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Discriminating Materials Using Physics-Informed Thermal Haptics in Virtual Reality

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Fig. 1. Identifying materials using a Conductivity-based thermal model.

***Abstract*—We present a hands-on demonstration showcasing dynamic thermal feedback based on simulated conductivity and thermal decay. Unlike current thermal feedback systems in Virtual Environments (VE) [1], which often render static object temperatures [2], [3], limiting haptic realism, our approach relies on a transient heat transfer model encoding the second law of thermodynamics. The system integrates Weart TouchDIVER Pro gloves with Meta Quest 3, to render a custom conductivity model which uses heat capacity and a thermal conductivity curve to actively render thermal effects. Like real world thermal feedback, this model renders unique heating (k') and cooling (λ) profiles based on simulated material properties for metal, wood and glass. In our testing, participants were able to distinguish different materials having the same temperature, simply by identifying their conductivity curve. During this demonstration, attendees will interact with visually distinct objects, feeling distinct thermal signatures upon contacting them with a virtual heat / cold source. The demo highlights the effectiveness of conductivity-based rendering using thermal entropy to create intuitive material perception solely through haptics, moving beyond static temperature cues.**

***Index Terms*—Thermal Haptics, Virtual Reality, Material Perception, Thermal Conductivity,**

I. Hands-on Demo Experience

Attendees participating in the demonstration will:

1) Wear the Meta Quest 3 headset and the Weart TouchDIVER Pro haptic gloves and calibrate their hands for the virtual scene.
2) Be immersed in a VR scene containing three visually distinct oblong blocks and hot/cold interaction flames.
3) Grasp a virtual block using Weart gloves and bring it into contact with the simulated hot or cold source to feel the dynamic heating or cooling sensations *(rate of change of temperature)*.
4) Attempt to identify the materials (metal, wood, or glass) based *solely* on the perceived thermal signature.
5) Optionally, place the identified block into the correspondingly labeled virtual bin.
6) Repeat with for the remaining blocks to identify and sort them according to their thermal profiles.

The typical duration for one attendee's core experience is estimated at **3-4 minutes**.

II. Novelty and Contribution

This demonstration offers valuable insights by:

- **Experiential Showcase:** Providing first-hand experience on how dynamic thermal rendering based on conductivity enables material discrimination beyond simply detecting hot or cold objects.
- **Physics-Informed Haptics:** Demonstrating the application of a practical conductivity model (incorporating thermal decay) generating richer thermal effects.
- **Beyond Static:** Identifying the perceptual variances in dynamically rendered thermal feedback across objects with the same temperature.
- **Integration Example:** Experiencing the integrating of Weart thermal gloves within a VR system for nuanced haptic feedback.

This interactive demonstration effectively showcases the potential of conductivity-based rendering for enhancing realism and information transfer in haptic VR experiences.

References

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