Hand Motion Prediction for Just-in-Time Thermo-Haptic Feedback

George Chernyshov
Keio University Graduate School of Media Design
Yokohama, Japan
chernyshov@kmd.keio.ac.jp

Kirill Ragozin
Keio University Graduate School of Media Design
Yokohama, Japan
kirill@kmd.keio.ac.jp

Cedric Caremel
Keio University Graduate School of Media Design
Yokohama, Japan
cedric@keio.jp

Kai Kunze
Keio University Graduate School of Media Design
Yokohama, Japan
kai@kmd.keio.ac.jp

ABSTRACT

This paper presents two innovative design solutions for thermal feedback displays in virtual environments. First solution is aiming to eliminate or decrease the time delay between the user action and onset of the thermal feedback using Machine Learning for user motion prediction. Second is the design of compact but efficient water cooling system necessary to provide cold sensations using peltier elements. Presented thermal display is wearable and battery powered.

CCS CONCEPTS

• **Human-centered computing → Virtual reality**; **Haptic devices**; • **Computing methodologies → Apprenticeship learning**;

KEYWORDS

Virtual Reality, Machine Learning, Neural Networks, Motion Prediction, Haptic Feedback, Thermal Feedback,

ACM Reference Format:
George Chernyshov, Kirill Ragozin, Cedric Caremel, and Kai Kunze. 2018. Hand Motion Prediction for Just-in-Time Thermo-Haptic Feedback. In *VRST 2018: 24th ACM Symposium on Virtual Reality Software and Technology (VRST '18), November 28-December 1, 2018, Tokyo, Japan.* ACM, New York, NY, USA, 2 pages. https://doi.org/10.1145/3281505.3281573

1 INTRODUCTION

The lack of high fidelity haptic feedback has been one of the main issues for Virtual Reality (VR) applications since the dawn of VR[1, 2]. Indeed, although the modern HMDs are often equipped with high resolution displays and can provide a decent looking picture for our eyes, there is no device that could provide realistic haptic sensations comparable to what we experience everyday in real life. Human somatosensory system is a very complex system and plays an important role in how we perceive and interact with the world, as it is responsible for most of our non audial-visual senses [4, 5]. The lack of stimulation of these senses greatly impacts the sense of agency and immersion that are so vital for a true virtual reality experience.

The implementation of haptic interfaces capable of providing realistic haptic sensations is indeed a very complicated task. Firstly, it has to stimulate all three kinds of tactile receptors in our skin: thermoreceptors, mechanoreceptors and nociceptors, and each of the receptor groups branches even further into narrower categories responsible for sensing only very particular and narrow category of stimuli. I.e. it is not possible to create the sense of slip using thermal display, nor stimulate Merkel Disks responsible for the sense of pressure the same way one would stimulate Pacinian Corpuscules that perceive mechanical vibration[3]. Another issue is that stimulation of the skin receptors requires mechanical or thermal coupling with the skin and mechanical actuation or change of the physical properties of the display, such as temperature. The application of mechanical pressure or thermal stimulation is obviously not instant and results in a delay between the interaction performed in a VR environment and the stimuli onset. Meaning after the user touches a virtual surface it takes time for the display to produce the corresponding feedback. Proposing a solution for the delay problem is the main focus of this work.

We propose a system based on TensorFlow, capable of predicting the hand position in virtual environment based on its previous movement. Knowing where the hand is going to be even 0.5 seconds in the future can greatly decrease the perceived delay between the performed interaction and haptic feedback onset. For this demonstration we are using a custom made thermal feedback glove capable of providing both, hot and cold sensations.

2 APPROACH

For the motion prediction we use reinforcement learning model based on TensorFlow. Unity is used as a simulator and rendering engine. Current hand position is recorded using a Leap Motion tracker mounted on a Vive headset. The basic workflow of the system is as following. The neural network receives the current hand position (in blue, Fig. 1) and is required to produce a prediction, such as changing the direction of the hand motion (in orange). The predicted hand position is extrapolated by using the hand previous positions and superimposing the network's output. For each correct prediction the network gets rewarded and penalized otherwise. This

VRST '18, November 28-December 1, 2018, Tokyo, Japan

ACM ISBN 978-1-4503-6086-9/18/11.
https://doi.org/10.1145/3281505.3281573

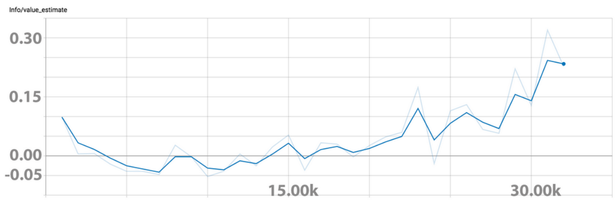

Figure 1: Value estimate graph demonstrating how prediction accuracy increases over the training.

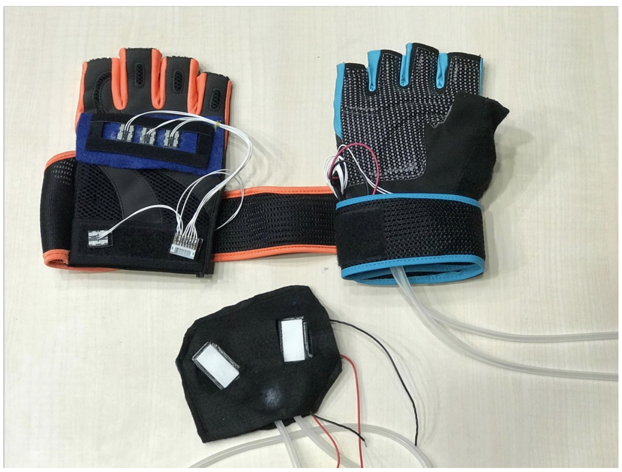

Figure 2: Prototype of the thermal feedback glove with 2 Peltier elements and water cooling.

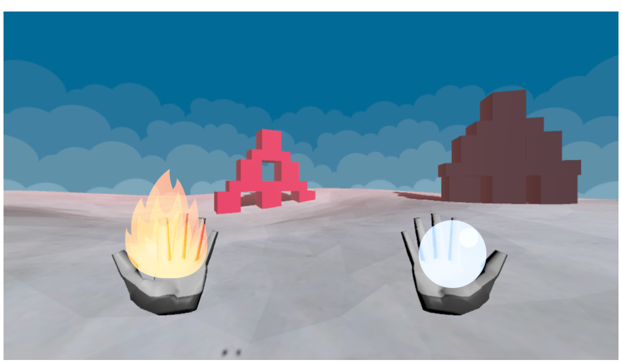

Figure 3: VR demo environment.

reward system informs the network about the nature of the task, as it is set to optimize its behaviour to increase the rewards, and minimize the penalties.

3 SETUP AND VR EXPERIENCE

The demo setup consists of a Vive HMD with a Leap Motion tracker mounted on it. For thermal feedback we develop a custom glove with multiple peltier elements and PWM driven SMPS circuitry controlling the polarity and amount of electrical current flowing through the Peltier elements. This way our device is capable of providing precisely adjustable cold and hot sensations on each Peltier element. Since the efficiency of the Peltier elements is not 100% and they require high currents, it results in gradual increase in temperature of the whole element after even a short time. Due to this, it is not possible to maintain a cold sensation for long. With this in mind we designed a direct water cooling system for Peltier elements to assure that our device can provide cold feedback for extended periods of time. The prototype is presented on Fig.2.

The main drawback of the prototype is the time delay required to change the element's surface temperature, for the presented prototype and use case, depending on the conditions this delay ranges between 0.5 - 2 seconds. We believe that the neural network prediction model of the hand motion is capable of solving this issue. If the system can predict when the user is going to perform an action requiring thermal feedback, such as touch a hot or cold object, it can initiate the feedback slightly before the user actually touches the object, thus providing just-in-time thermal feedback.

In the demo provided users are able to pick up, hold and throw fire and ice balls, experiencing corresponding sensations with their hands (See Fig.3). This simple interaction can disclose the full potential of using Machine Learning algorithms for motion prediction required for just-in-time haptic feedback.

4 CONCLUSIONS

This paper presents a novel approach to solving the thermal haptic feedback onset delay using a neural network capable of predicting the hand motion. Besides this the presented thermal feedback prototype is a wearable device capable of providing the cold sensation for any amount of time due to it's compact and effective water-based cooling system. If providing warm and hot sensations is pretty straightforward, cold feedback is much more complicated, since the excess of heat has to be transported away from the device and stored or disposed of. We believe our thermal feedback device design could be very interesting for the community.

ACKNOWLEDGMENTS

This work was supported by JST CREST grant number PMJCR16E1 (http://www.jst.go.jp/kisoken/crest/).

REFERENCES

[1] Grigore C. Burdea. [n. d.]. Keynote Address: Haptic Feedback for Virtual Reality.
[2] G. C. Burdea. 2000. Haptics issues in virtual environments. In *Proceedings Computer Graphics International 2000*. 295–302. https://doi.org/10.1109/CGI.2000.852345
[3] Seungmoon Choi and Katherine J Kuchenbecker. 2013. Vibrotactile display: Perception, technology, and applications. *Proc. IEEE* 101, 9 (2013), 2093–2104.
[4] Francis McGlone and David Reilly. 2010. The cutaneous sensory system. *Neuroscience and Biobehavioral Reviews* 34, 2 (2010), 148 – 159. https://doi.org/10.1016/j.neubiorev.2009.08.004 Touch, Temperature, Pain/Itch and Pleasure.
[5] Francis McGlone, Johan Wessberg, and HÃěkan Olausson. 2014. Discriminative and Affective Touch: Sensing and Feeling. *Neuron* 82, 4 (2014), 737 – 755. https://doi.org/10.1016/j.neuron.2014.05.001