Haptic Display of Representing Roughness

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Abstract. In this study, we examined methods of sensing roughness with haptic displays. We used a PHANToM DeskTop-E Device (Sensable Technologies) as our haptic device. Representation of paper quality applies to dictionaries, notebooks and other everyday items, not just calligraphy and washi paper(Japanese paper). In contrast, the discrimination thresholds were $Z_{0.75}$ = 1.0 [N] for dynamic friction and $Z_{0.75}$ = 0.25[N] for static friction. In the case of PHANToM DeskTop-E, we showed that we made a large range of the comparison friction.

Keywords: haptic device, virtual reality ,static friction, dynamic friction, PHANToM DeskTop-E.

1 Introduction

As a result of recent advances in three-dimensional (3D) video technology and stereo sound systems, virtual reality (VR) has become a familiar part of people's lives. Concurrent with these advances has been a wealth of research on touch interface technology [1], and educators have begun exploring ways to incorporate teaching tools utilizing touch properties in their curriculums [5,6]. However, when used as teaching tools, it is important that a touch interface provide a "feel" that is as close to reality as possible. This will make replacing familiar teaching tools with digital media incorporating VR seem more attractive.

For example, various learning support systems that utilize virtually reality (VR) technology [7] are being studied. Examples include a system that utilizes a stereoscopic image and writing brush display to teach the brush strokes used in calligraphy [8,9], the utilization of a robot arm with the same calligraphy learning system [10], a system that uses a "SPIDAR" haptic device to enable remote calligraphy instruction [11], and systems that analyze the learning process involved in piano instruction [12] or in the use of virtual chopsticks[13].

Additionally, since it is a basic rule of pen-drawn characters that even a slight displacement of the pen tip is impermissible, pen-drawn character reproductions must be within 1 mm tolerances and will appear out of balance if drawn too long or too short. In response, support system ems for penmanship instruction and similar applications on tablet PCs have been developed [14], and associated re-search indicates that both the curriculum and content are important factors for creating VR

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materials [5]. Penmanship instruction systems and similar applications using interactive haptic devices connected to networks have been devised, and various experiments have been performed into their usage [15].

We use PHANToM Omni device and obtained satisfac-tory results [16]. It is interesting to compare the results of this study with the former information [17]. In the main cause for the error is machine friction. We used PHANToM DeskTop-E device as a substitute for PHANToM Omni. We changed PHANToM Omni to PHANToM DeskTop-E with improve the accuracy.

Teaching calligraphy, for example, normally requires a paper medium for output. The smoothness of the paper medium will change depending on the paper quality. Accordingly, in this study, we examined methods of sensing roughness with haptic displays. Representation of paper quality applies to dictionaries, notebooks and other every-day items, not just calligraphy and washi paper (Japanese paper). We believe our experimental results provide elements of the basic information necessary for haptic devices to represent such roughness.

2 Experiment

In this study, we used a PHANToM DeskTop-E Device (Sensable Technologies) as our haptic device. It was attached to a control computer (CPU: Intel® Core™i5-4430[3.00GHz], RAM:8.GB, OS:64bit) running Open Haptics™ toolkit v3.0 as the control program [2].

We began by modeling images of the surface texture for notebook and other paper types using friction experiments. When creating friction via the haptic display, it was first necessary to determine what level of friction was discernible.

3 Experiment Overview

We conducted both dynamic and static friction experiments, during which we measured the threshold for frictional force and points of subjective equality. Five male test subjects, approximately 20-21years of age, participated in both experiments.

3.1 Experimental Method

The constant method for measurement was used. During the experiment, each test subject was presented with two stimuli to compare. They then comparatively scaled their subjective impression of the stimuli as “Rough”, “Equal”, or “Smooth”.

3.2 Type of Stimulus

The stimulus on which comparisons were based was called the standard stimulus (SS). For frictional forces, the SS was limited to one type of stimulus with a fixed range of physical quantities. The stimulus used for comparison with the SS was called the comparative stimulus (CS). A number of CS types were prepared in incremental quantities centered on the stimulus quantity of the SS. The friction used were 0.8-3.2[N] for dynamic and static friction (SS = 2.0), with seven types of stimuli prepared for each. Stimulus allocation is shown in Tables 1.

Table 1. Friction stimuli

Stimulus	S_1	S_2	S_3	S_4	S_5	S_6	S_7
Friction [N]	0.8	1.2	1.6	2.0	2.4	2.8	3.2

3.3 Experiment Procedure

Measurements were performed using one test subject at a time. The subject was seated in front of the PHANToM unit and given the pen component to hold. They then followed instructions displayed by the computer and moved their arm to draw a straight line on the model board using an arbitrary amount of force. Subjects were then asked to evaluate a total of 70 randomly presented stimuli combinations comprising seven combinations, including an SS pair, each shown 10 times. As the PHANToM only guarantees forces up to 7.9(kg-m/s2) (7.9[N])[2], the unit was restricted because the application of normal force greater than this level would not register.

4 Results and Discussion

A probabilistic model was introduced to analyze the experimental data. Data parameters were estimated using maximum likelihood[3].

4.1 Results

Frequency distributions of the measurements are shown in Tables 2 and 3. Si (i = 1,...,7) was the SS.

Parameter values for the data in Tables 2(a) and (b) were derived using maximum likelihood to obtain the results in Tables 3 and 4. Here μ is the average, σ is the distribution, c is the decision criterion, and $Z_{0.75}$ is the normal deviation with a cumulative probability of 0.75 at normal distribution. The upper and lower thresholds are $\mu + Z_{0.75}$ and $\mu - Z_{0.75}$, respectively.

These results yield Figures 1 and 2 the horizontal axis gives the exhibited stimulus values, or friction coefficients, and the vertical axis gives the likelihood or proportion of judgment. The small circles represent data values. A green star means the SS was judged to be stronger (Si < S4), a red square means the values were judged to be equal, and a filled in blue circle means the CS was judged to be stronger (Si > S4). The curve is the probability of the judgment from parameter values derived from the experimental data.

Table 2. Example of Friction Experiment

(a) Dynamic

Comparative Stimulus	Category		
	$S_4<S_i$	$S_4=S_i$	$S_4>S_i$
S_1	8	9	33
S_2	9	9	32
S_3	10	11	29
S_4	15	24	11
S_5	30	11	9
S_6	30	9	11
S_7	31	9	10

(b) Static

Comparative Stimulus	Category		
	$S_4<S_i$	$S_4=S_i$	$S_4>S_i$
S_1	0	0	50
S_2	0	3	57
S_3	0	18	32
S_4	16	24	10
S_5	42	8	0
S_6	47	3	0
S_7	47	3	0

Table 3. Parameter Values for Dynamic Friction Experiment

μ	Σ	c	$Z_{0.75}$	$\mu+Z_{0.75}$	$\mu-Z_{0.75}$
2.0142	1.4906	0.50768	1.0054	3.0196	1.008

Table 4. Parameter Values for Static Friction Experiment

μ	σ	c	$Z_{0.75}$	$\mu+Z_{0.75}$	$\mu-Z_{0.75}$
1.9623	0.36814	0.25358	0.24831	2.2106	1.714

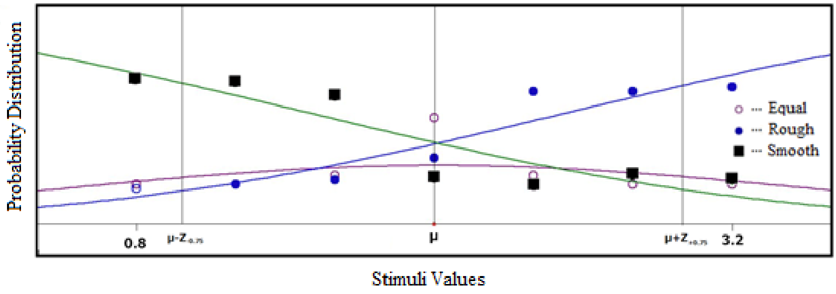

Fig. 1. Analysis Results for Dynamic Friction Experiment

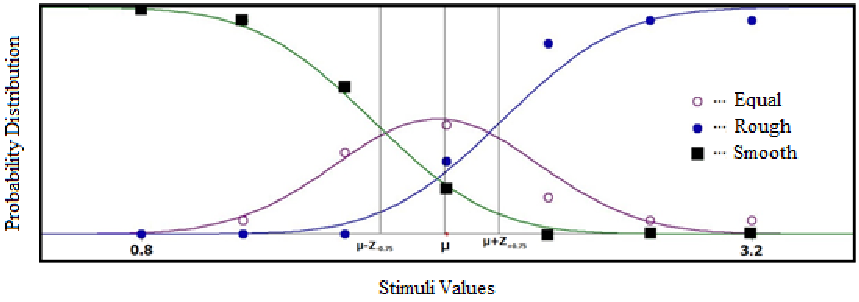

Fig. 2. Analysis Results for Static Friction Experiment

4.2 Discussion

From the results in section-4.1, it can be seen that if a friction of 2.0 is taken as the SS for dynamic friction, the point of subjective equality is $\mu = 2.01$. If a friction of 2.0 is taken as the SS for static friction, the point of subjective equality is $\mu = 1.96$. The margin of error between SS and point of subjective equality is small, indicating that the experiment contains few errors made by individuals. In contrast, the discrimination thresh-olds were $Z_{0.75} = 1.00$ for dynamic friction and $Z_{0.75} = 0.25$ for static friction.

5 Conclusion

In this study, we used haptic displays to measure points of subjective equality and the threshold of friction, an ele-ment of touch. However, because the force displayed by PHANToM units is the touch force transmitted through the hand holding a pen, the results provide deep sensory char-acteristics, not skin sensation, and are much larger than the frictional forces sensed by actual human hands[4]. Never-theless, a haptic display like this system is thought to be usable way of duplicating surface roughness for notebook pages or other similar materials when quantifying basic operating characteristics, such as writing in, touching and turning pages. The threshold of the dynamical friction coef-ficient of the PHANToM DeskTop-E has to make a stimulation values the wide range. The machine friction of PHANToM Omni is 0.26. However, the machine friction of PHANToM DeskTop-E decreased in 0.06. Therefore, In the case of PHANToM DeskTop-E, we showed that we made a large range of the comparison friction. In the main cause for the error is machine friction.

As a future topic, we will verify whether Weber's law can be applied to the discrimination threshold from the experimental results using alternate standard stimuli. We will also work to verify whether applying friction increases efficiency of the collision simulation.

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