

# HeatMagic: Intensity-adjustable Thermal Feedback System Based on the Vortex Effect and Thermal Radiation for Non-contact Thermal Interaction \*

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**Abstract.** Intensity-adjustable feedback technology can provide a highly realistic experience by providing stimuli that match visual information, and is expected to be used to recreate interactions in applications such as virtual reality (VR). We focused on thermal feedback, which is associated with temperature, pain, and emotion, and developed a novel intensity-adjustable non-contact cooling method. By adjusting the flow rate of ultra-low temperature air generated by the vortex effect, this method can provide cold stimuli of varying intensities. In this work, we propose HeatMagic, an intensity-adjustable thermal feedback system combining our novel cooling method with a heating method based on thermal radiation for non-contact thermal interaction, which allows users to interact with virtual worlds using their bare skin through thermal feedback.

**Keywords:** Thermal interaction · Non-contact · Vortex effect · Thermal radiation.

## 1 Introduction

With the advancement of virtual reality (VR) technology and the emergence of the Metaverse, the demand for haptic feedback technology, which can be used to create the feeling of “actually experiencing”, is also increasing. By providing feedback with an intensity corresponding to user input, it is possible to create a highly realistic experience. However, traditional haptic feedback technologies based on vibration are limited in their application. Consequently, the emergence of new feedback technologies was expected. In particular, thermal feedback related to temperature, pain and emotion has attracted a lot of attention.

Conventional thermal feedback technologies are implemented using mediums, such as ThermoAirGlove [1], and Therminator [2]. In this work, we aim to develop a novel thermal feedback system for non-contact thermal interaction, which

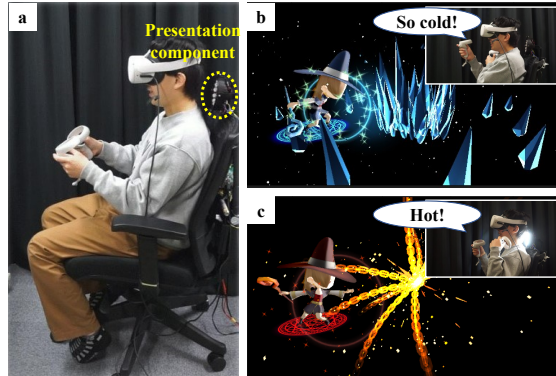
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allows users to interact with virtual worlds using their bare skin through thermal feedback without using a medium. First, we developed a non-contact cooling method based on the vortex effect [3]. By varying the flow rate of ultra-low temperature cold air generated by the vortex effect, different intensities of thermal feedback can be implemented. Then, we combine our unique cooling method with a heating method based on thermal radiation to develop HeatMagic, an intensity-adjustable non-contact thermal feedback system.

## 2 Demonstration

Fig. 1 shows the prototype system of HeatMagic and the appearance of demonstration. The presentation component consists of a cold air outlet and LEDs. Using PWM control, we adjust the flow rate of cold air and the current applied to LEDs to provide thermal feedback of different intensities. Using Unity 5, we developed a game in which the player faced a wizard who possessed ice and fire magic. We have prepared 3 different intensities of thermal feedback. Based on the magic, HeatMagic will provide thermal feedback at an appropriate intensity.



**Fig. 1.** Prototype system (a) and appearance of demonstration with cold magic (b) and hot magic (c).

## References

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