VIRTUAL REALITY AS A DESIGN AND VISUALISATION TOOL IN THE HOUSEBUILDING INDUSTRY

The housebuilding industry

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Durability of Building Materials and Components 8. (1999) *Edited by M.A. Lacasse and D.J. Vanier*. Institute for Research in Construction, Ottawa ON, K1A 0R6, Canada, pp. 2945-2954.

Abstract

Improving the quality of residential design is currently a research focus in Britain. However, little work has been done on the strategic use of IT to promote innovation in the British housebuilding industry. Advanced computer techniques can greatly facilitate the visualisation and appraisal of alternative design. The potential of virtual reality as a design and visualisation tool warrants consideration. Drawing on development work and an industrial survey of British house builders, a framework for the implementation of virtual reality is developed. This is discussed within the context of the house building process and housing developers' current use of IT for design and visualisation.

Keywords: virtual reality, house building, innovation, design generation, visualisation, computer-aided design

1 Introduction

The quality of British housebuilding is poor in comparison with other countries (Gann, 1996). Innovation has become the focus of academic research (Asibong and Barlow, 1998; Ball, 1999; Gann, 1996) and government initiatives (Egan, 1998). In order to be effective, innovative strategies must be supported by appropriate IT strategies (Watts *et al.*, 1998). Despite this, the role of IT as a facilitator of innovation has not been considered by previous research on housebuilding.

Advances in computer hardware mean that real-time 3D graphics applications, previously restricted to high end computers, can now be used on PCs, and such applications could be of great use to housing developers in the generation and visualisation of alternative designs. The traditional methods of housing production, and the typical cul-de-sac street layouts used in Britain will be unable to provide for all the patterns of dwelling required by future demographic and lifestyle changes (Asibong and Barlow, 1998). Demanding environmental and planning considerations will make the ability to visualize and evaluate proposed developments before construction increasingly important.

Research into the potential use of PC based virtual reality (VR) systems in housebuilding organizations is being conducted at Loughborough University. As part of this research, development work was conducted in collaboration with a housing developer (Whyte *et al.* 1998a), and technical issues relating to the generation of VR models for house builders (Whyte *et al.* 1998b) have been studied. This work has been supplemented by research into current CAD and IT use within the housebuilding industry and is being followed by an evaluation of the implementation of a VR system in a housebuilding organization.

The question addressed in this paper is whether British housebuilding companies can use VR as a design and visualization tool to effectively promote innovation within their organizations.

2 Characteristics of VR Technology

2.1 VR Systems

Virtual reality, which developed out of advanced work on military flight simulators and computer graphics, has now found application in fields as diverse as entertainment, medical research, marketing and architectural engineering (Watts, 1998). The latest generations of PCs and graphics boards are making the real-time 3D graphics that once required expensive specialist computer equipment possible on the desktop.

Popular computer-aided drawing (CAD) tools now offer 3D modeling and rendering capabilities at a relatively low cost on the PC. Interactive real-time 3D (or VR) is the next step, and it could be used for the visualisation and evaluation of design before construction. In addition to commercial VR packages, an international standard for 3D models, Virtual Reality Modeling Language (VRML), has been developed (VRML'97 - ISO/IEC 14772). This standard, which is not as ambitious as the STEP and IFC standards (Wix, 1997), deals only with the description of 3D geometry and simple behaviors. In itself VRML is limited, it does not provide a mechanism for the encapsulation of domain specific information, and is a simple text description comparable to the dxf format used by CAD packages. VRML is of interest to construction industry users, however, not only because VRML models can be viewed directly, but also as CAD packages such as Microstation, modeling applications such as 3D Studio, and proprietary VR applications such as Superscape now export directly to it.

The use of VR has been compared to CAD, animation/multimedia, hand-made physical prototypes and machine-made physical prototypes. Watts *et al.* (1998) characterize VR as having high realism, high interactivity and low marginal cost, in comparison with these other technologies. This may be the overall or ideal situation but due to limitations of the current hardware, as Table 1 shows, different types of VR vary in the degree to which they show these characteristics. On the PC, despite the increased potential for 3D graphic applications, there is still a trade off between the realism of a VR simulation and it's interactivity and speed.

Table 1: Characteristics of VR

Type of VR	Marginal Cost	Realism	Interactivity and Speed
Overall	LOW	HIGH	HIGH
VR Laboratory (SGIs peripherals)	HIGH	HIGH	HIGH
PC-based VR (speed important)	LOW	LOW	HIGH
PC-based VR (realism important)	LOW	HIGH	LOW

2.2 Optimization of VR models and data translation

Thus due to hardware limitations, attainment of realistic real-time interaction, which has been of critical importance to the developers of virtual reality, involves a trade off between the accurate portrayal of geometric and architectural information and the interactivity and speed at which the VR model can be run. In order to achieve frame rates of between 5 and 30 fps, VR models are optimized, through the use of primitive solids, billboards, distant dependant levels of detail (LODs), and selective loading (Whyte *et al.*, 1998b).

Complex and highly detailed CAD data, common in the construction industry, translate into excessively large VR models. Whilst accuracy is important for architectural visualisation, and models cannot be optimized to the levels used in computer games, some optimization is required so that user movement is not unacceptably slow. Housing developers currently wishing to exploit VR technology need to consider techniques for the translation and optimization of data derived from CAD. Although it is possible for them to model residential developments completely within VR packages, such islands of automation have been shown to be ineffective (Hazlehurst, 1995). An integrated use of virtual reality, with transfer of geometrical data from, or better, exchange of data with, CAD is desirable to avoid repetitive work.

2.3 Practical modeling approaches

Three different methods for the rapid generation of virtual reality models have previously been described (Whyte *et al.*, 1998b). These are the library-based, translation and database approaches.

- **Libraries of components**, archived for reuse within the VR environment, eliminate the need for repetitive data transfer and optimization of common parts, although significant time and effort is initially required to build up the library.
- **Straightforward translation and optimization** is appropriate for the generation of one-off VR models, for example when the design process is completed and the design is fixed and unchanging.
- **A database approach**, though not yet commercially implemented, describes the creation of a central building product model database, from which the building can be viewed through VR, as well as a range of other applications such as CAD. Such an approach would be suitable for rapid prototyping where optimization of the model for real-time viewing is not critical.

A series of customizable filters could help to automate the translation and optimization process, providing options for the reduction of geometrical information, the rendering and addition of behaviors to the resultant model. The substitution of pre-optimized geometries from a library of building objects could be an option during such a translation process.

3 Matching IT strategies and house building processes

3.1 IT and innovative housebuilding organizations

The interface between construction processes and IT support is discussed by Aouad *et al.* (1998) who describe a synchronized process/IT model for the co-maturation of process and IT and the strategic management of change. According to this approach IT introduction and application should be designed to suit the existing process capability, and a balanced profile of maturity is favored, even if this maturity is low. The nature of housebuilding processes and IT use within the housebuilding industry have been investigated in order to draw conclusions about the potential implementation of VR technology.

VR use helps to develop three features common to many leading innovative organizations. These features are a capacity to experiment in depth, involvement of all in the innovation process and an ability to capture ideas generated in the innovation process (Watts *et al.*, 1998). The relation of these features to housebuilding is shown in Table 2. American research into the adoption of technological innovations (Toole, 1998) has found that house builders who are more apt to adopt nondiffused technological innovations tap into more sources of information about the new products from portions of their organizational environments than do nonadopters. Communication of information across job functions within organizations seems to be important in the adoption of innovation.

Table 2: How VR use can help the British housebuilding industry to attain the characteristics of innovative organizations

Characteristics of innovative organizations	How VR use can help in housebuilding
Capacity to experiment in-depth	• PC-based VR is of relatively low-cost and hence provides a low-risk environment in which initial prototyping of innovative house designs can be tried. • Rigorous prototyping of new housetypes can take place to avoid costly failures.
Involvement of all in the innovation process	• Marketing staff and management are often unable to read drawings; the high realism of VR allows non-technical staff to contribute expertise to the design process. • Communication of information across job functions facilitates innovation.
Ability to capture ideas generated in the innovation process	• Need to change to improve the quality of housing and the type of houses built

3.2 The housebuilding sector

The British housebuilding industry is relatively small and fragmented, with the leading housing developer producing 14, 000 houses a year, and only 143 housing developers producing more than 100 houses in 1997 (NHBC, 1998). The regulatory and institutional framework and the structure of the industry are different from the Japanese housebuilding industry where production is factory based and the industry is more cooperative and vertically integrated with the housing developer in control of the supply chain. In Britain, construction is traditionally brick and block and it is sub-contracted to take place on site, the tendering process encourages secrecy and design of elements such as kitchens are carried out in the design chain.

Although the organizational structure of the large house building company varies from one developer to another, the typical house builder involved in speculative development can be seen as having a central office in which most of the house type design work is undertaken. Several regional offices then co-ordinate sites in their area, and are involved in site layout design and consultation with local planning officers, liasing with the on-site sales offices which market the finished products (Gillen, 1994).

Ranges of standard house types are used by most of the national house builders (Nicol, 1999). Facades are modified to meet planning requirements in different regions, but housing developers are reluctant to undertake structural changes, which require re-application for National House Building Council (NHBC) approval, and are unable to offer extensive customer customization. As land prices and management of a landbank have been critical strategic considerations for speculative developers there has been little investment in design and innovation is slow (Ball, 1999). However this may change (Asibong and Barlow, 1998) as government initiatives and comparison with the manufacturing industry has led to proposed changes in housing developers operational procedures (Gann, 1997).

3.3 Computer use for design within British house building

In the industry survey undertaken (Whyte, 1998) it was found that computers are used in the British housebuilding industry for design much more widely today than they were in the late 1980's. Seventy four per cent of the housing developers that replied to the survey had some CAD in-house. There was a wide range of CAD use within the industry however, with some housing developers having less than 10% CAD use whilst others reported over 90% CAD use. Whilst some housing developers are new to CAD, several of the larger housebuilding organizations had over a decade experience in using CAD. Unlike in the late 1980's (Ewin *et al*., 1990), today there are software companies specialized in producing software for the housebuilding market.

In many of the early CAD packages it was easier to redraw a feature than to try to alter it, and many of the housing developers interviewed described the kind of procedures necessary to get round problems with such software. The ability to alter a drawing is important to the housing developer, as it is rare that a housing design is started from scratch, instead existing housing designs are continuously altered and updated. One housing developer demonstrated the features of their current CAD system, Speedikon, which facilitate drawing alteration. There were a series of view filters that can be used to view different sets of data, and search-and-show capabilities: attributes can be searched for and then changed *en masse*. For example changes can be made to all types of door.

Industrial standards are not widely used in the housebuilding industry, and many companies have difficulty implementing company-wide standards. The BS layering standard is seen as unnecessarily complex and those housing developers that use it have software that defaults to these standards, others that have implemented in-house standardization have favored about 10 different layers. The CAD manager from one housing developer explained they tried introducing protocols for the use of CAD, but found this to be restrictive. Ultimately they hope to have a standardized system but hope that this will come about in a bottom up way, rather than being imposed from above.

3.4 Attitudes to VR in the British housebuilding industry

Interviews with housing developers that followed VR development work, shown in Figure 1, revealed that the realism of VR was seen as most useful for visualisation of design ideas by non-technical personnel (Whyte, 1998). Designers felt comfortable reading abstract 2D design information, whilst non-technical staff, such as marketing and sales staff, and external parties, such as customers and planners benefited from VR visualizations in order to input their particular expertise into the design process.

In relation to housetype design, some housing developers mentioned the low cost of VR in comparison with their current practice of producing physical prototypes of new house type designs for in-house appraisal. Although the justification of VR use sought in this inquiry is based upon its potential to facilitate innovation, rather than to cut costs, the low cost of VR encourages experimentation.

Fig. 1: A demonstration project shows the potential of VR for the visualisation of design ideas by non-technical staff

4 A Framework for the implementation of VR

A housing developer hoping to utilize VR technology has some decisions to make with regard to implementation. The kind of implementation strategy used is dependent upon the requirements made of the VR system and the process it supports. Different housebuilding activities make different requirements of the VR system as shown in Table 3. For example, the use of VR for presentation to clients requires a high level of realism, but this can be achieved by texture mapping a simple geometric model rather than creating a complex model. For detailed design and prototyping, more geometric information is required, but there is less need for photographic realism. As designers are better able to read abstract information, even less realism may be required at the early design stage.

The use of VRML or commercial VR systems would be useful at all stages of the housebuilding process, but different strategies are more appropriate to the different tasks. Translation and optimisation strategies need to be carefully considered in relation to the geometric accuracy, realism and interactivity required and the necessity of data transfer to and from CAD.

Table 3: VR characteristics required for different housebuilding activities

VR use	Geometric Accuracy required	Realism required	Interactivity	Data Transfer to/from CAD
Early Design	Medium	Low	High	Rapid transfer important
Detailed Design and Prototyping	High	Medium	Medium	Some transfer
Visualisation in-house	Medium	Medium	Medium	Some transfer
Presentation (to clients, planners etc)	Low	High	Low	One way transfer from CAD adequate

To support innovation the maturity of the IT strategy should be matched to that of the maturity of the process strategy. In an industry such as housebuilding where processes are undergoing scrutiny, the implementation of a VR system must suit current practice, but not be rigidly dependent on it.

5 Conclusions

British housebuilding companies need to build on their current computer use by investing in appropriate IT strategies to support innovation, in order to improve building and design quality, to respond to consumer needs and increase their competitive edge.

The use of PC based virtual reality as a design and visualisation tool can be used to promote innovation, and it has certain advantageous characteristics. Virtual reality allows experimentation in depth, involvement of both designers and non-technical staff in the innovation process and ideas generated in this process to be captured. These characteristics of VR can be used to facilitate innovation within house building organizations.

Introduction of VR ought to suit existing process and IT capability and an appropriate VR package is likely to share data with CAD and have an ability to support interactive viewing and change. The successful implementation of VR in related sectors and within housebuilding in other countries suggests that VR will be useful to housebuilders in Britain, but such experiences cannot be applied uncritically.

Large house builders with high levels of CAD use and experience, who invest in design, ies will be most able to harness the benefits of VR technology. Such progressive housebuilding companies will be able to use this technology to improve organizational efficiency and enhance their innovative potential.

6 Future Work

Research into the implementation of a VR system within a housebuilding organization is currently being undertaken. The theoretical principles developed in this paper will thus be tested against a real example where VR software is being implemented for use within the design process in a number of regional offices of a housebuilding organization.

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