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Eternal Sharpener – A Rotational Haptic Display that Records and Replays the Sensation of Sharpening a Pencil

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Abstract— **This paper proposes a simple 1 DOF rotational haptic display that achieves endless sharpening of a pencil. Many haptic applications have been proposed to present shapes, elasticity, viscosity, and other physical properties of the environment. While these are important to support many tasks such as teleoperation and computer aided design, we focus on the use of haptic display for amusement. We paid special attention to the feeling of "addictive comfortableness" induced by haptic stimulation. We take "pencil sharpener" as a typical example, because it is obviously comfortable and has addictiveness. Moreover, the mechanism is relatively simple because the sensation could be generated through 1 DOF haptic display. In this paper, we recorded force and sound of the real pencil sharpener and replayed the sharpening sensation through a haptic display.**

I. Introduction

THERE were many proposals of haptic devices. A typical product Cyber Grasp and Cyber Force [1] present a sense of touch to the fingers or a forearm, while bar type or spherical handles are used to convey haptic information in PHANToM [2] and SPIDAR[3]. Applications of the haptic display ranges from teleoperation and telesurgery [4] to CAD and entertainment.

We pay special attention to the application of haptic display to the field of entertainment. Although the haptic devices were used as "a part of" entertainment, such as a game pad, a joystick and a shock wear, it seems that there were very few proposal of entertainment that haptic display plays major role.

Yohan et al. [5]paid attention to the affectivity that is an important characteristic of the sense of touch. The concept of "Haptic Affect" will be promising haptic displays.

However, although affectivity will be an important aspect of haptic sensation, it seems that there is something that is more primitive, that is not affective, but is addictive. Music provides a good analogy to understand the difference between the two. The most primitive music is composed of pure rhythm, which is not affective, but is addictive. The first entertainment application that is solely composed of haptic display will be such thing.

We looked for the situation that is comfortable and addictive haptically in our daily life, and found one example. It is a situation of sharpening a pencil.

The pencil sharpener is obviously comfortable and has addictiveness. Moreover, it seems possible to achieve the virtual pencil sharpener by using 1 DOF haptic display. The 1 DOF rotational haptic displays were used in many previous researches including Maclean et al.[6], in which doorknob was taken as an example.

Our goals of the project are composed of following three steps. One is to replay the sharpening experience by a haptic display. Another is to quantify the addictiveness of the sensation, The other is to find principle of the addictiveness associated with haptic experience.

Anticipating the above goals, this paper focuses on the construction of a system that records and replays the sensation of a pencil sharpener.

II. Strategy: Record and Playback

THE device construct must display two types of sensation, audio and haptic. Naturally the audio signal will be played by a speaker, while the haptic signal will be generated by a DC motor.

The problem is how to mimic the behavior of a pencil sharpener. Common technique to achieve the behavior is to use physical model. However, it is obviously difficult to express the behavior of a pencil sharpener by using a usual spring mass dumping model, because dominant factor is friction induced by internal knife and pencil.

There is other proposed method to model the behavior of the contact phenomenon that is not purely modeled by simple physical properties[7]. The method is basically a curve fitting of a real recorded data by a function with four parameters, position, speed, acceleration and time. In this case, the "model" already does not have physical entity, but still it is quite a practical solution. However, in the situation of pencil sharpener, the vibration frequency range is so wide that this method does not work well. Currently, we do not find standard method for modeling a situation that includes wide frequency range, such as a pencil sharpener.

As another approach for record & playback, Hashimoto [8] had succeeded in adapting a simple method for his SUI (straw-like-user interface) system. The SUI is composed of straw, attached with electric valve and speaker, to enjoy the sensation of drinking. In the recording phase, the sound generated by drinking behavior was recorded a number of times, with varying sucking intensity. In the replaying phase, the recorded soundtracks are switched in real time according to the sucking pressure, which realized natural sensation of

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drinking with quite simple method.

We use the same technique as a first step. It is necessary to collect the vibration signal with different speed. But as the structure of the pencil sharpener is rotational, we will need to record data from only once cycle rotation.

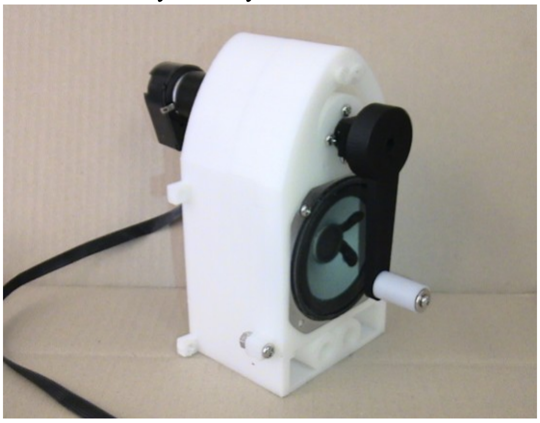

Fig. 1 Prototype device

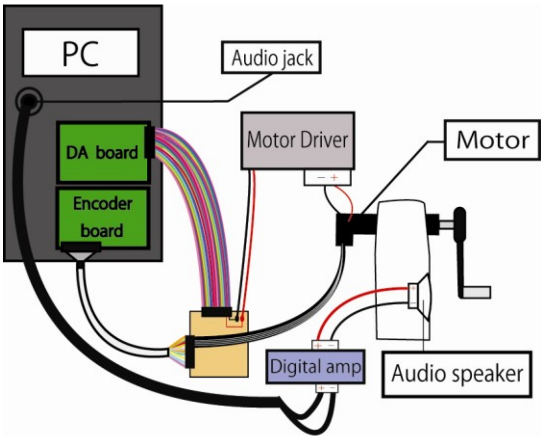

Fig. 2 System configuration

III. EXPERIMENT

A. System configuration

As described in section II, we need two systems, a recorder and a player. Of course we could record the input force by utilizing rigid motor and torque sensor, but that would be beyond the intended scale of this project. For this study, we manufactured a simple device which recorded and replayed data.

Fig. 1 depicts the prototype device and Fig. 2 illustrates the system used to record and present the sensation of sharpening a pencil.

The knob's axis is connected to the motor's axis. The handle of the knob could be rotated circularly. The motor used to estimate reaction force and vibration sensation was a 10W DC Motor which was attached to an encoder (MAXON Corp.). The motor driver was a JW-143-2 (Okatech Corp.) which supplied high current to motor. The encoder board and DA board was PCI-6205C, PCI-3523A (Interface Corp.). The audio speaker used to display sound was a standard product.

B. Recording experiment

The input data obtained from sharpening a pencil consisted of the sharpening force and angular velocity. This was used to recreate the sharpening sensation by measuring these elements. The resulting sound was also recorded.

Fig. 3 shows the mechanism used to record the characteristic vibration and sound generated by sharpening a pencil. The rotatable handle of the device was connected with the rotatable handle of a real pencil sharpener. Both were affixed to a ground, and tightly connected by paper tape.

The recording was made by actually sharpening a pencil while passing an electric current through the motor. The motor's refresh rate and measured frequency was 5 kHz. The pencil was a Uni-star (hardness HB, Mitsubishi pencil Corp.). The motor's velocity and current was measured while keeping the motor's angular velocity constant by PID control. In this experiment, it was expected that the electric current which passed through the motor would equal the rotating force of pencil sharpener's handle.

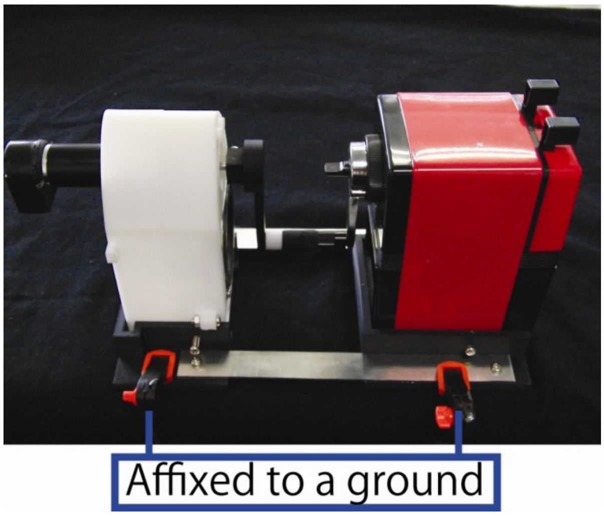

Fig. 3 Experimental figure: Each device is connected by paper tape. Both are affixed to the surface

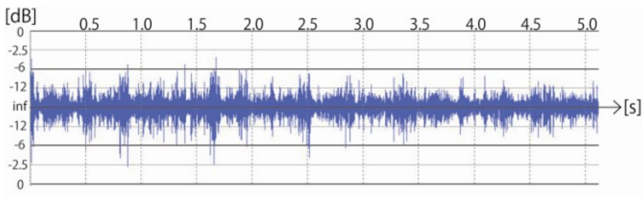

Fig. 4 Recorded sound

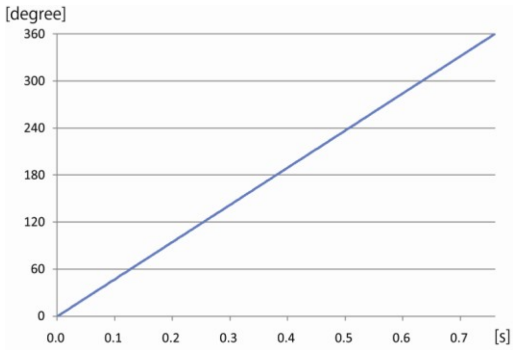

Fig.5 Position of the motor's angle through time

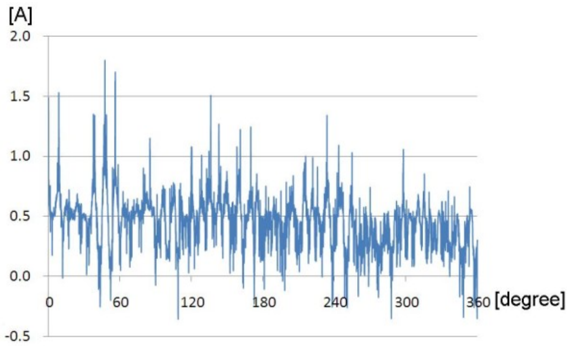

Fig. 6Results of the measured current

Fig. 4 shows a graph of the sound generated by sharpening. The sampling frequency was 44100Hz. As indicated byFig. 5, the motor rotated at a constant velocity. The motor's angular velocity was 78.9 rpm. Fig. 6 shows the measured current data. This is an example of one rotation cycle.

C. Output

The recording of the measured current displayed various frequencies. For modeling the sharpening sensation, it was necessary to determine which frequency domains cause the sensation felt when sharpening a pencil. Then, the domains were divided into three main sensation areas.

1) Force sensation domain(DC-to-50 Hz)
2) Vibration sensation domain(50 Hz-to-1 kHz)
3) Acoustic sensation domain(over 1 kHz)

In this experiment, we output the sensation by adjusting the gain in each frequency domain.

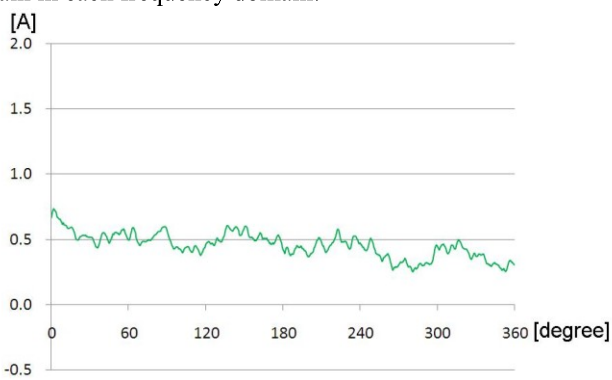

Fig. 1 Force sensation domain

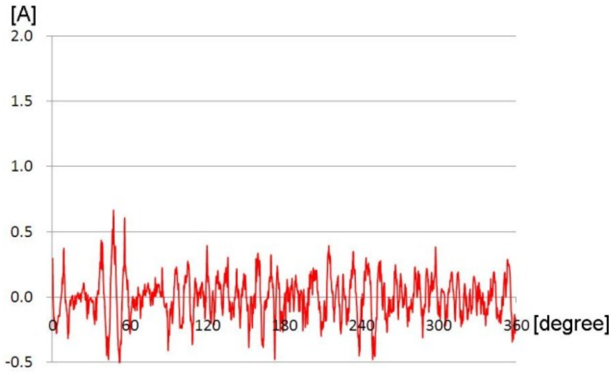

Fig. 8 Vibration sensation domain

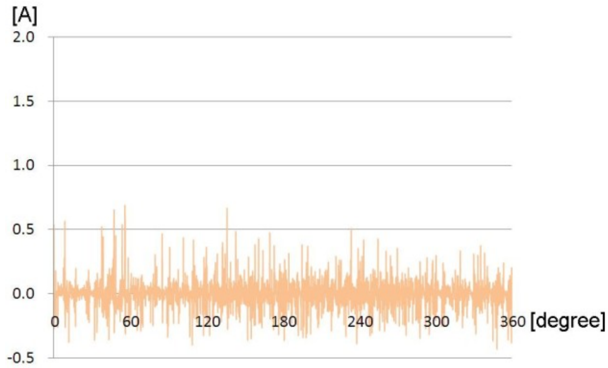

Fig.9 Acoustic sensation domain

Fig. 7, Fig. 8 and Fig. 9 shows the divided domains.

Next, utilization of the three domains was used to present the sharpening sensation. The main tactile sensation of the pencil sharpener is primarily generated by high frequency, while the element of reaction force is low frequency.

Initially, only the tactile sensation was presented through use of the vibration domain and the acoustic domain (Fig. 10). An examinee tested the output device and subsequently commented that the tactile sensation was closely approximated real pencil sharpener but stated that it lacked the sound and reaction force of a real pencil sharpener.


Fig. 10 Figure of output experiment

Next, recorded sound and the force sensation domain, as seen Fig. 4 and Fig. 7 , were added. The examinee commented that the sound lacked realism, and reaction force did not have a pencil sharpener's random nature. The sound and reaction force require further improvement.

IV. CONCLUSION & FUTURE WORK

IN this paper, the use of a rotational system has been proposed to present a novel haptic sensation. It was found that a rotational haptic display could use recorded data to present the sensation of sharpening a pencil.

In this simulation, experiment data was obtained at one angular velocity. However, for displaying a more realistic sensation, a state of all angular velocities should be measured to accommodate user's variable velocity input data.

For future works, the random nature of pencil sharpeners will be investigated to present a more accurate simulation. The realism of the sound needs improvement as well.

REFERENCES

[1] Immersion Inc.: http://www.immersion.com/.

[2] PHANTOM: http://www.sensable.com/index.htm.

[3] Ishii Masahiro, Cai Yi, Sato Makoto: Integration of Binocular Stereopsis and Haptic Sensation in Virtual Environment, IEICE technical report. Image engineering, Vol. 97, pp 41-46, 1998.

[4] Guillaume P, Herve D and Nicholas A: Real-Time Large Displacement Elasticity for Surgery Simulation: Non-linear Tensor-Mass Model, Medical Image Computing and Computer-Assisted Intervention , 2000

[5] Yohanan, S. and Maclean, K. E.: The Haptic Creature Project: Social Human-Robot Interaction through Affective Touch, in Proceedings of the AISB 2008 Symposium on the Reign of Catz & Dogs: The Second AISB Symposium on the Role of Virtual Creatures in a Computerised Society, vol. 1, pages 7-11, Aberdeen, Scotland, UK, April 2008.

[6] Karon E., MacLean and Jayne B. Rodersick: Smart Tangible Displays in the Everyday World: A Haptic Door Knob, Proceedings of the 1999 IEEE/ASME International Conference on Advanced Intelligent Mechatronics, pp204-208, 1999.

[7] Mark B. Colton and John M. Hollerbach: Reality-Based Haptic Force Models of Buttons and Switches, IEEE International Conference on Robotics and Automation, pp 497-502, 2007.

[8] Yuki Hashimoto, Naohisa Nagaya, Minoru Kojima, Satoru Miyajima, Junichiro Ohtaki, Akio Yamamoto, Tomoyasu Mitani and Masahiko Inami: Straw-like User Interface: Virtual Experience of the Sensation of Drinking using a Straw, Proceedings of the 2006 ACM SIGCHI International Conference on Advances in Computer Entertainment Technology, 2006.