Scalable Explorations

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ABSTRACT
Authoring environments should strive for effortless navigation, traversing the space-scale virtual space in order to comprehend relationships between distinct elements, provide landmark or reference objects to keep the user's orientation and perceptual cues that will enhance direction and depth perception. This paper will explore how the dynamic nature of 3-D virtual environments can provide new generations with powerful tools to explore disparate spatial scales, expand the modeling information and give them the ability to manipulate conceptually critical information that is governed by various scale parameters.

KEYWORDS: BIM; virtual space; scale; urban space

Scientific visualizations have gone through a metamorphosis from being solely digital representation of 2D drawings to dynamic multi-scale 3-D virtual environments. In the 1995 proceedings of CHI'95 Human Factors in Computing Systems, Furnas and Bederson first introduced the multi-scale concept as "space-scale" diagrams. This interface allowed users to manipulate objects and show them at different scales. The scale could have been constant and change gradually as with a zoom metaphor or varying on a single view as with a bifocal metaphor.

This paper concern is the concept of "scale", mainly architectural scale in 3-D virtual environments. It also aims to explore and contribute to the current dialogue about the potentials or limitations of using multi-scale interaction on virtual architectural. Multi-scale interactions can facilitate an understanding of large and complex models and is the basis of future architectural software. It will transform how we do and teach architectural design.

The meaning of the word "scale" has many definitions depending on the field of study. Most meanings concur that "scale" concerns mainly with a relation to something, either to the human body, as the case of the *Vitruvian* principles or to an internal mathematical relation as in the Golden section. Urban environments are ruled by different scale parameters depending on the interrelated elements such as the city, neighborhood, block, building and open space. Italian architect, Vittorio Gregotti, exhibited the "manipulative" notion of scale stating that the impact of architecture is not limited to the city boundaries but that architecture plays a pivotal role and contributes to the overall infrastructure, landscape and ecology of the territory. Gregotti identifies three scales of intervention; the geographic, the topographic and the object level. (Gregotti 1960).

The notion of scale relates to a "model" or a comparison to something else, and in a broader sense pertains to representation, which involves visual perception. To perceive is to take intellectual cognizance of something through the senses and through this process, the brain '*re-creates*' the experience in our imagination. Perceived size or scale can be in many cases unintelligible.

Humans perceive scale in real environments as a complex system of relationships and store it in a kind of "spatial" memory throughout life. A widely accepted theory in spatial cognition is that people use cognitive maps to store and structure spatial knowledge. A cognitive map is usually regarded as an internal representation of the spatial structures of an external environment (Golledge 1999; Tolman 1948). Spatial knowledge is grouped and organized to provide users with a comprehensive understanding of space at different levels of abstraction (Kosslyn et al. 1978). Research on the perception of metric properties of space, like distance, on virtual and real environments has shown that distances are not perceived the same in a real and a virtual environment. This may have an effect in experiments related to scale taking place in virtual environments (Mavridou 2006). The main factor that can affect perception on virtual environments is the issue of embodiment (Mavridou 2006). The perception of a moving observer versus static observer is remarkably different since the static observer is relying in the recreation (cognitive) and memory. The non-direct participation of the body can cause that changes in scale are not perceived. The artificial nature of 3-D virtual space allows us to zoom not only in and out of objects, but to see simultaneously all objects (distance objects) in focus and this can be deceiving. Humans experience "urban scale" moving through a composition of interrelated objects and the perception of scale is not a separate parameter. Authoring applications must use other means to communicate depth cues that are effective on abstract and/or incomplete 3-D scenes (Glueck 2009).

When students are designing a new 3-D object or scene they have to begin by constructing a mental image of the scene and keep in mind the urban connection. It also requires a proficiency in mentally transforming and manipulating 3-D objects (Tory et al. 2006). This can be a challenging task, particularly for users who are new to 3-D (Fitzmaurice et al. 2008).

Ken Perlin and David Fox were the first to introduce the idea for multiscale zooming at New York University in SIGGRAPH'93 where the user was able to zoom in an infinite two-dimensional information plane and make use of "magnifying glass" tool (Figure 1) that show contextual information depending on what part of the plane the user was seen (Kopper 2006).

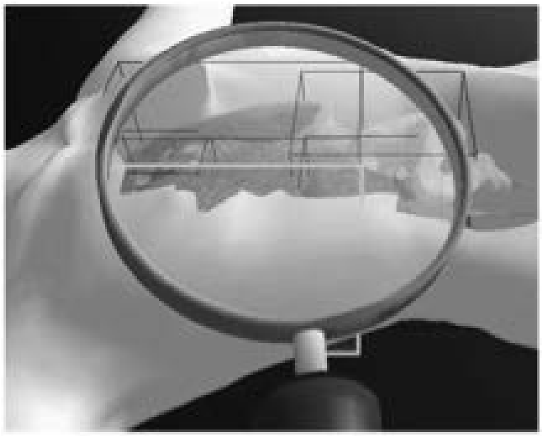

Figure 1. Levels of scale shown through the magnifying glass. Kopper, Regis, Tao Ni, Doug Bowman, Marcio Pinho. Design and Evaluation of Navigation Techniques for Multi-scale Virtual Environments. *Proceedings of IEEE Virtual Reality*, pp. 175-182. 2006.

In 1995, the "space-scale" diagrams provided the framework for representing both large spatial environments at different magnifications. Furnas and Bederson proposed the "space-diagram" concept (Figure 2) which created many copies of the original 2-dimension picture, one at each possible level of magnification (scale), and stacked them up to form an inverted pyramid and make them accessible all in the same picture frame (Furnas 1995).

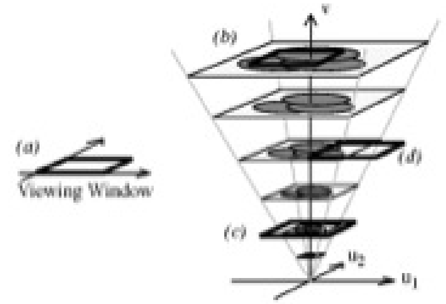

Figure 2. The viewing window (a) is shifted rigidly around the 3-D diagram to obtain all possible pan/ zoom views of the original 2D surface, e.g., (b) a zoomed in view of the circle overlap, (c) a zoomed out view including the entire origina picture, and (d) a shifted view of a part of the picture.

The "World in Miniature" (WIM) interface presented by Stoakley et al. (1995) was one of the earliest attempts to provide an overview plus detail on a 3-D interface. The WIM interface offered a 3-D overview of the whole world in a low level of detail to assist navigation in a virtual environment without losing location awareness. The original WIM interface was limited to a single, low level of detail (LOD) overview display (Figure 3).

To overcome this limitation, scalable WIM interfaces have been proposed by LaViola et al. (2001) and Wingrave et al. (2006). Alternatively, Pierce and Pausch (2004) extended the basic WIM interface with hierarchical maps that determine visible landmarks to assist navigation in large-scale virtual environments (Ji-Young Oh 2008). In 2006 Kopper et al. developed two navigation techniques to enable fluid navigation between multiple levels of scale. The main ideas of the techniques were to facilitate travel to different scales in a multi-scale virtual environment and interaction by changing the user size across orders of magnitude of scale changes.

In his seminal work, Kevin Lynch, Image of the City (Lynch 1960), wrote that in the real world landmarks helps us organize large spatial information. (Lynch 1960) In 2009, Bacim, Bowman and Pinho presented a study on the development of new wayfinding aid technique designed

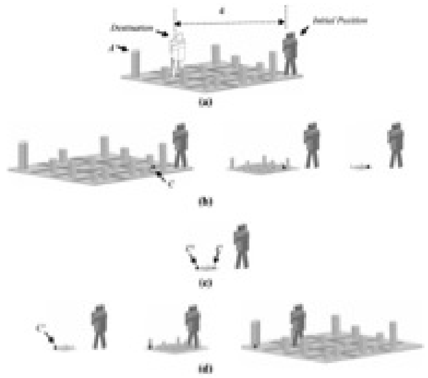

Figure 3- Scaling-as-traveling. An user's initial position, the target A, the travel destination, and the travel distance d. b The user contracts the world around a scaling center C. c The user adjusts the position of the scaling center to a new position C0. d The world is expanded around the new scaling center, and the user moves closer to the target A. Xiaolong ,Zhang "Multi-scale traveling: crossing the boundary between space and scale", presented at Virtual Reality, 2009, pp.101-115.

specifically for MSVEs also evaluated *the usability and performance* the technique by conducting an *experiment* (Bacim 2009). On the study, they identified two kinds of wayfinding information as necessary for traveling, one being spatial information and the other hierarchical information which both have different levels of scale (LoS). Spatial information is described as all that is concern with position and orientation of user and object (Figure 4). With spatial information, it is possible to determine in which direction to go to get to a specific level of scale, where this level of scale is positioned, and what is the orientation of a level of scale in relation to others (Bacim 2009). Hierarchical information is the information that assists the user to understand the relationships between different levels of scale, independently of their position in space. They highlight that there are differences between this information; spatial information is concrete and can be seen while hierarchical information is abstract since the levels of scales can be nested within.

The experiment used the MultiScale World-In-Miniature (MSWIM) technique, which is a modified version of the original WIM technique that allows users to zoom and pan what they are seeing in miniature. The Hierarchically-Structured Map (HiSMap) technique is based on the idea of showing the entire hierarchy structure formed by the levels of scale, so that users can view and select any level of scale at any time and compare it to baseline techniques implemented by Kopper. Kopper et al. work expanded on the target-based and steering travel techniques already established and implemented aids for spatial orientation such as a three-dimensional map containing a You-Are-Here (YAH) marker of users' current scale and a compass represented as the human body indicating the orientation of user relative to the highest level of scale (Kopper 2006). From the results of the experiment, they established that hierarchical information does helps users find a specific level of scale and travel there while spatial information helps users keep their orientation. Moreover, performance was enhanced when allowing users to search for a specific level of scale (Figure 4) without changing their current scale (Bacim 2009).

Glueck et al. have recent experiments with the addition of an omnipresent referential grid. The grid is centered at the origin on the virtual ground plane and will subdivide or combine gridlines depending on the degree of closeness to the object. Additional depth cues are provided by a system of "position pegs" (Figure 5) that overcome the limitations of the planar grid by revealing vertical position cues relative to the reference grid. The grid is semi-transparent in order to leverage the partial-occlusion depth cues, therefore, if the grid clips an object or if the object is below the grid there is a clear visual cue for the user.

Today, multi-scale technologies allow users to visualize large virtual spaces at different scales on geospatial environments and on a limited basis in anatomical investigations. The benefits of multi-scale virtual environments (MSVEs) are quite powerful not only for navigating and understanding large environments but also to analyze them. The capabilities to have different levels of scale gives the user the ability to identify how the structures relate to each other at different scales of intervention. Also, gives them a better understanding on how all the *elements relate to each other. Scale is indispensable when trying to establish a relationship among sizes, or relative sizes of things. Scaling is a design tool that allows building sense among systems bearing distinct natures (Cabral 2007). Each urban elements have an appropriate operating scale that depends on its' relational impact and scalar boundaries that may expand in-between scales.* One of the current difficulties is the incompatibility of Building Information Modeling to share information with the legacy GIS datasets. The problem with GIS systems is that the semantic structure of the data does not store geometric or physical

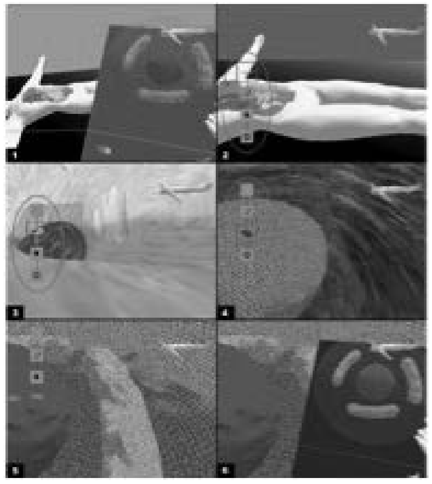

Figure 4- Bacim, Felipe, Doug Bowman, Pinho. "Wayfinding techniques for multi-scale virtual environments," 3-D User Interfaces, 2009. 3-DUI 2009. IEEE symposium on 3-D user interfaces 2009, vol., no., pp.67-74, 14-15 March 2009

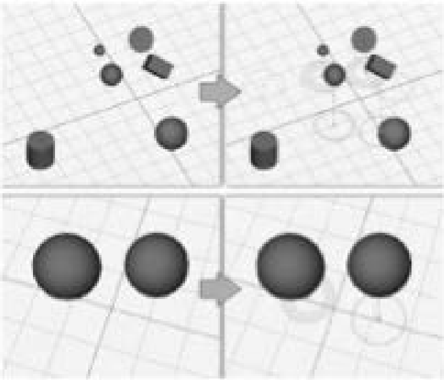

Figure 5- Two ambiguous scenarios: (top) parallel projection; (bottom) perspective projection. Glueck, Michael, Keenan Crane, Sean Anderson, Andres Rutnik, Azam Khan. Multi-scale 3-D reference visualization. In proceedings of Interactive 3-D Graphics and Games, I3-D'09, pages 225–232, 2009.

attributes of the elements and relationships between these elements, which are essential for urban analysis.

More research is needed not only to resolve the disjunction of the modeling datasets but also explore multi-scale interactions and design methodologies that facilitate coordinated data based in scientific analyses. At the building scale, BIM could benefit of the analytical power of the GIS tools and apply this Urban Information Modeling (UIS) with an open IFC standard. Creating an open architecture and compatibility of datasets will easily integrate 3rd party applications, add functionality and streamline the data flow.

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