Wrist Vibrotactile-augmented Interface Encoding Music Melody

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I. Introduction

The usage of haptic interfaces in music technology is growing, with vibrotactile feedback being a popular method for conveying musical information [1]. Both sound and vibration have physical waves, and music cannot be conveyed without the vibration of the sound source and the mediating item [2]. Previous studies have used vibration frequency, intensity, and waveform to convey articulation [3] and timing [4], but mapping pitch has been challenging. To address this issue, we propose a novel cross-modal mapping between musical melody and the properties of vibrotactile feedback using envelope frequency (***EF***) of vibration. We present a wrist-worn haptic-music interface that defines the musical semantics of vibration parameters, and evaluate its usability through user tests. This system has potential applications in musical expression and communication, enhancing the perception of melodic messages by listeners.

II. System Design and Implement

We created a vibrotactile-augmented interface in the form of a wristband, and we included a new parameter to describe the pitch: the envelope frequency of the vibration. We refer to a segment of vibration that is consistently non-zero in frequency over a period of time as a "vibration unit", and the vibration's envelope frequency (***EF***) is equal to the reciprocal of the vibration unit's period. To match the skin-adapted EF range, the melody's frequency band is rescaled and transferred to the motor.

Our setup employed the *UTG 2025A* waveform generator to drive the *AAC ELA1016* linear motor. Vibration frequency was controlled by adjusting the sine wave voltage, while EF was modulated by changing the frequency of the square wave voltage with the same amplitude. We wrapped a 5 cm wide double-layer elastic fabric with a vibration motor around the wrist, which was covered with a thin silicone sheet.

III. Methodology

We conducted a preliminary study with 15 participants (M=8, F=7, mean age=23.1, SD=1.46) to evaluate the efficiency of our vibrotactile-augmentation interface and determine the mapping mechanism of envelope frequencies.

Participants indicated their preferred mapping technique for pitch information (frequency or EF), modified three vibrational notes to match selected pitches (Do, Mi and So in C major), and were allowed to adjust their design after their experience with the scale. Then they provided their preferred range of accessible envelope frequencies. We also collected data on participant preferences for vibrational note playback, namely continuous or intermittent playback.

A. Outcomes

The user test revealed that participants favored EF mapping over frequency mapping for pitch information. While 5 participants preferred frequency mapping for its continuity, 10 participants found EF mapping more distinct, within the detectable range, and better at linking distinct vibrational notes to matching pitches.

The preliminary experimental findings showed that EFs between 5-55 Hz carried more information than those at frequencies of 150-300 Hz. Participants discovered that EF mapping used a lower proportion of the frequency band while modulating the vibrational form of Do, Mi, and So notes in C major for both strategies, indicating that vibrational signals parameterized by EFs can represent more complex melodic information in music.

The distribution of pitch over the EF spectrum was not uniform, with two consecutive vibrating notes spaced farther apart at higher EFs, according to participant reports.

IV. Future Work

We will recruit more participants, including musicians and non-musicians, to test our wearable vibration display prototype and further explore the EF-based tactile-auditory mapping strategy. Our investigation will focus on (i) the optimal EF range for pitch information, (ii) the minimum perceptible interval, (iii) the pitch distribution in the EF band, and (iv) the potential for the vibrating note style to reflect the musical genre.

Meanwhile, our study aims to investigate combining EF mapping methods and other tactile-auditory mapping techniques to transmit rich musical information, such as beats and melodies. We will also explore potential applications for aiding hearing-impaired individuals in accessing music information.

References

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