Enabling Low-cost Co-located Virtual Reality Experiences

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ABSTRACT

In this position paper, we argue that current virtual reality (VR) experiences in co-located and social settings are awkward and invoke strong feelings of uncertainty and lack of awareness of people and objects in the environment around users. We are exploring new design concepts and interaction techniques, as well as hardware modifications to existing head-mounted displays (HMDs), that enhance the feeling of togetherness and are able to create less awkward, co-located VR experiences. Our goal is to do this by providing participants easy, visual access to their environment and co-located participants, be they team members, friends, or family. This paper shares a selection of prototypes designed to accomplish this goal by creating new VR interfaces adapted for collaborative activities, utilizing mobile device rear cameras for body tracking and modifying low-cost VR HMD designs to improve quick transition to real-world views. Through evaluating our new interaction designs and hardware modifications in two studies, we aim to provide design recommendations for more collaborative VR experiences in co-located social settings.

CCS CONCEPTS

• **Human-centered computing** → **User studies**; **Virtual reality**; **Collaborative interaction**.

KEYWORDS

virtual reality, co-located, social, low-cost, head-mounted display, body representation

CHI'19 Extended Abstracts, May 4-9, 2019, Glasgow, Scotland UK
Proceedings of the 1st Workshop on Challenges Using Head-Mounted Displays in Shared and Social Spaces.

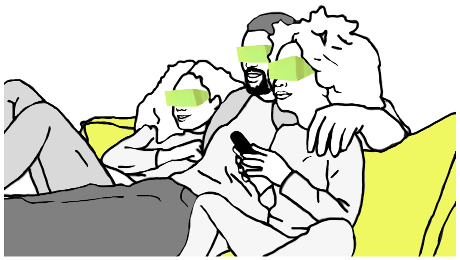

Figure 1: Illustration of an in-home VR entertainment scenario with co-located users.

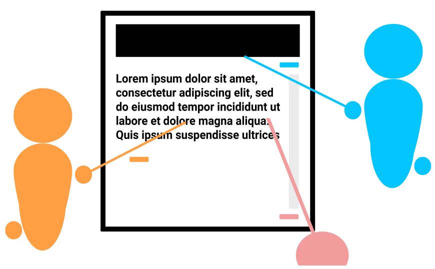

Figure 2: Illustration showing UI prototype example of collaborative editing in the context of a team product design meeting. Color lines and tags indicate visual version control features like state history and active editing.

INTRODUCTION

Since the conception of virtual reality (VR), much research has been done to replicate life in VR through understanding how people feel presence [7, 8] and experience [6]. Much of this work is from the perspective of single VR users and remote VR participants. Social VR experiences with co-located participants will be an increasingly important area of interest as commercial VR devices become more common in homes with families (see Figure 1) and in the workplace. As it stands, real-life interactions with a co-located person in VR are awkward and VR collaborations with co-located people lack the richness and flexibility familiar from real-world interactions.

The goal of our research is to develop a better understanding of the requirements of co-located, more social VR experiences, increasing participants' awareness of each other and potentially eliciting feelings of togetherness between participants. Our extensive literature review of social, collaborative, and co-located VR has informed the design of our prototypes and planned user studies.

PROTOTYPES

Our motivation is to design hardware and interactions that can allow participants' easy visual access to their environment and co-located team members, friends, or family. We conceive designs that allow users' easy access to reality, may ease the burden of interruptions during VR work and also encourage feelings of togetherness with others in their immediate vicinity. This could, in the future, make wearing VR in public more feasible and practical. We are exploring this concept in three ways: *(1)* by designing UI components that support interaction with co-located, non-VR collaborators; *(2)* by creating interaction designs that replicate co-located participants' body position and movements in the virtual scene based on low-cost, smartphone-based pose recognition, and *(3)* through a design exploration of HMD prototypes that provide easy visual access to the physical world.

VR interaction designs for better collaboration

By means of developing scenarios focused on interaction design around collaborative VR, we are developing several UI prototypes that better support co-located VR interactions.

One scenario, a team product design meeting, is considered for the interesting range of interactions and context available for the co-located participants. For this scenario, we are exploring several visual representations of interactivity, one of which is a collaborative editing visualization. In figure 2, we show a UI visualization with co-located participants' active editing and version history depicted through color coded lines and tags. We chose this interaction design to tackle the common collaborative editing problem of knowing which collaborator changed what and when. We believe this design will be useful as a virtual version control technique. The visual, color coded tracking of edits in real time allow users to achieve transparency into task progress and management in virtual collaborative activities.

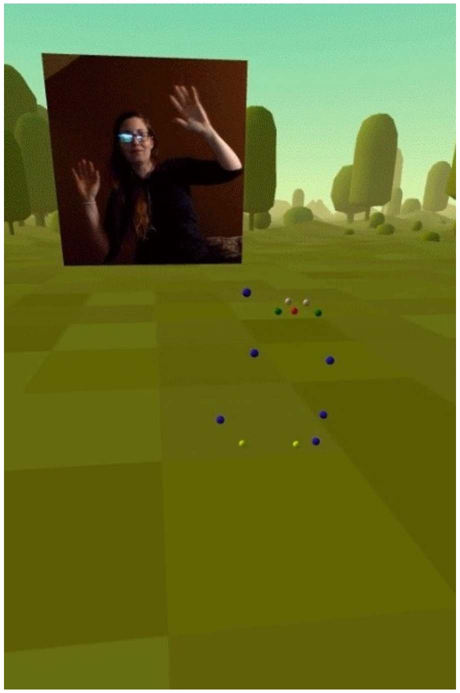

Figure 3: Mobile device camera-based body tracking in VR using tensorflow's posenet model for in browser pose detection and A-Frame, a web-based VR framework.

Ultimately, we feel that further exploration into this visualization technique would prove valuable as the ability to not only view users edits in real time, but also save users "paths" for asynchronous review.

Low-cost body tracking for co-located collaborators

In commercial applications that support motion capture, the type of body representation varies from just the head and hands to full body avatars. For mobile device HMD, there is little support for body position tracking or representation. We have created initial prototypes using A-Frame and a tensorflow-based, open-source JavaScript library leveraging camera feeds and IMU sensor data to provide low-fidelity body tracking without environment instrumentation (see Figure 3), which we adapted for collaborative VR activities.

We intentionally target low-cost technologies and web-based multi-user applications in order to capitalize on the flexibility of mobile VR technology. By building on future web technologies, we want to maximize user access to co-located VR experiences.

HMD hardware modifications for easy access to real-world views

Through our design explorations, we have found that many head-worn displays are not easy to remove quickly, and repeated removal for conversations with co-located users can be disruptive and uncomfortable. Inspired by research into mobile HMD interactions [2, 4], our design solutions focus on ways to provide easy access to real-world views quickly and with minimal disruption. To explore design options in low-cost VR, we altered Google Cardboard headsets. Our designs include ideas for one-eyed VR experiences, tilting and sliding visors (see Figure 4), as well as designs based on see-through AR techniques. Our initial results are promising for longer term VR HMD wear and for HMD wear in busy social settings.

PLANNED USER STUDIES

We are in the process of piloting two user studies exploring our design concepts for a variety of scenarios, tasks, and settings with interaction designs and hardware configurations as the dependent variables. While we cannot report any conclusive results yet, we are happy to share the research questions and our hypotheses associated with the planned studies.

What are key features of body representation to increase feelings of togetherness between co-located collaborators?

Research has been done on the effects of avatars in social experiences in the context of presence and embodiment [1, 3, 5, 9, 10], but we propose to study how the type of body representation of co-located participants affect feelings of togetherness in social VR activities.

Figure 4: Illustration of the visor HMD design, a head-mounted display that slides up when not in use.

We will do this by evaluating five pairs of participants during three scenarios in co-located VR: redecorating a room, shopping for clothing, and playing a game. Each scenario will be completed with an avatar in a different quality of representation, which will range from low fidelity (head and hands), medium fidelity (floating upper half body), to high fidelity (full body). The study will conclude with questionnaires on presence, engagement, and togetherness.

What are feasible and practical HMD modifications to increase awareness of the physical world and co-located VR users?

In this study, we focus on HMD modifications at the hardware level. To validate our hardware concepts, we will conduct a user study to find whether quick visual access to reality during co-located team VR collaborations will improve task performance.

Using our low-cost prototype designs, we will evaluate 5 pairs of participants in a future workplace setting. The pairs will each complete three scenarios: Organizing a virtual presentation in VR, designing a chart in VR with a co-located team mate who is not in VR, holding a virtual meeting with a remote team member. The study will conclude with questionnaires on engagement and togetherness.

CONTRIBUTION TO THE WORKSHOP

We hope to attend the CHI workshop on challenges of using HMDs in shared and social spaces to share our thinking and progress towards improving co-located, social VR. We are also interested in gaining insight into other workshop participants' study designs, especially in terms of metrics and tasks, for evaluating co-located VR experiences and hardware designs.

ACKNOWLEDGMENTS

We would like to thank members of the Information Interaction Lab, Sindhu Giri and Sophie Linn, for their feedback and contributions to our brainstorming activities and early prototype designs.

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