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Difference of the Sense of the Texture Between Visual and Touchable Cloth Object in VR Space

Yoshio Tsukuda[1] Masanao Koeda[1]

[1]Graduate School of Information Science and Arts, Osaka Electro-Communication University

Abstract

In a virtual reality (VR) space, the texture of cloth is perceived visually using the influence of three-dimensional computer graphics (3DCG) representing the cloth object surface material and movement. In recent years, research has been conducted on various dynamics-based cloth simulations in 3DCG. However, the relation between the mechanical parameters of the generated cloth and the texture of the cloth has not been clarified, and instead is implemented based on the sense of the 3DCG developer. In this study, we examine the differences of the texture sense between the visual texture of cloth objects and the texture when actively touching the cloth objects in a VR space, by changing mechanical parameters of the cloth. The experimental results with 10 subjects using a semantic differential method showed that the subjects did not feel a clear texture with most adjective pairs in the visual texture only. The subject obtained the texture more clearly by actively touching the cloth with no haptic feedback. It also was revealed that with some mechanical parameters, the sense of texture can be reversed between the visual-only feeling and the active touch of the cloth.

CCS Concepts

• ***Human-centered computing*** → ***User interface programming;***

1. Introduction

In a dynamics-based cloth simulation in three-dimensional computer graphics (3DCG), a generated cloth can be controlled by various mechanical parameters. However, when implementing the 3DCG cloth in various situations, it is not clear how a human feels when changing the mechanical parameters; instead, this concept is implemented based on the sense of the developer. Therefore, a situation could occur where a hard cloth implemented by the developer feels soft to a user.

A cloth may initially seem to be judged best by touch, rather than appearance. However, as described in the paper [NS90], when humans collect information from the real world, the influence of vision is greater than other sensory systems. It has been reported that a visual effect greatly affects a texture evaluation of a cloth.

Kawabe et al. [KTT05] proposed the concept of 'Representation' to the simulation of cloth dynamics in 3DCG animation. The effect was realized using a stable shape of the cloth that changes with time, called a 'time-varying stable form'.

Punpongsanon et al. [PIS18] proposed a projection mapping system that presents several textures of the cloth by projecting motion-controlled images on the surface of the cloth in the real world. The proposed method calculates the motion of the cloth using a near-infrared camera, and generates projection images that manipulate the cloth rigidity, based on the motion of the cloth in each frame. The movement of the projected image was the most important factor for presenting cloth stiffness.

These related studies have been conducted in the real world or 3DCG, but only with a visual cloth. The experiments have not been conducted within a virtual reality (VR) space.

In this study, we focus on the differences of the sense of the texture between the visual texture of the cloth, and the texture when touching the cloth in a VR space.

2. Experiment environment

We developed two VR systems for the evaluation; VISION and TOUCH. The VISION system is for evaluating the texture of the cloth with vision only (Figure 1). The TOUCH system is for evaluating the texture of the cloth when it is actively touched in addition to a visual evaluation. These systems are implemented on the Unity platform, and the cloth component provided with Unity is used for the cloth implementation. The cloth component can be controlled by the following mechanical parameters, to express the motion texture of the cloth: stretch rate of the cloth, bending stiffness of the cloth, and damping coefficient of motion.

In the VISION system, the displayed cloth objects are undulated with an external acceleration of 5 m/s^2 as if flying in a moderate wind, and they cannot be touched in the VR space. Four cloths are respectively placed 1 m to the front, back, left, and right of the subject. The size of the displayed cloths is 1 m $\times$ 1 m square, with a 10 $\times$ 10 vertex mesh.

In the TOUCH system, one cloth object is installed 1 m in front of the subject on the VR space, and the object can be touched by the VR controller, with no haptic feedback. The cloth object is installed with the cloth component using the same 10 $\times$ 10 vertex mesh as in the VISION system, and is touched and evaluated by the controller.

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3. Experiment and results

Using the systems described in the previous section, we examined the differences between visual-only texture evaluation and active-touch texture evaluation. In this experiment, the subjects were 10 males in their twenties.

The experiment was conducted with the following steps. The VISION system was activated, and the subject wore a head-mounted display (HMD) (HTC VIVE). The subject looked through the HMD at the cloth object placed in the VR space, and evaluated it using a semantic differential (SD) method. The following five adjective pairs, seemingly related to cloth texture, were used for the SD method: Clothy/Not Clothy, Hard/Soft, Not Resilient/Resilient, Heavy/Light, and Moist/Dry. Using these adjective pairs, the subjects evaluated each displayed cloth object in a range with 7 values, from -3 to +3. The following mechanical parameters were set from 0 to 1 in 0.5 steps: stretch, bending, and damping of the cloth component. In total, the combination of the mechanical parameters amounted to 27.

We selected the mechanical parameters with the highest and lowest and the second lowest results of the average of the evaluation. The reason why we also selected the second lowest result is that the cloth object is displayed like a board and not "Clothy" when the parameter of damping was set to 1, which evidently does not correspond to reality. As a result, 15 parameters in total were selected.

After the visual-only evaluation, an active-touch evaluation of the cloth was conducted using the TOUCH system. The subjects wore the HMD and held VR controllers in their hands, and touched a cloth object placed in the VR space. In this experiment, the mechanical parameters selected in the visual-only evaluation were the only parameters set.

In this paper, we present distinctive results only, owing to space limitations. Figure 2 shows a graph of the average and standard deviation of the evaluation results with the parameter of "Clothy" set. Figure 3 shows a graph of the average and the standard deviation of the evaluation results with the parameter "Resilient" set. The mechanical parameters set for "Clothy" are damping at 0, stretching at 1, and bending at 0, and were evaluated as "Clothy" when presented in the VISION system. Similarly, the mechanical parameters set for "Resilient" are damping at 0, stretching at 0.5, and bending at 1, and were evaluated as "Resilient" when presented in the VISION system.

In these graphs, red triangles represent the average of the evaluation results in the visual sense only, and blue triangles represent the average of the evaluation results when actively touching the cloth object. Focusing on Figure 2, the red triangles are near the center. This means that the subjects did not feel a clear texture in most adjective pairs. In contrast, the blue triangles are located in the upper right, and the subjects had a clearer texture feeling than with the visual sense only. In Figure 3, the red and blue triangles are placed at almost opposite positions from the center in most adjective pairs.

4. Conclusions

In this research, we developed a cloth presentation system in the VR space developed by Unity. The purpose of the system is to evaluate the differences in the sense of texture between a visual-only cloth and an actively-touched cloth. As a result, we found that the subjects did not have a clear texture in visual-only evaluation in most adjective pairs of SD method and obtained a clear texture when actively touching the cloth object with no haptic feedback. We also found that the sense of texture can be reversed between the visual-only feeling and the active touch of the cloth with some mechanical parameters.

As a future subject, we will conduct a statistical analysis of the acquired data. In addition, it is necessary to conduct a detailed survey on the mechanical parameters of the cloth.

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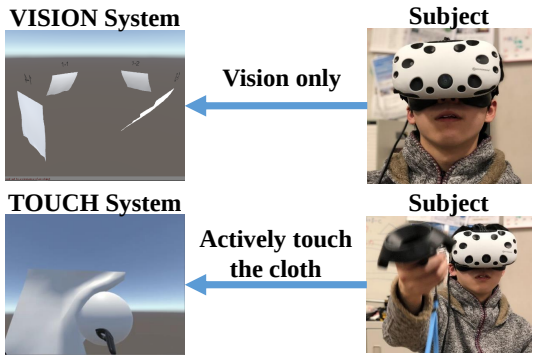

Figure 1: *VISION and TOUCH system used for the experiments*

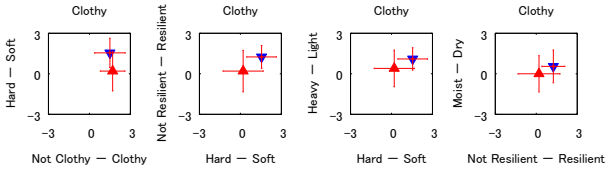

Figure 2: *Experimental results of average and standard deviation of semantic differential (SD) evaluation of the all subjects when parameter "Clothy" is set*

Figure 3: *Experimental results of average and standard deviation of SD evaluation of the all subjects when parameter "Resilient" is set*