Exploring Vibration Intensity Map Of Hand Postures For Haptic Rendering In XR

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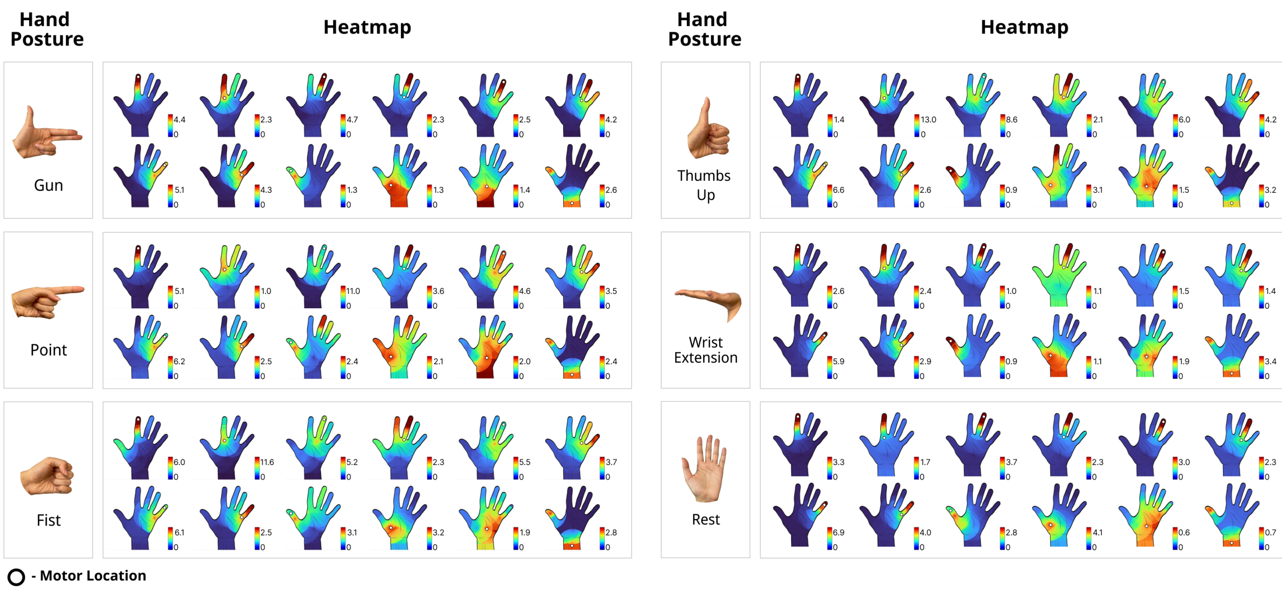

Figure 1: The whole vibration intensity map during hand postures shows the skin vibration intensity of each LRA motor (in order from left to right). Each unit is divided into hand postures including reference posture (Rest), 12 motors.

ABSTRACT

In this study, we explore the effect of hand posture on haptic experience within the hand. With the wide acceptability of using the hand as an input in the XR, it is important to find out the positive and negative effects of hand postures on the haptic experience. We measured the vibration intensity of the hand using an accelerometer on various hand postures. Our results showed that distinctive hand postures alter the vibrotactile actuator's tactile feedback across the hand.

VRST '22, November 29-December 1, 2022, Tsukuba, Japan

ACM ISBN 978-1-4503-9889-3/22/11.
https://doi.org/10.1145/3562939.3565672

CCS CONCEPTS

• **Human-centered computing → Interactive systems and tools**.

KEYWORDS

Haptic Experience, Hand Posture, Vibration Intensity

ACM Reference Format:
Youjin Sung, Yitian Shao, Rachel Kim, and Sang Ho Yoon. 2022. Exploring Vibration Intensity Map Of Hand Postures For Haptic Rendering In XR. In *28th ACM Symposium on Virtual Reality Software and Technology (VRST '22), November 29-December 1, 2022, Tsukuba, Japan.* ACM, New York, NY, USA, 2 pages. https://doi.org/10.1145/3562939.3565672

1 INTRODUCTION

Wearable haptic gloves have the potential to enhance realism, immersion, and presence in the XR (Extended Reality) environment by providing complex and precise tactile feedback. Prior research focused on understanding the fundamental behavior of vibrotactile signals [1], but little has been studied on how a hand posture affects one's haptic experience. Our research aims to analyze the quantitative skin vibration data on various hand postures to understand how tactile feedback sensations are altered.

2 VIBRATION INTENSITY MAP

Our approach is to measure the skin vibration across the hand on different hand postures. Then, we analyze how hand postures affect the vibrotactile feedback within a hand. To measure the skin vibration, we employ accelerometers to obtain low-level data on haptic perception.

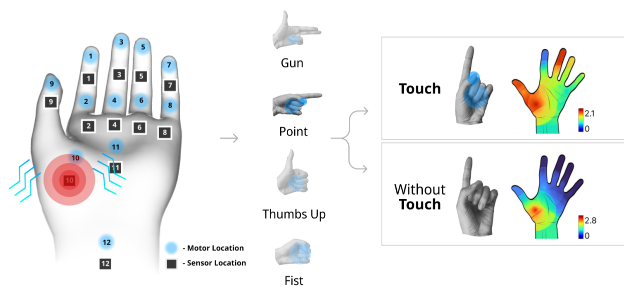

Figure 2: Sensor and motor placement (Left). A heatmap of different contact conditions. The 'Touch' condition reflects a more realistic vibration map during the hand posture.

2.1 Data Acquisition

To capture the acceleration data from six commonly used human hand postures (including rest posture), we designed an experiment based on the prior study [4]. We checked the contact area of each hand posture and observed the vibration data as shown in Figure 2. Based on the previous Hand Interaction Guide in VR and muscles activation[3], we chose a total of five commonly used hand postures (fist, point, gun, wrist extension, and thumbs up). We sampled the 39 analog signals by using Teensy 4.0 and a Multiplexer (CD74HC4067, Texas Instrument). 13 accelerometers (ADXL 335, Analog Devices) and 12 LRA motors (Linear Resonant Actuator with DA7280 from Dialog Semiconductor) were used.

2.2 Data Processing

The custom-built accelerometers (10mm $\times$ 10mm) were attached to the skin using adhesives. As shown in Figure 2, Motors 1,3,4,7, and 9 are attached to the tip of each digit accordingly. This reflects the common location in haptic gloves where motors are placed on the region with high spatial acuity. Motors 2,4,6, and 8 are located in hand regions where a ring is often worn. Motor 10 and 11 are located in the palm area and motor 12 is located on the wrist. We captured 39 analog signals from 13 accelerometers for three seconds at a 4.4kHz sampling rate resulting in 468,000 samples per trial. After detrending the signals, we bandpass-filtered the signal within the range of motor frequency -10Hz to motor frequency +10Hz that well matches the signal spectrum of the motor-elicited vibrations. To estimate the whole vibration value within a hand, we interpolate the root mean square amplitude from each sensor location [2, 5]. Setting borders between the fingers avoids inter-finger errors and makes it possible to reflect the effect of hand postures.

2.3 Hand Posture and Vibration

In Figure 2, we set two conditions for each hand posture based on whether the fingers contact each other or not. These conditions cause different outputs since vibration propagation alters due to contact conditions. Here, we focused on the 'Touch' condition for the main data acquisition since this reflects a more realistic hand posture condition. Our results provide new evidence on how distinctive hand postures affect the vibrotactile intensity within a hand. When you flex your fingers to make a hand posture, the distance between the motors and the sensors decreases. In the case of the fist, all fingers contact and influence each other. As the vibration intensity map is shown in Figure 1, the sensor 9 (Thumb) area is affected when the thumb is contacting the motor from other digits during hand postures like 'Fist' and 'Point'.

3 DISCUSSION AND FUTURE WORK

In this work, we observed that hand postures altered the distribution of the vibration caused by the attached vibrotactile actuators. Here, our results shed light on how hand movements possibly affect the haptic feedback experience of the user. In our study, the results showed that the skin vibration intensity map varies from each hand posture. This explains the phenomenon that haptic experiences may differ from each other even in the same virtual reality environment. The haptic perception may vary depending on their hand posture during the interaction. An implication of these findings is the potential for future research in improving the haptic experience with hand postures, which could further improve the haptic design process as well as the rendering pipeline.

ACKNOWLEDGMENTS

This work was supported by the National Research Council of Science and Technology and the Korea Creative Contents Agency (#CRC21011 & #R2022020068). Any opinions, findings, and conclusions expressed in this material are those of the authors and do not necessarily reflect the views of the funding agency.

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