

# Manipulation of the Perceived Direction of Wind by Cross-modal Effects of Wind and Three-dimensional Sound

Kenichi Ito, Yuki Ban, Shin'ichi Warisawa (The Univ. of Tokyo)

## Background

### Wind Display

- Devices to provide **wind sensation** to its users
- Reproduce wind directions by blowing from many wind sources



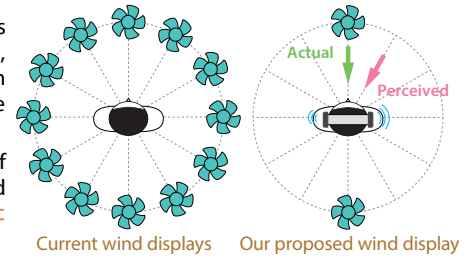
**Advantage** Presence of virtual reality (VR) is improved by the wind sensation<sup>[1]</sup>

**Problem** The devices are complicated due to many wind sources

[1] Rietzler, M., Plaumann, K., et al., "VaiR: Simulating 3D Airflows in Virtual Reality", In Proceedings of CHI '17, pp. 5669-5677, 2017. [2] Tolley, D., Nguyen, T., et al., "WindyWall: Exploring Creative Wind Simulations", In Proceedings of TEI '19, pp. 635-644, 2019.

## Approach

- To construct wind displays with **fewer wind sources**, we propose manipulation of the perception of the wind.
- The perceived direction of the wind may be changed due to **the audio-haptic cross-modal effects**.



**Approach** Present sounds along with the wind to induce the cross-modal effect

## Implementation

### 3D Sounds of Wind Localized in the Horizontal Directions

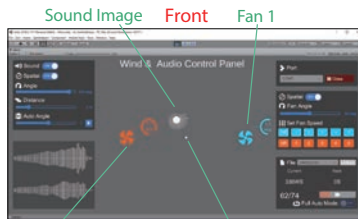
We recorded and presented **3D sounds** of wind localized in 12 directions (every 30°) by the **dummy head**.

### Three-dimensional (3D) Sound

- Humans can **localize sound sources** using the cue from the shape of both ears and heads (Head-Related Transfer Function; **HRTF**).
- We recorded 3D sound by a **dummy head** which simulates the real listening situation.



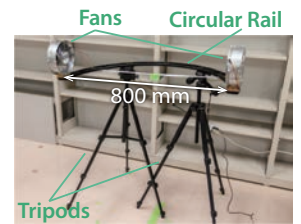
The recording environment by a dummy head



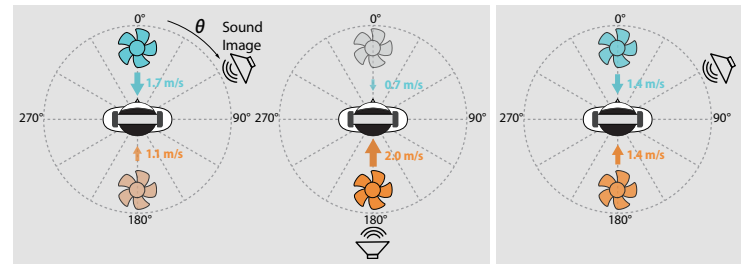
The software that controls the 3D sound & wind presentation

### Wind Presentation by Two DC Fans

- To present wind, we arranged **two DC fans** in front and back of the users.
- We **controlled the wind velocity** from 0 to 2.0 m/s in order that the directions of the actual wind and the sound image weren't too different.
- The controlled wind and the constant wind were compared in the experiment.



The appearance of our device



The condition of controlled wind velocity

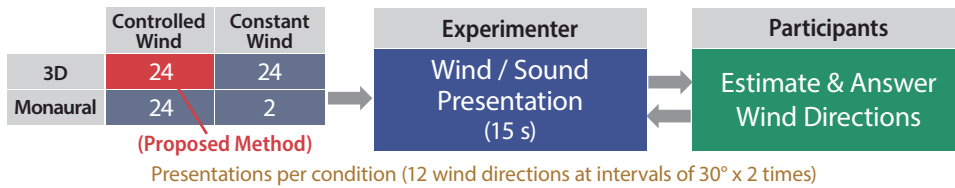
Constant wind velocity

**Sound** 3D sounds of wind localized in the desired wind direction were played

**Wind** The wind were presented by the two fans in front and back of users

## Experiment

We investigated the **effect of audio-haptic interactions** for the perceived wind direction.

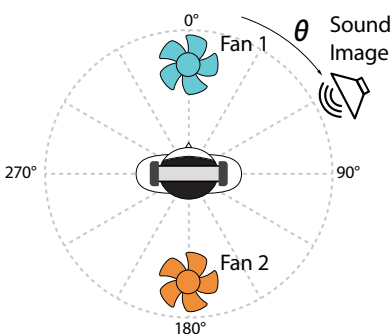


The experimental environment

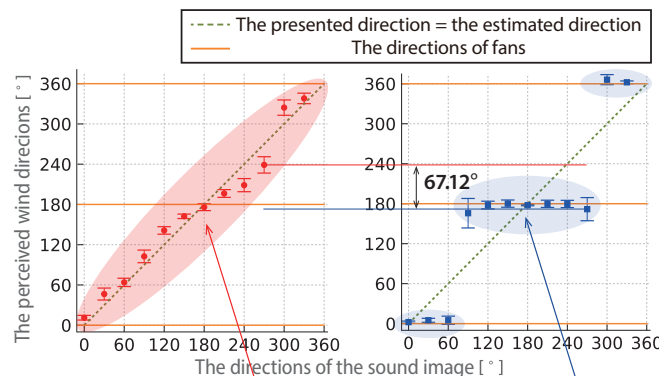


UI for answering

## Result



The experimental setup



(a) 3D sound & Controlled wind Scatter plots of the presented directions and the estimated directions

Close to the actual wind directions

The perceived wind directions were close to the directions of the sound image

## Conclusion

- The perceived directions of wind **changed by a maximum of 67.12°** by a combination of the wind and realistic 3D wind sounds.
- The actual wind directions were perceived with the monaural sound.

**Conclusion**

The perceived wind directions can be altered by the audio-haptic cross-modal effects