Training Spatial Knowledge Acquisition using Virtual Environments

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Project Staff

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1 Overview

Background on this project can be found in RLE Progress Reports Numbers 140 and 141.

A large portion of our effort during the past year has been directed towards the development of a generic simulation involving a World in Miniature or WIM (Stoakley, Conway, and Pausch, 1995). We believe that the WIM will prove to be a valuable training aid for the acquisition of configurational knowledge of specific spaces. The generic nature of the simulation will accommodate both completely virtual environments as well as virtual copies of real-world environments.

Additional efforts have been devoted to further improvement of our Automated VE Generation System and the preparation of a paper on this system for publication (Madden and Wiegand, 2000).

A paper, "Virtual Environments and the Enhancement of Spatial Behavior: A Proposed Research Agenda" (Durlach et al., 2000) was also completed during this reporting period, marking the results of a collaborative effort with other researchers outside MIT to outline a general research and development program in the area of VE-assisted spatial training.

In addition, as part of the work we are doing as a follow-on to our initial work on the acquisition of configurational knowledge (Koh et al., 1999), we have initiated some basic research concerned with perceptual and cognitive factors involved in spatial updating. More specifically, this work is concerned with how errors that occur in estimating the bearing and range of targets are affected by real and imagined translations and rotations, and with the implications of these results for models of spatial perception and cognition.

Finally, two reports have been written describing some personal experiences in the areas of wayfinding and acquisition of configurational knowledge (Garnett, 2000; Brooks, 2000).

Equipment acquisitions that have taken place during the year include the replacement of our aging VR4 head-mounted display (HMD) with a new Kaiser ProView 50, providing a significant boost to resolution and visual field, and the incorporation of an InterSense six-degree-of-freedom motion tracker to allow more accurate position and orientation sensing than was achievable with Polhemus equipment.

2 Automated VE Generation System

Development and incremental refinement has continued of the Automated VE-Generation System, which allows complex VEs to be constructed with significantly reduced manual effort from commonly available two-dimensional DXF floorplan files and mechanically acquired photorealistic texture information. A second prototype of the texture acquisition apparatus was designed and constructed, having a shorter distance of travel but more precise positioning ability. This second prototype will allow higher quality textures to be obtained in areas where fine detail is important, such as those containing textual signs and pictures. Also, its more compact envelope will allow it to acquire textures from smaller spaces, such as those associated with passage doglegs or cluttered environments. This will further assist in the primary goal of the automated VE-Generation System; to reduce the labor, time, and cost required to construct realistic VEs of complex spaces.

In order to illustrate and evaluate these savings, the Automated VE-Generation System and the second scanner prototype were used to create a new model of the 7th floor of our laboratory building, similar to the one used in the Koh experiments, but in VRML format. Quantification of the relative labor expenditure is difficult but a time saving of at least 50% was indicated.

3 World in Miniature

As indicated above, much of our effort has been focused on the use of a World In Miniature, or WIM, as a spatial training tool. A WIM is a supernormal artifact within a VE simulation, whereby a miniaturized representation of the entire virtual world is made available to the user as an object within the world, including the location and orientation of the user's avatar (see discussion of WIMs in Stoakley, Conway, and Pausch, 1995). Users are able to hold a motion-tracked physical representation of the WIM within their hands and move it in and out of the field of view and vary its position and orientation, in order to facilitate flexible examination, much as they would examine a 3-D map in the real world if such a map were available.

The WIM follows the user during movement through the virtual environment; the user may choose to have the WIM remain in view during movement, thus providing a real-time overview of the relative position of the avatar within the world, or may choose to alternate between hiding and showing the WIM as if storing and retrieving it from a pocket. The WIM tool that has been developed is a generic immersive simulation within DIVE, a collaborative VE system, that allows any VRML or DIVE model world to be equipped with a tracked WIM of itself and undergo real-time exploration by a user. An example shot of a user within the VE looking at the WIM is shown in Figure 1.

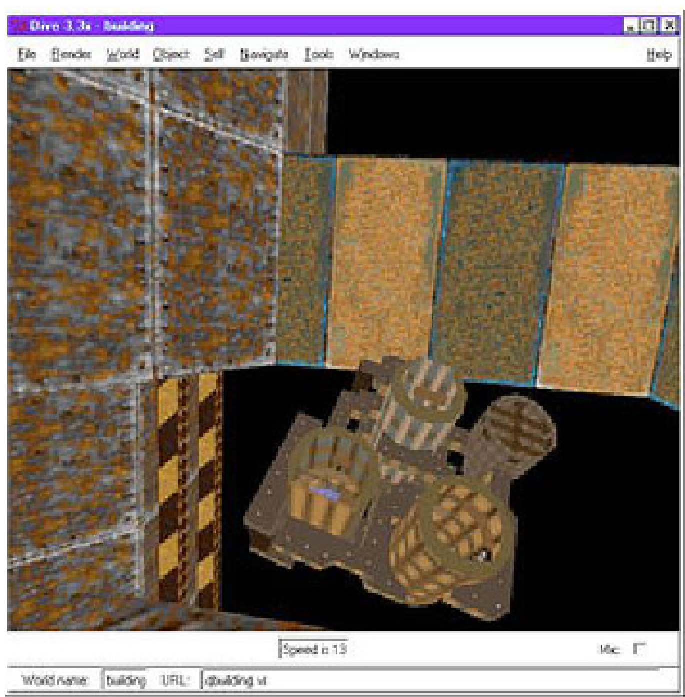

Figure 1: Example VE showing the WIM in the foreground

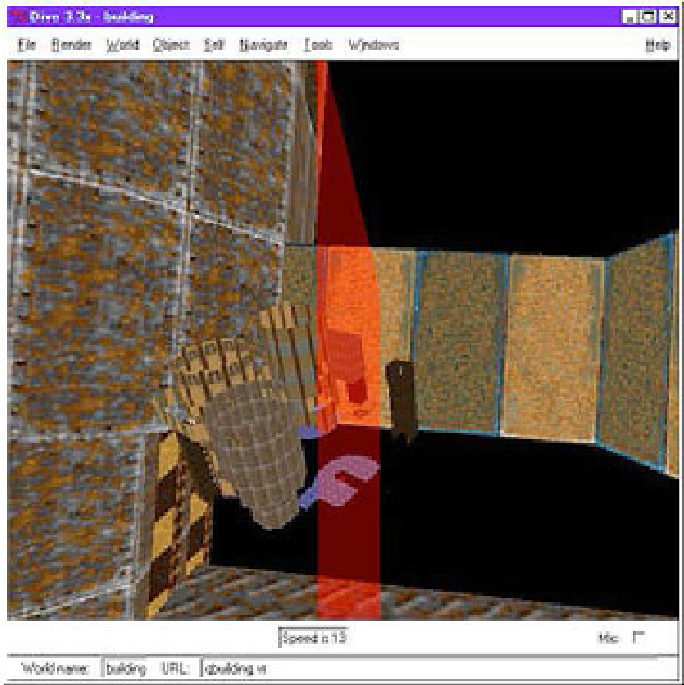

Figure 2: Removal of WIM detail using the saw

It is immediately apparent that a monolithic 3-D model of an indoor space would rapidly become quite useless as the level of complexity increases, due to occluding detail and the inherent difficulties in examining fine detail from an overview position. What separates our WIM from a simple virtual 3-D model of the space is that the user has the ability to disassemble it to further determine the substructure of the environment and localize the avatar. The current disassembly mode of the WIM is a transparent planar cutter or “saw” that is tracked with a hand-held physical analog just as in the case of the WIM. Wherever the saw intersects the WIM, the intersecting polygons are removed allowing the user to view the detail within. This enables the user to experience some kinesthetic feedback associated with distortion of the model, just as some kinesthetic feedback would be present when manually dissecting a real physical model. Figure 2 shows the example WIM from Figure 1 undergoing disassembly with the saw, and figure 3 shows a user immersed in the simulation, viewing the environment via a head-mounted display and operating the hand-held trackers for the WIM and the saw. Other WIM distortion modes are currently under consideration.

Figure 3: WIM simulation in use with HMD, WIM, and saw trackers

The development of the WIM will support experimentation into the usefulness of VEs in helping individuals acquire knowledge about specific spaces. Since maps are known to be an extremely useful real-world navigational aid, it seems likely that the inclusion of a three-dimensional WIM in a highly realistic VE could lead to a spatial training system that is extremely effective. The generic WIM simulator provides a platform for determining the effectiveness of such an approach to VE-assisted spatial training over a wide range of environments and a wide range of tasks to be performed in those environments.

4 References

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