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Virtual Scissors in a Thin Haptic and Force Feedback Environment

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The virtual scissors using virtual hands we propose enable users can cut virtual paper with their own hands. One purpose of our proposal is to facilitate implementing different tools simply by changing software parameters. Another is to make a general-purpose system with small-scale input and output devices for general applications, e.g., only using thin haptic information and force feedback. With such virtual reality (VR) scissors, we introduced feedback to cover any impressions such as interface interference during use. We evaluated whether an interaction occurred between vibration feedback and sound effects. Using this system, we found that users could manipulate virtual scissors through a data-glove similar to the use of real ones.

Keywords: virtual scissors, haptic and force feedback, thin feedback

1. Introduction

Many experiments in virtual reality (VR) research and object manipulation involve glove-like input devices [1]. The latest developments include gloves with vibrators in the fingertips for conveying information or that provide feedback forces to individual fingers.

Introducing haptic and force feedback usually involves larger, more expensive equipment, although fields such as medicine prioritize precision over cost, e.g., in the development of virtual scissors in which force feedback is considered [2].

In this research, we considered the virtual scissors system with thin haptic and force feedback [3, 4]. The system consists of only vibration feedback elements for small-scale size and low-price, because our goal is widely generalization. Among the proposals we considered are contact-point and noncontact-point vibration, introducing a cutting sound which is not calculated but a like sound effect, and providing an intentional feedback delay giving a "paper-cutting" sensation to the user, e.g., cutting thick paper.

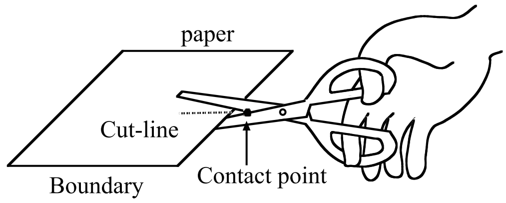

Fig. 1. Scissors and paper model.

We begin with an overview of virtual scissors and informative control, proceed with experiments and results, and close with conclusions. This technique might be not only for virtual scissors system but also for any virtual reality system to use at personal home [5].

2. Virtual Scissors

2.1. Scissors and Paper Model

We consider right-hand movement moving, opening, and closing a pair of scissors, but not picking up or putting them down (**Fig. 1**). Scissors are in continuous contact with the first thumb and forefinger joints, so we consider blade contact as a working point.

Virtual paper is defined as a flat plane with collective vertices connected by lines called a boundary. Lines created by cutting are called cut-lines. The only user operations considered are opening scissor blades, moving them while open, and closing them. Slide cutting as using knife is not allowed, then the finite-size line of the collective contact points is defined as cut-line after the operation of blade closing. Hence separating paper is not considered in this experiment.

2.2. Interaction Model

Scissor blades can interfere in the paper at the contact point, although the handles cannot. Virtual hand interference with paper is not considered. Then the path of the contact point is generated. The path is calculated as the cut-line only when it is inside boundary, although a path is not generated if the scissors is closed with no contacts on the paper.

Fig. 2. Vibrators on glove.

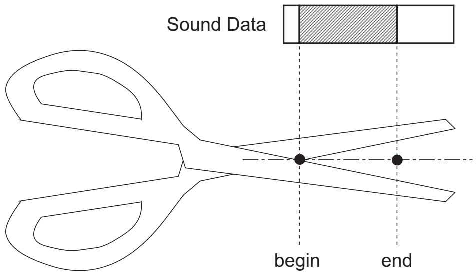

Fig. 3. Playback of cutting sound.

3. Feedback

3.1. Vibration

We give the operator some cutting feelings using vibrators of data glove, although it is different from the strict force feedback. On the glove, vibrators are set on the second and third joint of each fingers and palm (**Fig. 2**). First we have to consider the strength and the position of vibrational stimuli. Three levels of the strength were we thought as below; 1) an operator do not feel it excessively, 2) can feel it, and 3) feel strongly.

In considering where vibration would operate best, we at the first thought it is the finger which contacts with scissors. Cutting feeling by artificial vibration is already different from actual one, and vibrators are unfortunately set on the back of the finger. We used our ingenuities to vibrate other fingers which have no contacts with scissors and also palm in order to get quasi-feeling. Considering simplification, the system was set to give a constant vibration in action of cutting.

3.2. Cutting Sound

When cutting virtual paper, the system gives an operator CG (Computer Graphics) image to observe the virtual world visually. Using this system (probably many other systems), it gives not only CG image but also cutting sound. The sound was not computational, but recorded of the real sound of cutting. When cutting operation, it decided the playback part as follows (**Fig. 3**). The sound when the paper is cut was not considered for the thickness, the material of paper and also the shape, material and attitude of scissors, but considered for the position of contact point of scissors' blade. The playback part was decided only by the contact point. The beginning point of playback part is decided by the position of the contact point for whole of the blade and the end point is decided by the contact point when cutting operation ends in the same way.

In considering what sound would be best, we tend to regard as the same sound when using the same thickness paper of CG image, the same shape scissors and the same size scissors of CG image. However the system is already different at many points. For example, the visual image in 2D Display is limited, the image is not so real, and haptic and force feedback is thin. Then evaluation was done with some recorded sounds; some kinds of scissors and two materials as paper and cloth.

3.3. Intentional Delay

Heavy expression is sometimes introduced when execution speed of PC is slow. As we drag a mouse cursor or an icon, we feel it heavy when its response is a little delayed. We made an experiment as a new method to make an operator feel like cutting a thick piece of paper with scissors in the virtual space by an intentional feedback delay.

In related research, computer-mouse movement on a monitor was made faster or slower than actual operation. The system was impressed as a hillclimb and a downhill respectively. It gave an operator pseudo haptic [6].

Most of operator usually think high execution speed is best. However we cut thick paper slowly, and can not cut it fast because of the thickness. Our experimental system can input the value of an operator's hand motion and movement, calculate the interaction to the virtual environment and display the CG at 20 images per second. In other words, it contains 50 ms delay resignedly. But we can feel that we manipulate by ourselves. We generally can say that a virtual reality system is realized when the delay is under 100 ms. So we tried to make the delay over 100 ms (**Fig. 4**).

4. Experiments and Results

4.1. System Overview

The virtual scissors system was implemented on a PC (Pentium4, 2.80 GHz, 1 GB memory) in C language. Hand positioning was detected by a Polhemus 3SPACE FASTRAK and finger angles by Immersion Cy-

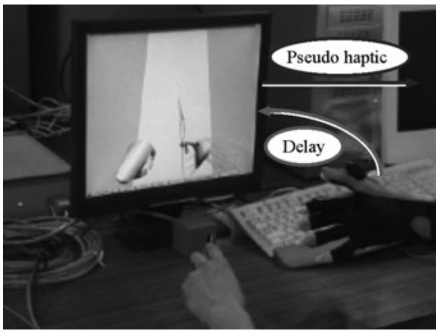

Fig. 4. Delay and pseudo haptic.

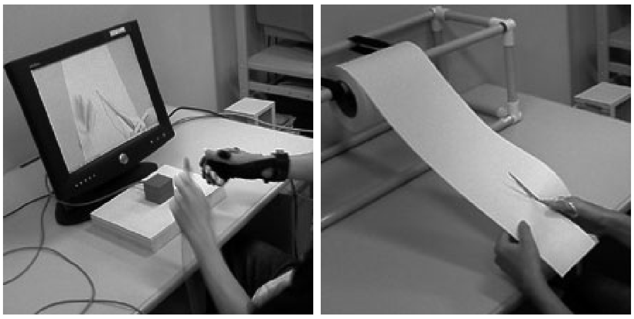

Fig. 5. System and overview.

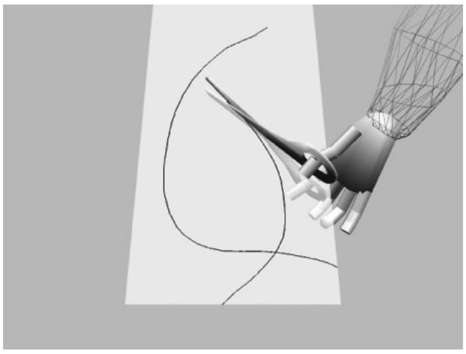

Fig. 6. Execution screen.

Table 1. Vibration reality and level.

pattern	point (average)
1	4.22
2	5.27
3	5.00
4	3.61
5	3.16

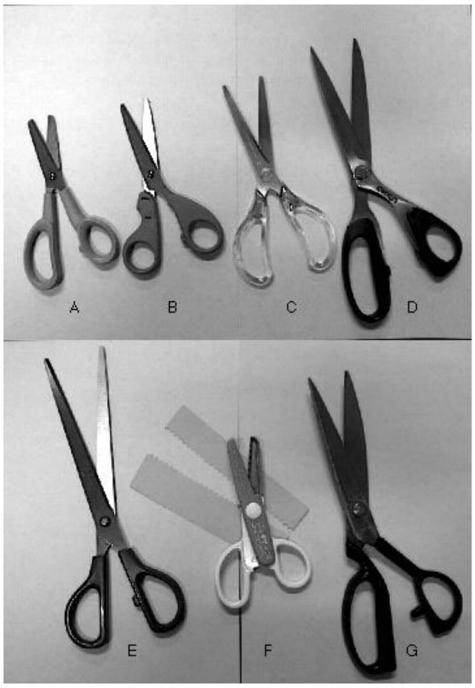

Fig. 7. Scissors A-G.

berTouch (**Figs. 5** and **6**). The CG image was refreshed at 20 frames/s. The virtual hand was assumed to be an adult male's. The 190 mm virtual scissors had 80 mm blades.

4.2. Vibration

In all experiments, the monitor was vertical and virtual paper tilted at 45-degree angle to the monitor. The right-handed subjects numbered six and had 10 minutes to work with the system before experiments. The subject could draw forth the virtual paper by the left hand movement.

Vibration experiment evaluated the strength and the position of vibration. Note that cutting sound effects were not used in this experiment. Pre-experimental study suggested that vibration at the ring finger and little finger gave poor results, as did strong vibration, so we focused on the thumb, forefinger, middle finger, and palm as vibration points, and set five patterns:

1. : finger strength 2, palm strength 2
2. : finger strength 2, palm strength 1
3. : finger strength 2, palm strength 3
4. : finger strength 1, palm strength 2
5. : finger strength 3, palm strength 2

where strength is:

1. : Not felt excessively.
2. : Felt.
3. : Provieds no vibration.

Each subject tried each pattern three times, for a totally of 15 times, in random order, evaluating the level as from 1 to 7 points after each test (**Table 1**). Results showed that felt palm vibration was effective, folloew by the middle finger and forefinger, where it was observed that these fingers sometimes contacted to the outside of handle of scissors in the pre-experiment result.

4.3. Cutting Sound

In cutting sound experiments, we evaluated effective cutting sound, and whether the real sound was necessary also in virtual scissors which was modeled with the real shape and material.

We prepared printer paper sheets, pieces of cloth 0.3 mm thick, and seven pairs scissors (**Fig. 7**), 6 of stainless steel (A to F) and blades 45, 60, 75, 105, 140, and

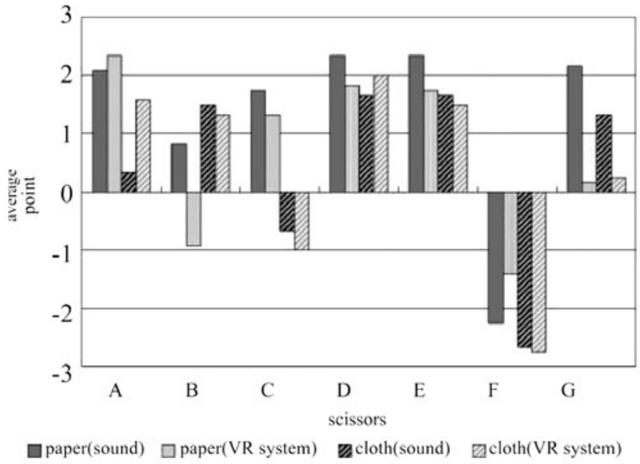

Fig. 8. Evaluation of cutting sound.

40 mm long. Scissors F, unlike A to E, which had plain straight blades, had a zigzag edge (pinking shears). Scissors G had a 100 mm blade and were of steel (dressmaker's shears) of the same size and shape as scissors D.

We recorded 14 types of cutting sound, and had six subjects evaluate them through a VR system, then the same 14 but original real sound. Note that no vibration feedbacks was provided in this experiment. Each subject listened three times to each sound in random order, evaluating it as good (+1 to +3) to bad (−1 to −3) (**Fig. 8**).

Scissors D and E scored higher than A to C. The cutting sound start position differed from the end one, with the difference increasing with blade length and longer blades being viewd more favorably. Scissors G and D had the same blade length but G scored lower in the VR environment, possibly because some subjects felt cutting operation was light as seen in their comments because steel scissors made sound with high frequency. We think that an effective sound frequency is necessary for the cutting operations.

4.4. Vibration and Sound Effect

Subjects were then asked to evaluate the effects of vibration feedback and cutting sound together under the following conditions:

1. : CG image alone
2. : CG image and vibration feedback
3. : CG image and sound effect
4. : CG image and vibration and sound.

The vibration pattern was set on the 3rd pattern and the cutting sound was set with the D sound mentioned before. Six subjects evaluated these conditions with scores of 1-7 points (**Table 2**). The vibration heightened evaluation certainly, although the effect by vibration feedback was lower than sound effect.

Table 2. Reality in different environments.

environment	point (average)
1	2.33
2	3.83
3	5.33
4	6.00

Table 3. Evaluation of cutting sound.

sound	vibration 1	no vibration
D	5.33	5.16
G	5.16	4.83
F	4.00	2.83

Table 4. Evaluation of vibration.

vibration	sound D	no sound
2	6.00	5.16
1	5.66	4.33
5	3.33	2.50

4.5. Interaction Between Vibration and Sound

To evaluate whether vibration and sound effect influenced each other, i.e., interacted. The cutting sounds the D (highest point), the G (middle point) and the F (lowest point) mentioned before are prepared for this experiment. The vibration pattern No.2 (highest point), No.1 (middle point) and No.5 (lowest point) mentioned in the section 4.2 are also prepared.

Each subject was asked to execute the following tasks:

1. For the cutting sounds D, G and F, subjects manipulated the scissors system with vibration pattern 1, and without any vibration, where they did not know there were only three patterns of the cutting sound. They answered the evaluation as level among 1 to 7 point for the sounds, not for the total system.

2. For the vibration pattern 2, 1 and 5, subjects manipulated the scissors system with cutting sound D, and without any sound effect, where they did not know there were only three patterns of the vibration. They answered the evaluation as level among 1 to 7 point for the vibration, not for the total system.

The results of average point are shown in **Tables 3** and **4**. The evaluation of both increased when adding another effect. It seemed there is an interaction between them and one effect could make another effect more effective.

4.6. Intentional Delay

Our system could be input motional values by the device calculate the interaction and display the CG image and cutting sound at 20 times per a second. It contained 50 ms delay, but we can generally judge it as real-time system under 100 ms delay in virtual reality field.

Table 5. Evaluation of delay.

subject	env. 1	env. 2	env. 3
a	good	good	bad
b	good	normal	bad
c	good	normal	bad
d	good	normal	bad
e	good	normal	bad
f	good	good	bad
g	normal	good	bad
h	normal	good	bad

The following three conditions were prepared:

1. : no delay (50 ms delay)
2. : 200 ms delay
3. : 500 ms delay.

And the system gave the subjects feedbacks of CG image, vibration and cutting sound in each environment.

10 minutes after experience at condition 1, eight subjects cut the virtual paper at each remaining condition. They tried each condition in randomized order, and answered evaluations as good/normal/bad and comments for them.

Two subjects evaluated condition 2 better than condition 1, and other two subjects answered the same evaluation for condition 1 and condition 2 (**Table 5**). We got comments for every condition 2 experiments like;

- It was heavy.
- Subject felt cutting thick paper.
- Scissors/paper is hard.

Four subjects evaluated condition 1 better than condition 2 according to their comments. As for condition 3, we got comments like;

- It was stressful.
- It was difficult to cut it straightly.
- Subject felt being old person.

Then we announced to them that the virtual paper was thick like cardboard in fact, and asked them to try again and answer again. So all of evaluations of condition 2 turned good, and the six of them was better than condition 1. From these results, the minuteness delay of haptic information is effective as force feedback. That is, time can be perceived as force.

5. Conclusions

In experiments to evaluate virtual scissors, vibration feedback is effective as force feedback, and the vibrational stimulus where man can realistically never touch, i.e., palm is also effective. Cutting sound feedback is effective on operational feeling, the sound which is replayed with the real scissors is also effective even if virtual scissors differ in size from actual scissors. An interaction occurs between vibration feedback and sound effect.

Intentional delay is effective as force feedback. The appropriate delay of minuteness makes an operator feel *heavy* and/or *hard*. Nevertheless our experiment after the announcement that the virtual paper was thick showed the delay was effective very much. Only delay is not so effective and the delay is probably just supplementary. So, for example, we have to use this method assuming thick paper of CG.

Their size and price preclude using many of the force and haptic feedback devices developed thus far for home use, while the vibrator system is used for the silent mode of mobile phone and video game controller. Although the data-glove we used is very expensive one, there are/were some data-gloves for video game in the market. It would be able to make a data-glove with vibrator at a low price in the future. Using this data-glove and the method proposed, various virtual reality system might be produced and sold, for example, for our home through the internet.

Despite some favorable results, bugs remain. We could not test sufficient statistical hypotheses for experiments because of too few subjects, meaning for example, that we tested some vibration and strength patterns but cut sound and delay, leaving them for future work. The *touchable Internet shopping system* also remains to be realized.

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References:

[1] K. Funahashi, T. Yasuda, S. Yokoi, and J. Toriwaki, "A Model for Manipulation of Objects with Virtual Hand in 3-D Virtual Space," Systems and Computers in Japan, Vol.30, No.11, pp. 22-32, 1999.

[2] A. M. Okamura, R. J. Webster III, J. T. Nolin, K. W. Johnson, and H. Jafry, "The Haptic Scissors: Cutting in Virtual Environments," Proc. the 2003 IEEE Int. Conf. on Robotics & Automation, pp. 828-833, 2003.

[3] K. Tanida, K. Funahashi, M. Ohmi, and M. Kusumi, "Embodiment Evaluation for Tools of Virtual Reality Technology -A Trial Evaluation by Measuring Hemodynamic Change in the Brain-," Transactions of Virtual Reality Society of Japan, Vol.12, No.1, pp. 3-10, 2007 (in Japanese).

[4] K. Funahashi, D. Kubotani, K. Tanida, and Y. Iwahori, "Pseudo Haptic Expression by Presentation Delay in Virtual Scissors System," Proc. the 12th Virtual Reality Society of Japan Annual Conf., pp. 393-394, 2007 (in Japanese).

[5] K. Funahashi, Y. Kuroda, and M. Mori, "A Study for Touchable Online Shopping System with Haptical Force Feedback," Proc. ICAT2008, pp. 297-300, 2008.

[6] A. Lecuyer, J.-M. Burkhardt, and L. Etienne, "Feeling Bumps and Holes without a Haptic Interface: the Perception of Pseudo-Haptic Textures," Proc. ACM SIGCHI, pp. 239-246, 2004.

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