Immersive Virtual Studio for Architectural Exploration

Gerd Bruder[*]   Frank Steinicke[†]   Dimitar Valkov[‡]   Klaus Hinrichs[§]

Visualization and Computer Graphics (VisCG) Research Group
Department of Computer Science
University of Münster
Einsteinstr. 62, 48149 Münster, Germany

Figure 1: Virtual studio: (a) modified video-see-through eMagin Z800 head-mounted display, and (b) augmented virtual self-representation (inset showing augmented virtual view), (c) augmented virtual desktop workspace (left inset showing applied green and blue color key segmentation, right inset showing applied green color segmentation only), and (d) markers used to place and combine designs.

ABSTRACT

Architects use a variety of analog and digital tools and media to plan and design constructions. Immersive virtual reality (VR) technologies have shown great potential for architectural design, especially for exploration and review of design proposals. In this work we propose a virtual studio system, which allows architects and clients to use arbitrary real-world tools such as maps or rulers during immersive exploration of virtual 3D models. The user interface allows architects and clients to review designs and compose 3D architectural scenes, combining benefits of mixed-reality environments with immersive head-mounted display setups.

Keywords: 3D user interfaces, virtual studio, mixed reality.

Index Terms: H.5.1 [Information Interfaces and Presentation]: Multimedia Information Systems—Artificial, augmented, and virtual realities I.3.7 [Computer Graphics]: Three-Dimensional Graphics and Realism—Virtual reality

1 BACKGROUND

Modern computer-based media have shown to be useful throughout architectural design processes and the life cycle of architectural constructions. In the last stages of the architectural design process, analog as well as digital models give architects and clients a good impression of the final result. In this context, immersive virtual environments (IVEs) have great potential to enhance architectural design. In IVEs users get a natural impression of virtual 3D designs from a realistic point of view via head-tracking, which allows them to turn and move their heads to explore the 3D models. In

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[*]e-mail: gerd.bruder@uni-muenster.de

[†]e-mail: fsteini@uni-muenster.de

[‡]e-mail: dimitar.valkov@uni-muenster.de

[§]e-mail: khh@uni-muenster.de

head-mounted display (HMD) environments users can explore 3D models at real scale by walking [10] or flying [1] through the virtual space. Recently developed user interfaces based on redirected walking [6] allow users to explore large virtual scenes on foot while walking in the restricted area of a VR laboratory. With information about the structure of virtual scenes, specifically in the context of architecture, large models can be subdivided in cells of approximately the size of the laboratory room, and explored sequentially using virtual doorways and portals as means for redirection, which ensure that the user does not collide with obstacles in the real world (cf. the Arch-Explore user interface [2]).

In the context of mixed reality environments, video-see-through HMDs provide application developers with the ability to combine views from the real world with rendered views to a virtual environment (VE). Using simple color keying approaches [5, 9] (cf. chroma keying), all areas of the camera images that show specific colors (such as green or blue) can be replaced by parts of a virtual scene. Virtual studios consisting of surfaces or entire rooms colored in green or blue allow effective background segmentation in a video-see-through HMD setup, such that these studios are applicable for VR-based training applications that require users to be able to see their own body and real-world equipment [4]. In these setups usually all areas of a camera image with the specific color are replaced with a corresponding virtual scene. Such virtual studios have great potential for architectural design, since they allow users to explore a 3D model from an ego-centric perspective, plus they enable users to see their own body and other real-world objects (such as rulers, pencils and sheets of paper) while they are immersed in the VE.

2 VIRTUAL STUDIO

We masked walls, floor and ceiling of our laboratory room in a green color suitable for color keying. Users are equipped with a video-see-through HMD, which captures camera images of the real surroundings and displays parts of these images to the user in real-time. Tracked position and orientation of the HMD in the room are used to render a view to a VE, and to align the virtual view and the camera images. We used the hardware and software setup as

introduced in the Arch-Explore user interface [2], and we adapted the eMagin HMD for video-see-through support using cameras (see Figure 1 (a)).

Visual Feedback

To mix the camera images showing the real world with a view of a virtual scene, we use a color keying approach that allows to combine real and virtual views in real time, and which limits the requirement for controlled room illumination [3]. Segmentation of foreground objects from the background works effectively as long as the background color does not occur in the foreground objects. We combine the real and virtual view by superimposing the segmented foreground pixels over the view to the virtual world using simple alpha blending. Since the cameras of the video-see-through HMD capture the real world in accordance to the position and orientation of the virtual view, the user is able to look down at his body and see a spatially stable representation of himself (see Figure 1 (b)). Recent studies motivate that the ability to see one's own body can enhance the user's sense of presence [3] and performance in distance judgment tasks [7]. In contrast to full-body motion tracking systems, which usually require the user to wear a motion capture suit and only provide a generic virtual body, virtual studios allow to display a user's actual body in a VE.

All real objects located in the virtual studio can be displayed to the user if their color can be distinguished from the uniform surroundings. However, in many situations it is not suitable to display all real objects at all times, e. g., in order not to disturb the impression of a 3D model. Therefore, we adapted the color keying algorithm [3] to separately display or hide real objects based on their color range. Figure 1 (c) illustrates a desktop workspace masked in blue, which can be displayed or hidden from the user's view. However, a stable segmentation is guaranteed only if these colors do not occur in the other objects that shall be displayed, such as the user's body.

Interaction

Besides mixing real and virtual views, video-see-through HMDs also allow optical marker tracking, such as using ARToolKit Professional. This results in a two-step tracking system: While the absolute position and orientation of the HMD is tracked in the virtual studio, ARToolKit supplies the relative position and orientation of markers as captured from the HMD-mounted cameras. ARToolKit markers are usually colored in black and white, however, we use markers colored in green (the color of the background in the virtual studio) and shades of blue, which does not significantly impact the ability to track the markers, but allows us to display or hide the markers conditionally to the user using the previously described color keying approach (see Figure 2 (a)).

We compute the absolute position and orientation of the markers in the virtual studio that are in the user's view, which we use to display assigned and aligned 3D models (see Figure 1 (d)). This allows users to experience a 3D model from an ego-centric perspective in the virtual studio, while being able to perform small changes and arrange components in the studio room via ARToolKit markers. For instance, this allows users to furnish rooms of a virtual building model using ARToolKit markers. Since we can conditionally display or hide ARToolKit markers from the user's view due to the color keying approach, this allows to display markers only in specific rooms or spaces of a virtual building model (cf. [2]), providing users with consistent and persistent use of markers.

In addition, we evaluate attaching ARToolKit markers to physical tools, which allows to track their position and orientation, and can be used for tool-specific interaction metaphors within the VE. Tracking position and orientation of physical objects such as the floor plan shown in Figure 2 (b) enables us to augment this information, helping the architectural design process. We further evaluate

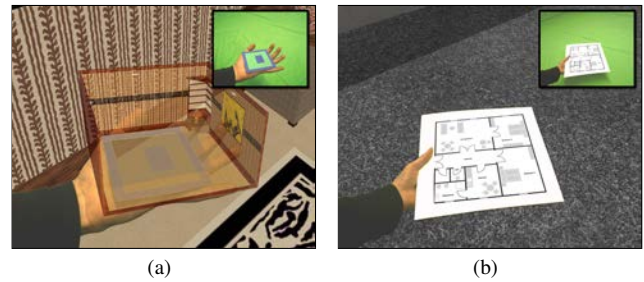(a)   (b)

Figure 2: Augmented working environment: (a) hand-held marker used to display a *worlds in miniature* 3D model, and (b) user reading a floor plan while being immersed in the virtual model. Insets show the real-world view.

using ARToolKit markers to provide users with a *worlds in miniature* [8] view of segmented parts of a virtual scene as illustrated in Figure 2 (a).

3 CONCLUSION AND FUTURE WORK

In this work we described a mixed-reality user interface for architects and designers to explore and design virtual 3D constructions. In the future we will pursue 3D interaction more deeply, providing architects with versatile 3D design tools, as well as simple and easy to use tracked physical tools for users to interact with a virtual model.

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