Combining Realities
Designing with Augmented and Virtual Reality

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Abstract: Augmented Reality (AR), the layering of reality and virtuality, can be used as a tool in architecture in model scale as well as in 1:1 scale on site. By combining real architecture models with virtual representations like e.g. wind simulation an intensive understanding for impacts can be observed. Coupling AR with further virtual environments (AR and Virtual Reality) in one scenario makes AR a tangible interface for VR and on the other hand supports the group discussion of distributed teams.

Keywords: Augmented Reality, Virtual Reality, Visualization, Interaction, Simulation

Introduction

Sketches, models, renderings and animations are well known methods for representing planned architecture. Computer technologies like Augmented Reality (AR) and Virtual Reality (VR) extend these methods in a way that allow representations and interactions beyond "real reality" (RR).

Each of these representations has its specific advantages and disadvantages. Additional benefits can be observed by coupling the technologies, by e.g. coupling RR with VR (that is AR), VR with VR or AR with VR. This allows picking out the specific interaction or representation advantages of each technology and combining them in a complementary way.

Augmented Reality as a standalone application

Whereas the number of project reviews using VR is quite large, there are only a limited number of project reviews using AR (some samples see http://www.hitl.washington.edu). However these reviews, especially on site, provide important sensory information of the surrounding. Due to the haptic experience while holding a physical model or moving around real objects, it is often easier for inexperienced users to interact with AR applications.

Visual interfaces and tracking

The visual interface and tracking are the main components in AR. Two different setups have been uses depending on the scenario:

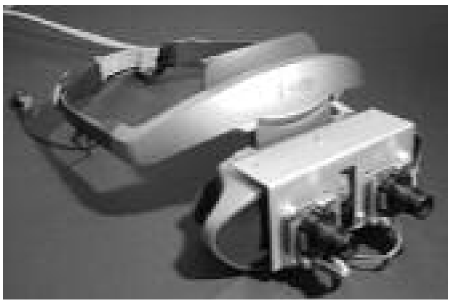

Figure 1. Cy-Visor with attached PAL cameras

A head mounted display, the Cy-Visor with attached PAL-cameras (see fig. 1)

A consumer DV camera connected via Firewire and a standard monitor.

The Cy-Visor with stereoscopic images for left and right eye is mainly used for single user review of models in a short distance, whereas the standard monitor fits better with group reviews.

Tracking is currently based on the ARToolKit of the Hitlab, University of Washington (Billinghurst & Kato, 1999). Markers positioned in a model (see fig. 2) or on site (see fig. 3) provide the necessary information to match and overlay the virtual and the real image.

on top of the video picture and thus always occlude virtual objects. By modeling parts of the real world and rendering them invisible, virtual objects look as if they where occluded by the real world object.

Scenario 1:

AR as a stand-alone application - model scale

AR as a stand-alone application is successfully used for:

Switching through various digital model alternatives (see fig. 2)

Overlaying architecture models or real world with scientific simulation results (see fig. 5b)

Figure 2. Virtual model in real architecture model scale 1:500. a) model with marker b) variant 1 with marker c)variant 2 occluding marker.

Software and data import

The software used for AR and VR is COVISE/COVER (Rantzau, D. et al., 1998). ARToolkit has been seamlessly integrated. The markers and thereby transformation matrices between marker and camera are used to either adjust the viewpoint or to move / rotate virtual objects.

The model geometry is described in VRML97 data format. Custom VRML nodes have been created to use VRML for AR applications. "ARSensors" act similar to traditional plane or cylinder sensors. Their output can be routed to transformation or script nodes and thus VRML objects can be positioned and oriented in six degrees of freedom.

The "coDepthOnly" group node renders invisible objects. Virtual objects are always rendered

To visualize the possible constraints of an urban design as well as switching through different alternatives, a partly finished architecture model is used to project the planned urban structure into the existing surrounding. A marker in the center of the site gives position, scale and orientation of the scene.

Figure 3. a) Setup of AR on site. b) Image recorded from camera with large visible marker. c) Same image in AR overlaid by virtual landscape.

Switching through the alternatives is done through keyboard input. Additional information and objects (like moving cars, etc.) are rendered together with the buildings. A rough model of the surrounding acts as an invisible occluder. Especially non-experienced users appreciated the easy and intuitive interaction.

Scenario 2: AR as a stand-alone application - on site 1:1

A similar setup is used for AR on site. Difficulties are the inaccuracy of the tracking, the moderate resolution of standard video cameras (720 x 576 pixels) and the small field of view of head mounted displays. Further tests have to be made to overcome these constraints. However one of the big advantages is, that one is getting more sensory information about the surrounding (smell, sound, etc.) than in VR.

Coupling virtual environments (AR and VR)

By coupling two or more virtual environments (like e.g. AR models, CAVEs or curved projections) the group collaboration aspect of distributed teams is supported. Collaborative sessions can be initiated through a web interface. A central server (VR broker - VRB) distributes messages between the virtual environments and provides a session management.

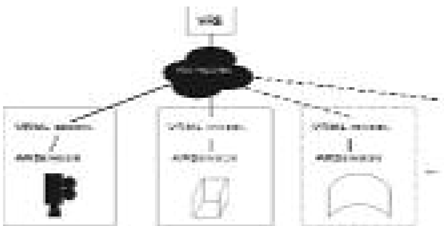

Figure 4. Scheme: VRB (VR broker) software coupling several AR and VR environments (like CAVE, curved powerwall, ...).

Scenario 3: Collaborative AR, VR and simulation

Scenario 3 combines the current work in AR - coupling AR with AR, AR with VR as well as AR and VR with simulation.

To overcome part of the shortcomings of augmented reality techniques like registration errors, latency issues and narrow field of view of typical HMDs a combination of AR and VR can be used with AR acting as tangible interface (Weller 1993, Fritzmaurice et al. 1997). Fig. 5a shows models of buildings in an urban context. Different markers on the model are used to represent either architectural elements (like fountain, roof, etc.) or simulation analysis (like particle traces).

By placing a marker into the model, the referenced virtual elements are placed in the scene. Removing the markers removes the virtual elements. Moving and turning the markers position

Figure 5. a) Two identical models for collaborative AR. b) representation on monitor from camera above model.

the virtual objects positioned accordingly. The position and orientation of the markers is tracked with the camera and the rendered objects are overlaid over the image captured by the camera (Fig. 5b).

The transition and rotation is transferred to the other AR setup (fig. 6a) as well as the CAVE environment (fig. 6b). Here the users can evaluate

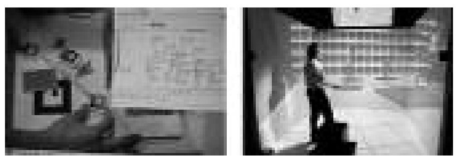

Figure 6.a) Screen of second AR model with COVISE interface b) AR elements and simulation shown in the CAVE.

the setting at scale 1:1 while other users can interact with the markers. The interaction in AR compared to interaction in a CAVE is intuitive and performed without any problems even by novice users. Many users realized how different the perception of space is between a model (small scale) and real scale space representation in the CAVE.

Showing just the visual appearance in architecture models is only a subset of what can be represented. The functionality of the building also has to be evaluated and thus has to be visualized. Airflow simulations for example can show thermal comfort as well as pollutant distribution. In this scenario, we overlay simulation results of computational fluid dynamics (CFD) over the architecture model (in AR) as well as the virtual model (in the CAVE). The CFD code is tightly integrated into COVISE and with the availability of high performance clusters changes can be calculated nearly in real-time. Thus the user is literally able to grasp the idea behind the model.

Conclusion and outlook

By applying the right combination, these technologies can support architects and planners in their work. Although using the same software basis, AR and VR are very different. Especially the interaction in AR is much more intuitive compared to VR. Issues in AR are on the one hand the display technique with its limited resolution and field of view and on the other hand the tracking accuracy. That's a field where the authors will put further effort.

Combing AR with VR has proven to be a very good way to combine traditional working methods with new technology. Especially inexperienced users can interact very fast. The difference of perception between the model and the 1:1 scale even for experienced architects is astonishing. This should be part of every architect's education to get a feeling for how the architecture built in a model would look like if built. Despite the current technical limitations, AR has the potential to become one of the key technologies for architecture, as it is a tool, which can be used in the office as well as on site or in a workshop.

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