Wearable Multi-Frequency Vibrotactile Display for Virtual Textures

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***Abstract*— Spatial constancy is a key characteristic of haptic texture sensations, in which temporal frequency content of contact-induced vibrations varies as a function of finger speed. Implementing these continuous changes in temporal frequency is non-trivial for many low-cost wearable vibrotactile texture displays due to narrow bandwidths of common LRA and ERM actuators. For such wearable haptic devices, we propose Pseudo-Frequency Modulation (PFM) to create an illusion of continuously changing temporal frequency by modulating only the amplitudes of multiple frequency components as a function of the sliding speed. Perceptual studies suggest participants can distinguish and describe distinct PFM textures, each of which has unique speed-dependent amplitude envelopes. Ongoing work will evaluate the perceived properties and utility of such virtual textures.**

I. Introduction

Vibrotactile displays can create the perception of textures in virtual reality by reproducing speed-dependent skin deformations [1]. Speed-dependent shifts in temporal frequency preserve spatial constancy and prove critical for the realism of coarse virtual textures [2]. Considering this and the relative ease of amplitude modulation, we propose Pseudo-Frequency Modulation (PFM), in which we modulate the amplitudes of a low and a high frequency component as a function of the sliding speed to create an illusion of continuous temporal frequency modulation.

II. Methods

We use a wristband-type device – with low obtrusiveness – to relocate the feedback. Fig.1 shows the device with a vibrotactile actuator (Actronika Hapcoil One) at the volar side.

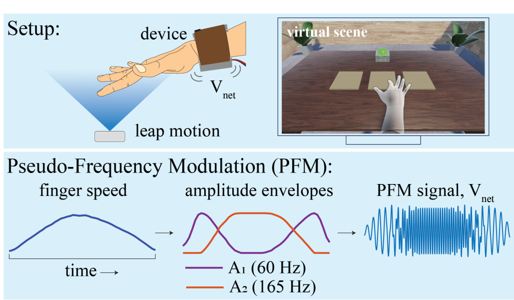

Fig. 1. Experimental setup and Pseudo-Frequency Modulation (PFM)

The input signal to the actuator achieves a desired vibration velocity amplitude V_{net} as the sum of two sinusoids with different frequencies and speed-dependent amplitudes, as shown in Fig.1. Only the low-frequency component is present at low finger speeds. As the speed increases, A_1 phases out while the high-frequency amplitude A_2 phases in. We modulate these amplitudes using the spatialization feature of Syntacts [3] and match peak velocity amplitudes – attained at a sliding speed given by temporal versus spatial frequency ratio – using the device's voltage characteristics. We calculate the instantaneous speed and define a virtual texture region using the fingertip position data from a Leap Motion Controller. Finally, we render a virtual scene with textures and a real-time visual of the user's hand using Unity.

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III. Preliminary Results

We conducted a psychophysical study (TAMU IRB2022-1042) with 15 participants (one left-handed, seven female, ages 18-34). Fig. 2 shows the results of this study.

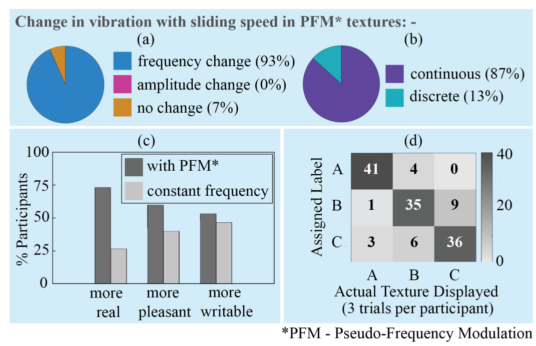

Fig. 2. Results of tasks to (a,b) describe vibration change with speed (c) compare PFM and constant frequency textures (d) identify PFM textures.

Fig. 2a,b show that participants perceived a continuous shift in frequency with the sliding speed in a PFM texture. They also rated this texture as more realistic than its constant frequency counterpart (Fig. 2c). Finally, participants were able to identify three different PFM textures with different design spatial periods (Fig. 2d). We suspect biases in pleasantness and writability results due to preference for low-frequency control texture and task comprehension issues. Ongoing studies will reassess these properties and quantify the utility of PFM textures.

References

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