Hapbeat : Single DOF Wide Range Wearable Haptic Display

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Figure 1: Left: The Hapbeat, Middle: How the device be worn, Right: Internal structure

ABSTRACT

Hapbeat is a single DOF haptic display, which enhances virtual reality experiences and music listening. It consists of two coreless motors and stiff string, and feedbacks compression forces of 0 to 600 Hz, i.e. from DC forces to high fidelity acoustic vibrations. The motors generate vibrations of up to 600Hz and the string transmits them. Comparing to existing devices, Hapbeat can generate powerful low frequency vibrations and transmit them to wide range of the user's body in spite of its compact body. The user can feel air pressures of powerful low frequency sounds, high fidelity vibrations of acoustic instruments and hitting of strong smashes.

KEYWORDS

Vibroacoustic device, Music listening, Virtual reality, Wearable device, Haptic

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1 INTRODUCTION

The spread of HMD VR reveals lack of haptic feedbacks and VR controllers start to equip vibrators, which gives limited haptic feedbacks to the hands. On the other hand, haptic feedbacks on body trunk is not widely spread. Some vibrotactile suits are proposed but wearing of them takes time and limit the clothings of the user. Moreover, they use vibration motors or linear vibrators whose bandwidths and/or vibration strokes are limited.

To solve the problem, we proposed a newsingle DOF haptic device named Hapbeat (Fig. 1) which gives strong force feedback with high temporal resolution within a compact and easy-to-wear device[Yamazaki et al. 2016]. It consists of two motors and a string wound around the user's body trunk. The device feedbacks both compressive force and acoustic vibration. As a result, the user can distinguish the strength of the hitting forces and the material of the sword, such as iron or bamboo.

Several vibroacoustic devices such as "body sonic system" have already been developed[Komatsu 2002] and used in entertainment facilities such as clubhouses and 4DX movie theaters. Some wearable devices [Woojer 2016] are also proposed but their bandwidths and powers are very limited, while our prototype provides strong and wide range of acoustic vibrations.

Here, we demonstrate wireless wearable devices for HMD VR applications.

2 TECHNOLOGY

Hapbeat has two coreless motors and an ultra high molecular weight polyethylene string. The string is worn on the user's body and pulled by two motors (Fig. 1 Right) whose current is controlled

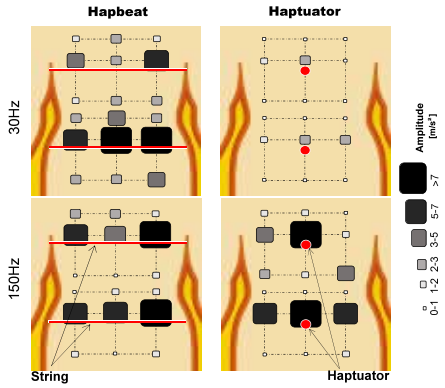

Figure 2: Comparision of Vibration Transmission

by an DC audio amplifier. Inputted sound signal rotates the shafts and changes the rotational directions quickly, so the string tight and relax the user's body repeatedly.

Hapbeat has several important advantages over linear vibrators.

First, it can transmits the vibration to a wider area of the body than conventional vibrators owing to the different contact region. While vibrators only contact on limited surfaces of the user's body, the string attaches around the body trunk.

Second, motors can play low frequencies well [Yem et al. 2016] because they can rotate infinitely regardless of their sizes. In contrast, small vibrators has limited linear stroke, which in turn limits the amplitude of low-frequency vibration, (Fig. 1 Right). In the range of ultra low frequency, the user feels the force rather than the vibration, though conventional vibrators can't generate any feelings.

Third, the proposed device can play high fidelity vibration. Conventional vibrators have limited bandwidth for high frequency because they should move their heavy bodies. In contrast, proposed device only moves light coreless rotors and a string. The wide bandwidth realizes strong attack or sudden force, which is useful to present hits of strong smash and slash. It also realizes to display high fidelity impact vibrations, which can be clues to recognize materials and structures of hit objects.

3 EXPERIMENTS

To illustrate the characteristics of Hapbeat, the proposed device, we compared Hapbeat and Haptuator.

Fig. 2 shows the amplitude of transmitted vibrations from the same input energy. The upper half shows that Hapbeat transmits low frequency vibration (30 Hz) efficiently, while Haptuator transmits a little. The lower half shows that Hapbeat transmits wider area even for higher frequency (150 Hz) where Haptuator works well.

Fig. 3 shows subjective impressions for enhancement of music listening with acoustic vibration by each device. We asked 10 participants to listen to two musics without vibration, with Hapbeat and with Haptuators. Visual Analog Scales are used to answer four impressions. It seems the quality of music including a bass drum was more enhanced by Hapbeat.

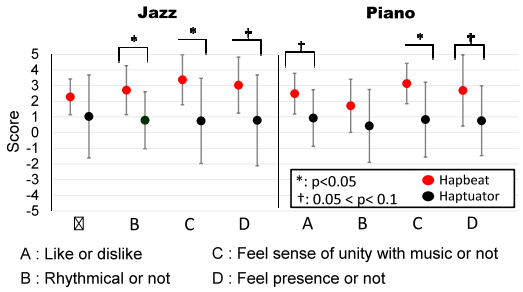

Figure 3: User Study Results

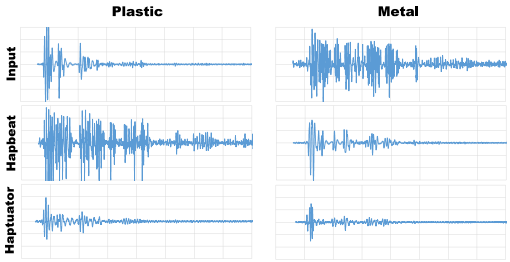

Figure 4: Comparison of Reproduced Vibration

Fig. 4 shows comparison of haptic effect for VR game. We measured acceleration of body trunk surface when it hit by a plastic stick and a metal stick. Then, we use the waveform, which is shown in the first row in the figure, as an input to drive Hapbeat and Haptuator to give the haptic effect of VR. The figure shows that the input waveforms are different for different materials of the stick and they are transmitted well by Hapbeat. On the other hand, Haptuator plays smaller and slowly rising vibration.

4 FUTURE

Hapbeat has a potential to be the de facto standard device for wearable haptic display for body trunk. In addition to HMD VR, it can be used for notification of various information, music listing, augmented and mixed reality. Even during conventional activities other than media consumption, the proposed device can be a private, secret and wider bandwidth haptic display without interfering to almost any conventional activities and communication channels.

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