The *Through-The-Lens* Metaphor: Taxonomy and Application

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Abstract

In this work, we present a set of tools based on the through-the-lens metaphor. This metaphor enables simultaneous exploration of a virtual world from two different viewpoints. The one is used to display the surrounding environment and represents the user, the other is interactively adjusted and the resulting images are displayed in a dedicated window.

1 Introduction

Virtual reality applications are often employed in various scientific areas where large scenes are visualized and interactively explored. The navigation in virtual environments (VE) is a crucial task defining the usability and acceptance of the application it is integrated in. The interaction with virtual scenes is an important issue as well. This includes remote object manipulation, which proved to be a valuable companion for interaction in virtual worlds.

2 Through-The-Lens Concept

The main idea of a *through-the-lens*-tool (introduced in [3]) is to provide a viewpoint, additional to the one used to display the surrounding scene. The scene as seen from this additional viewpoint is shown in an *output window* W_o (as shown in Figure 1 and Figure 2). The user is surrounded by one of these worlds, called the *primary* world. The *secondary world* is the copy of the world viewed only through a *magic lens* [1] in the primary world, which displays images seen by a virtual camera in the secondary world.

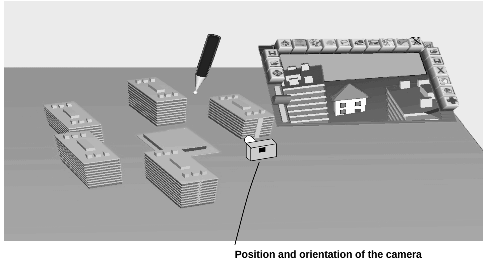

Figure 1. The secondary world can be explored only through a window in the primary world (in this case mapped on the interaction pad). The house visible in the secondary world exists in the primary world as well, however, it is not visible from the current viewpoint in the primary world.

The window in the primary world, through which the user views the secondary world is called *output window* (W_o). The virtual counterpart of this window in the secondary world we call *viewing window* (W_v). The primary and the secondary world, as well as the two viewpoints in each of these worlds may have different relations to each other.

Let us first consider the output window W_o. W_o can have three different states in the primary world:

- (case O1) fixed in the primary world;
- (case O2) fixed in the image plane of the user;
- (case O3) mapped onto an interaction pad that is held in the non-dominant hand of the user.

Regarding the additional viewpoint and the scene seen through the output window, there are also three conceptually different states of the secondary world:

- (case V1) the secondary world is fixed in the primary world's space;
- (case V2) the secondary world is fixed with respect to the viewing window;
- (case V3) the secondary world is fixed with respect to the primary viewpoint, which means that the secondary viewpoint is fixed in the secondary world.

Each of the states O1-O3 can be combined with each of the states V1-V3. Depending on the different states, various interaction concepts can be implemented.

3 Through-The-Lens Navigation Tools

The navigation tools we present in this work are inspired by the *eyeball-in-hand*, *scene-in-hand* [6], and WIM-techniques [2], but attempt to overcome their limitations: we do not apply the navigation to the primary viewpoint. Instead, we combine these tools with the above *through-the-lens* concept. In particular, we apply the manipulation described in the original techniques to the secondary viewpoint. Hence, the effect of the navigation is observed through the window, rather than applying direct transformation of the primary viewpoint. The following interaction tools are based on the pen and tablet paradigm described in [4].

TTL Scene-In-Hand The scene-in-hand technique provides a handle attached to the scene, where the translations and rotations of the handle are applied one-to-one to the scene. We start with two aligned viewpoints, which correspond to two aligned synthetic worlds. The user is able to manipulate the scene seen from the secondary viewpoint by grabbing a point of it and dragging it in the desired direction. When the secondary world is not attached to the interaction pen, this corresponds to the case O3V1 in the above notation.

TTL World-In-Miniature In contrast to the original WIM tool [2], with the TTL-WIM we do not map the miniature copy of the virtual world *on top* of the pad, but underneath the pad's surface. Thus, we create the impression of looking into the miniaturized world through a window defined by the pad on top of an imaginary box (case O3V2). The user interactively selects a region of interest dragging a box around it. The selection is made on the top of the bounding box. Afterwards the secondary world is appropriately scaled, providing a method for implicit navigation in the secondary world.

Proceedings of the IEEE Virtual Reality 2002 (VR'02)
1087-8270/02 $17.00 © 2002 IEEE

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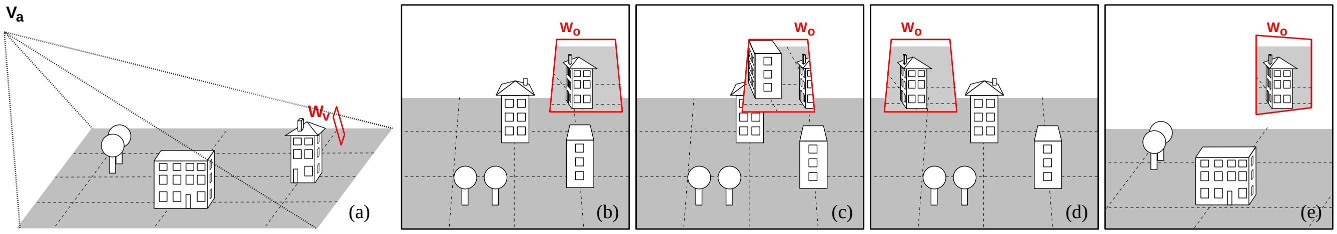

Figure 2. The position of the viewing window (W_v) is shown in (a). V_a is the current viewing position. In case the viewing window W_v is fixed in the secondary scene and the output window W_o is moved in the primary scene, the secondary scene moves with the viewing window as shown in (b) and (d). (c) and (b) illustrate the "scene fixed in space" scenario (O3/V1) with the secondary scene frozen in the space of the primary world. Detaching the secondary viewpoint from the primary, allows the user to travel the primary world, while staying at the same position in the secondary world (compare (b) and (e)).

TTL Eyeball-In-Hand Even though, the original eyeball-in-hand metaphor is simple to understand and requires a simple mental model of the scene, its limitations, like application radius and often caused user disorientation, make it unsuitable as a sole navigation technique. In order to circumvent these limitations, while still supporting the features of this metaphor, we introduced a preview window to the eyeball-in-technique.

The pen held in the dominant hand is used to explicitly define the secondary viewpoint (position and orientation) in the surrounding virtual environment. The scene, seen from this viewpoint, is displayed in the output window, which is mapped on the interaction pad. This tool implements the case O3V1 in the above notation when the camera is not attached to the interaction pen.

Entering the Secondary World Once the adjustment of the additional viewpoint in the secondary world is accomplished, the new location can be entered, thus providing navigation capabilities. In order to enter the secondary world as seen from the additional viewpoint, the user has to move the pad towards the face until the window W_o completely covers the viewing area. For this, the secondary world has to be fixed in the coordinate space of the primary world (O3V1).

4 TTL Manipulation of Remote Objects

We have shown in the previous section how the secondary world viewed through the output window can be adjusted such that a target location is viewed through it. After accomplishing this adjustment, the tracked stylus can be used to interact with remote objects. In this scenario, the secondary world has to be fixed with respect to the primary world's space (case O3V1). The user can now manipulate objects in the secondary world by reaching with the stylus into the frustum volume defined by the lens and the current viewpoint. If the stylus is outside this volume, it acts in the local environment in the normal way.

The change of context applied when the stylus is moved can be exploited to teleport an object between locations by drag-and-drop operations between volumes. As soon as the interaction pen and an object picked with it leave the view volume described above, the object is dragged to the primary world. Now the object can be manipulated and put back to its original remote location.

In a slightly more complex scenario, objects can be even transferred between *multiple* remote locations with drag-and-drop operations. In this way, the user can assemble a complex scene with fine details without having to change the viewing position in the primary world, while still being able to examine the scene from different viewing positions.

5 Conclusions

Although each of the proposed techniques has some limitations, the combination of all of them provides a powerful toolkit for exploring distant locations in virtual worlds. The set of all proposed techniques allows for covering all navigation categories [5]: searching, exploration, and maneuvering.

The application of the through-the-lens concept for navigation in virtual environments provides a powerful mechanism for implementing preview-enriched tools. This concept allows for exploring distant locations or hidden features of the virtual world surrounding the user, without having to virtually or physically fly/walk to the remote location.

Additionally, the proposed through-the-lens technique was also applied for manipulating distant objects, while still at their original location in their natural environment. It provides a universal technique for working with objects out of the user's physical reach and proved to be a valuable tool for assembling virtual worlds.

The proposed techniques have shown in informal trials with experienced and novice users that the underlying TTL concept is very intuitive and easy to use. Although it does not have a counterpart in the real life, we achieved convincing performance results applying the described TTL tools.

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