Dimensional Similarity in Human Perception of Slope for Networked Virtual Haptic Environments

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Outline

- Background
- Previous Work
- Purpose
- Object Perception System
- Slopes as Objects
- Calculation of Reaction Force
- Assessment Method
- Assessment Results
- Conclusion and Future Work

Background

Networked virtual environments with haptics

We can perceive the features of the shape, softness, and weight of an object through a haptic interface device by touching/holing the object.

When haptic information is transmitted over a network such as the Internet, which does not guarantee QoS (Quality of Service)

Network delay, delay jitter, and packet loss

QoE (Quality of Experience) deterioration

QoS control

For effective QoS control, we need to investigate human perception of object features such as the shape, surface smoothness, softness, and weight of the object.

Previous Work (1/3)

- **The inter-stream synchronization control between audio and haptic media streams is proposed [*1], as QoS control taking advantage of human perception**
- **Two perception ranges of inter-stream synchronization error are introduced**

- **Imperceptible range: Users cannot perceive the error**
- **Allowable range: Users feel that the error is allowable**

Problem

➢ **The ranges are not clarified so far.**

*1 Y. Ishibashi *et al.*, ACM Multimedia, pp. 604-611, Oct. 2004.

Previous Work (2/3)

Carried out QoE assessment of human angle perception[*2] for networked virtual environments.

Clarified the imperceptible range, allowable range, and perceptible range (i.e., all the users can perceive the angle difference) of angle perception.

Problem

The human perception of other features such as shape and surface smoothness has not sufficiently been clarified so far.

*2 J. Ma *et al.*, CECIT, Dec. 2021.

Previous Work (3/3)

Investigate the human slope perception on the *y*-axis[*3] by touching the surface of each slope with a haptic interface device by QoE assessment instead of angles[*2] in the object perception system.

Demonstrate that the human perception largely depends on the angle of the standard slope and the slope difference

Problem

- **The human perception on the *x*- and *z*-axes is not clarified.**

*3 A. T. Christian *et al.*, WSCE, pp. 6-10, Sep. 2022.

Purpose

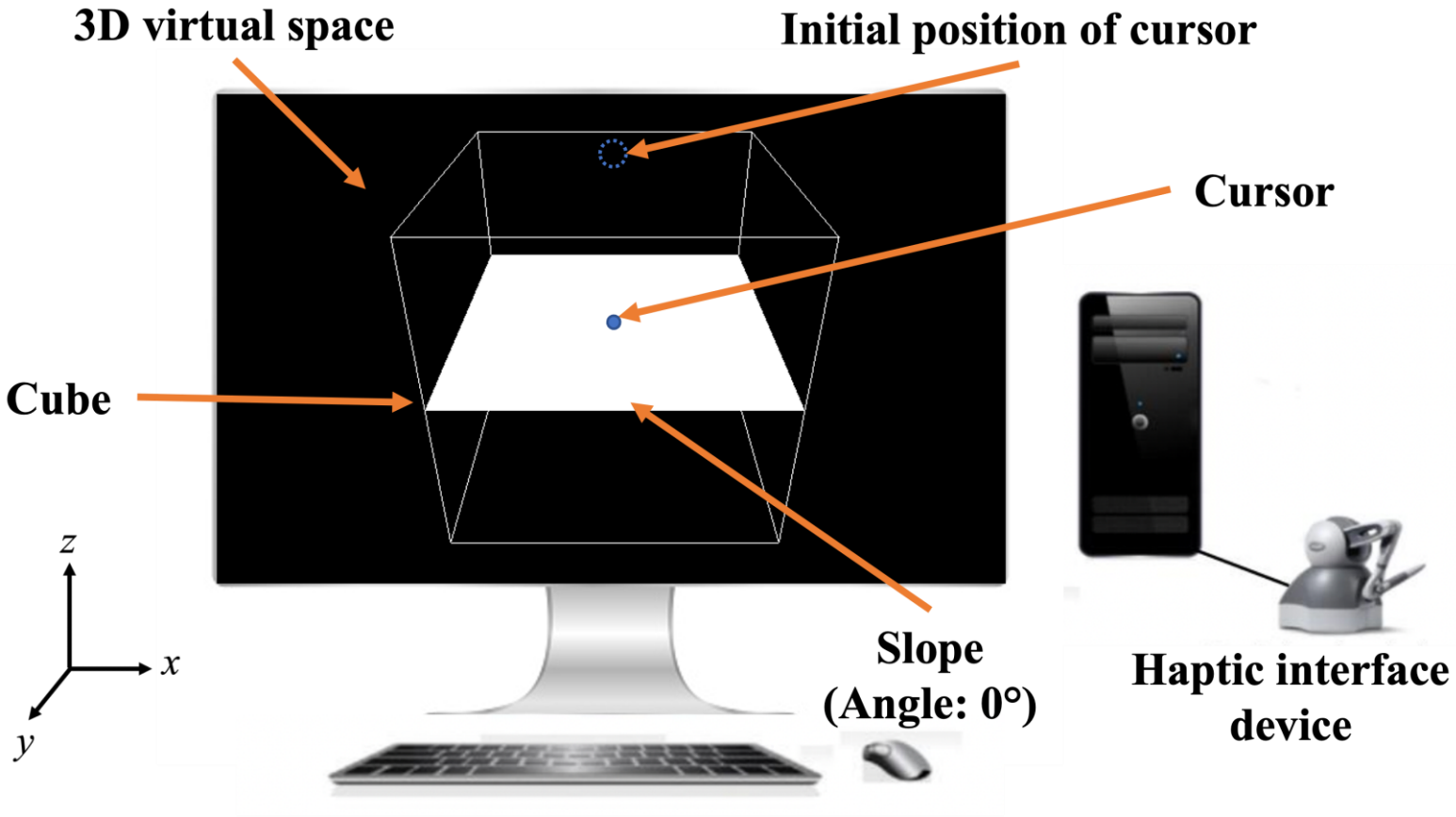
This work

- **We investigate the human slope perception on the *x*- and *z*-axes by QoE assessment.**
- **We make a comparison with our previous results[*3] on the *y*-axis.**

*3 A. T. Christian *et al.*, WSCE, pp. 6-10, Sep. 2022.

Object Perception System (1/3)

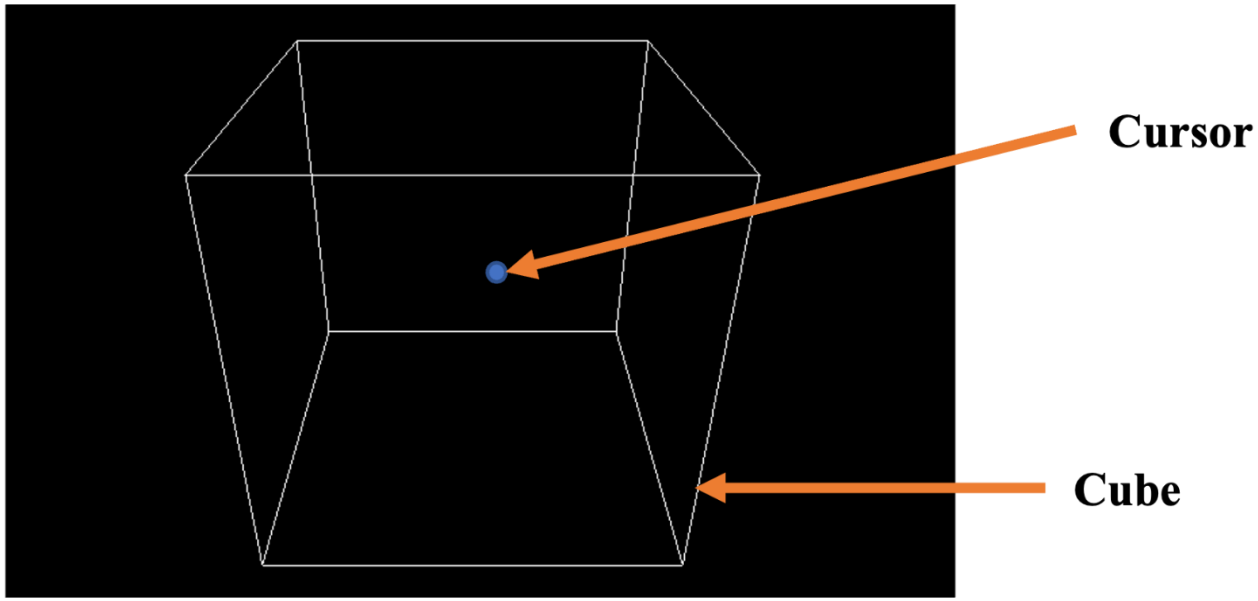
- **Visible mode:** User can look at slopes.



- **Invisible mode:** User cannot look at slopes.

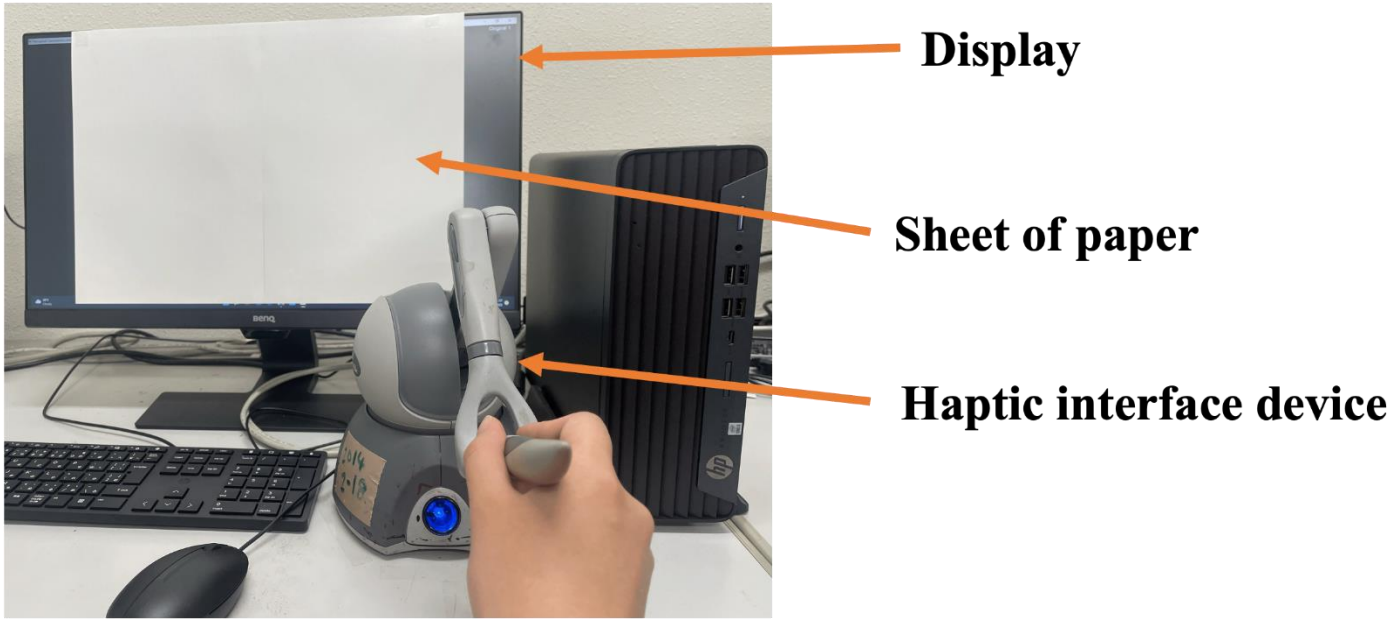
Object Perception System (2/3)

- **Invisible mode**



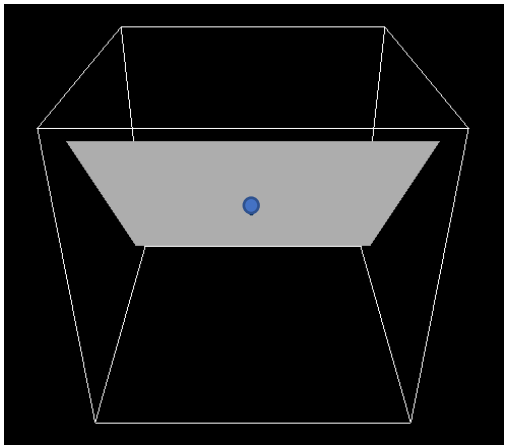
Object Perception System (3/3)

- **Invisible mode (covered by a sheet of paper)**

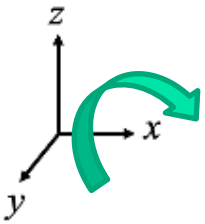


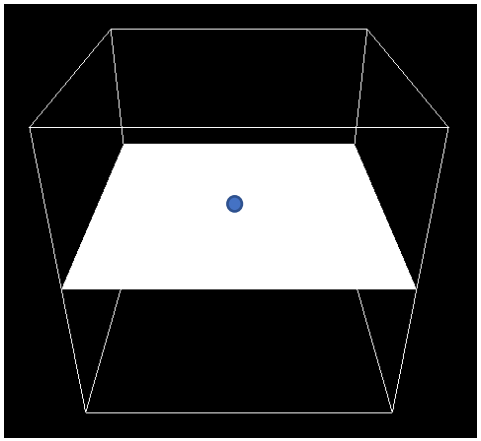
Slopes as Objects (1/2)

- ***x*-axis**

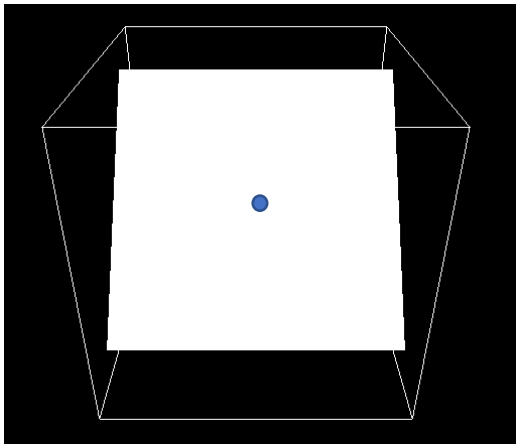


(a) Angle: -50°

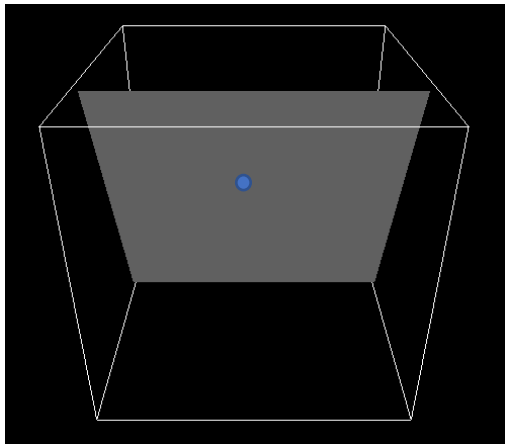




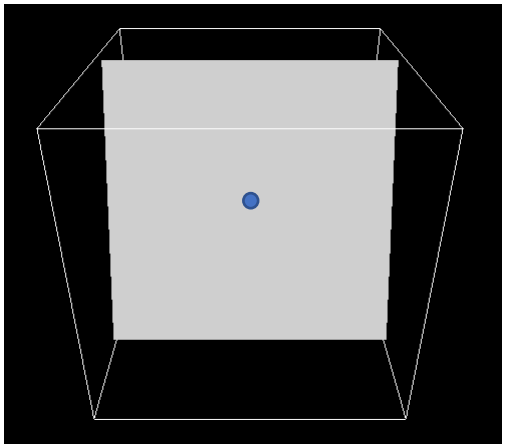
(c) Angle: 0°



(b) Angle: 50°



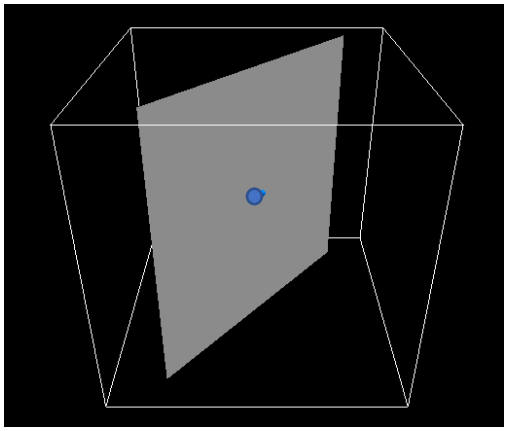
(d) Angle: -70°



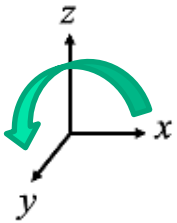
(e) Angle: 70°

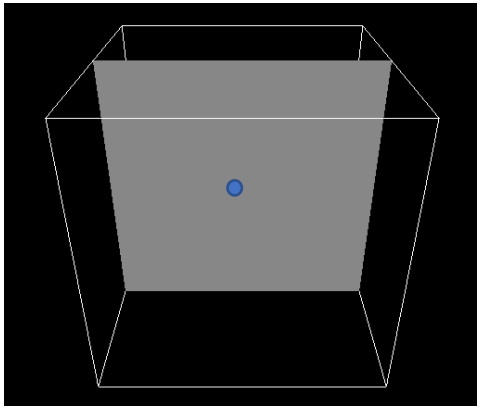
Slopes as Objects (2/2)

- **z-axis**

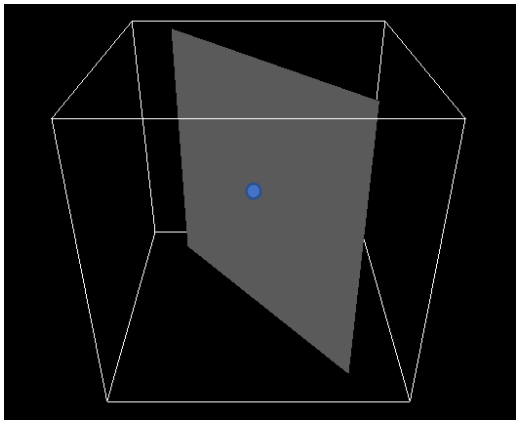


(a) Angle: -50°

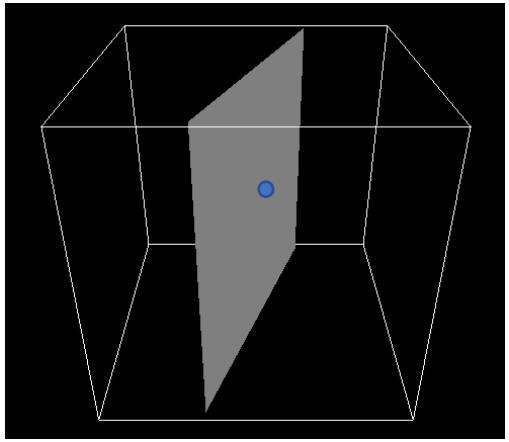




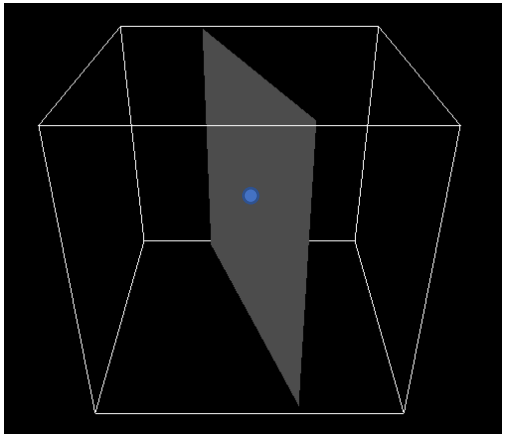
(c) Angle: 0°



(b) Angle: 50°



(d) Angle: -70°



(e) Angle: 70°

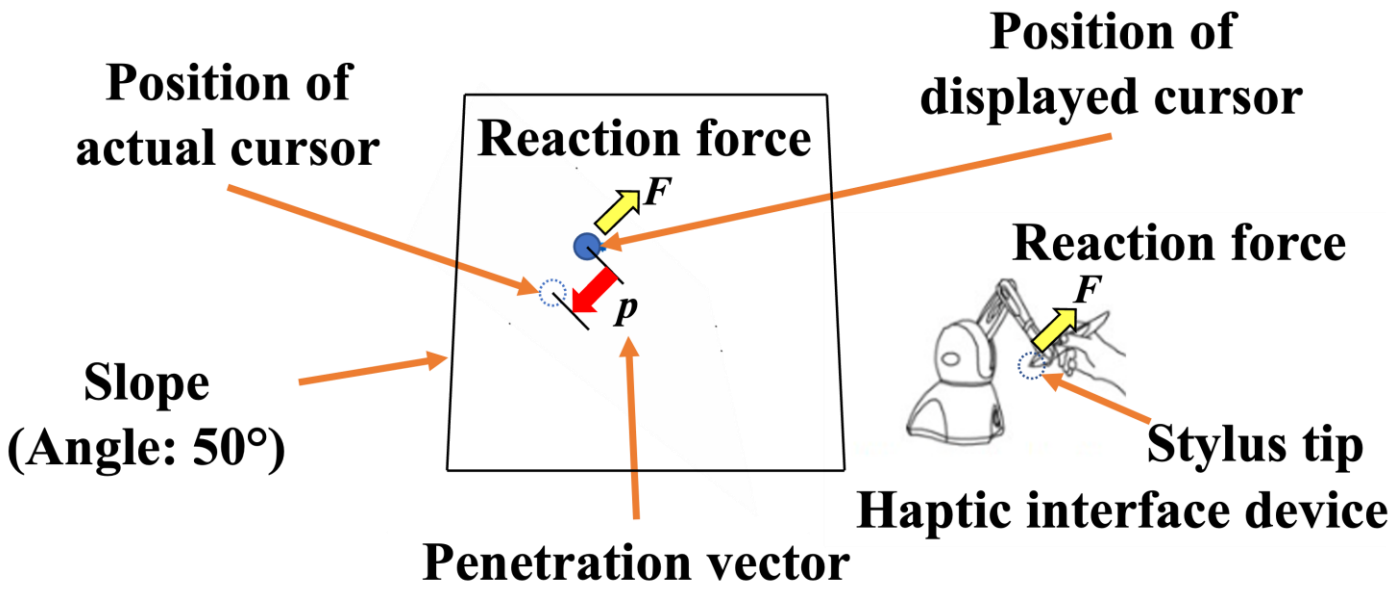
Calculation of Reaction Force (1/2)

The reaction force *F* is calculated by the spring-damper model.

$$\boldsymbol{F} = -K_s \boldsymbol{p}$$

K_s: **Spring (or elasticity) coefficient**

p: **Vector from the center of the displayed cursor on the slope surface to the center of the actual cursor**



Calculation of Reaction Force (2/2)

- **In networked virtual environments, as the network delay increases, $|p|$ becomes larger [*4].**

- **If the network delay fluctuates when we are touching a slope, we may not be able to accurately feel the slope angle accurately.**

It is important to investigate the human perception of slopes.

*4 M. Fujimoto *et al.*, IEICE Trans. Commun., pp. 589-592, Apr. 2004.

Assessment Method (1/3)

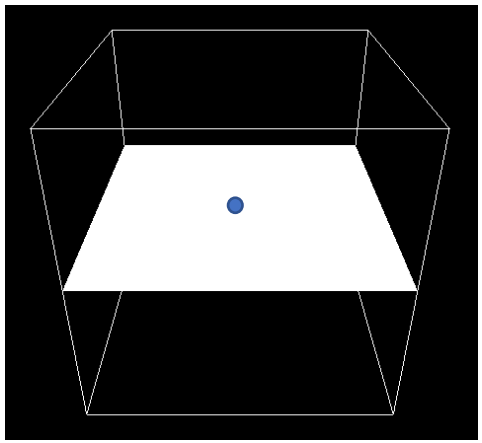
- **We handled five slopes (called the *standard slopes*) with rotation angles of 0°, ±50°, and ±70° on the *x*- and *z*-axes**

- **<u>Stimuli</u>: Comparison between each standard slope and other slopes (called the *test slopes*). Pairs of the standard and test slopes were presented in random order for each subject.**

- **Before the assessment, each subject practiced touching the standard and test slopes in the visible mode.**

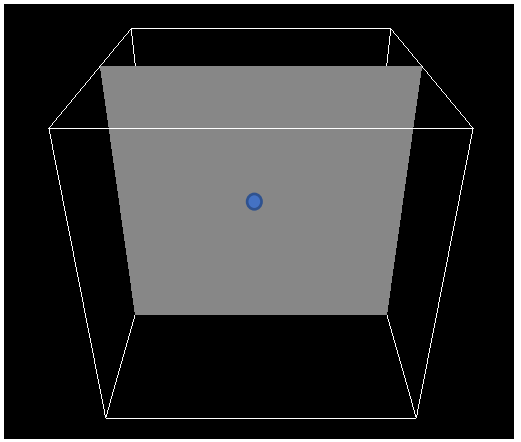
Assessment Method (2/3)

- ***x*-axis**



Angle: 0°

- ***z*-axis**



Angle: 0°

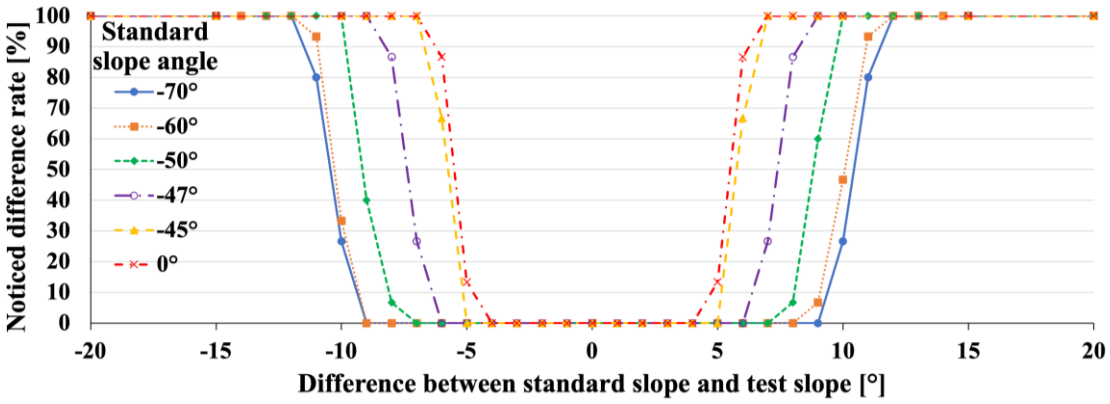
- ***x*-axis: Lowering the cursor from the top**
- ***z*-axis: Moving the cursor in from back direction**

Assessment Method (3/3)

- **The assessment is carried out in invisible mode. Also, the cursor is hidden by covering the display of the PC with a sheet of paper.**
- **Work: Trace the surface of each slope from right to left and from front to back about 4 times each direction for 10 seconds.**
- **Judgment: Answer whether the difference in angle between the standard and test slopes is noticeable or not.**
- **Subjects: 15 (13 men and 2 women)**

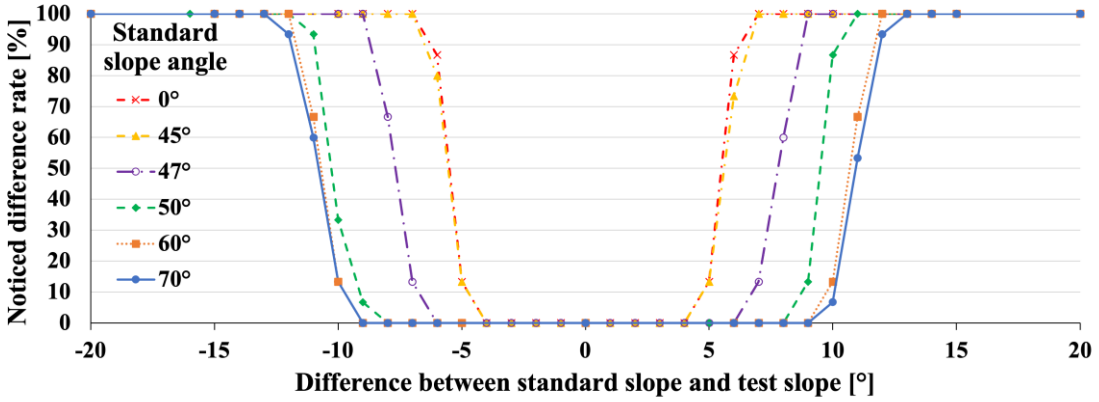
Assessment Results (1/2)

- *y*-axis



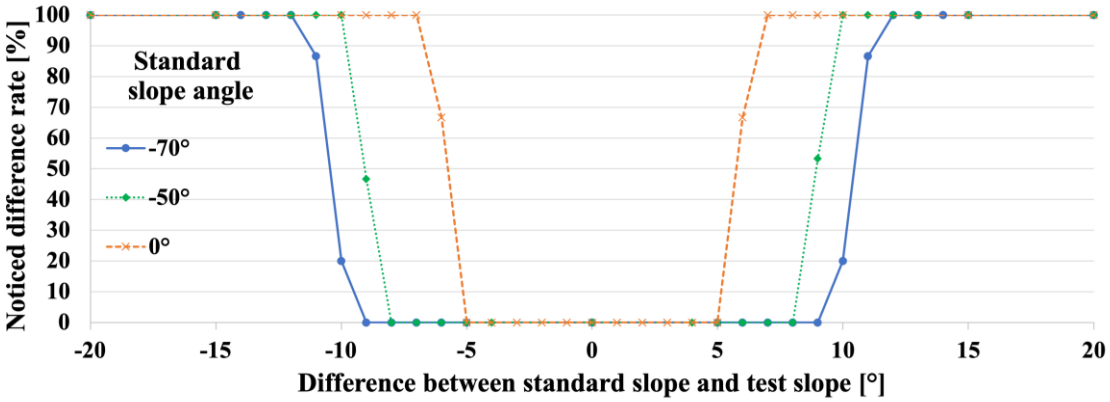
Noticed difference rate versus difference in angle between standard slope and test slope (angle of standard slope from -70° to 0°).

Noticed difference rate versus difference in angle between standard slope and test slope (angle of standard slope from 0° to 70°).



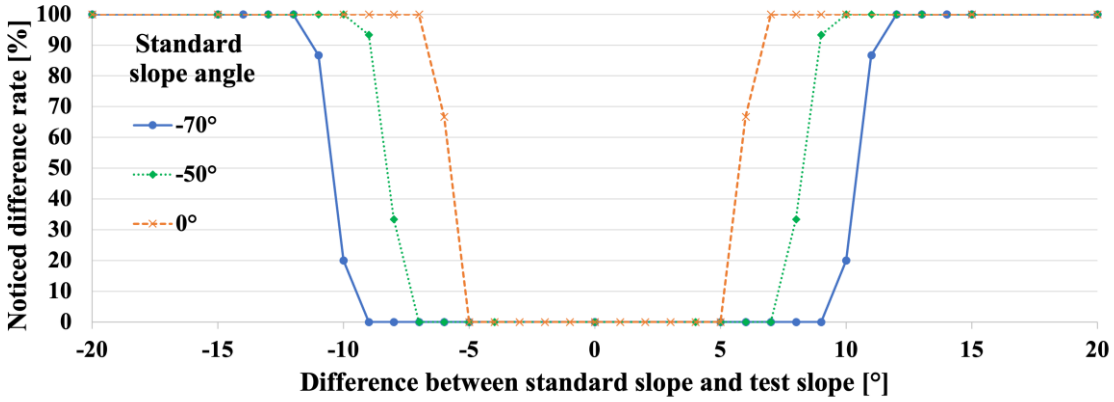
Noticed difference rate: Percentage of subjects who perceived the difference.

Assessment Results (2/2)



Noticed difference rate versus difference in angle between standard slope and test slope (angle of standard slope on the *x*-axis: from -70° to 0°).

Noticed difference rate versus difference in angle between standard slope and test slope (angle of standard slope on the *z*-axis: from -70° to 0°).



Noticed difference rate: Percentage of subjects who perceived the difference.

Conclusion

- **We examined the dimensional similarity in human slope perception with haptic sense for networked virtual environments by QoE assessment.**
- **We handled slopes on the *x*- and *z*-axes and made a comparison with those on the *y*-axis.**

➢ **We found that there is dimensional similarity in human slope perception among the three axes.**

Future Work

- **Discuss the assessment results in relation to the Weber's law (**"*The law states that the change in a stimulus that will be just noticeable is a constant ratio of the original stimulus.*" ***5).**
- **Study QoS control by taking account of human perception.**

*5 Britannica - Weber's law. Retrieved Fev. 17, 2023 from https://www.britannica.com/science/Webers-law.