SlopeNav: A Realtime Wearable Blind Ski Assistance System with Adaptive Path Planning for Simulated Environments

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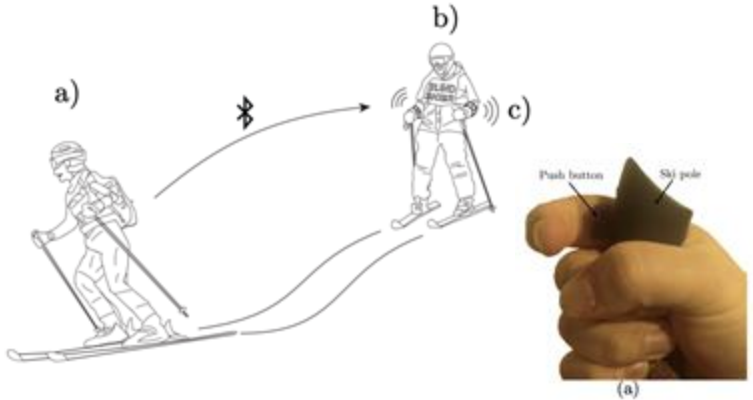
What is Blind Ski?

[1] Kanagawa BlindSkiClub https://kanagawa-blindski.com/

Related Work

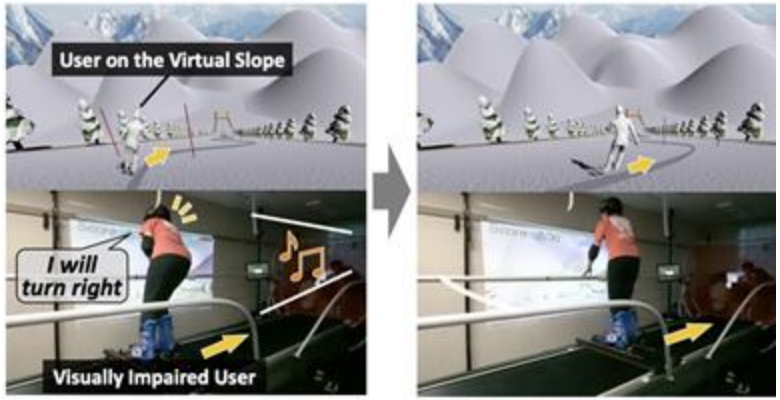
Communication Support[2]



◯ Usable in real environments

△ Human guide required

Practice on a simulator[3]



◯ No human guide needed

△ Restricted to pre-planned routes

[2] Aggravi et al., Haptic Assistive Bracelets for Blind Skier Guidance, AH '16
[3] Miura et al., Exploration of Sonification Feedback for People with Visual Impairment to Use Ski Simulator, AHs '23

Blind Ski Project Roadmap

Step 01

SlopeNav on Simulator

Obstacle avoidance in a ski simulation.

Step 02

SlopeNav & Human Guide on Real Slope

Providing guided skiing with sighted assistance.

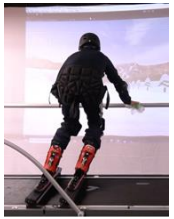
Step 03

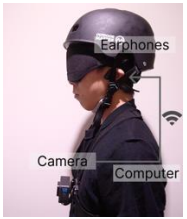
SlopeNav on Real Slope

Fully autonomous navigation on real slopes.

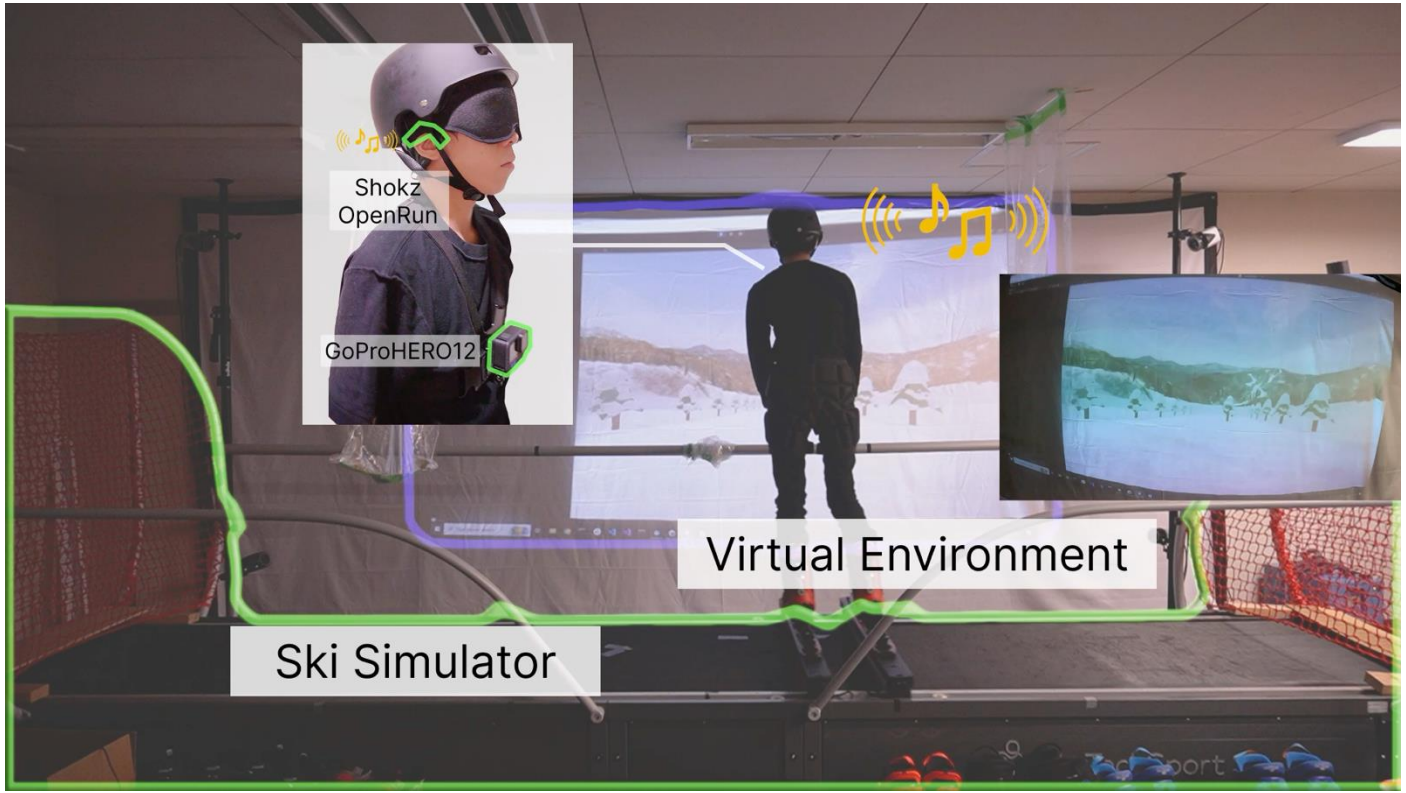
SlopeNav

A wearable system with adaptive path planning for simulated skiing.



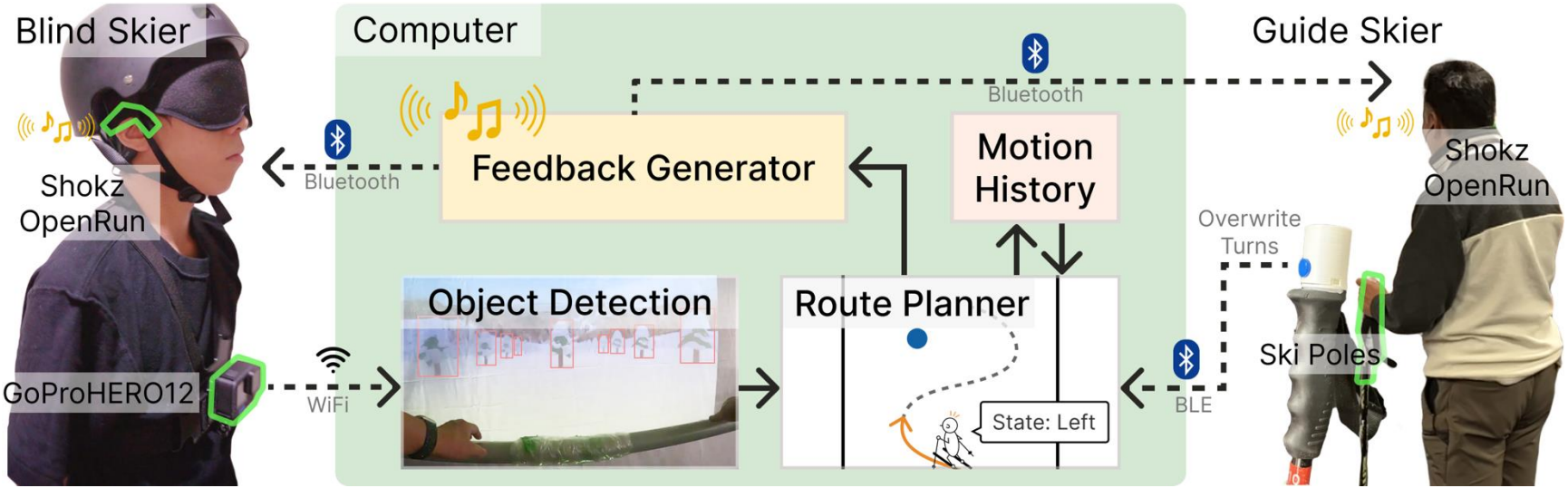


SlopeNav: Blind Ski Assistance System



System Overview

Object detection and **turn direction guidance**
→ Enables turning while avoiding obstacles



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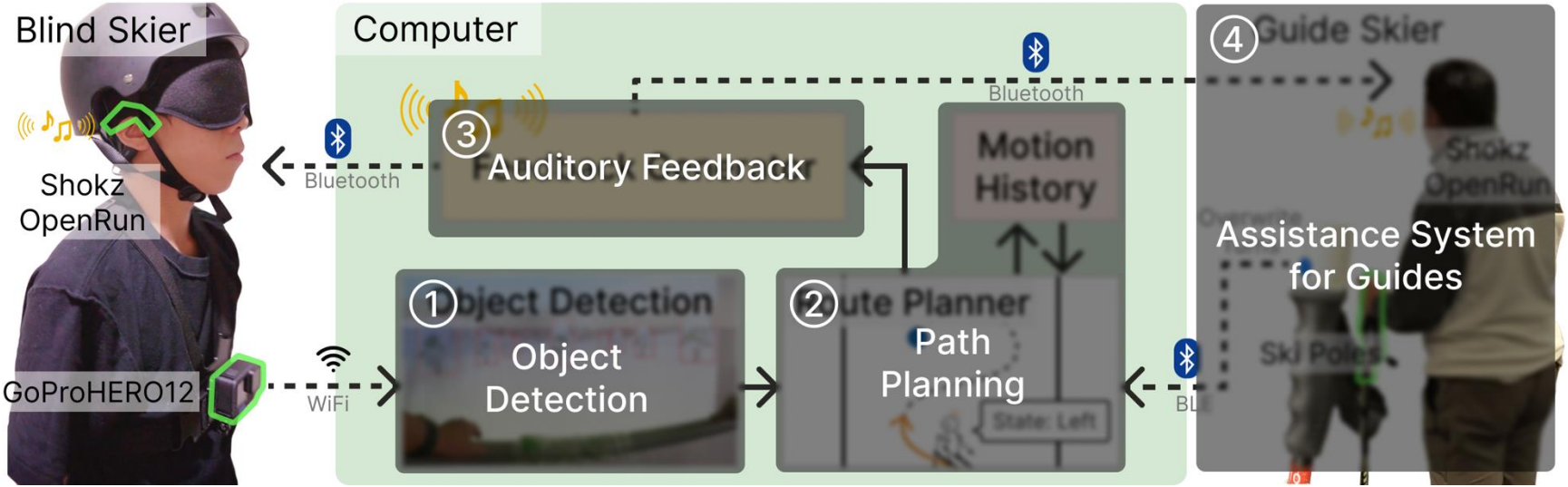
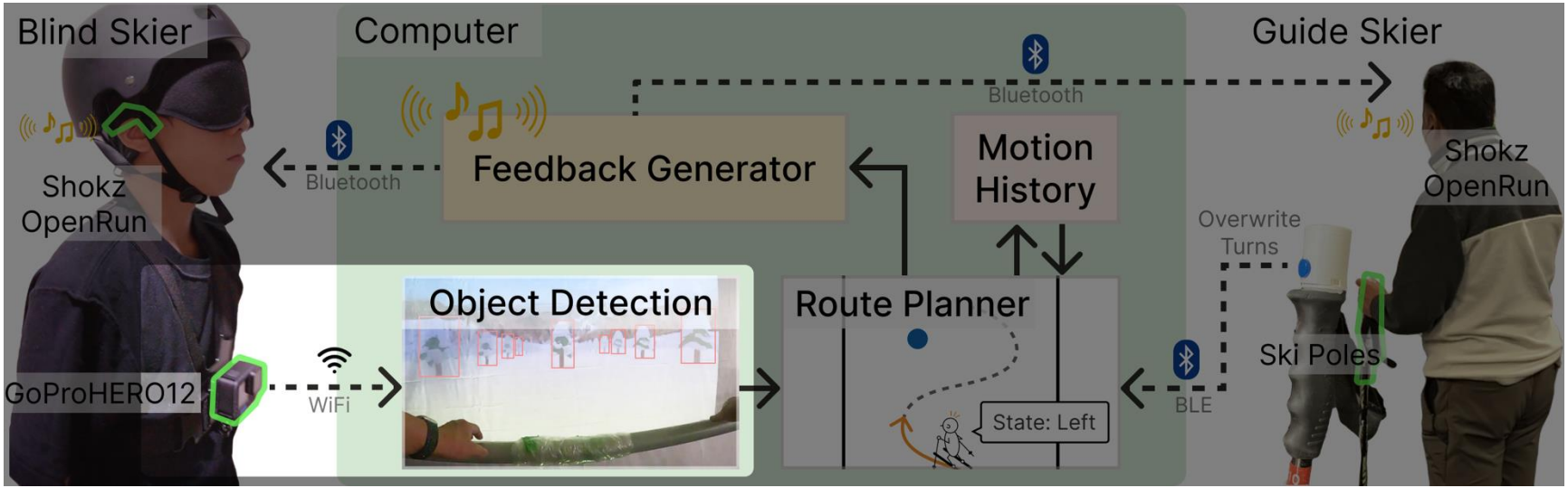
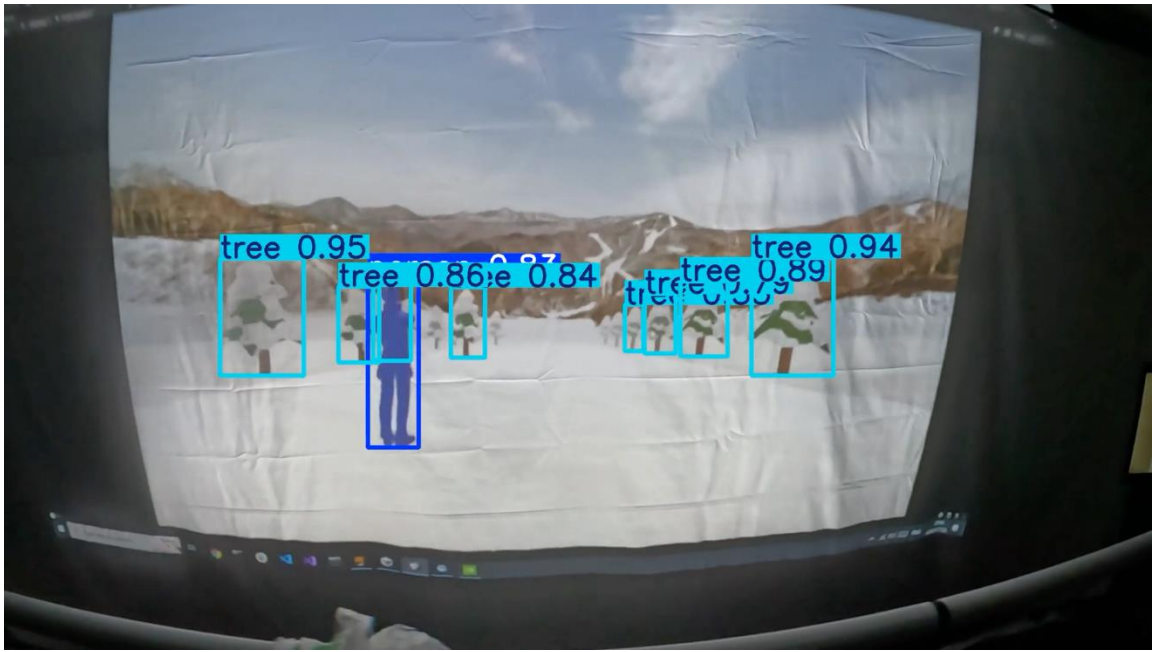


System 1. Object Detection

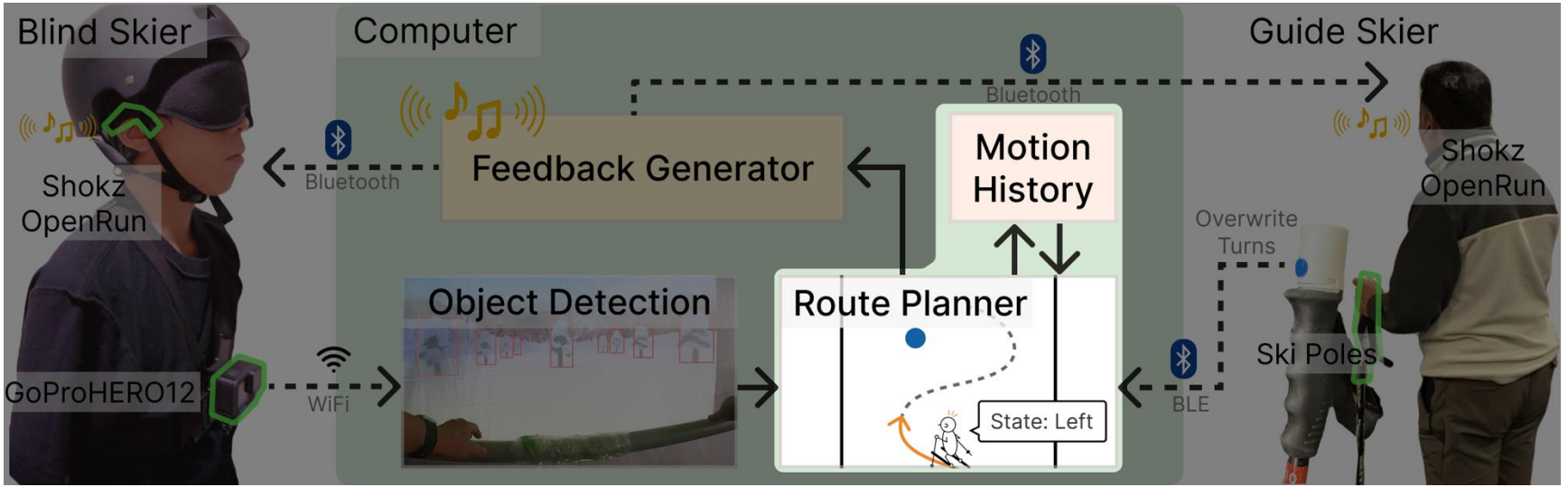


System 1. Object Detection

Chest-mounted camera detects obstacles using **YOLOv8**.
Trained on 1,200 simulation images and 600 real-world snow images.

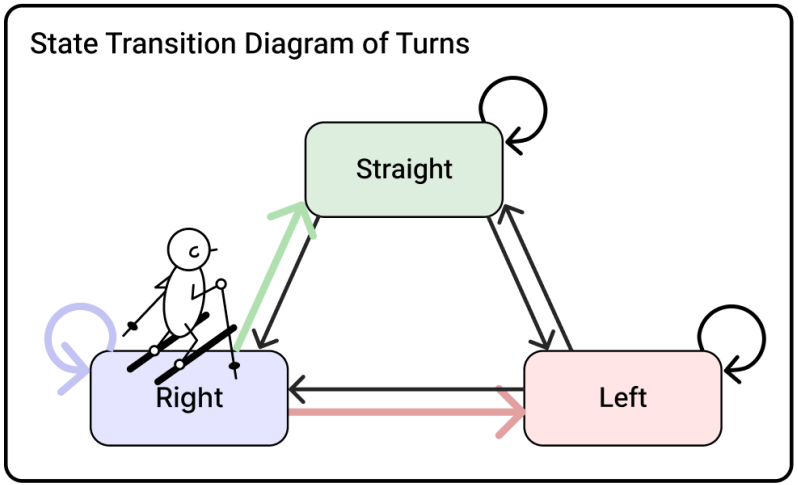


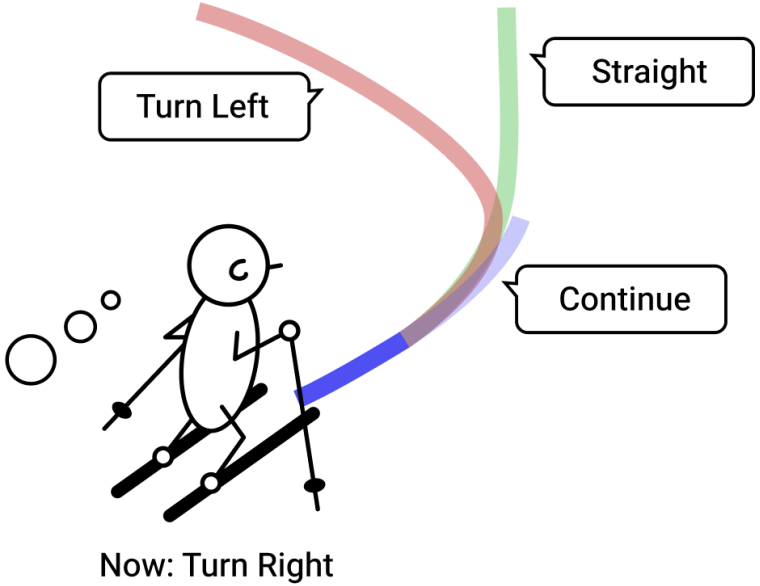
System 2. Path Planning



System 2. Path Planning

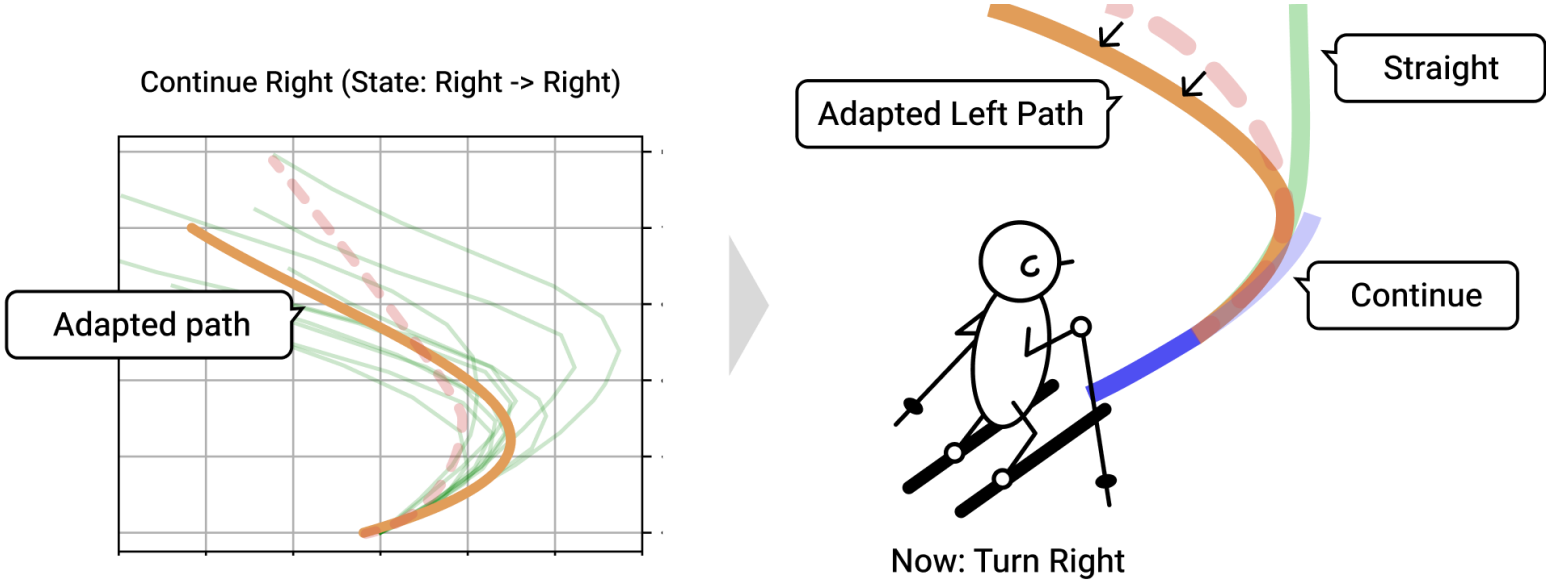
Plans safe turns based on obstacles and skier's movement.
Uses a state transition model with left, right, and straight states.



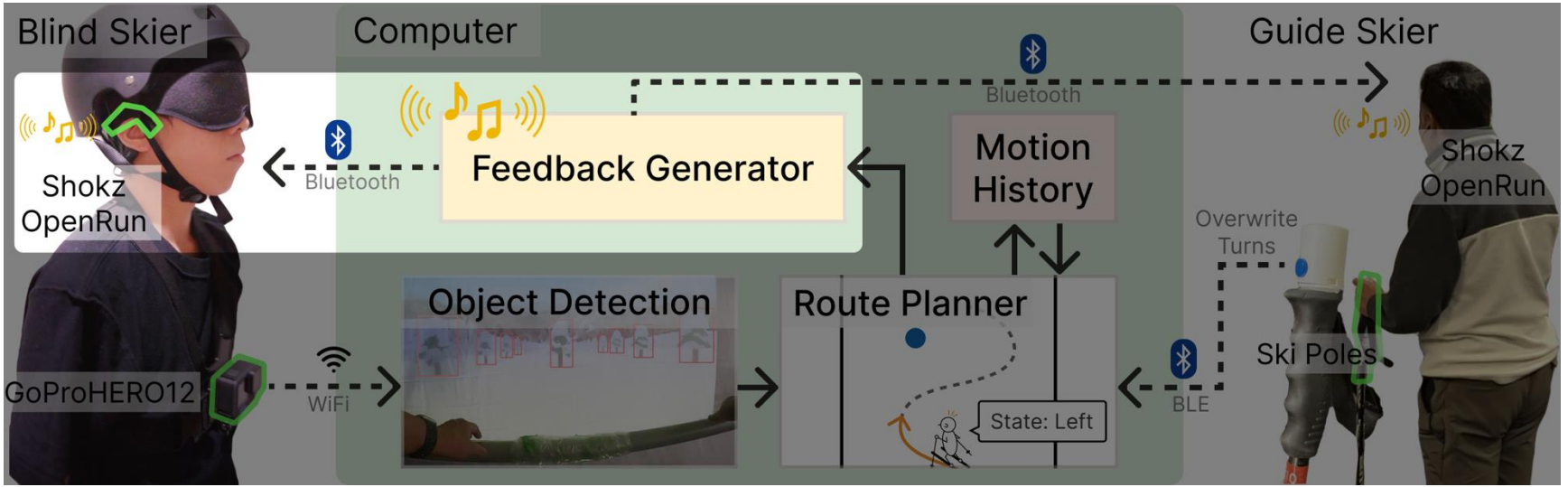


System 2. Path Planning

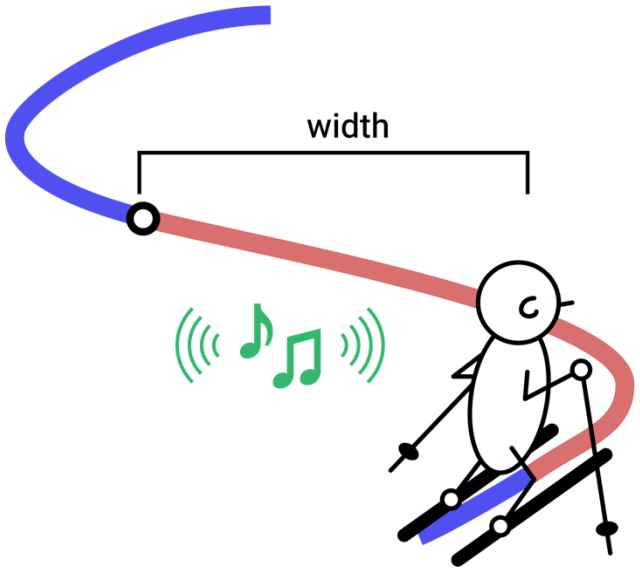
Adjusts turn size and feedback timing based on skier's past performance.



System 3. Auditory Feedback



System 3. Auditory Feedback



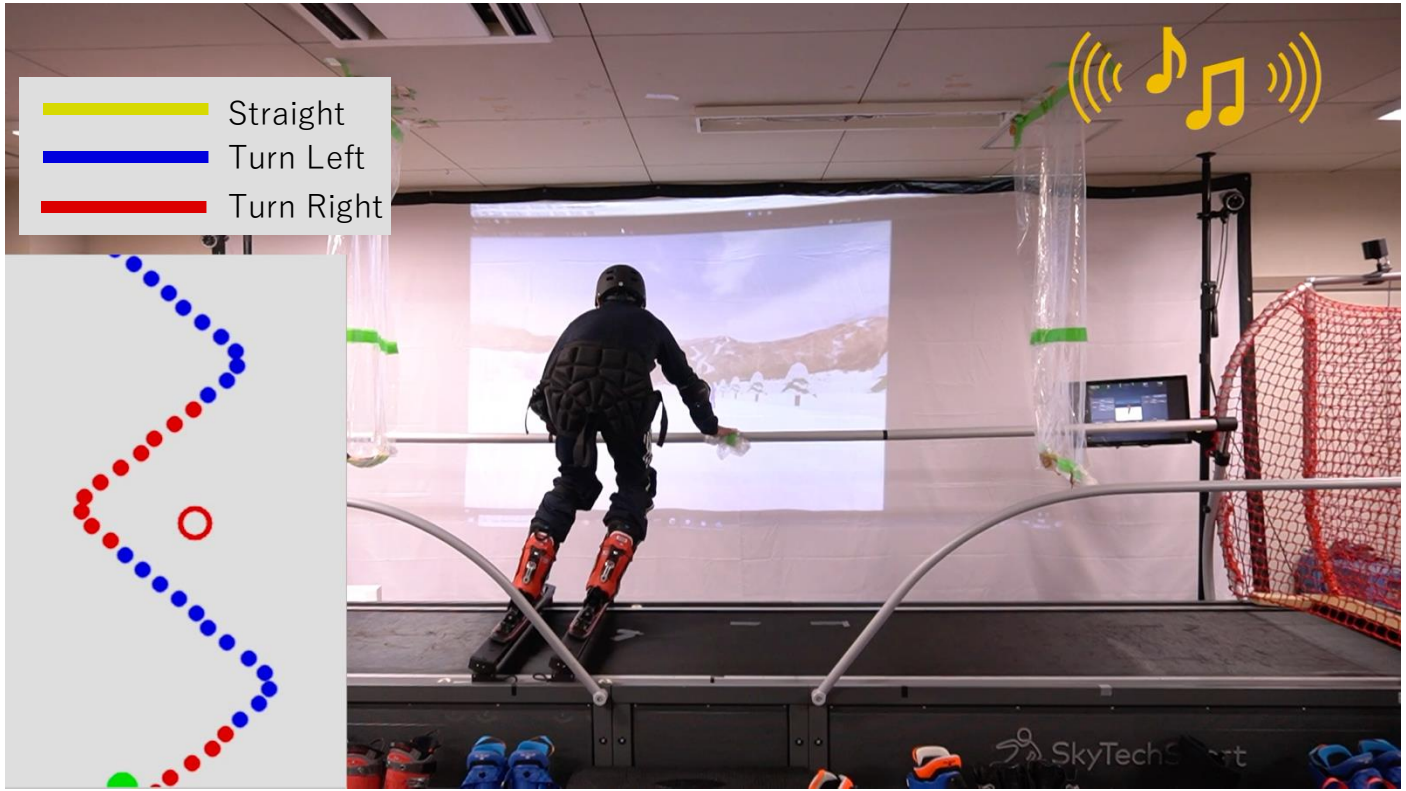
Continuous feedback reduces anxiety and improves confidence.

Stereo sound → turn direction
Pitch variation → turn width

Width to Pitch:

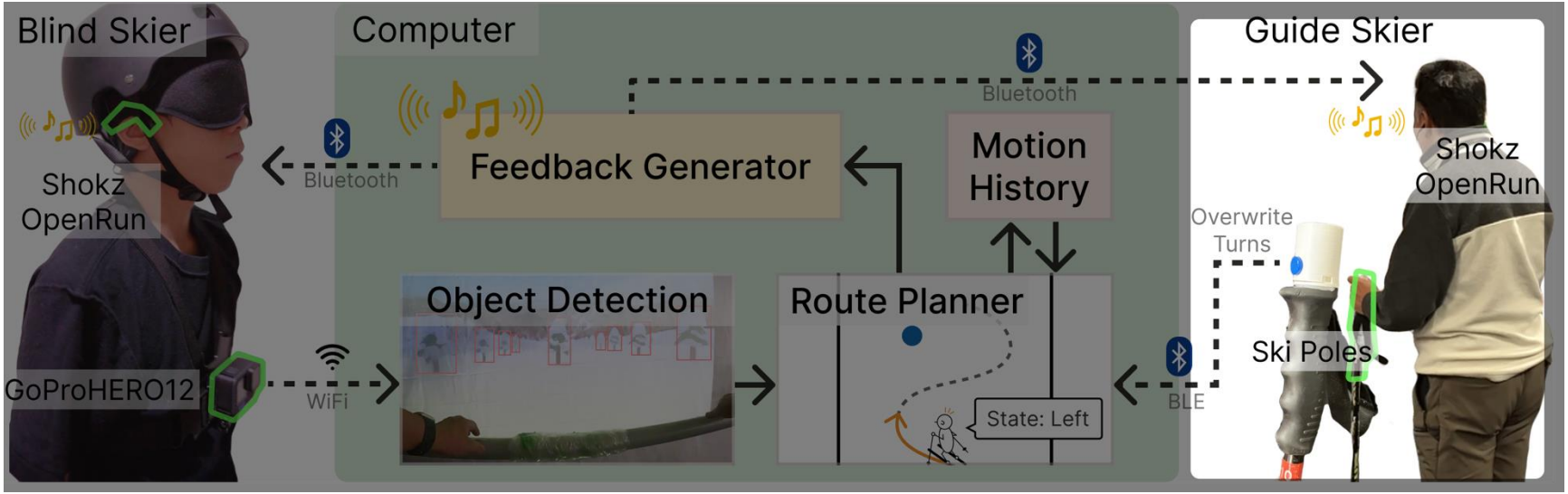
$$f = f_{\min} \cdot 2^{\text{diff} \cdot \ln\left(\frac{f_{\max}}{f_{\min}}\right) \cdot \frac{1}{\ln 2}}$$

System 3. Auditory Feedback



Planned Path

System 4. Assistance System for Guides



System 4. Assistance System for Guides

Earphones + **Buttons** Attached to Ski Poles
→ Guides can monitor and override system feedback.

Experiment - Indoor Ski Simulator

4 pairs (blind skier and sighted guide) + 4 sighted skiers
A 10m-wide straight course with 10 randomly placed obstacles

Conditions:

Guide: Human Guide

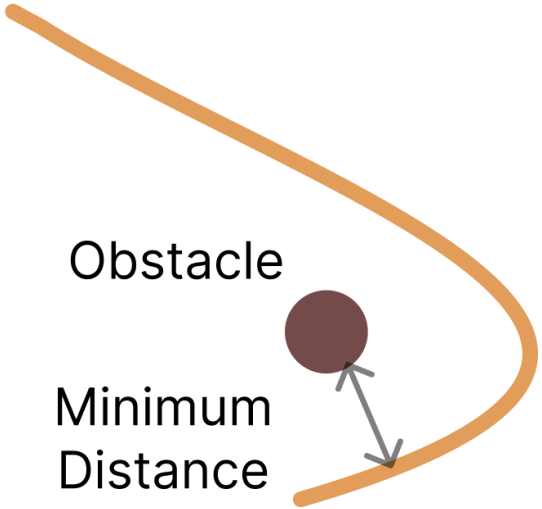
System: SlopeNav

Hybrid: SlopeNav + Guide

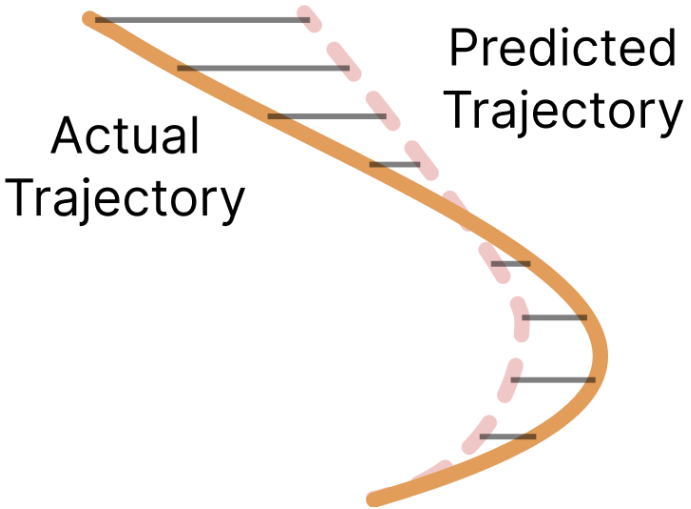
Experiment - Evaluation Metrics

We record the skier's trajectory to evaluate navigation safety and the effectiveness of adapted path planning.

Distance from Obstacles



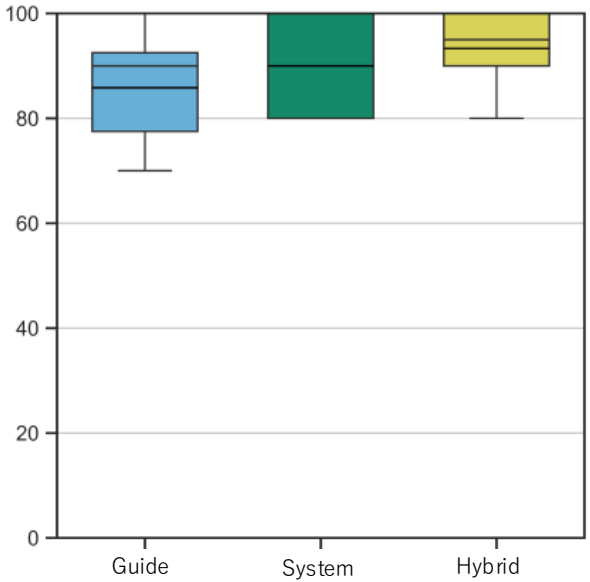
Average Displacement Error



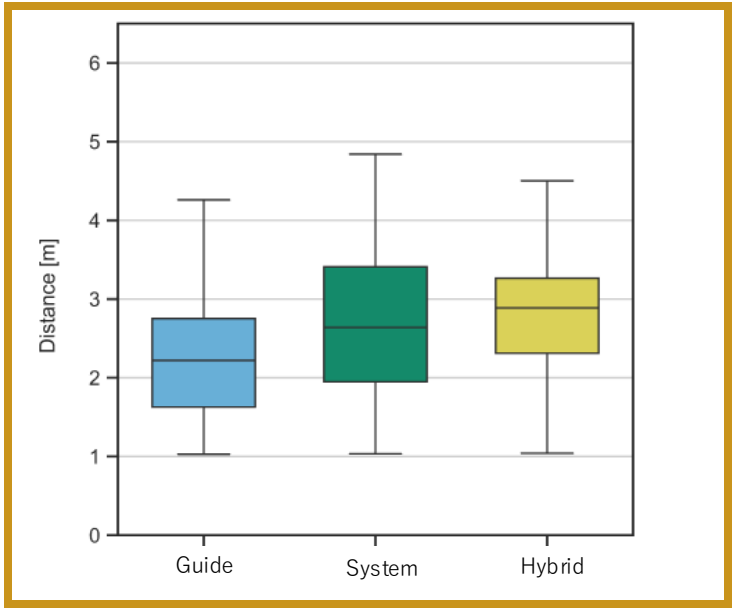
Result (PVI) - Safety

Distance to obstacles: **Hybrid** ≒ **System** ≧ **Guide**

Obstacle Avoidance Rate

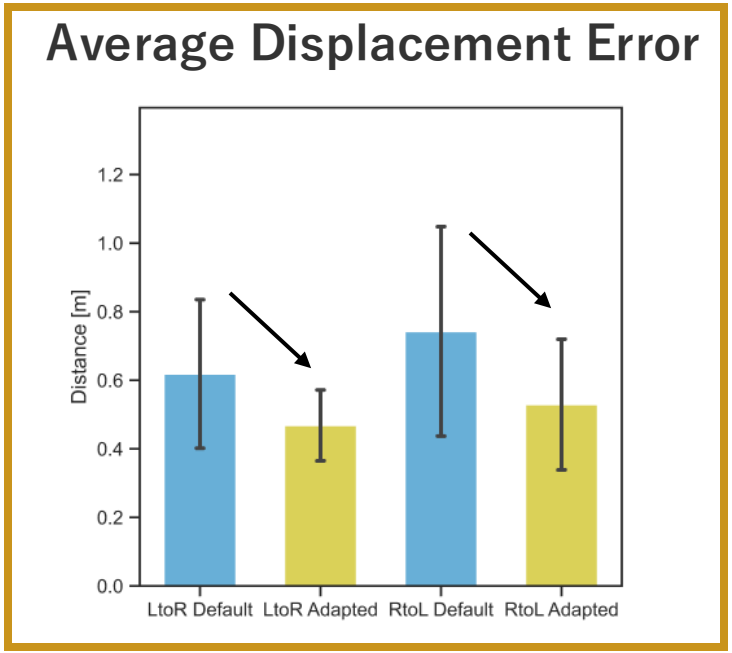


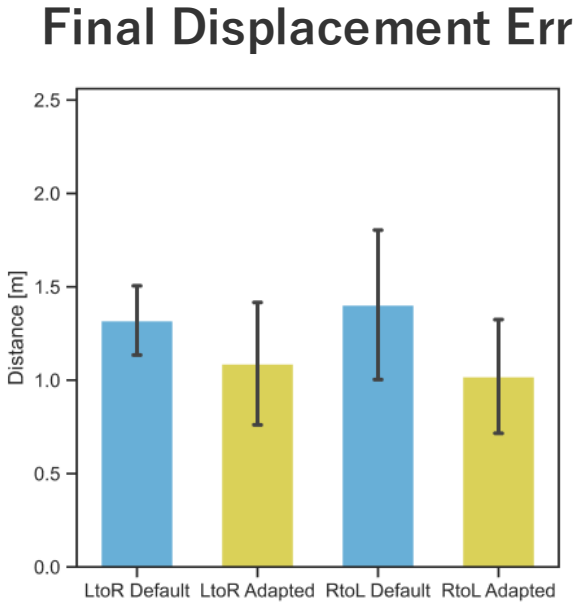
Distance from Obstacles



Result (PVI) - Safety

Prediction error: Adapted Path < Default Path
The adaptation of routes based on individual skills is important.

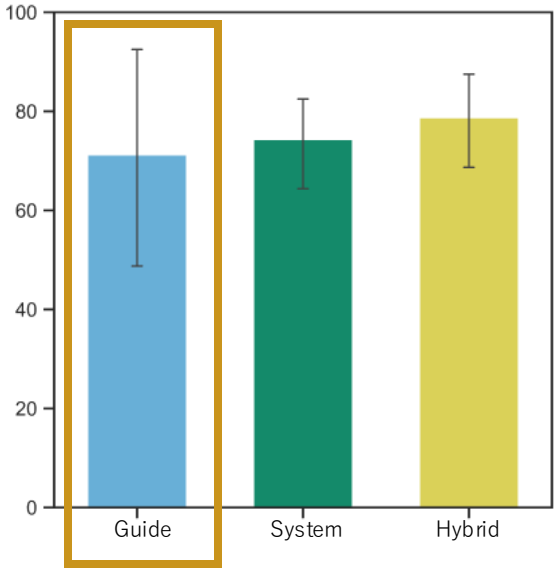




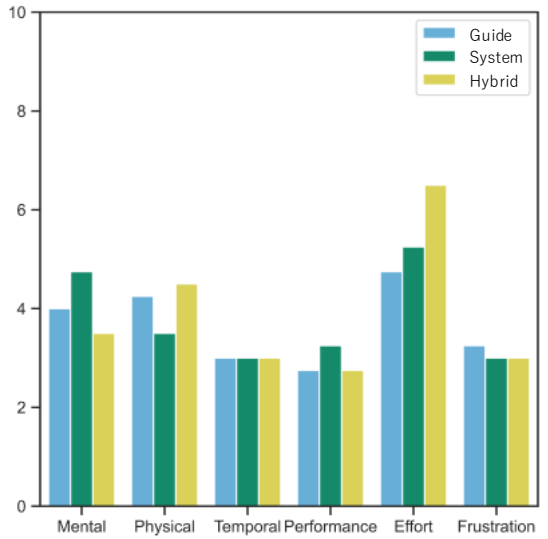
Result (PVI) - Usability

Usability: **Hybrid** ≒ **System** ≒ **Guide**
Guide SUS varies depending on the compatibility of the pair.

SUS scores



NASA-TLX

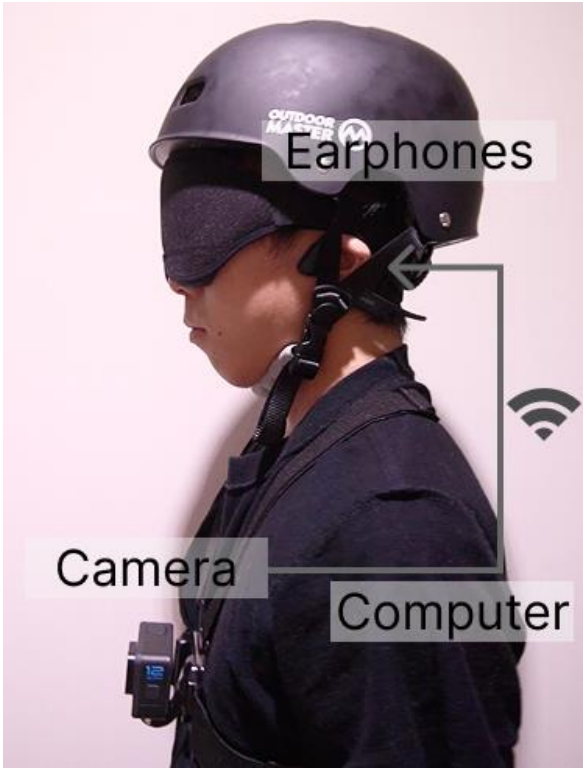


Limitations & Future Work

- **Obstacle Detection**
  - Improve dynamic obstacle prediction.
- **Path Planning**
  - Enhance planning with posture information.
  - Add speed planning and instructions.
- **Evaluation**
  - Conduct experiments on real snow slopes.
  - Recruit more diverse participants.

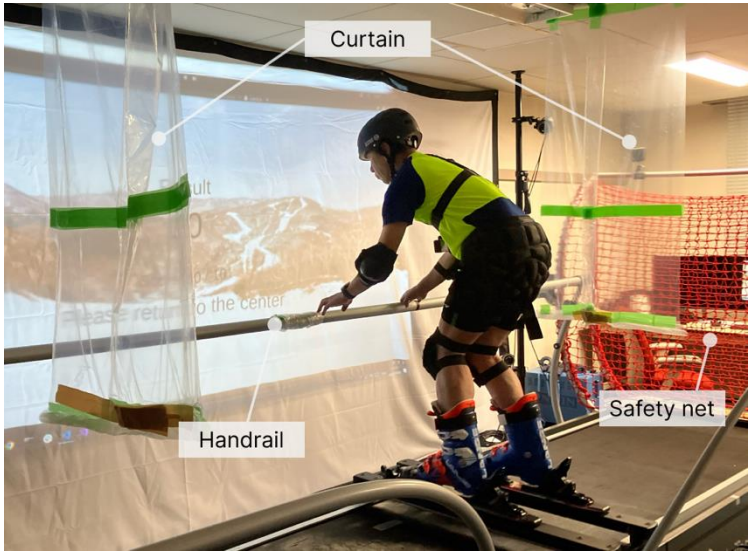
Conclusion

- We developed a **system for blind skiers**
  - **Obstacle detection** with a **chest-mounted camera**
  - **Adaptive path planning** considering skier's skill and environment
  - **Auditory feedback** for obstacle avoidance and continuous turn guidance
- User Study Results
  - Obstacle avoidance performance **comparable to human guidance**
  - **Continuous feedback** was effective in improving skier confidence



Indoor Ski Simulator

Build an indoor simulation environment for safety.



Preliminary Experiment

Conducted a preliminary experiment w
ith four pairs of blind skier and guide.

1. Guidance by the guide
2. Guidance using system sounds
3. Collaboration

→ Extracted system requirements

Preliminary Experiment

Extracted system requirements

D1. Direct guidance for obstacle avoidance

D2. Continuous feedback

D3. Route design adapted to individual skills

D4. Collaborative feedback with the guide

Result (PVI) – User Feedback - Sound

P3

✓ Continuous Sound

The continuous sound made it clear that the system was functioning.

P1

✓ Pitch of Sound

I could adjust the turn width in my own way based on the pitch.

G3(Guide)

✓ stable

Compared to human guides, the system's instructions feel more stable.

Result (PVI) – User Feedback – with Alert

Preliminary Experiment on Combining **Obstacle Alerts** with SlopeNav Navigation.

Q: Obstacle alerts are effective for obstacle avoidance?
A: 2.3/5 (Disagree)

P1

△ Difficult

It's difficult to distinguish between turn instructions and warning sounds.

P2

△ Warning Sound Anxiety

Hearing a warning sound might make me nervous and unable to perform my usual turns.

Result - Safety

The result variation **without adaptation** reveals individual differences in skills and preferences.