Energy-Efficient Vibrotactile Presentation for Mobile Devices Using Belt Winding

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***Abstract*— To enrich experience or to assist operation in mobile devices, vibration feedback is popularly used. In general, vibration actuator vibrates the whole body of mobile device to transmit vibrotactile sensation. However, it requires high energy to produce strong vibration because the actuator needs to vibrate large mass of the mobile device. In this study, we proposed a method to transmit vibration sensation to a hand with less energy, by vibrating a lightweight belt made of PET film covering the body of the mobile device. We developed a prototype using two DC motors to vibrate the film belt. The prototype can present vibration with two modes; touching on the belt (on belt), and belt covering on the fingers (under belt). We measured electric power required for presenting subjectively the same strength vibration and compared with conventional technique. Result showed that our prototype consumes significantly less energy than the conventional technique, especially for under belt condition.**

I. Introduction

To enrich touch experience or to assist the operation in mobile devices, vibration feedback is popularly used [1][2]. In general, vibration actuator vibrates the whole body of the mobile device to transmit vibration, but such a technique requires high energy because the actuator needs to drive large mass of the device.

On the other hand, in haptics research field, methods of attaching actuators to fingertips and directly stimulating the skin has been proposed. Yem et al.[3] [4]proposed to mount a small DC motor on the fingertip and present perceptual force by applying asymmetric acceleration. Minamizawa et al.[5] proposed to present vibration and force sensation by winding a belt attached to the fingertip using two DC motors. Since the actuator drives only the fingertip, they can present strong vibration sensation with low energy. However, the users need to mount the device on their fingertips, which is impractical for mobile environment, since the operation is mainly performed with the fingertips.

To present strong vibration sensation with low energy in mobile environment, we propose a method to transmit vibration by a belt winding mechanism. The backside of the mobile device is covered with a lightweight belt made of PET film, and two DC motors drive the belt. Unlike the conventional method, our method can present vibration sensation regardless of the size and weight of the mounted device, because the actuator drives only the belt and the skin touching it.

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In this paper, we report the details of the method that presents vibrotactile sensation with small amount of energy using the belt winding mechanism. For the evaluation of this method, we prepared a prototype made of smartphone case with DC motor mounters, two DC motors, and belt (Figure 1.), and compared the prototype with the conventional method in terms of the amount of electric power required for presenting the same strength vibrotactile sensation.

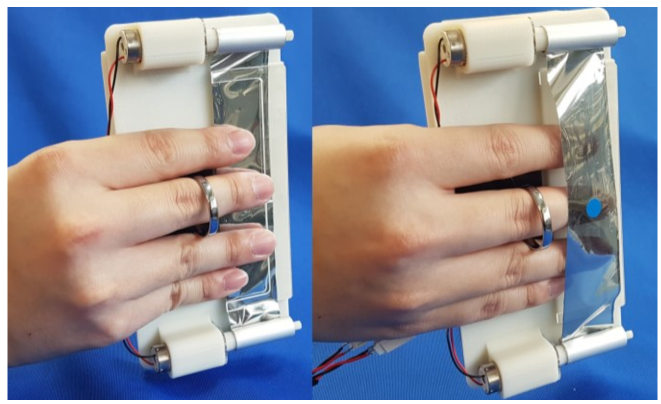

Figure 1. Overview of the protptype. (Left) Vibration is transmitted to the fingertip by touching on the belt in “On belt condition”, and (Right) to instep of the fingers by covering fingers in “Under belt condition”

II. Prototype and Evaluation

A. Hardware

Figure 2. shows the details of the developed prototype. The device consists of 3D-printed ABS resin smartphone case, smartphone hotmock (Xperia Z2, 147mm×73mm×8.2mm, 161g), grip ring (Banker Ring 3, i&PLUS, Japan), two DC motors (HS-V1S, S.T.L. JAPAN Inc., Japan), a belt winding shaft, and a belt made of PET film. We used also “guide” parts to limit the movement of the belt only to the horizontal direction. Audio signal is applied to the DC motors via the audio amplifier (RSDA202, RASTEME SYSTEMS Inc.) to vibrate the belt. Vibration is transmitted to the finger by touching the vibrating belt. The prototype can present vibrotactile sensation with two modes by changing contact condition between the belt and fingers. One is touching on a belt (Figure 1. Left) and the other is covering on fingers (Figure 1. Right).

B. Evaluation

We conducted an experiment to verify whether the proposed method can present vibrotactile sensation with less energy than the conventional method. In this experiment, we prepared a comparative device with vibrators (Haptuator Mark II, Tactile Labs) mounted and driven with constant power. We instructed the participants to adjust the volume of the audio amplifier so that the intensity of the sensation from the proposed device was felt the same as the comparative device, and measured the power required by the proposed device to present vibration. The experiment was conducted in two contact conditions, touching on a belt (on belt condition) and belt covering on fingers (under belt condition).

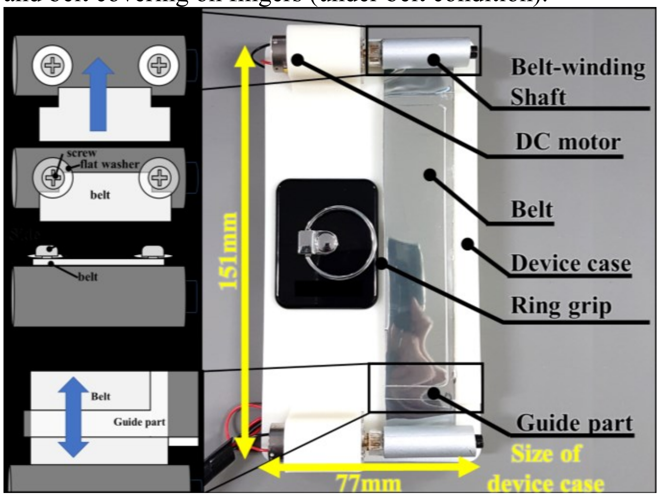

Figure 2. Configuration of the prototype

During the experiment, the electric power applied to both devices was constantly monitored by the method used in previous study [3], and the comparative device was always driven with 1W(watt).

We recruited nine laboratory members for "on belt condition" (21-33 years old, 8 men, and 1 female), and nine laboratory members for "under belt condition" (21-33 years old, 8 men, and 1 female, four members participated in "on belt condition"). First, the participants grasped the comparative device driven at 1W, and adjusted the volume of the audio amplifier so that the intensity of sensation from the proposed device was felt the same. The participants were allowed to grasp the devices for adjusting the volume as many times as they wanted. We prepared five frequencies (25Hz, 50Hz, 100Hz, 200Hz, 400Hz), and randomly presented five times per frequency.

The result of the experiment is shown in Figure 3. The vertical axis of the graph shows the average value of the applied electric power to the proposed device adjusted by the participant. The horizontal axis shows the frequency of presented vibration. The error bar shows the standard deviation. In "on belt condition", Wilcoxson's signed rank test between applied electric power of each frequency and 1 W applied to the comparative device showed no significant difference at 400 Hz ($p = 0.286$), but significant differences were confirmed at all other frequencies (all $p < 0.01$). From these results, in "on belt condition", it was suggested that the proposed device can present vibrotactile sensation with less power than the existing vibrator at 25Hz, 50Hz, 100Hz, and 200Hz.

In "under the belt", Wilcoxson 's signed rank test between applied power of each frequency and 1 W applied to the comparative device showed significant differences at all frequencies (all $p < 0.01$). From these results, in "under belt condition", it was suggested that the proposed device can present vibrotactile sensation with less power than the existing vibrator at 25Hz-400Hz.

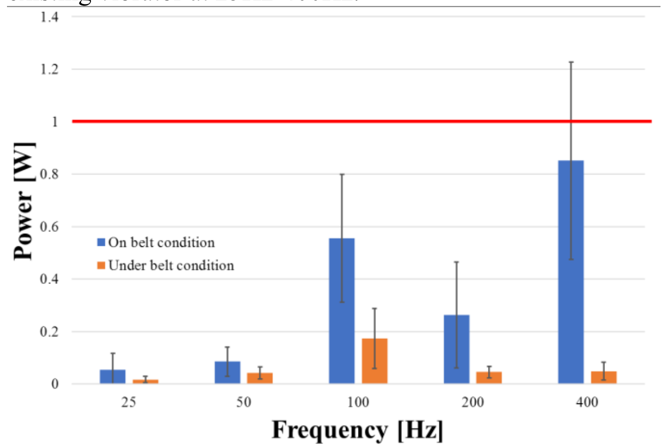

Figure 3. Answered power in “on belt condition” and “under belt condition” compared with the vibrator driven at 1W. Red line shows the electric power applied to the comparative device.

III. Conclusion

In this paper, we proposed a method of presenting vibrotactile sensation with less energy using belt winding mechanism in mobile environment. Our method transmitted vibration through a vibrated belt made of lightweight film. Our method can also present vibrotactile sensation with two modes by changing contact condition between the belt and fingers, touching on a belt and belt covering on fingers. To evaluate our method, we developed a prototype device based on our method. By comparing the power required for presenting vibrotactile sensation with the conventional method, it was suggested that the vibration can be presented with less energy.

Acknowledgment

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