Switching between Stabilization Control by Viscosity and Reaction Force Control upon Hitting in Remote Robot System with Haptics

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Background

[*1] T. Rikiishi *et al*., IEICE, BS-7-21, Sep. 2017.
[*2] R. Arima *et al*., IEICE, CQ2017, Jan. 2018.

- Remote robot systems with haptics have been actively 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.

Transmission of haptic sense over the Internet

QoE (Quality of Experience) degradation and instability phenomena in remote robot systems with haptics owing to the network delay, delay jitter and packet loss.

To solve the above problems, stabilization control by viscosity [*1] and reaction force control upon hitting [*2] have been proposed.

*2 T. Rikiishi, Nagoya Institute of Technology, Master Thesis, Feb. 2018.

Previous Work and Problem

- Stabilization control by viscosity outperforms the reaction force control upon hitting for soft objects *2.
- Reaction force control upon hitting outperforms the stabilization control by viscosity for hard objects *2.

↓

Combination usage of the stabilization control by viscosity and the reaction force control upon hitting may make the system more stable.

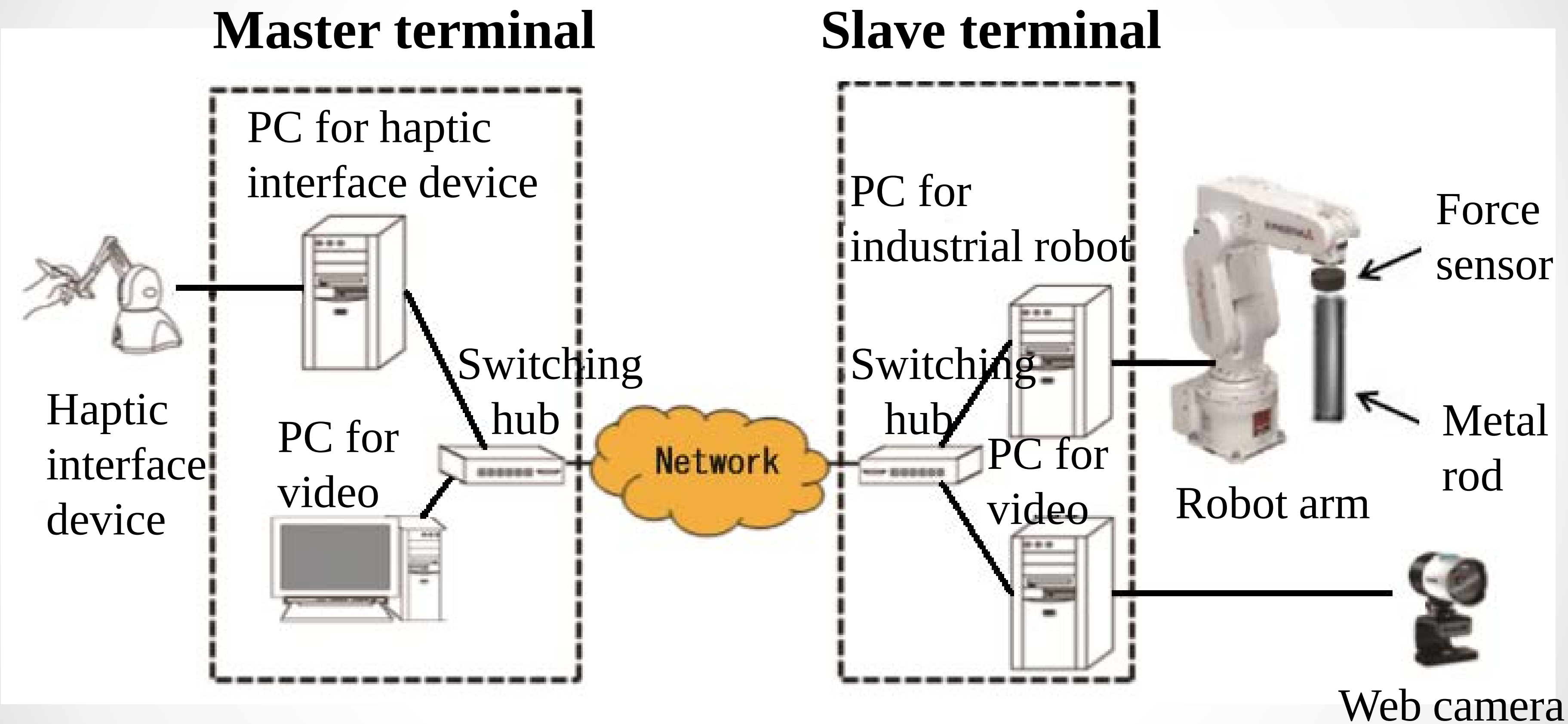
The usage has not been studied so far.

Purpose

This study

- We use stabilization control by viscosity for soft objects and reaction force control upon hitting for hard objects.
- We propose switching control which combines the advantages of the above two types of control for the remote robot system with haptics.
- We examine the effectiveness of the switching control by experiment.

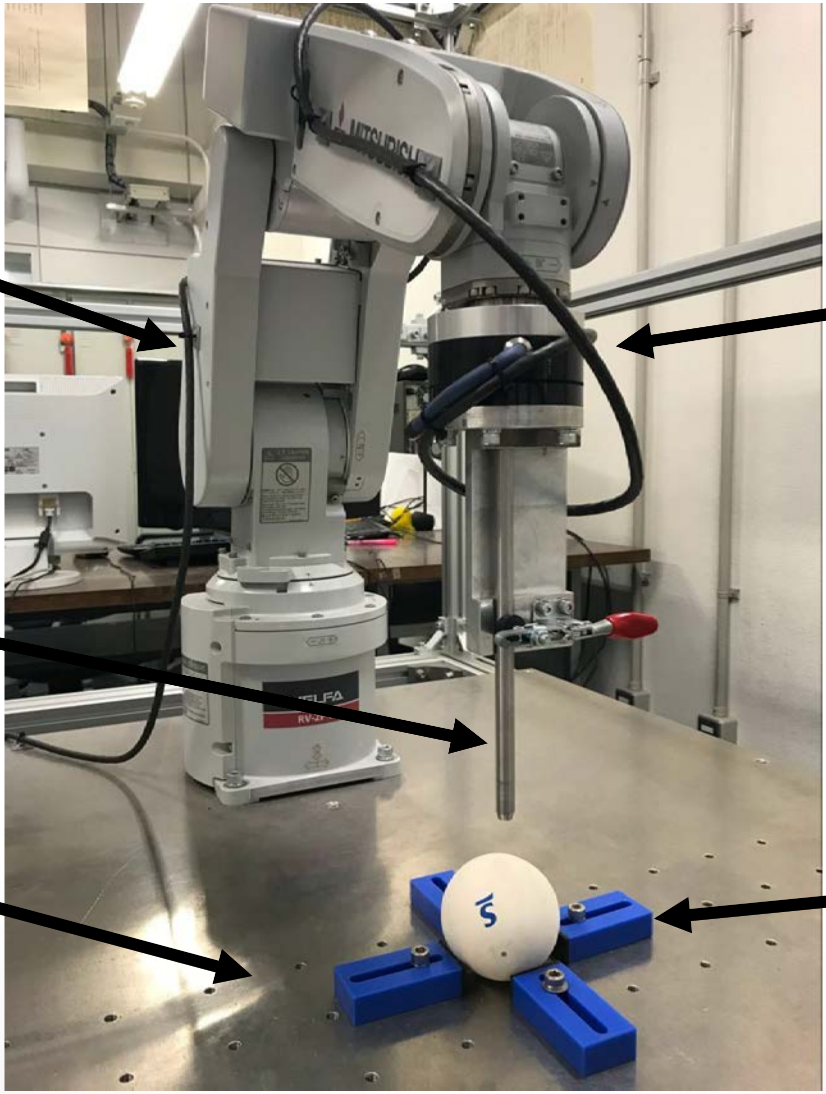
Remote Robot System



Industrial Robot

Industrial robot arm

Force sensor



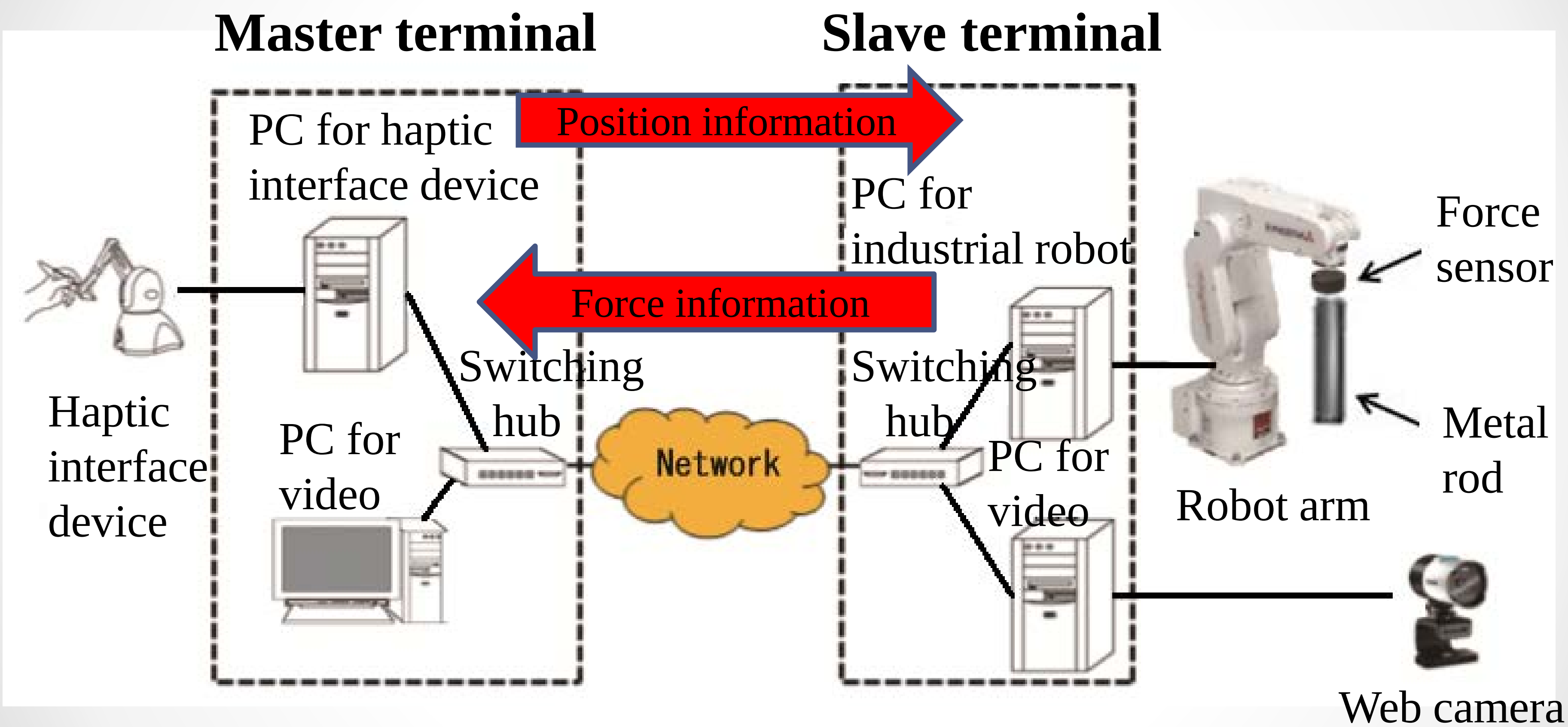
Metal rod

Metal platform

Holding jigs

Haptic Interface Device

Remote Operation



Calculation for Reaction Force

$$\boldsymbol{F}_t^{(\mathrm{m})} = \begin{cases} K_{\mathrm{scale}} \boldsymbol{F}_{t-1}^{(\mathrm{s})} & (K_{\mathrm{scale}} \boldsymbol{F}_{t-1}^{(\mathrm{s})} < 3.3\ \mathrm{N}) \\ 3.3\ \mathrm{N} & (\text{otherwise}) \end{cases}$$

(Maximum allowable reaction force)

$\boldsymbol{F}_t^{(\mathrm{m})}$: Reaction force outputted at time t (≥ 1)

$\boldsymbol{F}_t^{(\mathrm{s})}$: Force received from slave terminal at time t (≥ 1)

K_{scale} : Mapping ratio about scale of force

Force (Robot : Geomagic)
1 : 1 (1)

K_{scale}

Robot: Industrial robot
Geomagic: Haptic interface device

Calculation for Position of Industrial Robot

$$\boldsymbol{S}_t = 0.5\boldsymbol{M}_{t-1}$$

$\boldsymbol{S}_t$: Position vector of industrial robot at time t (≥ 1)

$\boldsymbol{M}_t$: Position vector of haptic interface device at time t (≥ 1)

Work space (Robot : Geomagic)
1 : 2 (0.5)

Robot: Industrial robot
Geomagic: Haptic interface device

[*1] T. Rikiishi *et al.*, IEICE, BS-7-21, Sep. 2017.

Stabilization Control by Viscosity

$$\boldsymbol{S}_t = 0.5\boldsymbol{M}_{t-1} - C_{\mathrm{d}}(\boldsymbol{S}_{t-1} - \boldsymbol{S}_{t-2})$$

C_{d} (=0.95 [*1]) : Coefficient related to viscosity

$\boldsymbol{S}_t$: Position vector of industrial robot at time t (≥ 2)

$\boldsymbol{M}_t$: Position vector of haptic interface device at time t (≥ 2)

*2 R. Arima *et al.*, IEICE, CQ2017, Jan. 2018.

Reaction Force Control upon Hitting

$$\boldsymbol{F}_t^{(\mathrm{m})} = \begin{cases} K_{\mathrm{scale}} \left(\boldsymbol{F}_{t-1}^{(\mathrm{m})} + K_i \boldsymbol{F}_{\mathrm{th}}\right) & \left(\left|\boldsymbol{F}_{t-1}^{(\mathrm{m})} - K_{\mathrm{scale}} \boldsymbol{F}_{t-1}^{(s)}\right| > \left|\boldsymbol{F}_{\mathrm{th}}\right|\right) \\ K_{\mathrm{scale}} \boldsymbol{F}_{t-1}^{(\mathrm{s})} & (\text{otherwise}) \end{cases}$$

$\boldsymbol{F}_t^{(\mathrm{m})}$: Reaction force outputted at time t (≥ 1)

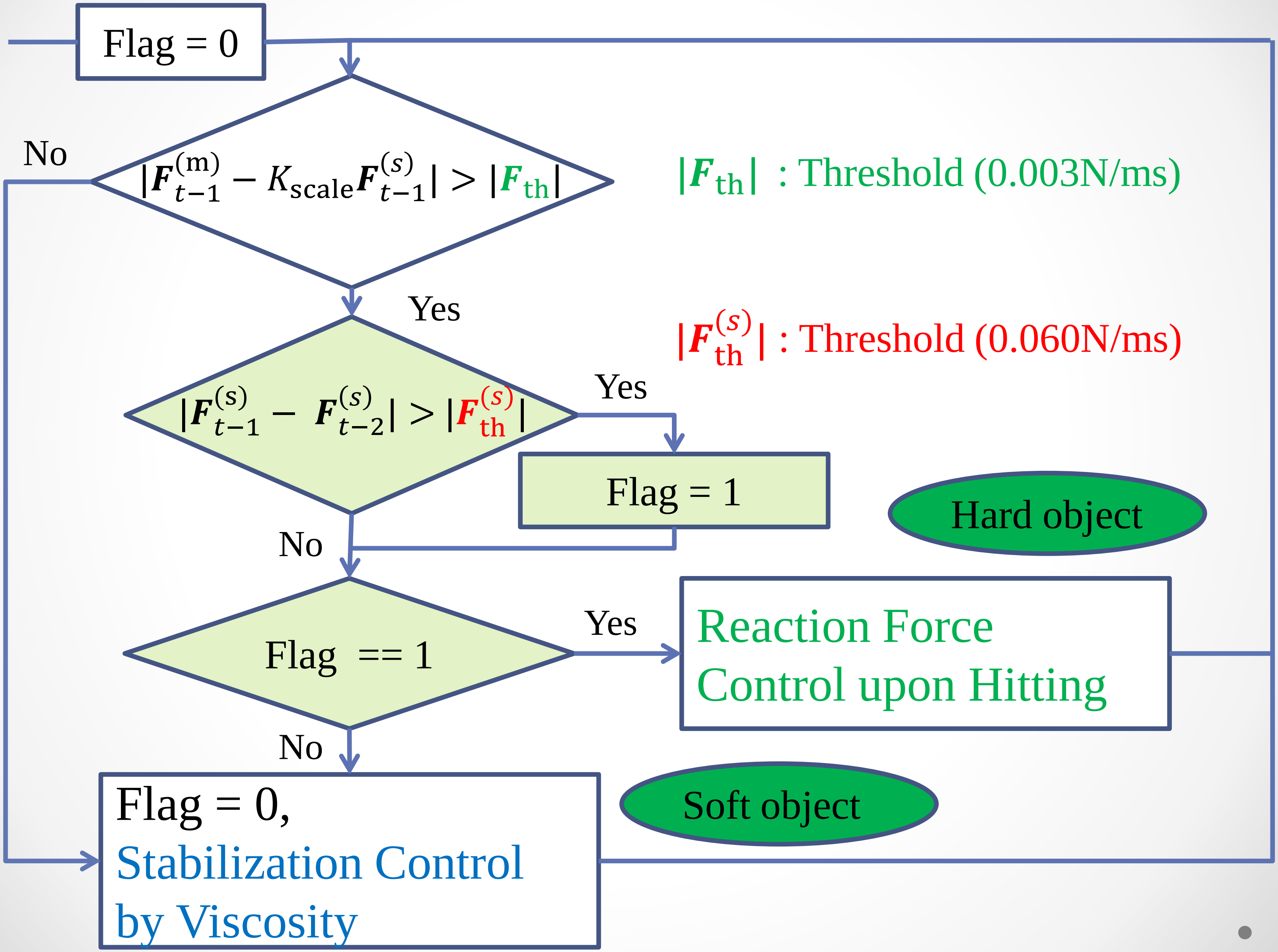
$\boldsymbol{F}_t^{(\mathrm{s})}$: Force received from slave terminal at time t (≥ 1)

K_{scale} : Mapping ratio about scale of force

$|\boldsymbol{F}_{\mathrm{th}}|$: Threshold (0.003N/ms),

K_i : $K_i = 1.000 + 0.001i$ $(i \geq 0)$ *2

Switching Control

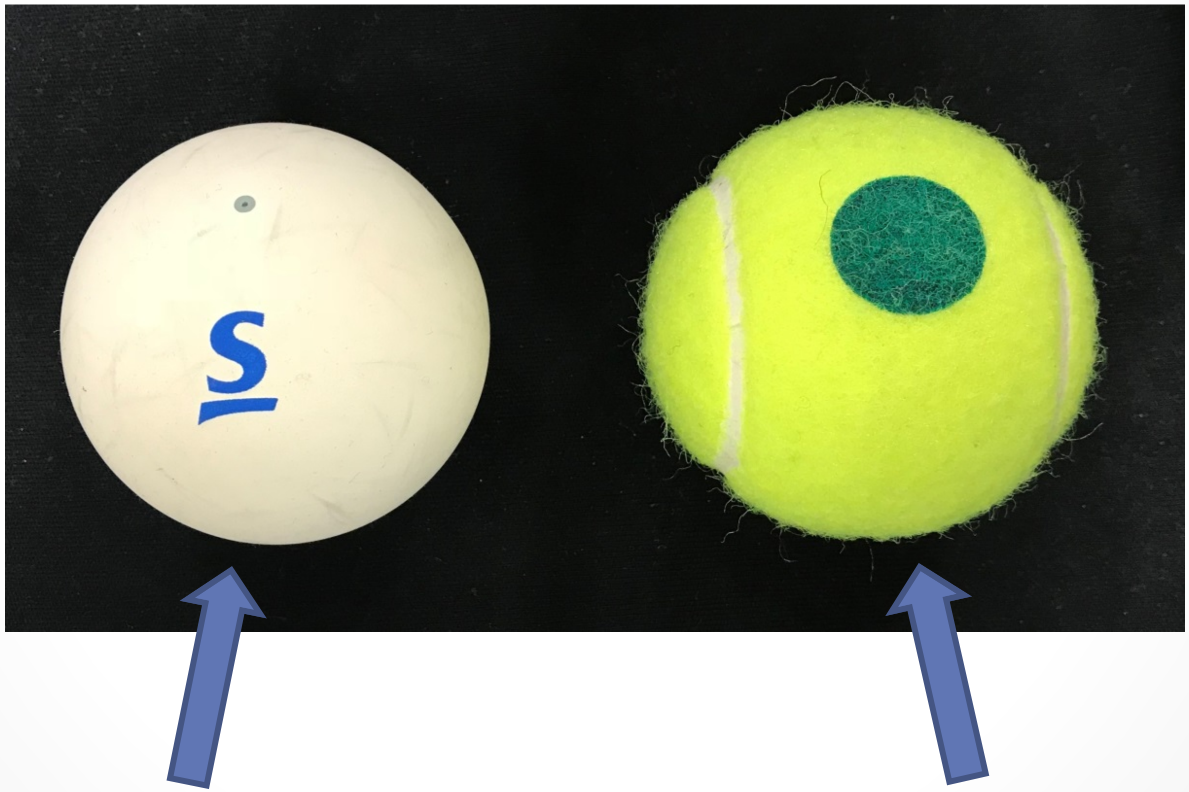


Experiment Method

- A user did work of pushing a soft tennis ball and a hard tennis ball with a metal rod attached to the tip of the robot arm.
- The industrial robot arm was set to move only in the vertical direction.
- Network delay was set to be negligibly small.
- The user pushed each ball five times for about 10 seconds by using the three types of control.

We measured the force of the industrial robot and the reaction force of the haptic interface device.

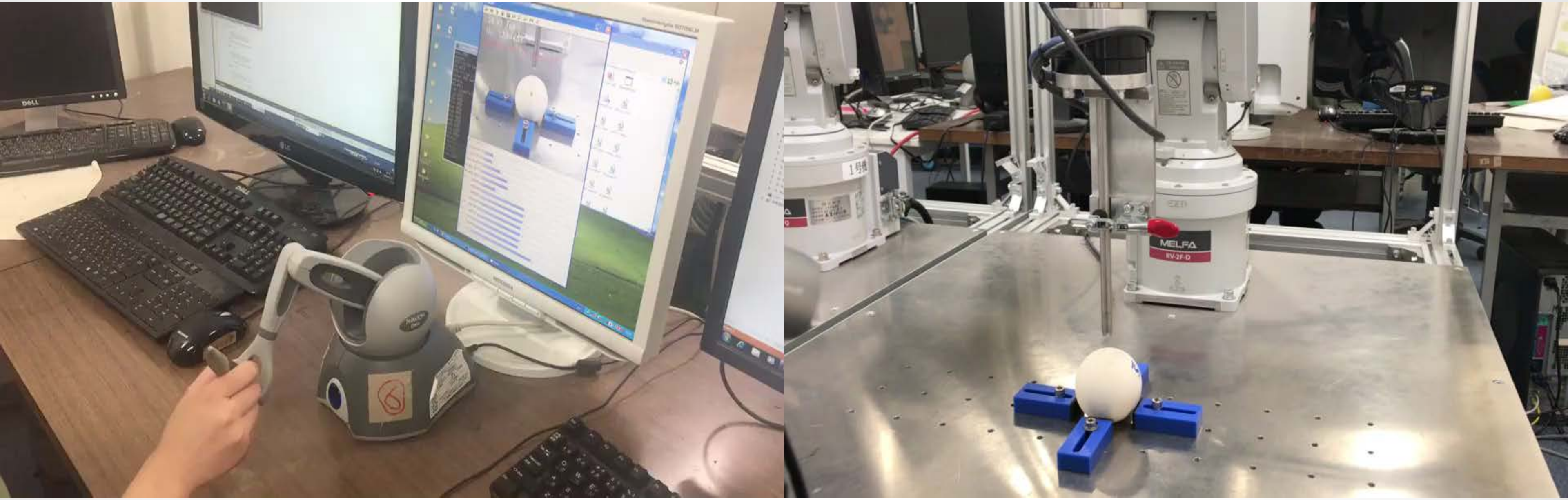
Two Balls



Soft tennis ball

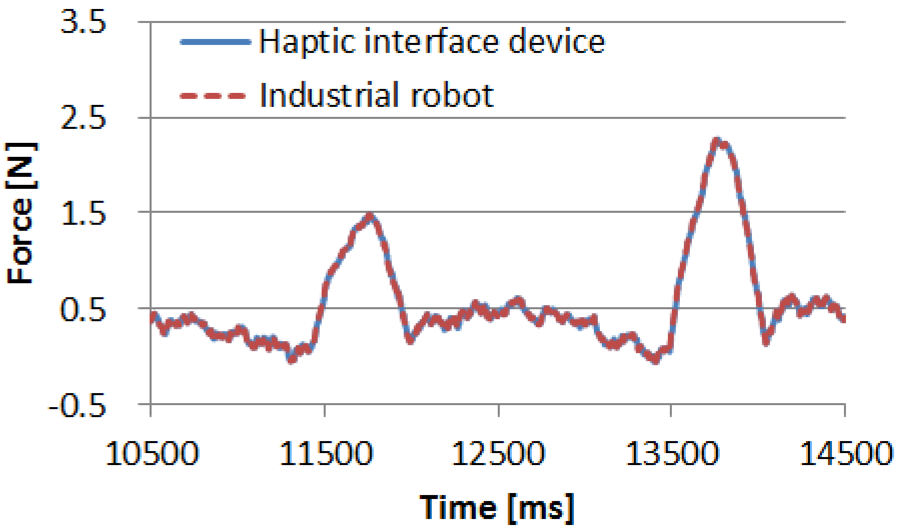
Hard tennis ball

Demo video – Pushing Soft Tennis Ball

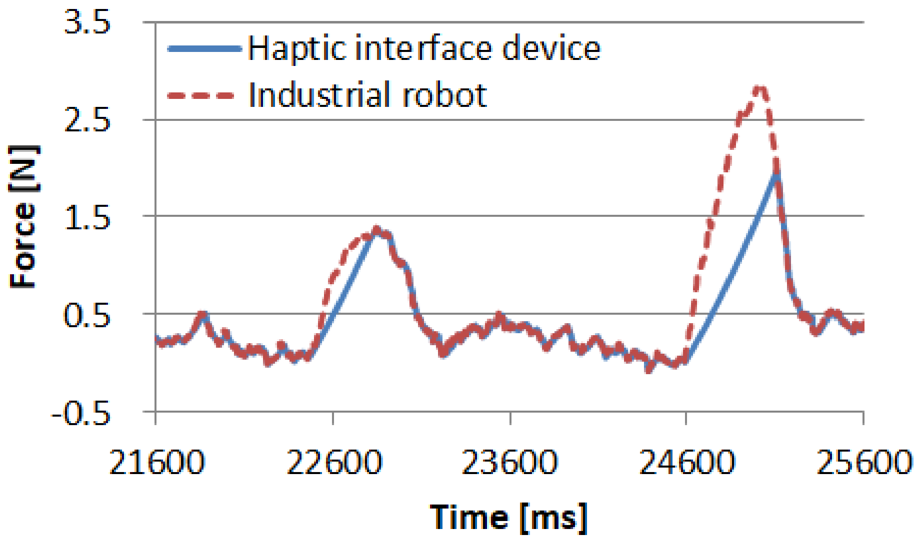


Use of switching control

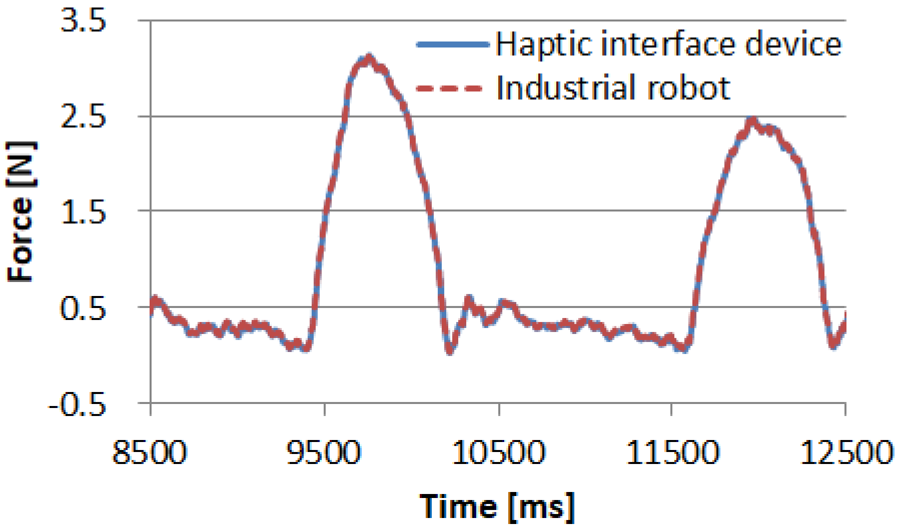
Experiment Results (1/2)



(a) Stabilization control by viscosity



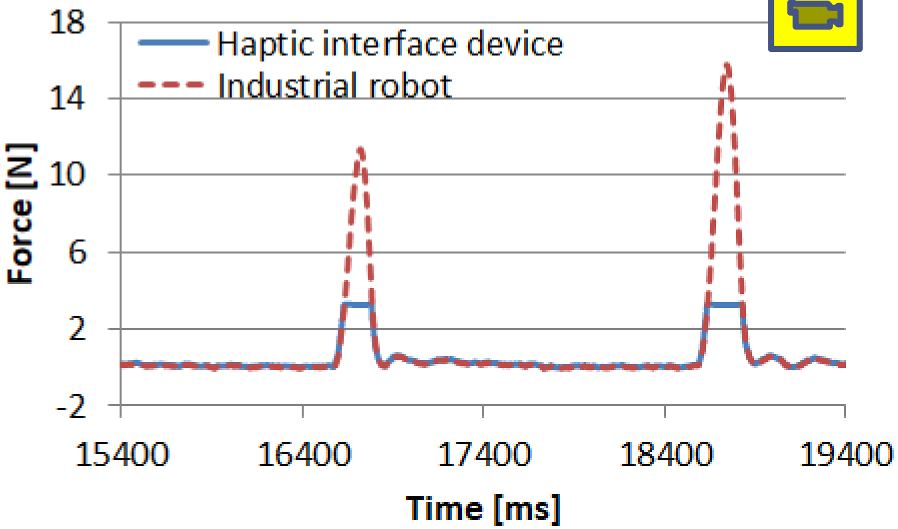
(b) Reaction force control upon hitting



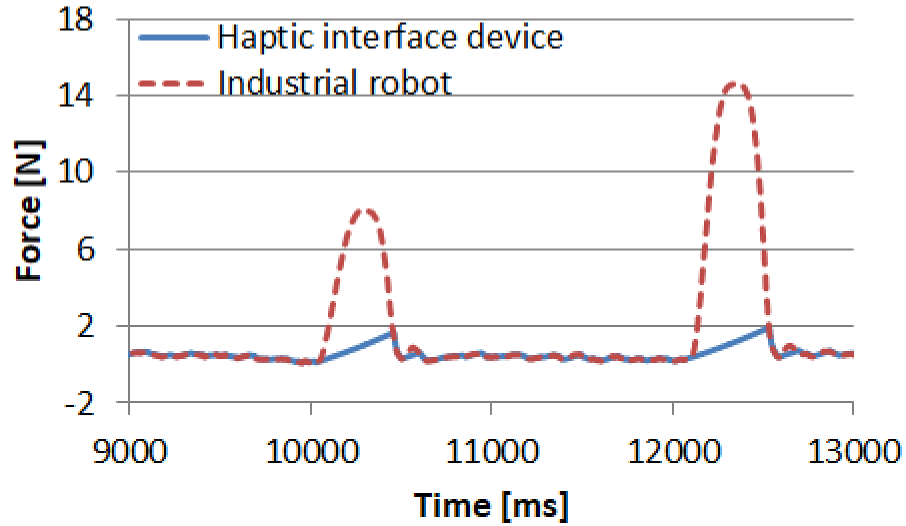
(c) Switching control

Force in soft tennis ball case

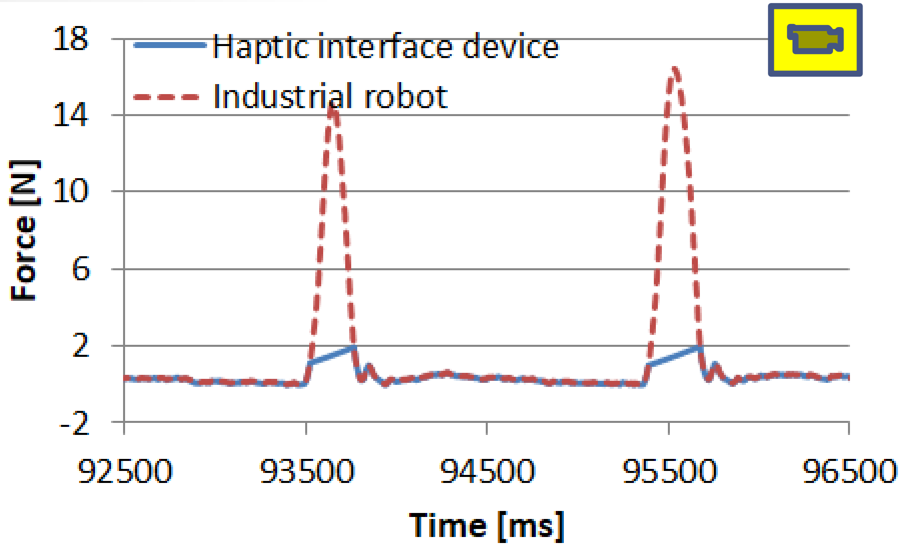
Experiment Results (2/2)



(a) Stabilization control by viscosity



(b) Reaction force control upon hitting



(c) Switching control

Force in hard tennis ball case

Conclusion

We investigated the effect of switching control by comparing with stabilization control by viscosity and reaction force control upon hitting for a remote robot system with haptics by experiment.

Switching control is the most effective among the three types of control.

Future Work

- Investigation of influences of network delay and packet loss under the switching control
- Experiment with other types of objects (e.g., sponge ball and rubber ball)
- Assessment of softness with switching control and other types of control