Navigation through Virtual 3D Worlds for Facilitating Children's Spatial Orientation

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Abstract

Spatial orientation is an important ability which should be encouraged in geometry courses of elementary schools. A preferred approach (in Germany) typically involves navigation and wayfinding tasks with pictures of a town depicted in a book. The use of computer-generated, virtual 3D worlds for teaching spatial orientation raises (especially for computer scientists) the two following questions: 1. How effective are particular navigation techniques, aids, and motion controls for facilitating children's spatial orientation and therefore the navigation in virtual worlds? and 2. What trade-off between realistic features and computer performance is optimal? A virtual 3D-city, developed in an interdisciplinary project, acts as a testing environment to answer these questions. Preliminary results indicate differences between navigation techniques of children vs. adults. The results will also be important to designers of virtual 3D worlds as educational software in general, who need such information for improving children's navigation in 3D space.

1. Introduction

Together with a research group specializing in didactics of mathematics we (the authors) are developing an educational software to teach children (grades three and four) spatial orientation. Spatial orientation is the ability to find physically and mentally one's way in two- and three-dimensional space [6]. Encouraging spatial orientation is one important aspect of geometry in the mathematics curriculum of elementary schools in the state Nordrhein-Westphalia of Germany. It is an important ability for understanding, interpreting and developing the world in which the children live. Typical assignments for teaching spatial orientation are navigation and wayfinding tasks with perspective projections of three-dimensional buildings and two-dimensional city-maps depicted in a book. Therefore teaching spatial orientation means to teach children (grade three and four) the use of words like 'right'/'left', 'above'/'below' or 'in front of'/'behind', the relationship between two- and three-dimensional representations and map materials handling.

From the point of view of Computer Science our interest in the above educational software is the wayfinding and navigation process of children in virtual worlds. In general *navigation* can be understood as "the process by which people control their movement using environmental cues and artificial aids such as maps so that they can achieve their goal without getting lost" [2]. Whereas *wayfinding* is "the process of determining the strategy, direction and course needed to reach a desired destination"[5]. Associated with navigation are the terms navigation techniques, navigation aid and motion control. We define these terms as follows:

Navigation techniques describe concepts people use to navigate through an environment, for example navigating using environmental cues like landmarks or using map orientation. *Navigation aids* are artificial aids such as a map or a wind rose. *Motion controls* are the hard- and software components for moving through an virtual environment. Possible motion controls are the mouse combined with direction buttons, keyboard or joystick without visible software components.

Our interest in navigation and wayfinding of children in virtual worlds is to analyse how effective particular navigation techniques, aids, and motion controls for facilitating children's spatial orientation are.

A number of researchers have studied different aspects of navigation and wayfinding in immersive environments [2], [3], [8]. Other work focus on specific navigation aids like 'World-in-Miniature' [9], [7] or 'Worldlets', a three-dimensional miniature virtual world fragment displayed in a browsable guidebook [4].

There are also previous studies on motion control, both in immersive [1] and non-immersive environments [10].

In contrast with these pervious studies our work focuses on navigation and wayfinding in virtual 3D worlds as educational software for facilitating spatial orientation in elementary schools and therefore on young children (grades three and four), who haven't the experience of adults with such tasks.

2. Current and future work

We have modeled and implemented a virtual city with

VRML 2.0, the Virtual Reality Modeling Language. The city consists of a realistic structure and typical buildings and items. Animated objects such as a bus or a train enliven this virtual world.
Navigation through the city, along the streets, can be done interactively with various navigation aids, e.g.

- 2D-map (bird's view), which shows the actual position of the user in the city and optionally displays the path covered so far
- road signs and a hard-copy of the city map
- a wind rose for orientation with the four directions of the compass

Motion control is performed interactively by the standard mouse and direction buttons (forward, backward, left and right). It is implemented through viewpoint animation by automatically keeping the viewpoint at a fixed height.
A first informal study with ten children (grade four) and ten university students was performed to see behavior and reactions by navigating through the virtual city. In this study subjects were given different wayfinding tasks either with a fix navigation technique and appropriate aids or with free choice of the named navigation aids. During performing their tasks the subjects were asked "to think aloud". The comments were recorded by video and in written notes by the evaluator.
An unexpected result was that adults hardly used road signs and the city map as navigation aid. Their orientation during the wayfinding tasks occurred mainly through buildings with particular characteristics (e.g. function, size or color). An explanation may be the relative small number of streets and the great number of particular buildings. Also the experience with three-dimensional computer games might influence the behavior of the subjects. Mostly the navigation aid of such games are objects and directions. Children's navigation behavior was similar, but this was not unexpected, because they were not familiar with city maps and street names.
Differences between the children and the adults occurred when they were asked to remember objects of the virtual city after the study. The buildings mostly named by the children were (by decreasing frequencies): the museum with the dinosaur, school and church. In contrast to that the major buildings named by the adults were: grocery, petrol station and church, and museum. The answers show that children and adults use different landmarks for orientation dependent on subjective perception and the experience in daily life. Another important result was that subjects (both children and adults) often focused on the motion control (mouse and direction buttons) rather than on their tasks.
Based on our preliminary study and on previous results in literature we are planning further tests and more formal studies for developing adequate landmarks, navigation aids and motion controls for children to improve their spatial orientation in virtual worlds. We are currently implementing various motion controls to test and therefore better understand their effectiveness for children as compared to adults. It is obvious that worlds with different structures demand different navigation techniques and aids as well as motion controls. Therefore we are additionally planning two further worlds such as a virtual lake (a sparse world) and a forest (a cluttered world), both in contrast to the dense city, to explore the dependency of navigation aids and motion controls on the structure of a world.
One important demand of the didactics group is, that the virtual city must look lifelike and representative so that its use has an application to spatial orientation in the real world. On the other hand an adequate computer performance during navigation is paramount for the same reasons. We are testing various features that fake reality (e.g. animated buses or different levels of textures) in order to find the optimal trade-off between realistic features and computer performance.

References

1. Bowman, D.A., Koller, D.,and Hodges, L.F., "Travel in Immersive Virtual Environments: An Evaluation of Viewpoint Motion Control Techniques", *Proceedings of VRAIS'97*, pp.45-52, 1997.
2. Darken, R.P. and Sibert, J.L., "A Toolset for Navigation in Virtual Environments", *Proceedings of UIST'93*, pp.157-165, 1993.
3. Darken, R.P. and Sibert, J.L., "Wayfinding Strategies and Behaviors in Large Virtual Worlds", *Proceedings of CHI'96*, pp.142-149, 1996.
4. Elvins, T.T., Nadeau, D.R. and Kirsh, D., "Worldlets - 3D Thumbnails for Wayfinding in Virtual Environments", *Proceedings of UIST'97*, pp.21-30, 1997.
5. Elvins, T.Todd, "Wayfinding 2: The Lost World", *Computer Graphics*, Vol.31, No. 4, November 1997.
6. Maier, P.H., "Räumliches Vorstellungsvermögen - Komponenten, geschlechtsspezifische Differenzen, Relevanz, Entwicklung und Realisierung in der Realschule", Peter Lang GmbH Europäischer Verlag der Wissenschaften, Frankfurt am Main, 1994.
7. Pausch, R., Burnette, T., Brockway, D., and Weiblen, M. E., "Navigation and Locomotion in Virtual Worlds via Flight into Hand-Held Miniatures", *Proceedings of SIGGRAPH 1995*, pp. 399-400, 1995.
8. Satalich, G. A., "Navigation and Wayfinding in Virtual Reality: Finding Proper Tools and Cues to Enhance Navigation Awareness", Master Thesis, University of Washington, 1995.
9. Stoakley, R., Conway, M.J., and Pausch, R., "Virtual Reality on a WIM: Interactive Worlds in Miniature", P*roceedings of CHI'95*, pp. 265-272, 1995.
10. Strommen, E., "Children's use of mouse-based interfaces to control virtual travel", *Proceedings of CHI'94*, pp. 405-410, 1994.

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