Ambient: Facial Thermal Feedback in Remotely Operated Applications

MHD Yamen Saraiji
Keio University Graduate School of Media Design
Yokohama, 2238526 Japan
yamen@kmd.keio.ac.jp

Roshan Lalintha Peiris
Keio University Graduate School of Media Design
Yokohama, 2238526 Japan
roshan@kmd.keio.ac.jp

Lichao Shen
Keio University Graduate School of Media Design
Yokohama, 2238526 Japan
shenlc@kmd.keio.ac.jp

Kouta Minamizawa
Keio University Graduate School of Media Design
Yokohama, 2238526 Japan
kouta@kmd.keio.ac.jp

Susumu Tachi
Institute of Gerontology, The University of Tokyo
Tokyo, 1138656 Japan
tachi@tachilab.org

CHI'18 Extended Abstracts, April 21–26, 2018, Montreal, QC, Canada
ACM 978-1-4503-5621-3/18/04.
https://doi.org/10.1145/3170427.3186483

Abstract
Facial thermoreception plays an important role in mediating surrounding ambient and direct feeling of temperature and touch, enhancing our subjective experience of presence. Such sensory modality has not been well explored in the field of Telepresence and Telexistence. We present Ambient, an enhanced experience of remote presence that consists of a fully facial thermal feedback system combined with the first person view of Telexistence systems. Here, we present an overview of the design and implementation of Ambient, along with scenarios envisioned for social and intimate applications.

Author Keywords
Thermal Feedback; Telexistence and Telepresence; Intimate and Ambient Interaction.

ACM Classification Keywords
H.5.2 [Information interfaces and presentation (e.g., HCI)]: User Interfaces-Haptic I/O

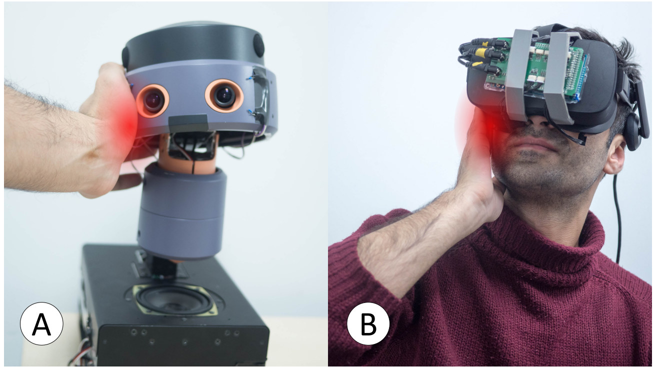

Figure 1: *Ambient* system constructed by two sides: A) a remotely operated telexistence robot with facial temperature sensing, and B) an HMD with thermal feedback capacity.

Introduction

We rely on our sensory feedback to realize and comprehend the environment surrounding us, and understand the boundaries of body and space through the loop of interaction. When perceiving the surrounding space through our bodies, we utilize our sensory organs and interpret their raw information in an unconscious manner maintaining our subjective feeling of presence, and affecting our behavior and thoughts [2]. Among these sensory feedbacks we use is thermoception, the sense of direct and indirect external temperature changes.

Thermoception plays an important role in mediating the ambient state of the environment, and plays both a direct and an indirect role in sensing changes around us. Temperature changes also affect our emotions and psychological state such as pleasantness and excitedness [8] in social situations for example. Its role also becomes prominent when the interaction is intimate and interpersonal. However, such sensory stimulus becomes dramatically limited when used in a mediated environment, such as in Telepresence and Telexistence scenarios. In such scenarios, our body is virtually transported to a different location and has limited access to the physical space, which is imposed by the used avatar robot. In this work, we address this limitation by exploring thermal feedback on the face in Telexistence systems through the proposed system, *Ambient*.

Ambient enables the users of Telexistence systems the awareness of facial thermal feedback through a customized Head Mounted Display (HMD) with thermal feedback modules and a remotely operated avatar system with adequately mounted temperature sensors. Figure 1 provides an overview of the proposed system, in which an anthropomorphic robot head can detect the facial temperature changes and transfers it to the user along visual and auditory feedback.

Related Work

In the field of Telepresence and Telexistence, a considerable amount of work has been dedicated to mediate the state of remotely operated avatars toward the operating user. Haptic feedback has been an important design consideration in such systems to maintain the quality of operation [5]. For example, finger modules [1] were previously proposed addressing the transmission of pressure, vibration, and thermal feedback for direct manipulation applications. In a relevant area of telecommunication, [6] showed the effect of haptic in transferring the social and intimate activities, such as hugging with remote people.

Body and facial thermal feedback were not widely investigated in teleoperated applications, but mainly used in media and entertainment [7]. In this work, we build on the previous work [4] to provide a thermal feedback experience in teleoperated applications and remote social interactions.

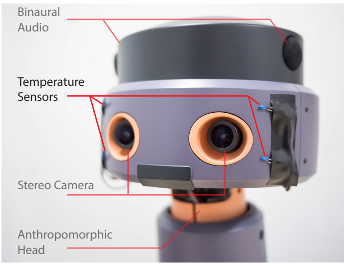

Figure 2: Robot face construction overview and sensors used to detect ambient and direct temperature changes.

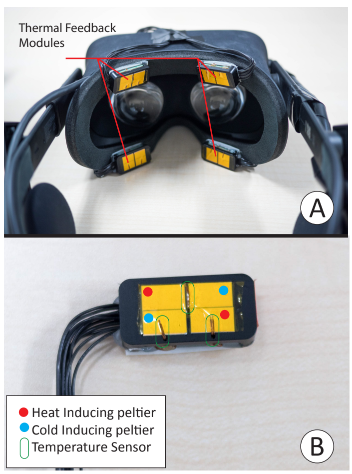

Figure 3: (A) Customized HMD (Oculus CV1) with four thermal feedback modules mounted to stimulate the skin. (B) Developed module construction with three temperature sensors and four peltiers for heat and heat stimulation and control.

Ambient Overview

Ambient consists of an end-to-end Telexistence system providing real-time control and sensory feedback to the user. An anthropomorphic Telexistence robot integrates stereo vision, binaural audio, and facial thermal feedback, as well as a three-axis rotation as shown in Figure 2. In the proposed design, four thermistor sensors (model: RS Pro NTC, 10kΩ) distributed on robot's face capture the indirect and direct temperature changes. The raw information of the sensors are embedded into the media stream along the visual and auditory feedback and are sent to the user in real-time (overall latency<$100ms$).

The user can access the robot using a customized HMD (model: Oculus CV1) that is shown in Figure 3(A). The design of the HMD includes thermal feedback capability while maintaining the ergonomic experience when operating through it. Four modules were distributed across the inner side of the HMD (touching user's skin) that match the positioning of the sensors placed on the robot. In this design, we deployed a previously developed feedback module [3] shown in Figure 3 that self-contain four peltiers and three thermistors. Two of the diagonal peltiers are responsible to induce heating, while the other diagonal two induce cooling. This design allows fast response to temperature changes [3]. The three thermistors are used in the control mechanism of the peltiers, creating a closed-loop temperature controller system. For safety and comfort reasons, we limit the minimum and maximum temperature presented by the modules to the range of $15°$ up to $35°$.

Facial Temperature Control

The Ambient system continuously senses, averages and calibrates both the robot sensors and the user's skin temperatures such that the facial temperature feedback is only triggered based on the changes that occur on the interaction with the robot's face. That is, the system does not match the exact temperature from the robot's sensors. Instead, with the changes in temperature on the robot's sensors, those changes are translated to the user's skin. In this manner, the system prevents any sudden temperature changes and lets the user experience a comfortable and subtle temperature sensation based on the interactions on the robot side such as touching the robot's face.

Thermal Interactions

We have tested *Ambient* using several thermal interactions to show the responsiveness toward temperature changes. Figure 4 shows three different interactions that highlight the thermal changes in the HMD. Thermal images (captured using FLiR 1 camera) shows the changes of temperature on the modules placed in the HMD. Direct touch via skin (A) and the use of cold objects (C) results in a sudden change in the temperature of the module, where the use of an indirect source, such as hair dryer (B), results in a smoother flow of temperature changes across the modules.

Experience

At CHI'18, Ambient will be demonstrated for the attendees who can experience it while interacting directly with others using the robot (for example intimate and close interactions as in Figure 5). Also, various props that trigger different temperature changes will be placed for the attendees to interact with (such as cold/hot sources and objects, ...etc).

Conclusion and Future Work

In this work, we presented *Ambient*, a proof of concept system to convey facial thermal feedback in Telexistence and remotely operated systems. We highlighted the role of temperature on the face in social and intimate scenarios, which current Telexistence systems do not provide. In this design, a remotely connected robot captures the direct and ambient

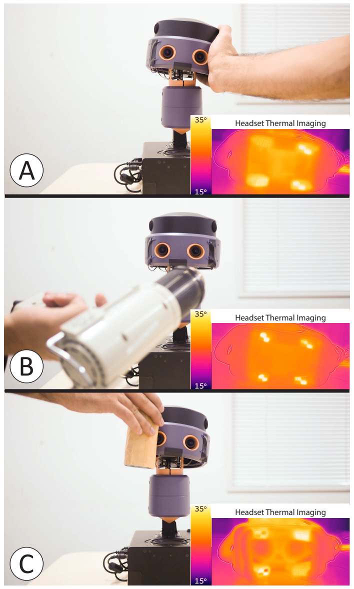

Figure 4: Various interactions with *Ambient*: A) direct touch to the face induces a sudden change in thermal feedback, B) airflow (hot/cold) results in a flow of changes over the modules, and C) use of cold/hot objects to result in temperature changes.

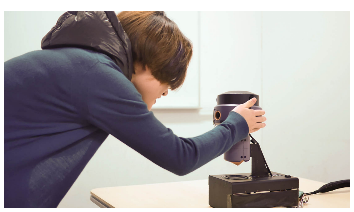

Figure 5: *Ambient* in remote intimate interactions with friends using cross-modal feedback.

temperature changes and mediates it to a customized HMD used by the user, and presents the corresponding changes into his face.

In this reported design, we have only used four feedback modules to convey the thermal state of the robot side into user's face. In this design, although the resolution was relatively low (4 points), it was sufficient to mediate the direct interactions and temperature changes on a local scale. We will carry on an expansion of this design to include wider distribution on the face and the neck. A user study will be conducted to evaluate the effectiveness of such design in intimate interactions.

Acknowledgements
This work is supported by JST ACCEL Embodied Media Project Grant Number JPMJAC1404.

REFERENCES

1. Tadatoshi Kurogi, Masano Nakayama, Katsunari Sato, Sho Kamuro, Charith Lasantha Fernando, Masahiro Furukawa, Kouta Minamizawa, and Susumu Tachi. 2013. Haptic transmission system to recognize differences in surface textures of objects for telexistence. In *Virtual Reality (VR), 2013 IEEE*. IEEE, 137–138.
2. Leonard Mlodinow. 2012. *Subliminal: How your unconscious mind rules your behavior*. Vintage.
3. Masashi Nakatani, Katsunari Sato, Kunio Sato, Yuzuru Kawana, Daisuke Takai, Kouta Minamizawa, and Susumu Tachi. 2016. A novel multimodal tactile module that can provide vibro-thermal feedback. In *International AsiaHaptics conference*. Springer, 437–443.
4. 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*. ACM, 5452–5456.
5. Susumu Tachi. 2015. Telexistence. In *Virtual Realities*. Springer, 229–259.
6. James Keng Soon Teh, Adrian David Cheok, Roshan L Peiris, Yongsoon Choi, Vuong Thuong, and Sha Lai. 2008. Huggy Pajama: a mobile parent and child hugging communication system. In *Proceedings of the 7th international conference on Interaction design and children*. ACM, 250–257.
7. Jordan Tewell, Jon Bird, and George R Buchanan. 2017. The Heat is On: A Temperature Display for Conveying Affective Feedback. In *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems*. ACM, 1756–1767.
8. Graham Wilson, Dobromir Dobrev, and Stephen A Brewster. 2016. Hot under the collar: Mapping thermal feedback to dimensional models of emotion. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems*. ACM, 4838–4849.