# AmbioTherm: Simulating Ambient Temperatures and Wind Conditions in VR Environments

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## ABSTRACT
As Virtual Reality (VR) experiences become increasingly popular, simulating sensory perceptions of environmental conditions is essential for providing an immersive user experience. In this paper, we present Ambiotherm, a wearable accessory for existing Head Mounted Displays (HMD), which simulates real-world environmental conditions such as ambient temperatures and wind conditions. The system consists of a wearable accessory for the HMD and a mobile application, which generates interactive VR environments and controls the thermal and wind stimuli. The thermal stimulation module is attached to the user's neck while two fans are focused on the user's face to simulate wind conditions. We demonstrate the Ambiotherm system with two VR environments, a desert and a snowy mountain, to showcase the different types of ambient temperatures and wind conditions that can be simulated. Results from initial user experiments show that the participants perceive VR environments to be more immersive when external thermal and wind stimuli are presented as part of the VR experience.

## CCS Concepts
**•Human-centered computing → Interaction paradigms; Mixed / augmented reality; Interaction devices;**

## Author Keywords
Ambient temperature; virtual wind; virtual reality; multimodal interaction

## INTRODUCTION
The development of visual, auditory and tactile stimuli have been the mainstream research focus in Virtual and Augmented Reality (VR and AR) systems [3]. However, to achieve true immersion, one of the most important aspects that is yet to be realized in VR is the simulation of real-world environmental conditions. For example, ambient temperature and wind characteristics of a VR environment can significantly enhance the user's perception of being in a real, physical space that is being simulated in VR [1, 2].


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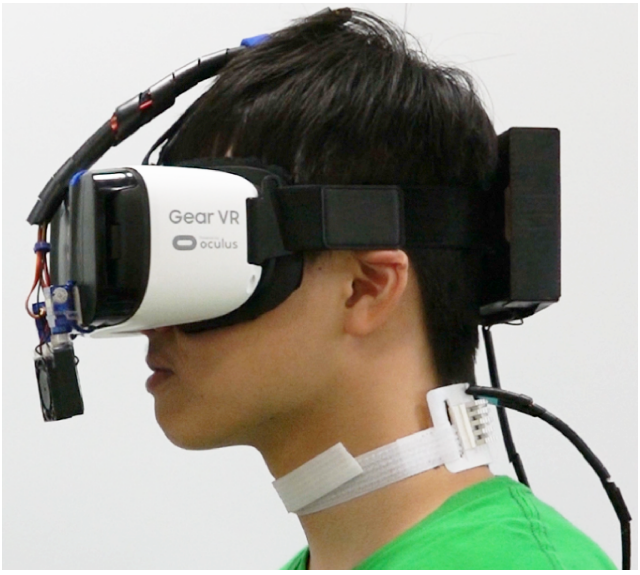


**Figure 1. A participant is using the Ambiotherm system with a Samsung™ Gear VR HMD. The control module is attached at the back.**

Ambiotherm is a fundamental sensory simulation technology that can be integrated with existing VR HMDs to provide controlled thermal and airflow sensations that can be used to simulate ambient temperatures and wind conditions respectively in virtual environments. The novelty of this work is not only the simulation of environmental conditions but also the ability to deliver customized simulations with respect to users' perceptions of, and interactions with, the VR scene. For example, this technology can be applied in VR sports and related activities, such as skiing, hiking, racing or paragliding in which the ambient temperature and winds are an essential part of the users' experience. As shown in Figure 1, when using the device, virtual wind and temperature sensations are delivered using the fans and Peltier elements. Furthermore, we envision that this work will enable a new design space for the VR and AR designers to integrate multisensory interactions within simulated environments.

## METHOD
The Ambiotherm system consists of three main modules (as shown in Figure 2): the control module, the ambient temperature module, and the wind simulation module. As a means of providing controlled thermal stimulation to simulate ambient temperatures, it utilizes two Peltier elements (for rapid heating

and cooling) with varying voltage and polarity applied to them. Both of the Peltier elements are attached to heatsinks to provide efficient temperature control. This module is worn on top of the spine behind the user's neck. This location on the upper body is chosen for two reasons: 1) to provide high levels of comfort, and 2) to provide a perception of overall temperature change (similar to the effects of induced hypothermia [4]). Additionally, wind conditions are simulated using two 5V fans mounted on servo motors facing the user's cheeks. The servo motors are used to simulate the direction of the wind, while the technique of Pulse-Width Modulation (PWM) is used to simulate the strength. These thermal and wind simulations are controlled by a microcontroller that receives commands from the VR environment via Bluetooth.

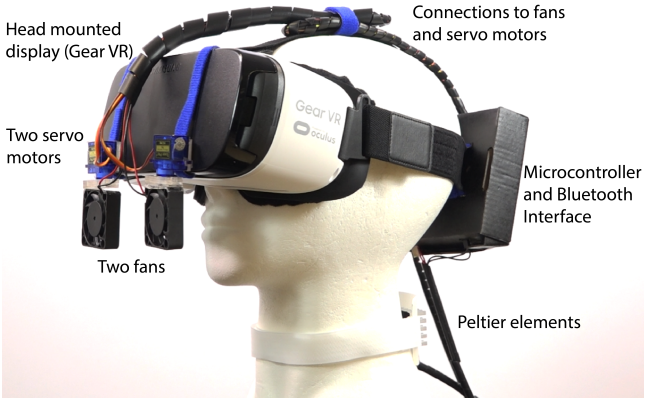


**Figure 2. Main components of the Ambiotherm system: two fans and servo motors are used to simulate the wind conditions, while Peltier elements are used to simulate the ambient temperatures.**

## EXPERIMENTAL RESULTS

An initial user experiment was conducted with 15 participants (8 males and 7 females with an average age of 23 years) using a Samsung Gear VR and a Note 5 mobile phone. For the experiment, two contrasting VR environments were developed on the Unity platform[1]: a desert and a snowy mountain. User input controllers were not used for this experiment and the participants were instructed to explore the VR environments by following an animated character, which automatically navigates through the environments. Based on the environment, the system automatically outputs hot and cold stimuli along with various wind patterns. Two sessions were conducted (Gear VR vs. Gear VR combined with the Ambiotherm) in which users were asked to explore both VR environments twice, in the sequence "desert, snow, desert, snow" (duration of each session was approximately 4 minutes). After each session, the participants were asked to answer a short questionnaire, which was prepared based on three aspects: perception, stimuli, and user experience. The initial findings, as illustrated in Figure 3, clearly show that participants prefer the Gear VR combined with the Ambiotherm for enhanced experience during the simulations.

## DEMO EXPERIENCE

During our interactive demo, participants will be provided with various interactive VR environments. As the user travels through different VR environments, they will experience thermal and wind sensations that simulate real-world conditions congruent to those displayed in the respective VR environment. For example, as users travel through a snow environment, cool thermal sensations and wind stimuli will be provided to simulate the coldness and cross-winds associated with this particular environment. For the user's safety and comfort, thermal stimuli will be restricted to an approximate range of 15°C - 35°C for a maximum duration of approximately 20 seconds.

[1]https://unity3d.com

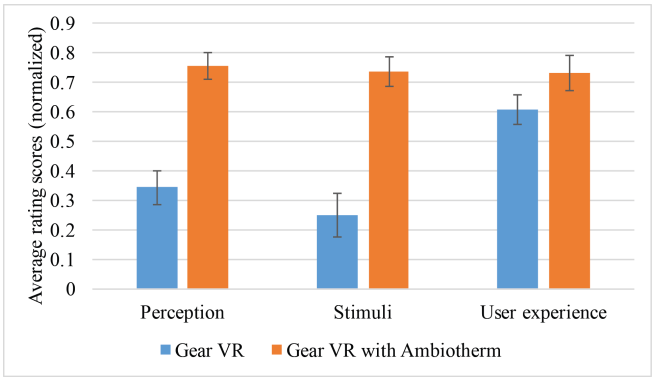


**Figure 3. Normalized average rating scores received for three different aspects of the system: perception, stimuli, and user experience (error bars display standard error, n = 15).**

## CONCLUSION

In conclusion, this paper presented Ambiotherm as a system for simulating environmental conditions as part of VR experiences. It uses two Peltier elements, two fans, and two servo motors to simulate ambient temperature and wind conditions accordingly. Initial user experiments show that users perceive greater immersion while exploring VR environments with the Ambiotherm system. Further studies should be conducted to refine these multisensory stimuli and to establish a taxonomy for future VR developers to integrate simulated environmental conditions within their VR simulations.

## ACKNOWLEDGMENTS

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