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Interactive navigation interface for Virtual Reality using the human body

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ABSTRACT

The use of Virtual Reality (VR) and interactive real-time rendering in urban planning and building design is becoming more and more common. However, the integration of desktop-VR in the urban planning process suffers from complicated navigation interfaces. In particular, people unfamiliar to gaming environments and computers are less prone to interact with a VR visualization using keyboard and mouse as controlling devices. This paper addresses this issue by presenting an implementation of the XBOX 360 Kinect sensor system, which uses the human body to interact with the virtual environment. This type of interaction interface enables a more natural and user-friendly way of interacting with the virtual environment. The validation of the system was conducted with 60 participants using quantitative and qualitative methods. The result showed that participants perceived the interface as non-demanding and easy to use and the interface was perceived better in relation to mouse/keyboard interaction. The implemented interface supported users to switch between different architecture proposals of an urban plan and the switching positively affected learning, understanding and spatial reasoning of the participants. The study also shows that females perceived the system as less demanding than males. Furthermore, the users associated and related their body (human interaction interface) to VR, which could indicate that they used their body during spatial reasoning. This type of spatial reasoning has been argued to enhance the spatial-perception.

1. Introduction

The use of 3D city models and Virtual Reality (VR) are becoming more common in urban planning and building design. VR is a visualization and communication medium that makes it possible for all interested parties to have access to a common representation and a better understanding of the planned urban environment. In the urban planning and building design process there are many different stakeholders involved with different backgrounds and information processing capabilities. VR can facilitate processes so that participants can better understand, identify and analyze problems together to improve communication and decision-making and thereby the future urban environment (Al-Kodmany, 2002; Kjems, 2005). However, VR has not attained the impact and penetration in the planning processes as was predicted in the literature. The complicated navigation interfaces are perceived as one of the main reasons for this lack of impact (Lubanski, 2007). Stakeholders within the urban planning processes are very positive to use the VR-medium during meetings with help of a computer skilled facilitator or navigator, but have little interest or self-confidence to navigate the VR themselves due to the complicated navigation interface (Lubanski, 2007; Sunesson et al., 2008). Similar to computer games, the navigation and interaction with desktop-VR is often performed by using a keyboard and mouse. Unfortunately, many traditional 2D input devices (e.g. keyboard and mouse, joystick) are unsuited to tasks required in 3D applications, as they require a mapping from 2D input to 3D positions in space (Issacs, Shrag, & Strauss, 2002). Many users find them unwieldy and unnatural to use in 3D applications (Lubanski, 2007; Stannus, Rolf, Lucieer, & Chinthammit, 2011). Although this type of user interface works well for computer skilled persons and gamers it can be an interaction hurdle for many of the end-users within the urban planning processes. These end-users are often less familiar with this type of computer interaction. This has resulted in the evolution of new and existing input devices in order to improve the facilitation of the user's interaction with the VR-medium. In this context, Natural User Interface (NUI) is an attractive solution to this navigation issue. There are multiple definitions of NUI, but we apply the following: "A Natural User Interface is a user interface designed to *reuse existing skills* for interacting directly with content" (Blake, 2010). This implies that the NUI enables the user to *operate technology through intuitive actions* using gestures, voice, touch and the NUI becomes invisible in a way that the user *does not have to put a lot of cognitive efforts* into interaction. Furthermore, it is also important that the NUI is *easy to learn* and that there is a *quick transition from novice to skilled* user while using the system. The user

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interface should also support the specific task performed by the user. In the urban planning process, typical user tasks are to navigate through virtual space; to understand the virtual space; and to judge different design alternatives and their implications to the new and existing build environment. The purpose of this study was therefore to find a user-friendly and natural way to navigate and interact with VR in the context of urban planning and building design. In this context, the interaction interface has always been a problem in which end-users have had difficulty to handle the VR themselves. One of the consequences of the complicated navigation interfaces is that the end product from VR is presented to the general public in rendered images and movies. In such, the client surpasses the complicated interaction handling and navigation through VR. However, as a result, the full potential of the VR, in terms of enhanced communication and understanding regarding future projects, is not utilized. Fortunately, the development of new hardware technology, that supports NUI, has made it possible to use the XBOX Kinect for interaction with the computer. With this technology the user can apply the human body as the interface, which has the potential to provide a more user-friendly and natural interface with the 3D-model. Several studies discuss different types of navigation interfaces using XBOX Kinect for hand and arm gestures (D'Souza, Pathirana, McMeel, & Amor, 2011; Park, Park, & Kim, 2012; Stannus et al., 2011). Furthermore, other research suggests that using the physical-human rotation and movement provides a better understanding and spatial perception (Riecke et al., 2010; Ruddle & Lessels, 2009). While several studies look into different types of navigation interfaces like walking when using a Head Mounted Display (HMDs) (Bruder, Steinicke, & Hinrichs, 2009; Riecke et al., 2010; Ruddle & Lessels, 2009), no studies have investigated desktop VR with physical-human rotation and movement with the XBOX Kinect. In this context, we wanted to investigate physical-human rotation and movement such as leaning forward/backwards and rotation of the shoulders when navigating in VR. Therefore, we are interested in: how such a NUI supports navigation, user-experience, on-demand switching between different design alternatives, and perception of space in urban plans presented in VR. We implemented an interface that uses the human body to navigate in VR during design reviews. The aim has been to implement a very simple NUI with limited functionality that is discrete, easy to learn and reuse existing skills through intuitive actions with little cognitive effort. Additionally, the user interface also supports on-demand switching between different design proposals, which could decrease cognitive load that supports better learning, understanding and reasoning. This will hopefully facilitate a more widespread use of 3D city models and VR in urban planning and building design. The paper addresses the following research questions: (a) how does the user experience a human-body interactive interface? (b) How does the navigation with the body impact spatial-perception and reasoning of the space? (c) How does support for on-demand switching between different architecture proposals affect learning, understanding and reasoning?

The paper is organized as follows: The next sub-section presents related work; Section 2 presents our implementation of the user interface; Section 3 includes method and validation of the interface; Section 4 includes results, Section 5 discusses the results and future work.

1.1. Related work

The most common navigation interface in desktop-VR is the use of mouse, keyboard, joystick and spaceball. The implementation of these interaction interfaces is dependent on the technical implementation of the interface and on the task that is performed with the interface. Ware and Osborne (1990) indicated that their "*Scene-In-Hand*" metaphor (e.g. orbiting model investigation) was well suited for manipulating an object, but less good for navigation; whereas the opposite was true of their "*Flying Vehicle Control*" metaphor (e.g. virtual walkthrough investigation). Therefore the technique used for a particular 3D application is typically chosen based on its suitability for the tasks required by the application. Furthermore, there is no ultimate solution to how the implementation of the navigation system should be performed. The implementation diverges depending on how many degrees-of-freedom have been implemented in the navigation interfaces. The degrees-of-freedom describe how many camera movements are possible with the navigation interface. Three of the six degrees-of-freedom involve translation: forward/backwards, left/right, and up/down. First-person shooter games generally provide five degrees-of-freedom: forwards/backwards, slide left/right, up/down (crouch/lie), yaw (turn left/right), and pitch (look up/down). In this study we investigate virtual walkthrough navigation. In virtual walkthroughs for urban planning and design, the up and down manipulation of the camera is often not supported. In these walkthroughs, the viewer only receives the opportunity to view the model from a pedestrian point of view. In virtual walkthroughs of urban sites, the number of degrees-of-freedom of movement varies between two and four. Furthermore, the more degrees-of-freedom the user-interface supports, the more demanding the interface becomes for new, un-experienced users to learn to navigate. However, excluding important degrees-of-freedom movements from the navigation interface can cause viewers to feel constrained in their task performance.

Using the human body as an interface has been an active research topic in the last two decades within the fields of Human–Computer Interaction (HCI) and Computer Vision (Bruder et al., 2009; Moeslund, Hilton, & Krüger, 2006; Poppe, 2007). Studies apply different interfaces from Head Mounted Displays (HMD) to motion capture systems. These studies suggest that interfaces with body movement can enhance navigation performance and experience (cf. Riecke et al., 2010; Ruddle & Lessels, 2009). However, several of these systems require motion caption systems and expensive equipment that make the systems impractical for use in other situations, such as controlling navigation in VR during design reviews. Furthermore, it was not until 2010, when the XBOX 360 Kinect sensor system was released. This system supports NUI and is affordable to everyone. The Kinect sensor provides an opportunity to achieve an interaction interface, not only for the Microsoft Xbox 360, but also for ordinary computers. Several studies have investigated support for hand and arm gestures using XBOX Kinect (D'Souza et al., 2011; Park et al., 2012; Stannus et al., 2011). However, the result from these studies has shown that users get slightly fatigued after 8–10 min because of the continual movement of the arm (D'Souza et al., 2011). We argue that the use of physical-human rotation and movement during the navigation is not only user-friendly but also enhances understanding of the virtual space.

1.2. Understanding the virtual space

The use of the human body for navigation can facilitate a better understanding of the virtual space. When it comes to spatial-perception, -reasoning, -orientation, -navigation, and -memory the human mind analyses the visual space within two parallel systems, i.e., self-centered *egocentric* reference frame and an environment-centered *allocentric* reference frame (Burgess, 2006). Both systems interact during the encoding and retrieval of spatial knowledge (Plank, Müller, Onton, Makeig, & Gramann, 2010). In the egocentric reference frame, the viewer compares him/herself with the object in 3D space. During this self-to-object process, the distance and bearing are processed independently of the global environment. As the viewer navigates through the environment, egocentric