IT IN COLLABORATIVE BUILDING DESIGN (IT-CODE)

Yoke-Chin Lai

Dept. of Building Technology & Structural Engineering, Aalborg University, Sohngaardsholmsvej 57, 9000 Aalborg, Denmark.
i6ycl@civil.auc.dk

Per Christiansson

Dept. of Building Technology & Structural Engineering, Aalborg University, Sohngaardsholmsvej 57, 9000 Aalborg, Denmark.
pc@civil.auc.dk

Kjeld Svidt

Dept. of Building Technology & Structural Engineering, Aalborg University, Sohngaardsholmsvej 57, 9000 Aalborg, Denmark.
ks@civil.auc.dk

Yoke-Chin Lai, Per Christiansson, Kjeld Svidt

ABSTRACT: *Location and time independent interaction and collaboration among the multidisciplinary competencies of building industry at early design stage highly influence the quality of final building products. A cross-platform IT supported virtual workspace is therefore necessary. This semantic web based distributed virtual workspace will be built on meta-structured languages, XML and RDF, and integrated with ontologies to serve as a dynamic knowledge pool for decision-making support. Virtual building with time tracking capability to formulate the redundant building's descriptions throughout its simulated lifecycle to support decision-making is a resolution to replace physical prototype. A temporal database will be formulated to populate all of the necessary properties of a virtual building for archiving, retrieving, processing and producing building artifacts/documents fast and efficiently. A demonstrator at low-medium cost will be developed for public access in a distributed environment to enable consistent evaluation from the participated end users.*

1. INTRODUCTION

Since decades ago various methodologies have been implemented by the building industry worldwide to produce high quality buildings within shortest time frame and at reasonable costs. The consensus achieved after years of effort is to keep efficient collaboration among all of the participated competencies throughout the building process of a particular project [Kalay, 2001]. Information Technology (IT) supported collaboration are being developed rapidly to integrate the existing knowledge islands that established in between different building processes as well as various groups of expertise. It has been realised that attempts made at the earlier stage of building process, i.e. the planning and design stages will be more effective to attain better mutual understanding, integration and collaboration among the clients, architects and engineers (Christiansson 2001). Knowledge sharing and transfer are one of the main activities in collaboration. Since the last decade, it has been a great dispute in this aspect that share and transfer knowledge may be beneficial to the participants in a collaboration instead of resulting in loss of competitive advantage [Ingirige et al., 2002]. This dispute stimulated studies in regard to the knowledge-sharing environment, which revealed that the efficiency of a collaboration can be improved by a proper knowledge sharing environment [Dixon, 2000]. Integrating the existing IT tools associated with their respective features, such as co-editing, co-browsing, web conferencing, etc., in order to create an efficient knowledge sharing environment is therefore a research interest for promoting the quality of building industry [Ingirige, 2002][Bikson, 1996]. Apart from being integrated into the role of knowledge management, integration of IT tools to assist the design process is apparently another concern to facilitate the process itself while assisting in handling the important digital building artifacts as well as the "by-products", such as the design rationale, that is generated along with the process. IT is therefore considered as a popular way to enable the accomplishment of efficient information communication and knowledge transfer via the dynamic web [Christiansson 2000].

Considering the utilisation of web services that can improve the quality of collaboration has motivated the evolution of such technologies in building industry since the 1990s. The advantage of using web services is to efficiently communicate the relevant information and knowledge representations fast, reliable and bi-directionally regardless of time and geographical location constraints. Meanwhile, it has also been recognised that web service is a good media to store, process and manipulate the mass amount of building artifacts that generated timely even for a single building structure [Zhu et al. 2001] [Christiansson, 2000]. Some attempts have been initiated for the development of web-based applications particularly in the aspect of project management [Stouffs, 2002]. The main aim of these applications is to integrate the developing web-based technology into building projects in order to facilitate the project management process. However, application of web services in the early design stage, such as planning and conceptual design remains a rare case up to date.

Studies with respect to the use of IT-based communication were carried out on certain local construction industry by some researchers. One of the typical examples performed by the Danish building industry in regard to this survey study demonstrated a generally encouraging development tendency. This IT barometer survey indicated that 80% of office-based employees own personal computer and e-mail address, and 23% of firms possess some experience of project webs [Howard, 2001]. Easy accessibility and the maturity of such technologies and services motivate fully utilisation of IT tools to create a collaborative application that can demonstrate promising effects to support as well as to stimulate the active collaboration between the owners and the architectural engineering design teams at the earlier stage of a building project [Christiansson, 2000]. This collaborative application is expected to consist of functionalities including fast capture the requirements specified by the owners, fast prototype the contextual design of a new building and reuse of experiences and solutions accumulated from previous project cases.

Meta-model is a hot discussion topic that arises the study interest with respect to providing better interoperability and flexibility of data exchange [Amann et al., 2000][Draskic, 1999][Christiansson, 2000]. There is an argument that the use of meta models in design process may devote to benefits including to reduce system complexity, provide model flexibility, and integrate multiple and heterogeneous databases [Draskic, 1999]. This argument has inspired the application of the concept of meta-model into building industry in order to facilitate in managing the mass amount of product models and all other relevant information that generated throughout the design process. The concept of using meta-data to reduce the complexity while improve the navigability of data stored in a data repository has been well known since the last decade. We argue that making use of the intrinsic characteristic of meta-data to create a self-descriptive meta model is expected to solve the problem of information island in the building industry. Numerous instances demonstrated that meta-data models might support better data and information interoperability, and also fast navigation, mapping and retrieval of any information/data of interest [Draskic, 1999]. Meta model may then serves as a simple building core model to form the basis of a collaborative virtual workspace while handling the redundancy of sub-models that are nuisance for store, access, retrieve and transfer during the design process.

In this regard, we argue that it is the time to create an IT-based collaboration system that will utilise the advantage of semantic web to support the design process in particular at the earlier stage of the process. This paper will present the framework of this ambitious prototype system, namely the IT-CODE that integrated with new functionalities can improve collaborative design as the main objective. Such functionalities will be further described and discussed hereafter. However, details of the technical approaches used in the development process are out of the scope of this article.

1.1. The Current Shortcomings

Excessive data and information generated from a building project is always an unsolved shortcoming occurred in building industry. In order to deal with such mass amount of data, the concept of product modelling has been implemented since long ago. This concept associated with its well-developed techniques have been sufficiently developed as standard knowledge in the field of information technology construction [Rebojl et al., 2002]. In accordance with Björk [Björk, 1989], product model is useful to integrate all necessary relevant data for all of the computer-supported phases throughout the life cycle of the product into a single model. This essential task of product modelling has however resulted in a main problem, i.e. the complexity of the model [Eastman et al., 1998] that reduces the accessibility, navigability and retrievability of the associated data. Apart from that, another problem that arises from the use of product model is associated with the definition standard of the basic elements that are used to form the complicated model structure. Several attempts have been taken to solve this problem, ranging from the previous STEP application protocol to the latest IFC standard. Promising improvement with respect to the data interoperability is attained after those large software developers that involved in the IFC standard development process initiated the promotion of IFC. However, this development does not assist effectively in solving the problem that arises from dealing with the excessive information and repetitive data. Such problem has resulted in extra time use for data mapping, query and retrieve. Thus, there is a need to develop a system embedded with meta-model that can describe and represent effectively all of the necessary information, data, product and process models that are required for and created from the design process.

Physical building prototype is a conventional methodology used by the design team to represent the idea as well as to evaluate the buildability of a conceptual building. This method may result in the delay of important decision-making process while spending extra project expenses. Meanwhile, time navigation that is applicable to virtually describe the building process is also unavailable for the physical building prototype with limited functions. Thus, virtual building that enhanced with temporal navigation is expected to provide various alternative digital buildings, which is important to support decision-making during the design process [Christiansson 1999]. Alternatives of digital building that are built throughout the design process will then be an approach not only in supporting decision-making but subsequently facilitating the real construction process [Christiansson et al., 2002].

Design is a non-static, complicated and constraints satisfaction process. There is no single and correct design solution due to its heavy dependency on uncertain criteria and subjective assessment [Fruchter, 2002]. Design solutions are therefore generated by an iterative process to satisfy mainly the clients-specified requirements [Moore et al., 1999]. However, previous studies indicated that approximately 50% of the daily design works are tempted to be in a routine basis rather than to be creative because of time and budget constraints [Moore et al., 1999]. This arise the need to establish an efficient project memory management system. The project memory management system is also anticipated to support innovative design by providing features to reuse both of the external and tacit design knowledge, including design rationale and the previously designed artefacts and/or components.

2. COLLABORATIVE DESIGN SYSTEM

In view of the above-mentioned background, a collaboration system that integrated with the below-described functionalities is therefore in need.

1. Support decision making for innovative and routine design.
2. Enhance close collaboration in a design team through Semantic Web. Meanwhile, both face-to-face and distributed working environment are supported.
3. With the explosion of information on the current web and the increased use of intranets within corporation, it is increasingly essential to have methods in organizing and understanding the information that is already available [Gregg et al. 2002]. The concept of semantic web that consists of systematically structured documents, models, ontologies and semantic annotations, has therefore emerged in order to improve the interoperability to solve such rapidly growth situation [Bernes-Lee et al., 2001]. Metadata model is claimed as a good mechanism to access such machine-processible information sources [Amann, 2000][Gregg et al., 2002]. Metadata models will be developed as the kernel structure of this system. The meta-models are expected to sufficiently describe the large quantity of sub-models. Evaluation with respect to their integrity with such vast number of sub-models generated throughout the design process is necessary. Elimination of information redundancy is therefore expected through the contribution of the meta-models.
4. Embedded with a dynamic knowledge management system that is capable to explicitly and persistently manage design knowledge representation owned by the geographically dispersed team members. The knowledge management system should be capable of fast and incremental prototyping the alternatives and ideas formulated in collaboration with the project owners (clients). Underlying product modelling should also be supported through accessing libraries of IFC based product models. Documenting, versioning and indexing design rationale will also be available to facilitate the future reuse of previous solutions and experiences. Automated capture of design rationale is planned as part of the development of this system to fulfil this objective. Meanwhile, this knowledge management system will be capable to support development of ontologies that are effective to describe the expanding domain-specific knowledge so that collections of information and data can be structured systematically at meta level.
5. An elaborate, precise and automated web-search function will be developed using ontologies to manipulate knowledge representations that are stored in multiple and heterogeneous digital information containers. The use of ontologies is of interest because of the crucial role they play in enabling web-based knowledge processing, sharing, and reuse between applications. Ontologies have been defined as share of formal conceptualisations of particular domains, and can provide a common understanding of topics that can be communication between people and application systems [Decker et al., 2000].
6. Good visualisation and user-friendly interface will be incorporated to improve the interactivity between users. The system will support both face-to-face and distributed working environment.

2.1. Conceptual System Framework

The development of this conceptual system remains at its infancy stage. Every detail of the technical approach is yet decided at the time instance when this article is prepared. Continuous changes will be imposed on the system for consistent upgrade. The following figure (Figure 1) therefore illustrates merely the provisional architecture of the system framework on which IT-CODE is built. This section will explain the system architecture with some details in regard to the tasks of the constituted system components. Generally, the system is divided into four levels as indicated in the figure, i.e. the user level, application level, knowledge intervention level and repositories level to distribute the developing efforts into several stages. Every level is responsible for particular functionalities designated within its scope. The user level will be developed to comprise user-friendly human-machine interface to support both online and offline digital collaborative working environments. However, there will be only limited functions available when the IT-CODE works offline. These necessary functions including capturing the client's requirements specification, documenting the design rationale, providing the search resource categories conforming to the predefined user environments, enabling the accessibility to the local user/team databases through conventional navigation and direct query and subsequently retrieving the information of interest, incorporating with other software applications that are commonly implemented for synthesis and analysis purposes, augmenting the asynchronous communication with synchronous interactive facilities, implementing mechanism to monitor the user-presence on this web-based collaborative system. For the detail of awareness on WWW and CSCW systems, please see [Liechti et al., 1999].

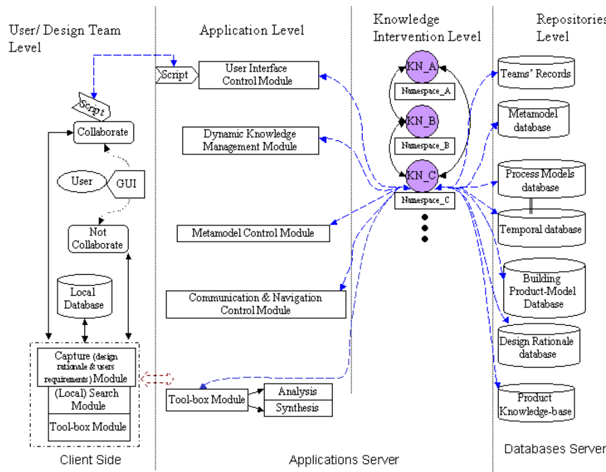

Figure 1: System Architecture of IT-CODE

To date, the second level, which is the application level, will embody five control modules. The User Interface Module will function mainly as a mediator to interconnect the client (here refers to the user of IT-CODE system) with the server. Peer-peer communication approach, which is necessary to reduce the networking workload, will also be handled here. Synchronisation between user (client)-server, and between user-user is another responsibility of this module. The Dynamic Knowledge Management module will serve most of the functions correlated to design knowledge manipulation, such as capturing user's (here refers to the owner of the building project) requirements specification, capturing design rationale, manipulating knowledge nodes and repositories and the relations between them, and defining the content schema, structure schema and mapping schema of the shared virtual working-space of this system. Overlapping of functions may be noticed between this module and some of the functions provided in the User Level. Such overlapping is somehow planned deliberately to ensure that the system can function sufficiently when it is offline. When the system is connected online, the Dynamic Knowledge Management module will take over to control activities that originally managed by the functions embodied in the User Level.

The meta-model control module will be responsible for managing information systematically at meta-level so that the information will be both machine and human processible. Development of meta-model and ontologies, respectively, is generally the main function. As claimed by Maedche [Maedche, 2001] that construction of ontologies is remarkably essential for the success and proliferation of semantic web. Considering this argument concurrently with the paradigm shift from ordinary web technology to the semantic one, the capability with respect to ontologies construction is therefore incorporated to ensure sustainability and expandability of the system. Ontology is utilised to describe the knowledge of a specific domain, which hereby refers to every individual design case (or project). The Communication and Navigation Control Module will manipulate all relevant activities in regard to the purpose of communication and navigation in both synchronous and asynchronous modes, such as video conference, live chat, e-mail, co-browsing, co-editing, etc. As a rule of thumb, such facilities are necessary to motivate interaction and communication among team members who participate in distributed collaboration. To date, the last module allocated to the Application Level is the Tools-Box Module. This module will be responsible for managing all activities associated with the implementation of all incorporated design tools, including both synthesis and analysis software that are commonly used in the building design aspect. Compatibility of IT-CODE with some software platforms, for instance the CAD modelling software, is remarkably necessary to ensure its cross-platform portability. IT-CODE is tending to be developed as a plug-in application to eliminate the potential high-price constraint as imposed on small-scale users by sophisticated software applications that developed by well-known software vendors.

The Knowledge Intervention Level will act as a mediator to channel the request sent from the previous two levels to the appropriate database for further actions. The concept of knowledge node that is originated from Christiansson [Christiansson, 1998] will be adopted in this level. In accordance with Christiansson [Christiansson, 1998], knowledge node is a high level processing unit that consists of three main functions, i.e. disseminate information on request or channel automatically, enable user bi-directional communication and feedback capabilities via multimedia interfaces, and access to local knowledge container and possibly meta-knowledge correlated to the other knowledge nodes. In our case, each individual knowledge node is analogous to a knowledge domain, which hereby may be a particular project (design case). Knowledge node is a stand-alone individual but can also be integrated to each other to form information linkages. It provides collaborative virtual workspace that can be customised with certain extent of project specific characteristics for the project participants. Each node will be designated with a specific namespace as a location identifier. Ontology (meta data schema) [Maedche et al., 2001] will be used to describe the knowledge content, including the associated product and process models of every individual knowledge node. RDF (Resource Description Framework), which is a foundation for processing metadata [W3C, 1999], will be implemented in ontology construction. Meanwhile, RDF schema mechanism will be useful to define classes and properties, which are instantiated in a RDF description. For instance, in a RDF description, Model A (subclassof) is described as a Product-Model (propertyof) of a project, House A (Class). The vocabularies used in this RDF description, i.e. Model A, Product-Model and House A, are meaningless to the machine except they are well defined in somewhere else. RDF schema is therefore necessary to play the vocabulary-definition role to define all vocabularies used in the RDF description, i.e. to define House A as Class, Model A as subclassOf, and Product-Model as propertyOf.

To date, the Repositories Level is planned to comprise several separated databases in each of which is responsible for a particular group of archive. Basically, the knowledge nodes typically identified as URIs (Uniform Resource Identifiers) on the WWW will interconnect all these separated databases, which each will provide part of the information needed to comprehend data for fully describing the building design process as well as the building itself. The Users' Records database will be used to store the contact details of project participants, the current and history locations identified by IP addresses as they are login to the system, etc. The metamodel database will be responsible for the storage of all metadata, ontologies, and metamodels that are generated throughout the current design process as well as those generated from previous projects. The process models database will be integrated with a temporal database in order to enable the creation of time-navigatable virtual buildings [Christiansson et al., 2002]. Meanwhile, this database will also archive process models of respective projects. The Design Case-Base will be storage of product models generated from previous design projects. Design Rationale Database is the one to store the captured design rationale, i.e. history, reasoning and decisions made throughout the design process. Product Knowledge Base may provide information with respect to knowledge required for design and evaluation purposes, such as building codes, relevant standards, specification and etc. Such information may exist as linkages to the respective external resources or the knowledge itself that stored in the database. The whole database server may probably not be apparent as a central server but several distributed servers owned by different competencies groups such as the architectural and engineering institutions involved in a project.

3. DEVELOPMENT AND POTENTIAL IMPLEMENTATION

The development of this system remains at an early stage while its design of web-based user interface is under progress when this article is prepared. A prototype demonstrator of the system will be developed for dissemination in distributed environment to enable incremental and consistent evaluation from the participated end-users.

In general, this conceptual system framework primarily aims at contributing value-adding services to the existing sophisticated software applications commonly used in building design process. Such domain-specific software applications as CAD system, Building Compliance Checking system, Structural Analysis system, Virtual Building system, etc., rarely provide necessary features/services on the whole to support a distributed, dynamic interactive, decision-making support, and experiences reusable collaborative virtual design workspace. Such a workspace offered by IT-CODE can be analogous to a knowledge pool, which partly portrays the idea of Memex [Bush, 1945] to this IT-oriented decade by augmenting with the cutting-edge IT-based technologies. Bush [Bush, 1945] described Memex as "…a device in which an individual stores all his books, records, and communications, and which is mechanized so that it may be consulted with exceeding speed and flexibility. It resembled a desk.... Within would lie several gigabytes (if not more) of storage space, filled with textual and graphic information, and indexed according to a universal scheme..." Findings from the ongoing DIVERCITY project (Distributed Virtual Workspace for enhancing Communication within the Construction Industry, EU project IST-1999-13365) regarding definition, design and implementation of web-based distributed workspaces will be taken into account in the project. [Christiansson et al., 2001][Christiansson et al., 2002].

Implementation of this system may enable scenario comparison to support decision-making during the design process by acquiring the project-related information/data from multiple and heterogeneous resources fast and concisely as input to the respective software applications that activated subsequently for further processing. This remarkable feature is expected to expedite the design process in a way to reduce time spends for manually comparing the digitalised data. The project owners, potential building users (if available at the early project phase), architects and engineers are therefore anticipated to be beneficial from the IT-CODE system.

4. CONCLUSION

This paper presented an ambitious software system that is essential to support collaborative design for buildings. A provisional conceptual framework of this system was delineated and described with detailed context. The framework encapsulates the functional modules required to operate the system and all relevant databases with the knowledge management mechanisms that serve as the kernel structure to form a semantic web based, new version Memex machine [Bush, 1945]. The system will be developed to encourage modular software component interaction, to have an open and dynamic architecture to be compatible with multiple hardware and software platforms, to maintain future expandability, in order to fulfil the requirements of building designers. Merely a very preliminary concept of this system was presented here whereas lots of attempts are undergoing to make such an ambitious system a reality.

REFERENCES

Amann, B. et al. (2000), Integrating ontologies and thesauri for RDF schema creation and metadata quering, Int J Digit Libr, 3, 221-236.

Bernes-Lee, T., Handler, J., Lassila, O. (2001), The Semantic Web, Scientific American, 284(5), 34-43.

Bikson, T.K. (1996), Groupware at the World Bank in Ciborra, C.U. (Eds), Groupware and Teamwork: Invisible aid or technical hindrance, Wiley.

Björk, B.C. (1989), Basic Structure of a Proposed Building Product Model, Computer Aided Design, 21 (2), 71-78.

Bush, V. (1945), As We May Think, Atlantic Monthly (July), http://www.theatlantic.com/unbound/flashbks/computer/bushf.htm.

Christiansson, P (2001), Capture of User Requirements and Structuring of Collaborative VR Environments, Proc. Of Conf. AVR II & CONVR 2001, 1-17.

Christiansson, P. (1998), Using knowledge Nodes for Data Discovery and Data Mining, Artificial Intelligence in Structural Engineering Information Technology for Design, Collaboration, Maintenance and Monitoring, Lecture Notes in Artificial Intelligence 1454, Ian Smith (Ed.), Springer-Verlag Berlin Heidelberg, 48-59.

Christiansson, P. (1999), Properties of the Virtual Building, 8th International Conference on Durability of Building Materials and Components, Information Technology in Construction, 2909-2919.

Christiansson, P. (2000), IT in Distributed Open Learning Environments, Construction Information Technology 2000 – Taking the Construction Industry into the 21st Century, G. Gudnason (ed.), Icelandic Building Research Institute, 197-208.

Christiansson P, Svidt K, Skjærbæk J O, Aaholm R, 2001, "User requirements modelling in design of collaborative virtual reality design systems". International Conference on Construction Information Technology. Mpumalanga, Soth Africa, 30 May - 1 June 2001. (pp. 40/1 - 40/12)

Christiansson, P., Dawood, N., Svidt, K. (2002), Virtual Building (VB) and Tools to Manage Construction Process Operations, Proc. of CIB W78 Conference 2002.

Christiansson P., Da Dalto Laurent, Skjaerbaek J. O., Soubra S., Marache M., 2002, " Virtual Environments for the AEC sector - The Divercity experience ". ECPPM 2002 European Conference of Product and Process Modelling. eWork and eBusiness in AEC. 9-11 September 2002, Portoroz, Slovenia. (8 pp.)

Decker, S. et al. (2000), The Semantic Web: The Roles of XML and RDF, IEEE Internet Computing, Sept-Oct.

Dixon, N.M. (2000), Common Knowledge: How Companies Thrive by Sharing What They Know, Harvard Business School Press.

Draskic, J., Goff, J-M. L., Willers, I. (1999), Using a Meta Model as the Basis for Enterprise-Wide Data Navigation, http://www.computer.org/proceedings/meta/1999/papers/58/rmcclatchey.html.

Eastman, C., Augenbroe, F. (1998), Product modelling strategies for today and the future, Proc. of CIB W78 Conference 1998, The Life Cycle of Construction IT Innovations, The Royal Institute of Technology, Stockholm, Sweden.

Fruchter, R., Demian, P. (2002), Knowledge Management for Reuse, Proc. of CIB W78 Conference 2002.

Gregg, D., Goul, M., Philippakis, A. (2002), Distributing Decision Support Systems on the WWW: the verification of a DSS metadata model, Decision Support Systems, Vol. 32, 233-245.

Howard, R. (2001), Use of information technology in building, BYG.DTU Rapport r-008, www.byg.dtu.dk/publicering/rapporter/byg-r008.pdf.

Ingirige, B., Sexton, M., Betts, M. (2002), The Suitability if IT as a Tool to Facilitate Knowledge Sharing in Contruction Alliances, Proc. of CIB W78 Conference 2002.

Kalay, Y. (2001), Enhancing multidisplinary collaboration through semantically rich representation, Automation in Construction (10), 741-755.

Liechti, O., Sifer, M., Ichikawa, T. (1999), The SGF Metadata Framework and Its Support for Social Awareness on the World Wide Web, World Wide Web (2), Baltzer Science Publishers BV, 191-208

Maedche, A, Staab, S. (2001), Learning Ontologies for the Semantic Web, IEEE Intelligent Systems and Their Applications, Vol. 16 (2), 72-79.

Moore, C.J., Lehane, M.S.(1999), Development of a case representation strategy for a bridge design case base, Engineering Structure (21), 219-231.

Rebolj, D., Cus-babic, N., Tibaut, A., Magdic, A. (2002), Evolution of a Road Product Model, CIB Proc. of W78 Conference 2002.

Stouffs, R., Tuncer, B., Sariyildiz, S. (2002), Empowering individuals to design and building collaboration information spaces, Proc. of CIB W78 Conference 2002.

W3C (1998), http://www.w3c.org/RDF.

Zhu, Y. et al. (2001), Web-based Construction Document Processing Via Malleable Frame, J. of Computing in Civil Eng., July.