

Human Perception of Ellipsoids for Networked Haptic Virtual Environments



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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/holding the object.

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

**QoE (Quality of Experience)
deterioration**

*Network delay, delay jitter,
and packet loss*

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

QoS control



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, as QoS control^{*1} 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 influence of object weight^{*2} and softness^{*3} change on human perception.
- Carried out QoE assessment of human angle perception^{*4} for networked virtual environments.



Clarified the **imperceptible**, **allowable ranges**, 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

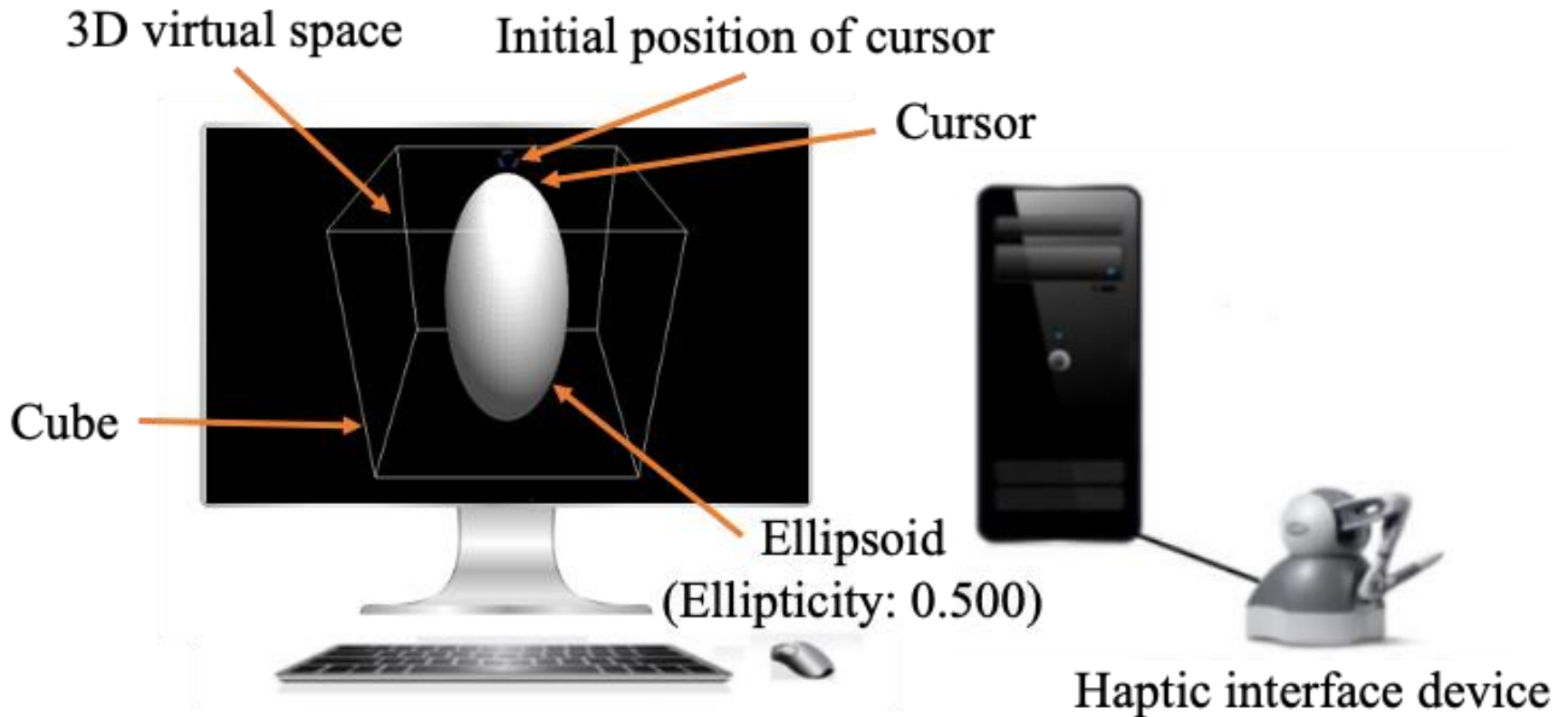
This work

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

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

Object Perception System

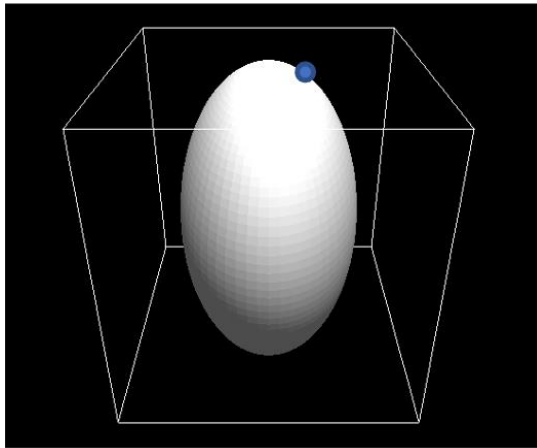
- **Visible mode**



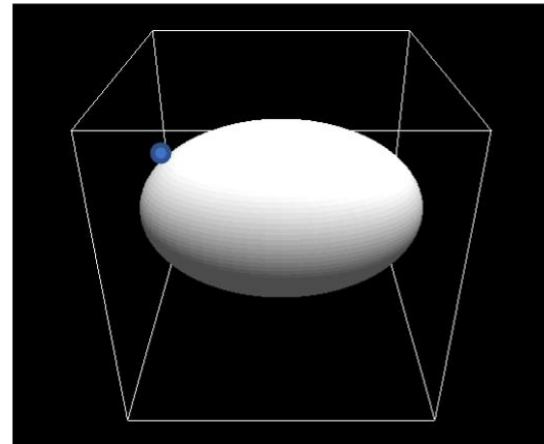
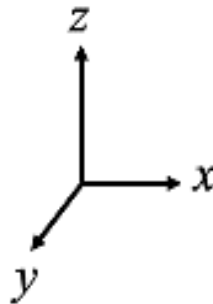
- **Visible mode:** User can look at the ellipsoids.
- **Invisible mode:** User cannot look at the ellipsoids.

Ellipsoids as Objects

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



(a) Ellipticity: 0.375



(b) Ellipticity: -0.375

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

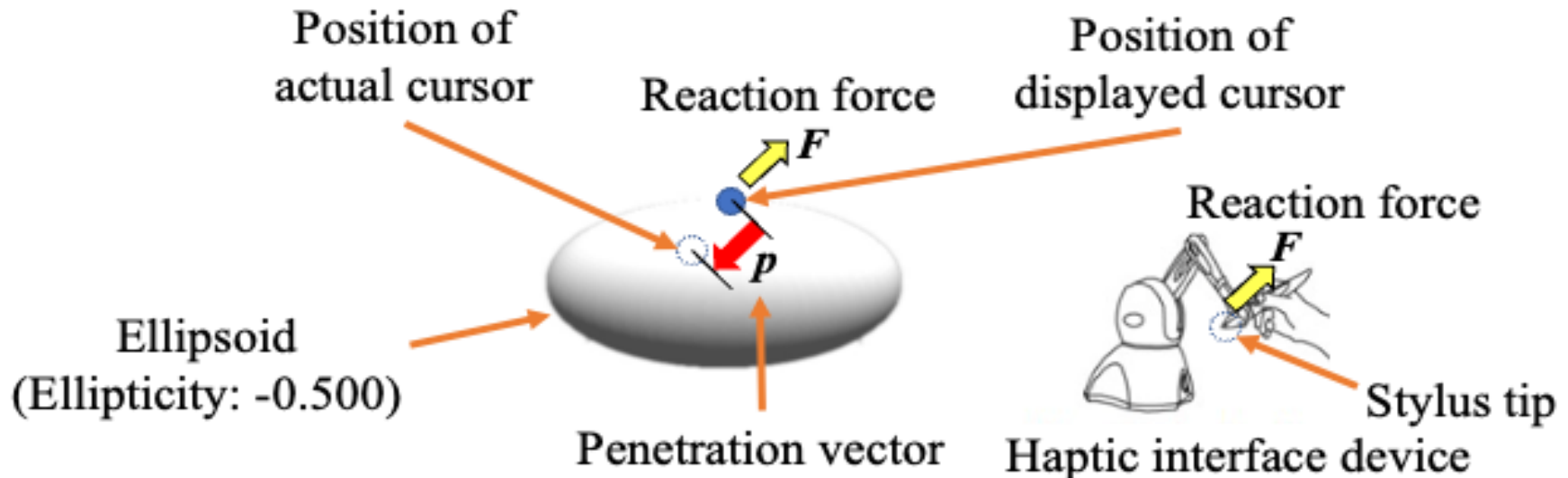
Calculation of Reaction Force (1/2)

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

$$F = -K_s p$$

K_s : Spring (or elasticity) coefficient

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)

- 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 ellipsoids.

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



Assessment Method (1/2)

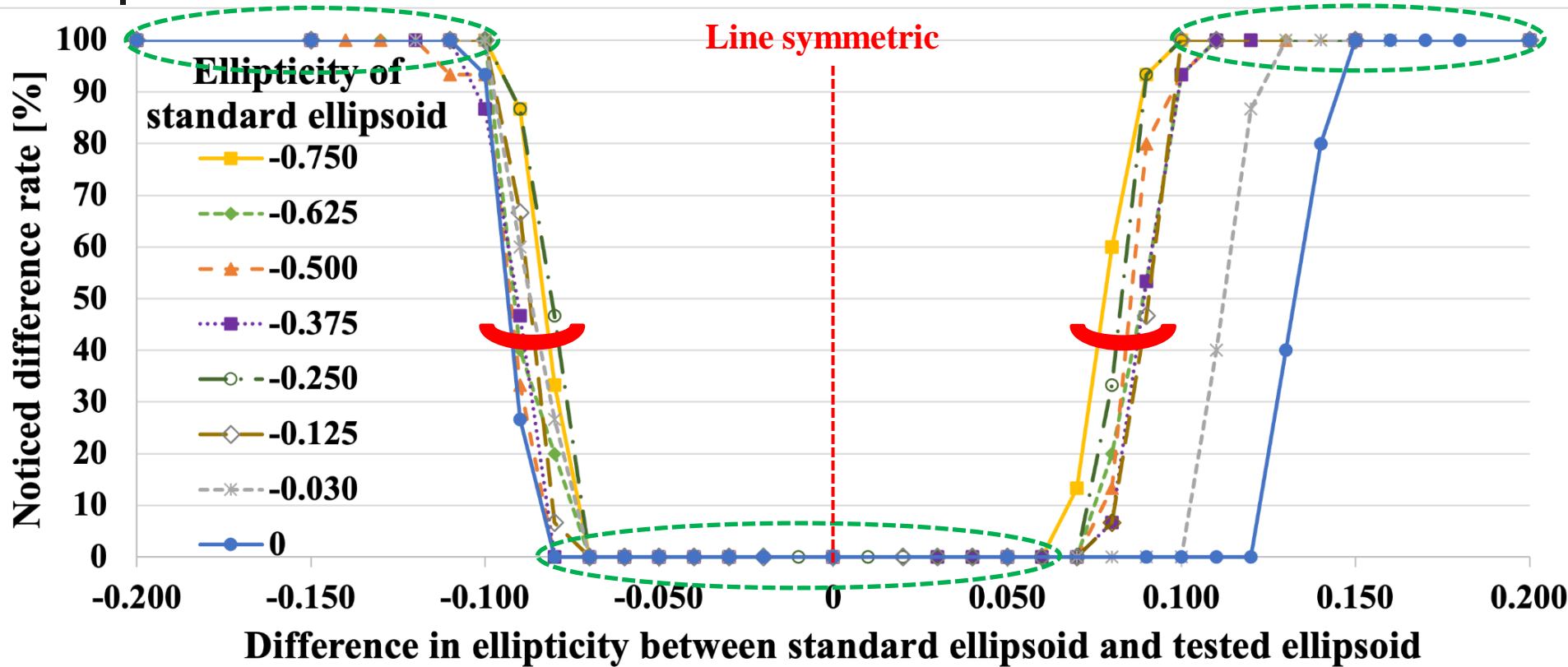
- We handled fifteen ellipsoids (called the *standard ellipsoids*) with ellipticities of ± 0.030 and from -0.750 to 0.750 at intervals of 0.125 .
- Stimuli: Comparison between each standard ellipsoid and other ellipsoids (called the *tested ellipsoids*). Pairs of the standard and tested ellipsoids were presented in random order for each subject.
- Before the assessment, each subject practiced touching the standard and tested ellipsoids in the visible mode.



Assessment Method (2/2)

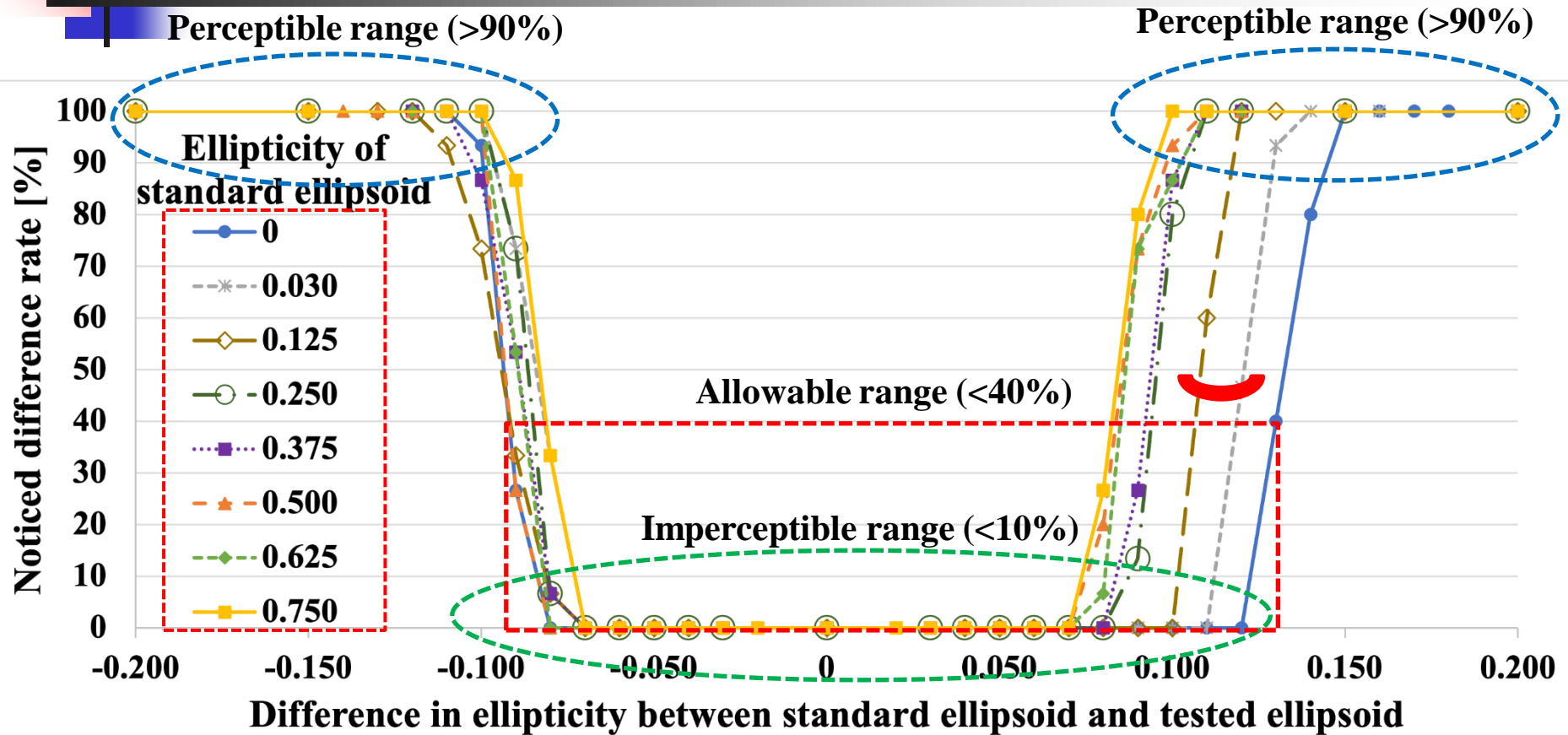
- **The assessment is carried out in invisible mode. Also, the cursor is hidden by covering the display of the PC with a sheet of paper.**
- **Work: Trace the top surface of each ellipsoid from right to left and from front to back about 4 times each direction for 15 seconds.**
- **Judgment: Answer whether the difference between the standard and tested ellipsoids is noticeable or not.**
- **Subjects: 15 (male:13, female: 2, ages: between 21 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 ellipsoid perception for networked haptic virtual environments by QoE assessment.**
- **We handle fifteen standard ellipsoids and made a comparison with tested ellipsoids for each standard ellipsoid.**



- **The noticed difference rate is largely dependent on the ellipticity of the standard ellipsoid and the difference in ellipticity.**
- **We showed how to obtain the imperceptible, allowable, and perceptible ranges of human ellipsoid perception.**



Future Work

- **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.**