VIRTUAL ENVIRONMENTS FOR THE EVALUATION OF HUMAN PERFORMANCE

Towards Virtual Occupancy Evaluation in Designed Environments (VOE)

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Abstract. Analyzing and evaluating designs for modifications to suit the requirements of human performance is typically performed only after the architectural spaces and structures have been built and used, a process that is known as retrofit or *post-occupancy evaluation*. For people with disabilities, there is a special need to overcome this problem by evaluating the suitability of their home environments before the construction phase. Our work introduces a new methodology in which virtual reality (VR) is used for *virtual pre-occupancy environmental evaluation (VOE).* Our study demonstrates the potential of the VOE concept by developing an interactive living environments model to evaluate human performance before the construction phase. This paper presents an interactive virtual environment, 'HabiTest', as well as the initial results of a usability evaluation of this interactive environment.

1. Introduction

Retrofitting is the process whereby a built environment is modified to eliminate functional and operative problems discovered after occupancy. Retrofit is a common and costly process that we try to obviate by experience, intelligent planning, and quality simulations of the future environment. The better and more faithful is the simulation, the easier it is to visualize and anticipate the future environment. However, there are limitations to visual simulations, and there is no substitute for actual life experience in the built environment.

The exploitation of virtual reality (VR) for environmental simulation and testing is a technology that promises a high degree of environmental verisimilitude, an efficient platform for interactivity with actual future users, an efficient basis for functional trials in actual usage, the potential for implementing modification and retrials in the modeled environment, and modest costs and spatial requirements. Users interact with displayed images, move and manipulate virtual objects, and perform other actions in a way that engenders a feeling of actual presence, and immerses their senses, in the simulated environment (Rizzo et al. 2005; Schultheis, and Rizzo, 2001; Weiss and Jessel, 1998). Users are provided with visual, audio and, in some instances, haptic and olfactory feedback of their performance. One of the cardinal features of virtual reality is the provision of a sense of actual presence in, and the control over the simulated environment (Slater, 2003), and the role of human behavior (Oxman et al., 2004). Due to the ecological validity that VR environments can provide, one of the primary therapeutic applications of VR relates to training and learning various everyday activities within the context of the user's own spatial environment. Examples include learning to navigate a wheelchair, becoming familiar with a building's layout, food preparation in a kitchen and orientation in a supermarket.

The present research reports on an experimental application of this technology in the design and pre-occupancy testing of dwellings for people with disabilities, a form of design in which functional requirements are critical, and in which environments are highly user-specific due to the uniqueness of personal disabilities.

2. Functional Performance Evaluation of Environments for People with Disabilities

People with disabilities are often severely limited in their ability to function independently in their homes or at work as a result of physical, cognitive or sensory environmental barriers (Iwarsson, et al., 1998).

Pre-occupancy environmental evaluation aims to achieve an environment that can be fully utilized by the user for its intended purposes (Nielsen and Ambrose, 1999). The objective is to achieve an environment that facilitates the individual's ability to perform every day activities by providing designed compensation for their functional loss. Environmental modifications of conventional dwellings are necessary in order to make them suitable for disabled users; this is an inseparable part of the rehabilitation process in the western world. However, environmental modifications to an existing physical home environment are fraught with difficulties. Thus simulations of designed environments are a means to obviate the need for post-occupancy modifications by identifying specific problem areas of individual disabled users and making pre-occupancy modifications to designed, or existing, home environments. Most current applications of VR in design simulate our experiences in virtual spatial environments as an alternative to our experiences in the real physical space. In architectural design, virtual simulations are most common for the evaluation of environmental performance related to people who do not have special needs. For example, Yan and Kalay (2005) presented a VR simulation for predicting and evaluating the impact of the built environment on human inhabitants. In their application, a simulation system comprises a usability-based building model and a virtual-user model with avatars emulating the physical behavior of real users in relation to environmental performance. Maver, Harrison and Grant (2001) developed a VR program that can simulate a physical environment for people who have some form of physical or sensory impairment, in their case, for people with mobility and visual impairment. They developed a wheelchair motion platform that was designed and developed to allow wheelchair users to navigate and explore a virtual representation of buildings.

A major objective of this research was to develop and test a virtual environment for achieving pre-occupancy design evaluation employing VR technology. The study addressed the problem of assessing accessibility by developing and evaluating a user interactive living environments model that will facilitate the planning, design and assessment of home and work settings for people with physical disabilities. We have accessibility of a building in the early stages of design or in the redesign of existing buildings. This interactive model is implemented via an immersive VR system for the evaluation of human performance such as navigation and performance of specific tasks. In this report we also present initial results of a usability evaluation of this interactive environment by actual users.

In our approach, the aim is to evaluate how particular people with unique personal disabilities will perform specific simulated physical tasks in a designed, or built, environment. VR is employed as an interactive environment to simulate specific living environments and to evaluate their performance with respect to specific levels of performance of particular individuals. This approach aims to provide users with disabilities with predictive opportunities based upon their own personal experiences of performing tasks in the environment. Emphasis has been placed upon simulating human performance in relation to motion in space and task performance with a high degree of accuracy and detail. Such an approach can provide information for the design and construction of, and interaction within, customized environments that are ecologically valid and can be carefully evaluated with respect to their level of difficulty. We have developed a simulation environment, HabiTest to serve as an interactive tool that facilitates evaluation of living and work environmental settings for individuals with physical disabilities. HabiTest responds to user-driven manipulations and supports future modification of current designs.

3. The Habitest Tool

HabiTest is an interactive tool that assists, to design and evaluate both the built environment and the user's performance in a virtual environment. This tool has been designed to address the needs of the environmental design modification intervention process as well as the needs of the pre-occupancy evaluation of new designs. HabiTest is also designed in a way that enables all the participants of the design process to evaluate the environment from the view point of its actual user – the client.

The construction and simulation of these environments was carried out using EON Reality's tools. Our initial feasibility testing employed three alternate points of view, available to the user: a first person view, a third person view, and a bird's eye view. Accurate collision detection enhanced the user's ability to gather relevant data from the simulation process.

The software recorded collision occurrences into a database. Furthermore, auditory, visual and haptic feedback to the user prevented the attainment of positions that are physically invalid. The ecological validity of this simulation allows the user to identify corners or narrow passages that, although passable, would be difficult and inconvenient to navigate on a daily basis due to number of moves and collisions they would necessitate.

3.1. DESIGNING THE KEY-FEATURES

HabiTest must enable users to navigate independently within realistic virtual environments while allowing them to identify any barrier that blocks their ability to navigate or to perform tasks in these environments. HabiTest supports layered presentation; since each object is associated with a particular layer, the display and elimination of any object is simple. A number of key features were considered to be essential: real time rendering; accurate collision detection of objects and walls; low cost portable tool that could be readily implemented in clinical and home settings; navigation that is easy and intuitive; an avatar representing the user within the environment having realistic characteristics (i.e., seated in a wheelchair with anthropometric measurement similar to an actual user).

In addition to the design requirements of ease of use and intuitiveness, the selection of a navigation tool was based on considerations of people who drive an electric wheelchair, being the main targeted population for HabiTest. Since most electric wheelchairs are operated with joysticks we selected a force feedback joystick, specifically Logitech's Wingman and Microsoft's

SideWinder. Both of these devices provide vibratory collision feedback to the user, enhancing the realism of the environment when the user collides into a wall or furniture while navigating.

The HabiTest environments may be projected onto a large surface using a video projector and several of the joystick buttons that have been programmed to enable users to look around. This option is available to users both while standing in one place and while navigating within the environment. A benefit of large scale projection is the ability of engaging a group of people in the design and testing process (Knight and Brown 1999).

We have also provided a virtual hand which is controlled by the user. The hand may be seen in the environment at any time and it has several levels of control. The first level of control is achieved by putting the hand at a fixed distance in front of the user's eyes; when users wish to perform any manipulation with the hand, they may move the hand separately from head movements.

4. Usability Tests and Evaluations

The purpose of the initial usability testing was to verify ease of navigation within HabiTest. None of the participants had had any experience with environmental modifications, nor were they experienced in the playing of computer games that required navigation. Following a short demonstration, each participant was given a trial period of ten minutes. Upon completion of the trial period, the participants were given up to 20 minutes to perform certain navigation tasks. Participants appeared to be stymied by the narrow FOV and they expressed great frustration. As a result of the FOV difficulties observed in two initial pilot tests we decided to expand the FOV via the two options, projection onto a large surface using a video projector and programming of several of the joystick buttons to enable users to look around in a way similar to how people turn their heads to the right, left, up and down while exploring a new environment.

In the second usability test, ten healthy volunteers participated in this study. A new setting was created for the purpose of this testing, a rendered model representing the inner area of the main section of the University's Dean of Students office (see figure 1). The area contains considerable furniture making it difficult to navigate. Some locations are not accessible for a person who uses a wheelchair. Indeed, some of the furniture must be removed when students who use a wheelchair enter the premises.

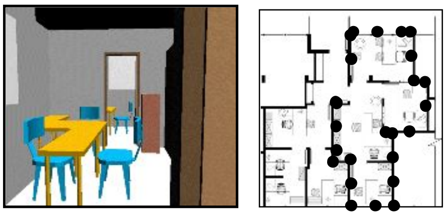

Figure 1. View of the modeled environment

The left figure illustrates a "first person" view of one of the rooms showing its furniture. The right figure illustrates the blue print of the entire area; the dotted line shows the area used for testing. Participants were shown how to use the joystick to navigate within HabiTest and given a trial period. One clearly visible virtual object (plant, plate with fruit, toy train and a red phone) was placed in each of the four rooms. Participants were requested to navigate within the virtual world to each object and "touch" it with a blue "hand" that appears on the screen. The moment the hand touched the required object, the hand turned red and the object reacted in a distinctive manner: the plant grew bigger, the train started moving, the phone rang and one of the pieces of fruit moved up and down. Similar tests were done including a navigation tests (see figure 2). During these tests, participants were represented within the virtual environment as if they were sitting in a wheel chair (first person viewpoint). All actions were performed using the joystick's programmed buttons.

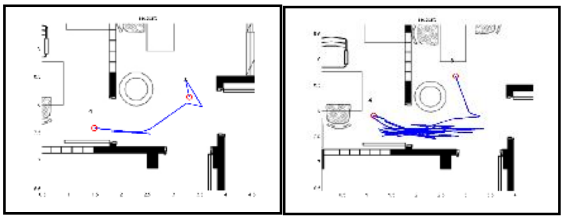

Figure 2. Testing navigation styles

5. Summary and Conclusions

In order to overcome the problem of *post-occupancy evaluation*, that is analyzing and evaluating designs for making modifications only after the architectural spaces and structures have been built, we have demonstrated in this study the potential of a VR tool to facilitates the test and evaluation of human performance by employing a *virtual pre-occupancy evaluation* media.

Currently most users in our experiments seem to have spent time to negotiate their virtual wheelchair in the VR environment. It is not yet clear to us if these difficulties are due to cognitive difficulties, such as knowing where the user is currently located and planning to be next, or whether the difficulties are primarily operational, such as controlling the wheelchair with an inadequate control device with insufficient feedback informing the user where and why there are navigation difficulties with the wheelchair. Such consideration should be defined in our next set of experiments in order to test the different tasks and the tools that can assist in these difficulties. For example, a top down projection of a wheelchair in a strictly 2D floor plan view could be displayed, in which various control devices could then be used to maneuver the wheelchair through that floor plan. Only after the user can move around the environment in a 2D display mode, he should experiment with the additional difficulties such as restricted visibility and limited orientation. We are planning to run such experiments to validate our assumptions and tool.

The work is currently being carried out by Orit Palmon under the supervision of Prof. Patrice L. (Tamar) Weiss of the University of Haifa, Faculty of Social Welfare & Health Studies, Department of Occupational Therapy, University of Haifa and Prof. Rivka Oxman of the Technion, Faculty of Architecture and Town Planning. Noam Glikfeld is acknowledged for his technical support.

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