Expert Systems With Applications 63 (2016) 284–294

Contents lists available at ScienceDirect

Expert Systems With Applications

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

An intelligent system for the acquisition and management of information from bill of quantities in building projects

María Martínez-Rojas[a,*], Nicolás Marín[b], M. Amparo Vila Miranda[b]

[a] Department of Building Construction, c/Severo ochoa, s/n, 18071 Granada, Spain
[b] Department of Computer Science and Artificial Intelligence, c/Periodista Daniel Saucedo Aranda, s/n, 18014 Granada, Spain

ARTICLE INFO

Article history:
Received 23 February 2016
Revised 28 June 2016
Accepted 7 July 2016
Available online 12 July 2016

Keywords:
Bill of quantities
Intelligent system
Construction
Project management

ABSTRACT

Construction projects success largely depends on a good access to and management of information, which is stored in different databases and applications (even on paper). This heterogeneity makes the management and decision making process difficult. One of the most relevant documents in the project management context is the Bill of Quantities (BoQ), which is a collection of work descriptions specifying, in a textual way, the nature of the different tasks needed to be done in order to achieve the project goal. Since there are no standards for developing the BoQ, its structure and linguistics vary among practitioners, making the acquisition and management of the information contained in this document very laborious. In this paper, i-BoQ, an intelligent system for retrieving and structuring data coming from BoQ, is presented. As we will see, intelligent capabilities together with a friendly web-based application allow to easily acquire and manage integrated BoQ information for supporting decision making in the construction project management.

1. Introduction

The construction industry is more and more taking advantage of the benefits provided by Information and Communications Technologies (ICT) to support data management. This industry is extremely information-dependent since important amounts of information need to be transferred and exchanged during the project life-cycle. For example, in a construction project, even a small one, huge amounts of information are contained in textual data coming from specifications, plans, process control, inventory management, cost estimating and control, and scheduling (Soibelman, Wu, Caldas, Brilakis, & Lin, 2008). However, these data have many diverse formats and are stored in different databases and applications (Baalousha & Èçelik, 2011; Beach, Rezgui, Li, & Kasim, 2015; Ergan & Akinci, 2012; Wang, Zhong, Zhang, Yu, & Li, 2015). In fact, it is usual that documents are stored in paper form. As a consequence, construction projects are associated with huge and usually unstructured datasets generated from several sources (Al Qady & Kandil, 2015).

The ability to manage large volumes of data is increasingly turning into an essential issue in a society based on knowledge. But not only data management (in a strict sense) is needed; in the same way, the process which allows knowledge discovery, specially from textual data, in large datasets is turning more and more important for organizations (Torres-Parejo, Campaña, Delgado, & Vila, 2013). For this purpose, Information Systems and, particularly, solutions created within the Business Intelligence area, help managers to obtain a better understanding of their commercial procedure and operations in order to support better business decision-making for future projects (Fan & Li, 2013; Hajdasz, 2014; Irani & Kamal, 2014; Xiao & Fan, 2014).

In the construction project domain, a great deal of documents are necessary to support the different important management tasks, as for example: contracts, tenders, control execution, etc. However, one of the most relevant documents is the Bill of Quantities document (BoQ), which is used by project practitioners along the whole project life cycle. In early stages, BoQ provides a list with detailed work descriptions and quantities that comprises the tasks needed to be accomplished in order to achieve the project goal, enabling contractors to prepare tenders efficiently and accurately. During the post-tender stage, it provides a basis for the control of the different work and cost planning, allowing in addition the valuation of executed work for the purpose of making payments to the contractor (Nadeem, Wong, & Wong, 2015).

The BoQ is quite different in its wording and internal structure depending on the professional that has developed it. This diversity produces several problems from a textual data management perspective, such as: increasing the complexity level for information

* Corresponding author.
E-mail addresses: mmrojas@ugr.es (M. Martínez-Rojas), nicm@decsai.ugr.es (N. Marín), vila@decsai.ugr.es (M.A.V. Miranda).

http://dx.doi.org/10.1016/j.eswa.2016.07.011
0957-4174/

retrieval, poor interoperability between different management systems, and hard information reuse (Al Qady & Kandil, 2013; Forcada, Casals, Roca, & Gangolells, 2007; Niknam & Karshenas, 2015).

In order to reduce this diversity, standards should be proposed. However, the standards applied to construction documents are not as matured as it is desirable, which is an obstacle to computer-integrated construction research efforts (Chassiakos & Sakellaropoulos, 2008; Dawood, Akinsola, & Hobbs, 2002). The recognition of this problem has led to the ongoing development of such standards by the International Organization for Standards (ISO) and the creation of Industry Foundation Classes (IFC's) by the International Alliance for Interoperability (IAI). Although these standards hold the promise of facilitating the construction management information, their generalized use can only be expected in the long run. Meanwhile, in some countries, a standard exists for providing a common framework for documents organization and management among project organizations (e.g. Masterformat (2015) and Uniformat (2015)). Unfortunately, again, the use of these proposals is not widespread among practitioners.

This problem is specially relevant when trying to store BoQ's data in a common repository because both the linguistic descriptions and the structure of each BoQ document may be defined in a different way. As far as we are concerned, there are no systems in the literature that allow to do that.

In this paper, we present i-BoQ, an intelligent system which allows an integral BoQ information management. The system is comprised of three modules: acquisition, edition, and retrieval. As we will see, the acquisition module makes possible to upload data coming from BoQ documents and store them in a structured common repository regardless the structure and linguistic description of the BoQ. The classification is performed through the use of a multi-criteria aggregation model. The edition module, in turns, provides user-friendly validation and edition functionalities for imported data, while the retrieval module supports ease access to stored information.

After this introduction, the remainder of the paper is structured as follows. Section 2 reviews related research while Section 3 is devoted to explain in detail the current problem in the elaboration of BoQ document. Section 4 focuses on the description of i-BoQ's functionalities and an evaluation of the system is described in Section 5. Finally, conclusions and guidelines for future research end the paper.

2. Related research

As mentioned in the introduction, the vast majority of information generated and exchanged during the construction life cycle is stored in documents. In this sense, some research studies have developed electronic document management (EDM) systems and web-based project management systems for improving the information management and communication in construction projects (Chassiakos & Sakellaropoulos, 2008; Wang et al., 2015).

In last years the use of EDM systems and web-based solutions has been the fastest growing IT-application in construction (Chassiakos & Sakellaropoulos, 2008; Dawood et al., 2002; Wang et al., 2015). The use of these technologies benefits contractors in issues such as removing a great deal of paper documents, improving access to data, allowing common documents between agents in different locations, eliminating discrepancy and misunderstanding in the versions of documents, and recording data in a multimedia form. Unfortunately, a limitation of most existing electronic management and web-based systems is that they follow a rather document-based philosophy offering less improvement from tradition than desired (Mao, Zhu, & Ahmad, 2007). In addition, most of them are rather static and allow limited interactivity with end-users or have been mostly directed to data transfer applications and less to information modeling (Chassiakos & Sakellaropoulos, 2008). In summary, many important problems remain to be solved: data collection in most cases is still manually performed and there are difficulties regarding data sharing and data integration (Martínez-Rojas, Marín, & Vila, 2016).

The lack of approaches that automatically extract information from existing documents makes information management and integrated data query very difficult. Consequently, to take advantage of the useful information contained in construction documents, automatic data extraction from existing documents and organization techniques need to be developed as a first step in the construction of integrated repositories. In the literature, there are proposals that attempt to automatically create an organizational document structure over an existing classification structure (Caldas, Soibelman, & Gasser, 2005), or based on semantic similarities, (Al Qady & Kandil, 2013, 2015). However, understanding contexts and extracting semantic concepts and relationships from a collection of text documents are still major challenges for computers, even in domain-specific applications such as the management of construction documents (Fan, Xue, , & Li, 2015).

Focusing on the particular case of BoQ document, to the best our knowledge, there are no proposals in the literature that allow an integral BoQ information management, and, as we have commented in the introduction, this is the goal pursued by the system presented in this paper.

3. Heterogeneity in BoQ documents

As we have mentioned in the previous section, the BoQ document describes the works to be done in order to achieve the project goal. This is one of the most relevant documents since it contains crucial information to carry out most of the important tasks during the project life cycle (e.g. procurement, planning, control execution, etc.) (Akbar, Mohammad, Ahmad, & Maisyam, 2015; Shamsulhadi Bin Bandi, 2014). During the early stages, this document is the basis of other important management tasks, as for example: to prepare tenders, contracts and planning. After this stage, BoQ provides relevant information to valuate executed work or to control the project development.

Within the BoQ document, a hierarchical grouping of work in different levels following a work breakdown structure can be found. Each descending level represents an increasingly detailed definition of the project work. The lowest level of this structure contains the so called *work descriptions*, which textually describe the nature, resource, unit, material, size, etc. of the different tasks needed to complete the project.

Unfortunately, it is very difficult that practitioners can manage information contained in this document in an integrated way due to the following drawbacks:

- Due to the *lack of reference standards* to structure this document, owners, designers, and contractors tend to develop own internal rules according to the specifications of their proprietary standards. This problem is recognized by one of the main companies, Presto (2015), that has developed a cost management tool to assist in the elaboration of the BoQ document. This company is aware of the heterogeneity problem that exists in this document, which prevents exchange and search of information in an automated and integrated way. Moreover, it makes very difficult the comparison of similar projects that have been written by different professionals (RIB Spain, 2016).
- Despite *several tools* that assist in the generation of BoQ document are available (e.g. Presto (2015), Premeti (2015), and Arquimedes (2015)), they are editors that only offer a reference price database with structures and descriptions based on internal classification methods (e.g. Batiprix (2015) from France