Redirected Reach in Virtual Reality: Enabling Natural Hand Interaction at Multiple Virtual Locations with Passive Haptics

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Abstract

In many virtual reality applications, it would be ideal if users could use their physical hands to directly interact with virtual objects while experiencing realistic haptic feedback. While this can be achieved via interaction with tracked physical props that correspond to virtual objects, practical limitations can make it difficult to achieve a physical environment that exactly represents the virtual world, and virtual environments are often much larger than the available tracked physical space. Our approach maps a single physical prop to multiple virtual objects distributed throughout a virtual environment. Additionally, our work explores scenarios using one physical prop to control multiple types of object interactions. We explore considerations that allow physical object manipulation using orientation resetting to physically align the user with a physical prop for interaction. The resetting approach applies a discrete positional and rotational update to the user's location when the user virtually approaches a target for interaction, and the redirected reach approach applies a translational offset to the users virtual hand based on the positional difference of the virtual and physical objects.

Index Terms: H.5.1 [Information interfaces and presentation]: Multimedia Information Systems—Artificial, augmented, and virtual realities

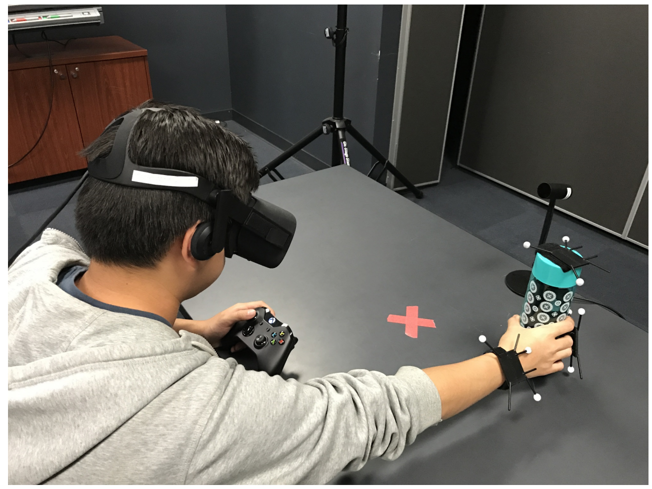

Figure 1: The physical setup used for the study. Participants sat at a table and could reach and move a tracked prop (a plastic bottle). Tracking markers were placed on the wrist and fingers of the user's right hand, and the left hand was used to operate the analog stick of a game controller. Participants could rotate in a swivel chair.

1 Introduction

Realistic interaction with 3D graphical environments is often one of the primary goals of virtual reality (VR). In many cases, the gold standard for object selection and manipulation would be if users could naturally use their real hands to directly interact with virtual objects while experiencing realistic haptic and tactile feedback. One straightforward and effective alternative is to use *passive haptics*, which involves the use of simple physical props that correspond to virtual objects [2]. However, practical limitations can make it difficult to arrange physical props in such a way that accurately represents the virtual world, and virtual environments are often much larger than the available tracked physical space.

To partially address this issue, researchers have explored manipulating rotations to align virtual and physical objects to allow realistic physical interaction (e.g., [3]), and perceptual illusion can be used to simulate virtual interactions that differ from the real world (e.g., [4]). Azmandian et al. [1] enabled reaching for props by warping the virtual body and virtual space so the user's virtual hand position was shifted in the direction of a virtual object, but the technique did not allow the choice of interacting with multiple objects.

Our research is motivated by the need for flexible techniques that allow free choice and can work in practical home-VR setups that make use of a head-mounted display (HMD). As such, we investigate accessible and viable techniques for natural haptic interaction that can work in convenient tabletop VR setups such as when a user is seated at a desk or standing in front of a table. For this reason, the research presented in this poster explores methods that allow physical hand interaction with passive props while the user remains at the same physical location.

We configured and studied the combination of *resetting* and redirected reach, two approaches that enable passive-haptic interaction in situations with head-coupled rendering and virtual locations. We demonstrate and evaluate our techniques in a VR game (see Figure 2) that uses a single physical prop to control variable types of virtual interactions with different virtual objects distributed across a large virtual environment.

2 Techniques

Our research considers *resetting* to align the user's body orientation towards a given physical forward direction (i.e., the direction with physical prop, and we incorporate *redirected reach* to help match the physical and virtual hand in such a way that facilitates hand interaction with the prop.

2.1 Resetting

Resetting is a straightforward method for adjusting the orientation of the virtual environment to match the needed physical coordinate space. Numerous prior projects have demonstrated the use of resetting (e.g., [5]). Our implementation uses a fade-to-black transition effect, then instantly updates the virtual world so the virtual interactive object matches the real-world prop direction, and then fades

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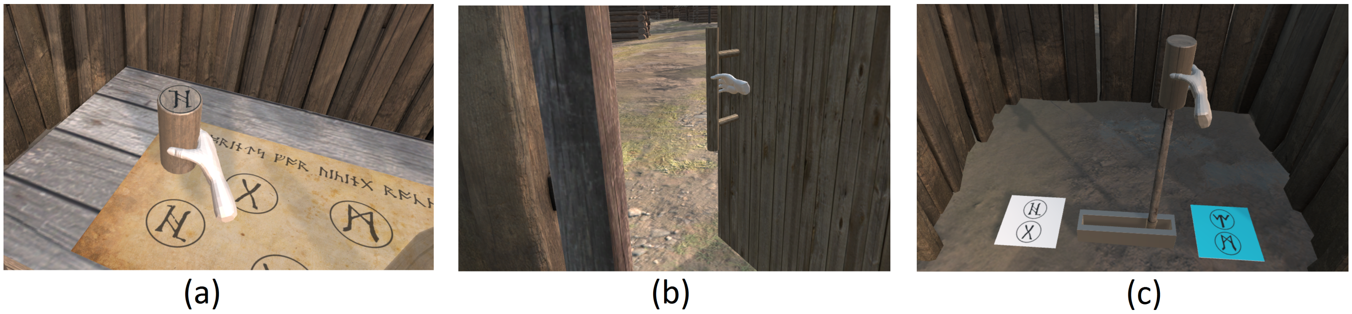

Figure 2: Different types of interactions in the game: (a) moving a puzzle piece to match symbols, (b) opening a door, and (c) operating a switch.

back to the virtual scene. The resetting transition triggers when the user moves near an interactive virtual object. A complete resetting transition took one second in our implementation.

After the transition, the virtual orientation has been changed so that physically turning to face the virtual object will physically align the user with the physical prop. To help users understand the resetting transition, our technique displays an arrow to denote the shortest direction of physical turning required to face the interactive object. As an additional rectification step, along with the virtual world rotation, the technique also adjusts the position of the virtual camera to be directly in front of the virtual interaction zone.

2.2 Redirected Reach

While *resetting* helps in physically aligning the user's reference frame with the prop for interaction, the position of the physical prop may not always in an ideal position for interaction. This is especially true when using one prop to correspond to multiple virtual objects in an environment because each object can be positioned differently within its interaction zone.

To account for any remaining mismatch, we apply translational offsets to the virtual hand in such a way that will allow the user's real hand to correctly reach the physical real-world prop. The translational offset requires the calculation of the difference in translational values of the virtual object and the physical object. The offsets are calculated upon entry to an interaction zone with an interactive object. The offset is then applied to the virtual hand, which adjusts the hand's position in virtual space. In our implementation, the virtual hand is only visible when the user enters the interaction zone, so the hand appears with the offset already applied. This way, the user does not observe any change in the hand position.

3 Preliminary Evaluation and Discussion

We implemented our resetting and redirected reach to test our techniques for natural hand interactions in a table-top VR experience. Our implementation involved a seated experience using an Oculus Rift CV1, a game controller for virtual travel, and an Optitrack optical tracking system with rigid body markers for hand and prop tracking (see Figure 1). We conducted a study with 12 participants to compare the passive haptic approach to an air grasping version, which did not use resetting and used pinch gestures without a physical prop for object manipulation. We collected user feedback about usability, frustrations, and preferences from a brief immersive game experience that involved virtual travel and manipulation of virtual objects in various locations to solve a simple puzzle involving three different types of object interactions: (1) cylindrical puzzle pieces that could be picked up, moved, and set down, (2) large switches that slide back and forth along a fixed track, and (3) doors that swing open by moving the door handle (see Figure 2).

Overall, the results demonstrate that the resetting approach was successful and usable in a game environment allowing free exploration and choice of interactions. Our work demonstrates use of a single prop to control different types of interactions using different transfer functions to preserve moderately high levels of interaction fidelity for each interaction. Generally, many participants were interested in interacting with a physical prop, and the responses from participants indicate that they could keep track of their physical orientation in the real world with the resetting applied.

Some participants reported constant awareness of their physical surroundings due to resetting used to align with real-world objects. While not necessarily problematic, these results could suggest reduced sense of presence. Participants reported a higher sense of control and realism while interacting with a physical prop as compared to the air grasping without tactile feedback.

Additionally, our results show participants had preferences of different types of interactions. Freely moving and placing the puzzle objects in 6-DOF to specified targets was the favorite interaction as it followed a direct mapping to the real world task performed. In contrast, they felt that opening doors did not work as well since there was a learning curve involved in how the physical object should be moved, and the prop control did not directly match the real-world interaction of opening a door.

We plan to conduct a larger user study to evaluate our approach along with alternatives for passive-haptic interaction. In future work, we also want to explore the possibility of having multiple virtual targets at the same location and apply prediction for target selection for reaching different objects based on gaze and movement of the virtual hand. Also, our work uses a basic cylindrical object as a proxy for multiple virtual objects having a similar cylindrical form factor (i.e., handles and cylindrical puzzle objects). While the sizes of the virtual objects were not accurate compared to the physical prop, no users commented on noticing these differences in scale and size. Exploring different 3D shapes as primitives for physical props can be an interesting area of research for future work.

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