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MODEL COMMAND

Spatial comprehension of 3D digital environments

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Abstract. The paper explores innovative methods of navigation for experiencing and spatial comprehension of complex 3D digital environments. Common navigation modes of digital environments are difficult to learn and use within complex multi level digital models and often result in the viewer becoming disoriented or stuck. By drawing on concepts from computer gaming and spatial way finding this research will explore intuitive navigation systems. These systems enable the user to engage and experience the digital space much more profoundly than current CAD and BIM model viewing software. The paper demonstrates these navigation spatial cognition systems through three case studies.

Keywords. Navigation; BIM; spatial comprehension; orientation.

1. Introduction

Digital 3D models are common tools in design and construction processes. Yet, interacting within these models can be frustrating, progressively as the models increase in complexity. Due to the increased use of building information modelling (BIM) during the design phase, the construction and facilities management phases now have access to comprehensive digital models. Resulting in a different type of spatial cognition and investigation required of a complete model compared to the creation and editing of a digital model. There is a comprehensive collection of research around the navigation in virtual environments dating back over 20 years. Yet navigation and disorientation are still significant problems (Kopper et al., 2006; Khan et al., 2008). This research project primarily explores methods of navigation for experiencing complex 3D digital space. With the increased use of BIM comes the importance of accessing location-based information. The scope of this paper focuses on post content-creation to the intellection of complex digital models.

Michael Glueck and Azam Khan (2011) of Autodesk Research argue that "Navigating an environment is intrinsically linked with understanding that environment." Current CAD software predominantly provide methods of navigation to aid in the creation of 3D digital models based around modal tools for example; pan, zoom, orbit, etc. All of these tools provide a disjointed singular method of navigation, making navigation extremely infuriating, confusing and disorientating delaying the understanding of the environment for the user.

In the context of this paper a complex digital model is defined as a three-dimensional model, constructed with CAD or BIM software, of a building that has detailed interior and exterior geometry, is multi-storied, and strong spatial presents at multiple scales. It is difficult to view the entire model from one scale. This is in comparison to an object with little or no interior definition that can be completely viewed by orbiting around the objects centre while at a constant scale.

2. Spatial Cognition

"Navigation is the cognitive process of acquiring knowledge about a space, strategies for moving through space, and changing one's metaknowledge about a space," according to Laura Leventhal (Jul and Furnas, 1997).

A user who is exploring a model (not creating or editing) needs to generate a 'grasp' of location and orientation of the building, what Malpas (2007) refers to as a spatial frame, that is used to create what Tversky (1993) describes as a cognitive collage to develop a spatial mental model. The cognitive collage consists of different factors, hieratical representations, cognitive perspectives, cognitive reference points, alignment to other locations, rotation to frame of reference, and more, can distort spatial comprehension. How can these factors develop navigation and spatial cognition within a complex digital model?

2.1. NAVIGATION

The main navigation tools in CAD software are effective at the navigation of an object (a simple model) compared to complex models (e.g. a digital model of a building). Pan, zoom and orbit enable fast navigation of a simple model, these tools do not translate well for navigation and spatial comprehension of complex digital models. A number of software packages include spatial navigation tools; walk, fly and look that try to address navigating complex models, however these tools are mono-functional. They only work in one role and the user has to change tools from Walking to Looking, interrupting the users flow, creating a fragmented navigation experience. Researchers Glueck and Khan (2011) state "interacting with these environments can be challenging for users, especially as these environments increase in complexity and scale."

It is easy to become disoriented and lost within a digital building model when only using standard CAD model navigation tools. The model elements are non-solid representations of real-world building components that can be passed through by the viewer, contributing to disorientation and a loss of sense of scale. The paper explores a range of navigation and orientation systems to enable efficient spatial comprehension via more usable humanistic methods of navigation. Commercial computer game engines enable a multi-functional first person (and third person) navigation view that provide a consistently scaled view of a digital space that is navigated by walking or flying. This mode of navigation provides the viewer a smooth and uninterrupted navigation flow that enables a stronger understanding of scale and relationships, spatial cognition within a proposed building than standard mono-functional navigation tools. A number of recent reviewing software packages have included these options of navigation tools, however it is still possible to become stuck in corners–if one attempts to move through solid geometry–and lost.

Construction drawings have developed in relation to the technologies available to architects and restrictions of the media. Within the established protocols of construction drawings, no conventions currently exist for the review and navigation of 3D digital building models. A number of "standard tools" of navigation operate across different software packages, however each tool operates slightly differently in each package resulting in confusion and conflict for the user.

2.2. ORIENTATION

Comprehending ones orientation within a complex digital model increases with difficultly in parallel with model complexity. Users cognitive collage and spatial cogitation is informed by their spatial frame of reference and task. Currently there are not many orientation markers beyond the model geometry in CAD viewing software that aid in providing clues to the users. Recent additions of CAD viewing software have included real world constraints of user collision and gravity, basic light and shadow rendering. These additional orientation aids are still very crude and can still be a hindrance to movement with in a complex digital model. Alongside the constraints has been the addition of 'saved views' that an author can predefine. Although useful for creating fast access to predetermined spatial locations, there is a disconnect for a user new to a model as there is no orientation to or from the saved view, resulting in a gap in their spatial mental model. The following case studies explore possible methods to improve spatial cognition.

3. Case Studies

The case studies have developed sequentially, starting with the Point Model that was an investigation into methods of navigation used with in computer gaming on desktop and tablet computers. After a critical review of existing software and case study one, Pathfinder Model, case study two was developed to help improve spatial cognition during basic model navigation by introducing innovative methods of navigation. A third case study, Space Trace, explored an abstracted spatial condition utilising sensors to control the navigation of the model. Significant methods explored in the case studies include a prolonged transition or spatial transition and artificial intelligence (AI) path finding.

3.1. POINT MODEL

The Point Model addresses modes of navigation that draws from the game Epic Citadel 2010 by Epic Games, Inc., that enables players to tap the screen to move their avatar to the touched location. To enable this to happen with a mouse click, Point Model introduces a glowing yellow pointer in 3D space that, on holding the left mouse button, the user can move it around the visible part of the model (Figure 1 and 2). Then once the user has located the pointer at a desired destination a left mouse button click moves the view to that location. The movement is a

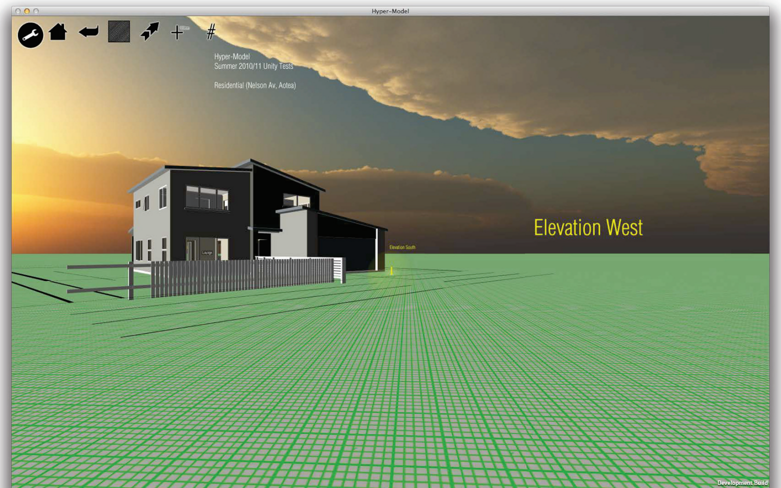

Figure 1. Point Model starting view.

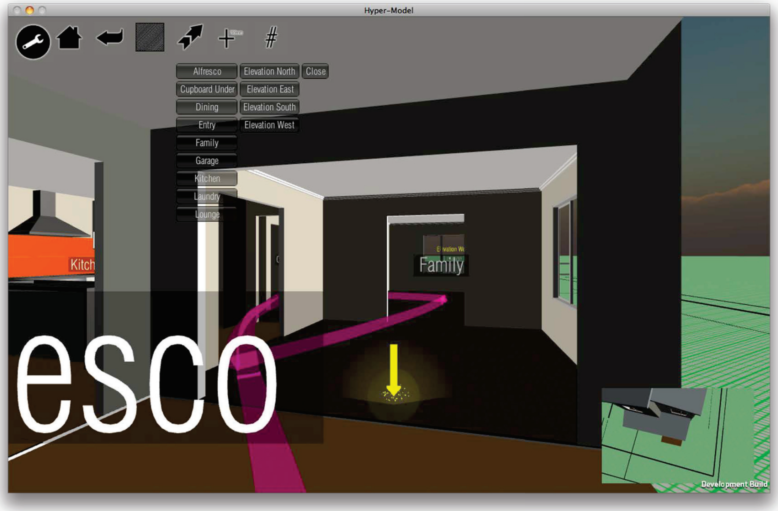

Figure 2. Point Model yellow arrow and magenta trail.

timed transition through digital space that helps to build the spatial cognition of the user. Providing the user with a destination based navigation rather than the use of navigation tools to get to desired location.

With the spatial transition of the view, a magenta coloured trail or breadcrumb is left, providing the user a visual marking of their movement through the model, providing another element that helps to build the users spatial mental model (Figure 2). The trail has a defined life, and dissolves after one minute, so as not to over complicate the digital space. It is a straight-line movement to the pointer, resulting in the possibility of the becoming blocked by solid geometry, requiring another movement.

At any time the user can used the 'WASD' keys – a standard computer gaming navigation control for walking forward (W), backward (S), sideways (A and D) – to walking the user whilst clicking and holding the left mouse button to look around, multi-function navigation mode. Other navigation methods include; a small location plan in the bottom right of the screen, that locates the users in context of the building, a home button that returns the user to a fixed starting point, and Undo Move button that transports the user to back to their last location.

3.2. PATHFINDER MODEL

On reflection of the navigation methods explored in Point Model, all of the methods introduced needed further devolvement. The spatial transition used with in

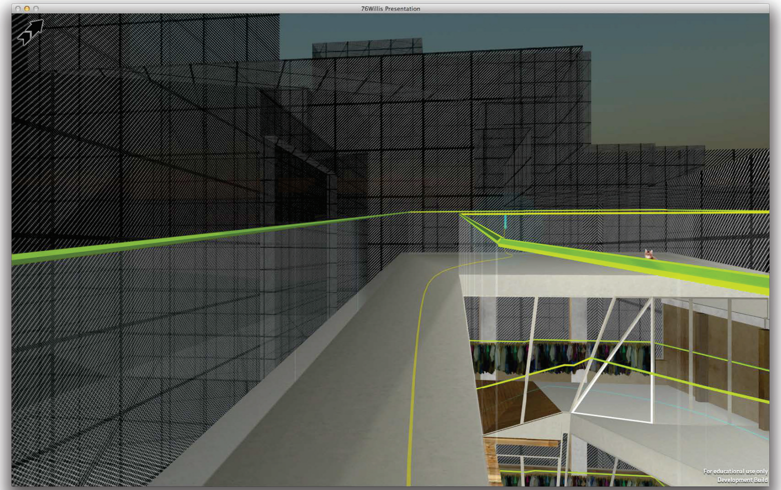

Figure 3. Pathfinder Model, thin yellow indicative trail and cyan trail travelled.

Point Model did not respond to the realities of the building model or aid in improving spatial cognition of the model. In the Pathfinder Model we unitized AI to generate dynamitic spatial transition in real-time that are formed by a 'navigation mesh' that overlays the geometry mesh. Depending on current location and selected destination depends if you are flown or walked. The improved spatial transitions, succour to build spatial; cognition, orientation, location, direction and relationships, by moving the user through a path to the destination a sense of distance and scale is provided. This is not common in CAD and BIM software, and is usually gained from designing and modelling the project, much harder to comprehend from just exploring a finished digital model.

Building on the Pointer Model, a line transparent cyan trail (or breadcrumb) is left representing the path you have travelled, in addition, once you start a spatial transition, a line transparent yellow line is drawn indicating the path you will follow (Figure 3). Both of these aid in building the users spatial comprehension by charting their path suggested and travelled, to stop confusion over time, the trails disappear after 30 seconds. If the user decides to move to another objective, the spatial transition can be stopped in its tracks directed to another destination or the user is free to walk around.

Predefined views have been created to provide standard architectural representations in perspective projection of elevations and plan. The user is then able to scan through the building to gain sectional information (Figure 4). Currently there

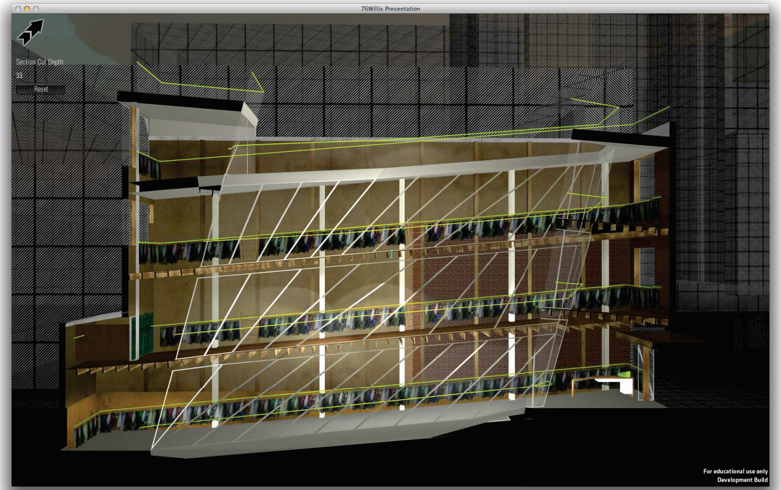

Figure 4. Pathfinder Model section view.

are no predefined section cuts, which is an aspect that the author is investigating further.

Darken and Sibert (1993) have cited spatial audio as a navigation technique in virtual environments, one that is currently not used within CAD and BIM models. This was introduced in Pathfinder Model as a simple sound track for the interior and another for the exterior space. The aural scape provided the user an omnipresent indicator of a binary condition of interiority. The spatial audio gave non-visual navigation assistance, but did not provide any architectural indication of the quality of space beyond a sense of interiority. The author plans to develop further models that explore the audio qualities of space to aid in spatial comprehension.

3.3. SPACE TRACE

Space Trace explored methods of navigation in experiencing an abstracted 3D digital environment compared to the previous two case studies. The project was setup to explore non-standard ways of providing spatial comprehension of a complex unfamiliar digital model.

The context of the project was within a blind peer reviewed exhibition, within the three-day symposium, Wellington LUX, the result of a partnership between Massey University College of Creative Arts, Oslo School of Architecture, Oslo, Norway, Wellington City Art Gallery and Whanganui Art Museum. By drawing

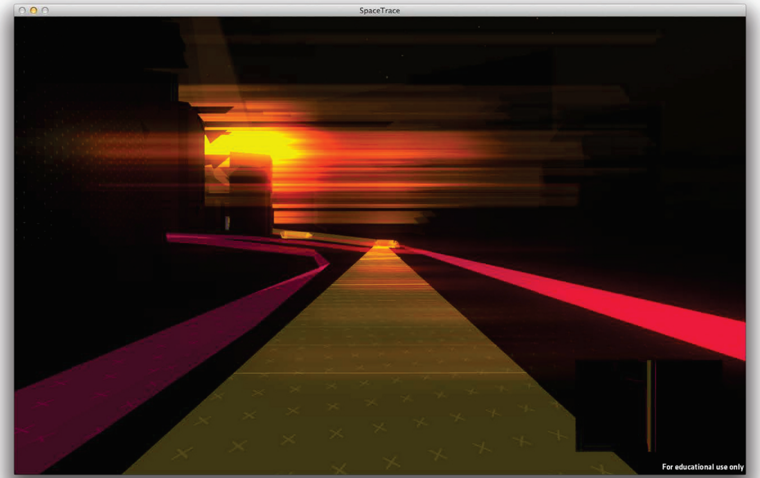

Figure 5. Space Trace, thick yellow indicative trail and magenta trail travelled.

on computer gaming and spatial way-finding, the project demonstrates innovative navigation systems beyond conventional approaches. The work incorporates motion data driven navigation consisting of a static building model and real-time data digitally reconstructed light, geometry and sound. It enabled viewers' to have interactive experience of a spatial context by providing wide trails of yellow light to predefined spaces, creating virtual vibrant violet breadcrumbs to aid navigation and spatial comprehension (Figure 5).

The project enabled exploration of non-standard input to control the sequence of predefined destinations within the model. The installation reacted to the motion of people with in the gallery space moving the viewers through the digital model. The reactive travel through the model provided the viewers a unique understanding of the digital space with out having to control the movement. The project provided an opportunity to move beyond conventional CAD viewing and navigation systems. The findings from Space Trace will be developed into future case studies within architectural projects.

4. Improving Spatial Cognition

Current CAD and BIM software focuses on navigation methods for editing geometry with little consideration to succour spatial comprehension of architectural models. This is due, in part, to limited processing power and attention on 2D papers based outputs. With the increase of complex BIM models a need to provide effective access to complex digital models has followed. A number of software packages have attempted to address this issue, all struggling to provide empowering navigation and spatial cognition.

Researchers Glueck and Khan (2011) state that intellection and navigation are interconnected, a statement that historically has not been evident in the software. In providing users methods to grasp frames of reference that build a near complete cognitive collage, beyond mono-functional navigation tools, enable enhanced benefit of BIM models for post design tasks. Within current software it is problematic to grasp position, orientation and interiority resulting in users becoming lost and frustrated interacting with a complex digital model.

5. Conclusion

The case studies have emphasised methods of navigation that can assist in spatial comprehension of complex digital models compared to current CAD software. By providing users with spatial transitions that guide them through a building model enabling users an assisted 'gasp' of their location and orientation. Developing this further in case study two, Pathfinder model, with AI navigation to allow dynamitic path finding.

The principle academic contribution of this research paper is that a single method or technique of navigation is an inadequate approach to providing spatial cognition of digital architectural models. Rather the interface between the tools and the conditions within the model needs to be considered in refining, and creating new, navigation methods. That spatial comprehension and navigation are fundamentally connected and is critical in the development of approaches to aid spatial cognition. The pathfinder model illustrates a connected approach that assists the viewer in building a spatial mental model of a digital proposal.

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