# Elastic Connections: Separating and Observation Methods for Complex Virtual Objects

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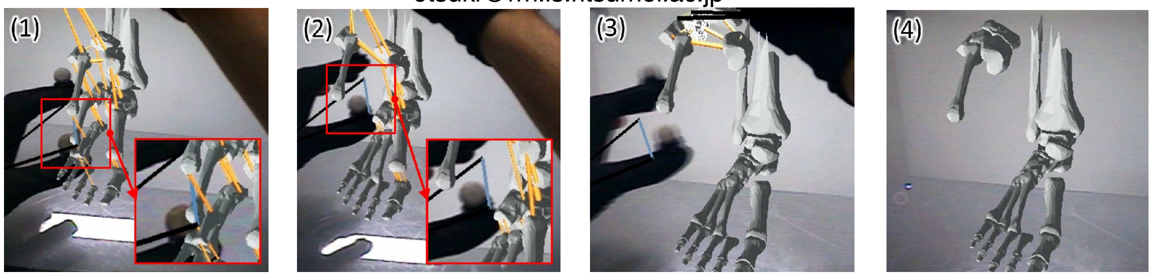


**Figure 1. Lifting and separating the group of parts by cutting virtual rubber bands between parts. After the user releases the parts, separation is complete.**

## Categories and Subject Descriptors

H5.2 [**Information interfaces and presentation**]: User Interfaces - *Interaction styles*

## Keywords

3D interaction; VR; MR; AR; Observation; Ungroup; Connection; Relationship; Gesture.

## 1. 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 3D space. In some modeling software, parts of such objects are grouped and manipulated together, but not individually, for efficient operation. However, separating operations are often necessary for partial observation or manipulation. We propose a system that realizes gesture-based separation and observation of a group of parts from complex virtual objects in 3D space. One practical application of our system is for training, such as learning the structures of the human body or industrial products.

Volume cursors [1, 2] are simple ways to select multiple targets simultaneously; however, in highly complex multi-part objects, it is difficult to avoid selecting unnecessary parts. Our method allows users to flexibly select objects using the connections between parts. There are existing techniques that utilize geometric relationships [3, 4] to automatically select multiple parts as a single group; however, these studies did not consider the connection strength between associated parts. We believe that the connection strength between parts is important when observing and separating the varied structures of complex objects, in which the size and shape of parts may vary significantly. For example, if bone, muscle, and blood vessels are interconnected in the geometric relationships within a model of the human body, and the user needs only bone structures, the connection strength based on semantic relationships is required. For example, the connections between parts of the same category may be stronger than the connections between parts in a different category.

## 2. PROPOSED METHOD

Figure 1 shows the operations required for a user to separate the parts of a foot bone model using our method. In our system, parts are connected by a "virtual rubber band," and the width of this band indicates the connection strength between connected parts. When the user lifts a part, the connected parts are also gradually lifted, relative to the distance of the user's hands movement. The user can observe the connections and the strength between the parts in detail through visual feedback that illustrate the expansion and contraction of the virtual rubber band. To assist understanding, the visual feedback is accompanied by auditory feedback, such as the stretching sounds of a rubber band.

If all parts are expanded at once, users will lose the original shape of the object, and it can become unclear which parts they wanted to separate. This is why we expand gradually relative to a user's hand movement. This method is based on Shiozawa's method [5]. Users can separate a group of parts freely by cutting the connections with their other hand, observing connections. However, even though the user lifts a single part, other parts will stay in contact with each other. In other words, the user cannot cut all connections between parts. Therefore, to create space between parts, we implemented a force-based algorithm [6], and use elastic and Coulomb forces for calculating the behavior of the parts.

## 3. FUTURE WORK

Through student trials, we found that the suitable spacing size varies depending on the user. We plan to implement a function for adjusting this spacing size. Currently, the connection strength is mapped to the virtual rubber band width. We also plan to map it to the spacing between the parts; for example, by making the space where the connection strength is strong short, a user can easily understand each group. Additionally, we are going to demonstrate the user study, evaluate the usefulness of our method, and examine the appropriateness of the interactions in detail.

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