DIVERCITY: A VIRTUAL CONSTRUCTION DESIGN & BRIEFING ENVIRONMENT

Yusuf Arayici, School of Construction and Property Management, University of Salford, Greater Manchester, UK,
Marjan Sarshar, School of Construction and Property Management, University of Salford, Greater Manchester, UK,

ABSTRACT

DIVERCITY is a large EU funded project in the area of construction IT undertaken by a European consortium of researchers and practitioners from the construction industry. It is the acronym for Distributed Virtual Workspace for enhancing Communication within the Construction Industry and the prototype that presents the mechanism to smoothly and collaboratively conduct the construction projects from early briefing to the detailed design and even further by the end of the construction phase. To be precise, DIVERCITY aims to supply a shared virtual construction design and briefing environment that enables the construction industry to better undertake the client briefing and design review phases of a project.

DIVERCITY comprises three main workspaces, which are client briefing, design review and construction workspaces respectively. Whilst the Client Briefing workspace enables architect to interact and communicate with client for capturing client needs, the design review workspace allows design team to review the design solution in different respects and the construction workspace helps the planner evaluate optimum buildability for a building through communication with other parties of the design team.

The paper presents the DIVERCITY system and its main six components: Client Briefing, Lighting, Acoustic, Thermal and Heating Simulations, Visual Product Chronology, lastly Site planning & Analysis, how each of them handles different aspects of a construction project in a construction supply chain and how they complement each others to constitute a seamless integrated computer environment for the sake of excellence of briefing and design and construction planning.

Keywords: Briefing, Collaborative Workspace, Distributed Environment, Planning, Simulation, Visualization.

INTRODUCTION

The Construction industry is one of the major sectors with 780 billion Euros: it means that the construction industry is the largest industry in the industrial employment in Europe with 11 million workers, which equals 7% of the working population. Furthermore, owing to being dependent on the construction industry, 22 million jobs are created in other sectors (Brussels, 1997).

Although many sectors such as automotive, manufacturing and services sector have very much benefited from IT for better competitiveness, the construction industry have had some difficulties on the same route, which resulted in the construction industry lagging behind the other sectors. The constraints that the industry have had can be outlined as follows:

- The construction industry is fragmented by nature (Faraj, I., Alshawi, M. 1999). Added to this fragmentation between design team and construction professionals, a high level of complexity of the work flow resulting from a high number of different companies working on the same project increases the inefficiency of the fragmentation. For example, repeated processes or functions, duplications due to the lack of communication and standardisation that causes waste and lead times in the project lifecycle, extra cost to the client for non added value activities, etc.

- Design processes are separated from the construction processes which increases the uncertainty and incompatibility between the design solution and actual construction, i.e. poor buildability (Faraj, I., Alshawi, M. 1999): High uncertainty caused by site conditions as well as modifications in the projects that take place after the actual construction on site has already started leads to discontinuities between the design and the project execution (Coudret, F., Lombardo, J.C., Marache, M., Soubra, S., 2001).
- Clients and some other stakeholders such as local authorities, residents, etc might have different and wrong perception due to the lack of understanding the 2D architectural and engineering drawings (Coudret, F., Lombardo, J.C., Marache, M., Soubra, S., 2001) or vice versa: Design team could not fully understand the client needs due to lack of communication, a shared platform, an understandable VR tool by both client and architecture. In the end, these constraints bring about client dissatisfaction.

In the past, researchers have used IT for providing numerous decision support systems for the professionals involved in the industry (Faraj, I., Alshawi, M., 1999). However, these systems have created islands of automation and are far from achieving an acceptable level of integration across disciplines and across the design and construction processes (Faraj, I., Alshawi, M., 1999), and (Kartam N.A., 1994).

It is recognised that greater benefits can be obtained and the above constraints can be greatly reduced if a complete integration based on VR tools is achieved. In this respect, major benefits of a desired integrated VR environment are considered as follows:

- Improving the co-ordination and communication between the client, design team members and construction professionals by using standard formats, and intuitive VR tools.
- Evaluating the design at the very early stages of the project lifecycle in terms of architectural, technical, financial and environmental aspects since VR tools allow design team to have a quick and high quality feedback on the project (Faraj, I., Alshawi, M., 1999).
- Doing what-if scenarios at the detailed design stage to assess the design solution in lighting, acoustic, thermal aspects.
- Closing the gap between the design team and construction team and providing them with an integrated platform in which they can collaborate for the best buildability and applicable construction planning.

AIMS AND OBJECTIVES

In order to respond the above requirements of the construction industry, DIVERCITY aims to develop a shared virtual construction workspace that will enable the companies to conduct client briefing, design review, simulate what if scenarios, assess buildability, communicate and co-ordinate design activities between stakeholders involved in the project. Overall the DIVERCITY aims to increase the construction companies' competitiveness through integration of technology. The Research project has the following objectives:

- Creation of a **client-briefing workspace,** which can facilitate interaction and communication of design ideas between the client and the architect.
- Creation of an interactive **design review workspace,** which can facilitate multi-disciplinary design reviews involving different stakeholders of a construction project, i.e., planners, architects, designers, civil-engineers, electrical engineers, contractors, facility managers and security personnel, etc.
- Creation of a virtual **construction workspace,** which can assess the buildability (construction sequence, scheduling, material handling etc.) of a building.
- Specification and development of a **software framework for integrating the above three workspaces** and sharing them over networks to support collaboration between geographically distributed project team members.

DIVERCITY APPLICATIONS

To achieve its aims, the DIVERCITY project has developed six VR based application prototypes, namely: Client Briefing, Lighting Simulation, Acoustic Simulation, Thermal and Heating Simulation, Site Planning and Analysis and Visual Product Chronology.

Client Briefing Application: Pre CAD

The Client Briefing application; Pre CAD represents the interface between the client and design team: It is the mechanism for communication of ideas, the exploration of concepts and the presentation of the design. It is intended to produce a single initial design, agreed upon by all parties, and as this design is iteratively and progressively turned into a formal detailed design, feedback is obtained in order to drive the design process forward.

Recent research carried out at the university of Salford (Barrett P., Stanley C., 1999) suggests that Client Briefing should not be seen as an event but as a process, which works in an iterative manner to refine the design. Figure 1 shows the DIVERCITY Client Briefing process and a Pre CAD VR environment. In order to achieve this process, the design team needs to be able to present their design to the client in a manner that the client can easily understand. This presentation process may generate new inputs into the design from either the client or the design team. These resultant inputs may be either new parameters for the design, or simple modifications that may be made at the time of the presentation.

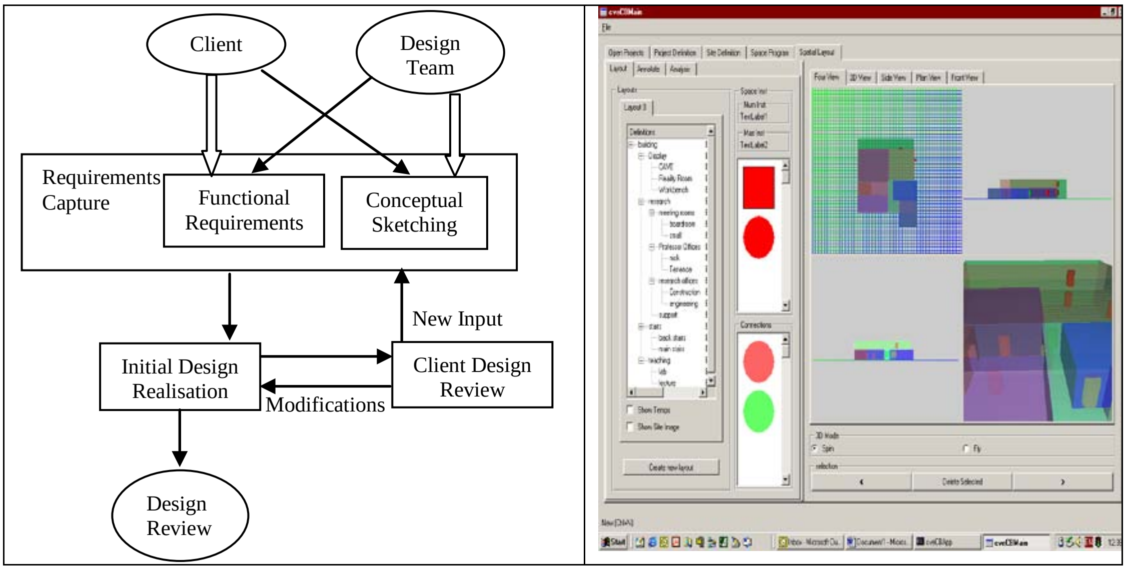

Figure 1: DIVERCITY Client Briefing Process and Pre CAD VR Environment for Client Briefing

Design Review Applications: Lighting, Acoustic and Thermal Simulations

In the design/Construction process, detailed design is an important phase where the inputs are represented by a rather architectural design (usually drawings on a 1:1000 scale) and the outputs are precise definition of all technical domains related to the design, e.g. structural design, heating and thermal, lighting, acoustic, fire safety, etc (Shelbourn M., Soubra S. & J. Martin, 1999).

Although state-of-the-art software tools exist for the detailed design stage, throughout the user requirements capture in the DIVERCITY project, it has been observed that these existing tools suffer from two important limitations: (Shelbourn M., Soubra S. & J. Martin, 1999)

- **Discontinuities** between the different software tools. This makes the reuse of the results of one technical domain as an input for another technical domain practically impossible;
- **Lack of 3D real-time inspection** features. Consequently, members of the project team spend too much time trying to (i) understand the project information (ii) to describe this information to one another.

In order to greatly reduce the above limitations, in the DIVERCITY context an interactive design review workspace that allows the project teams to visualise and interact with the project on a multidisciplinary basis has been created. The main features of the design review workspace are as follows:

- Supporting continuous design between different phases and within the detailed design phase using IFC (Industry Foundation Classes), which means that the calculation results yielded for one technical domain can be reused as an input for another technical domain.
- Model Driven Approach that allows project teams to share the same view about the project through a visual and shared conceptual model. As a result substantial improvements can then be made on the communication level between the project teams.

Design Review applications within the DIVERCITY scope are:

- **Lighting Simulation** by means of which user can visualise, with a photo realistic rendering, the lighting conditions of each space taking into account both natural and artificial light sources.
- **Acoustic Simulations** allowing the user to experience what it would be like to live and work in the spaces of the building
- **Heating and Thermal simulations** in order to assess both energy consumption of a building and thermal comfort conditions in each space;

Lighting Simulations

The lighting simulation module of DIVERCITY provides realistic simulation of light transfers. Moreover, it is the first time that a lighting simulation involving radiosity provides interactive solutions to the user. They can change and move objects or lights in the building and see updated simulation interactively.

The lighting application will enable the user to look at different ways of lighting the spaces by clicking and dragging objects into spaces and placing them at different locations within the space. The reflections and contrasts from surfaces of furniture, walls, windows, etc can be viewed, enabling the user to place lights in their optimal positions for best lighting in the room. Some example layouts are provided for the client or user to see how different positions affect the light in the space. Furthermore, the effect of natural daylight on the spaces can be viewed in the simulation. Figure 2 shows some lighting simulation analysis from different perspectives.

Figure 2: Examples of a rendered scene and object motion in the lighting Simulation

Acoustic Simulations

The acoustic module of DIVERCITY offers users the ability to automatically read the CAD-model, to interactively change materials of the building components (walls, floors…) and to “listen” to the acoustic environment inside a building, taking into account sound scenes inside and outside the room.

Acoustic simulation enables the user to have a realistic experience of the acoustic of a space in building. It yields sounds that can be perceived by the user and used very easily to evaluate the project from acoustic point of view.

Thermal Simulations

The thermal module of DIVERCITY offers users the ability to automatically read the CAD-model yielded by a CAD tool supporting IFC export, to interactively change materials of the building components (walls, floors,) and to simulate variation of temperatures in different rooms and calculate exploitation costs.

The application enables the user to obtain quick feedback on the thermal performances of the building including a realistic visualisation of the temperatures in each thermal space and relevant information about exploitation costs related to the HVAC system. The client or user can change the materials of the building in order to reach a compromise between comfort conditions on one hand and exploitation costs on the other. Thermal analysis can be a complex task taking into account diverse parameters such as building geometry, climatic environment, HVAC systems, behaviour of the occupants, infiltration and natural ventilation, air quality and pollutant transport (Shelbourn M., Soubra S. & J. Martin, 1999).

Construction Workspace Applications: Site Planning and Analysis, Visual Product Chronology

The DIVERCITY construction workspace aims at providing functionality to allow for rehearsing, evaluation, and optimisation of the construction planning stage. It can be thought of as testing the constructibility of a building by assessing both temporal and spatial aspects resulting from a planned schedule so as to identify and resolve potential conflicts that would otherwise impose high costs if treated at a later stages (Fernando T., Kähkönen K. et al, 2001).

Site Planning and Analysis

This application aims to design a modelling and simulation platform for supporting the construction site analysis stage, and allow the evaluation and optimisation of the construction site layouts. In particular, it addresses the space planning aspects by assisting with the representation and management of spatial requirements in the construction site (Tawfik H. & Fernando T., 2001). The main functions that are carried out by the site-planning application are as follows.

- Site layout initialisation: initial layout is generated by the user interacting with a VR environment and populating the construction site with different spaces (vehicles, building components, temporary facilities, etc), taking into account schedule information. Alternatively, an initial site layout is constructed from GIS or CAD data.
- Safety analysis: determines the hazard zones of site spaces such as cranes, vehicles and equipment, according to their variable degree of risk and dimensions.
- Space analysis: defines movement path and fields of vision for people and vehicles, and evaluates accessibility and visibility in the site.
- Optimisation: the generation of a favourable spatial arrangement of the site using an optimisation algorithm, a user defined risk minimisation, space use -efficiency- maximisation and travelling cost minimisation criteria.
- The Buildability Schedule provides information on the changing spatial dimensions of objects in the site over time, such as the size of the building or the material store, etc. This information could then be fedback to the site modelling and optimisation modules, to evaluate the site layout at different stages of the construction period on the site.

Visual Product Chronology

The second application of the construction workspace in DIVERCITY is a 4D VR simulation application namely Visual Product Chronology that step by step shows how the progress a construction project will look like in practice. The application links a standard IFC based 3D building model with associated construction schedule, which can be prepared with off the shelf project management software package (Fernando T., Kähkönen K. et al, 2001). The first basic process of using 4D simulation application is about linking Building Model with Project Task Model. The IFC building product model provides the standard for storing all this information. The additional processes firstly cover the situation where task timings have been changed using project management software package and there is a need to update the IFC 4D building model with this data. Secondly, the additional processes facilitate the conversions between IFC task model and the used project management software package. Afterwards, updated 4D IFC model is converted to VRML format for simulation. Subsequently, the software makes it possible to simulate the building schedule for example, day by day. The stage that will be reached at the construction site can be seen on the computer display. The easiest way to use the software is to access it by using an Internet browser, but it is also possible to take advantage of it in virtual-reality studios. Figure 3 shows the process flow and simulation display of the Visual Product Chronology.

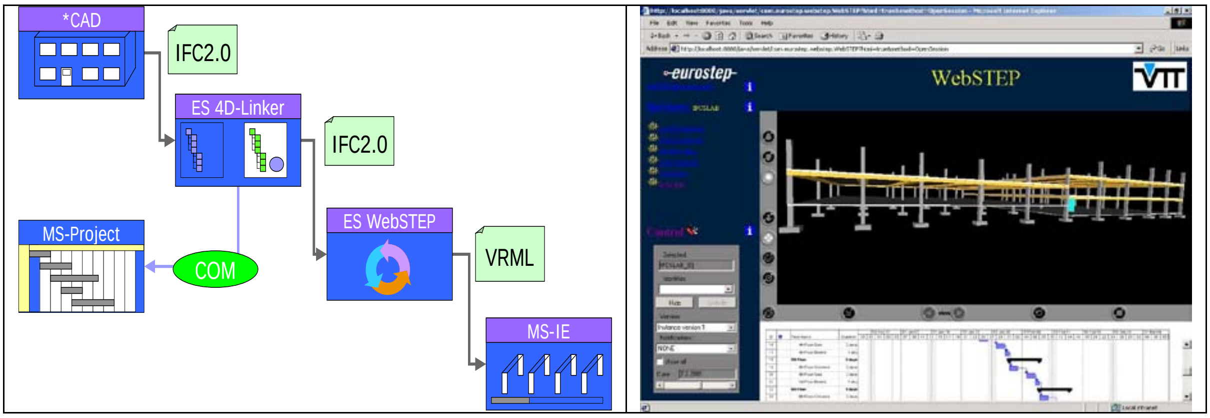

Figure3: VPC Process Flow and 4D simulation display

COMMUNICATION AND INTEGRATION

Communication Layer

The Communication Layer is at the heart of the distributed features of the DIVERCITY system. It provides support to allow virtual collaborative spaces at geographically distant sites to work together.

The communication layer of DIVERCITY employs XML as the distribution layer for the exchange of information. The implementation of communication layer is based on SOAP (Simple Object Access Protocol) Internet protocol. One of the main advantages of SOAP protocol is that it deals with proxies and firewalls, which are often very strict in the industry domain (Da Dalto L., Gobbetti E. 2001). The communication layer provides the followings.

- Communication between heterogeneous systems, architectures and languages.
- Robust and secure messages transfer
- Time performances to allow real time collaboration (only for specific messages-3D scene motions and updates).
- Multi-user management including identifications and access control.

Product Modelling

IFC has been used as the product modelling technology, which was developed by the International Alliance for Interoperability (http://www.iai.org.uk). The IFC defines a single object model of buildings shared by all IFC compatible applications. IFC project models enables the users to exchange information accurately and error-free (Christianson P, et al 2002). That is to say, an IFC sketch produced in the Pre CAD application can be distributed over the communication layer and loaded to the other DIVERCITY applications without any duplications and repetitions throughout the project lifecycle.

As well as the IFC, ISO Part 42 of STEP (Standard for the Exchange of Product Data) is also employed to keep track of a geometric representation within the DIVERCITY kernel. Basing our common geometric representation on this standard has enforced common comprehension of geometry by different Data Structuring Layers (Christianson P, et al 2002).

CONCLUSION

The paper has described the DIVERCITY R&D effort. The DIVERCITY project aims to develop innovative workspace technologies for the briefing and design phases of the lifecycle. The DIVERCITY system incorporates six main applications each of which responds some special end user requirements from early briefing to the detailed design and the construction monitoring stages. Those applications can run comfortably within the DIVERCITY framework. Output of one application can be distributed and be input to another application, which denotes a seamless integration and collaboration for the stakeholders.

The DIVERCITY project has succeeded in gathering science and industry in a collaborative, exploitative and enriching workspace. The traditional barriers between special disciplines were broken down to establish collaboration scenarios based on mutual visions (Christianson P, et al 2002).

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