ThermoReality: Thermally Enriched Head Mounted Displays for Virtual Reality

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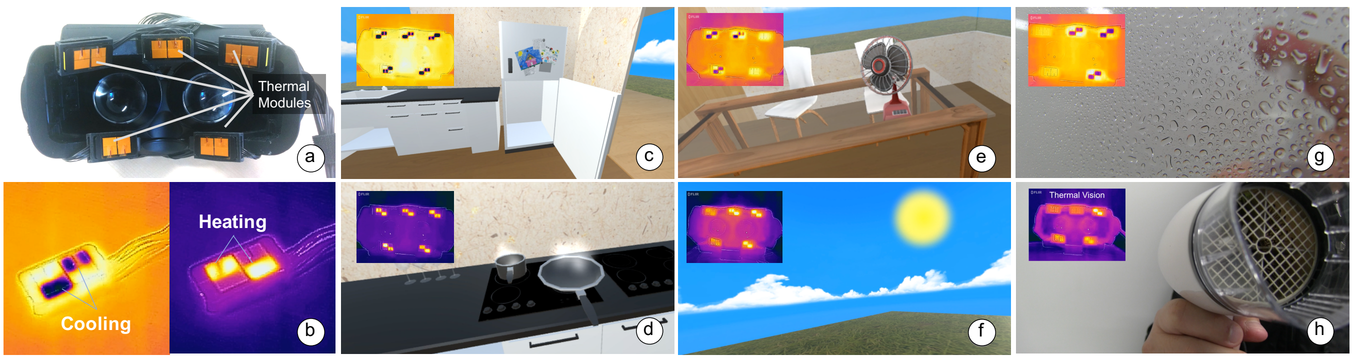

Figure 1: The ThermoReality system and applications: (a) ThermoReality HMD with five thermal modules; (b) Thermal images of a thermal modules cooling (left) and heating (right); Virtual Reality application (insets depict the thermal image of the triggered thermal cues): (c) openening a fridge, (d) standing in front of stove, (e) feeling the cold moving wind from a fan, (f) feeling the warmth of the sun on the face; Adding thermal cues to real videos: Feeling the spray of water on the face (g) Feeling the warmth of a hair dryer

CCS CONCEPTS

•Human-centered computing → Haptic devices;

KEYWORDS

thermal display; thermal haptics; head mounted display

ACM Reference format:
Zikun Chen, Wei Peng, Roshan Peiris, and Kouta Minamizawa. 2017. ThermoReality: Thermally Enriched Head Mounted Displays for Virtual Reality. In *Proceedings of SIGGRAPH '17 Posters, Los Angeles, CA, USA, July 30 - August 03, 2017,* 2 pages.
DOI: 10.1145/3102163.3102222

1 INTRODUCTION

With rise in the popularity of virtual reality, head mounted displays (HMDs) have become a main piece of hardware that delivers an immersive experience to the user. As one of the approaches to further enhance the user's presence in the virtual reality environment, haptic feedback has been widely used in the current VR space.

Haptic technologies have also begun to integrate with the HMDs in order create a richer experience to the users. De Jesus et al. [de Jesus Oliveira et al. 2016] implemented spatial vibrotactile cues by embedding the headset with a set of vibrotactors around the head.

Similarly, in ThermoReality, we explore adding another dimension of feedback, thermal haptic feedback integrated with the HMD. Therefore, our motivation to explore thermal feedback on the face was due to the ability to co-locate the thermal feedback with the visuals of the HMD and additionally, face is one of the most thermally sensitive sites on the human body [CHOO 1998].

2 THERMOREALITY SYSTEM

The ThermoReality prototype is shown in Figure 1 (a) with five thermal modules on a facial interface of a HMD. Five 2cm x 1.5cm thermal modules [Sato and Maeno 2012] were attached to the HMD using a custom 3D printed rig. These modules are able to increase or decrease (heat or cool) the temperature with relatively high speeds. Each module consists of four peltier modules of which two diagonal peltier modules are used for heating and the other two diagonal modules are used for cooling (Figure 1(b)). In this manner, using the thermal summation principle [Yang et al. 2009], the modules are able to deliver fast thermal cues to the users.

SIGGRAPH '17 Posters, Los Angeles, CA, USA
 978-1-4503-5015-0/17/07...$15.00
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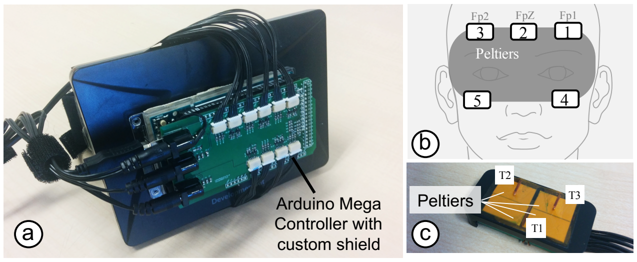

Figure 2: The system set up of ThermoReality (a) The driver circuit attached to the front of the HMD (b) The contact locations of the user's face (c) Close up of thermal module. T1, T2 and T3 are temperature sensors where T1 contacts the skin during use

When ThermoReality is worn by a user, the peltier modules are in contact with the three locations (indicated in standard EEG 10-20 system[1] for standardization) on the forehead, and the area under each eye as depicted in Figure 2 (b). When the HMD is worn, these locations are in constant contact with the user's face. Each peltier module is driven by a full bridge motor controller and all modules are controlled by an Arduino Mega microcontroller[2](Figure 2 (a)) employing a closed loop PID (proportional, integral, derivative) temperature controller for accurate temperature control. The T1, T2, T3 temperature sensors (Figure 2 (c)) are used for the closed loop control where T1 directly measures the skin temperature.

3 EVALUATIONS

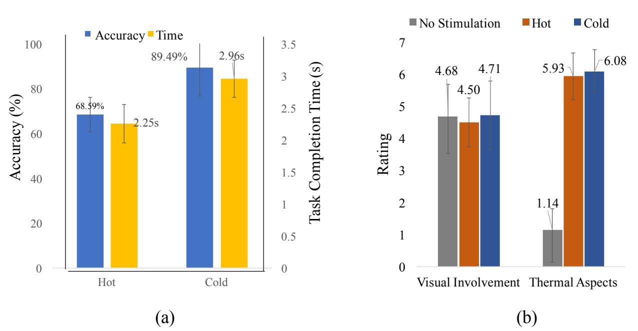

Figure 3: Evaluation results of ThermoReality (a) Directional cues (b) Immesion study

We evaluated the system under three contexts. For all our evaluations, we start the stimulation from the skin temperature and change the temperature at 3^0C/s rate for 1s.

Providing directional cues: We provided 9 directional simultaneously actuated thermal stimulations (hot and cold) as directional cues and evaluated the accuracy of recognition (Figure 3(a)). The results indicated that the Cold feedback performed significantly better relative to Hot feedback [Peiris et al. 2017].

Providing moving thermal patterns: We evaluated and provided moving thermal sensations on the userfis face. The interstimulus interval between two thermal modules was adjusted to implement the moving sensations [Chen et al. 2017]. Our results indicate that the accuracy of recognition of dynamic stimuli was approximately 71.84%.

Enhanced Immersion: We conducted a qualitative study to evaluate the immersion of the user while using the proposed system. The results indicate that the user can feel a significantly higher level of thermal immersion while using the system [Peiris et al. 2017] (Figure 3(b)).

4 APPLICATION SCENARIOS

In our first applicationscenario , the user enters a virtual kitchen and is able to interact with various typical equipment such as a fridge, pots and pans, fans, etc. As such, each of these equiment trigger with various thermal cues. For example as depicted in Figure 1(c), as the user opens the fridge, she feels a cold immersive feeling and next, the steam from the pot and pans provide hot immersive thermal cues(Figure 1(d)). As she moves to fan (Figure 1(e)), the wind from the fan trigger dynamic thermal cues that moves across her face. Finally, as she moves out doors, the warmth from the sun creates more dynamic thermal cues on her face, which, are triggered based her head movement (Figure 1(f)).

In the next scenario, the users are also able to step beyond the virtual environment to experience real videos with thermal haptic cues. For this purpose, we integrated thermal cues to few videos as seen in Figure 1(g)(h). In this demonstration, the users are able to feel the thermal cues based on the content of the video. For example, as in Figure 1(g) the video image displays the user's face being sprayed with water. This triggers the thermal cues to recreate this sensation. In addition, users are able to experience situations such as a blowing hair dryer (Figure 1(h)) on the face.

5 ACKNOWLEDGEMENTS

This work was supported by JST ACCEL Embodied Media project (JPMJAC1404), Japan. We would also like to extend our thanks to Ziye Chen for the support in the completion of this work.

REFERENCES

Zikun Chen, Roshan Lalintha Peiris, and Kouta Minamizawa. 2017. A Thermal Pattern Design for Providing Dynamic Thermal Feedback on the Face with Head Mounted Displays. In *Proceedings of the Eleventh International Conference on Tangible, Embedded, and Embodied Interaction (TEI '17)*. ACM, New York, NY, USA, 381–388. DOI:http://dx.doi.org/10.1145/3024969.3025060

JOSEPH C. STEVENS KENNETH K. CHOO. 1998. Temperature sensitivity of the body surface over the life span. *Somatosensory & Motor Research* 15, 1 (1998), 13–28.

Victor Adriel de Jesus Oliveira, Luciana Nedel, Anderson Maciel, and Luca Brayda. 2016. Localized Magnification in Vibrotactile HMDs for Accurate Spatial Awareness. In *EuroHaptics 2016*. 55–64.

Roshan Lalintha Peiris, Wei Peng, Zikun Chen, Liwei Chan, and Kouta Minamizawa. 2017. ThermoVR: Exploring Integrated Thermal Haptic Feedback with Head Mounted Displays. In *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems (CHI '17)*. ACM, New York, NY, USA, 5452–5456. DOI: http://dx.doi.org/10.1145/3025453.3025824

Katsunari Sato and Takashi Maeno. 2012. *Presentation of Sudden Temperature Change Using Spatially Divided Warm and Cool Stimuli*. 457–468.

Gi-Hun Yang, Dong-Soo Kwon, and Lynette A. Jones. 2009. Spatial acuity and summation on the hand: The role of thermal cues in material discrimination. *Perception & Psychophysics* 71, 1 (2009), 156–163.

[1]https://www.trans-cranial.com/local/manuals/10_20_pos_man_v1_0_pdf.pdf
[2]https://www.arduino.cc/en/Main/arduinoBoardMega