Once the details have been allocated to the item it then moves from being new to existing [12]. The National Aeronautics and Space Administration utilises a valuable cost estimation model that is similar to this, which incorporates clear processes for undertaking estimation. This style of process does, however, provide only an abstract portrayal of estimation requirements. This is particularly clear when considering the Eurostat survey method, which cannot be analysed by computers. Quantity surveying, in relation to project cost estimation, requires the completion of systematic or analogical tasks. They undertake these processes, using historical data, to build a cost estimate. In general, cost estimation activities require the detection of an analogical link between the project in question and the previous work, associating the specifics of the project with their equivalent points, leading to a clear result. Mair et al. [13] state that an electronic form of Case-based reasoning cycle allows the development of an altered and approved outcome. As a result, as highlighted by RSMeans [14] and The Building Cost Information Service [15] problems are solved by linking the outcomes of previous work to current challenges.

On the other hand, there has been very little investigation into the cognitive reasoning that a specialist puts in place when reaching a decision or the ways in which this can be linked to the activities of cost estimating. Kiziltas et al. [16] argue that these factors are so often not documented that the details are not available to other specialists. As a result, very few studies have been carried out into the process or attempts made to summarise the rationale behind it. Research in the construction engineering field often focuses on algorithmic features because organisations are generally more at ease with a statistical approach because organizations concern individual subjective input as a 'black box' and hasn't been captured in the system. [17–19]. Hughes [20] explains that researchers are not content with such an undesirable attitude towards specialist knowledge, although an effective means of reinforcing this has not yet been established [16,21,22].

Attempts have previously been made towards automating the cost estimation process within BIM, and for this reason a broad investigation into intelligent solutions for cost estimation is required [23–27]. It should also be noted that the reports discussed have been selected from a literature review of over 100 sources. These were identified using keywords such as semantics model; construction; design; building; built-environment; ontology; resource description framework (RDF); semantic web ontology language (OWL); and IFC (dated between 2002 and 2015).

The process of identifying the most appropriate work related items for expense estimation can be effectively carried out using OWL and semantic web rule language (SWRL) [27]. The data collected is extracted from an IfcXML file, to which semantic analysis is performed to produce a range of working conditions. This class of file allows data regarding measurements, methodology and materials to be gathered, thereby offering a clear indication of the items required for expense estimations to be made.

Technological advances in information management in the construction industry tend to be heavily dependent on the functionality of the latest internet release [28]. This is often referred to as knowledge demonstration and allows for the possibility of major steps forward in innovative processes. A key feature of this approach is that it must allow for interrelated functionality between different software products, not excluding web-based and intelligent offerings. When focusing on the construction industry the software products that they must work with are those featuring the ISO-10303 Standard Exchange of Product Data (STEP). Moreover, the IFC was created, using the specific elements of STEP, as a building information model to be used in the construction industry. The semantic heavy model has led to the improvement of building information through the use of semantic technologies. Overall, the main aim is to develop the current availability of building information through the production of data that can be electronically processed.

OWL is often regarded as offering the best expertise representation language, specifically from a visual point of view, due to it being effective, well-known and widely supported. It should be highlighted that this study does not take into account offerings available in other languages, although it remains the case that information relating to engineering processes does not include a wide range of semantics and pragmatics [29].

It is vital that the model produced has the ability to build a degree of understanding while supporting individual input. For this reason, the usefulness of the model is largely focused on semantics, which allow for precision in the results produced and functionality of the model. Where they are unclear, the outputs are open to interpretation and unfortunately, the building models available tend to lack adequate semantic detail. An example of such can be seen on traditional computer-aided design (CAD) programmes, which provide sophisticated drawing options but lack a human perspective (e.g. simple geometric shapes). In other words, most traditional CAD drawings rely on user interpretation of constructed primitive geometric shapes and are not semantically marked-up with relationships and labels. This is a result of an absence of semantic details. In fact, the principle behind BIM was to construct models that make use of object-based images, to