Mo2Hap: Rendering VR Performance Motion Flow to Upper-body Vibrotactile Haptic Feedback

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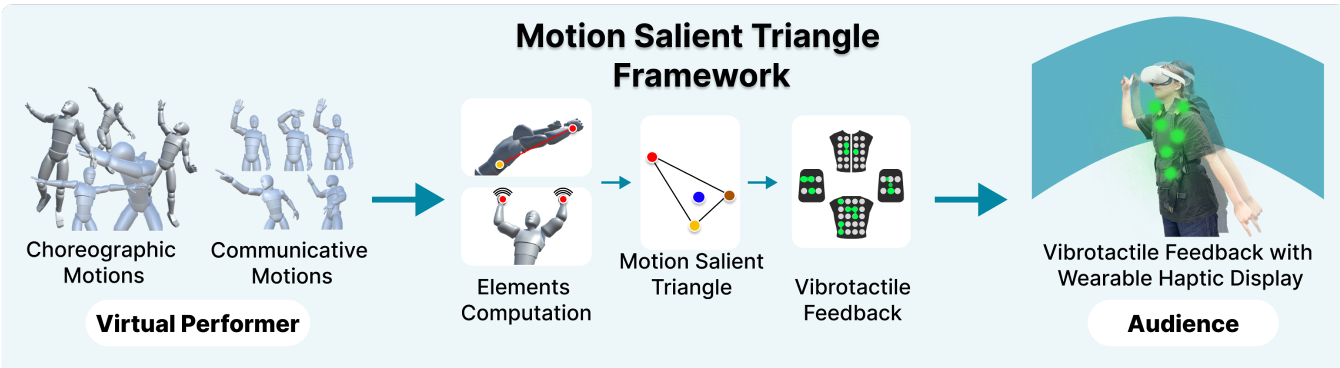

Figure 1: We propose a motion-to-tactile framework that creates realistic VR performance experiences by translating the performer's motion in real-time.

ABSTRACT

We introduce a unique haptic rendering framework that transforms the performer's actions into wearable vibrotactile feedback for an immersive virtual reality (VR) performance experience. To capture essential movements from the virtual performer, we propose a method called Motion Salient Triangle. Motion Salient Triangle is a real-time 3D polygon that computes haptic characteristics (intensity, location) based on motion skeletal data. Here, we employ an entire upper-body haptic system that provides vibrotactile feedback on the torso, back, and shoulders. This haptic rendering pipeline enable audiences to experience immersive VR performance by accommodating the performer's motions on top of motion-to-haptic feedback.

CCS CONCEPTS

• **Human-centered computing** → **Haptic devices**; **User interface programming**.

KEYWORDS

Haptics, Rendering Framework, VR Performance

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1 INTRODUCTION

With the advent of virtual reality musical performances, audiences may now actively engage in virtual concerts without physically being present. A 360-degree perspective of the virtual stage and real-time engagement with online players improved the experience of "Being There" (Sense of Presence) in Virtual Reality (VR) [4]. As indicated in [6], overcoming a few issues in social co-presence (e.g., allowing performers to vary degrees of social interactions or providing subtle physical indicators of audience participation) has the potential to enable distributed liveness for distant platforms such as VR. Previous work has helped to enhance the movements of virtual avatars in VR to increase co-presence [2, 5, 7, 8]. Still, researchers continue to focus largely on visual and aural clues, limiting the prospect of further increasing the experience of presence.

We offer an autonomous haptic rendering pipeline that turns the performer's entire 3D motion data into meaningful vibrotactile feedback inspired by earlier work. The higher the immersive level, the more viewers will feel like virtual performers, strengthening the experience of embodiment under a specific VR performance. We use an upper-body wearable setup to provide effective vibrotactile feedback to users. We encourage an immersive VR performance by integrating vibrotactile aids into our autonomously generating haptic feedback technology, allowing audiences to fully comprehend the performance environment.

2 SYSTEM DESIGN OVERVIEW

2.1 Performance Motion Analysis

We analyzed 156 minutes (41 video clips) of recorded concert footage to understand the tendency of motions performed by artists in both offline and online (VR) performances. Movements can be classified as "choreographic" or "communicative" motions by evaluating the performances. "communicative" in this context denote roles for sharing emotions and nonverbal communication between audiences [2], *e.g., handing a mic, induce clapping*. "choreographic" includes a technique for performing movements in the dance. According to the results of this survey, motions were mostly generated by upper-body movements, which necessitates using a robust rendering algorithm to support the above behaviors when translated to upper-body vibrotactile haptic feedback.

2.2 Motion Salient Triangle

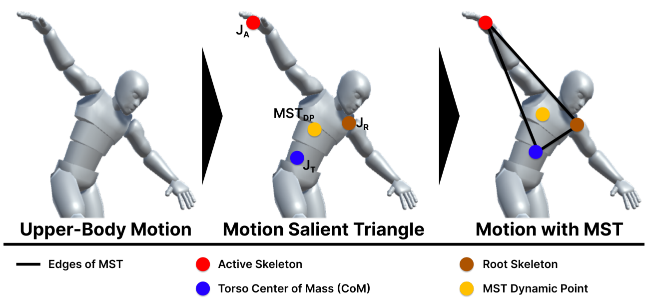

Figure 2: Overall concept of MST. From the original upper-body motion (Left), we extract key elements vertices for MST (Middle). Then, we concatenate the vertices with edges (Right) and create a 3D triangle called motion salient triangle (MST).

MST is a novel real-time approach utilizing 3D coordinate and orientation values from skeleton data consisting of 32 joints (acquired from Azure Kinect DK). Figure 2 illustrates the overall concept of the **MST**. we assign hand joint coordinates as active joint coordinates J_A that represents rich information from motion. In this work, we formulate 3D joint coordinates as $J = (x,y,z)$. We further define root joint coordinates (J_R) and the center of mass of torso coordinates (J_T). As shown in Figure 2, J_R represents a stable point on the shoulder located opposite to J_A side, which reflects the balanced position while carrying out diverse motions. Since the shoulders' translation displacement is low compared to other joints during the performer's motion, we pick shoulders for J_R. J_T provides a stable point inside of a torso, which mostly sticks to its initial position. Using these two stationary points, our proposed algorithm considers both micro-level motion flow and the macro-level stream of movement in continuous frames.

MST is a 3D triangulation, which the **MST Dynamic Point** is also located in 3D coordinate system. Translating its position to a 2D vibrotactile display eventually requires this system to project 3D coordinates to 2D coordinates. Therefore, we designate the *Target Point*, calculated from a centroid point of shoulder skeletons and the centroid points from each front and back torsos. Then we draw a ray-cast starting from **MST Dynamic Point** and ending with the *Target Point*.

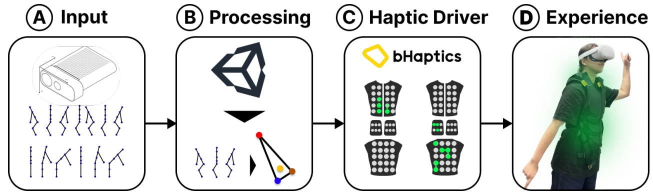

Figure 3: Overall workflow. (A) We collect 3D motion data, (B) compute the joint-based spatiotemporal measurements, and (C) render the associated vibrotactile parameters based on our proposed algorithm. (D) Users experience real-time tactile feedback translated from the VR performance.

Controlling the intensity and position of the haptic proxy is required for an immersive vibrotactile haptic sense [3]. As a result, we concentrated on intensity and position values as factors to adequately express the haptic feeling generated by the performer's motions.

The vibration rendering results will be the point where the connected ray hits the haptic display. Regarding the ray-cast hitting the haptic display on continuous frames, it will consecutively vibrate with different actuators. To accurately simulate the sensation of the upper-body movement, we adjust the intensity level according to the distance of MST_{DP} to J_T. We control the ERMs' intensity parameter value to convey the performer's motions effectively. Depending on the distance value of MST_{DP} to J_T, the level of tactile intensity is linearly combined. The larger ROM gets, the higher the tactile amplitude is.

Users can easily recognize the flow of movements from the performer by adapting tactile intensity in accordance with the distance, which represents the quantity of motion from the performer. Motions like choreographic and communicative motions containing precise and dynamic contexts would benefit from the proposed intensity control technique.

Figure 4: Overall hardware configuration. Users wear a customized haptic vest along with haptic sleeves on both shoulders.

3 DEMO APPLICATION

We present a demo which comprises two distinct sessions. The first session affords participants the opportunity to engage with the virtual performer's discrete motions, encompassing a repertoire of six distinct movements that persist for duration ranging from 15 to 30 seconds (*e.g.*, *"waving hands", "side to side hip-hop motion"*). The primary objective of this session revolves around comprehending the underlying concept of our research and delving into the experiential aspect of perceiving the performer's motions alongside the provision of vibrotactile feedback. In the subsequent session, participants are invited to immerse themselves in a virtual concert hall, whereby they are empowered to select their preferred musical compositions. In accordance with the choreographic structure of each complete song, participants will encounter haptic feedback derived from both choreographic and communicative motions. During this session, participants can freely engage in dance-like movements alongside the virtual performers, thereby experiencing the intricate dynamics, all enhanced by the haptic feedback originating from the virtual performer's actions. This work utilizes wearable vibrotactile suits and Tactosys equipment from bHaptics[1]. We chose pairs of Tactosys on both shoulder sides to feel more naturally rendered motion flow from the performer. Following Figure 4 shows the overall image of how we attached the Tactosys to the shoulders above. Oculus Quest 2 is utilized for users to view virtual performance.

4 CONCLUSION AND FUTURE WORK

This demo proposes a novel approach utilizing **MST**, translating the performer's motions to vibrotactile haptic sensation. As a preliminary of this system, we implement the variance of location and intensity from the 3D triangle (**MST**) to convey the motion flow. We mainly focus on a virtual solo performer. The current MST-based algorithm is hard to reflect multiple performers' motions into representative haptic feedback. Therefore, it is our interest to find an effective method to exert meaningful haptic feedback from multiple performers and then distribute them to audiences.

ACKNOWLEDGMENTS

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