Dollhouse VR: A Multi-view, Multi-user Collaborative Design Workspace with VR Technology

Hikaru Ibayashi[1]* Yuta Sugiura[2]* Daisuke Sakamoto[1] Natsuki Miyata[2] Mitsunori Tada[2]
Takashi Okuma[2] Takeshi Kurata[2] Masaaki Mochimaru[2] Takeo Igarashi[1]

[1]The University of Tokyo [2]National Institute of Advanced Industrial Science and Technology (AIST)

Figure 1: *Dollhouse VR interface (center) for asymmetric collaboration with two different views and interaction styles. Top-down view for the designers (left) and immersive view for the occupants (right).*

1 Introduction

This research addresses architecture-scale problem-solving involving the design of living or working spaces, such as architecture and floor plans. Such design systems require two different viewpoints: a small-scale internal view, i.e., a first-person view of the space to see local details as an occupant of the space, and a large-scale external view, i.e., a top-down view of the entire space to make global decisions when designing the space. Architects or designers need to switch between these two viewpoints to make various decisions, but this can be inefficient and time-consuming. We present a system to address the problem, which facilitates asymmetric collaboration between users requiring these different viewpoints. One group of users comprises the designers of the space, who observe and manipulate the space from a top-down view using a large tabletop interface. The other group of users represents occupants of the space, who observe and manipulate the space based on internal views using head-mounted displays (HMDs). The system also supports a set of interaction techniques to facilitate communication between these two user groups. Our system can be used for the design of various spaces, such as offices, restaurants, operating rooms, parks, and kindergartens.

∗ Hikaru Ibayashi and Yuta Sugiura are joint first authors

SA'15 Emerging Technologies, November 02 – 06, 2015, Kobe, Japan.
ACM 978-1-4503-3925-4/15/11.
http://dx.doi.org/10.1145/2818466.2818480

2 Related Work

Our work stands on research in tabletop computing and immersive environments. Regarding tabletop computing, we were inspired by Underkoffler et al. [1999], who demonstrated a tangible interface that simulates architecture using environmental information (like winds), and Rekimoto and Saitoh [1999] who presented an augmented surface that supports the design of a virtual three-dimensional (3D) environment with physical objects and a large display. Our contribution is to integrate an internal view into such a design system using a HMD and provide communication between the designers and occupants.

Regarding immersive environments, our main inspiration comes from the world-in-miniature (WIM) technique, which allows efficient navigation and manipulation of a virtual environment for a user with a head-mounted display using a miniature model of the environment held in one hand [Stoakley et al. 1995]. We map this miniature model to the tabletop surface and use it to communicate with users outside the virtual environment.

3 Dollhouse VR

Our system consists of a multi-touch tabletop device and HMDs (Figure 1, Center). The tabletop device provides a top-down view for designers and the HMDs provide internal views for occupants. We first explain the main user interfaces for these two groups of users, and then explain the interaction techniques that connect them.

3.1 External and Internal Views

The external or top-down view is provided on a large tabletop interface and allows designers to manipulate the space, such as by changing the layout of the space in the 3D virtual environment (Figure 1, Left). Designers are able to manipulate the space as if they were playing with a “doll's house”. We assume that multiple designers use this interface simultaneously. All interaction involves touch interaction (dragging or tapping on the interface).

The internal view provides a first-person view of the virtual environment to its occupants (Figure 1, Right). Occupants see the environment using a HMD.

3.2 Interaction to Facilitate Communication

It is critical to achieve fluent, efficient communication between the two user groups. Communication with other people in an immersive environment is particularly difficult because a HMD covers the user's face, especially the eyes, making it difficult to support natural face-to-face communication. To alleviate this problem, we introduce two interaction techniques to facilitate communication between the users. Our goal is to provide awareness of users' locations and their actions in the space.

3.2.1 See-through Ceiling

We made the ceiling of the virtual space transparent and use it as a communication channel between the designers and the occupants. From the designers' perspective, they can see the occupants moving around in the space through the ceiling. The head orientation of an occupant is visualized as the head orientation of the corresponding virtual character (doll) in the space. This allows the designers to see the occupants' behavior and intentions based on their head and finger motions. The occupants can see the designers' faces by looking up at the ceiling. The designers' faces are captured by a camera mounted on the tabletop device, and the captured view is mapped to the ceiling (Figure 1, Right). If an occupant wants to speak to a designer, the occupant looks at the designer's face. The designer can also look at the occupant to establish a social communication channel. This allows natural awareness of the designer's location, and facilitates natural, efficient communication.

3.2.2 Pointing Target of Interest

The see-through ceiling allows both user groups to see the other users' viewing orientation. However, it is also desirable to see the users' finger orientations to infer their intentions more precisely. Therefore, we track users' finger positions and show them to the other users. Tracking of a designer's finger is straightforward, as the touch-sensitive tabletop device detects finger positions. We then follow the "God-like" interaction technique [Stafford et al. 2006], which the system visualizes designer's finger as a large one coming down from the ceiling in the immersive view for the occupants (Figure 2). In this way, an occupant can easily recognize what the designer is pointing at or manipulating.

An occupant's finger is traced using a smartphone as a touch sensor attached to the HMD (Figure 3). If the occupant wants to point at an object in the immersive environment, the habitant simply touches the corresponding position on the frontal surface of the HMD (more precisely, the occupant touches the intersection between the HMD screen and a line connecting the occupant's eye and the target). The designers then see the occupant's finger orientation via the posture of the doll, which points to the target using its arm.

4 Implementation

Our current implementation is mainly designed for furniture layout for restaurants. We created the Dollhouse VR system with Unity 5 on a laptop computer (Windows 8 on Microsoft Surface). A HMD (Oculus lift DK2) and a large interactive tabletop display (Iiyama ProLite T2735MSC) are connected to the laptop computer, which shows the immersive view to the HMD and the top-down view to the tabletop display. The two applications are connected to share information on furniture positions. We collected 3D furniture models

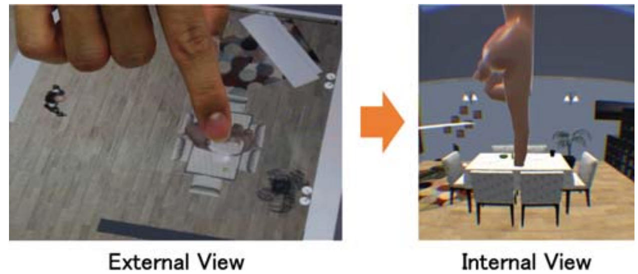

Figure 2: *The system visualizes large finger coming down from the ceiling in the immersive view for the occupants.*

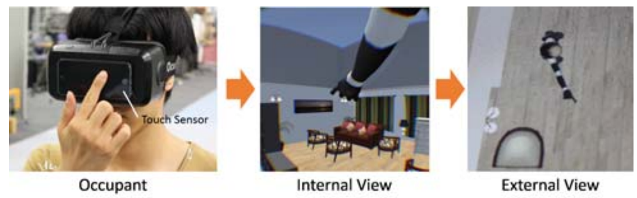

Figure 3: *The occupants can point out objects in VR environment by touching the frontal surface of the HMD.*

from Unity asset store and arranged them in a virtual house model. A physical engine is used to handle collisions. A smartphone is attached to the HMD to allow a occupant to point to an object in the virtual environment directly to show their intentions. The smartphone is connected to the laptop via a wireless network (WiFi).

Acknowledgements

This work was supported by CSTI, SIP (Innovative design/manufacturing technologies).

References

REKIMOTO, J., AND SAITOH, M. 1999. Augmented surfaces: a spatially continuous work space for hybrid computing environments. In *Proceedings of the SIGCHI conference on Human Factors in Computing Systems*, ACM, 378–385.

STAFFORD, A., PIEKARSKI, W., AND THOMAS, B. 2006. Implementation of god-like interaction techniques for supporting collaboration between outdoor ar and indoor tabletop users. In *Proceedings of the 5th IEEE and ACM International Symposium on Mixed and Augmented Reality*, IEEE Computer Society, 165–172.

STOAKLEY, R., CONWAY, M. J., AND PAUSCH, R. 1995. Virtual reality on a wim: interactive worlds in miniature. In *Proceedings of the SIGCHI conference on Human factors in computing systems*, ACM Press/Addison-Wesley Publishing Co., 265–272.

UNDERKOFFLER, J., ULLMER, B., AND ISHII, H. 1999. Emancipated pixels: real-world graphics in the luminous room. In *Proceedings of the 26th annual conference on Computer graphics and interactive techniques*, ACM Press/Addison-Wesley Publishing Co., 385–392.