Human Slope Perception with Haptic Sense for Networked Virtual Environments

Amedayenou T. Christian[1], Yutaka Ishibashi[1], Pingguo Huang[2], Kostas E. Psannis[3]

[1]Nagoya Institute of Technology, Japan
[2]Gifu Shotoku Gakuen University, Japan
[3]University of Macedonia, Greece

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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 (1/2)

Proposed the inter-stream synchronization control between audio and haptic media streams, in which two perception ranges of inter-stream synchronization error are introduced [*1], as QoS control taking advantage of human perception.

- **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 (2/2)

- **Investigated the influences of object weight[*2] and softness[*3] changes on human perception.**
- **Carried out QoE assessment of human angle perception[*4] 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 L. Wen *et al.*, WSCE, pp. 200-204, Dec. 2019.

*3 R. Arima *et al.*, IEICE Technical Report, CQ2017-98, Jan. 2018.

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

Purpose

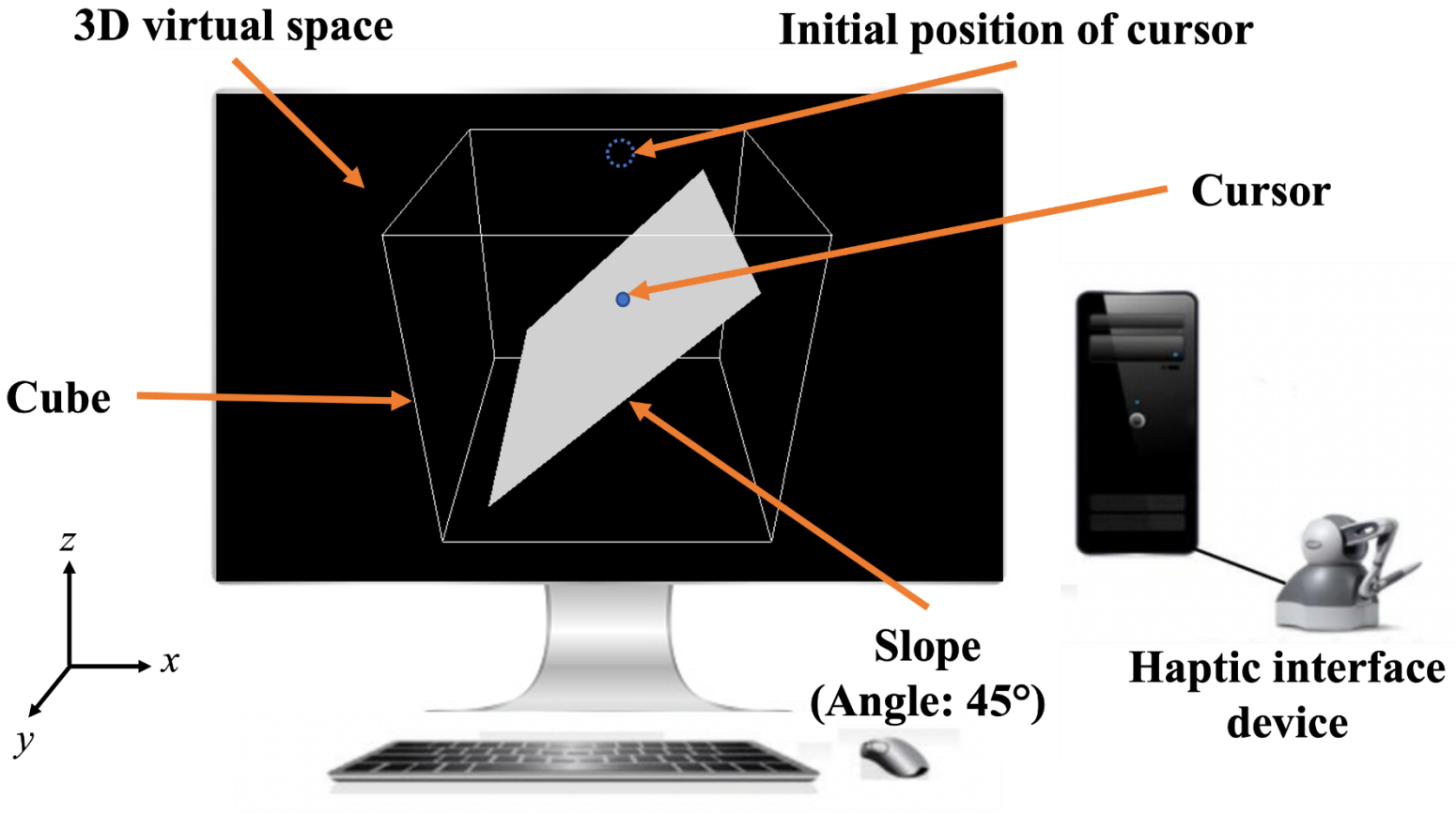
This work

- **We handle eleven slopes as objects instead of angles[*4] and ellipsoids[*5] in the object perception system.**
- **We investigate the human slope perception by touching the surface of each slope with a haptic interface device in QoE assessment.**

*4 J. Ma *et al.*, CECIT, Dec. 2021.
*5 A. T. Christian *et al.*, ICCCM, July 2022.

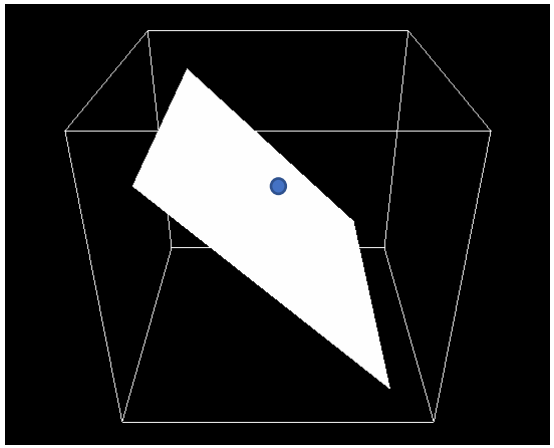
Object Perception System

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

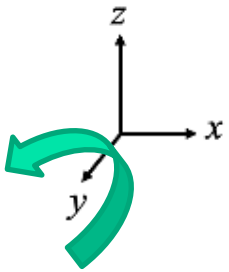


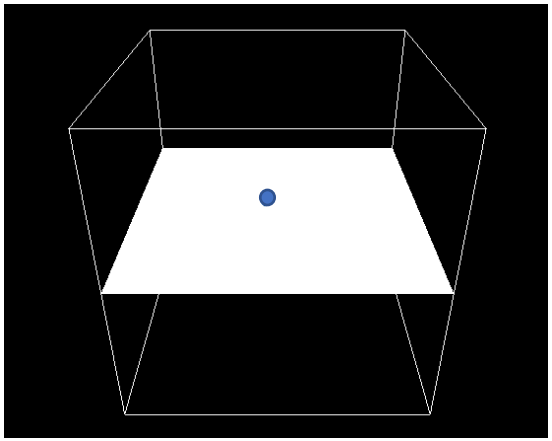
- **Invisible mode:** User cannot look at slopes.

Slopes as Objects

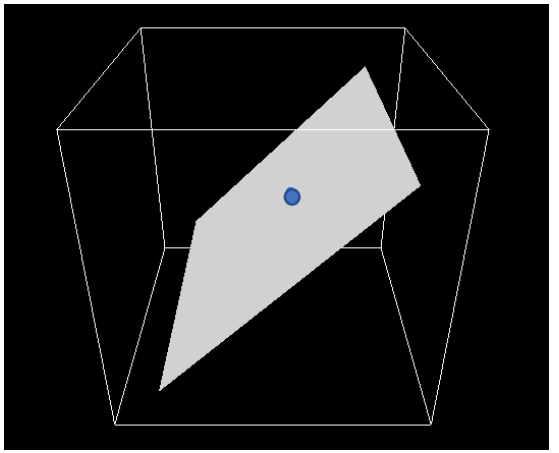


(a) Angle: -45°

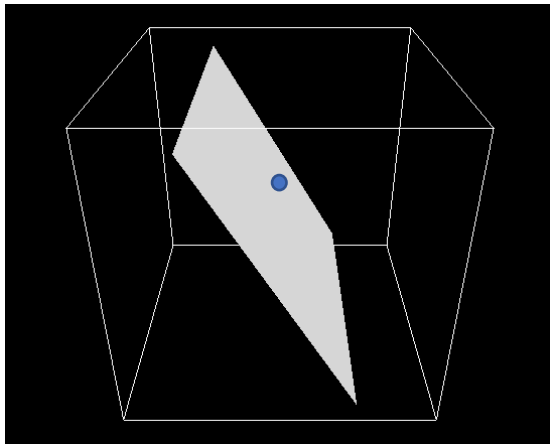




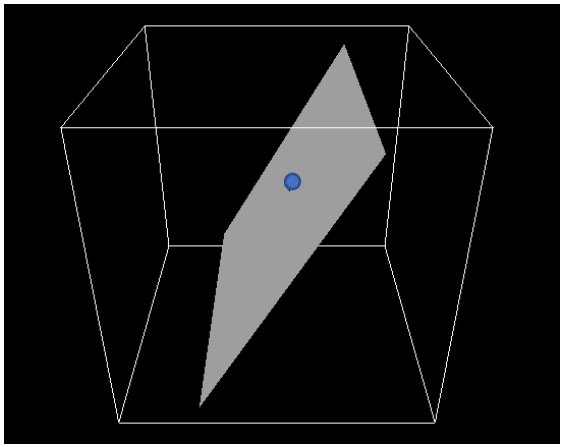
(c) Angle: 0°



(b) Angle: 45°



(d) Angle: -60°



(e) Angle: 60°

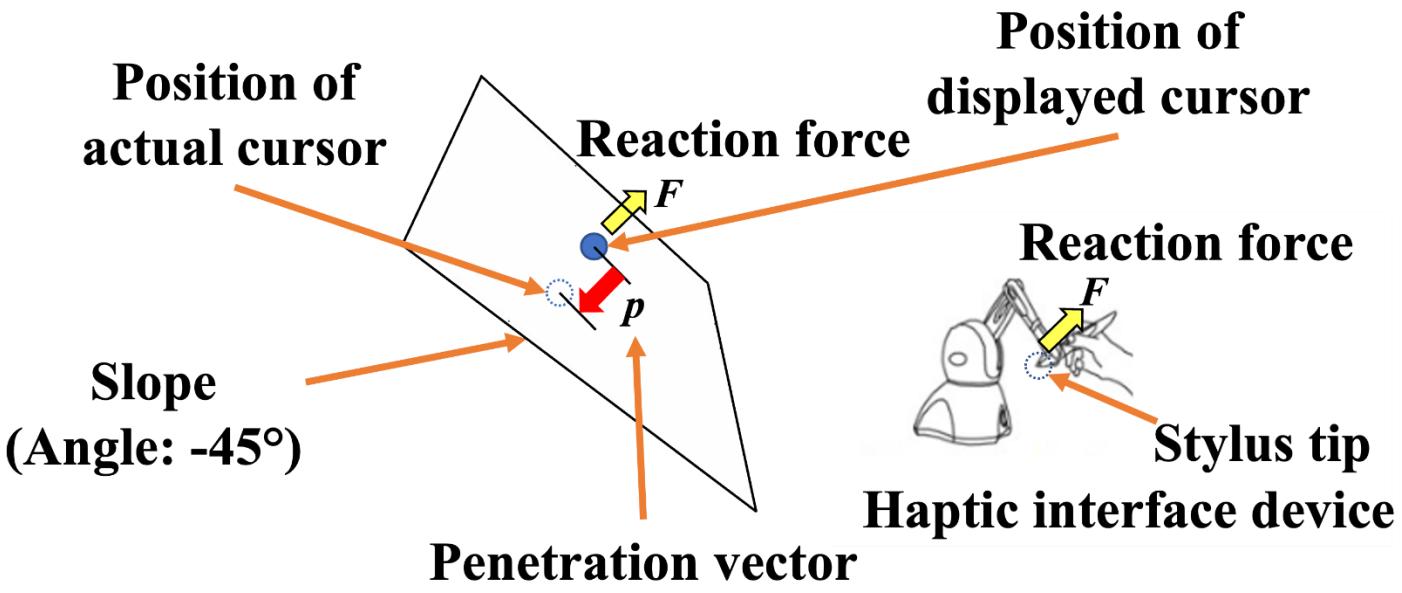
Calculation of Reaction Force (1/2)

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 [*6].**

- **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.

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

Assessment Method (1/2)

- **We handled eleven slopes (called the *standard slopes*) with rotation angles of 0°, ±45°, ±47°, ±50°, ±60°, and ±70° on the *y*-axis**

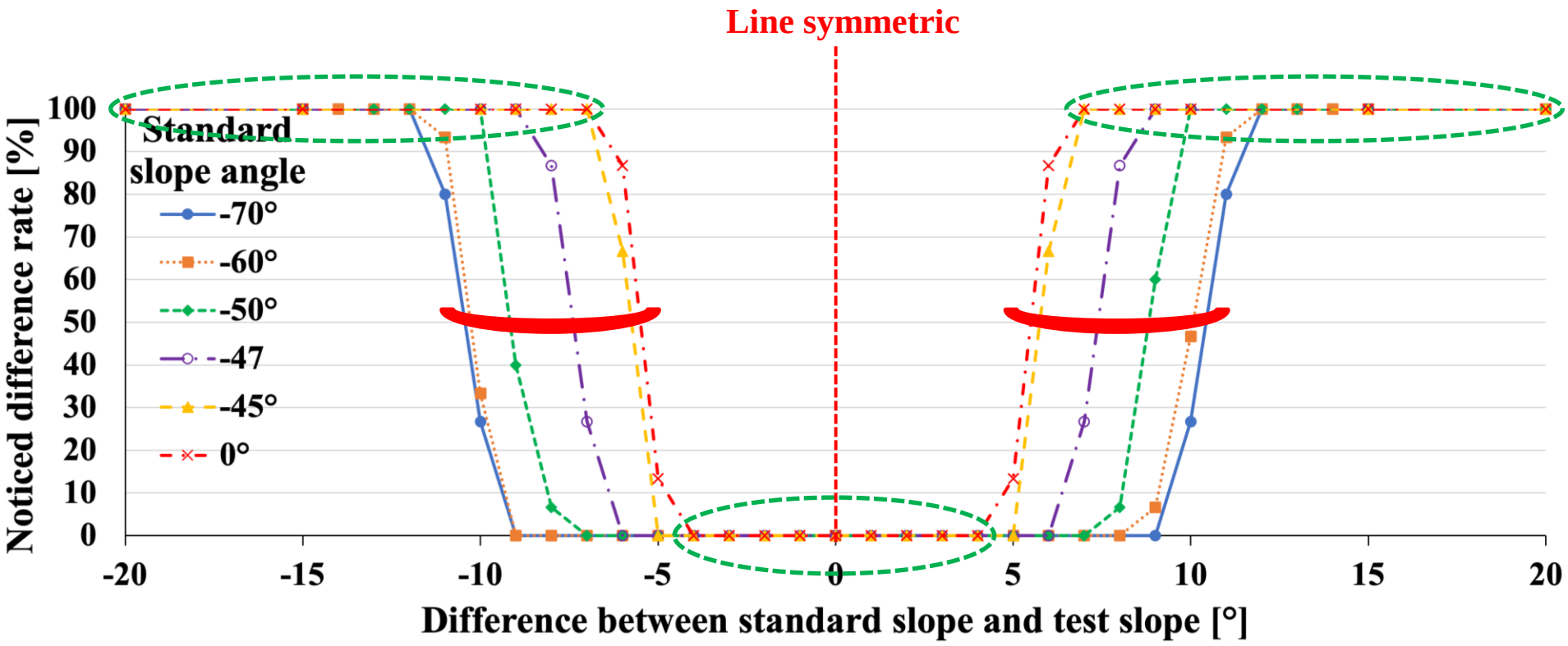
- **<u>Stimuli</u>: Comparison between each standard slope and other slopes (called the *test slopes*). Pairs of the standard and test slopes were presented in random order for each subject.**

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

Assessment Method (2/2)

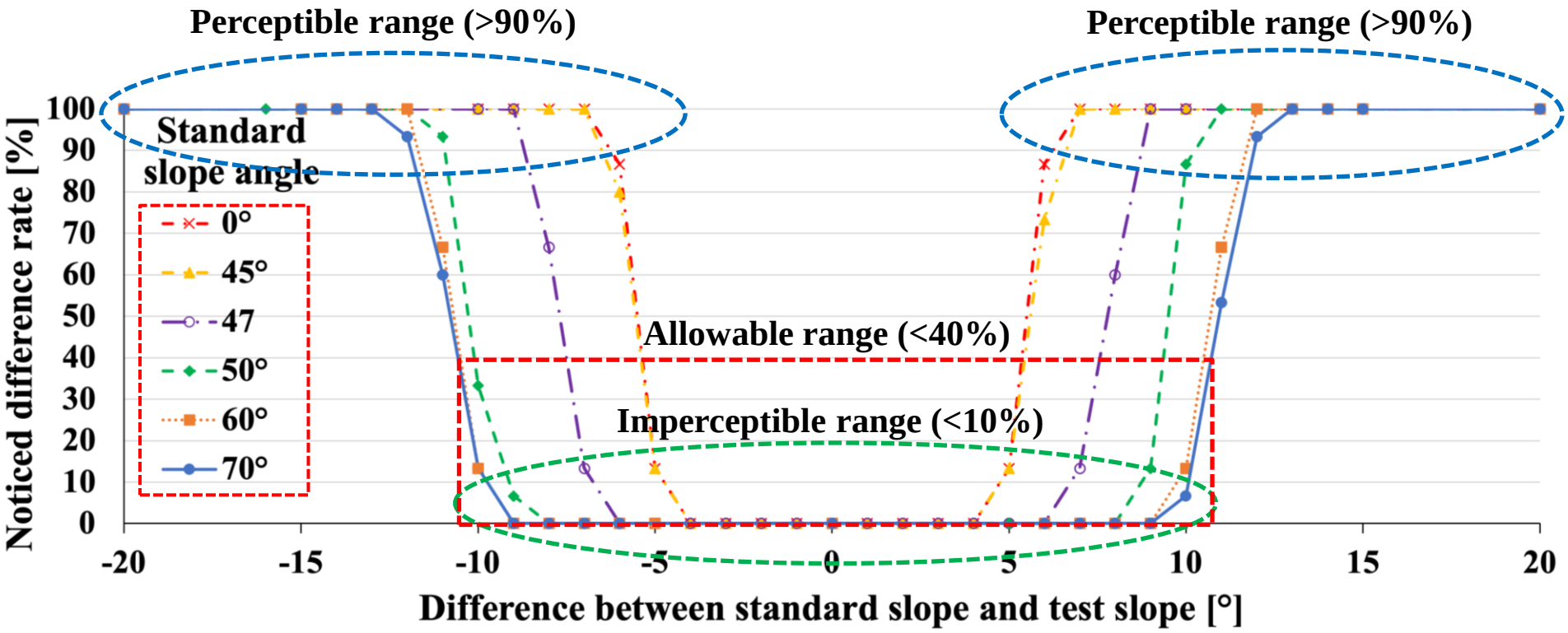
- **The assessment is carried out in invisible mode. Also, the cursor is hidden by covering the display of the PC with a sheet of paper.**
- **Work: Trace the surface of each slope from right to left and from front to back about 4 times each direction for 10 seconds.**
- **Judgment: Answer whether the difference in angle between the standard and test slopes is noticeable or not.**
- **Subjects: 15 (12 men and 3 women, ages: between 23 and 38)**

Assessment Results (1/2)



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

Assessment Results (2/2)



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

Conclusion

- **We examined the human slope perception with haptic sense for networked virtual environments by QoE assessment.**
- **We handled eleven standard slopes and made a comparison with test slopes for each standard slope.**

- **Line-symmetric properties with the respect to the line of 0° for all the standard slopes.**
- **We showed how to obtain the imperceptible, allowable, and perceptible ranges of human slope perception.**

Future Work

- **Examine the human slope perception for angles with rotation on the *x*-axis and *z*-axis.**
- **Discuss the assessment results in relation to the Weber's law.**
- **Carry out the assessment by changing how to touch the slopes and the mechanism of the reaction force generation.**