
Touch & Detach: Physics-based Unbinding and Observation of Complex Virtual Objects in 3D Space

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Abstract

The main contribution of this study is the stable and intuitive detach method, named "Touch & Detach," for 3D complex virtual objects using gesture-based operations in mixed reality space. In general modeling software, parts of a complex 3D object are grouped in a multi-level hierarchy for efficient operation and ungrouping is necessary for observing or manipulating a part in detail. Our method uses real-world bond metaphors (such as glue or a joint) to prevent incorrect operations and improve the system's operational feeling and responsiveness. This paper presents the details of our proposed method and an informal user study.

Keywords

Augmented Reality; Mixed Reality; Unbinding and observation; Gesture; Physics; Auditory feedback; Metaphor.

ACM Classification Keywords

H.5.2 [Information interfaces and presentation]: User Interfaces - Auditory (non-speech) feedback, Interaction styles, Input devices and strategies; H.5.1 [Information interfaces and presentation]: Multimedia Information Systems - Artificial, augmented, and virtual realities.

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General Terms

Design, Human Factors

Introduction

Today's technology enables users to manipulate complex, multi-part 3D virtual objects such as industrial products, structures designed by CAD, and models of the human body in large 3D space.

In general modeling software, parts of such a complex 3D object are grouped in a multi-level hierarchy and manipulated together, but not individually, for efficient operation. Therefore, an ungrouping operation is necessary when the user wants to pick up only one part of a complex object and observe it in detail from various directions or manipulate it.

In this study, we consider a gesture-based ungrouping and manipulation method for virtual objects that are grouped in a multi-level hierarchy in mixed reality space. The example of partial ungrouping is shown in Figure 1.

However, in such circumstances, users tend to make unexpected movements and accidentally detach a group of parts while rotating or moving an object. This occurs because the detection of gestures and the recognition of spatial relationships in a 3D display are not always accurate.

In the real world, objects are connected or bonded by materials such as glue or a magnet. Therefore to detach them, the appropriate power must be applied at the appropriate position and that prevents accidental detachment.

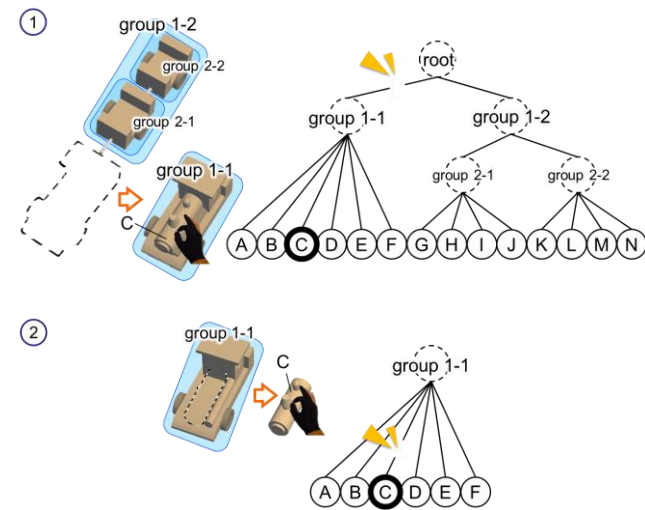


figure 1. Example of our system's operation. User can detach and observe virtual 3D objects grouped in a multi-level hierarchy.

We propose the method installing this kind of metaphor in real life for ungrouping and named it "Touch & Detach" (Figure 2). This method provides the users with both visual and auditory feedback based on the metaphor, and it improves the operational feel and helps users avoid incorrect operations.

Related Work

Several studies have examined various manipulation techniques because manipulating virtual objects is a fundamental operation. For a case where the virtual object that a user wants to manipulate is complex, in other words, there are many other virtual objects in the 3D space that obstruct the user's view, Grossman [1] proposed a technique that spreads overlapping objects when the ray cursor is on them. Olwel [2] proposed

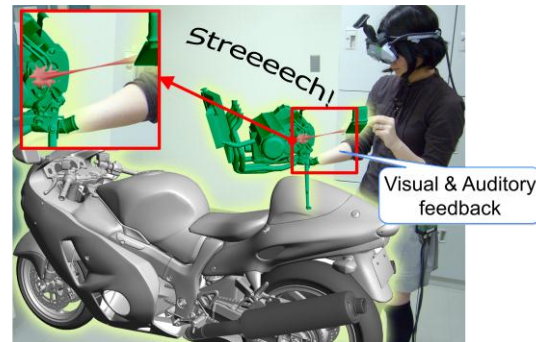
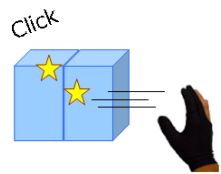
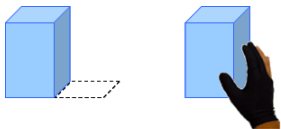


figure 2. Concept sketch of "Touch & Detach". User can pick up a group of parts of the 3D virtual objects that they need, and observe it.



(a) When the user releases the part in the effective area, it returns to its initial position, and a clicking sound is provided.



(b) When the user releases the part outside the effective area, it stays where the user placed it. The ungroup is complete.

figure 3. Magnet metaphor: The behaviors when the user moves the part from first position.

Flexible Pointer in which users can bend the ray cursor. In Stoakley's method [3], users can manipulate a distant object by manipulating a copy of it in their hands. Unlike our method, these studies target selecting one object from many and do not consider grouping and ungrouping or focus on detaching.

Techniques have been proposed to observe complex objects that display the inner parts [4, 5] or separate the outer parts automatically depending on the position of the cursor [6]. These methods focus on the removed or separated outer parts and on the observation of occluded inner parts; they do not consider manipulating the removed or separated outer parts. In contrast, in our system, the user can detach one group of parts of a complex object and observe it while moving or rotating the object.

Many studies that apply the metaphor of physical behavior in the real world to virtual object manipulation have been proposed. For example, gravity and

collisions [7] or magnetic force [8] were applied to the manipulation of virtual objects in virtual reality space, and recently, Wilson [9] introduced pseudo-physics for interacting with virtual objects in a tabletop system. Use of a metaphor makes the manipulation of virtual objects more natural and comfortable. We apply such a metaphor to the detaching operation of virtual objects. We expect our method to result in comfortable object manipulation and improve responsiveness.

Proposed method

Problem of traditional method

In the real world, an object can be detached into parts by applying the appropriate power at the appropriate position. One of the metaphors that can be used is the magnet metaphor, proposed by Kitamura [8], for manipulating virtual objects. First, we considered applying this metaphor to our system.

In this system, we use the model in which magnets are placed on the surface of each part and connect each other. If a part is in the effective area of another part's magnetic force, the forces interact. When the user releases the part, it returns to its initial position (Figure 3a). Conversely, when a part is out of the effective area, it remains at the position where the user released it and the ungrouping is complete (Figure 3b).

However, when using the magnet metaphor, the users do not know how far they have to move the parts to ungroup it because they cannot estimate the magnetic force itself.

Rubber-like glue metaphor

To solve this problem, next, we used a rubber-like glue metaphor. In this metaphor, the user can check the

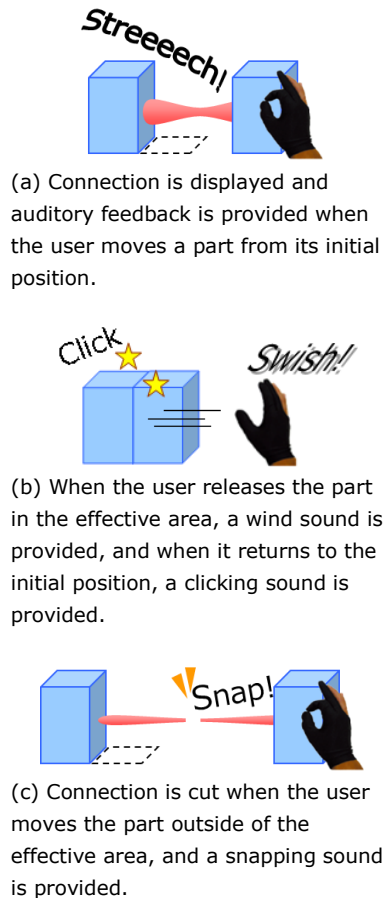


figure 4. Rubber-like glue metaphor

current conditions with visual and auditory feedback while detaching.

When the user detaches a group of part using this metaphor, the rubber-like glue that is applied on each surface of the part expands and contracts depending on the distance between the parts; simultaneously, its width also changes (Figure 4a). When the user releases the part in the effective area, it returns to its initial position, similar to the case in magnet metaphor (Figure 4b).

The adhesive force between parts F_{adh} is proportional to the strength of the glue k_{str} , the size of the bonding surface A_{adh} , and the distance between the parts (equation 1):

$$F_{adh}(A_{adh}, \mathbf{p}_{p1}, \mathbf{p}_{p2}) = k_{str} A_{adh} |\mathbf{p}_{p1} - \mathbf{p}_{p2}| \quad (1)$$

\mathbf{p}_{p1} is the 3D position of the center of the constraint surface selected by the user and \mathbf{p}_{p2} is that of the paired surface. The size of the effective area d is given by equation (2) using k_{str} and A_{adh} :

$$d(A_{adh}) = k_{str} A_{adh} \quad (2)$$

If the part is in the effective area ($|\mathbf{p}_{p1} - \mathbf{p}_{p2}| \leq d$), when the user releases it, it is drawn by F_{attr} and returns to the initial position.

In addition, when the user moves a part toward the limits of the effective area, the rubber-like glue becomes thin, and finally it breaks, canceling the adhesive force (Figure 4c). The ungrouping is complete. Our system also provides auditory feedback in the

situation when the user pulls the rubber-like glue, releases a part, part returns to the initial position, and rubber-like glue breaks.

Joint metaphor

The rubber-like glue metaphor is applied to the operation of ungrouping a group of objects one by one, but we also have to consider the operation of ungrouping multiple groups together. For this operation, we introduced a joint metaphor, and the users can switch between these metaphors depending on their purpose during the operation.

The system displays virtual joints at the connections between groups as visual feedback, and it indicates the point where the user can detach the parts (Figure 5). The user can remove all joints by using a slapping gesture and unbind all the groups at once.

Figure 6 shows the difference of operation between the rubber-like glue metaphor and the joint metaphor.

System configuration

We developed a mixed reality (MR) system (Figure 7) that uses the proposed methods. Users view the MR space through a video-see-through head-mounted display (HMD, Canon VH-2002). Hand gestures are detected by a ViconPeaks motion capture system. It uses infrared technology to enable tracking of finger positions and the position and orientation of the HMD. Auditory feedback is presented through a speaker.

Implementation results and user studies

Figures 8, 9, and 10 show examples of a user detaching parts using the metaphors. We compared user operations with and without use of the metaphors.

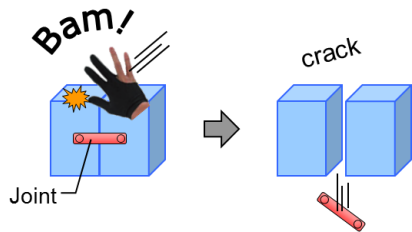
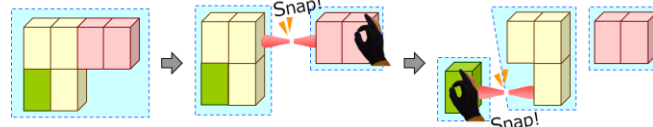
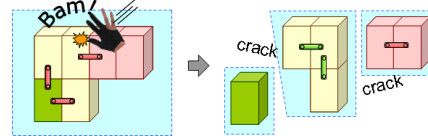


figure 5. Joint metaphor: Ungroup with a "Slapping" gesture



(a) Rubber-like glue metaphor: Ungroup one by one.



(b) Joint metaphor: Ungroup at once. After ungrouping, new joints which connect groups of next child hierarchical level are shown.

figure 6. The difference between Rubber-like glue metaphor and Joint metaphor

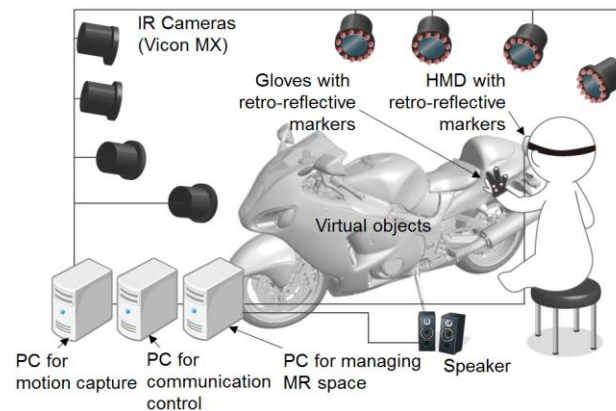


figure 7. System configuration

In this user study, users ungroup virtual objects which are grouped in a multi-level hierarchy, freely. Subjects are five students. All users preferred the operations using the metaphors because the beginning and ending of detaching was clearer and the operation was

comfortable. Therefore, we can state that the metaphors we implemented avoided unexpected operations and improved the operational feeling.

We then collected comments about each metaphor. Because the rubber-like glue metaphor supplied considerable visual and auditory feedback, the current conditions of the operation are easy to understand. Using the joint metaphor, the user can unbind all the group of parts at once. The different functions of the metaphors suggest that the operating efficiency can be increased if the metaphors are switched during operation.

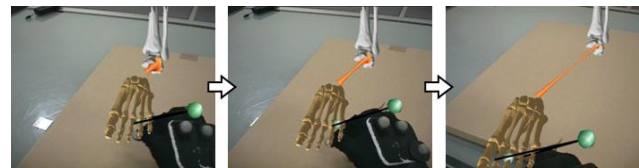
Conclusion and future work

In this study, we proposed a method by which users can separate a complex virtual object in MR space into small parts. This method avoided incorrect operations and improved comfort of operations by providing visual and auditory feedback to users using the real-world metaphors. Although we realized this method in MR, it is possible to apply this method to operation in virtual reality.

In our future work, we plan to apply new metaphors and increase the number of choices available to the users, to adjust the parameters of each metaphor's behavior via experience; and to analyze and consider the most suitable sound among the many sound effects available.

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(a) The user selects and pulls the parts.



(b) After the user releases them, they move back toward the initial position.



(c) The rubber-like glue breaks when the user pulls the parts out of the effective area.

figure 8. Rubber-like glue metaphor

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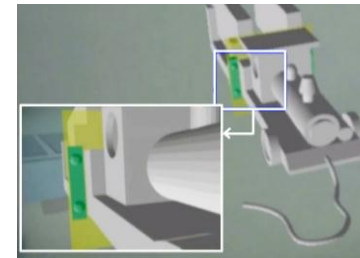


figure 9. Joint metaphor:

Display of virtual joints where the parts connect.

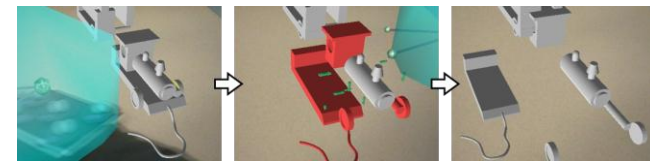


figure 10. Joint metaphor: Parts and joints spread apart.

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