Asymmetric Interaction between HMD Wearers and Spectators with a Large Display

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Figure 1: Example of the spectator view. Left: semi-immersed user exploring the virtual environment and interacting with motion controllers. Right: HMD wearer exploring the same environment, and communicating with their partner through voice and pointers.

Abstract

Head-mounted displays (HMDs) provide the wearer with a highly immersive virtual reality experience, but they obstruct communication with the outside world. This makes it difficult to communicate or share the virtual experience with viewers outside of the headset. The aim of this project is to develop a better spectator solution for collaborative tasks and demonstrations. We propose an approach which allows the spectator to take control of their viewing experience and interact with the HMD user in a natural way. They are able to control their own camera and point in the virtual world. This interaction enables spectators to effectively communicate, collaborate, and feel semi-immersed without the need to wear a HMD.

Index Terms: Human-centered computing—Interaction paradigms—Virtual reality; Human-centered computing—Interaction paradigms—Collaborative interaction;

1 Introduction

In this paper, we present a method which allows the user of a head-mounted display (HMD) to communicate and collaborate with people outside of the headset. The solution targets scenarios like live presentations or multi-user collaborative systems, where it is not convenient or cost-effective to develop a VR multiplayer experience and supply each user with an HMD. The most commonly-used solution for spectating VR in these kinds of scenarios is display mirroring, where the HMD user's perspective is shown on an external screen. Our goal was to improve upon this second-hand spectating experience by providing the viewers with their own camera control and means of interacting with the virtual world. We propose an approach that allows a spectator to take part in an experience with an HMD wearer with an asymmetric VR setup. We render the virtual world in a large-scale tiled video wall, where the spectator can either follow the immersed user's point of view or freely look around the environment. To improve collaboration between users, we implemented a pointer system, where the spectator is able to point at objects on the screen and place a marker directly into the virtual world. We performed a user study that shows that the proposed approach positively contributed to the ease of communication between users and was considered useful. Our contributions are summarized as follows:

- System implementation of our approach covering display set-up, camera control, and virtual interactions.
- A user study that analyses how well the system works in a collaborative setting.

2 Spectator View Implementation

Our spectator view implementation consists of two parts: the large screen immersive display set-up and the interactions with the virtual world. The virtual interactions include controlling camera orientation and mapping a pointing gesture from the screen into the virtual environment. In our implementation, the spectator is not able to control their spacial position, only the orientation of their camera.

2.1 Large Scale Immersive Display

The large scale immersive display was configured to make the spectator's experience closer to that of the HMD wearer. This was accomplished by arranging eight 55-inch displays in a 4×2 grid, increasing the spectator's horizontal field of view (FOV) to match the wide-angle perspective provided by the HMD. The displays were also arranged on a slight curve, which has the benefits of increasing spacial presence [2] and reducing viewing angles [1].

2.2 Camera Control and Interaction

The spectator is given two motion controllers. One is used for camera control, and has two buttons. The first button is the trigger, which gives the spectator control over their camera's rotation when held down. The "eyeball in hand" [3] motion tracking method

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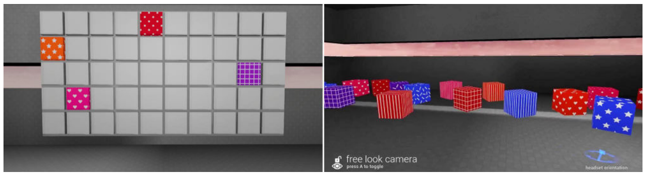
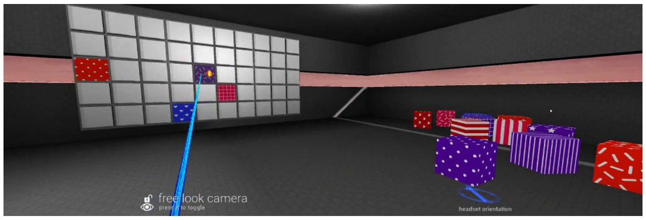


(a) Left: The test grid, as shown in one of the printed sheets given to the spectator. Right: The cubes in the room.



(b) The VR user places a cube into the grid. The orange sphere in the centre of the grid is the spectator's marker which indicates where they are pointing.

Figure 2: Virtual environment for the user study.

was implemented, where the spectator takes control of the virtual camera as if it were held in their hand. The other button toggles free-cam mode, which sets the behaviour of the camera when the spectator is not controlling it. If free-cam mode is disabled, the camera snaps back to following the VR user's perspective when the spectator releases the trigger. If free-cam mode is enabled, the camera stays where the spectator left it. This allows the user to perform "ratcheting" motions to turn the camera around fully without having to maintain an uncomfortable hand position.

The spectator is able to interact with the virtual world with the second motion controller. If they hold the trigger on this controller and point it at the display like a laser pointer, a virtual marker is spawned in the virtual world on the object they are pointing at.

2.3 Task Design

To evaluate our system, we designed a collaborative task to be completed in pairs. One participant uses a HMD, and the other acts as the spectator. The virtual environment is a square room with a large grid on one wall. The other walls display 40 unique moving cubes with various colours and patterns (Figure 2(a)). The VR user is able to pick up these cubes and place them in the grid (Figure 2(b)). The spectator was provided with a printed screenshot of the grid with four cubes placed in it (Figure 2(a)). The goal for the subjects is to find the cubes which were displayed in the screenshot and place them in their corresponding locations. To avoid users memorizing the room layout, the virtual cubes were randomly placed at the beginning of each trial.

3 Results

We conducted a quantitative study where 24 participants (75% male, age range of 20-30 except one above 30) completed the collaborative task. We measured the duration of each trial and how long each tool was used. There were two independent variables which were either enabled or disabled in each condition: the spectator's independent camera (C = enabled) and the pointer tool (P = enabled). In the baseline condition (B) the spectator used basic display mirroring. We had 20 participants in the study, who all completed one trial for each condition in each role. We found that users were able complete the task on average 13% faster when the pointer tool was enabled. We also found that users put the available tools to use, averaging at 31% of the time (7% standard deviation) throughout all conditions. The summary of the results for the statistical tests can be found on

Table 1: Summary of the statistical tests for total time, separated by technique.

	PC-C	PC-P	PC-B	C-P	C-B	P-B
Z	-1.571	-1.000	-1.571	-0.457	-0.029	-0.629
p	.116	.317	.116	.648	.977	.530

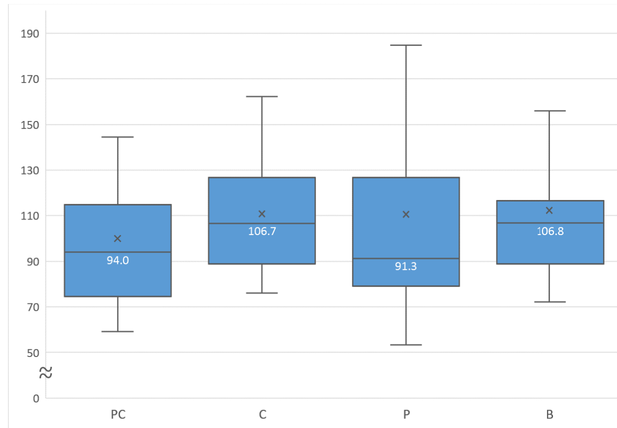


Figure 3: Box plots representing the total time per trial in seconds.

Table 1. We asked the users to complete a qualitative survey after each trial, and the responses showed that the tools were considered to be useful from the perspective of both spectators and HMD users.

4 Conclusion

We presented an approach for a spectator system in an asymmetric VR scenario where one user is immersed in the environment through a HMD, and the spectator is semi-immersed by interacting with a large-screen display. Interaction for the spectator is done through motion controllers where they can freely explore the virtual environment, decoupled from the HMD user's perspective. The spectator can also point at virtual objects through the large-screen display to communicate with the HMD user. Our user study showed that the our approach enabled the spectator to communicate effectively, allowing each user to focus on different areas of the environment to solve a collaborative task. In future work, we will further explore the user interface for both users, increasing their awareness of where their partner is looking at, and the relative position between each user.

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