A Study for Virtual Scissors System under Thin Haptic and Force Feedback Environment

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***Abstract*—This paper proposes the virtual scissors system using virtual hands. Users can cut virtual paper with their own hands. The purpose of this system is to make it easy to implement different tools by only changing parameters in software. Other purpose is to make system with small-scale input and output devices for general applications, for example, only using thin haptic information and force feedback. In this VR (Virtual Reality) scissors system, various feedbacks were introduced in order to cover any impressions such as the interference feeling for interface problem while using the virtual scissors and cutting the virtual paper. Using this system, users can manipulate and cut virtual scissors through a data-glove as similar to real ones.**

I. Introduction

Many researches on object manipulation in virtual space have been proposed. These virtual reality technologies are being applied to the medical area, space developments and amusement attractions, and these demands for the VR technology are getting higher. In this virtual object manipulation technology field, there are many researches using glove type input device [1]. The development of input device itself has been advanced, the glove is marketed which has vibrators at fingertips to convey information and the glove which can make feedback forces to each of four fingers and thumbs with wire.

On introducing haptic and force feedback, however, the size of equipment probably will be large-scale and more expensive. Of course in some field, i.e. medical field, priority is often given to precision over cost, hence, for example, virtual scissors system has been proposed in which the force feedback is considered [2].

In this research, we considered the virtual scissors system with thin haptic and force feedback [3][4]. Especially, the system consists of only vibration feedback elements for small-scale size and low-price, because our goal is widely generalization. One of our proposals was that we considered vibrating not only at the contact points but also at non-contact points, and giving the cutting sound which is not calculated but a like sound effect. Other was that we gave an intentional feedback delay on the system to make an operator have feeling like cutting a thick piece of paper.

In this paper, we describe firstly the outline of virtual scissors system and next the informative control method. Then we would like to show the experiments and results. This technique might be not only for virtual scissors system but also for any virtual reality system to use at personal home.

II. Virtual Scissors System

A. Model of Scissors and Paper

In our system, we consider the scissors which moves, opens and closes following the movement of the right hand (Figure 1). For simplification, taking and releasing scissors are not considered. The scissors are always contacted with the thumb's first joint and forefinger's first joint of the right hand. Then the Contact point which blades contact each other as a working point is calculated.

The virtual paper is defined as a plane, not curved, and as collective vertices. And the lines connecting vertices together are called Boundary. The newly-created lines by cutting operation are called Cut-line. Here the operator doesn't execute any operations except for closing blades, opening them and moving while opening them, i.e., 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.

B. Interaction Model

In this model, the blade parts of the scissors can interfere in the paper at the Contact point, although the handle parts do not interfere. At the same, the interference of virtual hand with the paper is not considered. The cutting operation is executed only as closing action by the operator, moving scissors as moving action and opening blades as opening action. 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.

III. Feedback

A. 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 (Figure 2). First we have to consider the strength and the position of vibrational stimuli.

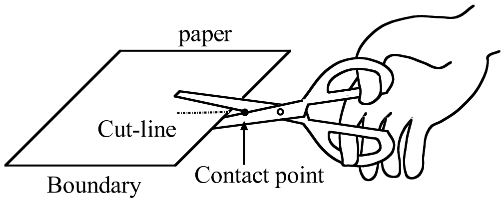

Fig. 1. Model of scissors and paper

Three levels of the strength were we thought as below; 1) an operator dose not feel it excessively, 2) can feel it, and 3) feel strongly.

So where would be best position to vibrate? Of course we at the first thought it is the finger which contacts with scissors. However cutting feeling by artificial vibration is already different from actual one, and vibrators are unfortunately set on the backside of finger. We used our ingenuities to vibrate other fingers which have no contacts with scissors and also palm in order to get quasi-feeling. And furthermore considering simplification, the system was set to give a constant vibration in action of cutting.

Fig. 2. Vibrators on glove

B. 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 (Figure 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.

So what kind of 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.

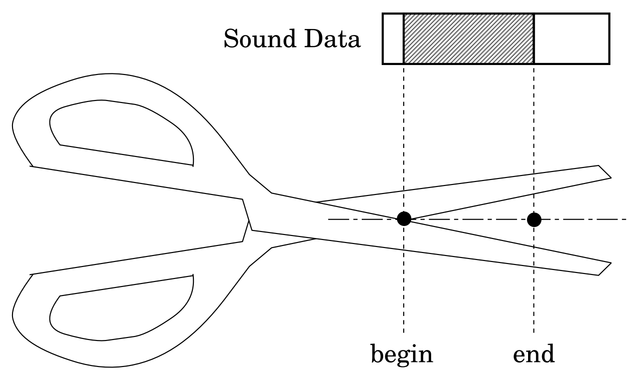

Fig. 3. Playback part of cutting sound effect

C. 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 experimental design 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.

There are some related researches: one of them proposed that making the motion of a mouse cursor on a monitor faster/slower than the movement of bodily operation. The system was impressed as a hillclimb and a downhill respectively. It gave an operator pseudo haptic [5].

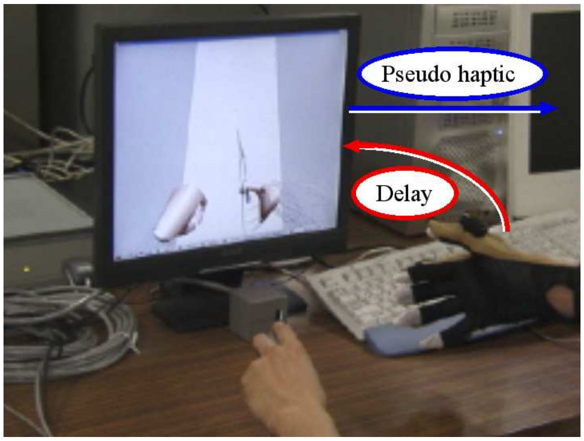

Fig. 4. Delay and Pseudo haptic

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 50ms 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 100ms. So we tried to make the delay over 100ms (Figure 4).

IV. Experiment and Result

A. System Overview

The virtual scissors system mentioned above was implemented on a PC (Pentium4, 2.80GHz, 1GM memory) with C language. The position of hand was detected by Polhemus 3SPACE FASTRAK and the angles of each finger were detected by Immersion CyberTouch. The system appearance and CG image of this system are shown in Figure 5 and 6. It refreshed the CG image at 20 frames/sec. The virtual hand shown in CG was assumed as that of adult man's. And the length of virtual scissors was given 190mm with 80mm blade.

B. Vibration

In all experiments, the monitor was set up vertically and the virtual paper was tilted as 45 degrees to the monitor. The number of right-handed subjects was six and they had 10 minutes experience of this system before experiments. The subject could draw forth the virtual paper by the left hand movement.

In the first experiment, the strength and the position of vibration (note that there were no cutting sound effects in this experiment) were evaluated. However, vibration at ring finger and little finger did not give good results in pre-experiment. And strong vibrations made feel bad. Hence we focused on the thumb, fore and middle fingers and the palm at vibration points, and set five patterns as follows;

1) fingers: strength 2, palm: strength 2

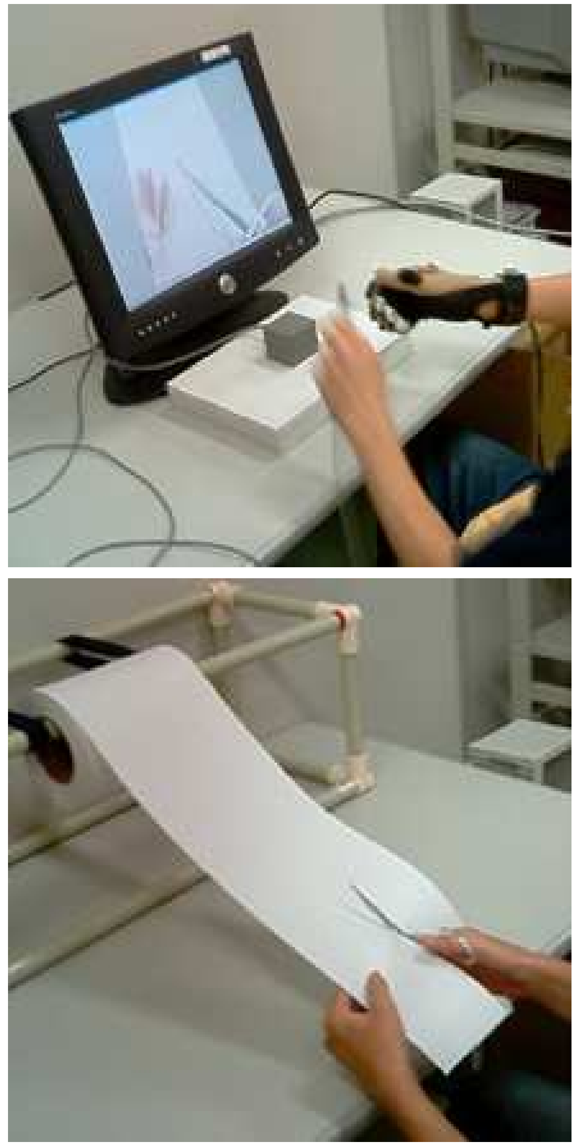

Fig. 5. System overview and Image

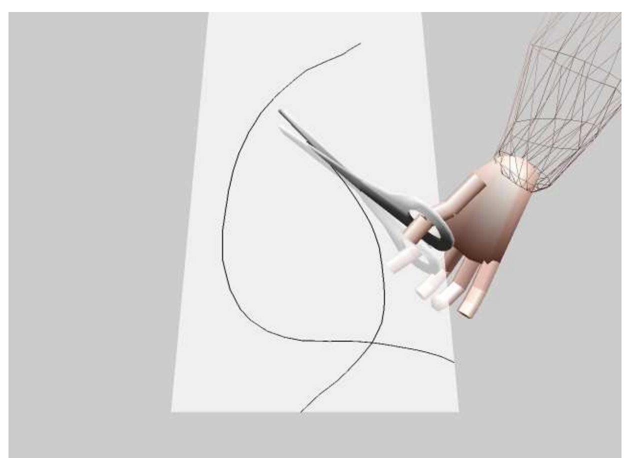

Fig. 6. Execution screen

TABLE I
REALITY FOR VIBRATION PART AND LEVEL

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

2) fingers: strength 2, palm: strength 1
3) fingers: strength 2, palm: strength 3
4) fingers: strength 1, palm: strength 2
5) fingers: strength 3, palm: strength 2

where strength is;

1) the subject dose not feel it excessively
2) the subject can feel it
3) no vibration

Every subject was tried three times for each pattern, that is, they totally tried 15 times in randomized order. After each test, they answered its evaluation as level among 1 to 7 points. The result of their averages is shown in TABLE I. The result shows that a little vibration at palm was effective. Vibrations at middle finger and the next forefinger were also effective, where it was observed that these fingers sometimes contacted to the outside of handle of scissors in the pre-experiment result.

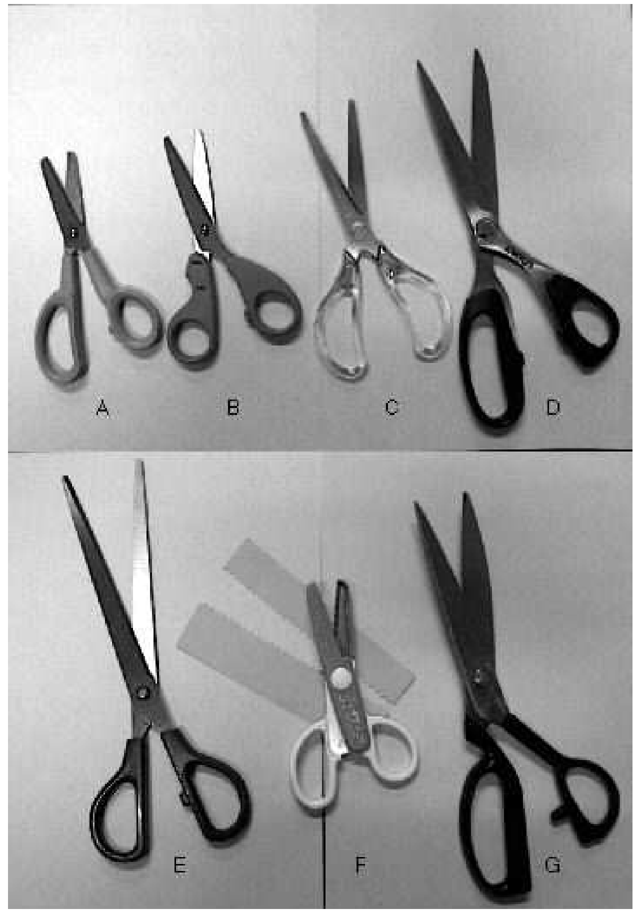

Fig. 7. Scissors A-G

C. Cutting Sound

In this experiment, we evaluate what kind of cutting sound was effective, and whether the real sound was necessary also in virtual scissors which was modeled with the real shape and material.

We prepared some sheets of general paper (for printer) and some pieces of cloth which was about 0.3mm of thickness, and seven kinds of scissors as follows;

A) 45mm blade length, stainless steel
B) 60mm blade length, stainless steel
C) 75mm blade length, stainless steel
D) 105mm blade length, stainless steel
E) 140mm blade length, stainless steel
F) 40mm blade length, stainless steel, the cut-line will be zigzag
G) 100mm blade length, steel, dressmaker's shears, as same as D in size and shape

These seven scissors are shown in Figure 7. Then we recorded 14 kinds of cutting sound, and we asked six subjects to evaluate the 14 kinds of cutting sound through VR system (note that there were no vibration feedbacks in this experiment) and the same 14 kinds of original real sound without VR system. Each subject was listened to three times for each sound in randomized order. When a subject felt a sound good, the subject pointed $+1$ to $+3$, when felt bad, pointed -1 to -3. The result is shown in Figure 8.

In the result of this experiment, it is seen that scissors D and E got higher points than A to C. The beginning position of cutting sound is different from the end one, and the difference became bigger when blades got longer. We could guess that long blades made subjects feel better. Although the blade length of scissors G is the same as scissors D, it got lower evaluation in the VR environment. We can guess the reason is that 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.

D. Vibration and Sound Effect

Then the effects of vibration feedback and cutting sound were evaluated together. Following four conditions were prepared first;

1) only CG image
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. Next we

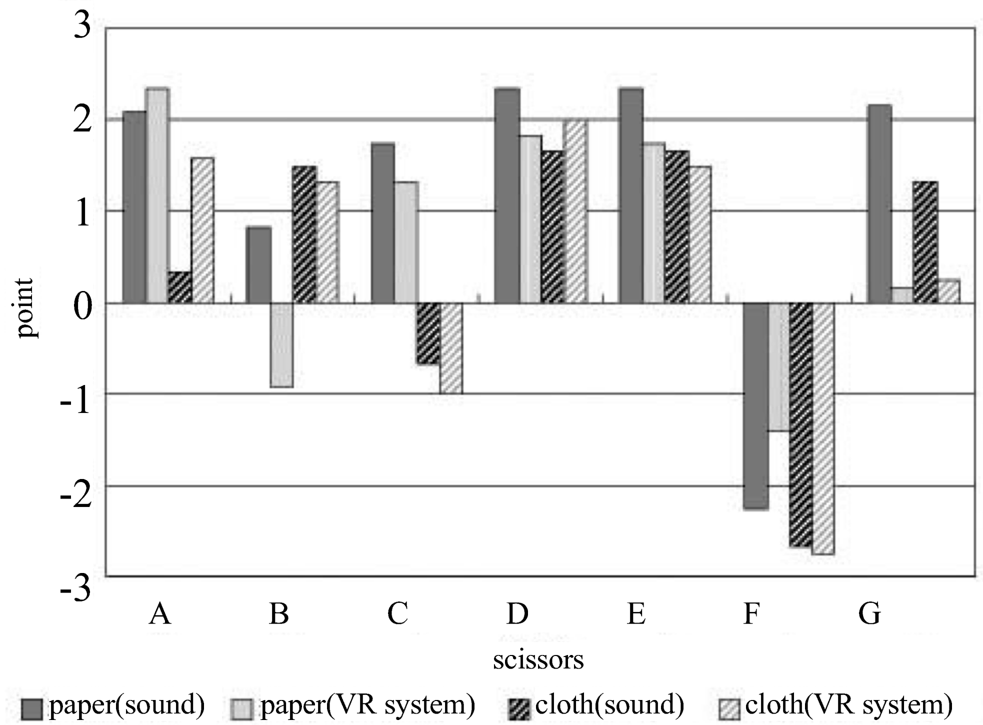

Fig. 8. Evaluation of cutting sound

TABLE II
REALITY UNDER EACH ENVIRONMENT

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

asked six subjects to evaluate these four conditions by 1-7 points. The result is shown in TABLE II. The vibration heightened evaluation certainly, although the effect by vibration feedback was lower than sound effect.

E. 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 50ms delay, but we can generally judge it as real-time system under 100ms delay in virtual reality field.

Here three conditions were prepared as follows;

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

TABLE III
EVALUATION FOR EACH DELAY

subject	environment 1	environment 2	environment 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

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.

V. Conclusion

Experimental evaluations were done using virtual scissors system. The vibration feedback is effective as force feedback, and the vibrational stimulus where man can realistically never touch, i.e., palm is also effective. The cutting sound feedback is effective on operational feeling, the sound which is replayed with the real scissors is also effective even if the virtual scissors size is different from real one.

The intentional delay is effective as force feedback too. 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.

Many kinds of force and haptic feedback device have been researched and developed, but the size and price of most of them are not for home use, while the vibrator system is used for the silent mode of mobile phone and video game controller recently. 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.

Good results were obtained, but there are some points to be improved. For example, we tested just some patterns of vibration position and strength level, cutting sound, and delay time. As a future subject, these above problems are remained to be solved. Many patterns of them should be tested and analyzed, and the optimized pattern should be found automatically. It also remains as our task that *Touchable Internet Shopping System* should be realized.

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