Retargeting Destinations of Passive Props for Enhancing Haptic Feedback in Virtual Reality

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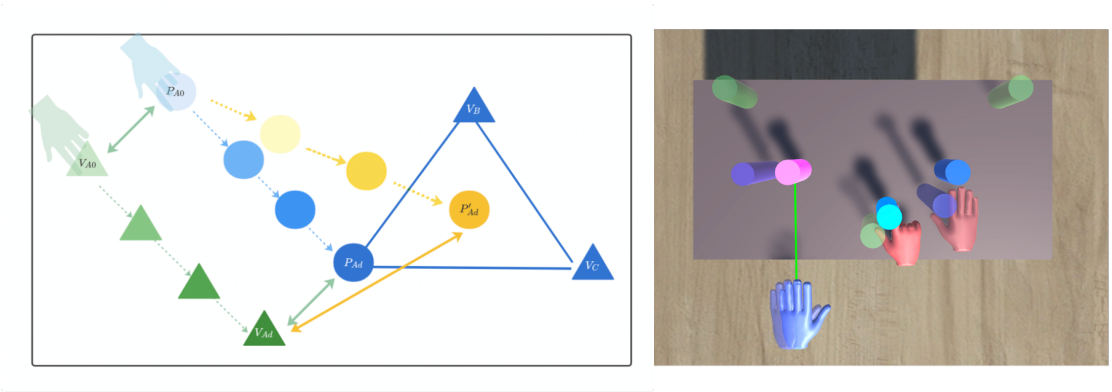

Figure 1: Left: A top view of applying the basic retargeting technique (blue circles) or our RP approach (yellow circles). The triangles indicate the virtual objects. The virtual object V_{A_0} grabbed by the user will be placed at V_{A_d}. The blue circles show the trajectory ($P_{A_0} \rightarrow P_{A_d}$) of the physical prop with the basic retargeting technique, and the yellow circles show the physical prop's trajectory ($P_{A_0} \rightarrow P'_{A_d}$) with RP. The physical prop is closer to the other two virtual objects (V_B and V_C) when it is put down with RP. Right: A screenshot of our prototype. There are 3 virtual objects(pink, light blue, and blue) and 2 physical props (purple). The specific destinations of the virtual objects are indicated by the semi-transparent green cylinders. The right hand (opaque red) is grabbing a virtual object (the light-blue one). The semi-transparent hands and the purple cylinders represent the physical hands and physical props respectively, which can't be seen by the users in VEs

Abstract

Haptic retargeting is a commonly used technique to match passive props to virtual objects for adding tactile feedback in Virtual Reality (VR). However, researchers have mainly focused on single-hand retargeting and applied these techniques primarily for tasks of touching objects. In this work, we propose a novel retargeting solution for tasks of grabbing and placing objects in VR, called redirected placement (RP), which is applied when placing virtual objects. The key idea of this method is that when the user places the virtual object, it can enable the user to place the physical prop in a position that is easier to match with multiple other virtual objects, without being detected by the user.

Index Terms: Human-centered computing—Human computer interaction (HCI)—Interaction paradigms—Virtual reality;

1 Introduction

Virtual reality (VR) is a compelling technology that allows users to have a sense of immersion in virtual environments. In addition to visual and auditory feedback, many studies have focused on haptic feedback in VR, bringing users a more realistic experience. Due to the challenge of matching of physical and virtual objects, some researchers proposed haptic redirection (HR) techniques [1] which use the visual dominance of humans to let users feel haptic feedback even when there is a deviation in the position of virtual and physical objects.

Current haptic retargeting techniques [2–5] only consider adjusting the offset between the physical hand and the virtual one before touching the object. Continuing to redirect the hand to make the subsequent interaction easier after the object is grabbed has not been studied yet. Our initial idea is to suppose the physical prop can be placed at a relatively close position to multiple virtual objects that the prop can represent. In that case, it would need less redirection the next time the user touches one of these virtual objects represented by this prop. Therefore, in this work, we propose a method called *redirected placement* (RP), which applies retargeting when the user places a virtual object to make the passive prop be redirected closer to the other virtual objects and we find that the number of times users miss the physical props with RP in our prototype.

2 Techniques

In this section, we introduce the details of our *redirected placement* approach which is extended based on the basic haptic retargeting techniques [1, 3].

2.1 Basic Haptic Retargeting

The idea of haptic retargeting is to increase the deviation of the virtual hand relative to the physical hand when the hand is moving so that when the virtual hand moves to the position of the virtual target, the offset between the virtual hand and the physical hand is equal to the gap of the virtual target and its corresponding physical prop. The following briefly introduces how the basic retargeting approach works, which start with when a virtual object is selected as the target.

After the user selects a target, our control system will choose a selectable physical prop closest to this virtual target and match them

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as a pair. Let P_p be the position of the physical prop and P_v be the position of the virtual target. So the target offset T_t is:

$$T_t = P_v - P_p \tag{1}$$

Since the users do not have to return to the warping origin after each interaction, the origin offset of the hands is:

$$T_o = H_v - H_p, \tag{2}$$

where H_v is the position of the virtual hand, and H_p is the position of the physical hand and the new warping origin. So the offset applied to the virtual hand can be computed as follow:

$$W = \alpha T_t + (1-\alpha)T_o\,, \quad \alpha = \frac{D_s}{D_s + D_p}, \tag{3}$$

where D_s is the distance between the warping origin H_o and the current position of the physical hand H_p, D_p is the distance between H_p and the position of the physical target P_p.

2.2 Redirected Placement

We want to guide users to place the physical props close to other virtual objects when they put down the object with RP, so the next time users pick up these virtual objects, they will be able to be redirected to the physical prop using a relatively small offset. It is difficult for the computer to know the destination when the user is putting down an object. To make our problem easier to solve, we used no more than four virtual objects with two physical props for haptic feedback. We also designed a scenario that requires the user to complete the task of placing the objects at the specified locations, so that we can determine the location of each virtual object to be placed. After the simplification, our problem is to determine where the physical object is to be redirected based on the positions of the other virtual objects in the scene.

We decide to redirect the placement of the physical object where the sum of the total distance to other virtual objects in the scene is the smallest, since we want to decrease the distance between the physical prop and the other virtual objects that may be interacted later. For example, Fig. 1 shows a top view of the tables, the user is interacting with the green virtual object V_{A_0} and there are two other blue virtual objects placed on the table. The physical prop P_{A_0} has a origin offset with V_{A_0}, so it will be placed at P_{A_d} when the object is moved from V_{A_0} to V_{A_d} when we only apply the basic haptic retargeting. But with our redirected placement technique, the physical prop can be placed at P'_{A_d} where is closer to the two blue virtual objects.

The method to compute the redirected placement position of the physical prop is briefly introduced as follow. First, we calculate the origin-destination of the physical prop P_{A_d} based on the virtual destination and the current offset between the virtual and physical objects. Then, we use P_{A_d} and positions of the other virtual objects to compute the new destination P'_{A_d} which will be used to initiate new retargeting of the virtual hand. After the new destination of the physical prop is determined, we can initiate a new target offset for retargeting.

3 Implementation

We used an OptiTrack system with four Prime 13 cameras to track the hands and objects. As Fig. 2 shows, objects were tracked as rigid bodies with unique marker patterns tied to each object. We tied a set of markers on each wrist to track the transform of the wrists as rigid bodies. In addition, we also tied marks on the fingertips to check the grabbing and releasing actions. We developed the VR scenes based on the virtual reality toolkit (VRTK)[1] with Unity3D 2019.4.22f1c1 and deployed it on the Oculus Rift HMD for display.

[1] VRTK. https://www.vrtk.io

(a) (b)

Figure 2: Setups. (a) the physical props pasted with non-reflective tape and unique marker patterns, (b) the setting of the hand is to tie the marker patterns on the wrist and fingertips.

Our prototype scene is shown on the right side of Fig. 1. Users can use the ray to select the virtual object to be moved, and then move the object to the specified position. In the process of the user picking up the object, we will apply the basic retargeting, and in the process of the user placing the object, we will apply the redirected placement technique.

4 Conclusion and Future Work

In this work, we proposed a novel retargeting approach applied retargeting when placing virtual objects to make the passive prop be placed in a position closer to other virtual objects, so-called *redirected placement* (RP) and the prototype we implemented validates that our approach has the potential to enhance haptics in VR.

In our future work, we will conduct more detailed user studies to evaluate how our method can enhance the haptic feedback of interaction in VR, and what impact it has on the user's subjective tactile perception.

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