

Mobile Displays for Cross-Reality Interactions between Virtual and Physical Realities

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ABSTRACT

We present two use cases of mobile displays in cross-reality interactions between users immersed in Virtual Reality (VR) and users present in the Physical Reality (PR) by using the mobile display to show select artefacts of interest. The first use case is the “Substitutional Display” where a display serves as a passive haptic for an artefact. Both VR and PR users can then move the artefact by physically moving the display. The second use case is a “Virtual Artefact Handover” which allows the VR user to pass artefacts onto the PR user’s display. We envision this handover as a natural interaction where the VR user moves the artefact onto a virtual proxy of the display the PR user is holding, after which the artefact is displayed for the PR user to see.

CCS CONCEPTS

• **Human-centered computing** → **Virtual reality**; **Mixed / augmented reality**; **Collaborative interaction**.

KEYWORDS

virtual reality, physical reality, mobile displays, cross-reality interaction

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1 INTRODUCTION

Virtual Reality (VR) and Augmented Reality (AR) have become increasingly affordable as more consumer Head-Mounted Displays (HMDs) are developed. HMDs do however provide an isolated experience, making it difficult for bystanders present in the Physical Reality (PR) to interact with the HMD user. Because of this Collaborative Virtual Environments [10] involving both VR and PR users need to be carefully designed for efficient collaboration.

We refer to such a scenario involving users on multiple points on the Reality-Virtuality Continuum [5, 8] as Cross-Reality (CR), for example a scenario where users in VR and PR are collaborating on the same virtual artefacts. For some users it is more desirable

to be in VR, such as a trainee who needs to feel as if they were at the place of the training, whereas others benefit from remaining present in the PR, for example a teacher who needs to remain aware of the behaviour of their group of students.

Mobile displays, for example in the form of a tablet computer, provide PR users with a portable view inside the Virtual Environment (VE) of the VR user. We present an overview of how mobile displays have been used for this purpose. Then we propose a method for increased spatial awareness while using the mobile display as a portal into the VE, *Portal and Miniature*. We then propose two methods of using mobile displays for representing single artefacts: *Virtual Artefact Handover* and *Substitutional Display*.

2 RELATED WORK

Mobile displays have been used to provide PR users with a view into the VE from the VR user’s perspective. This has the disadvantage that the PR user has less agency over which parts of the VE they are able to view. The advantage of this approach is that it can be implemented at the platform level, as was done in TransceiVR [4]. TransceiVR also implements support for the PR user to freeze the video and make annotations in the VE.

In ShareVR [11] a mobile screen was mounted on a motion controller which provided a “portal” with a view into the VE from the PR user’s perspective, and also allowed the PR user to interact with elements of the VE. Additionally ShareVR also included a floor projection and a monitor showing the VR user’s perspective. It is not clear whether the PR user requires the floor projection for spatial navigation. We want to investigate whether we can improve the PR user’s overview when they are using a mobile display as a portal, by providing them with an additional miniature VE visualisation. Miniatures of the VE have been proposed for locomotion [6] as well as for collaboration with PR users [1, 3]. They provide a better overview of the VE [1] but do not scale well to larger VEs.

Mobile screens can be used to visualise single artefacts out of the VE. Spindler et al. [9] present tangible windows for interaction with a tabletop 3D environment. One of these interactions is the *fish tank* where the tangible window serves as a physical proxy. In BISHARE [12] a system is presented for using a smartphone together with an AR HMD. It allows moving virtual artefacts between the phone screen and the environment. This is done using gestures, swiping the virtual artefact up on the phone to move it out of the screen, and moving the virtual artefact on to the phone to move it back into the screen.

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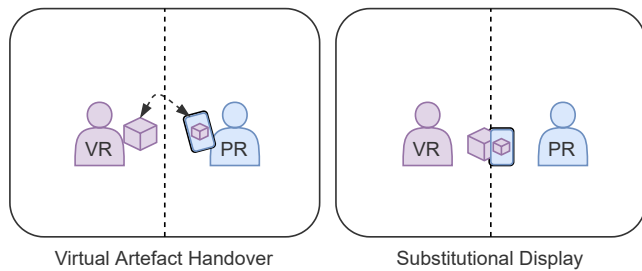


Figure 1: “Virtual Artefact Handover” allows co-located VR and PR users to discuss the same virtual artefacts after performing a hand over gesture. By moving the PR user’s mobile display and VR user’s motion controllers close together, the VR user can place virtual artefacts on the screen, or take them out of it. “Substitutional Display” uses the display as a passive haptic artefact, allowing both the VR and PR users to see and manipulate it as a single artefact.

3 VISUALISING SINGLE VIRTUAL ARTEFACTS

We present two methods of using mobile displays to present virtual artefacts. The first is “Substitutional Display” and the second is “Virtual Artefact Handover” (Figure 1).

3.1 Substitutional Display

The “Substitutional Display” matches each virtual artefact with a display, which then serves as a passive haptic [9], similar to the concept of substitutional reality [7]. This allows co-located VR and PR users to see the same artefacts in the same locations, as well as manipulate them in the same fashion (ie. physically moving the displays). Virtual artefacts that are larger than the physical screen need to be scaled down in order to be visible to the PR user, which can cause the VR user to see an artefact as being larger than how the PR user sees it.

This approach requires a physical display for each virtual artefact, which does not scale well. Additionally it forces the artefacts in the VE to follow the physical constraints of the physical displays, which might not be desired. Because of these limitations we also propose “Virtual Artefact Handover”.

3.2 Virtual Artefact Handover

“Virtual Artefact Handover” requires the PR user to carry around a display, which we will use for a natural transition of artefacts between VR and PR users. The PR user’s mobile display will need to be motion tracked in order to provide the VR user with a target for where to place the virtual artefact. Additionally the PR user themselves can also be presented as an avatar [2].

In order to “hand over” an artefact to the PR user the VR user first needs to pick it up, either using hand tracking or motion controllers. They can then move it towards the virtual representation of the PR user’s mobile display, and place the artefact on the display in order to transition it into the display for the PR user to see. Depending on the requirement of the application the artefact can either transition

from VR to PR, or be duplicated and have a separated existence in both VR and PR.

We wish to compare this natural “hand over” to a supernatural approach where the VR user can select objects, which are then “beamed” onto the handheld display. For example the VR user would be able to wield a futuristic device with which they can select an object and then press a button to move it to the PR user’s display, without needing to interact with the VR user directly. The object could then either dematerialise and appear on the PR user’s display, or remain visible to the VR user but show an indicator that it is currently also being viewed by the PR user.

4 CONCLUSION

We discussed how mobile displays have been used in Cross-Reality and then proposed two novel uses for them. “Substitutional Display” aims to use mobile displays as passive haptics for virtual artefacts. In “Virtual Artefact Handover” the PR user uses the mobile display as an interface to receive and visualise virtual artefacts from the VR user. In future work we aim to implement and evaluate these techniques compared to baseline conditions.

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