Impact of Fidelity in 3D Space Visualisation Across the Construction Asset Lifecycle

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ABSTRACT

3D virtual building models are used to help clients reach decisions during concept and detailed design phases. However, previously published research provides evidence for discrepancies between human perception of virtual and physical spaces; thus perceiving each virtual dimension (height, width, depth) differently from its physical counterpart, with varying percentages. This can affect clients’ effective decision-making during coordination if 3D virtual representations are not perceived identical to their physical equivalent. This paper discusses the impact of these discrepancies beyond the design phases and into the whole lifecycle, construction and operations. Moreover, descriptive and inferential statistical analysis provides evidence of relationships between the physical and virtual perception differences in dimension, discussing possible factors contributing to perception discrepancies affecting the individual viewer, in 2 main areas 1) 3D authoring software 2) psychophysical factors. Possible solutions are also proposed to accommodate for the discrepancy between physical and virtual spaces.

KEYWORDS

3D Model Visualization, Architectural Design, Building Information Modelling, Construction Lifecycle, Space Perception, Virtual Reality, Visual Cues

1. INTRODUCTION

Designers and architects use different forms of digital space representation in the construction industry to represent to clients prospective buildings, and try to faithfully depict reality. These include CAD tools (Computer Aided Design) providing 2D representations, from which, 3D representations of the objects could be derived using geometric models. In parallel, GIS (Geographic Information Systems) allow non-graphical attributes to be linked to geometric representation through grids or matrices. Currently, visualisation is depicted using 3D Building Information Models (BIMs), which can be interlinked together or with GIS, with rich non-graphical information attached inside them (Isikdag et al., 2011). The visualisation can either be a solitary model or inside a virtual environment / world e.g. Second Life.

According to Parsons (1995), with these visualisation tools, both quantitative and qualitative information can be represented about spaces. Quantitative information expresses spatial relationships among people and objects e.g. length, height, size etc., in an absolute or numeric manner, while qualitative information provides a “sense of place”, e.g. architectural style of building, sounds, urban characteristics (Pereira et al., 2013). However human perception of 3D models’ virtual space sizes, represented by this quantitative information, has been evidenced to differ from human perception of the same space in reality that this information represents, as explained subsequently. Typically, 3D visualisations and simulations are chosen by designers to communicate with their clients – illustrating space design ideas, functionalities and sizes. However, if those digital visualisations do not portray size and dimensions of a space truthfully, this gives the client a false perception of what the space would
actually look like once built. This might result in wrong decisions at design phase based on incorrect information, which would only be realised after construction is complete, rendering it impossible or expensive to change, causing both usability and financial losses. For example, during planning stage, local authority might reject new development permissions due to the ‘uncertainty’ factor in the appearance or design. However, with realistic and accurate 3D animation and visualisation, the uncertainty can be eliminated to gain approval and building permits more easily (Trivedi, 2013).

Other applications / advantages of fidelity in representing real-life spaces is in 3D flight simulations and driving simulations for crash avoidance training or to assess the effect of distracting tasks on situation awareness. If a training pilot or driver is trying to develop sensitivity in taking split-second actions/reactions based on proximity, environment or dimensions/altitudes of spaces in the simulation, then this can be detrimental if this does not represent real-life dimensions when he actually is flying or driving; as delayed or premature life-threatening decisions can be made (Tian et al., 2012). Even an everyday application such as the Global Positioning System (GPS) device has shown problems where users misinterpret distances shown on it to those in reality and take turns on the road which are either too soon or farther than required. This is extremely inconvenient especially for those who have hearing impairment and cannot rely on the audible instructions with the GPS device (Greenberg and Blommer, 2011).

Considering this, methods to visualise 3D spaces and simulations should be enhanced to depict reality accurately. These include (Salamin et al., 2006): 3rd person view (i.e. watching an animation on screen) where the user can see his avatar moving relative to the space or imagine watching someone else moving, but does not feel embedded inside it himself; or using 1st person view (by wearing a virtual reality Head Mounted Display-HMD) where the user feels immersed inside the environment and completely surrounded by it. Lack of stereo-vision associated with that could hinder evaluating distances, but could be partially compensated by the 3rd person perspective that increases the field of view. The scope of this paper is limited to comparing the difference in perception between real-life spaces and 3rd person view of virtual spaces. The consequent sections demonstrate further uses of 3D visualisation fidelity in the construction lifecycle, and the author’s research conducted in this area.

2. IMPORTANCE OF 3D VISUALISATION FIDELITY THROUGHOUT THE CONSTRUCTION LIFECYCLE

The previous section outlined the traditional usage of 3D visualisations from 3D models as used in the initial concept and design phases of a construction project. However, fidelity in representing 3D spaces is also essential for usage within all phases of the construction lifecycle including construction, operations and facilities management. Kamat and Martinez (2001) emphasise that Simulation modelling and visualisation can help significantly in designing and decision-making for complex construction operations where traditional methods prove ineffective or unfeasible. 3D visualisation can provide valuable perception of the restraints of alternative construction operations, which can otherwise be non-quantifiable, non-presentable and extremely complex if they are only mentally evaluated and visualised by experienced construction planners, which is the current practice. Such operations include designing temporary piling systems, retaining walls, tolerances for manoeuvring of equipment, working space for personnel, mobilisation of tools, crane space and movement etc. Furthermore high fidelity in representation of the 3D virtual space is crucial especially in specific health and safety issues that can be at high risk if not designed with accurate 3D visualisation of the space e.g. manoeuvrability problems at loading and dumping areas in earth-moving operations, the restricted visibility of the crane operator in steel girder erection, overcrowding in particular work
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