Human Perception of Curved Surface with Haptics for Networked Virtual Environments

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Outline

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

Background (1/2)

A number of studies have focused on networked virtual environments with haptics.

Through a haptic interface device, it is possible for a user to precisely perceive the shape, surface smoothness, softness and weight of an object by touching/holding the object.

Background (2/2)

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 features such as each object's shape, surface smoothness, softness, and weight.

Previous Work (1/2)

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

Proposed the inter-stream synchronization control between audio and haptic media, where two perception ranges of inter-stream synchronization error are introduced, as QoS control[*1]

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

Problem

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

Previous Work (2/2)

*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.

- **Investigated the influence of object weight[*2] and softness[*3] change on human perception.**
- **Carried out for networked virtual environments QoE assessment of human angle perception[*4] .**

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

Problem

➢ **The human perception of shape and surface smoothness has not sufficiently been clarified so far.**

Purpose

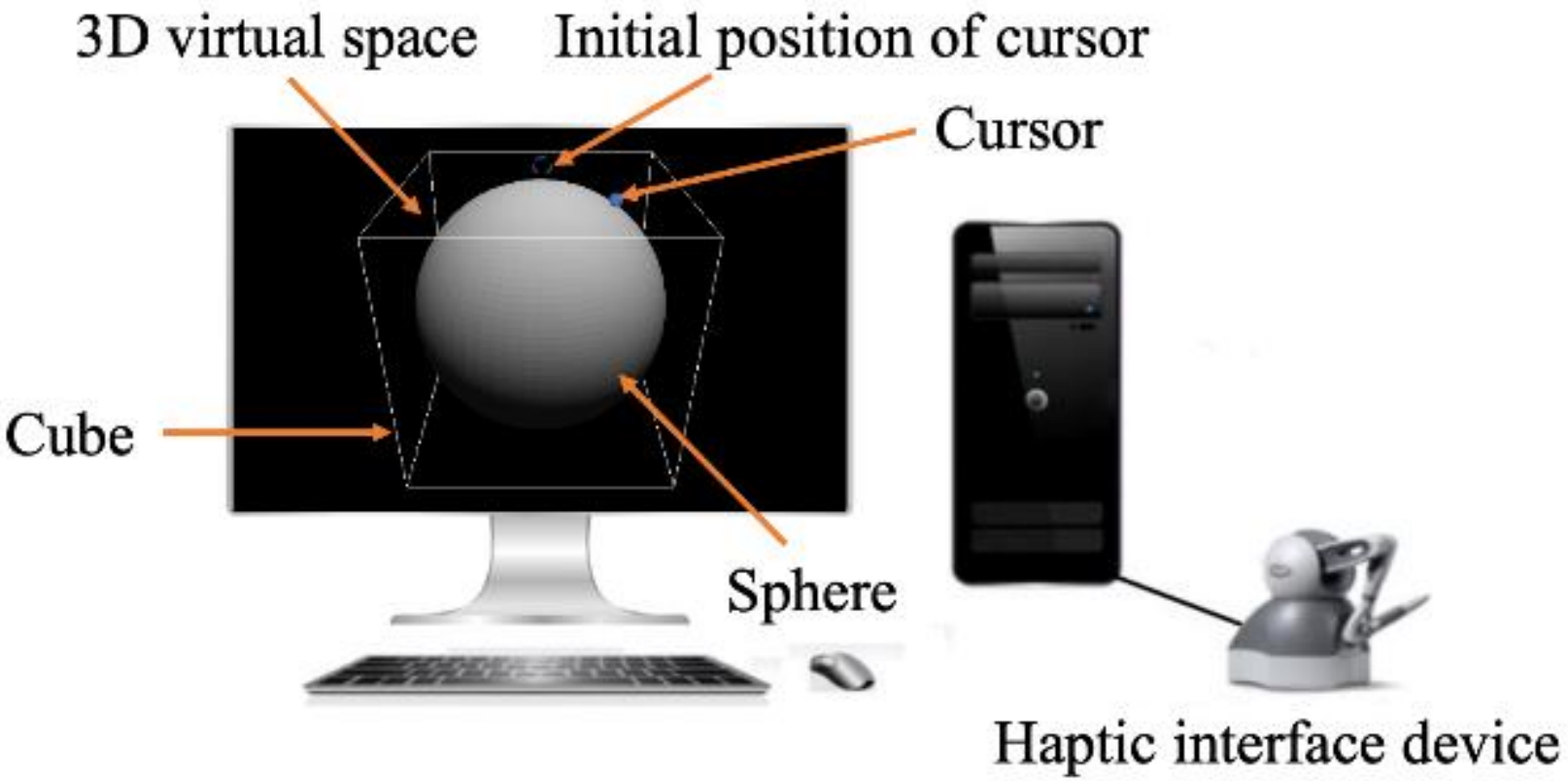
*4 J. Ma *et al.*, CECIT, Dec. 2021.

This work

- **We handle ellipsoids (including a sphere) as objects instead of angles in the object perception system[*4].**
- **We investigate human perception of curved surfaces by touching the surface of each ellipsoid with a haptic interface device by QoE assessment.**

Object Perception System (1/2)

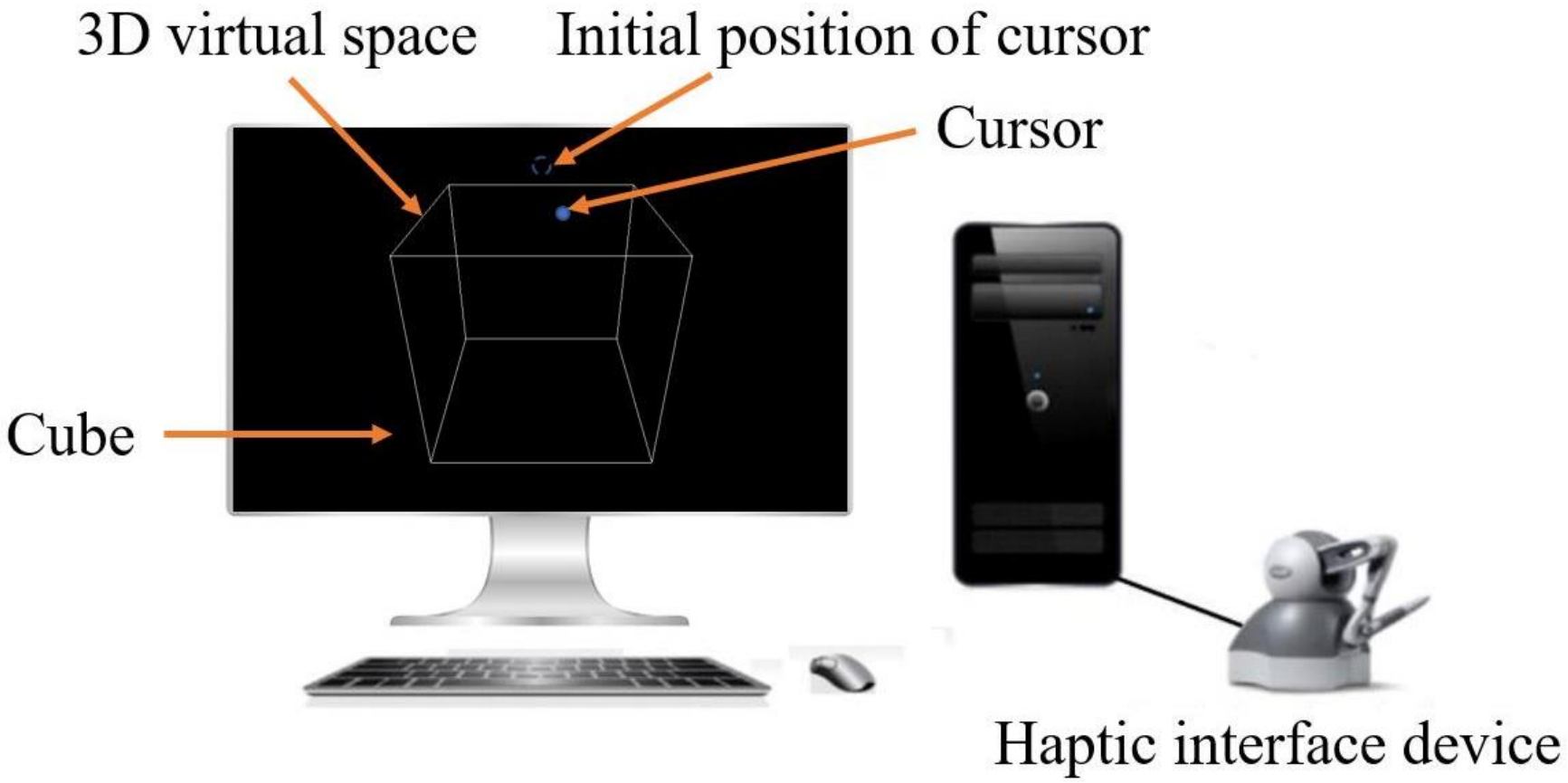
- **Visible mode**



- **Visible mode:** user can look at the sphere/ellipsoids
- **Invisible mode:** user cannot look at the sphere/ellipsoids

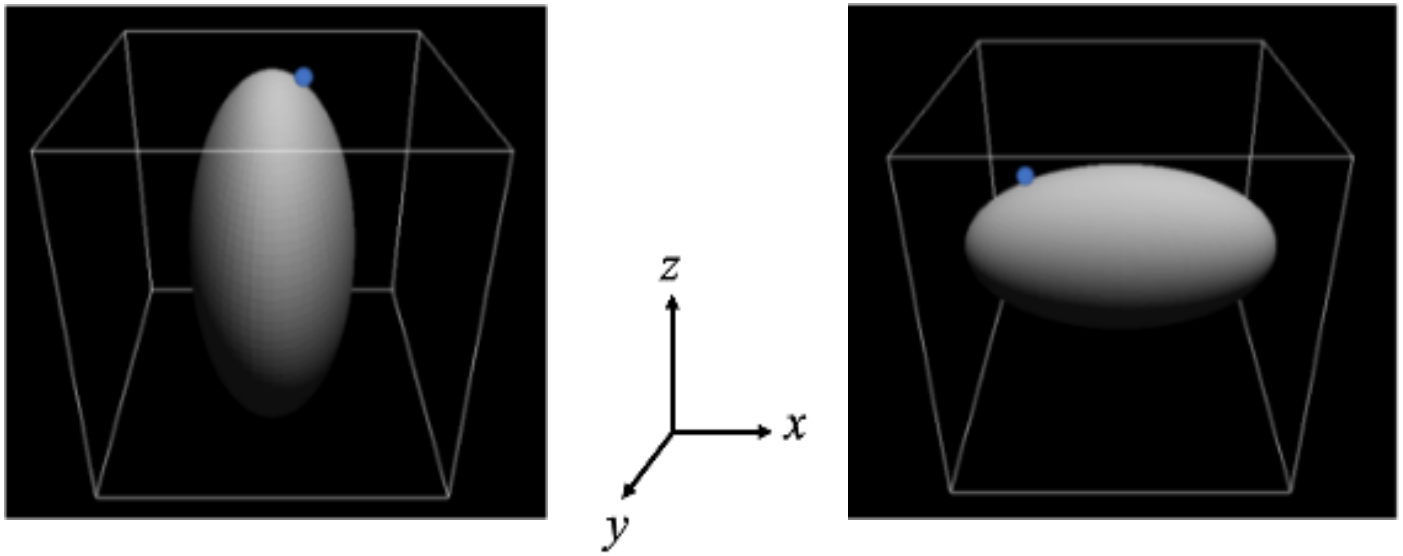
Object Perception System (2/2)

- **Invisible mode**



Ellipsoids as Objects

To differentiate the two ellipsoids, we express the ellipticity of the ellipsoid in (b) by the negative value of the ellipticity of the ellipsoid in (a).



(a) Ellipticity: 0.50

(b) Ellipticity: -0.50

The negative ellipticity means that the ellipsoid with the positive value is rotated by 90° on the y-axis.

Calculation of Reaction Force (1/2)

*5 3D Systems, *version 3.2*, 2013.

- **The reaction force is calculated by the spring-damper model [*5]. The reaction force is obtained by:**

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

$\boldsymbol{F}$: **reaction force**

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

$\boldsymbol{p}$: **vector from the center of the displayed cursor on the ellipsoid surface to the center of the actual cursor**

Calculation of Reaction Force (2/2)

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

- **In networked virtual environments, as the network delay increases, $|p|$ becomes larger [*6].**

- **If the network delay fluctuates when we are touching a curved surface, we may not be able to accurately feel the curviness of the ellipsoid.**

→ **It is important to investigate the human perception of curved surfaces.**

Assessment Method (1/4)

- **We handled three curved surfaces (called the *standard surfaces* here) by using ellipsoids with ellipticities of -0.50, 0 and 0.50.**

- **<u>Stimuli</u>: Comparison between each standard surface and other curved surfaces (called the *tested surfaces*). Pairs of the standard and tested surfaces in random order.**

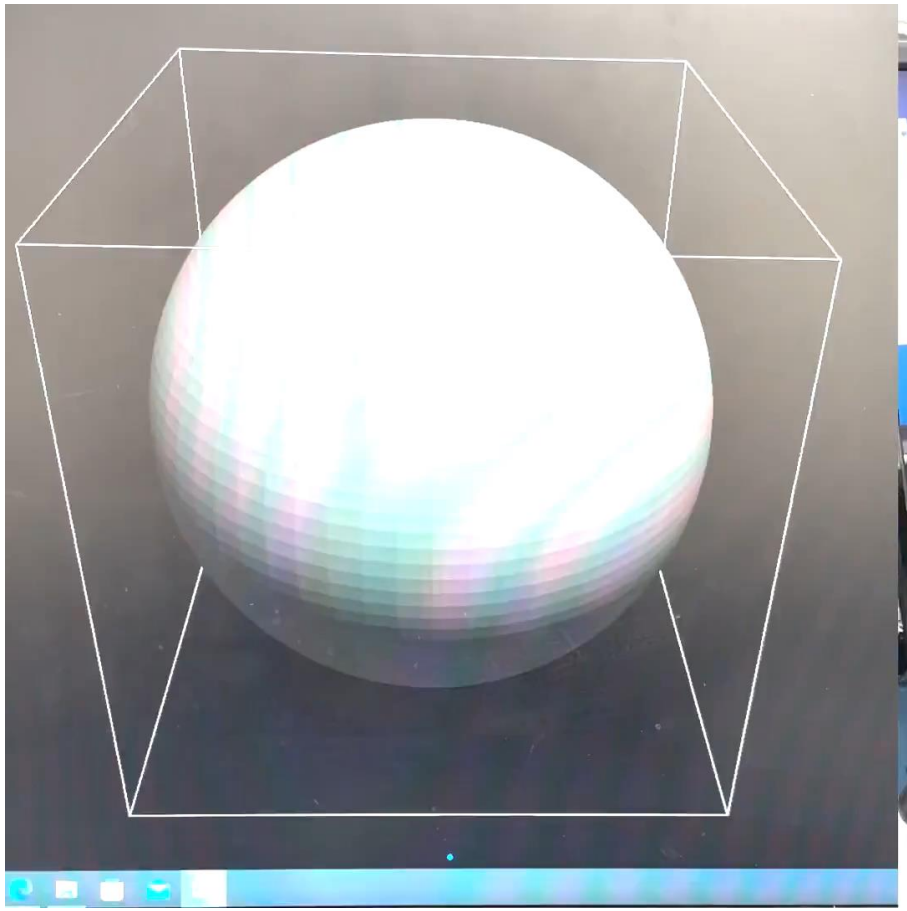
- **Before the assessment, each subject practiced touching the standard and tested surfaces in the visible mode of the object perception system.**

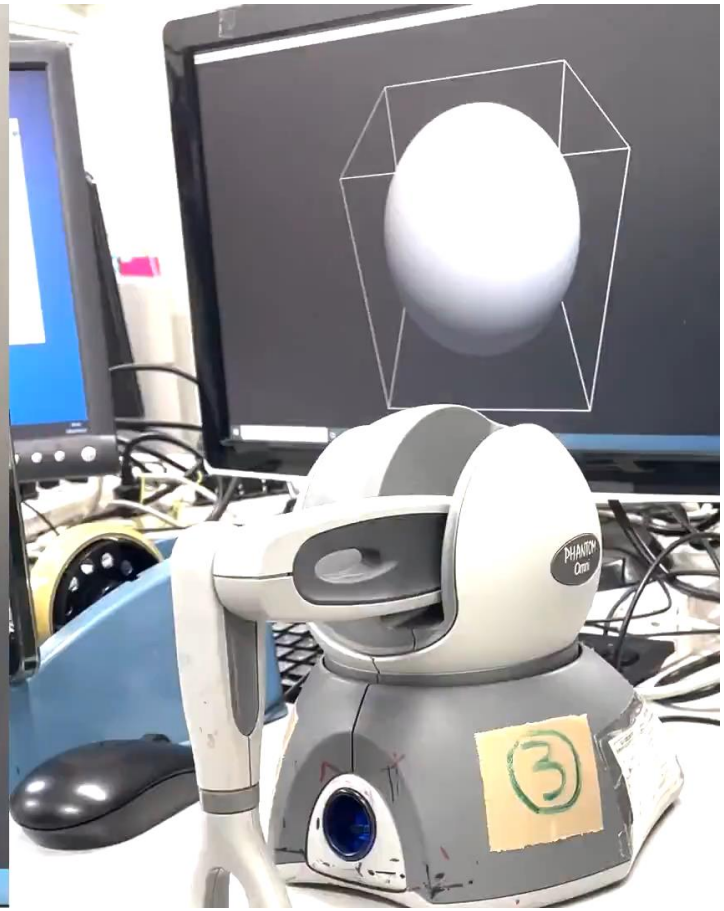
Assessment Method (2/4)

- **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.**
- **<u>Work</u>: Trace the top surface of each ellipsoid from right to left and from front to back about 4 times each direction for 15 seconds.**
- **<u>Judgment</u>: Answer whether the difference between the standard and tested surfaces is noticeable or not.**
- **<u>Subjects</u>: 15 (male:13, female: 2)**

Assessment Method (3/4)

- **Demo video: Practice**

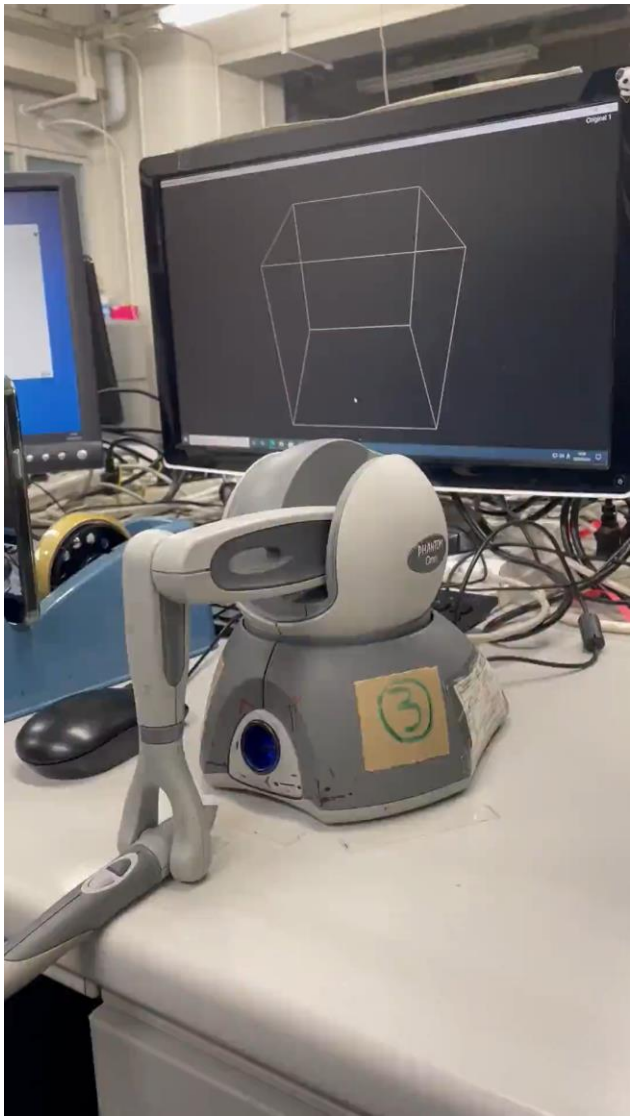




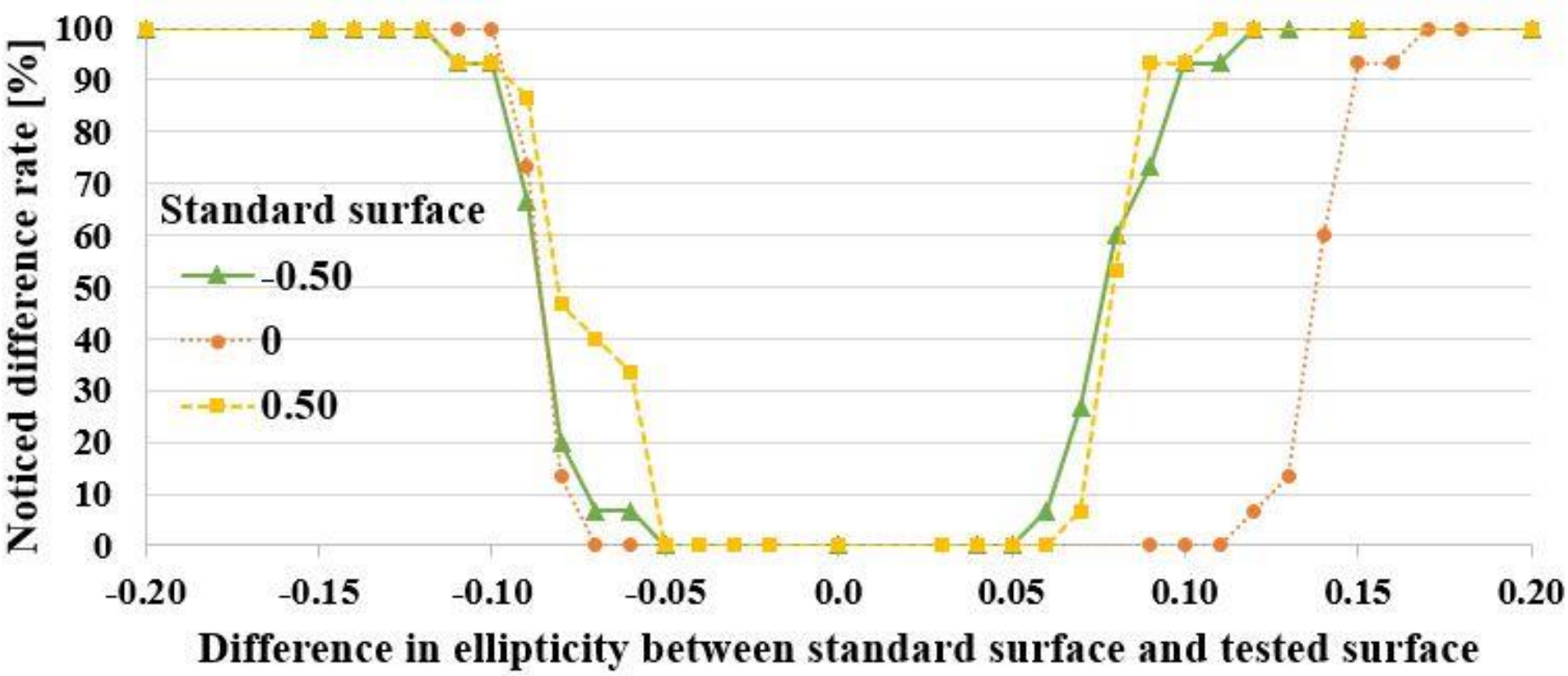
Assessment Method (4/4)

Demo video: During the assessment

- **Assessment is conducted in the invisible mode of the object perception system.**
- **Use a sheet of paper to cover the display of the screen to make sure that the subject does not see the movement of the cursor.**



Assessment Results



Noticed difference rate versus difference in ellipticity between standard surface and tested surface.

Conclusion

- **We examined the human curved surface perception for networked haptic virtual environments by QoE assessment.**
- **We handle three standard surfaces and made a comparison with other curved surfaces for each standard surface**

- **Line-symmetry properties with the respect to a line of 0 for the standard surface of -0.50 and 0.50.**
- **This is not the case for the standard surface of 0**

Future Work

- **Assess the human perception of the curved surface represented by ellipsoids with the other ellipticities such as -0.25 and 0.25 to discuss the result more in details.**
- **Employ the visual sense as well as the haptic sense and clarify the effect of each sense.**
- **Examine human perception of other shapes and surface smoothness.**