THE PROMISE AND PROBLEMS OF IMPLEMENTING VIRTUAL REALITY IN CONSTRUCTION PRACTICE

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ABSTRACT

Virtual reality (VR) can be used as a powerful tool to extend the possibilities of visualising the built environment before construction.

This paper describes work conducted at Loughborough University in collaboration with a leading British housing developer, and highlights the need to balance the differing agendas of academic research and the competitive modern workplace. Through consultation with our industrial partner the potential of VR to contribute to design generation, consultation with planners and product marketing was identified. A prototype project raised important issues relating to the smooth transfer of VR techniques from research into practice in the building industry.

The major technological issue, addressed by this paper, is the inherently different structure of CAD and VR models. As CAD packages often determine the way in which three dimensional geometric data is stored in the building industry, the present differences between CAD and VR systems lead to both implementation and data transfer problems. Construction companies are inhibited from using virtual reality as the overlap between CAD and VR skills is insufficient, with building professionals remaining unfamiliar with VR concepts.

Transfer of data from CAD to VR systems is problematic. Three different strategies for overcoming this problem are described. These are: to build a library of standard parts within the VR system; to rely on imperfect model conversion from CAD to VR through translators; or to use VR and CAD as interfaces to a central database.

Advances in CAD technology and the emerging standards for data transfer will facilitate integration of CAD and VR data. Whilst our prototype project demonstrates the potential of Virtual Reality in practice, further work on improving the compatibility of CAD and VR systems is necessary before widespread industrial acceptance and commercial viability are attainable.

Keywords: Virtual Reality, CAD, VRML, design generation, product marketing, housing developer.

1. INTRODUCTION

In Britain, most new housing is built speculatively by private housing developers, using standard housetypes (Nicol, 1997). Research is taking place at Loughborough University into the use of desktop virtual reality (VR) to evaluate and improve the quality of new residential development.

Figure 1 A standard housetype from a British housing developer.

The potential for housing developers to use VR in the design, consultation and marketing phases is being investigated. This paper discusses some of the practical considerations relating to the creation of VR models of buildings from CAD data, and describes a pilot project, undertaken in collaboration with a leading British housing developer.

2. VR MODELS AND CAD DATA

In the construction industry, geometric building data is stored in CAD systems, such as AutoCAD, and Microstation. Whilst it is possible to build up VR models from scratch within VR packages, it is widely agreed that transfer of the geometrical building data from CAD is desirable for applications of VR within the industry (Bourdakis, 1996; Alshawi, 1994). One reason that transfer of data is desirable is that it reduces the repetition of tasks in both CAD and VR. Another is that the tools provided for model creation in VR packages are not as sophisticated as those provided in CAD packages, as the production of construction and architectural models has not been the main objective of the programmers who have developed VR packages.

Differences between CAD and VR.

Whilst 3D CAD has evolved from primative 2D design packages, VR has developed out of advanced work on flight simulators and computer graphics (Bertol, 1997) hence differences in CAD and VR systems are arise out of their different evolutions. The different nature of CAD and VR models, and the lack of overlap between CAD and VR skills can be seen as major barriers to the introduction of VR in the building industry.

Organisation of models

Most VR systems organise their worlds hierarchically, as a tree of different geometries, each of which inherit the translations and orientations of their parents and pass on their own translation and orientation to their children. Superscape and VRML are examples of VR packages structured in this way. Such an explicit hierarchical structure is not currently used by the traditional CAD packages widespread in industry.

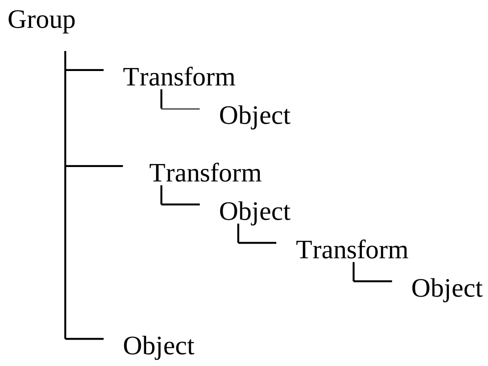

Figure 2 Simple diagram showing the hierarchical structure of VRML, a desktop based VR modelling language. Transform nodes hold translation and orientation information.

Because CAD was originally developed as a 2D drafting package, X and Y are the default horizontal plane, with Z describing the vertical. However in VR, X and Z are the default horizontal plane with Y describing the vertical (Bourdakis, 1997).

Established versus emergent technology

CAD is an established technology: high functionality is achievable without resorting to scripting and programming languages, routines can be automated, and systems can be easily customised as there are many third party plug-ins and libraries of routines already in existence.

In contrast VR is an emergent technology and there is often a need to use programming languages to provide greater functionality. The necessity to interact with VR by programming or entering points and color values numerically is due to the evolution of VR out of work on simulators and advanced computer graphics. As VR authoring tools become more established and sophisticated, they may well develop more user-friendly interfaces.

Transfer of data from CAD to VR.

The current process of translation from CAD into VR is normally a one-off one way or “downstream” process. A CAD model is translated into VR, either directly, or through the intermediate stage of a rendering package. The resultant model is then optimised and behaviours are added.

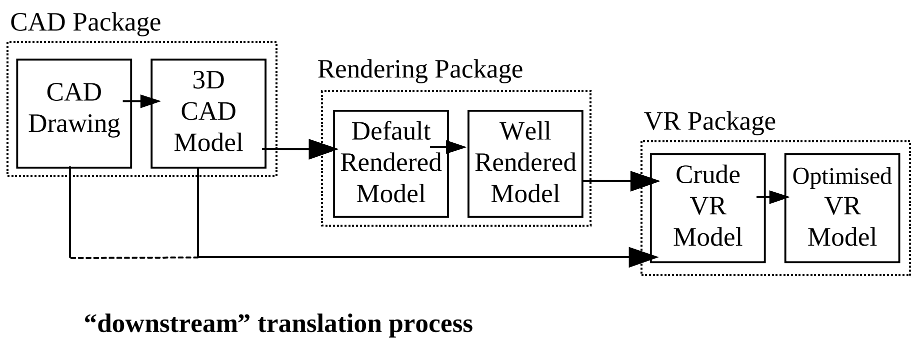

Figure 3 The current process of translation from CAD to VR is a one way “downstream” process.

This process of translation requires an expert user as users often need to structure data on the CAD drawing by creating blocks and organising layers to facilitate the translation process. There is no recognised standard method for organising this data and translator specific optimisations are all too common, as are non-industry standard methods. There is a trade-off between the amount of time spent reordering the CAD model to suite the translator, and the amount of time optimising the resultant VR file (Bourdakis, 1997). Also the translation process often includes inefficencies or, worse, wild inaccuracies.

The geometry of the VR model that the construction industry user creates from CAD data is likely to be complex, and the translation process itself often creates files that are unnecessarily large and 'bloated'.

3. OPTIMISING PERFORMANCE

For PC based VR systems to allow a viewer to participate in complex 3D virtual environments in real time, optimisations must take place. The environment must be realistic and convincing, but the computation time required to run it must not slow user movement to an unacceptable level.

Techniques used to optimise are unnecessary within the CAD environment, with which building professionals are familiar. Their use requires a trade-off between speed on the one hand, and graphics quality and accuracy on the other. Common techniques, used by both games developers and the VR community are the simplification of geometrical data, the use of distance dependant levels of detail and selective loading.

Primative objects, such as spheres, cubes and cylinders; and tiled texture maps, are used to simplify the amount of geometric data in a model. This reduces the number of polygons and hence increasing the speed at which the world can react to user input. Such simplifications can be inappropriate to the representation of building and construction data, apart from the massing models used at the early design stage.

An alternative is to replace complex geometry with simpler geometry when it is far enough away from the viewpoint for the eye not to perceive the loss of detail. Multiple models are produced, and up to 10 levels of detail can be created to optimise the speed with which the user can experience the virtual environment. For complex builidings the generation of different levels of detail is difficult to automate (Funkhouser et al., 1996).

Visibility sensors can be used to determine which part of the model is being viewed and therefore which geometry needs to be loaded and rendered and which scripts need to be active (Roehl et al., 1997; Funkhouser et al., 1996).

Illegibility of VR files translated from CAD often increases the difficulty of optimising a VR model after translation. "It is normal to spend a few hours or even days, hand-optimising the translated file" (Bourdakis, 1997). If the original CAD file is subsequently changed, the processes of translation and optimisation will need to be repeated.

4. BUILDING VR MODELS

Three current strategies for building VR world are presented. These are to build a library of standard parts, to rely on imperfect model conversion through translators, and to use virtual reality as an interface to a central database.

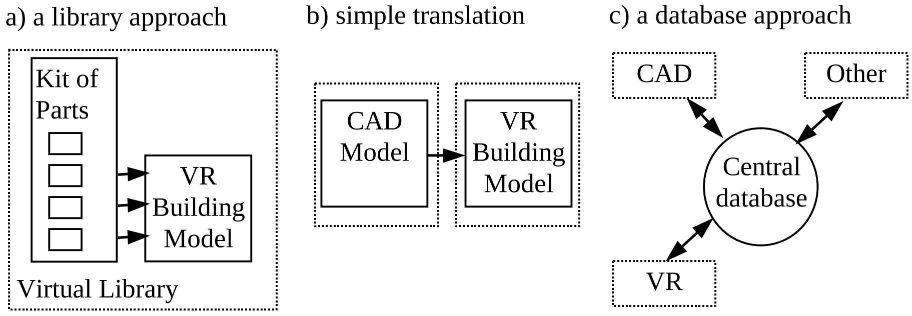

Figure 4 a) a library of standard parts b) simple translation and c) a central database approach.

A library-based approach.

A library-based approach is where a set of reusable components, for use within the VR environment, are generated. This approach has been used for construction sequence simulation (Adejei-Kumi, 1997; Retik, 1997) where much information is about processes rather than geometric objects, and research has been undertaken into its use in networked systems (Scott Howe, 1997) where the library of standard parts would come directly from manufacturers. This approach eliminates the need for repeated data transfer and file optimisation, but time is initially required to build up the library of parts. The components in the library can be built up from CAD data or modelled completely within the VR system. The approach is particularly successful when standard parts are frequently reused or when complicated activities, which cannot be represented in CAD, are associated with the sets of geometrical data.

A straightforward translation approach.

A straightforward translation approach is more appropriate when geometric data is predominant and there are fewer activities associated with the data. CAD is more refined as a 3D authoring tool and this approach is often taken for urban models (Bourdakis, 1996, 1997) and can be used in conjunction with algorithms for optimisation.

A database approach.

A database approach is where a central database controls component characteristics and both CAD and VR are used as graphical interfaces to that database (Aoaud, 1997; Alshawi, 1995). The building model is created in the central database and viewed through the CAD or VR applications. Thus a change made through either application, CAD or VR, changes the central building model in the database and is instantly viewable through other application. Whilst this approach allows the designer to make alterations quite easily, it does not allow for any optimisation of the VR model and therefore may be inappropriate for real-time viewing of larger complex building or urban models.

5. APPLICATION OF VR TO HOUSEBUILDING

In the work at Loughborough University, housebuilding has been taken as a case study for the application of virtual reality in construction. Residential development currently accounts for seventy percent of all urban land (Ball, 1996), and the demand for housing is growing. Therefore the ability to assess housing developments before construction is of great interest to urban planners and housebuilders as well as to potential customers.

After initial discussion with the housing developer it was agreed that the project would investigate the use of VR for design generation, consultation with planners and product marketing. Design is an iterative process and the use of VR for design generation will necessitate either some upstream translation process, or the repeated translation of CAD into VR. For design generation, the VR model does not need to be as well optimised, as it does for the presentation of ideas to planners and clients. A VR model for consultation could be an optimised VR model with the option of interactively substituting different housetypes onto the site layout. A VR model used for marketing purposes, must be highly optimised and rendered, but it shows a final product and there is less need to interact with and change the model in real time.

Figure 5 a) CAD drawing to show the new development in context. b) 3D CAD model. c) VR model of a single housetype. d) VR model of the streetscene with a single housetype.

The housebuilding industry is standardised to an extent common in the manufacturing industries (Gann, 1996). The number of standard housetypes used by any particular housing developer is relatively low. The housing developer involved in this project used fifteen basic layouts, with variations to the facade and detailing bringing the total number up of house types to about forty.

Experimentation was undertaken to ascertain an effective method of creating and optimising a VR model for the housing developer. The housing developer wanted to use the VR system to rapidly create and evaluate proposed developments, in order to assess the appropriate usage of different housetypes.

A pragmatic approach to model creation.

The standardisation of housetypes within the housebuilding industry lends itself to the production of a library of reusable forms. The library- based approach is more appropriate than straightforward translation as it eliminates repetitive transfer of data. The database approach would allow changes in VR to be seen in CAD, but would not allow optimisations and levels of detail to be associated with individual housetypes.

Figure 6 A standard housetype in the street layout.

After consultation with the housing developer, it was agreed that a library of these standard housetypes, with their associated levels of detail and optimisations could be built up. The advantage of this approach is that the speed with which a mock up street layout of any prospective site could be produced is much greater, once the library has been created. The site data can be transfered from CAD to VR on a one-off basis and the 3D models of standard house types can be placed in the appropriate positions directly from the library.

6. FUTURE DEVELOPMENTS

As Object Oriented CAD systems are introduced into the building industry the difference in the structure of CAD and VR models will be significantly diminished and the overlap of CAD and VR skills will be increased. Emerging standards for data transfer may also have an impact on the integration of CAD and VR data.

The VRML community, which is leading the development of PC based VR, is currently working on VRML 3.0 which will further enable multi-user worlds. Although their mandate is wider than the concerns of the building industry user, the direction that they take will have considerable effect on the viability of desktop VR in the industry in the short term.

7. CONCLUSIONS

In the pilot study a library-based approach to building the VR model was used, as the standard housing types are reused on different sites, and this approach would allow the rapid creation of site models. From our work, we have found that a greater overlap between CAD and VR skills would greatly facilitate the adoption of VR within the industry.

Whilst a one-off, one-way process is acceptable for the application of VR for product marketing, design is an iterative process. For VR to be an effective tool in design generation there needs to be the potential to propogate changes made in the 3D CAD model, into a pre-existent VR model, or to register changes made to the VR model “upstream” in the CAD model.

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