Neck Strap Haptics: An Algorithm for Non-visible VR Information Using Haptic Perception on the Neck

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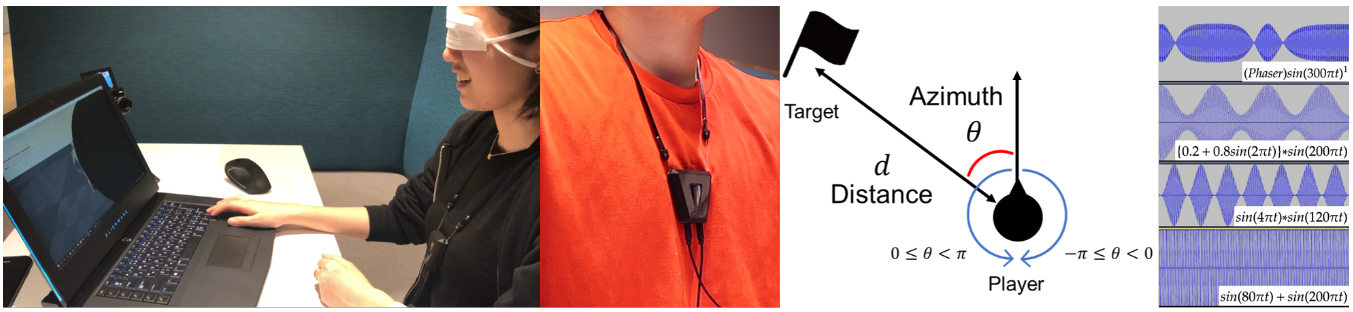

(a) (b) (c) (d)

Figure 1: (a)Overview of the experiment (b)Hapbeat-Duo (c)Algorithm parameters (d)Base waves used in the experiment

ABSTRACT

In this poster, we propose a new haptic rendering algorithm that dynamically modulates wave parameters to convey distance, direction, and object type by utilizing neck perception and the Hapbeat-Duo, a haptic device composed of two actuators linked by a neck strap. This method is useful for various VR use cases because it provides feedback without disturbing users' movement. In our experiment, we presented haptic feedback of sine waves which were dynamically modulated according to direction and distance between a player and a target. These waves were presented to both sides of the users' necks independently. As a result, players could reach invisible targets and immediately know they had reached the targets. The proposed algorithm allows the neck to become as important a receptive part of body as eyes, ears, and hands.

CCS CONCEPTS

• **Human-centered computing** → **Haptic devices**; *Virtual reality*; • **Hardware** → *Haptic devices.*

KEYWORDS

Haptics, Neck Perception, Wearable Device, VR

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1 INTRODUCTION

The neck is a desirable 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. Previous studies have shown that vibration on the sides of neck muscles affects standing posture, walking speed, and walking route[Bove et al. 2001; Ivanenko et al. 2000]. About hardware, Reza developed a collar type haptic device which has small vibrators arranged in arrays[Taghavi 2015]. Unfortunately, Kelly proves that neck is not sensitive enough to determine the exact point of stimulation[Morrow et al. 2016]. However, haptics researchers generally use devices which have small vibrators arranged in arrays to convey directional and distance information by controlling actuate patterns[Hogema et al. 2009; Jones et al. 2009]. This method is effective for various parts of a body (e.g., buttocks, arms, or back), but does not work on the neck.

In this poster, we proposed a new algorithm of haptic feedback utilizing neck perception and a Hapbeat-Duo, a prototype of simple two actuators linked by a neck strap. This method demonstrates direction, distance, and object type not by controlling vibration location but rather by modulating parameters (e.g., amplitude and phase) of vibration waves dynamically according to the distance and azimuth between a player and a target.

2 OUR PROPOSAL

We used electric signals equivalent to audio wave data as an input. The amplitude, frequency, waveform, and/or characteristics of an envelope (frequency, phase, waveform) of the wave were modulated related to the distance d and the azimuth θ shown in Fig.1 (c). In

addition, t represents elapsed time (msec) in a system. Here is a general formula.

$$A_1(d,t)\, A_{2_{L,R}}(\theta,t)\, F(t)$$
$$(-\pi < \theta < \pi, 0 \leq d, 0 \leq t)$$

$A_1(d,t)$ modulates the amplitude of the input signal and/or the frequency of the envelope related to the distance d. $A_{2_{L,R}}(\theta,t)$ modulates the amplitude, phase delay, and/or frequency of the input signal envelope related to the azimuth θ. $F(t)$ represents an original waveform which is a target of the modulation function.

Various specific functions can be considered (e.g., linear, exponential, or logarithmic) but in this poster, we tested the following formula and the wave image is shown in Fig.2.

$$C_1 e^{-d}\, (C_2 \pm C_3 sin\theta) sin(\omega_e t \pm C_4 sin\theta)\, sin\omega_o t \qquad (1)$$
$$(\omega_e \ll \omega_o\, ,\, -\frac{\pi}{4\omega_e} \leq C_4 sin\theta \leq \frac{\pi}{4\omega_e}\,)$$

C_{1-4} are constant parameters. ω_e, ω_o are angular frequencies of envelope or original sine wave. The sign of the θ term represents a difference of input signal between the left and right actuators. A positive θ represents that the target is located at the left side of the player.

To utilize the algorithm, we used a Hapbeat-Duo (Fig.1 (b)), a newer model of our previous work[Yamazaki et al. 2016]. It has two core-less DC motors linked by a neck strap. The dynamic range of frequency and amplitude is high enough to be perceived the modulation. Vibrations on either side of the neck do not resonate with each other because the connector is not a rigid body but a flexible neck strap, made of satin ribbon. Therefore, the device can render various distinguishable vibration waves on both sides of the neck independently.

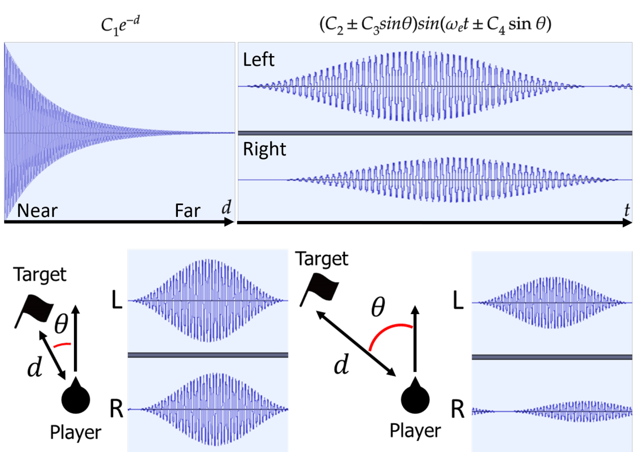

Figure 2: (Top) The image of modulated wave by eq. (1) (Bottom) Modulation example by eq. (1) according to the positional relation between the player and the target

3 REACHING AN INVISIBLE TARGET

In this experiment, five participants were asked to find an invisible target by haptic feedback using the proposed algorithm and a Hapbeat-Duo device. Four different waveforms (Fig1. (d)) were created using an audio editor (Audacity), and each of them was assigned to a target. 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) 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.1 (a). We first explained the algorithm verbally and showed how the vibration transmitted to the player by directing a game character toward a visible target ($sin(4\pi t)sin(120\pi t)$ is assigned) 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. 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. Additional research will investigate differences in time-to-target scores.

4 FUTURE WORK

Although further studies are needed in order to find effective parameters and functions, we propose the new algorithm to convey distance, direction, and object type by utilizing neck perception and a Hapbeat-Duo. Because it is highly convenient and doesn't disturb users' actions, haptic neck perception can be combined and used in various VR use cases such as free-roaming gaming, exhibitions, and consumer use. The proposed algorithm allows the neck to become an important receptive body part, as eyes, ears, and hands are today. Adding neck perception can greatly improve the use of consumer haptics.

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