Widespread the Hapbeat：Tension Based Necklace Type Haptic Display

Yusuke Yamazaki[1], Hironori Mitake[1], Shirai Akihiko[2], Shoichi Hasegawa[1]

[1] Tokyo Institute of Technology (Japan) [2] GREE, Inc. (Japan)
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ABSTRACT

Hapbeat is a wearable haptic device which can easily enhance the immersion of digital contents such as VR, gaming, music, movie, etc. In this paper, I explain a basic mechanism of Hapbeat and a series of challenges to widespread it into the public.

1 INTRODUCTION

My fundamental motivation is to realize haptic feedback becomes a basic expression method just like audio-visual does. The mainstream of haptic researches is focusing on hands to improving operability of digital information. The researches become utilized in fields of surgery operation, CAD modeling , teleoperation, and consumer devices like smartphones or gaming controllers. Those are important and usable but missing another side of an important feature: affecting emotions.

Just like audio-visual, or even more, haptic feedback affects your emotions. For example, feeling the air pressure of sounds in live performances or in theaters, interaction with your family or partner, or any kind of comfortable and pleasant feelings. These feelings are evoked not only at hands but at your entire body. There are many types of research trying to enhance the immersion of entertainment contents, and the stimulated body part is diversified. Those are unique and interesting but there is a great gap to be used in the real world.

2 WHAT IS HAPBEAT?

Hapbeat is a necklace-type haptic device which can generate and transmit powerful hi-fidelity haptic feedback to users by just wearing like a necklace. It's due to the unique mechanism using the combination of a motor and string.

The unique point is Hapbeat can display ultra-low frequency (0-20Hz) which is difficult to play with general audio devices or small vibrators. Therefore, it can play the unique vibration such as air vibration generated by an explosion or bass drum, or human heartbeat, and those are important for enhancing the immersion of music, video games, VR contents, or movies.

Thanks to its reasonable cost and usability, it can be used in various propose such as not only in huge facilities but in small-scale facilities, events (e.g. live performance, disco, or e-sports), or sold as consumer products as an audio device or a gadget for video or VR games.

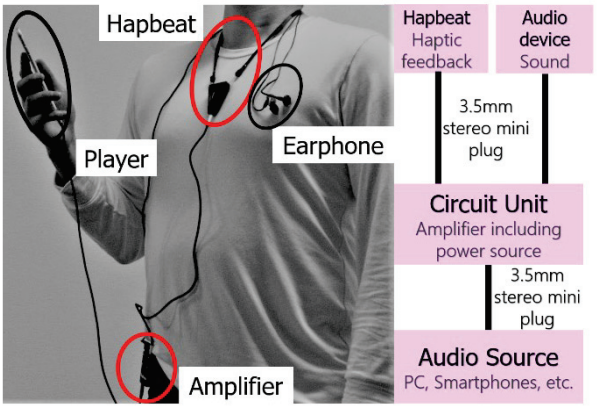

Fig. 1 Hapbeat overview
(Left) Appearance (Right) configuration

2.1 MECHANISM

Fig. 2 shows the mechanism of linear vibrators, which are ordinarily used in general haptic devices, and Hapbeat. General haptic devices have trouble the trade-off between the power of vibration and the size due to the mechanism of a linear vibrator. Fundamentally, it moves the weight linearly and the enclosure is moved by the reaction force. That movement vibrates the contact point of human. This can be done by a simple mechanism using a weight, mechanical spring, coil, and magnet, but it has a trade-off. As you see in Fig. 2, the maximum stroke of the weight is limited by the size of its body. It means the vibration amplitude is physically fixed by the size of vibrators because the stroke directly turns into the amplitude. This is crucial for producing powerful low-frequency vibration. Therefore, it is difficult to make a small and powerful linear vibrator. This can easily imagine if you think about small speakers cannot produce powerful sound especially in low frequency. (The mechanism of speakers and a linear vibrator is almost the same. Speaker moves cone paper instead of weight.)

In contrast, we developed a totally new mechanism using a motor and a string which breaks the trade-off. As you can see in Fig. 2, a string is mounted on the motor pulley. The rotation of the motor shaft turns into linear movement of the string and it becomes vibration which is transmitted to the human body. The key point is that the rotation is not limited by the size of motors or enclosure. It means the stroke of vibration is unlimited therefore it can generate powerful vibration especially in

low frequency regardless of its size. Hapbeat also has an advantage in hi-fidelity because it uses a coreless motor i.e. the moving part is very light (the coil and string). In addition, it can transmit vibration to wider part of body area because the transmission part is string, not the enclosure. The following experiment shows this characteristic.

2.2 EXPERIMENT: VIBRATION TRANSMITTION

Fig. 3 shows experimental result comparing Haptuator (linear vibrator) and Hapbeat (Principle version winding string around the body). As you see, Hapbeat transmits vibration to wider area of a body part and vibrates well in both 30Hz and 150Hz. In comparison, you can see Haptuator only transmits vibration to a narrow range around the contact point. In addition, it cannot generate well in 30Hz. Therefore, this result shows that Hapbeat is more suitable for giving haptic feedback on wider part of the body such as body trunk or upper chest. If you need more detail, please review our previous work [1].

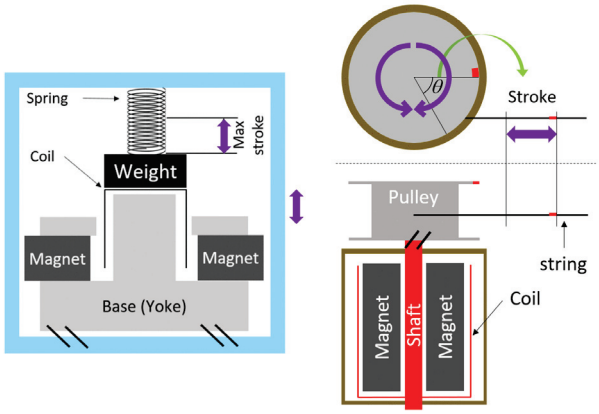

Fig. 2 Mechanism Comparison
(Left) Linear vibrator VS (Right) Hapbeat
The purple arrows indicate how they move

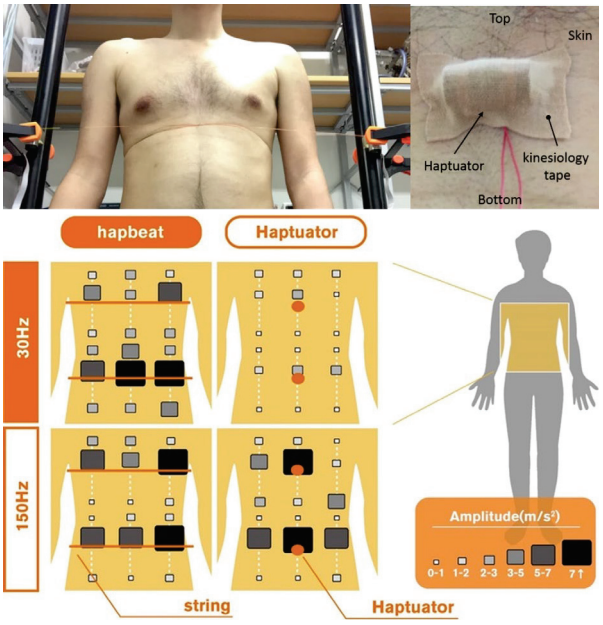

Fig. 3 Experiment result
The top figure shows the experiment condition. The bottom figure shows the result of vibration amplitude measured on the body. The locations of squares are the measured location. The size of the squares shows the amplitude.

3 UTILIZE NECK HAPTICS FOR NAVIGATION

In the previous section, I mentioned the ability to transmit simple vibration. That is undoubtedly useful and important to enhance the immersion of the contents, but Hapbeat can also transmit more complex information such as distance and direction towards a target. To do so, we use Hapbeat-Duo (Fig. 4), an advanced model of necklace-type which can control both sides of neck strap individually by two motors embedded.

The reason for focusing on the neck haptic is that it is desirable to place for wearable devices because neck devices are easy to wear, don't limit users' movements, and are comfortable to use. Effective haptic rendering on the neck enables new and practical applications for VR.

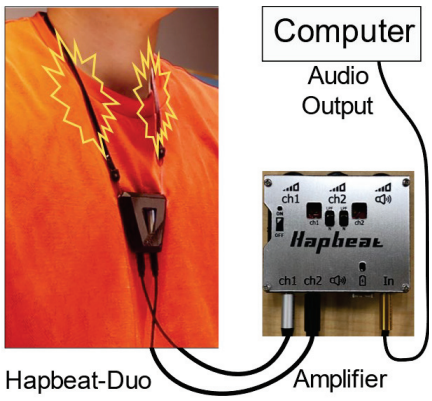

Fig. 4 Hapbeat-Duo configuration

3.1 RELATED STUDIES

Previous studies have shown that vibration on the sides of neck muscles affects standing posture, walking speed, and walking route [2,3]. About hardware, Reza developed a collar type haptic device which has small vibrators arranged in arrays. Unfortunately, Kelly proves that the neck is not sensitive enough to determine the exact point of stimulation [4].

However, haptics researchers generally use devices which have small vibrators arranged in arrays to convey directional and distance information by controlling actuate patterns [5,6]. This method is effective for various parts of a body (e.g., buttocks, arms, or back), but does not work on the neck.

3.2 METHOD

Instead of using arrays of vibrators, we use only two actuators. We modulate parameters (e.g., amplitude and phase) of vibration waves dynamically according to the distance and azimuth between a player and a target

(Fig. 5).

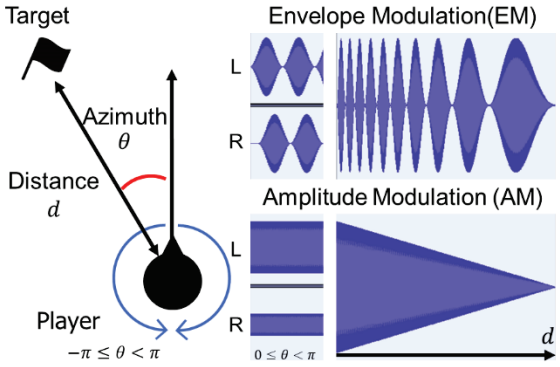

Fig.5 Definition of distance and azimuth, and example of modulation model.

3.3 EXPERIMENT: REACHING INVISIBLE TARGET

To verify our method works well, five participants were asked to find an invisible target by haptic feedback using the proposed algorithm and a Hapbeat-Duo device. The rendering algorithm is expressed using a sound function of the game engine (Unreal Engine4 ver. 4.21) to confirm whether the general stereophonic sound algorithm (logarithmic attenuation function and spatial biannual specialization method is selected) can be applied or not. Strictly speaking, the sound algorithm differs from the proposed formula, but we verified that the important functions (i.e., the attenuation by the distance and the modulation of the envelope by the azimuth, which combines EM and AM model shown Fig. 5) correspond to our algorithm. Additionally, we presented an impact wave (10Hz sine wave, duration of 0.2 seconds) when the player reached the targets to indicate success.

An overview of the experiment is shown in Fig. 6. We first explained the algorithm verbally and showed how the vibration transmitted to the player by directing a game character toward a visible target as a tutorial. It took about 30 seconds for each player. Next, the player sought the invisible targets with their eyes open i.e., he/she could only see the player character and the ground. Finally, the player wore a blindfold and sought the targets.

As a result, all five participants succeeded in reaching three individual targets using only haptic feedback. They told us they could recognize the increasing vibration amplitude the target. A distinction between left or right was much easier than perceiving distance due to the difference of phase and amplitude of the envelope. Some told us that they felt the vibration flowing from side to side on their neck when the target was located on their side. Furthermore, they could immediately tell they had reached the target due to the impact wave.

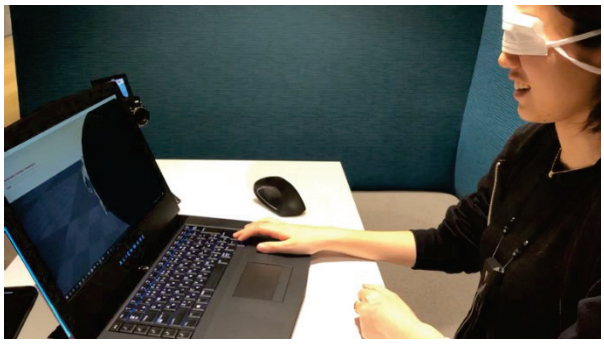

Fig.6 Experiment overview

4 THE WAY TO COMMERCIALIZATION

The most important point to achieve my motivation, realize haptic feedback becomes a basic expression method, is sharing Hapbeat. The best way to do so, especially the case of hardware, is selling the device. So, we've developed many types of prototypes shown in Fig. 7.

First three models (May. 2015 to Jul. 2016) are developed for demonstrating in an academic conference. We use a commercial audio amplifier to drive and Maxon motor for the motor unit. The experience is great, even compared to the recent model, but it was far from a product in terms of usability and cost (especially Maxon motor is too expensive). From Sep. 2016 model, we focus on productizing.

Integrated amplifier circuit into the enclosure and use a cost-effective coreless motor.

Then we launched Kickstarter project to start manufacture but failed to raise fund. Feb. 2017 model is a prototype used in the project. There are a couple of failed reasons to be considered, but the most crucial reason is difficult to imagine the experience only by watching the teaser video. In addition, we noticed the belt type is still too bothering to use in daily life by hearing from potential users. We lacked the aspect of how it can be used in daily life and who will use it. For example, where it will be used in? Home, office, or on the train? Who will use that? Musician, music listener, or live house enthusiast? And so on.

Therefore, we focused on developing the rentable necklace model (Nov.2017 model). We rent it to applicants for two weeks and interviewed them about their personal backgrounds, when and where they used, what kind of music or any other contents they listened or played, and so on.

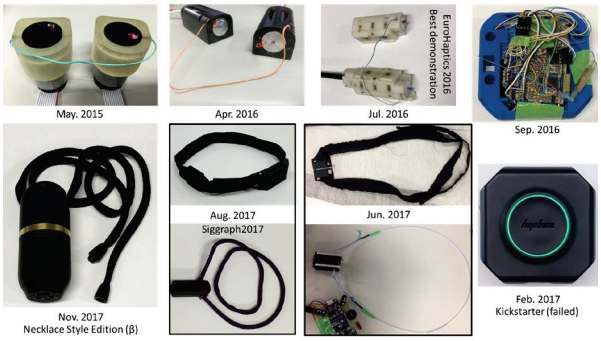

Fig.7 Prototypes of Hapbeat

Finally, we developed the latest model shown in Fig. 1. This model has been sold more than 200pcs. We especially focus on productivity this time. Simple and easy to assemble is very important to productize because it decides the total cost, durability, and quality.

5 NEXT STEP

Of course, we are still at the start point of achieving my goal. The next step is establishing a system to get continuous income. This is quite challenging because we should propose definite motivation to pay money. We think music listening will be the first market but not for sure. However, we can maintain our activity for a long time because we suppress continuous cost. Maybe it takes a long time, but we keep going an honest effort.

6 CONCLUSION

In this paper, we described my work related to Hapbeat and the way of social deployment. We are facing the difficulty of developing a new haptics market even if our devices are great at the performance, easy and practical to use, and relatively reasonable prices. We have to keep working on creating and developing more effective content or usage to deploy haptics technology to the world.

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