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TOWARDS VIRTUAL PROTOTYPING IN THE CONSTRUCTION INDUSTRY: THE CASE STUDY OF THE DIVERCITY PROJECT

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Abstract. This paper emphasises the importance of construction IT research and reviews some future research directions in this area. In particular the paper explores how virtual prototyping can improve the productivity and effectiveness of construction projects, and presents Divercity as a case study of research in virtual prototyping. Divercity was an EU funded project, which created six virtual applications for briefing and detailed design of construction projects.

This paper examines the output of the Divercity project and concludes by highlighting three barriers to the deployment of virtual prototyping in construction, at an industrial scale. Major industry bodies need to address these barriers in order to excel progress.

1. Background

In the past decade, construction companies have spent a great deal of effort and resources in improving their business processes. New forms of innovative project management, supported by recent IT developments, have appeared in response to ever-growing pressure from owners to complete projects on time and deliver high quality buildings.

Construction has become an information intensive industry; and a new activity has emerged from the process of managing projects, establishing itself as a discipline in its own right: *information management* (Construct IT 2000).

Despite the interest and effort applied by leading companies, information management in the construction industry is still in its infancy. Construction projects involve a large number of direct stakeholders (clients, professional teams, contractors) and indirect stakeholders (local authorities, residents, workers). There are significant barriers to communications between the stakeholders. Many researchers have acknowledged the limitations of current approaches to the management of information in projects (Kiviniemi 1999) (Aouad, 1997) (Alshawi, 1996). Most of these limitations are due to:

- Much project information is stored on paper as drawings and written documents. This is frequently unstructured and difficult to use. It is also easy to lose or damage (Construct IT 2000). Thousands of documents are shared during a typical project, leading to significant human errors in managing the versioning of these documents.
- This process leads to incomplete understanding of the planned construction, functional inefficiencies, inaccurate initial work or clashes between components.
- People responsible for collecting and archiving project data may not always understand the

specific needs of those who will use it, such as those involved in building maintenance.

- The data is usually not managed while it is created, but instead it is captured and archived at the end of the construction stage. This means that people who have knowledge about the project are often likely to have left for another project by this time – so their input is not captured.
- Lessons learned are not organised well and are buried in details. It is therefore difficult to compile and disseminate useful knowledge and best practice to other projects (Watson and Marir 1994).

Construction IT (CIT) research promises to respond to many of these challenges. This paper first examines a vision for the future of CIT research. This vision identifies two key directions in CIT research, namely: integration and collaboration.

Using these concepts, construction virtual workspaces (VWs) are used to develop virtual prototypes for analysing and testing of buildings. VWs transfer much of the text based project information into visual information, which can be shared among the project team. This technology reduces many of the communication challenges of the industry.

This paper explores the meaning and scope of VWs. It then describes the Divercity research project, as a case study of VW. Divercity was an EU funded project, which had the objective of developing a virtual workspace for construction briefing and design. Divercity developed six end user applications, plus a virtual collaboration environment.

VWs such as Divercity are technically advanced and offer new working paradigms for the industry. However there are major industrial barriers to uptake of VW technologies. These include: (i) confrontational culture within the industry; (ii) fragmentation of business interests among the different phases of the construction lifecycle; and (iii) an innovation gap between research prototyping and industrial implementation. The paper concludes with the review of some implementation barriers.

2. A Vision for Construction IT

Visioning is a process that can assist in the development of future generation of ICT for the construction industry. Sarshar (2000) developed a vision for construction IT. Sarshar portrayed a scenario where all stakeholders can produce their relevant project information and post it on an electronic "project information board". Each user has appropriate access rights and can manipulate the necessary information on demand. This vision has been termed construction "integration", by many researchers (Issa, 1999) (Alshawi, 1996).

In this vision for construction IT, the users of this information board need not be tied to their computers and office network for connections and access. Advances in communications technologies allow users to manipulate information in any format, and in any geographical location. This is known as construction "collaboration".

The following sections expand on the definition of "integration" and "collaboration".

2.1. CONSTRUCTION INTEGRATION

Currently, construction project information is captured in documents and 2D CAD drawings. The construction parties may share these documents and drawings using an electronic environment. But problems arise as the volume of documents and drawings and their versions increase (Sarshar 2002).

The "project information board" approach is a means of sharing project information, via a shared conceptual product / process model. Information is entered once and is used by all stakeholders, during a project. Some of the benefits of the integrated approach include:

- Much of the project information can be presented in a visual rather than textual format. This eases communications and information sharing (Issa 1999, Thabet 1999, Brandon 1999).
- Many aspects of the building can be simulated to improve client briefing and design reviews (Sawhney 1999) (Shi 1999).
- Such interactive technology can be used to consider life cycle issues such as environmental impact, space planning, facilities management, emergency evacuation, security and constructability during design reviews. This can facilitate concurrent engineering by involving clients, planners, architects, designers, civil engineers, contractors, facility managers and security personnel (Sarshar 2000, 2002).
- It is easier to use past project knowledge and information for new developments.

2.2. CONSTRUCTION COLLABORATION

Construction Collaboration is an area, which investigates how the supply chain can access and manipulate the "project information board", irrespective of their geographical location. The key elements of this collaborative environment include (Divercity Handbook 2003, Christiansson *et al.*, 2001):

- Advanced administration tools for distributed personal, team, and project information repositories;
- Access to virtual building models and collaborative environments through wireless networked technologies and low cost virtual reality environments;
- Appropriate security levels for sharing the information over the inter/intranets;
- Process and workflow management tools to support variations in working practices between different projects;
- New generations of ICT tools, which facilitate collaboration and communication with end-user.

3. Virtual Construction Workspace

The above vision sets the agenda for future CIT research. Within this scope, there is increasingly a call from construction IT researchers to develop a "virtual construction workspace" or use "virtual construction prototyping" in order to design and test the buildings, before physical construction.

Christiansson (2001), defines this virtual workspace as: 'The VW is a new design room, which facilitates new and existing design processes. VW uses mixed reality technologies. The VW will host all project partners from the conception of a project. It provides appropriate access and visibility (for persons and groups) rights, during the different phases of a project lifecycle. VW promotes the creation of shared values in a project. It thus acts as a communication space, providing project information in the right format. VW co-ordinates access to general and specific IT-tools '.

Christianson (2001) specifies the types of models and tools that should support the VW. These include:

- *Building organizations and management processes* including links to the project external processes like those provided by information and component suppliers,
- The building (*virtual building*, VB) and it's components,

- Production systems and *construction* activities,
- *Usage and maintenance* of the building artifact,
- *User models* that will highly influence computer interfaces and collaboration styles,
- *ICT tools* especially those that are new and unfamiliar to the process participants,
- New types of services and linked building applications,
- VW *administration* processes.

Issa (1999) explains that visualisation in conjunction with integrated (/ model driven) construction systems can be expected to:

- Enable designers, developers, and contractors to use the VR system and virtually test a proposed project before construction actually begins.
- Offer "walk-through" views of the project so that problems can be found and design improvements can be made earlier.
- Provide a free flow of information between CAD systems and other applications work packages, in order to minimise misinterpretation between project participants.
- Facilitate the selection of alternative designs, by allowing different plans to be tested in the same virtual world.

Other researchers who placed visualisal prototyping high on their research agenda include: Thabet (1999), Hobbs (1999), Grassi (1999), Brandon (1999), and Belle (1999).

4. Divercity[1]

DIVERCITY was an EU funded project (1999-2002) (Divercity Handbook 2003), (Christiansson 2002). The project used IFC standards in order to develop a toolkit for shared virtual briefing and design, in the construction industry. This toolkit allows construction companies to conduct client briefing, design reviews, simulate what if scenarios, test constructability of buildings, communicate and co-ordinate design activities between teams.

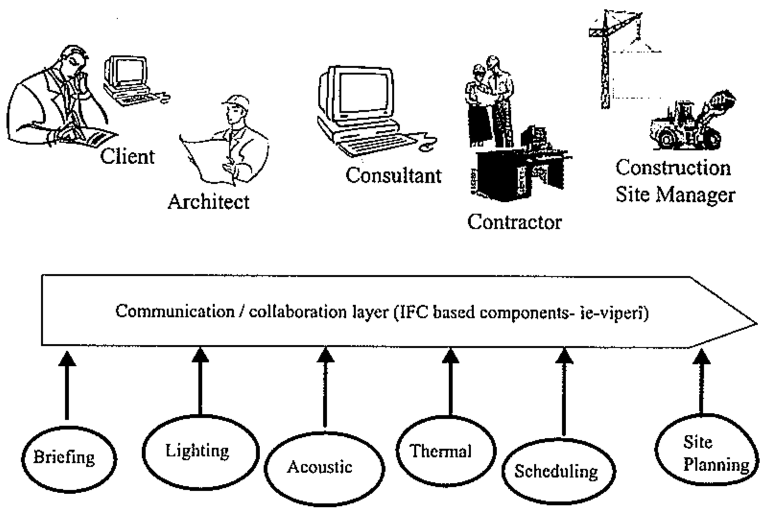

Figure 1. The divercity virtual workspace

[1]DIVERCITY, Distributed Virtual Workspace for enhancing Communication within the Construction Industry, EU IST-1999-13365

DIVERCITY has developed virtual workspaces that improve communication and collaboration. DIVERCITY has focused on three construction processes, i.e. (i) client briefing; (ii) design reviews; and (iii) site operations and constructability.

DIVERCITY allows users to produce designs and simulate them in a virtual environment. The designs are IFC based and can be viewed by all stakeholders within the project team.

DIVERCITY uses a distributed architecture, and enhances concurrent engineering practices during briefing and design. It allows teams based in different geographic locations to collaboratively design, test and validate shared virtual projects. DIVERCITY comprises of six applications, as shown in figure 1:

1. Client Briefing: This supports clients and designers during briefing. It provides tools for capturing strategic and spatial requirements and allows experimentation with alternate spatial layouts, in a visual format (Aspin 2002, Patel 2002).

2. Acoustics Simulation: This application automatically reads CAD drawings (in an IFC format), and allows changes to building materials on-line, in an interactive manner. The user can "listen" to acoustic qualities of the building, and change the design to achieve desired noise levels (Marache 2002, Coudret 2001).

3. Thermal Simulation: This application automatically reads CAD drawings (in an IFC format), and allows changes to building materials on-line, in an interactive manner. The users can simulate the energy consumption of the building (/or rooms) and select appropriate material for energy efficiency (Marache 2002, Coudret 2001).

4. Lighting Simulation: This provides a realistic simulation of lighting. The users can change and move objects or lights in the building and see lighting simulation in an interactive manner (Thery 2001).

   One novel characteristic of this application is the mathematical algorithms, which are used for simulation. Lighting simulations generally take a long time (several hours). In most cases, DIVERCITY algorithms allow real time simulation and only take a few seconds. This facilitates interactive and collaborative simulation (Gobbetti 2002).

5. Site Planning: The site planning and analysis application aims to evaluate the space use and safety in the construction site, and provide ways to generate enhanced construction site layouts with respect to time and safety criteria (Tawfik 2001, 2002).

6. Visual Product Chronology: The Visual Product Chronology application provides visualisations over the various data and their interdependencies. In these visualisations the "Time" aspect is crucial. The application links the time tags with the appropriate building components and their data. This results in the visualisations of the status of the building and its components at the selected point of time (Kähkönen 2001).

Information exchange among the applications is possible via IFC standards. Stakeholders in different geographical locations can share an application via a communication layer, titled "e-viper" (see figure 1). For example a client in a city (e.g. Manchester), can communicate with the architect in another city (e.g. Helsinki). The client and the architect can review the lighting simulation, simultaneously, using e-viper. If the architect changes the lighting locations or design, the client can see the changes in real time. Alternatively, the client can change the lighting design and the architect can immediately see the new requirements.

A distribution manager within e-viper controls access rights to the virtual model.

5. Barriers to VW in Construction

The increasing maturity of the IFC standards (international standards for construction modelling), as well as the long term research in construction IT is resulting in leading edge VW applications for the construction industry, such as Divercity. However, the industry uptake is very slow. VW will impose major change management efforts on individual organisations. As well as organisational change management challenges, VW requires some change management at an industrial level.

Some of the barriers to the uptake of VW, at an industrial scale, include:

- Cultural- The construction industry is a mature and fragmented industry. Many projects lead to adversary relationships and legal claims. In this environment divulging too much information is perceived to increase risks, during litigations. Many construction professionals are reluctant to disclose information, which is contractually unnecessary. The increasing use of existing project extra-nets, is paving the way for some cultural change in terms of information sharing.
- Macro economies- The VW implies increased effort and investment at the early stages of the project life cycle in order to improve the end product (building) quality and productivity and to reduce waste. The different project phases are normally conducted by different organisations. There is a need for re-distribution of costs in favour of project briefing and design phases. This will allow a reduction in costs during construction and maintenance phases. At present most clients are unaware of this issue, and macro economy issues are not addressed.
- Innovation process gap- Most VW environments stop at a research prototyping level, while VWs need to be piloted on real construction projects. Industrialists often participate in the user requirements capture and specification of the VW prototypes, however, piloting on real construction projects is a rarity. This results in insufficient understanding of how of the prototypes will impact construction business and organisational practices. Piloting also provides an opportunity for increasing awareness among the practitioners. Due to the lack of piloting, construction professionals are largely unaware of the developments in VWs.

Absence of piloting in Western Europe is primarily due to insufficient research funding for this key element in research. During the Divercity project, there was significant funding for the research phase of the project. However, there was no follow up funding to maintain the research momentum and learn from the piloting experience.

These industrial issues need to be addressed by major clients and contractors, professional bodies as well as research funders.

6. Summary

This paper presented a vision for the future of construction IT, which is driven by the need for integration of information and use of collaborative tools for effective communications. This can be achieved via the development of a construction virtual workspace (VW), which allows briefing, design and testing of the building, prior to physical construction.

The output of Divercity research is presented. Divercity was an EU funded research, which developed a VW for construction briefing and design. It contains six applications (/toolkits), namely: (i) briefing; (ii) lighting simulation; (ii) acoustics simulation; (iv) thermal simulation; (v) scheduling simulation (visual product chronology); and (vi) site planning simulation.

These applications can collaborate, via a collaborative tool titled "e-viper". E-viper allows the applications to be shared in different geographic locations. Construction stakeholders can review the virtual designs and update them, during a virtual meeting.

Industrial uptake of environments such as Divercity has remained limited. Some industrial barriers to implementation of VW include: (i) cultural as well as risk issues related to information sharing; (ii) macro-economy issues related to increased effort in virtual prototyping during briefing and design; and (iii) insufficient research funding, for piloting of research prototypes on real construction projects.

References

Alshawi, M. (1996) *"SPACE: integrated environment"* Internal Paper, University of Salford, July 1996.

Aouad, G., Marir F., Child T., Brandon P. and Kawooya A. (1997) *"Construction Integrated Databases- Linking design, planning and estimating, The OSCON approach"*; International Conference on the Rehabilitation and Development of Civil Engineering Infrastructures. American University of Beirut, pp 52-60, June 1997.

Aspin, R., Fernando T., (2002) *"Development and Exploration of Conceptual Building Function-to-Form Relationships"*. ECPPM 2002 European Conference of Product and Process Modelling. eWork and eBusiness in AEC, Portoroz, Slovenia.. 9-11 September 2002

Belle, R. A., (1999) *"Bridging the Globe: Engineering and Construction Solutions for Sustainable Development in the Twenty-First Century"*, Berkeley-Stanford CE&M Workshop, Stanford 1999.

Brandon, P. S., (1999) *"Product Process Development in 2000 Beyond"*, Berkeley-Stanford CE&M Workshop, Stanford 1999.

Construct IT (2000), Construction Modelling Methodologies for Intelligent Information Integration (COMMIT), Construct IT Centre of Excellence, UK, ISBN 1-900491-76-1

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., Da Dalto Laurent, Skjaerbaek J. O., Soubra S., Marache M., 2002, *" Virtual Environments for the AEC sector - The DIVERCITY experience "*. ECPPM 2002 Proceedings European Conference of Product and Process Modelling. eWork and eBusiness in AEC. (Editors: Ziga Turk, Raimar Scherer). Swtes & Zeitlinger Publishers, Lisse The Netherlands. ISBN 90 5809 507 X. 9-11 September 2002, Portoroz, Slovenia. (pp. 49-55)

Coudret, F., Lombardo, J., Marache, M., Soubra, S. (2001), *"DIVERCITY: A VR application for the Construction Industry"*. Virtual Reality International Conference, Laval Virtual 2001, 16-18 May 2001.

Divercity Handbook (2003), *"The Divercity Project: A Virtual Toolkit for Constructin Briefing, Design and Management"*, University of Salford, UK.

Gobbetti, E., Spanò, L., Agus., M., (2002) *"Hierarchical higher order face cluster radiosity"*. Technical Report CRS4 TR/, CRS4, Centre for Advanced Studies, Research, and Development in Sardinia, Cagliari, Italy. March 2002.

Grassi, M. D., Zorgno, A. M., (1999) *"The Virtual Construction Enterprise"*, Berkeley-Stanford CE&M Workshop, Stanford 1999.

Hobbs, B., (1999) *"Harnessing the Power of VR- The Potential for VR as a Virtual Integrated Environment for Project Development in Construction"*, Berkeley-Stanford CE&M Workshop, Stanford 1999.

Issa, R., (1999) *"Virtual Reality: A Solution to Seamless Technology Integration in the AEC Industry"*, Berkeley-Stanford CE&M Workshop, Stanford 1999.

Kiviniemi, A., Laitinen, J., Lautanala, M., (1999) *"Defining a Research Agenda for AEC"*, Berkeley-Stanford CE&M Workshop, Stanford 1999.

Kähkönen, K., (2001) *"Visualising the Construction Progress"*, Industrial Horizons (VTT customer magazine), April 2001

Marache, M., Coudret, F., Lombardo, J., Aspin, R., Tawfik, H., Fernando, T. (2002) *"Virtual Environments for the AEC sector"*. eWork 2002, Prague, The Czech Republic. 16-18 October 2002.

Patel, N., Campion, S. Fernando,T. (2002) *"Evaluating the Use of Virtual Reality as a Tool for Briefing Clients in Architecture"*, Information Visualisation 02, London, July 2002.

Sarshar, M., Betts, M., Abbott, C., Aouad, G., (2000) *"A Vision for Construction IT 2005-2010"*, RICS (Royal Institute of Chartered Surveyors) Research Series, Dec 2000.

Sarshar, M., Tanyer, A., Aouad, G., Underwood, J., (2002) *"A Vision for Construction IT 2005-2010: Two Case Studies"*, Engineering, Construction & Architectural Management, Issue 2, April, 2002.

Sawhney, A., (1999) *"Research and Development Plan for the AEC Industry"*, Berkeley-Stanford CE&M Workshop, Stanford 1999.

Shi, J. J. (1999) *"Computer Simulation in AEC and its Future Development"*, Berkeley-Stanford CE&M Workshop, Stanford 1999.

Tawfik, H., Fernando, T. (2001), *"A simulation environment for construction site planning"*, The 5th IEEE International Conference on Information Visualisation, London, UK, 25- 27 July 2001

Tawfik H., Fernando M., (2002), *"A simulation tool for multi-perspective site layout analysis"*. ECPPM 2002 European Conference of Product and Process Modelling. eWork and eBusiness in AEC, Portoroz, Slovenia. 9-11 September 2002

Thabet, W., (1999). *"Design-Construction Integration Through Virtual Construction for Improved Constructability"*, Berkeley-Stanford CE&M Workshop, Stanford 1999.

Thery, S., Da Dalto, L., Dupuy, Y., Balet, O., Paulin. M. (2001), *"Realistic Rendering in Interactive Architectural Design"*. VRIC, Virtual Reality International Conference, Laval Virtual 2001. (CSSI also had a demonstration stand at the conference. (Brochure and papers).) 16-18 May 2001.

Watson, I. D., & Marir, F. (1994) *"Case-Based Reasoning: A Review"*. The Knowledge Engineering Review, Vol. 9 (iii), pp. 327-54.

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