Hands-on Virtual Clay

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Abstract

This paper presents a new interaction system designed for hands-on 3D shape modeling and deformation through natural hand gestures. Our system is made of a Phantom haptic device coupled with a deformable foam ball that supports pressure sensors. These sensors detect forces exerted by the user's fingertips, and are used to control the configuration of a compliant virtual hand that is modeling soft virtual clay. During interaction, the user is provided both passive tactile feedback through the foam ball, and realistic visual feedback since the virtual hand deforms due to its interaction in the virtual environment. The combination of all these feedbacks provides the artist with a good immersion allowing for effective sculpting in a virtual world.

Keywords: Virtual sculpture, shape modeling, interaction system

Index Terms: H.5.2 [Information Interfaces and Presentation]: User Interfaces—Input devices and strategies; I.3.7 [Computer Graphics]: Three-Dimensional Graphics and Realism—Virtual reality

1 Introduction

Currently, 3D modeling systems do not offer the artist the possibility of sculpting virtual clay as naturally as he would do it with his hands. Generally, he must deal with the underlying mathematical representation of the model - for instance control points - to modify a surface. In recent years, several virtual clay models solved this problem, providing excellent clay-like behavior [3, 1]. But none of these systems provide a device that allow the user to sculpt the clay with a virtual hand, even though hands are the most natural tool which an artist would use. This is the problem addressed by this paper.

1.1 Related work

There exist many solutions for providing hands-on interaction with virtual environments. The most common approach is to use 3D hand models that directly reproduce in virtual the position and posture of the user's hands, such as data gloves or motion capture with markers. The problem with this approach is that it involves making gesture in the air. Hence, the absence of any contact not only generates fatigue but also makes precise gesture or fingers' positioning more difficult.

An alternative approach is to use a real object as a proxy for the virtual piece of clay [4, 5]. The proxy of [5] provides a passive tactile feedback that is a good compromise between a cost effective active feedback and no force feedback at all. While a proxy can provide a tangible support for the user's hand to avoid fatigue, it does not help for positioning the clay or the virtual hand.

Our idea is to combine a proxy, which offers passive tactile feedback, with a Phantom device that allows position control of the virtual hand with respect to the clay (Figure 1).

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1.2 Contributions

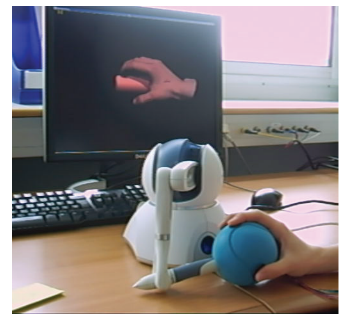

Figure 1: Our new sculpture device

This paper presents a new system that allows hands-on sculpting and provides the immersion of the user through three feedbacks:
- a visual feedback of the interaction through a realistic deformation of the compliant virtual hand;
- a passive tactile feedback through a deformable foam ball;
- a possible active feedback through a Phantom device that allows control of the virtual hand's position.

2 Virtual clay and virtual hand

We extend the real-time clay model of [1] by combining it with a physically based virtual hand model similar to [2].

2.1 A layered real-time model for virtual clay

The model of virtual clay we use [1] is simulated through a 3D grid storing the density of the clay in each cell (0 for an empty cell, and 1 for a full cell). The surface is defined as the iso-surface at 0.5 of clay density and rendered with a standard *Marching Cubes*. This implicit representation enables the modeling of shapes of any topological genius. Clay behavior is captured using a layered model (Figure 2).

- The first layer allows the user to apply *large scale deformations* such as bending or twisting by computing the displacement of matter in each cell.
- The second layer ensures *mass conservation* by checking the density of clay in each cell. If a cell contains a density greater than 1 then the matter in excess is recursively poured into the neighboring cells.
- The third layer ensures *surface tension*. It prevents the clay from spreading over space and thus avoids giving the impression the object's volume is decreasing.

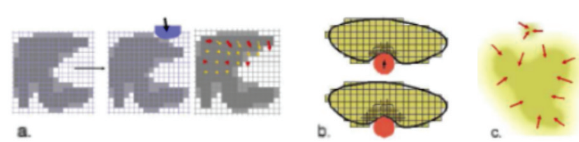

Figure 2: (a) Large scale deformation. (b) Mass conservation. (c) Surface tension (from [1])

2.2 Physically-based virtual hand

The virtual hand we use is simulated through a spring-based skeleton (Figure 3). When a virtual hand's finger is in contact with a virtual element, a force is applied to the fingertip. Using experimental compliance values [2], this force propagates along finger's joints and the hand reaches another equilibrium position.

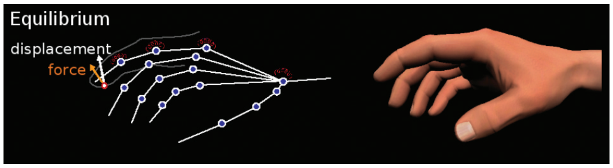

Figure 3: Left: Spring-based system of the virtual hand
Right: Model visualized by the user

3 New device with passive tactile feedback

We designed a device that combines a Phantom device for controlling the global position of the virtual hand in the virtual environment, with a proxy (here a foam ball) to provide passive tactile feedback (Figure 4).

Figure 4: Foam ball with sensors

The foam ball is fixed to the extremity of the Phantom device, and supports five pressure sensors, each one dedicated to one user's finger. By applying pressure on these sensors, the artist is able to control independently the behavior of each virtual finger. Each virtual fingertip is then considered as a sculpting tool and deforms the clay, as detailed in [1]. In contrast with proxy-less systems, the user can easily evaluate the action he is applying on the virtual clay. We experimented with active feedback by applying on the Phantom arm a resultant of the reaction forces exerted by the clay on the virtual hand. These forces are the same as those used for visual feedback, and are described next.

4 User immersion through visual feedback

During a sculpting session, simulating realistic visual behavior for the virtual hand is essential for the user to consider it as his own hand. To achieve this, the virtual hand's shape must not only depend on the desired gesture, but also on contact with the environment. We thus extended the clay model to output reaction forces in contact situations.

The direction and amplitude of the reaction force are computed according to the gradient of the clay surface at the contact point, and to the density and fluidity of the matter. A fluid friction force in the tangent direction is added. For instance, the smaller the fluidity is, the more the clay resists deformation, and in turn a larger force will deform the virtual hand. When the virtual hand is passive, i.e., when the user does not apply pressure through virtual fingers, the resulting reaction forces allow the virtual hand to bend naturally in contact with the clay, as shown in Figure 5 (left). If the user applies a larger pressure on the sensors, the deformation of the virtual hand becomes smaller and clay will deform as in Figure 6 (left).

In addition to this realistic deformation, another visual clue is added to help the user understand the position of the virtual hand with respect to the clay. In real life, when people want to catch something, they open their hand before making contact with the object. This behavior is reproduced by opening gradually the virtual hand when approaching the clay. This shows the artist he is about to touch and maybe unintentionally alter the clay. This effect is illustrated by Figure 5 (right).

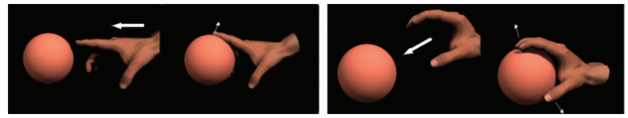

Figure 5: Left: Deformation of the index during passive contact
Right: The hand gradually opens when approaching the clay

5 Results

Our new device allows the artist to apply not only local deformations such as adding or removing matter, flattening or smoothing the surface, but also global deformations such as bending or twisting. This is done by simultaneously applying pressures on sensors and controlling the Phantom device to move the virtual hand (see Figure 6). Our evaluations resulted in a good validation for visual and passive tactile feedbacks, and 3D positioning, while the haptic force on the Phantom arm was considered not continuous enough for effective help.

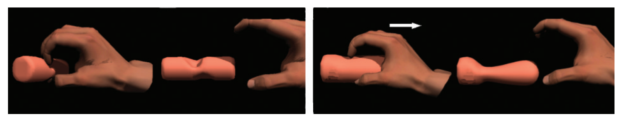

Figure 6: Pinching and stretching virtual clay

6 Conclusion

We provide a new device for hands-on sculpting that allows to control not only the global position of the virtual hand but also the motion of the virtual sculpting fingers by applying pressures on sensors. The combination of passive tactile feedback through a proxy and realistic visual behavior of the hand provides a good immersion for the artist, allowing precise shape modeling and deformations. We are still working on improving this device by improving finger control and addressing the limited workspace problem due to the size of the Phantom arm.

References

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