# A Non-Contact Thermal Display by High and Low Temperature Radiation Sources

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**Abstract.** A novel non-contact thermal display has been developed by use of higher and lower temperature radiation sources than that of human skin surface. The skin surfaces are warmed or cooled due to the amount of the energy into/out of the surfaces. In the prototyped system, a controllable infrared heating lamp and frozen ice-packs were employed for the radiation sources. The effectiveness of the system was physically confirmed, and warm and cool sensations were elicited to the human users.

**Keywords:** non-contact, thermal display, infrared radiation

## 1 Introduction

Thermal displays as somatic sensation displays have been emerging to enhance virtual reality, in addition to force and tactile displays[1]-[3]. In most of them, heat-conduction and convection have been employed to stimulate thermal sensations, and tactile sensation is stimulated simultaneously. In our study, infrared radiation sources, of which temperatures are higher and lower than that of skin surface, have been employed in order to develop a non-contact thermal display. The radiations stimulate thermal sensation independently, and elicit warm and cool sensations. These properties will enhance flexibilities to build virtual environments and applications. In this paper, the principle, prototype and characteristics are described.

## 2 Principle

Non-contact thermal displays proposed here are based on the Stefan-Boltzmann law. Two objects, of which absolute temperatures are denoted by $T_1$ and $T_2$(K), respectively, are placed near the human user as shown in Fig.1. The surface temperature of the user is $T_0$. If these objects and the user are blackbody, the radiant emittance $I$ (W/m$^2$) at the user surface is given by equation (1).

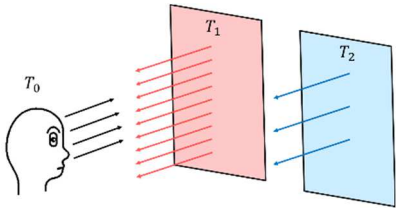


**Fig. 1.** Energy transfer between user and two objects

$$I = \sigma ( T_0^4 - T_1^4 - T_2^4 ) \quad (1)$$

where $\sigma$ is the Stefan-Boltzmann constant. $I$ indicates energy transfer between the user and surrounding objects. If $I > 0$, the energy is transferred from the user to the surrounding objects and the user surface is cooled, and vice versa. Hot and cool objects are prepared, since hot object temperature is more easily controllable than cold one.

## 3 Prototype

A thermal display system shown in Fig.2 was prototyped. An infrared lamp and two ice packs are placed in front of the user. Guillotine shutters in front of radiation sources work for quick change of the radiations. A hood, of which inside is aluminum-plated, is used between radiation sources and the users for guiding the infrared radiations. The lamp output and shutters are controlled by a PC.
A 0.2mm thick lead plate and thermopile sensors were used to measure temperature changes by the radiations. With this prototype, the lead temperature was changed between 21 and 45°C, and human subjects felt warm and cold.

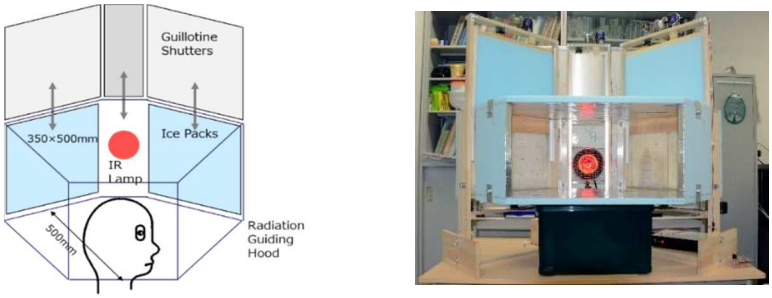


**Fig. 2.** Prototype of non-contact thermal display using high and low temperature radiation sources. Left: schematic diagram, Right: Appearance photograph

## 4 Conclusion

A non-contact thermal display based on infrared radiations was developed, its effectiveness was confirmed, and the subjects felt warm and cool. This system is expected to be applied to various XR systems, such as super-realistic theaters.

## References

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