Hybrid Traveling in Fully-Immersive Large-Scale Geographic Environments

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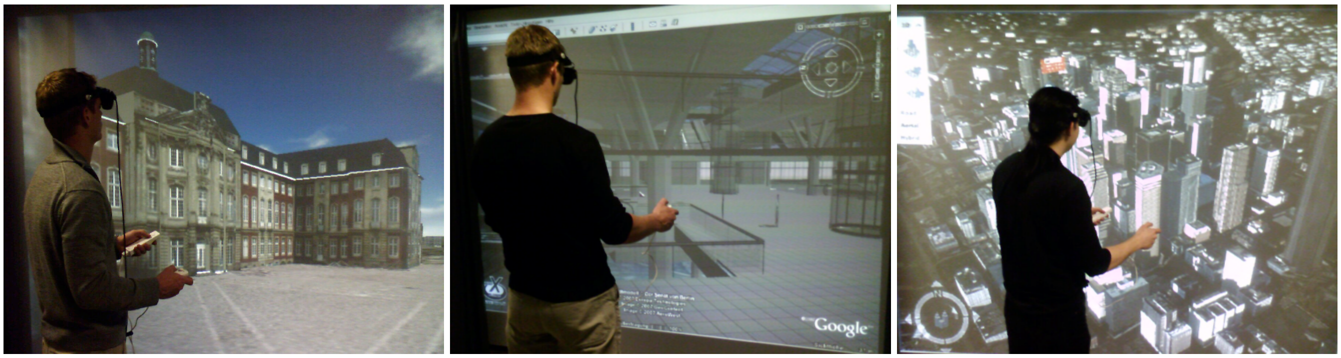

Figure 1: Using hybrid travel approaches (left) in outdoor pedestrian mode using scaled user movements in a 3D building evaluation system, (middle) in indoor pedestrian mode displayed in Google Earth, and (right) in outdoor mode in Microsoft Virtual Earth.

Abstract

In this paper we present hybrid traveling concepts that enable users to navigate immersively through 3D geospatial environments displayed by arbitrary applications such as Google Earth or Microsoft Virtual Earth. We propose a framework which allows to integrate virtual reality (VR) based interaction devices and concepts into such applications that do not support VR technologies natively.

In our proposed setup the content displayed by a geospatial application is visualized stereoscopically on a head-mounted display (HMD) for immersive exploration. The user's body is tracked in order to support natural traveling through the VE via a walking metaphor. Since the VE usually exceeds the dimension of the area in which the user can be tracked, we propose different strategies to map the user's movement into the virtual world intuitively. Moreover, commonly available devices and interaction techniques are presented for both-handed interaction to enrich the navigation process.

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Keywords: virtual reality, navigation, hybrid traveling

1 Introduction

Exploration and visualization of geospatial data is of importance in many areas, e.g., in tourism, disaster planning, urban planning and terrain exploration. Hence numerous 3D geospatial applications, e.g., Google Earth or Microsoft Virtual Earth, are available and on the rise. For these applications semi- as well as fully-immersive VR systems have proven their enormous potential [Bowman et al. 2004]. Usually immersion is supported by stereoscopic projection or immersive displays. However, most web-based geospatial applications do not natively support stereoscopic visualization and interaction in immersive VEs. The fact that specialized plugins, e.g., to integrate stereoscopy into Google Earth, are available and popular shows that there is a demand for these extensions. In order to improve the user experience in such environments it is essential to apply natural paradigms to explore the VE, or even better to overcome drawbacks and restrictions of the real world. The most natural way to travel through a virtual 3D city environment is to walk as a pedestrian, thus locomotion interfaces should be provided [Usoh et al. 1999]. Nevertheless navigation in VR is often performed by standard hand-controlled input devices in order to specify direction, speed and acceleration of movements. Extending navigation to support walking can be done by tracking the user's movements. An obvious approach would be to map the user's gaits one-to-one into the real world to the corresponding movements in the VE. However, the user's movements are usually restricted by a limited tracking area, and in most cases constrained by a small workspace in the real word. Below we present concepts to overcome such limitations.

2 System Setup and Framework

In this section we describe the framework and setup used to realize hybrid navigation concepts. In order to be able to process and manipulate data from any visualization application in a VR environment, we have developed a software framework [Steinicke et al. 2007], which gives us full control over the 3D data to be visualized. This framework enables us to control any 3D content rendered with OpenGL or DirectX. Virtual scenes used in such applications are usually organized by exploiting *display lists*, which contain several 3D rendering function calls defining the structure as well as the visual appearance of the VE. We can hijack the function calls and perform arbitrary state changes before rendering the display lists.

We explore different geospatial applications, e.g., Virtual Earth, with an *eMagin Z800 3D Visor* HMD with a diagonal field of view of only 40 degrees having SVGA resolution. Since this HMD is very lightweight, it can be worn comfortably even for a longer time period. It is connected to a laptop packed in backpack the user has to carry. Since the user should be able to freely walk in our lab we use an optical infrared-based tracking system. The tracking volume is about $5m \times 4m \times 2.5m$, and thus the user can walk within this area. When both cameras capture corresponding markers, this information is applied to the virtual world: the head position is mapped to the position of the virtual camera defined in any geospatial application. Furthermore, real hands and feet are mapped to the extremities of the user's virtual avatar which we can add to the display list defining the geospatial VE. In addition we exploit the *Nintendo Wii remote* in combination with the *nunchuk*. The nunchuck is equipped with a control stick with two DoF and two additional buttons. The Wii remote control supports four cursor buttons and six additional buttons, and auditive as well as simple haptic feedback. Since the entire communication is performed optical-based, by WLAN or BlueTooth, no wires (that connect devices to a host) disturb the user.

3 Hybrid Navigation Concepts

With the described framework we are able to modify any 3D content of geospatial applications. In particular, we can manipulate certain parameters of the virtual camera with respect to the tracked data by a one-to-one mapping, i.e., if the user moves one meter in the tracking coordinate system, this movement is mapped to a one meter movement in the VE. Although this canonical mapping allows a natural exploration, it has obvious limitations, since the area in which the user can interact is clearly smaller than the VE a user wants to explore. Hence, we map control stick movements of the nunchuk to corresponding movements in the virtual world. In order to further improve the performance when using the combination of Wii remote controller respectively the nunchuk and walking by feed, rotations constrained to the yaw axis can also be performed by using the Wii remote.

Rocket-Belt Metaphor

Walking as a pedestrian provides a very natural way of moving through a virtual environment. This way of movement is constrained by the natural phenomena of gravitation which restricts the user's activity area to the ground plane. To overcome this drawback we have implemented a *rocket-belt metaphor*, which allows virtual flying like using a rocket belt (see Figure 1 (right)). The Wii remote can be used to climb and descend, while the nunchuk determines the direction of flight. When pressing the up respectively down cursor button of the Wii remote the user climbs respectively descends, while the altitude does not change when no button is pressed. The climb can be further pointed out to the user by using auditive and haptic feedback supported by the Wii remote controller. This feature increases the user's notion of a rocket.

Visual Bookmarks

Since the amount of geospatial data is very large, (re-)localization of regions of interest can be a difficult task. In order to prevent a loss of orientation, we have integrated a bookmarking concept. The user can define two kinds of spatial bookmarks, *individual bookmarks* and *path bookmarks*. Individual bookmarks are markers positioned within the geospatial environment, which are easily accessible via *jump-to-bookmark* concepts, i.e., an interpolated flight along a B-spline from the current position to the selected region of interest can be initiated. Bookmarks can also be used to define a path through the geospatial environment. Therefore, the user defines the path once by tracking it manually or by specifying the control points defining the curve.

Scaled User Movements

In order to allow the user to explore a larger region by using walking, head movements or the described travling concepts using the Wii, the mapping between the user's action and the corresponding camera movements can be scaled. By using a non-uniform scaling vector $s = (s_{xz}, s_y, s_{xz})$, we map a relative real world movement vector $m = (x, y, z)$ to a virtual camera movement of $(s_{xz} \cdot x, s_y \cdot y, s_{xz} \cdot z)$. The scaling vector s can be configured manually via the buttons on the Wii remote. We apply the same scaling value s_{xz} to horizontal movements in the xz-plane, but optionally use a different value s_y for vertical movements. This enables the user to move fast over the earth's surface displayed by the application, whereas vertical movements change the view position of a pedestrian. Alternatively, the user might also use larger scaling values for vertical movements, which allows her to explore from a higher altitude or to zoom in.

In cooperation with psychologists we have revealed how large scaling values can be chosen such that users can still move comfortably. Among other factors, such as duration of the experiment as well as the user's personal skills, this depends on the *optical flow stimuli* presented to the user. Optical flow describes concepts about the motion of objects within a visual representation. The more objects are presented close to the user, the more optical flow is perceived by the user. Consequently the scaling vector must be chosen smaller in order to allow intuitive mapping of movements, where the user is not confused. We have experienced with different scaling components from 1 to 20 with respect to the optical flow. In geospatial environments, the flow is minimal on flat terrains whereas in the optical flow is maximal, for instance, in busy streets of houses. In this case the usage of small scaling values, e.g., 1 to 3, is beneficial, while less optical flow allows to use higher scaling values, i.e., up to 20, such that the user even might not recognize that her movements are transferred with a scaled mapping. Preliminary tests have shown that users learn to use these different mapping concepts very easy and fast. Hence, also larger scaling values may be appropriate, and the user may access these mappings and sense them as accustomed mechanisms after using them several times.

4 Discussion

The described setup and framework allows us to apply the introduced concepts for any 3D visualization application based on OpenGL resp. DirectX; we are not restricted to artificial environments designed for VR interaction purposes only, but the concepts are applicable in real world applciations.

Currently, the described scaling values have to be predefined manually with respect to certain areas in the VE regarding their potential optical flow. At present, we work on a mechanism to apply different mappings automatically, for example, by analyzing the optical flow using *images differential analyses*.

References

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