DIVERCITY: A VIRTUAL CONSTRUCTION DESIGN & BRIEFING ENVIRONMENT

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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.

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

57 a high number of different companies working on the same project increases the inefficiency of the
58 fragmentation. For example, repeated processes or functions, duplications due to the lack of communication and
59 standardisation that causes waste and lead times in the project lifecycle, extra cost to the client for non added
60 value activities, etc.
61 • Design processes are separated from the construction processes which increases the uncertainty and
62 incompatibility between the design solution and actual construction, i.e. poor buildability (Faraj, I., Alshawi, M.
63 1999): High uncertainty caused by site conditions as well as modifications in the projects that take place after the
64 actual construction on site has already started leads to discontinuities between the design and the project
65 execution (Coudret, F., Lombardo, J.C., Marache, M., Soubra, S., 2001).
66 • Clients and some other stakeholders such as local authorities, residents, etc might have different and wrong
67 perception due to the lack of understanding the 2D architectural and engineering drawings (Coudret, F.,
68 Lombardo, J.C., Marache, M., Soubra, S., 2001) or vice versa: Design team could not fully understand the client
69 needs due to lack of communication, a shared platform, an understandable VR tool by both client and
70 architecture. In the end, these constraints bring about client dissatisfaction.

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

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

81 • Improving the co-ordination and communication between the client, design team members and construction
82 professionals by using standard formats, and intuitive VR tools.
83 • Evaluating the design at the very early stages of the project lifecycle in terms of architectural, technical,
84 financial and environmental aspects since VR tools allow design team to have a quick and high quality feedback
85 on the project (Faraj, I., Alshawi, M., 1999).
86 • Doing what-if scenarios at the detailed design stage to assess the design solution in lighting, acoustic, thermal
87 aspects.
88 • Closing the gap between the design team and construction team and providing them with an integrated
89 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

110   To achieve its aims, the DIVERCITY project has developed six VR based application prototypes, namely: Client
111   Briefing, Lighting Simulation, Acoustic Simulation, Thermal and Heating Simulation, Site Planning and Analysis
112   and Visual Product Chronology.
113
114   **Client Briefing Application: Pre CAD**
115
116   The Client Briefing application; Pre CAD represents the interface between the client and design team: It is the
117   mechanism for communication of ideas, the exploration of concepts and the presentation of the design. It is intended
118   to produce a single initial design, agreed upon by all parties, and as this design is iteratively and progressively
119   turned into a formal detailed design, feedback is obtained in order to drive the design process forward.
120
121   Recent research carried out at the university of Salford (Barrett P., Stanley C., 1999) suggests that Client Briefing
122   should not be seen as an event but as a process, which works in an iterative manner to refine the design. Figure 1
123   shows the DIVERCITY Client Briefing process and a Pre CAD VR environment. In order to achieve this process,
124   the design team needs to be able to present their design to the client in a manner that the client can easily
125   understand. This presentation process may generate new inputs into the design from either the client or the design
126   team. These resultant inputs may be either new parameters for the design, or simple modifications that may be made
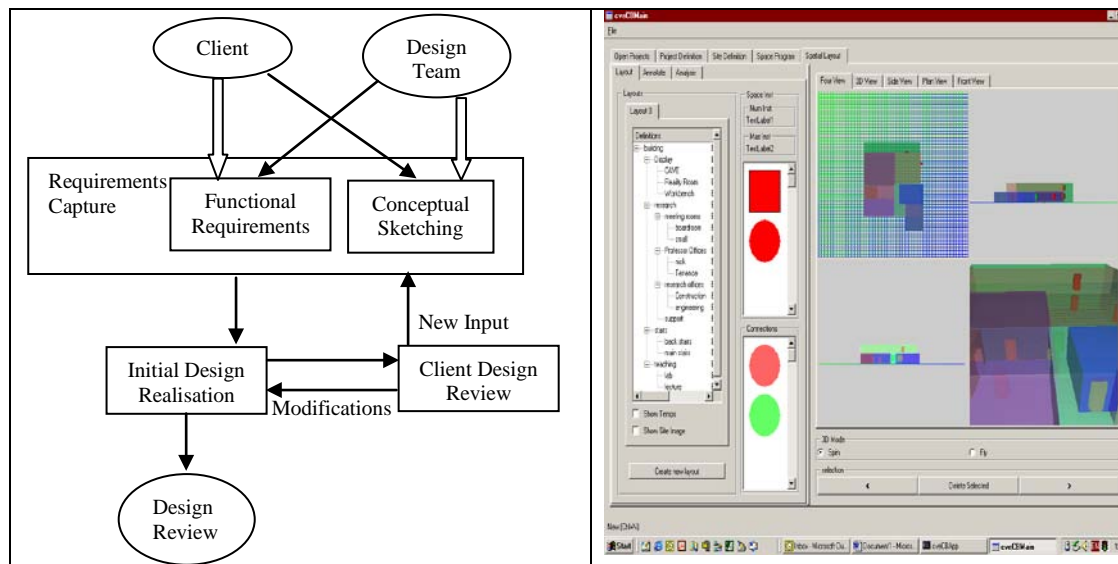127   at the time of the presentation.
128

129   Figure 1: DIVERCITY Client Briefing Process and Pre CAD VR Environment for Client Briefing
130
131   **Design Review Applications: Lighting, Acoustic and Thermal Simulations**
132
133   In the design/Construction process, detailed design is an important phase where the inputs are represented by a
134   rather architectural design (usually drawings on a 1:1000 scale) and the outputs are precise definition of all technical
135   domains related to the design, e.g. structural design, heating and thermal, lighting, acoustic, fire safety, etc
136   (Shelbourn M., Soubra S. & J. Martin, 1999).
137
138   Although state-of-the-art software tools exist for the detailed design stage, throughout the user requirements capture
139   in the DIVERCITY project, it has been observed that these existing tools suffer from two important limitations:
140   (Shelbourn M., Soubra S. & J. Martin, 1999)
141
142   •   **Discontinuities** between the different software tools. This makes the reuse of the results of one technical
143   domain as an input for another technical domain practically impossible;
144   •   **Lack of 3D real-time inspection** features. Consequently, members of the project team spend too much time
145   trying to (i) understand the project information (ii) to describe this information to one another.
146

147 In order to greatly reduce the above limitations, in the DIVERCITY context an interactive design review workspace
148 that allows the project teams to visualise and interact with the project on a multidisciplinary basis has been created.
149 The main features of the design review workspace are as follows:
150
151 - Supporting continuous design between different phases and within the detailed design phase using IFC
152 (Industry Foundation Classes), which means that the calculation results yielded for one technical domain can be
153 reused as an input for another technical domain.
154 - Model Driven Approach that allows project teams to share the same view about the project through a visual
155 and shared conceptual model. As a result substantial improvements can then be made on the communication
156 level between the project teams.
157
158 Design Review applications within the DIVERCITY scope are:
159 - **Lighting Simulation** by means of which user can visualise, with a photo realistic rendering, the lighting
160 conditions of each space taking into account both natural and artificial light sources.
161 - **Acoustic Simulations** allowing the user to experience what it would be like to live and work in the spaces of
162 the building
163 - **Heating and Thermal simulations** in order to assess both energy consumption of a building and thermal
164 comfort conditions in each space;
165
166 **Lighting Simulations**
167 The lighting simulation module of DIVERCITY provides realistic simulation of light transfers. Moreover, it is the
168 first time that a lighting simulation involving radiosity provides interactive solutions to the user. They can change
169 and move objects or lights in the building and see updated simulation interactively.
170
171 The lighting application will enable the user to look at different ways of lighting the spaces by clicking and dragging
172 objects into spaces and placing them at different locations within the space. The reflections and contrasts from
173 surfaces of furniture, walls, windows, etc can be viewed, enabling the user to place lights in their optimal positions
174 for best lighting in the room. Some example layouts are provided for the client or user to see how different positions
175 affect the light in the space. Furthermore, the effect of natural daylight on the spaces can be viewed in the
176 simulation. Figure 2 shows some lighting simulation analysis from different perspectives.

177

178
179 Figure 2: Examples of a rendered scene and object motion in the lighting Simulation
180

181 **Acoustic Simulations**
182 The acoustic module of DIVERCITY offers users the ability to automatically read the CAD-model, to interactively
183 change materials of the building components (walls, floors…) and to "listen" to the acoustic environment inside a
184 building, taking into account sound scenes inside and outside the room.
185
186 Acoustic simulation enables the user to have a realistic experience of the acoustic of a space in building. It yields
187 sounds that can be perceived by the user and used very easily to evaluate the project from acoustic point of view.
188
189 **Thermal Simulations**

190 The thermal module of DIVERCITY offers users the ability to automatically read the CAD-model yielded by a
191 CAD tool supporting IFC export, to interactively change materials of the building components (walls, floors,) and to
192 simulate variation of temperatures in different rooms and calculate exploitation costs.
193
194 The application enables the user to obtain quick feedback on the thermal performances of the building including a
195 realistic visualisation of the temperatures in each thermal space and relevant information about exploitation costs
196 related to the HVAC system. The client or user can change the materials of the building in order to reach a
197 compromise between comfort conditions on one hand and exploitation costs on the other. Thermal analysis can be a
198 complex task taking into account diverse parameters such as building geometry, climatic environment, HVAC
199 systems, behaviour of the occupants, infiltration and natural ventilation, air quality and pollutant transport
200 (Shelbourn M., Soubra S. & J. Martin, 1999).
201

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

205 The DIVERCITY construction workspace aims at providing functionality to allow for rehearsing, evaluation, and
206 optimisation of the construction planning stage. It can be thought of as testing the constructibility of a building by
207 assessing both temporal and spatial aspects resulting from a planned schedule so as to identify and resolve potential
208 conflicts that would otherwise impose high costs if treated at a later stages (Fernando T., Kähkönen K. et al, 2001).
209

Site Planning and Analysis

211 This application aims to design a modelling and simulation platform for supporting the construction site analysis
212 stage, and allow the evaluation and optimisation of the construction site layouts. In particular, it addresses the space
213 planning aspects by assisting with the representation and management of spatial requirements in the construction
214 site (Tawfik H. & Fernando T., 2001). The main functions that are carried out by the site-planning application are as
215 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

232 The second application of the construction workspace in DIVERCITY is a 4D VR simulation application namely
233 Visual Product Chronology that step by step shows how the progress a construction project will look like in practice.
234 The application links a standard IFC based 3D building model with associated construction schedule, which can be
235 prepared with off the shelf project management software package (Fernando T., Kähkönen K. et al, 2001). The first
236 basic process of using 4D simulation application is about linking Building Model with Project Task Model. The IFC
237 building product model provides the standard for storing all this information. The additional processes firstly cover
238 the situation where task timings have been changed using project management software package and there is a need
239 to update the IFC 4D building model with this data. Secondly, the additional processes facilitate the conversions
240 between IFC task model and the used project management software package. Afterwards, updated 4D IFC model is
241 converted to VRML format for simulation. Subsequently, the software makes it possible to simulate the building
242 schedule for example, day by day. The stage that will be reached at the construction site can be seen on the
243 computer display. The easiest way to use the software is to access it by using an Internet browser, but it is also
244 possible to take advantage of it in virtual-reality studios. Figure 3 shows the process flow and simulation display of
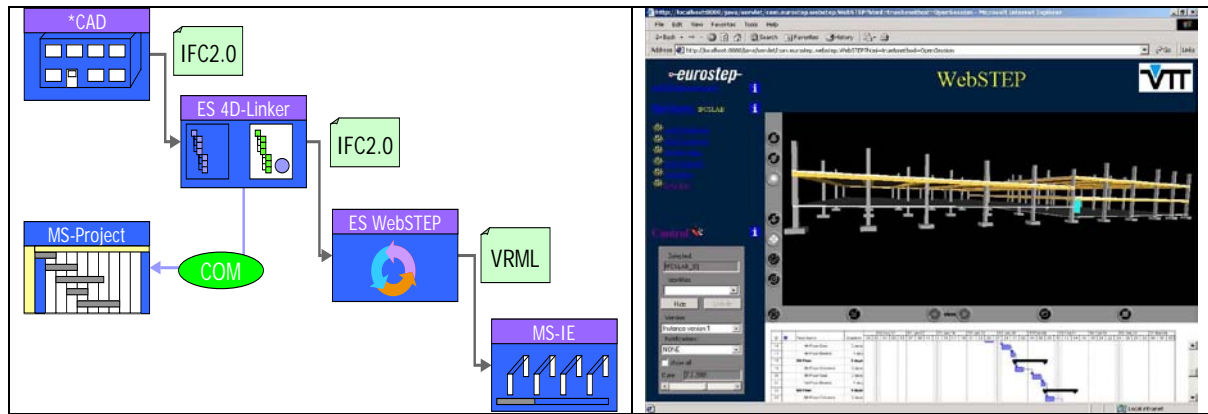245 the Visual Product Chronology.
246

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.

290 The DIVERCITY project has succeeded in gathering science and industry in a collaborative, exploitative and
291 enriching workspace. The traditional barriers between special disciplines were broken down to establish
292 collaboration scenarios based on mutual visions (Christianson P, et al 2002).
293

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