Prototype of semantic interoperability between different modalities of 2D-CAD design

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ABSTRACT: The diffusion of specific computational tools for Architecture, Engineering and Construction (AEC) has generated a great amount of digital data in the last years. However, it is necessary for the sector to promote a standardization of such data so that they can be shared among the participants and partners of a design project. Trying to correct the problem of information exchange and mainly of data interoperability, a research project was carried out within design offices in the south of Brazil, identifying the problems and quantifying losses according to the lack of interoperability. For generation of information starting from the CAD design and as a way of enlarging the communication among the partners, a study was held about the use of the IFC classes (Industry Foundation Classes) – a pattern used to transfer data among design modalities. The result was an application of syntactic conversion of attributes of the IFC classes for XML, to attest the viability of technical integration and to transfer information to a web-based environment. As a result of the investigation, a prototype was elaborated for transferring information from CAD design to web-based applications. By using IFC classes, a program was developed in Java language for the syntactic and semantic exchange, with the automatic conversion of the information for standard XML. It was observed that the decrease of interoperability problems, checking the viability of technical integration of the design with the shared information through the web.

1 INTRODUCTION

Many studies carried out in the research area of civil construction indicate that the fragmentation of the productive chain is one of the major problems in this particular area. Studies such as those proposed by Aouad (2000), Construction Task Force/UK (1998), Banwell (1964) and Higgin & Jessop (1964), for example, reveal that a great number of communication problems in project design are often caused by lack of coordination, low efficiency, poor quality, and isolated corrective measures. Latham (1994), in his "*Review of Construction Procurement*", has confirmed the same findings in which certain working practices have a negative effect on the relations between agents, and as a result, these practices may increase costs and lower the quality of construction products.

The findings of the aforementioned studies show how difficult it is to solve these long-standing problems which occur in various different countries, each one with their own specificities. In order to overcome these difficulties, structural solutions in the area are necessary along with the integration of agents participating in the construction processes and their adaptation to current computer tools available on the market, thus softening such difficulties during the interchange process of information between agents.

Nicolini et al. (2001) points out that nowadays there is an emerging consensus not only on diagnosis, but also on what needs to be done in order to find an effective solution to the relations between agents in the productive chain. A more relational and consistent way must be created in order to foster collaboration in the activities along the chain, thus reducing interruptions in the process usually caused by poor communication, fragmentation of the industry and of a disintegration culture (i.e. agents acting as adversaries).

Today's approaches for exchanging electronic and paper-based project information (e.g. standardized semantic models, software wrappers, and electronic or paper-based sharing of visualizations and documents) do not respond to the information interaction challenges of project teams.

Future research and applications will show to what extent standard-based product models combined with computational mechanisms – which infer information not explicitly available from a product – can support the specific information needs of the project (Haymaker et al, 2000).

Be that as it may, actions become necessary in the investigation of the existing specific problems in the sector. In this paper, I would like to explore the problems related to the exchange of information between participants in a design project, focusing on the interferences between the types of design.

2 INFORMATION EXCHANGE IN THE DESIGN PROCESS

Information exchange is essential for the production of a quality design. Many actions taken by companies and researchers aim to enable an adequate integration of designers with the use of computational tools.

However, research still needs to formalize the modeling, sharing and exchange of scalable, testable, and sound information to support decision making in project teams (Liston et al. 2001):

- The current information exchange mechanisms need to be complemented with an approach that responds to the needs of project teams.
- Interactive multi-user, multi-application, and multi-device user interfaces need to be designed.
- The effectiveness of project teams in making decisions needs to be measured to assess the power and generality of the information exchange mechanisms and the user interfaces.

By observing the new conditions for the integration of agents in the process, this relationship can be extended to other participants in the productive chain. According to Murray et al. (2001), many advantages can be obtained from the Inter-relationship between agents. The involvement of the contractor, for example, in the design elaboration process can add improvements to the process as whole in at least two ways:

- The first one has to do with the fact that the contractor can provide information that eliminates future unnecessary costs.
- The second one is related to the fact that designs usually lack significant detailing, and in this sense the contractor can provide information that can be used to extend constructability, thus contributing to the improvement of the quality of the project.

The increase of productivity, which is always the main focus in the design process, can be achieved through a rigorous analysis of the requirements in the initial phase of the project, the incorporation of the difficulties found in subsequent phases, and the rigid control over the modifications until the end of the building process, enabling a reduction of time in the design phase and in the number of requests for modifications. In this sense, knowledge management, which maintains a symbiotic relationship with the advances in computer technology, can become a great ally in searching and extracting information from databases by means of computational tools.

The ever-growing use of Information Technology (IT) as an integration instrument has opened up new possibilities for improving data flow between the participants of a design process, reducing errors, improving coordination, maintaining the integrity of data, and as a consequence improving the quality of design (Faniran et al, 2001).

One of the most important benefits offered by IT to the civil construction area is the automation of processes (Love and Ganasekaran, 1997). According to Aouad (2000), various factors interfere with the possibility of integrating technologies of information in the construction industry such as the fragmentation of the productive chain; lack of standardization in the exchange of information between systems; lack of transparency in the processes; poor quality in the management of industries, companies and projects.

Many studies have focused on the improvements that have been achieved in the processes: (i) through the integration in 2D and the modeling in 3D (Anumba, 1989), graphical and non-graphical data (Anumba and Watson, 1991), integration of databases (Brandon and Betts, 1995), the use of interfaces and data structure (Anumba e Watson, 1992; e Li et al., 2000), the development of web-based environments for the integration of projects, among others.

Despite the steady growth of research in IT, there are still lots of questions that need to be answered in the construction sector (Love et al, 2000). Various IT-based projects implemented in the construction sector are cited by Love (1998): COMBINE, COMMIT, ICON, SPACE, RISESTEP, CIMSteel, CONCUR, GEN, VEJA, RATAS, ISO-STEP, IAI/IFC. Design projects of network integration in the construction sector are presented by Faraj, et al (2000): Project ATLAS, COMBI, OSCON, OPIS, plus the aforementioned COMBINE, ATLAS, RATAS.

The question of language is pointed out by Cutting-decelle et al. (2001), in the LEXIC project which suggests the use of a particular language system to solve the problem of meaning among the terms used in construction. In this sense, the PSL (Process Specification Language) created by the National Institute of Standards and Technologies (NIST), in order to standardize the language of process specification, thus serving as an inter-language tool for minimizing issues of interoperability between applications and processes.

3 REQUIREMENTS FOR STANDARDIZED INFORMATION

The increase of information generated by computational tools (e.g. CAD) in design projects has created a growing concern about how this information should be transferred automatically [In the case of if searching an effective interoperability, if it not only needs a syntactic equivalence enters the entities represented for the systems, but also the equivalence of concepts and meanings of these entities]. Many efforts have been made in order to contemplate standards in adjusting "common Projects" for the community that uses the same parameters of data. Some works offer systems based on the concept of ontology. In the case of the organization of ontology, some basic characteristics must be taken, as the follow:

– Open and dynamic: To adapt it to the changes of the associated domain, having to be automatic;
– Scalable and interoperable: It must be easily scalable for an ample adaptable domain and the new requirements;
– Easy maintenance: It must be at the same time dynamic and of easy maintenance for specialists;
– Consistent Semantically: It must keep the coherent concept and relationships;
– Independent of context: The ontology does not have to contain very specific terms in a certain context, because it deals with sources of data of wide scale;

One of the first semantic standards for the construction area was developed in 1986 by the AEC STEP group, which presented a proposal of indefinite and open standard (with the contribution of Jim Turner and Wim Gielingh (Tolman, 1999)). Through a model of general reference, called GARM (General AEC Reference Model).

More recently the efforts to develop the STEP, together with the spreading of the IFC created by the International Alliance for Interoperability (IAI – 1995), represent the most recent efforts of standardization in the construction sector.

Despite the present efforts, many difficulties have to be faced when one of the standardization systems are implemented, some of these difficulties are described as follows:

– The uncertainties regarding the data obtained from the transference and integration of software information;
– The necessary communication between the industry and the standardization is inefficient;
– Existence of small project teams, with focus on the different types of customers, thus limiting the standardization of solutions;
– The size of the companies is an important factor, therefore the standardization in small companies is relatively easy if compared with great companies having great volumes of procedures;
– Some questions, for example: the incompatibility of the hardware and the interoperability of software enter the chain of participants.

4 THE RESEARCH IN DESIGN OFFICES

The current research has investigated the problems related to the use of information among the participants in a design project, suggesting solutions based on recent technologies (it is important to stress that the 2D design was the only one used).

Resultant of this investigation consolidates a suggestion of information parameters to a protocol of distributed information among the agents of the design.

This study has contributed to the identification of the information necessary to manage interference problems among design projects, suggesting how these data can be modulated and used with the aid of computational tools and the Internet. The use of a standard in the transferring of information led to a model, which is adapted to the existent procedures in the process design and increased as innovation the resources of the IFC classes.

Also as way to present and defend the necessity of incorporating new procedures and tools for the integration of the design process, the internal processes of the offices which were investigated and the knowledge they accumulated and registered were collected, not the mention the accumulation of information regarding the following points:

– Problems resulting from lack of interoperability;
– Activities of manual detailing;
– Problems of data exchange;
– Difficulties of quantification and budgets;
– Stoppage for revision of projects;
– Extra time with mitigation and expense with modification of design.

During the research process in the design offices, the following mechanisms were considered:

– Structure of the collection of data, identifying the significant internal questions;
– Instruments of work: the analysis of documents and processes of each office;
– Characterization data of the office through a structuralized spread sheet;
– Accompaniment of the diverse stages of design, with control of cost, time, modifications and deficiencies of the project;
– Dataflow of the process, identifying the activities carried out and the main procedures adopted; the Interview structuralized with specialists, searching to absorb the intellectual capital of the company.

The observation of the design process was carried out having as its basis a division of the stages, for each modality of design: architectural design, structure, HVAC, electric.

Inside the process, the existing elements of information and relations were identified with the agents in the development of the design process.

Each occurrence of data exchange, use of information for another participant, or any action affecting productivity was identified and refined in a quantitative spreadsheet. The results are presented below:

Table 1. Loss in design (2D) due to lack of interoperability

Design modality	Loss in design (%)	General
Arquitectural	31	**22 %**
HVAC	24	
Eletric	19	
Structure	16	

In view of the identified losses, a computer program (translator) was created to help to eliminate the losses detected in the research with an exchange of information between the participants making use of web. The functioning of the software is identified as follows.

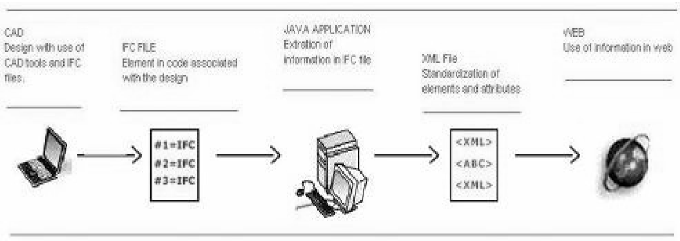

Figure 1. Caption Development process of software to resolve communication problems in design.

5 CONCLUSIONS

The solution presented in this paper shows that it is possible to transfer information automatically from a drawing environment (CAD) to a web-based environment, through literal information (i.e. using transcribing language XML of classrooms IFC).

This type of syntactic conversion of attributes of IFC language for use in XML can become a valuable tool for some of the processes in building design. As previously shown, some standards are already being developed and they lack exactly the association of IFC classes with standard XML.

The experiment has confirmed the possibility of using simple tools, as the prototype developed herein, to solve problems that still represent a dilemma to the development of the design process.

Moreover, the software (translator) developed demonstrates the practical viability of the technical integration through the web, resulting in an experience that offers significant advantages to the process of exchange of information in design.

REFERENCES

Aouad, G. et al. 2000 *An industry foundation classes Web-based collaborative construction computer environment: WISPER*, Automation in Construction, n. 10, p. 79–99. Available in: http://www.elsevier.com/locate/autcon.

Anumba, C.J. 1989 *An integrated two-dimensional and three-dimensional data structure for a structural engineering CAD system*, Thesis PhD, University of Leeds, Leeds.

Anumba, C. J.; Watson A.S. 1991 *An integrated CAD data structure for structural engineering*, Computing Systems in Engineering, vol. 2, n. 01 p. 115-123.

Anumba, C.J.; Watson A.S. 1992 *An innovative approach towards designer-oriented CAD systems*, The Structural Engineer, vol. 70, n.09 p. 165-169.

Banwell, H. 1964 *The placing and management of contracts for building and civil engineering work*, HMSO, London.

Brandon, P.; Betts, M. 1995 *Integrated Construction Information*, E&F Spon, London.

Cutting-Decelle et al. 2001 *PSL: A common language for the representation and exchange of process information in construction*, In: 1st International Conference on Innovation in Engineering and Construction, 2001, Loughborough, UK. Proceedings Loughborough: Loughborough University. p. 865-878.

Faniran, O.O.; Love P. E. D.; Anumba, C. J. 2001 *Methodological issues in design construction integration*, Logistics Information Management, vol. 14, n. 5/6, p. 421-426.

Faraj A. et al. 2000 *An industry foundation classes web-based collaborative construction computer environment: Wisper*, Automation in Construction, 10, 79 – 99. Available in: http://www.elsevier.com/locate/autcon.

Haymaker J.; Ackermann E.; Fischer, M. 2000 *Meaning Mediating Mechanism: A prototype for constructing and negotiating meaning in collaborative design*, Artificial Intelligence in Design, John Gero (ed.), Kluwer Academic Publishers, 691-715.

Higgin, G. e Jessop, N. 1964 *Communications in the building industry: The report of a pilot study*. Tavistock Institute of Human Relations, London.

International Alliance For Interoperability. Available at: http://www.iai-international.org.

Jacoski, C. A. 2003 *Integration and interoperability in building design – an implementation with IFC/XML*. 217f. Thesis, Federal University of Santa Catharine, Florianópolis, SC, Brazil.

Latham, M. 1994 *Constructing the Team*. Joint Review of Procurement and Contractual Arrangements in the United Kingdom Construction Industry, HMSO, Tavistock Publications, London.

Li, H. et al. 1998 *Design concept as a model for modeling design process and its knowledge*, International Journal of Construction Information Technology, vol. 06, n.1, p. 87 - 103.

Liston K., Fischer M., Winograd T. 2001. *Focused sharing of information for multi-disciplinary decision making by project teams*. Electronic Journal of Information Technology in Construction – ITCON. Available in: http://www.itcon.org.

Love, P. E. D; Gunasekaran, A. 1997 *Concurrent engineering in the construction industry*, Concurrent Engineering: Research Applications, vol. 05, n. 02, p. 155 -162.

Murray, M.; Nkado, R.; Lai A. 2001 *The integrated use of information and communication technology in the construc-*

tion industry In: Construction it Africa, Proceedings Mpumalanga: CIB-International Council for Building Research Studies and Documentation n. 39. Available at: http://buildnet.csir.co.za/constructionitafrica/authors/Papers/w78-039.pdf.

Nicolini, D.; Holti R.; Smalley Mark. 2001 *Integrating projects activities: the theory and practice of managing the supply chain through clusters*, Construction Management and Economics, n.19, p. 37-47, 2001. Taylor e Francis Ltd, ISSN 0144-6193. Available at: http://www.tandf.co.uk/journals.

Tolman, F. P. 1999 *Product modeling standards for the building and construction industry: past, present and future*, Automation in Construction, n. 8, 1999, p. 227–235.