Remote Haptic Calligraphy Measuring Deviation from Model

Shota Ohtani[1], Yutaka Ishibashi[1], Pingguo Huang[2]

[1]Nagoya Institute of Technology, Japan

[2]Gifu Shotoku Gakuen University, Japan

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Outline

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- Purpose
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- Adaptive Viscoelasticity Control
- Assessment Method
- Assessment Results
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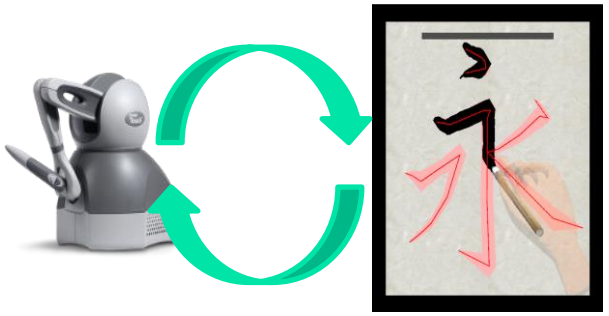
Background (1/2)

Systems that transmit force information remotely have been actively researched.



As such a system, there is a **remote haptic calligraphy system**.

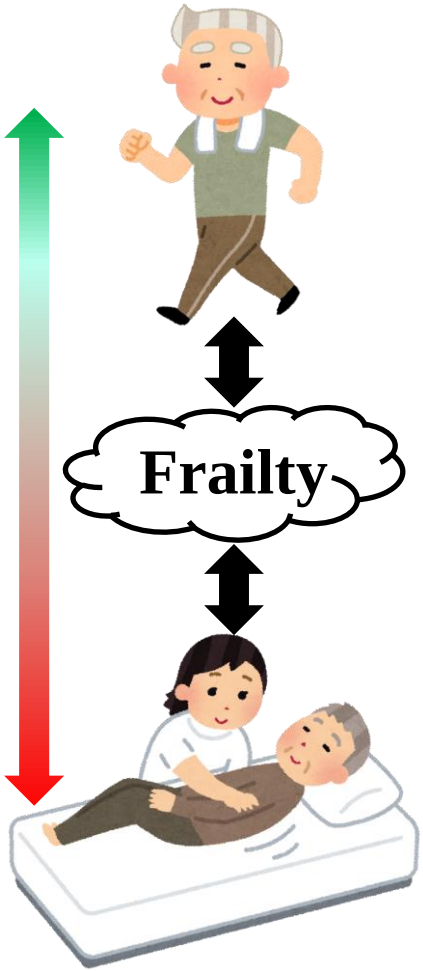
Users can do **calligraphy** at different places while perceiving force by using haptic interface device.

Background (2/2)

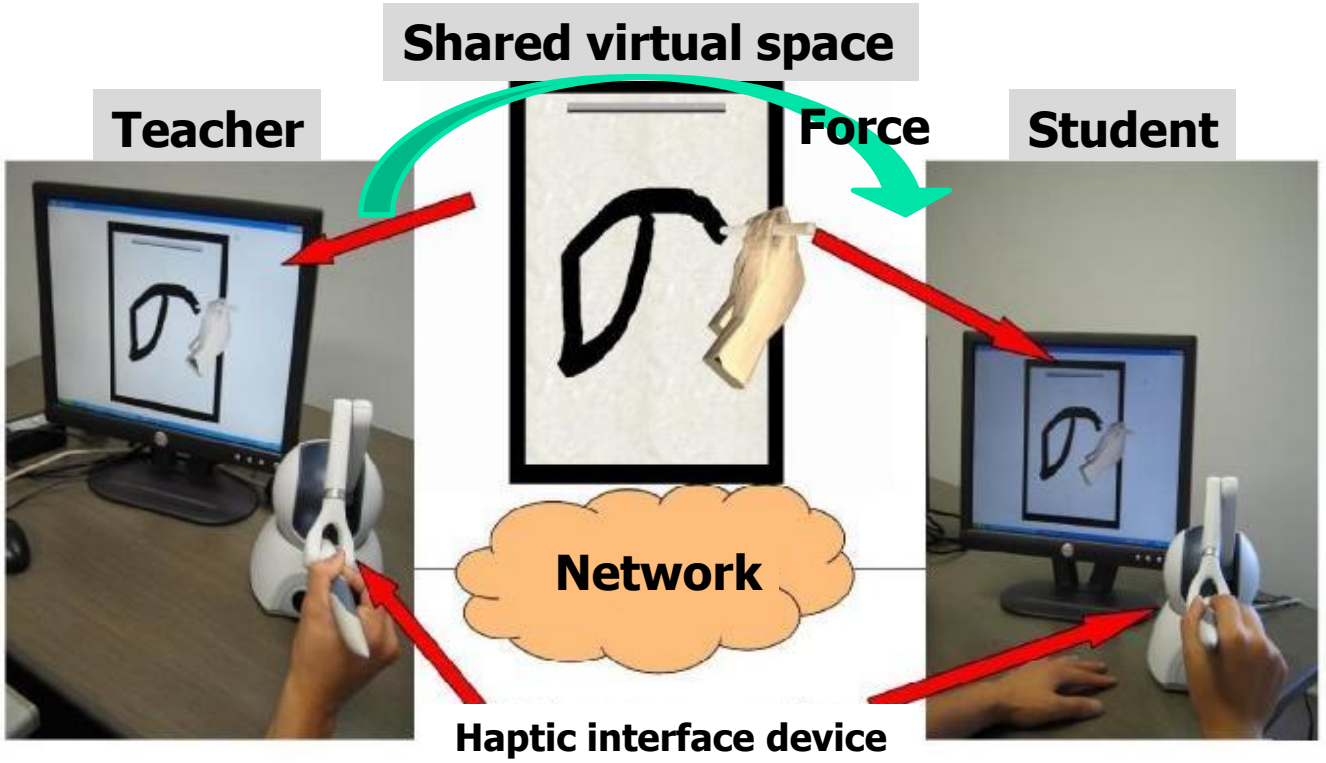
- The demand for medical and caregiving services is rapidly increasing.

It is important to make the prevention of the ***frail*** state, which is an intermediate stage between "healthy state" and "nursing care state".

The development of the **remote haptic calligraphy system** which can efficiently support the early detection and prevention of *frailty*, is expected to be utilized as *tailor-made frailty prevention technology*.



Previous Work (1/2)

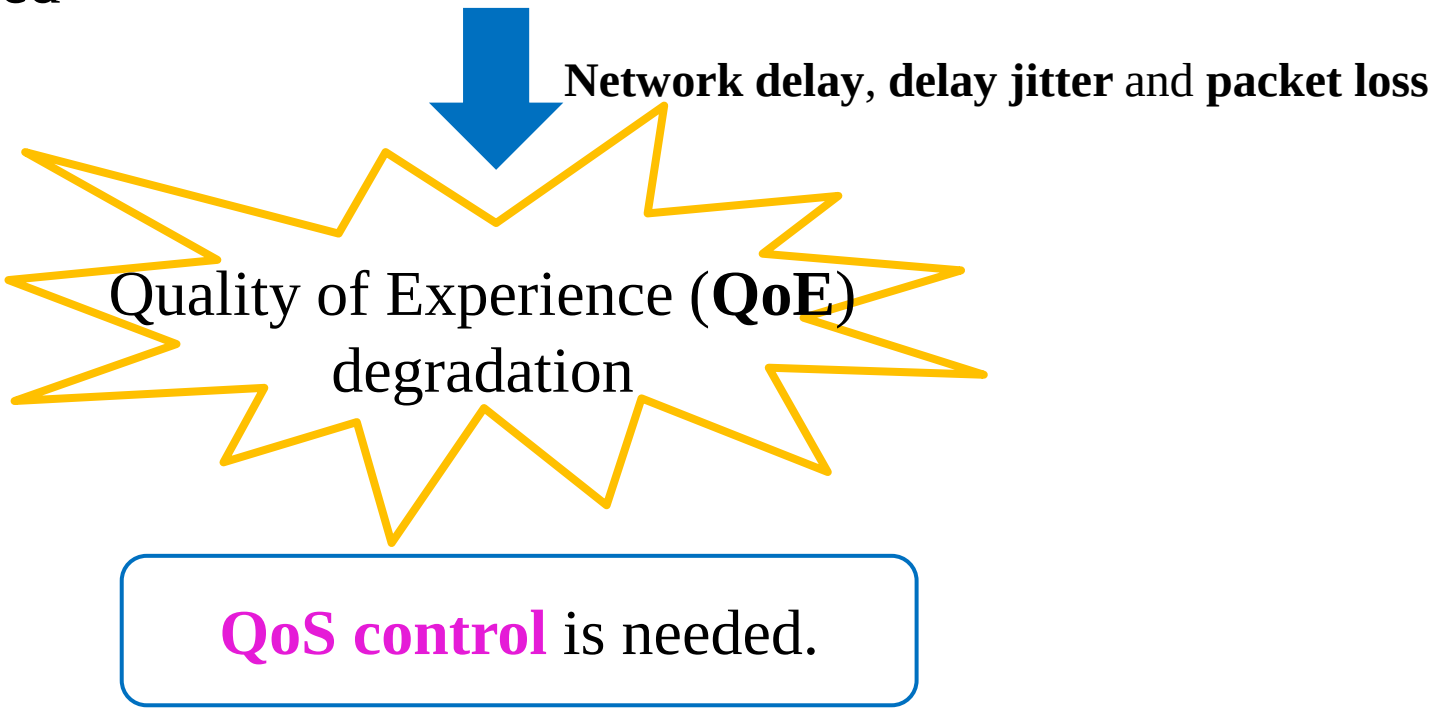


- ✓ One haptic interface device (**Teacher**) is used to control the another (**Student**) [*1].
- ✓ The student can feel the force of teacher.

*1 Y. Ishibashi *et al.*, ACM SIGCHI ACE, pp. 79-86, June 2007.

Previous Work (2/2)

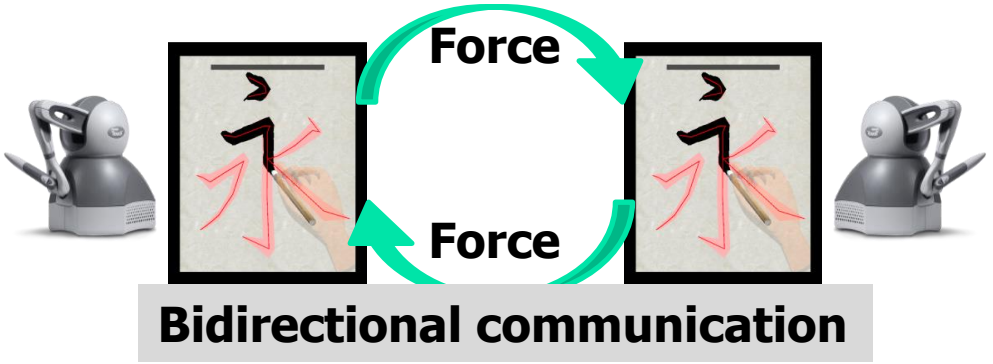
When transmitting force information over a network like the Internet, where the Quality of Service (**QoS**) is not guaranteed



Purpose of This Work

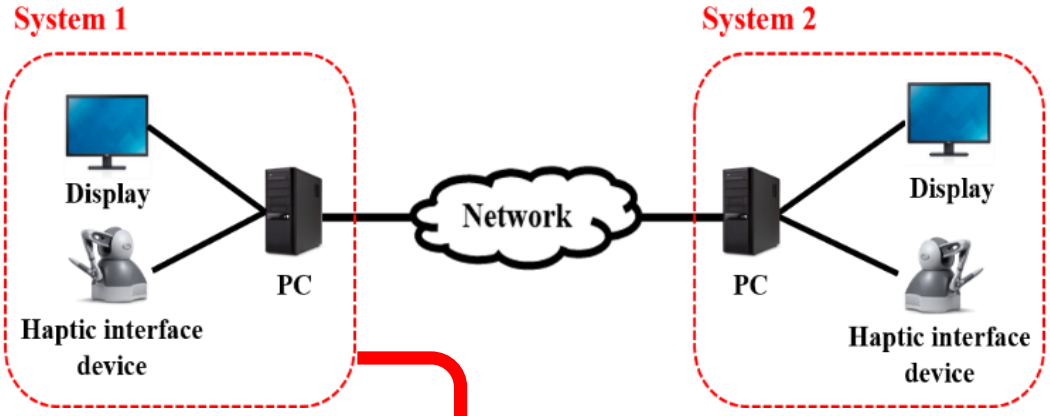
- We apply **the adaptive viscoelasticity control**[*2] as QoS control to the **remote haptic calligraphy system**.

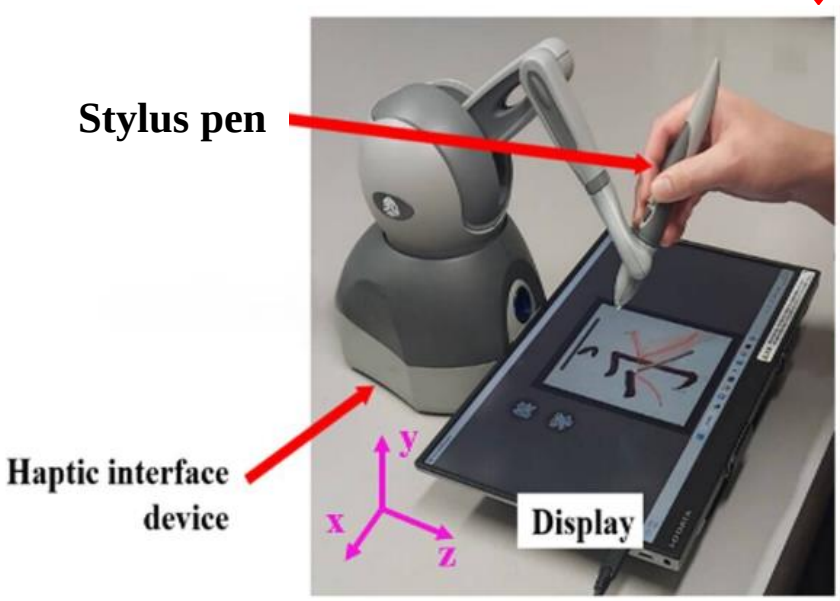
- We investigate the **influence of network delay** on the collaborative work of writing characters between two remote haptic calligraphy systems through QoE assessment.

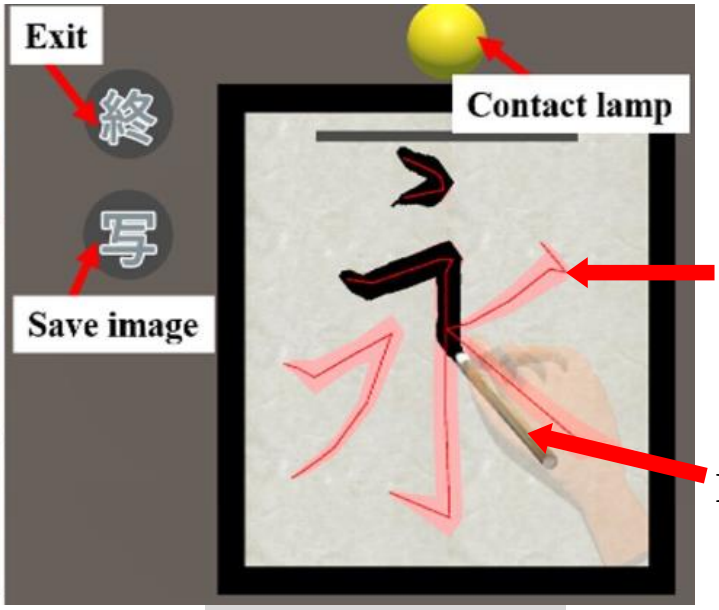


*2 T. Abe *et al.*, IEICE Trans. Commun., vol. J103-B, no. 1, pp. 38-46, Jan. 2020.

Remote Haptic Calligraphy System (1/3)

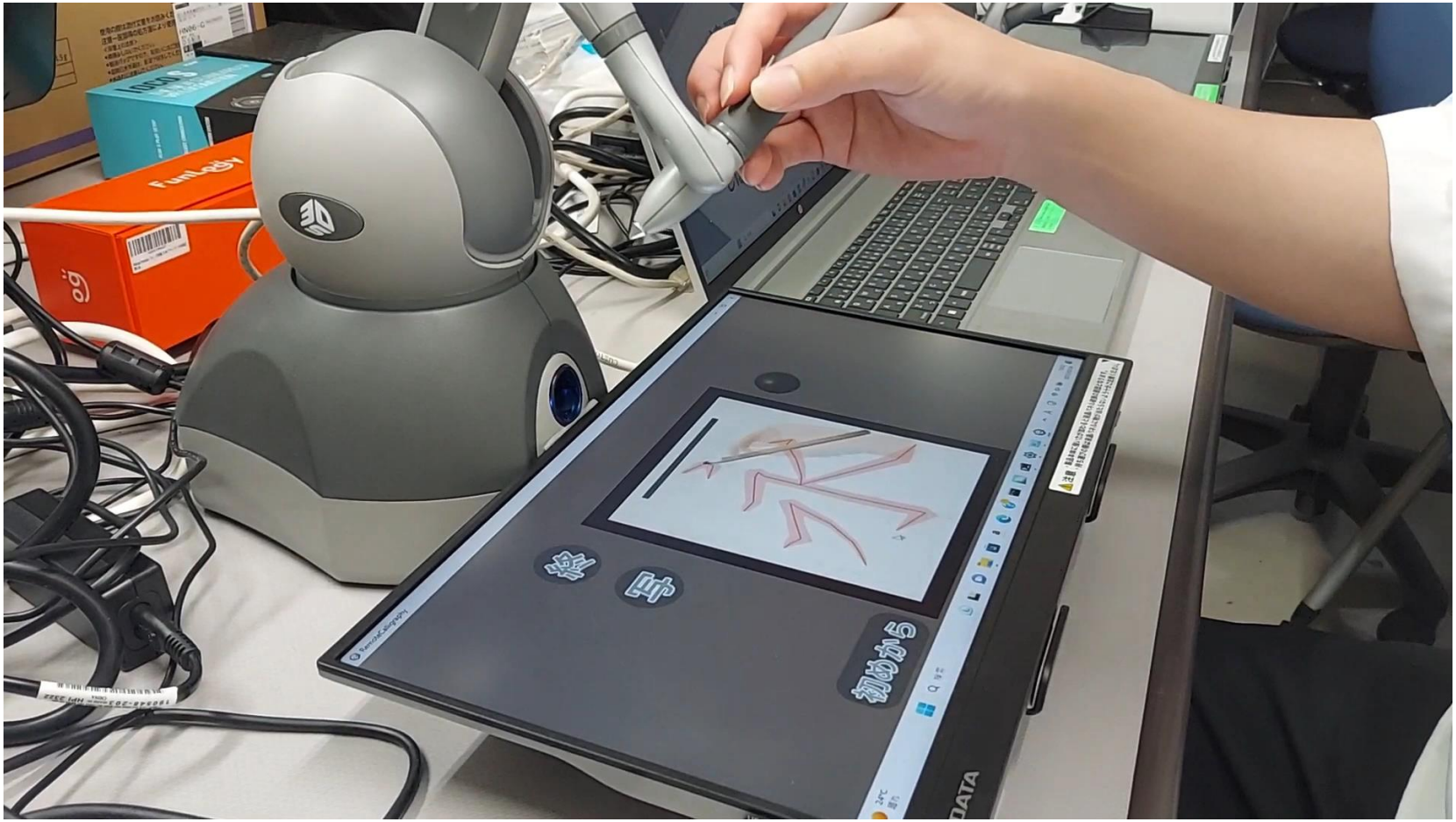






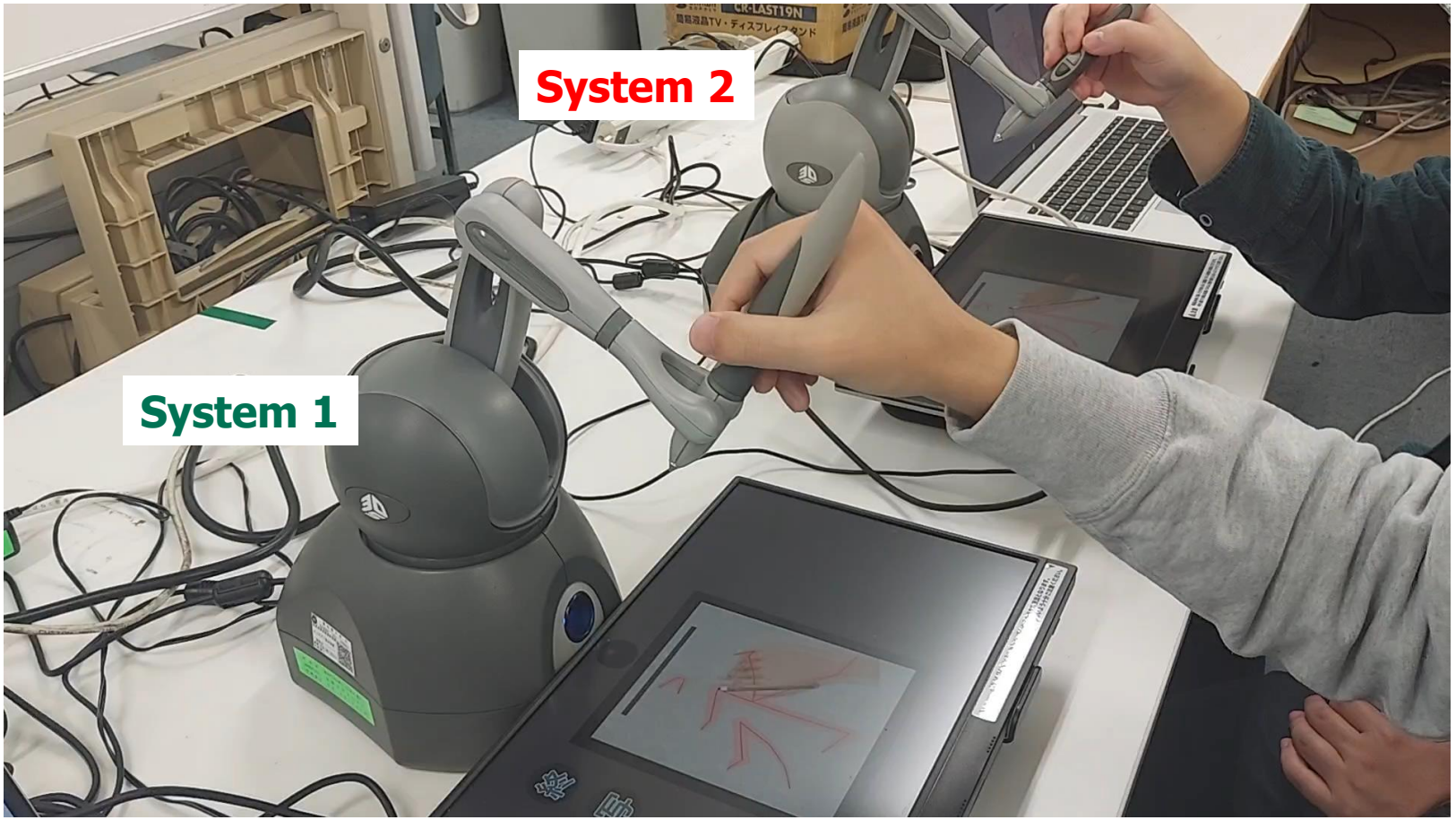
Virtual Space

Remote Haptic Calligraphy System (2/3)



Remote Haptic Calligraphy System (3/3)

✓ **Bidirectional communication**



Adaptive Viscoelasticity Control

*2 T. Abe *et al.*, IEICE Trans. Commun., vol. J103-B, no. 1, pp. 38-46, Jan. 2020.

$$\boldsymbol{F}_t = K_s(\boldsymbol{S}_{t-1} - \boldsymbol{M}_{t-1}) + K_d\left(\dot{\boldsymbol{S}}_{t-1} - \dot{\boldsymbol{M}}_{t-1}\right) - \boldsymbol{F}_{\text{stiff}} - \boldsymbol{W}_{\text{stylus}}$$

$$\boldsymbol{W}_{\text{stylus}} = \begin{cases} 0 & (x \; and \; z - axes) \\ 0.225 & (y - axis) \end{cases}$$

- $\boldsymbol{F}_t$: Force applied to haptic interface device at time t ($t \geq 1$)
- $\boldsymbol{S_t}$, $\boldsymbol{M_t}$: Position vector of Slave's and Master's own haptic interface devices at time t
- $\dot{\boldsymbol{S}}_t$, $\dot{\boldsymbol{M}}_t$: Velocity vector of Slave's and Master's own haptic interface devices at time t
- $\boldsymbol{F}_{\text{stiff}}$: Reaction force from virtual paper in virtual space
- $\boldsymbol{W}_{\text{stylus}}$: Weight of stylus
- K_s : Spring coefficient
- K_d : Damping coefficient

✓ The control is adjusted so that the reactive force **decreases** as the network delay increases.

Assessment Method (1/2)

- ✓ Each subject was asked to score **how much force they felt** based on the following five-grade impairment scale, and Mean Opinion Score (**MOS**)[*3] was calculated.

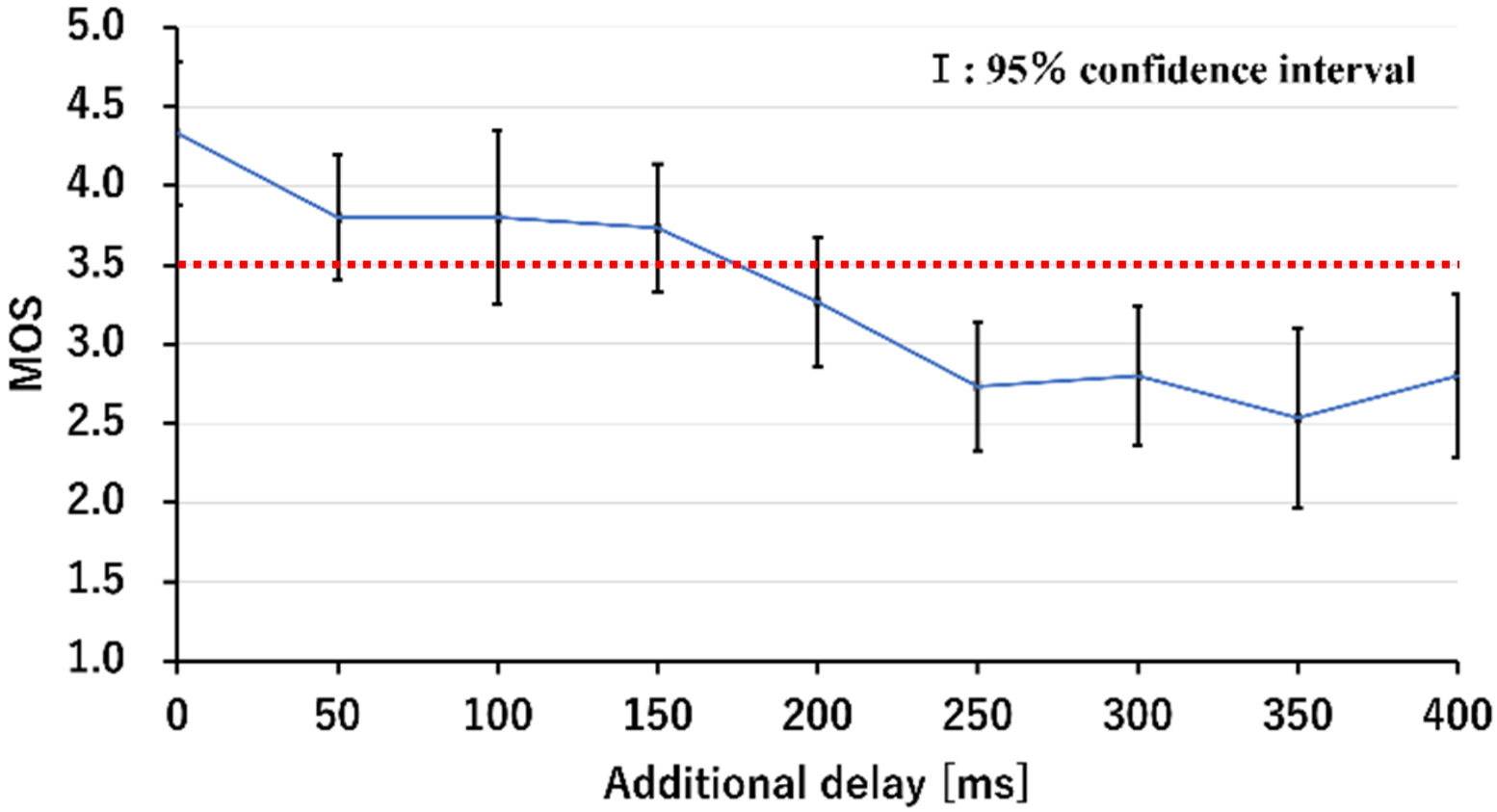
Score	Description
5	Strongly feel force of other user
4	Feel force of other user
3	Somewhat difficult to feel force of other user
2	Difficult to feel force of other user
1	Not feel force of other user at all

*3 ITU-R BT. 500-11, 2002

Assessment Method (2/2)

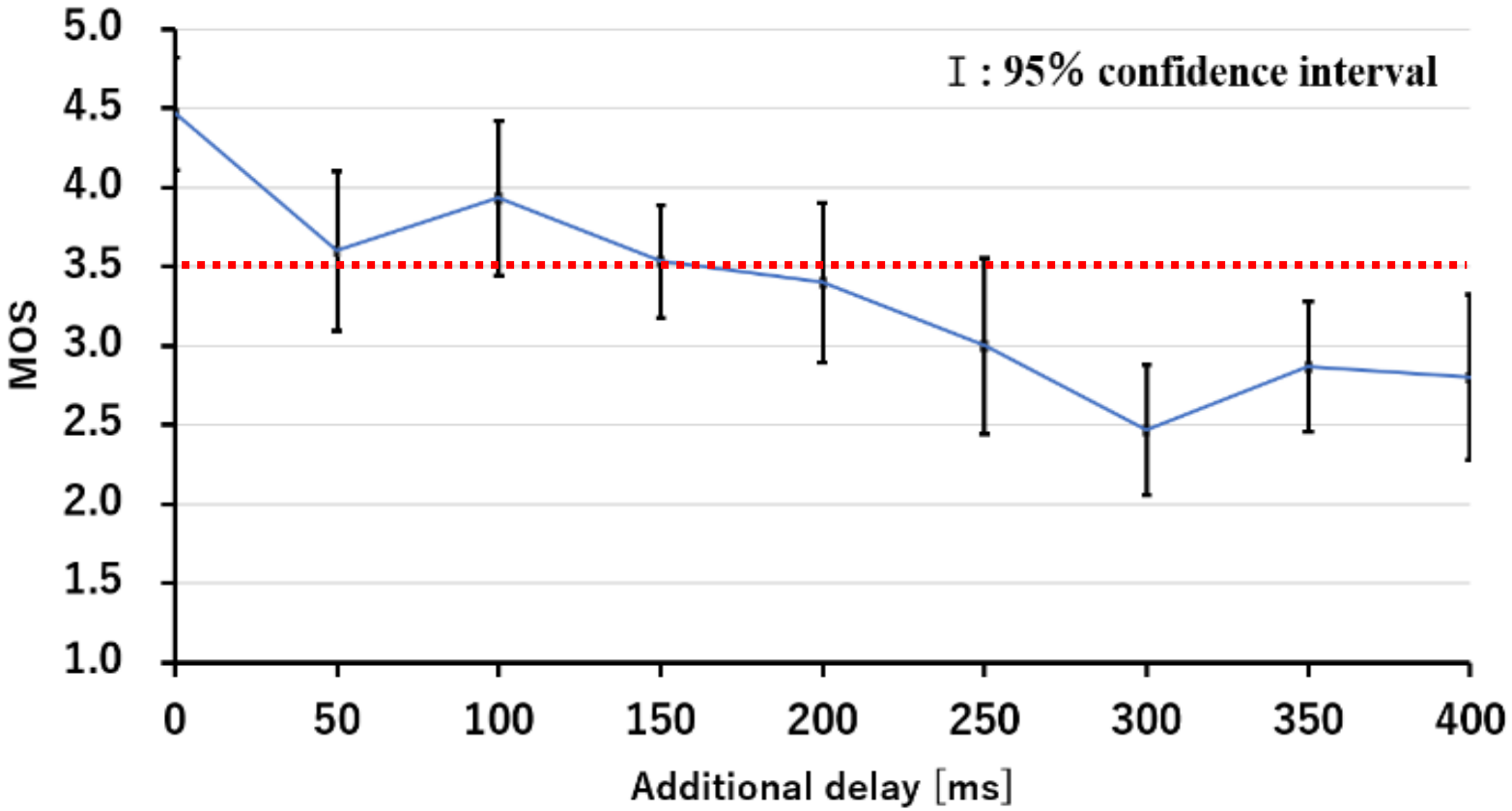
- The haptic interface device of **System 1** was always operated by **the same operator**, while **each subject** operated the haptic interface device of **System 2**.
- They collaboratively wrote a character "永" following the *model* while feeling the force from each other.
- The additional delay was changed from **0 ms to 400 ms** at intervals of 50 ms in random order for each subject.
- The subjects were grouped into two groups; **15 elderly persons** (ages between 68 and 91) and **15 students** (ages between 21 and 36).

Assessment Results (1/2)



Elderly persons

Assessment Results (2/2)



Students

Conclusion

We dealt with the task of writing characters “永” in a **remote haptic calligraphy** system, and investigated the influence of the network delay through QoE assessment.

✓ No large problem when network delay ≤ **150 ms**

- **Future Work**
  - Plan to investigate the relationship between thre results of this experiment and frailty.