Effects of Stabilization Control and QoS Control for Cooperation between Remote Robot Systems with Force Feedback

Kazuya Kanaishi[1], Yutaka Ishibashi[1], Pingguo Hung[2], and Takanori Miyoshi[3]

[1]Nagoya Institute of Technology
[2]Gifu Shotoku Gakuen University
[3]Nagaoka University of Technology

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Background

- ✓ **Remote robot systems with force feedback have actively been researched.**
- ✓ **It is possible to transmit the information about the shape, weight, and softness of a remote object by using haptic interface devices.**
- ✓ **The efficiency and accuracy of work can largely be improved by using the remote robot system with force feedback.**

When we transmit haptic information over the Internet, which does not guarantee QoS (Quality of Service)

Network delay, delay jitter, and packet loss

- **QoE (Quality of Experience) degrades**
- **Instability phenomena occur.**

QoS control and stabilization control

Problems

*1 K. Kanaishi *et al.*, IEICE Technical Report, NS2019-119, Oct. 2019.
*2P. Huang *et al.*, IJCNS, vol. 12, no. 7, pp. 99-111, July 2019.

Previous experiment*1

- ✓ **Performed the collaborative work by using the two remote robot systems and apply the adaptive Δ-causality control as QoS control**
- ✓ **By this control, we can adjust the output timing of position information between terminals according to the network delay.**

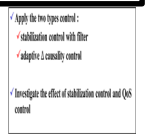
- ✓ **The influence of network delay can greatly be alleviated.**

- ✓ **To avoid instability phenomena, the reaction force is multiplied by 0.1 to the force detected by the robot's force sensor.**
- ✓ **It is difficult for the user to perceive the force sufficiently.**
- ✓ **We can solve the problems by applying stabilization control*2.**

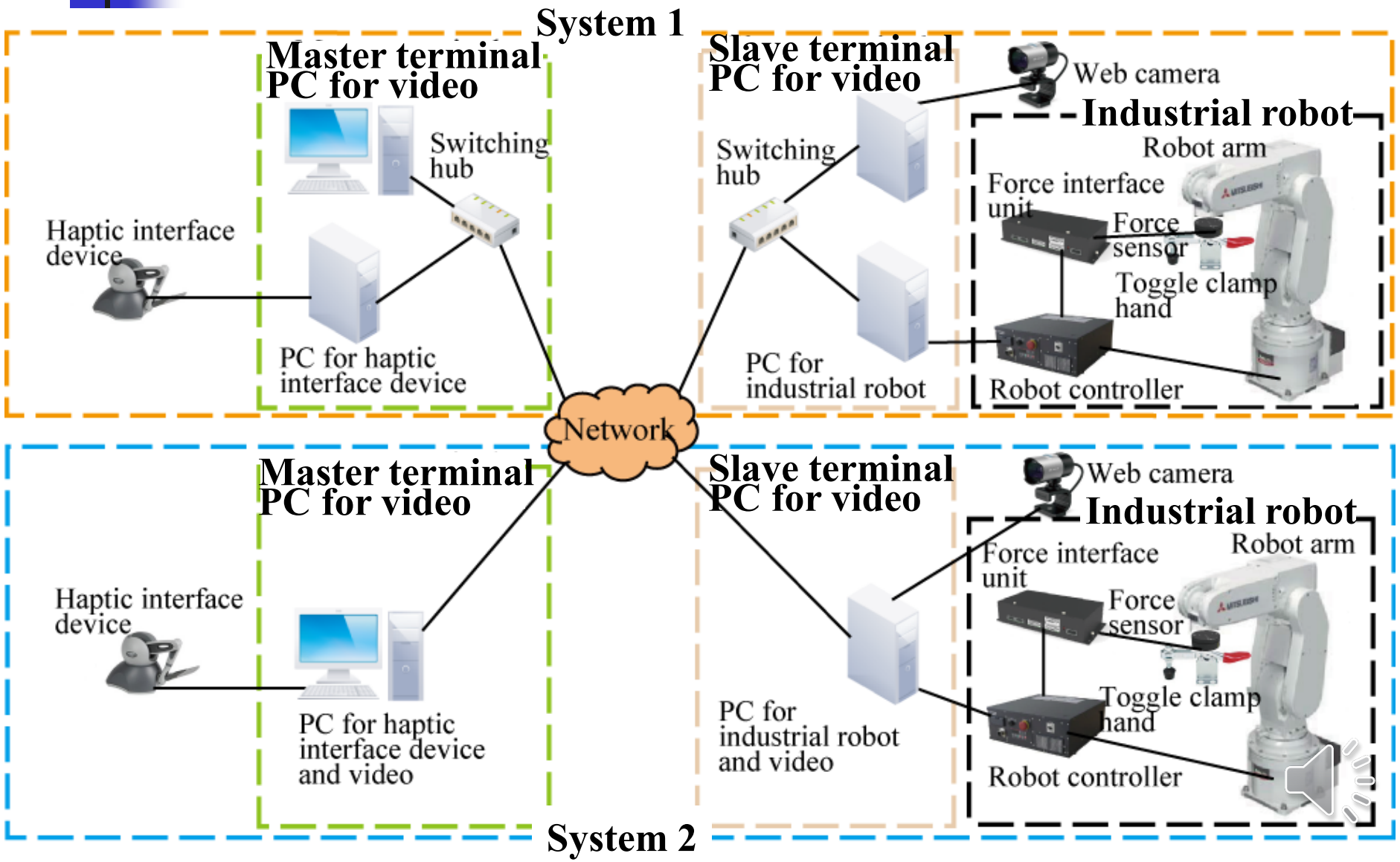
Purpose

This work

- ✓ Apply the two types control :
  - ✓ stabilization control with filter
  - ✓ adaptive Δ causality control
- ✓ Investigate the effect of stabilization control and QoS control by experiment

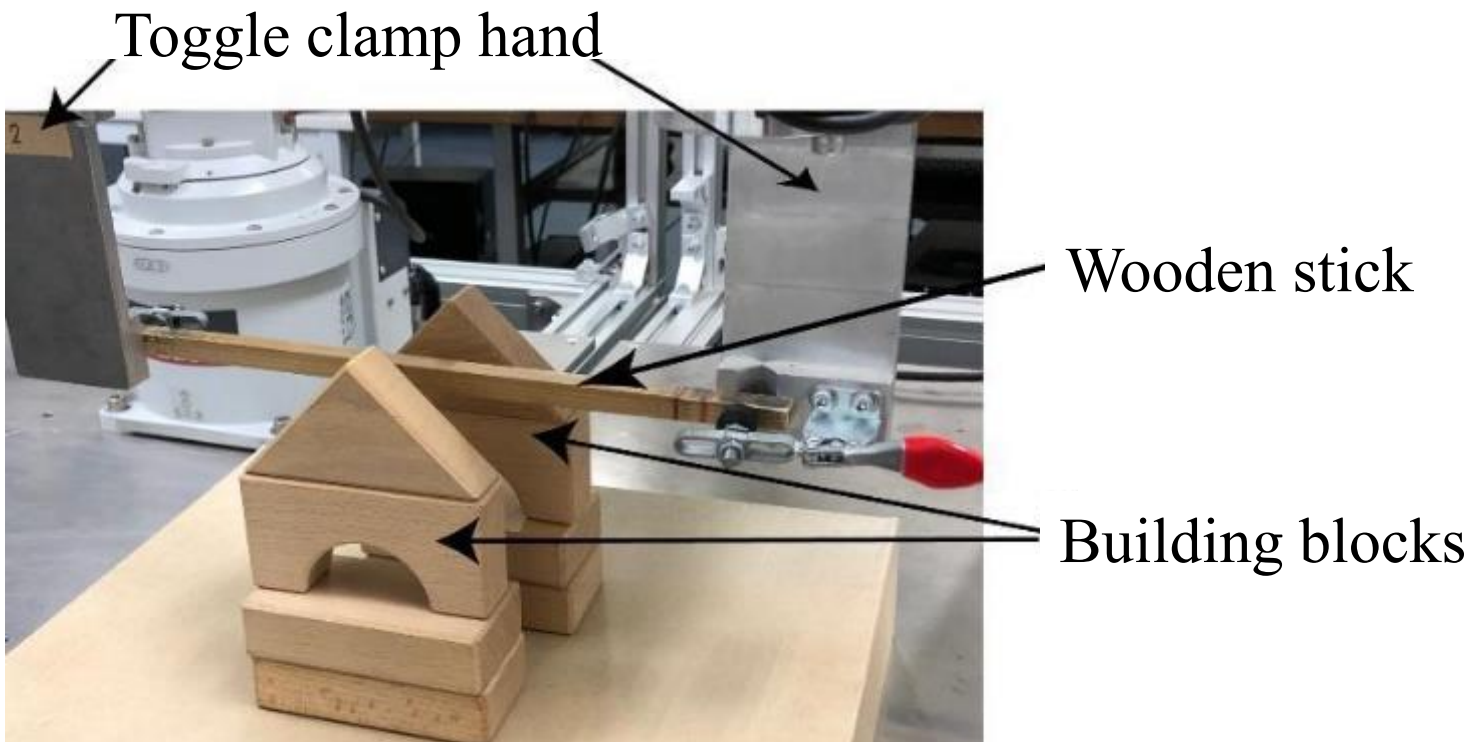


Remote robot systems with force feedback



Carrying object together

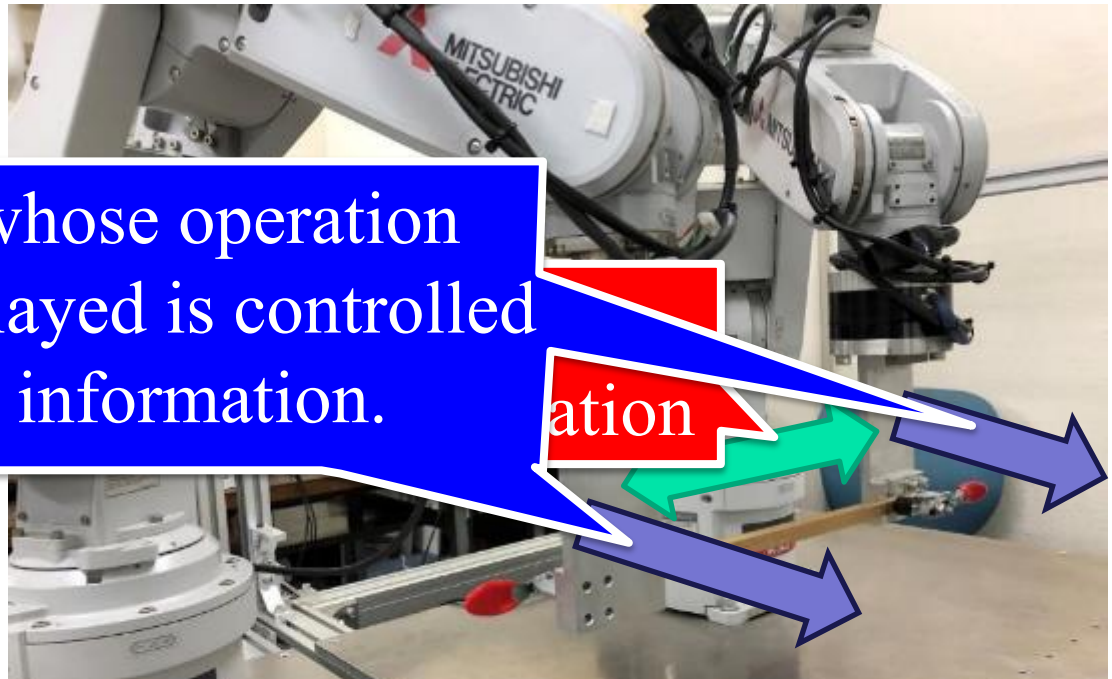
- ✓ **Move a wooden stick together by the two industrial robot arms while watching video.**
- ✓ **In order to move the robot arms in almost the same way always, we push and drop the uppermost block of the piled building blocks by moving the robot arms together with the force feedback devices.**



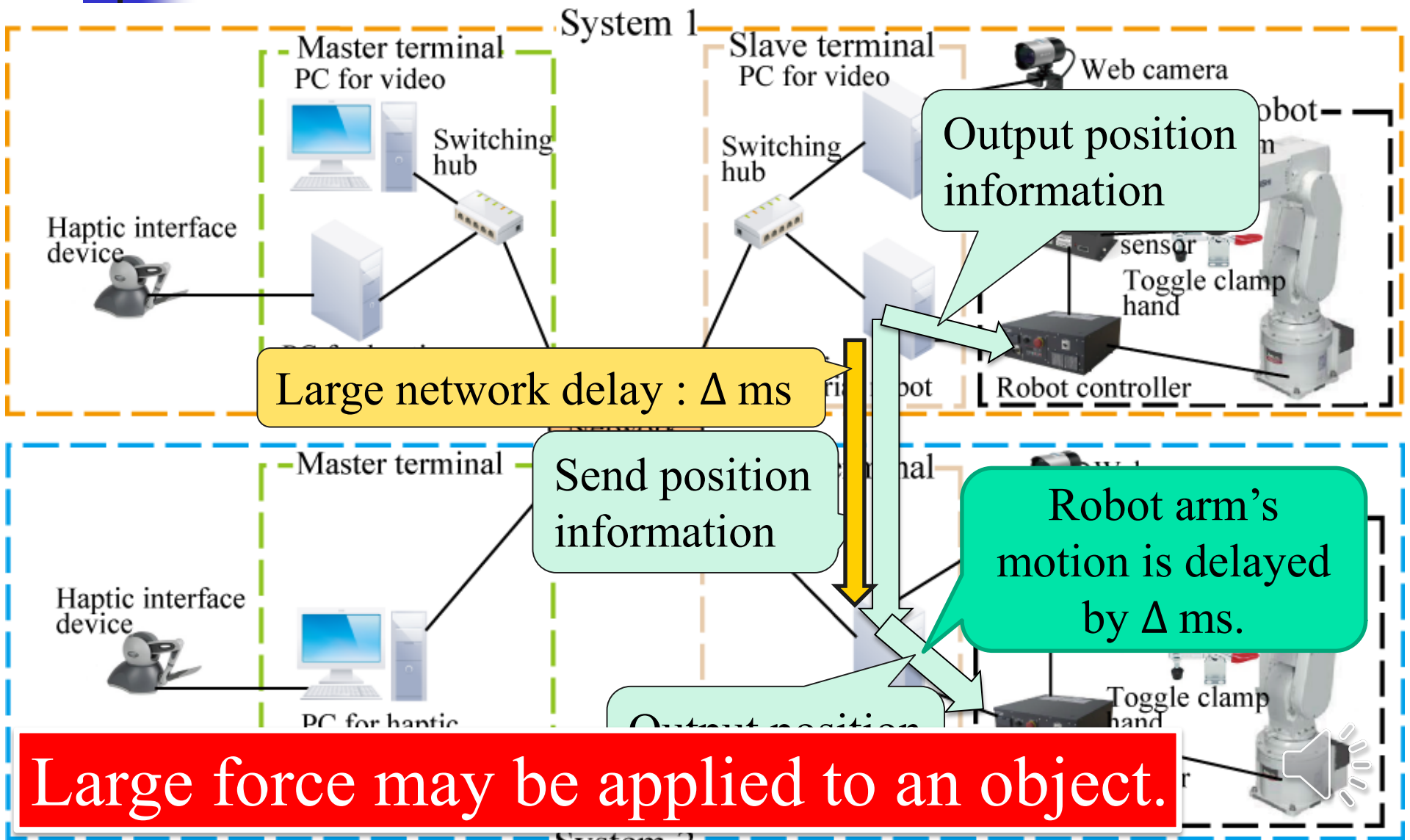
Demo video

Cooperation method between systems

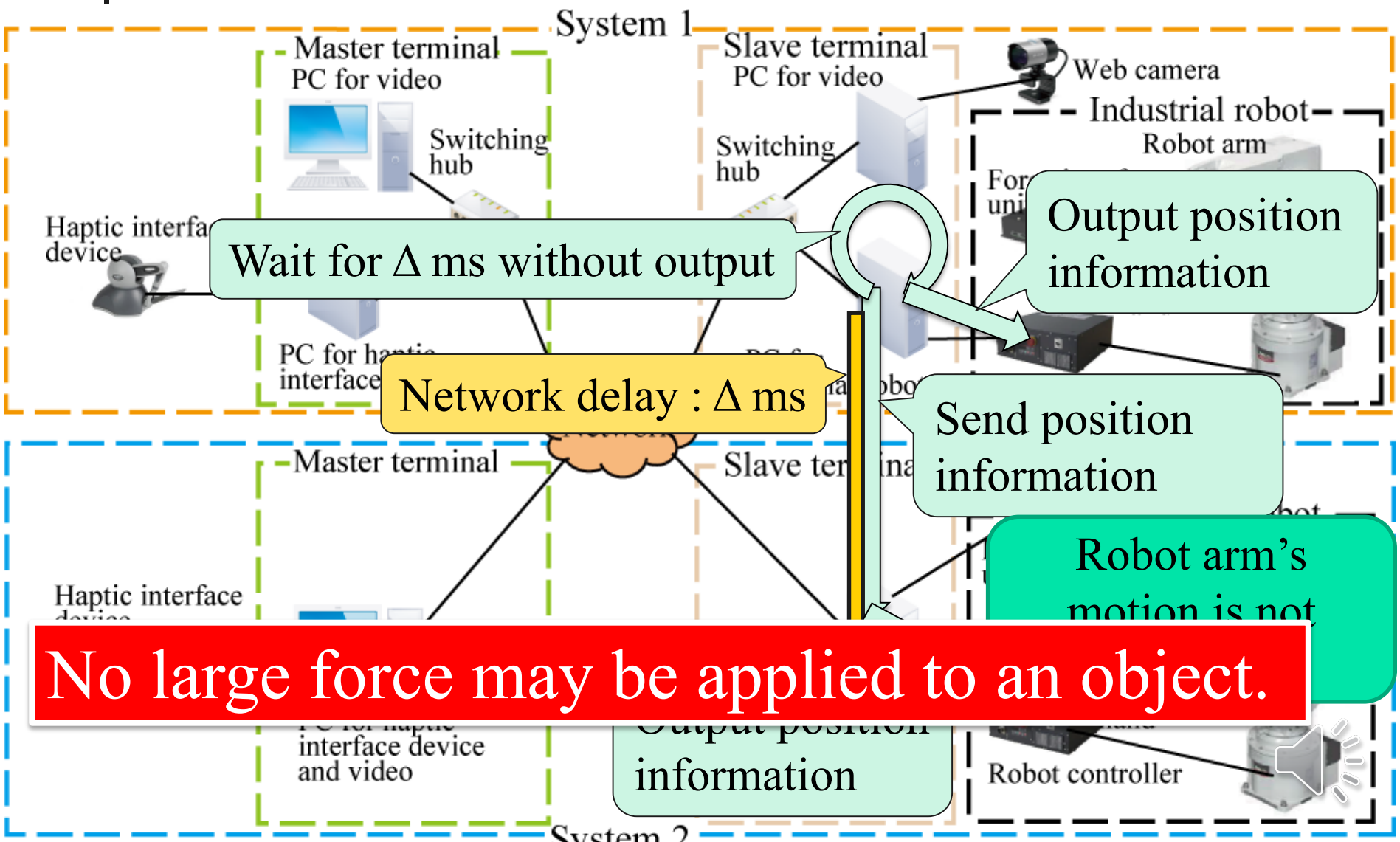
- ✓ The position information of the robot arm at each system is transmitted to the other system.
- ✓ The robot arm whose operation timing is delayed is controlled by using the information.



No QoS Control



Adaptive Δ-causality control (1/2)



Adaptive Δ-causality control (2/2)

[*3] T. Abe *et al.*, Journal of IEICE, vol. 91, no. 2, Feb. 2008.

- **Δ is set to the smoothed network delay.**

$$\begin{cases} \Delta = d_0 \\ \Delta = \alpha\Delta + (1-\alpha)d_t & (t \geq 1) \end{cases}$$

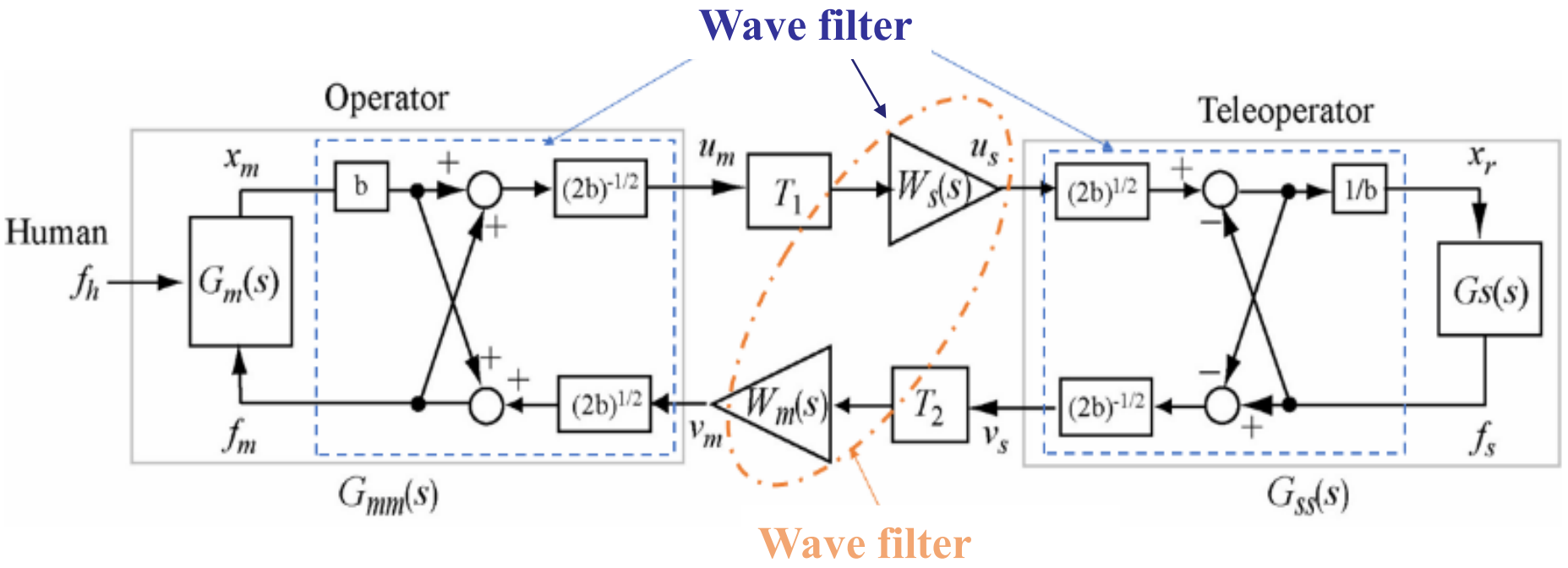
Smoothing coefficient $\alpha = 0.998$[*3]

d_t : Network delay at time t

- **Information received after generation time + Δ is discarded as old and useless information.**

Stabilization control with filters

*[2]P. Huang *et al.*, IJCNS, vol. 12, no. 7, pp. 99-111, July 2019.



- ✓ The stabilization control with filters uses the wave filter in combination with the phase control filter.
- ✓ The control can make the remote robot system with force feedback stable against any network delay*[2].

Experiment method

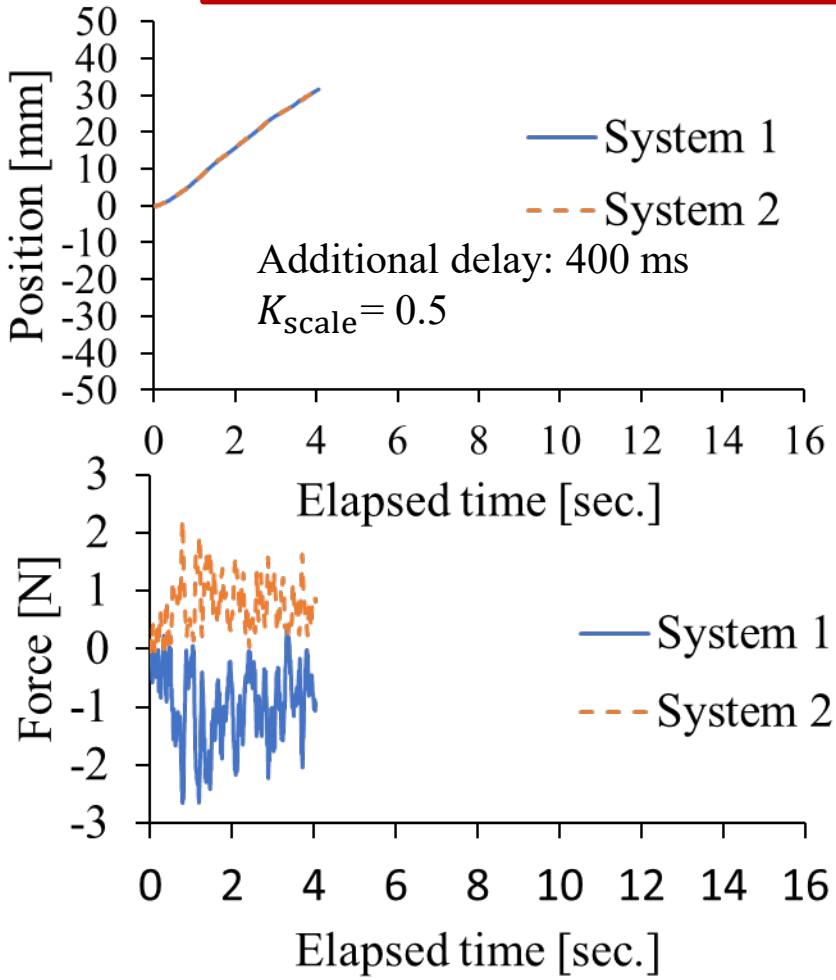
- ✓ **We generated a constant delay (called the *additional delay*) for each packet transmitted between the two systems by a network emulator.**
- ✓ **We measured the force sensed by the force sensor.**
- ✓ **Set the robot so that it does not move vertically and horizontally to ensure stable operation.**

Experiment results (1/2)

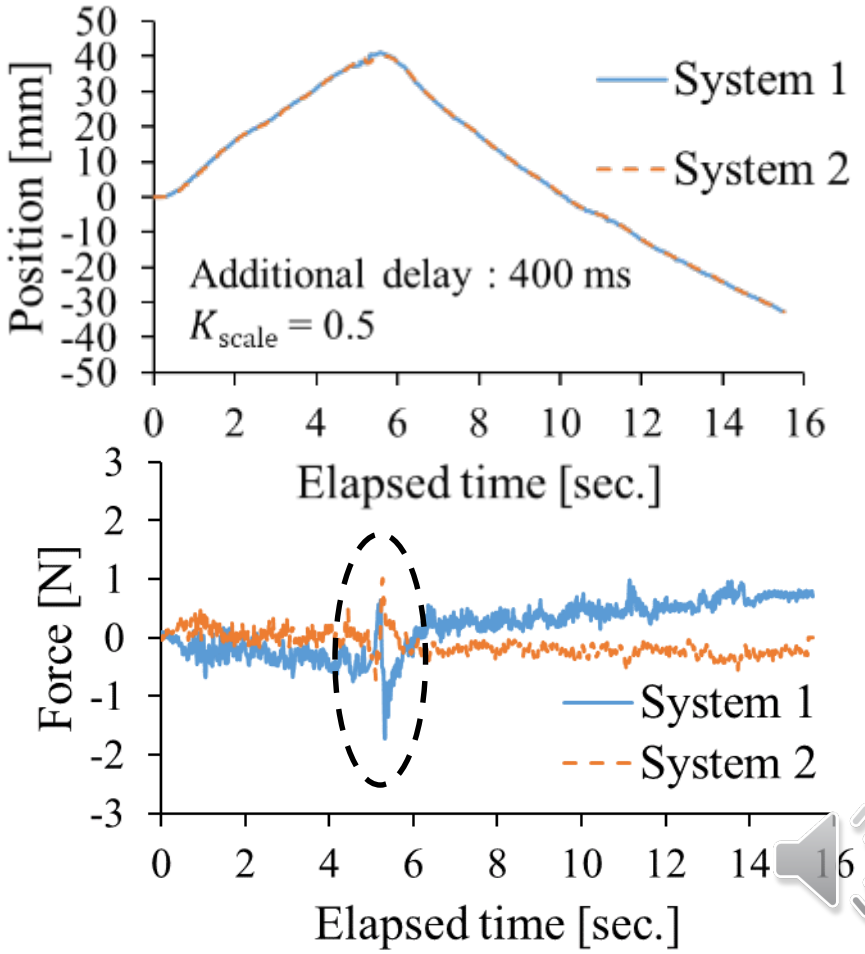
Effect of stabilization control

Position and force with QoS control

No stabilization control



Stabilization control

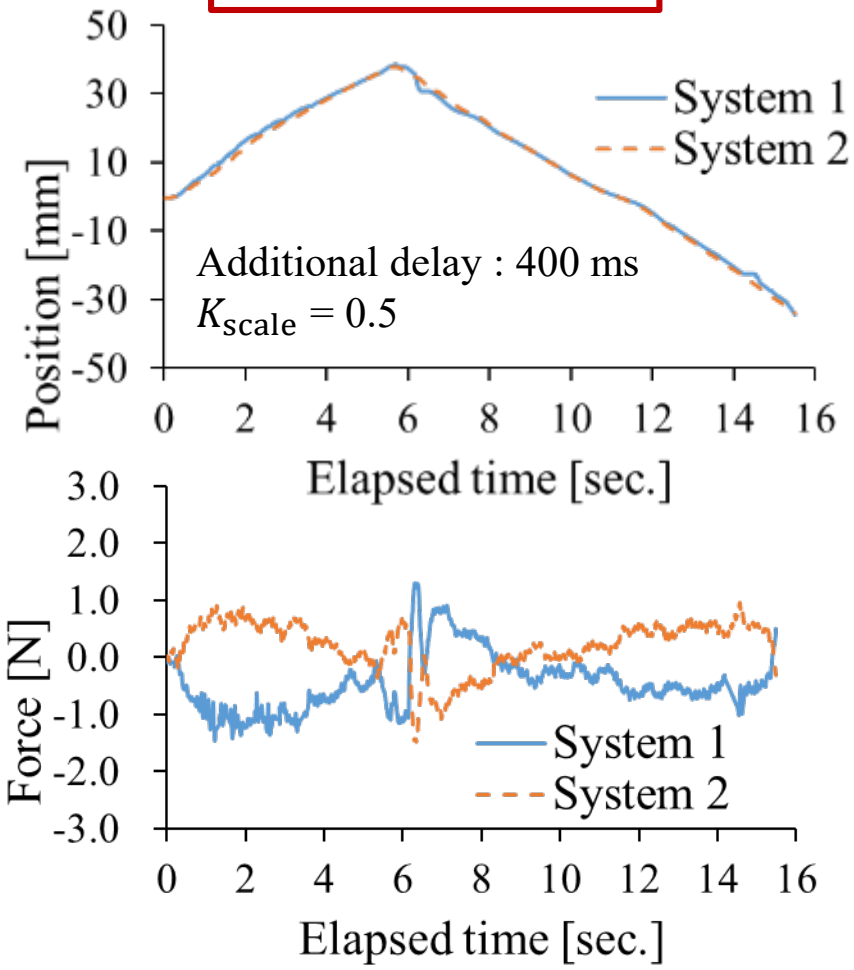


Experiment results (2/2)

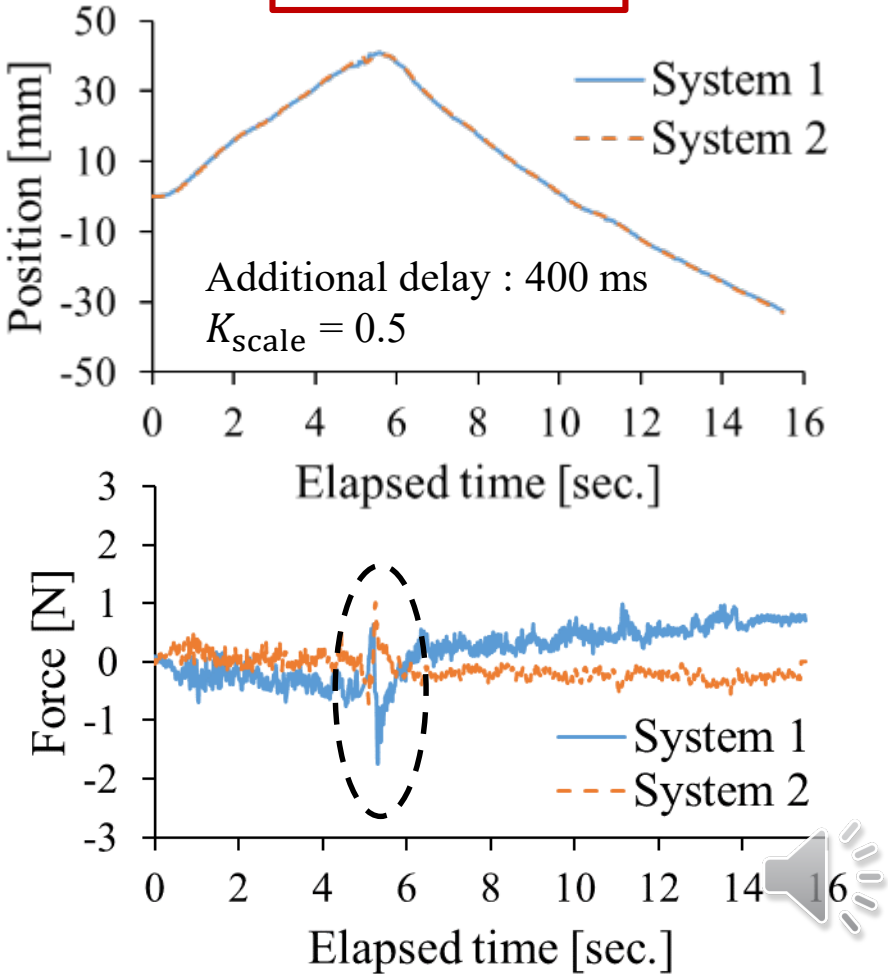
Effect of QoS control

Position and force with stabilization control

No QoS control



QoS control



Conclusion

- ✓ We applied the stabilization control with filters and the adaptive Δ-causality control to the remote robot systems with force feedback.
- ✓ We investigated the effects of the two types of control.

- ✓ The instability phenomena and large force applied to the object can greatly be alleviated by the two types of control.

Future work

- ✓ **Further improve the stability of the systems**
- ✓ **Reduce large force when reversing the operation direction**