B. Dave, A. I. Li, N. Gu, H.-J. Park (eds.), *New Frontiers: Proceedings of the 15th International Conference on Computer-Aided Architectural Design Research in Asia CAADRIA 2010*, 391–398. ©2010, Association for Research in Computer-Aided Architectural Research in Asia (CAADRIA), Hong Kong

OBSTACLES OF UTILISING REAL-TIME 3D VISUALISATION IN ARCHITECTURAL REPRESENTATIONS AND DOCUMENTATION

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Abstract. This paper describes obstacles in using current generation software for real-time 3D visualisations in architectural representations. The obstacles discussed are focused on three areas, controllability of first person view navigation, spatial quality of real-time environment and geometry interoperability. With the increased influence of leading 3D computer games, how can AEC industries leverage the potentials they offer, advanced user interaction and realistic spatial environments. The paper compares CAD and BIM software with current generation 3D computer Game engines.

Keywords. Real-time; visualisation; game engine; architectural representation.

1. Introduction

This paper describes obstacles in using current generation software for real-time 3D visualisations in architectural representations. Real-time 3D computer graphics differ from traditional pre-rendered computer graphics of a still image or sequence of frames by providing rendered 3D computer models of actual or proposed physical environments that allow for user movement, interaction, and information exchange. The freeform views provided in CAD and BIM software packages are designed for modelling, they do not present an intuitive way of understanding and experiencing a digital building. Computer game engines enable a first person view that gives a stronger understanding of scale and relationships of a proposed building. “Drawings are fundamentally paper-based in format. Drawing symbols and formatting conventions have evolved primarily because paper is a two-dimensional medium” (Eastman, 2008).

The builder has to translate the 2D information into 3D, as building information modelling becomes the default 3D modelling methodology in architectural practice. How can the intelligent BIM model be leveraged to supplement or replace traditional paper-based documents with real-time 3D visualisation formats?

Currently a number of software packages are available such as Navisworks by Autodesk or modifications (mods) of commercially offered 3D computer games (Unreal Tournament by epic, Half-life2 by Valve) that are being utilised to enable real-time navigation and interaction of proposed and existing building projects. At present there are still a number of obstacles that result in an unsatisfactory final output or a complex workflow that is required to provide an engaging environment.

The construction of digital models for real-time visualisation currently requires optimising of geometry, lights and textures to run smoothly. Due to the real-time rending process, geometry optimisation plays a significant role in the final quality of real-time 3D visualisation. The geometry created in standard CAD and BIM applications can result in excessively complex models once translated into real-time 3D software. To date the gaming industry has overcome this problem with the use of intelligent skinning of the model geometry with textures to provide the illusion of detail. Using textures to offer detail does not provide the accurate information required for the construction industry.

Interoperability between software packages is a major impediment in an efficient workflow. The purpose built applications begin to smooth out the transfer of model data compared to modded game engines but the resulting output is not as compelling as is possible with the current generation computer game engines.

These findings come from a body of research that has been dealing with methods of using real-time-3D visualisations to supplement construction documentation. To date the research has been centred on overcoming the current obstacles of interoperability with CAD and BIM data for real-time 3D visualisation. Research to date has begun to demonstrate that use of real-time 3D visualisation in architectural and construction workflow could be used to enhance understanding of proposed buildings for all parties involved. The possibilities that this technology presents are considerably more advanced than 2D paper-based documentation. Further research needs to be carried out on the usability and requirements of real-time 3D visualisation in architectural and construction industries.

2. Software

The software has been reviewed as part of ongoing research into methods of utilising 3D CAD and BIM models to supplement construction documentation. The software has been split into two categories, commercial 3D computer game engine and commercial CAD or BIM software. The software packages reviewed in this paper are listed in table 1.

The criterion of comparison of the software focused on three areas, controllability of first person view navigation, spatial quality of real-time environment and geometry interoperability. The paper is the result of research with and from teaching undergraduate students different CAD, BIM and 3D real-time computer game engines over the last 6 years.

Table 1. Reviewed software

CAD and BIM		**Computer Game Engine**	
Software	Company	Software	Company
SketchUp	Google	Half-life 2	Valve
VectorWorks	Nemetschek	Crysis	Crytek
Revit	AutoDesk	Unreal engine 3	Epic
Navisworks	AutoDesk	Esperient Creator	Esperient

3. Controlling view

Autodesk Research states in a paper titled Safe 3D Navigation, "Typical commercial 3D CAD tools provide modal tools such as pan, zoom, orbit, look, etc. to facilitate freeform navigation in a 3D scene. Mastering these navigation tools requires a significant amount of learning and even experienced user can find learning confusing and error prone." (Fitznaurice, 2008). These types of navigation tools can affect any sense of scale, context and relationships between items. Gravity and sense of ground are often reduced or suspended. This may be fine for constructing 3D models but for viewing and understanding an unseen or proposed building can result in confusion and frustration.

Computer game engines enable a first person view that provides a consistently scaled view of a digital space that is navigated by walking or flying. This mode of navigation provides the viewer a stronger understanding of scale and relationships within a proposed building than standard modal navigation tools.

Of the commercial CAD and BIM software packages that provide a controllable first person view, most resort to using the mouse as the primary method to manage navigation. This is a complicated and confusing navigation method to learn and control. The mouse can only control view direction or view location (movement) at a time resulting in an awkward navigation technique, supporting navigation control only and having to change tools to interact with the model.

With an emerging generation of AEC workforce have grown up immersed in complex and sophisticated 3D computer games that are controlled by typical keyboard keys WASD (‘W’ to move forward, ‘S’ to move backward, ‘A’ to move left and ‘B’ to move right) and the mouse to control view direction and enable interaction with the model. This system is used by millions of computer gamers globally and replicated by console video gaming systems hand-held controls such as the Microsoft X-box and Sony Playstation. These methods need to be utilised to provide the next generation of workforce with a digital 3D environment they are comfortable navigating within.

Johns and Lowe (2005) “found that through experiencing their designs in the first-person and within the constraints of a ‘physical’ system [real-time 3D computer game engine] students were able to gain a much-enhanced understanding of the landform, spaces and structures and seize time-based design opportunities not present when working in other media. Four major benefits of using real-time modeling over physical scale modeling identified by the students were: comprehension of scale, engagement of other senses with sound, understanding space and time, and the ability to interact with others in a virtual landscape.”

4. Spatial quality

The final image quality of a digital 3D model has an impact on the viewer’s comprehension of its spatial properties. One of the benefits of current generation of real-time 3D computer games engine is their ability to produce near realistic rendered digital environments, see figure 1. However, CAD and BIM software has stayed focused on paper based outputs and functional realism, see figure 2. Kalay (2004) explains “much of the information that is conveyed by drawings is implicit and relies heavily on interpretation…the relationship between the walls and the space they enclose is a matter of interpretation…” Within real-time digital environments textures, physics, lighting and shadows are important in providing an increased spatial cognition, which together, are not present in current CAD and BIM software.

The use of textures to help provide detail without the increased polygon count and reduced processing power has provided the gaming industry with a convincing method to give the illusion of detailed spatial environments. This method does not provide the required accurate detail for construction interpolation; currently only a select few building projects provide a completely detailed single 3D model. The digital model construction techniques used in AEC industries predominantly rely on providing the detailed construction information in 2D drawing format. Not discussed in this paper in any detail is the ability of computer game engines to enhance spatial comprehension with 3D sound and physics.

Figure 1. Example of real-time rendering engine of Crytek.

Figure 2. Building model as viewed in Autodesk Navisworks.

5. Geometry optimisation

Almost all CAD and BIM software packages use boundary representation or B-rep for representing model geometry. The B-rep model consists of more than just geometry (shape), additionally containing topology (how things are connected), and tolerances (how closely do they actually fit together). This combination of model data is then accessed by the CAD systems to define a valid B-rep model. Most real-time 3D software requires a triangulated polygon mesh model. Objects created and sorted as polygon meshes are constructed of vertices, edges, faces, three and four sided polygons and surfaces. However many renderers may only support 3-sided faces or polygons.

The process of translation from CAD and BIM software to a real-time 3D computer game engine may work smoothly in theory but in practice can cause major problems when converting the model data to a format that can run efficiently in real-time 3D software. The translation process often returns unexpected results that can cause major difficulties in running a real-time digital environment. Model geometry can be triangulated further dramatically increasing polygons, decreasing frame-rate and producing slow unresponsive navigation. In some situations model geometry can be relocated completely. Figure 3 shows examples of geometry triangulation of a door frame and model components relocated within a Revit Architecture model translated for use in a game engine.

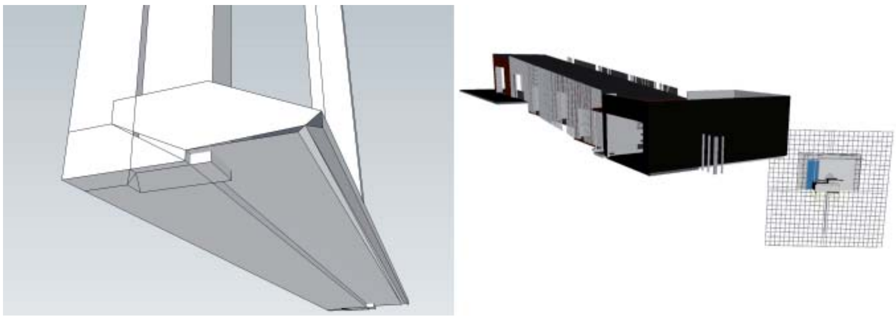

Figure 3. Translated geometry from REVIT.

"However there are governing aspects of the game environment that tends to emphasise an economy of polygons. The frame-rate at which the processor is able to render scenes is directly proportional to the amount of complex polygonal faces it needs to surface and the lighting effects associated with them. For this reason, geometries that are composed of simple triangulations are more efficient than complex 3D surfaces" (Pickersgill, 2007).

Current BIM software use components that consist of 2D/3D elements. A 2D symbol for representation in plan view and a 3D model, enabling drawings to comply with 2D conventions while working on a single 3D model with 'live' 2D drawings, is being used. The author proposes that an option to reduce the required translation time from BIM software to real-time 3D software is that BIM components should have a third element which is a reduced polygon representation that enables smoother workflow between software types.

9. Conclusion and future work

There are work-rounds or methods to deal with all of the obstacles listed above; currently all require a multi-step process unusually involving a number of different software packages (and are unidirectional) or optimised remodelling of building geometry. The benefits of being able to access proposed and existing buildings in real-time 3D digital environment are beginning to outweigh the stated complications; navigation control, spatial quality and geometry interoperability. Number of polygons and spatial quality will become less of an obstacle as processing power continues to increase.

CAD and BIM software is focused on modeling and 2D output. Only recently has the software started to develop 3D digital methods of view and navigation control in real-time for spatial cognition of an unfamiliar buildings. These viewer control methods and spatial quality are still underdeveloped compared to the current generation of 3D computer game engines. Interoperability of CAD and BIM is still not a smooth process unless the user is working within a software suit such as Autodesk. It is still a major obstacle in utilising real-time 3D visualetation in architectural representations and documentation.

As software and hardware continue to improve so will the required amount of information and detail digital models will need to provide, requiring new methods of interaction. Additional research needs to be conducted to test the usability of first person navigation and interaction.

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