Tether-Handle Interaction for Retrieving Out-of-Range Objects in VR

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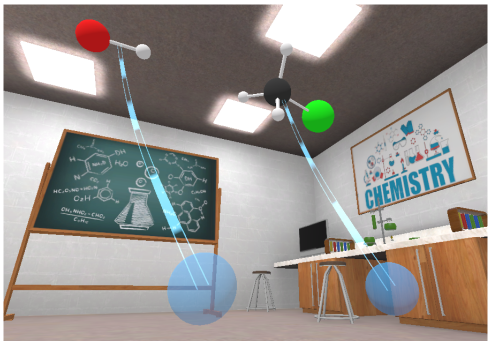

Figure 1: Handles are connected by tethers to molecules that moved out-of-reach in an interactive chemistry simulation.

Abstract

Many VR applications allow users to grab and manipulate virtual objects, whether it be with a motion-tracked controller or a hand-tracked gestural input system. However, when objects move out-of-reach, standard grabbing interactions become less useful. Techniques for retrieving distant objects often use separate interaction metaphors from the main grabbing technique, such as pointing or hand extension. However, to avoid such metaphor switching, and to avoid cluttering a controller or gestural interface with multiple functions, we created a novel object retrieval technique that dynamically presents a grabbable handle tethered to a distant object.

Index Terms: Human-centered computing—Virtual reality; Human-centered computing—Interaction techniques

1 Introduction

Virtual reality (VR) supports a wide range of interactions and applications, including creative tools and educational simulations. One of the most fundamental and intuitive interactions for VR applications is to select, grab, and manipulate objects, whether it be with a motion-tracked handheld controller or a naturalistic manipulation system powered by whole-hand tracking. A "grab to select" interaction may be a key interaction in a VR application wherein the user primarily interacts with nearby objects, such as building blocks or tools in a VR sandbox. However, to select more distant objects, a distance selection and grabbing scheme becomes useful to avoid navigation (locomotion), especially for seated or stationary VR use. There has been substantial research on ways to allow users to select and move distant objects without navigation. Most techniques use different interaction metaphors than "regular" grabbing, such as pointing or hand extension.

In our VR applications, such as the molecular dynamics simulation pictured in Figure 1, a user can select an object by first moving the controller or hand to the object. This triggers a highlight effect that indicates interactability, and then pressing a trigger or closing the fingers will grab the object. The user can move and release grabbed objects in a naturalistic way.

Upon release, an object may move out-of-reach, for example, because it is thrown or because it is subject to forces in a physical simulation. We wanted to allow retrieval of such objects in a seamless manner, without switching to different or more complex grabbing metaphors for this special case. So, we created a distance selection and grabbing technique that leverages the standard in-range grab by presenting an in-range grabbable "handle" tethered to each relevant object that has moved out of range. The technique may also be used for objects initially located out-of-range.

2 Related Works

Well-known distance selection and grabbing techniques can be categorized broadly into 3 categories: hand motion mapping, raycasting, and proxy object manipulation. These techniques aren't mutually exclusive; for example, the HOMER technique by Bowman et al. uses raycasting to allow the user to select a distant object of interest, but hand motion mapping is used to manipulate the grabbed object itself [1].

Techniques that use hand mapping are often discussed as being more natural or intuitive, because we instinctively reach out for remote objects. Non-linear hand mapping allows a VR application to provide an area of precise motion near the user, while transitioning to more exaggerated motion as reach distance increases [4]. However, practically speaking, raycasting has been shown to perform more effectively in many cases than hand motion mapping for distance selection tasks, even in dense scenes or when partially occluded objects are present [8]. For raycasting-based selection techniques, it is often difficult to orient one's hand or controller precisely enough to point at distant objects, but casting the ray from a fixed origin on the body can reduce this issue, as shown in the pointing technique comparison by Jota et al. [2]. With appropriate visual feedback, such as the "sticky ray" suggested by Steinicke et al. [5], using a cone rather than a thin ray can also reduce the precision demands of pointing-based selection. Compared to these existing techniques, our proposed method uses direct hand mapping at all times and does not require the user to precisely point their controller or hand at out-of-reach objects.

The Worlds-in-Miniature method [6] presents representations of distant objects (proxy objects) to a user. These linked representations are in direct reach of the user, allowing the use of normal interaction techniques. The Through-the-Lens metaphor [7] extends this concept by proposing the use of a movable window, through which the World-in-Miniature can be manipulated. The more recent ViewfinderVR [3] explicitly adapts the Through-the-Lens technique for use as a distance selection method for VR applications, projecting a region of the user's view onto a "screen" to which the user can then reach out to select distant objects in the region. The handles of our proposed technique can be considered roughly analogous to proxy objects for the purposes of the selection process, but we do not use a 1:1 mapping between manipulation of the handle and manipulation of the object itself.

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3 IMPLEMENTATION AND RATIONALE

3.1 Selection

Our distance selection technique engages when any object leaves the reach of the user. Specifically, if the distance between the object and the user's estimated shoulder position (a constant downward offset from their head position) is greater than the user's comfortable reach threshold (for simplicity, set to a distance of 0.4 meters), a semi-transparent line or tether appears connecting the distant object to a floating handle. The far end of the tether is attached to the object's center, and the handle is placed within the user's reach by finding the point closest to the object on the sphere representing the user's range of comfortable reach.

In our current implementation, the tether is rendered as a pull cord with a dip in the middle, generated using a simple sine wave. This curve was added specifically, as we believed the grabbing interaction would feel more natural when the tether appeared to be elastic. This depiction is intended to suggest that there is some sort of non-rigid physical connection between the handle and the object. In implying this connection, we aim to indicate that moving the handle towards the user's body will likewise move the object towards the user.

3.2 Grabbing

The user can select, grab, and manipulate the handle in the same manner as they would grab and manipulate an object. If the user grabs and moves the tether's handle towards themselves, the tether retracts and the object rapidly moves towards the handle position. When the object reaches the handle position, the handle disappears, and the user's grab is transferred from the handle directly to the object. In other words, if the user maintains the grab during the entire interaction, they do not need to perform a second grab to start directly manipulating the object once it is close enough.

This technique mirrors the real-world interaction of pulling an object by a string, and thus avoids being overly abstract or fantastical (pointing or gesturing to "telekenetically" summon a distant object), and thus potentially more intuitive than other techniques.

Our distance grabbing technique is especially relevant in seated or stationary VR applications in which the user does not need to move around, either physically or virtually (although we still allow it). To provide for cases in which the user does choose to move around slightly, either physically or virtually, we continually keep track of each handle's distance from the user. When any handle moves outside of the user's absolute reach range (i.e., a range slightly larger than the comfortable reach range mentioned earlier), we re-spawn the handle to move back within the comfortable range, and we then animate it slightly to alert the user to the fact that the handle has changed position.

3.3 Further Considerations

In applications using many distant objects, visual clutter may result when many tethers and handles are presented simultaneously. Our example applications involve no more than 4 or 5 interactable objects at once. In applications with many manipulable objects, distant objects that the user is uninterested in would need to be filtered out of the tether creation process. We are exploring techniques for controlling the visibility of object tethers based on identifying objects of interest with eye tracking, hand position, and object type.

Some VR applications (especially games) have environments with many obstacles, which may pose a concern for our system, as either the tether or handle could be rendered inaccessible to the user. An improved tether creation algorithm might, in this case, modify the handle position or apply additional curvature to the tether so that it avoids intersecting objects.

4 CONCLUSION AND FUTURE WORK

Our tether-handle object grab approach allows users to retrieve out-of-range objects by pulling in-range handles, which themselves behave largely like other objects in the virtual environment. We anticipate that our technique will be more intuitive and require less precise motions than some other commonly used distance grabbing techniques. So far, we have integrated the approach into two applications and tuned some parameters (such as the tether activation threshold and appearance delay) with informal usability tests.

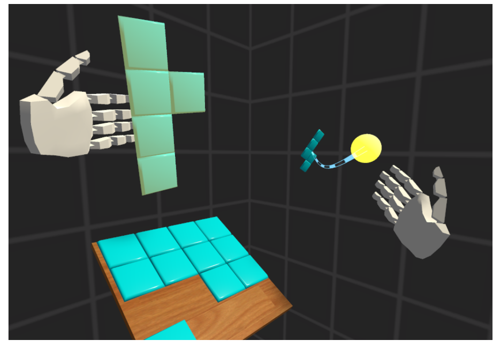

Figure 2: A handle is connected by a tether to an out-of-reach puzzle piece in a puzzle-solving game. The handle is highlighted to indicate that it is interactive and can be grabbed.

We have designed a study to evaluate the performance of our distance grabbing technique with versions of the classic distance grabbing methods incorporating relevant improvements identified by more recent research. This study will be performed in the context of several simple game-like tasks, such as the puzzle-solving game shown in Figure 2. Subjects will be asked to retrieve distant objects and manipulate them to complete the tasks, and we will record relevant metrics, including task completion time and subjective preference. We also plan to test extensions to our technique that address the considerations and shortcomings listed above so that it may be of wider applicability.

ACKNOWLEDGMENTS

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