Knowledge-based Collaborative Environment for SMEs in Construction Sector

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Abstract: The present paper focuses on the topics of "Collaborative Working Environments", "eBusiness-Future forms of organisations, Technology and Applications" and "Semantic and Knowledge based systems". It is based mainly on the Collective project Know Construct (COLL-CT-2004-500276) starting in March 2005. The main objective of the project is to develop a common internet-based platform for SMEs and owned by construction industry associations, to provide two main general functionalities: an innovative decision making support system regarding the products characteristics, applications and other consultancy services for SMEs' customers, and a system for SMEs to support an advanced form of co-operation through the creation of Knowledge Communities of SMEs in Construction Industry.

1. Introduction

The European construction sector is characterised by a high level of fragmentation, with a large number of participants in each construction project, being the large majority SMEs as subcontracted units. To increase flexibility and profitability, the bigger construction companies have significantly reduced the scope of their activity and consequently the number of employees, focusing on the core tasks of the construction process and subcontracting most of the work to specialized SMEs. The sector is still characterised by a low level of education (in average), low productivity, low quality and expensive maintenance and disposal. The narrow technical specialisation of these subcontracted SMEs must be replaced by significantly wider technical competence through integrated teams as knowledge communities, followed by on time, within budget works completion.

Taking into account these needs, the consortium comprising local Construction Industry Associations, SMEs associated to them from the same area and RTD organisations from four European countries decided to initiate the research project with a main goal defined as the development of an innovative solution of Internet Platform for Knowledge-based

Customer Needs Management (CNM) and for Knowledge Communities Support (KCS) for SMEs in Construction Industry. The goal is to contribute to enable the European SMEs in construction sector to increase the application level of the state-of-the-art, knowledge-based ICT solutions in their business relations to customer and mutual co-operation.

In order to successfully meet the challenges described, the KNOW-CONSTRUCT (KC) project consortium has defined its main objective as the development of a common platform for knowledge based systems, which provides a combination of two general functionalities:

- **Customer Needs Management (CNM) System as** an innovative decision making support system regarding the product characteristics, product applications and related consultancy services. Main functionalities: browsing community resources; general browsing; searching materials/products/components/procedures; searching services/domain/context; interactive, web-based consultancy.

- **Knowledge Community Support (KCS) System** as a System to support an advanced and efficient formation of communities of SMEs in construction industry, through their specific knowledge integration, management and reuse via a common knowledge base. Main functionalities: knowledge sharing, knowledge community building, content management, knowledge structure management, information collector and external search manager.

The platform will be owned by associations, which will offer to their SME members the possibility to establish individual CNM systems between SMEs and end-users. The SMEs which use the platform will also take benefit of Knowledge Community Support System allowing them the establishment of alliances in order to face larger construction projects promoted by the big construction firms. The associations will use the solution provided by the platform to help their associated SMEs to attain closer co-operation and knowledge exchange among them, so they can stay strong into the business.

2. Relationship with the state-of-the-art

In the recent past, many efforts were made to produce standard systems for construction products classification such as in the European project e-Construct [3] where the bcXML, a XML version for Building and Construction Industry was developed and an appropriate taxonomy was introduced. On the other hand, the European project e-Cognos [2] aimed at the development and deployment of an open model infrastructure and a set of tools for effective and consistent knowledge management within collaborative construction environment. The results of these projects are used as a starting point to advance. Know Construct will complement e-Construct by working in the field of Customer Needs Management and will also complement e-Cognos by performing the knowledge management at a higher level, this is to say, at industrial association level.

The most relevant standards, ontologies, terminologies and classifications were identified, such as ISO 12006-2 [6], ISO 12006-3 [7], EPIC, UNICLASS, BATIBASE, EDIBATEC, MASTERFORMAT, IFC Model, ICIS LexiCon, BS6100, BARBi [8] or BauNetz-Infolines, among others. The projects related to Know Construct which will conform part of the methodology are CRISP, E-CORE, PICK [9], PROMISE [10], REMOTE [11], AIM [12] and WISE [13].

In order to establish an effective combination of e-KCS and e-CNM systems for SMEs, several RTD topics are addressed: e-collaboration, ontologies, knowledge management including methods for knowledge acquisition, structuring and retrieval, eCNM approaches,

trust and security, tele-working technology, etc. The consortium carefully studied these topics in order to identify approaches that are most appropriate.

2.1 Ontology

Ontology building has to serve as a basis for the knowledge representation from the related domains in Construction Industry. There are currently several research experiences; the most important are the aforementioned e-COGNOS and e-Construct projects. What is needed for Know Construct is a means for continuous update/maintenance of ontologies enabling long life of knowledge systems.

When evaluating and reusing (mapping) existing construction ontologies, it was decided to deal with the specific reality of the SMEs of each country and with each Construction Industry Knowledge (CIK) Community. The KCS system would need to have a local ontology that would answer the KC partners' particular professional and cultural needs and attend to its social context of use. It was decided to take this fact into account and look at this possibility as part of the standardised way to develop ontologies in the sector, but in such a way as to keep a common central ontological content (structure, attributes, relations, etc.) from where to derive the more specific ones. Therefore the solution proposed is to develop an inter-organizational knowledge management system for CIK Communities which will be built upon distributed ontologies locally managed and centrally integrated with CIK Ontology. The central ontology (CIK ontology) reflects standards and related classification schemes in the industry and the local ontologies will account for the individualised SME conceptual schemes, i.e. they will be strongly related to the consortium partners' needs.

2.2 Software

A survey of the SW solutions available in construction industry was carried out. The relevance is in the concept of providing knowledge-based services to customers and information exchange among partners using Internet technologies. No software that effectively combines e-CNM and e-KCS functionality and assures effective knowledge sharing among SMEs in the construction industry has been found.

From the technologic perspective, the system developed in this project will be independent of the operating system. All the technology that will be used is either implemented in the Java platform or uses standard protocols for the exchange of information. This will allow for the portability between hardware, thus reducing the risk usually associated with the scalability of web based applications. The protocols used are either those defined by the W3C [4] or any other "de facto" standard that is widely accepted and used.

2.3 Expected Innovation

Starting from the stated business and technical objectives and basing on the analysis of the state-of-the-art and current standards [5][6], the main problems addressed leading to innovations are:

- Methods for the creation of Knowledge Communities of SMEs in construction industry, where the Associations play the crucial role of enablers of alliances.
- To establish or re-use an adequate domain related ontology, as well as a classification system for this sector applicable in the SMEs environment.
- An inter-organisational practicable knowledge management system for Construction

Industry Knowledge Communities that allows the establishment of strategic alliances among SMEs.

- New forms for a representation of the experience-based knowledge, widely present in construction industry.
- An open-architecture Internet based platform for a combination of the two basic functionalities (CNM and KCS systems).
- New means of CNM, a cost effective tool affordable for SMEs to provide innovative “web based dialogue” between SMEs and their customers, aiming at an interactive decision support tool to be used for customer problem solving.
- Investigation of efficient approaches for “training”. Efficient incorporation of the training capabilities within the methods and tools to be developed, taking into account SME needs, represents a further step forward beyond the state-of-the-art.

3. Business scenarios

The scenarios described below are related to some of the most probable situations found in everyday work of the IAG member SMEs, where the system is intended to provide support.

Scenario 1: "Search for product information/documents"

Potential individual customer or SME looks for information about a construction product. The user logs in eCNM system and selects the product through the product categories/groups according to the ISO 12006-2/EPIC table. After navigating through an appropriate number of steps (in each step an appropriate number of selection boxes/lines are offered) a set of products is presented. The user chooses one of the entries of the result set to get more detailed information. The product's/manufacturer's web-site is displayed with a detailed information, providing also links to documents with more specific information about the product, application notes and other product related knowledge.

Scenario 2: "Search for Partner"

SME user - IAG member, looks for a partner with specific competence (complementary or identical) in order to answer to the tender for the project overriding its power. The user logs in eCNM system, and enters "Search for partner". The three categories of competence (1) Products (2) Works and (3) Entities/Objects are offered. System also looks for the existing offers of other associations and sends the invitation/call to participate to the (automatically and/or manually) selected available potential partners.

Scenario 3: "Customer Feedback"

The system user or customer wants to insert some specific feedback related to a product implementation, functionality or an improvement of a characteristic. In order to facilitate the feedback insertion process and the subsequent analysis of the inserted comments/suggestions and their structuring, the customer will be lead through the above described CI areas up to the specific product, service or other topic. During the feedback insertion customer can use some of the above described functionalities as support for precise feedback definition.

Scenario 4: “Navigate legal information”

A work supervisor needs to have an idea of the legislation related with a given construction area, but does not exactly know what and where to look for the needed information. Then, he or she uses the semantic navigation facility of KCS that enables to browse a set of legal documents and notes according to several categories and perspectives: KC user selects “Navigation” from the system options; the system presents a top level graphical view of the classification scheme; the user selects “Legislation” and continues to go down the hierarchy until the suitable category is found; the system shows a list of content.

4. Overall system description

The overall functional description of the system is represented in figure 1 below, which shows some of the main general functionalities of both CNM and KCS modules.

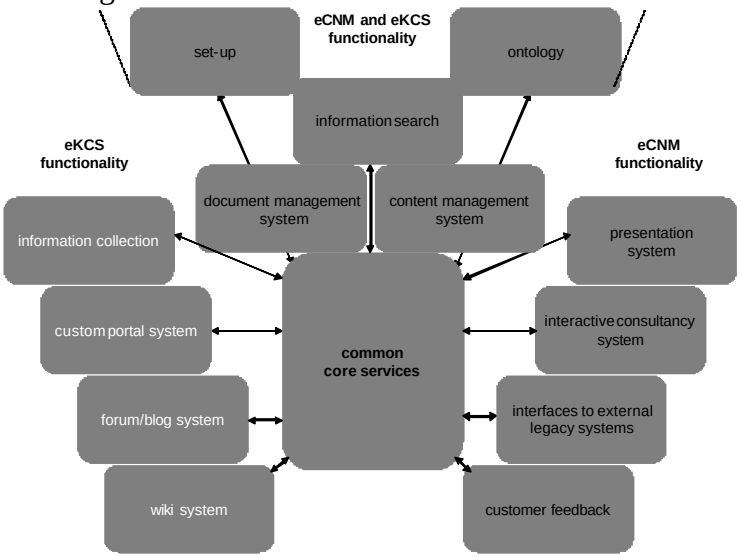

Figure 1: Overall Functional system description

The system architecture is described in the figure 2 below. The three main elements represent the KCS, CNM and the KC-back-end. The KCS and CNM will be connected via the Client API, which will allow client applications to request services and obtain results. The back-end will be responsible for the management and manipulation of the OWL (Web Ontology Language) schema and instance data. It will also provide basic administrative functions that will allow the management of the OWL. Both the KCS and CNM elements represent complete applications. They provide not only the services and functions required, but also the user interface. All OWL related functionalities required by these elements, however, will be implemented by the KC back-end. Any additional functionality that is required will be specified and implemented for the KCS and CNM elements, specifically including any services required for tagging and querying.

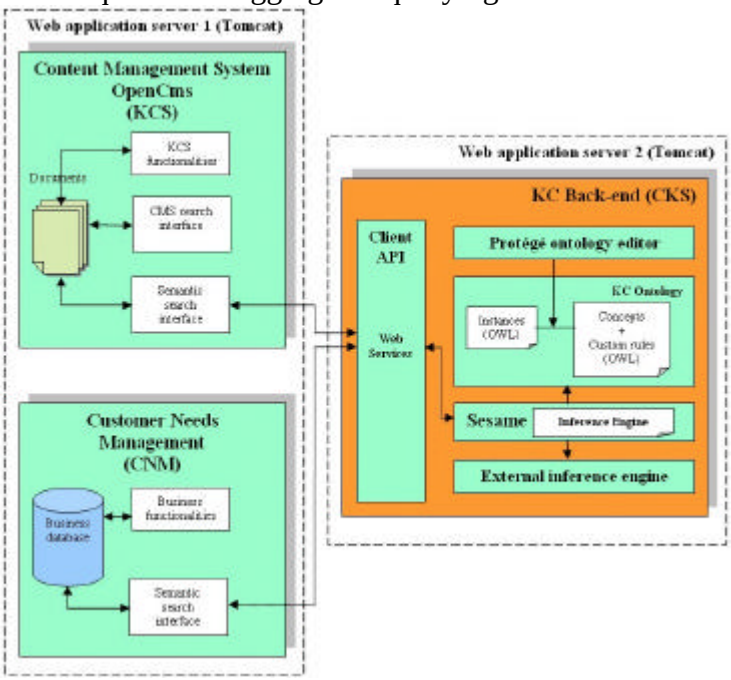

Figure 2: Overview of System Architecture

The KC back-end element will include:

- **A knowledge base schema** (OWL Schema): this schema contains the description of the concepts supported by the KCIS (Know-Construct Information System). It will hold a set of classes, properties and relationships. In addition to this, a set of restrictions will also be used to better describe the concepts and their interrelations.

- **A knowledge base instances** (Information in the form of an OWL instance source): this data source will hold the instances of the classes described with the knowledge schema. It will provide test data for the queries and will include the documents that have been labelled (or tagged) by the user community.

- **Inference engines**: one or more inference engines will be used to check the consistency of the ontology where is the ontology described and also allow for the querying of the instance data. This module may also include a set of custom inference rules.

- **Query engines**: one or more query engines will be used to accept, parse and query the instance data. Such queries include simple statements of the RDF or OWL graph. It will also include a set of queries that will allow a user to flexibly obtain information from (disparate and distributed) data sources.

- **A client API (CAPI)**: will provide a consistent interface between the CKS and any clients application, which will be implemented for the KCIS. This includes the deployment of Web Services in order to communicate the CKS, more concretely the ontology, with the external applications such as KCS and CNM.

- **Ontology Container (Sesame) API**: is an API that will process requests from the CAPI (see point above). Essentially it receives requests to either manipulate or query the knowledge base (both schema and instance data) and accordingly return a result code or the data obtained from OWL data sources.

The system specification identified until now may be summed up into the following set of core functionality:

- **Document storage and management**: the basic information unit is a document (file, sound, image, etc.). All this information will be made accessible through a web browser. As many of these documents will be created, imported and changed within the KCIS system itself, it will also be able to store and manipulate them with a Content Management System (CMS).

- **Document tagging or labelling**: every document will describe a given number of concepts and will somehow be related to other concepts. Such documents and concepts will be manually linked to the concepts. A document (as a whole or one of its elements such as a section or paragraph) will be labelled or tagged with a given property or relation.

- **Data query**: once the documents have been tagged (or labelled), they can be searched. Simple or parameterized queries are received and processed by the KC-back-end. The data is collected and returned in a document according to a pre-defined format.

- **Data Visualization**: information will first and foremost be made available visually no matter whether it is text or images. The KCIS provides a way to open and view documents whether for labelling or standard information consumption. It also provide means to view the ontology (including meta-data) in order to label or tag the parts of the documents and finally provide a way to list and analyse the query results.

5. Conclusions and future work

The development of this customer needs and community knowledge management platform, including the application procedures of construction products and best practices using the identified norms and classification system, is considered by the KNOW-CONSTRUCT consortium partners (which include industrial SMEs and Associations of Construction Industry in four European countries) an important contribution for the improvement of the performance of the SMEs in the sector.

Along the current running period of 12 months, associations and SMEs in the consortium have identified industrial requirements and business scenarios, the methodology and system design have been completed and the system prototype is now under development. In the next working period of 1 and a half years, a basic prototype will be installed in a Portuguese association. The first approach when developing the method and the platform was to install the whole prototype in one association. But, after learning that the complete system can be very complex to use at once, we have agreed the installation of a reduced and basic version of the prototype (the Content Management System part). After the installation, the semantic and innovative functionalities will be incrementally introduced according to the feedback collected from the association and SME users, who get the most benefit of the project. We believe that this is a more correct approach in order to allow the adaptation of the future users to the system. One important aspect regarding the development of the platform is the development approach by independent modules. This innovative approach allows the users to employ the online system while the offline part is being developed. Once the offline part is updated with a new user driven functionality, it will be published and converted to the online system via the CMS. Users will have immediate access to that feature and the next incremental development cycle will start.

For the purpose of quantitative monitoring of the success of this approach, some metrics will be used regarding the KCS part: number of complex projects won through alliances constitution using the platform, time for complex offers issuing and cost of working force. Also, some metrics will be used regarding the CNM part: cost for SME end-user visits, speed of answering to customer general requirements (e.g. application instructions, replaceability, etc.) and to after sales requirements (e.g. maintenance). The business metrics will also be measured: reduction of costs and increasing of the turnover.

The incremental development approach mentioned above will assure the success of the project because the functionalities will be user driven developed and directly assessed over the installed prototype. At the end of the project, the association will own the complete system and the associated SMEs will be able to use it to increase their competitiveness.

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