Comparison of Stabilization Control for Writing Characters in Remote Robot System with Force Feedback

Ruzhou Ye[1], Yutaka Ishibashi[1], Pingguo Huang[2], Yuichiro Tateiwa[1]

[1]Nagoya Institute of Technology, Japan
[2]Gifu Shotoku Gakuen University, Japan

2021 3rd International Conference on Computer Communication and the Internet (ICCCI) June 25-27, 2021

Outline

- Background
- Previous Work
- Purpose
- Remote Robot System with Force Feedback
- Calculation of Reaction Force and Position
- Experiment Method
- Experimental Results
- Conclusion and Future Work

Background (1/2)

Remote robot systems with force feedback have been actively researched.

It is possible for users to perceive shapes, weights, and softness of remote objects hit/touched by robot arm through a haptic interface device (i.e., force feedback).

⬇

The efficiency and accuracy of operations through a robot are expected to be improved largely.

Background (2/2)

When force information is transmitted over the Internet, which does not guarantee QoS (Quality of Service)

Network delay, delay jitter and packet loss

QoE (Quality of Experience) degradation

Instability phenomena occur

- **Stabilization control**
- **QoS control**

Previous Work (1/3)

*1 P. Huang *et al.*, IEICE Technical Report, CQ2016-125, Mar. 2017.
*2 T. Rikiishi *et al.*, IEICE Technical Report, MVE2017-19, Sep. 2017.

- **Investigated the effect of the stabilization control with filters by experiment in which a user pushes a soft object with a robot arm[*1].**

→ **The control can stabilize the remote robot operation without large dependence on the network delay and delay jitter.**

- **Proposed the stabilization control by viscosity and investigate the effect of the proposed control[*2].**

→ **The stabilization control by viscosity can suppress instability phenomena.**

Previous Work (2/3)

*3 R. Arima *et al*., IEICE Technical Report, CQ2017-98, Jan. 2018.
*4 Q. Qian, *et al*., IEEE TENCON, pp. 32-37, Oct. 2018.

- **Proposed the reaction force control upon hitting and compared the proposed control with stabilization control with filters[*3].**

→ **Clarified which domains (e.g., types of work) the proposed control is applied to effectively.**

- **Made a comparison among the previous three types of stabilization control and the switching control by pushing objects (balls) with different softness by a metal rod attached to the robot arm[*4].**

→ **The switching control is the most effective for soft objects, and the stabilization control with filters is the best for hard objects.**

Previous Work (3/3)

*5 E. Taguchi *et al*., IJMERR, vol. 9, no. 1, pp. 87-92, Jan. 2020.

- **Cooperative work of carrying an object together between two robots is handled, and the previous three types of stabilization control are compared by experiment[*5].**

The stabilization control with filters is the most effective.

◆ **The best stabilization control depends on types of work.**

Purpose

This work

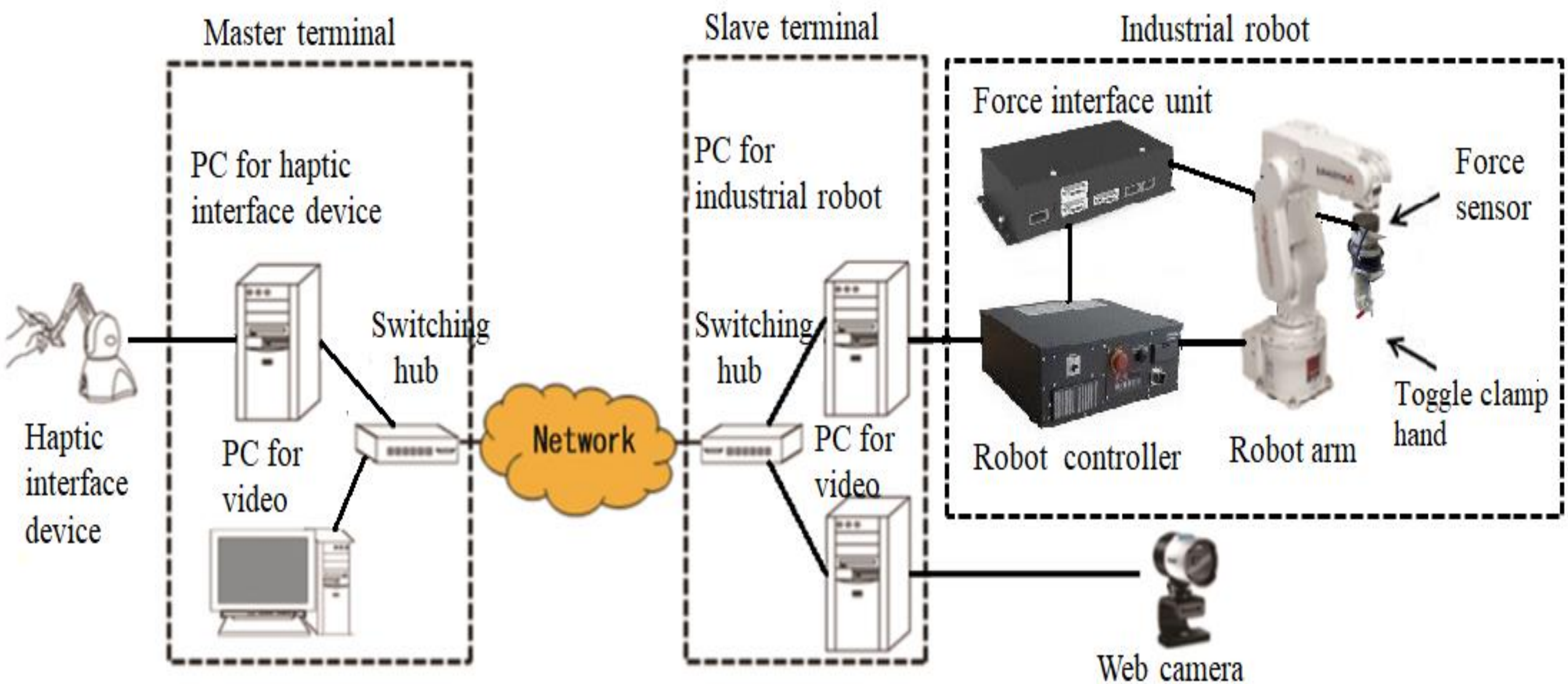
- **Examine effects of the three types of control by writing characters.**

  Easy for confirmation

- **Make a comparison among the three to obtain the best stabilization control.**

- **Examine the influences of network delay on writing characters.**

Remote Robot System with Force Feedback



Calculation of Reaction Force

*6 K. Suzuki *et al.*, IEICE Technical Report, CQ2015-42, Sep. 2015.

Reaction Force Outputted at Master Terminal

$$\boldsymbol{F}_t^{(\mathrm{m})} = K_{\mathrm{scale}}^{(\mathrm{F})} \boldsymbol{F}_{t-1}^{(\mathrm{s})}$$

- $\boldsymbol{F}_t^{(\mathrm{m})}$ **: Reaction force outputted at master terminal at time t ($t \geq 1$)**
- $\boldsymbol{F}_t^{(\mathrm{s})}$ **: Force received from slave terminal at time t**
- $K_{\mathrm{scale}}^{(\mathrm{F})}$ **: Mapping scale about force between industrial robot and haptic interface device**

($K_{\mathrm{scale}}^{(\mathrm{F})} = 0.25$ **[*6]**)

Calculation of Position

Position of Robot

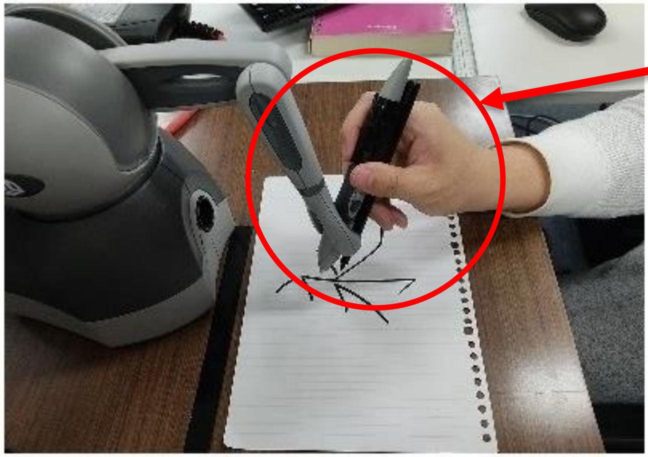
$$\boldsymbol{S}_t = K_{\text{scale}}^{(\text{S})} \boldsymbol{M}_{t-1}$$

- $\boldsymbol{S}_t$ **: Position vector of industrial robot at time *t* (*t* ≥ 1)**
- $\boldsymbol{M}_t$ **: Position vector of haptic interface device at time *t***
- $K_{\text{scale}}^{(\text{S})}$**: Mapping scale about work space**

Experiment Method (1/3)

*6 K. Suzuki *et al*., IEICE Technical Report, CQ2015-42, Sep. 2015.

- **Two types of work (writing with pen and without pen [*6] at the haptic interface device, robot always has pen)**
- **Two different pens (ink brush and ballpoint pen)**
- **Three different types of stabilization control**
  - Reaction force control upon hitting
  - Stabilization control by viscosity
  - Stabilization control with filters
  - No control

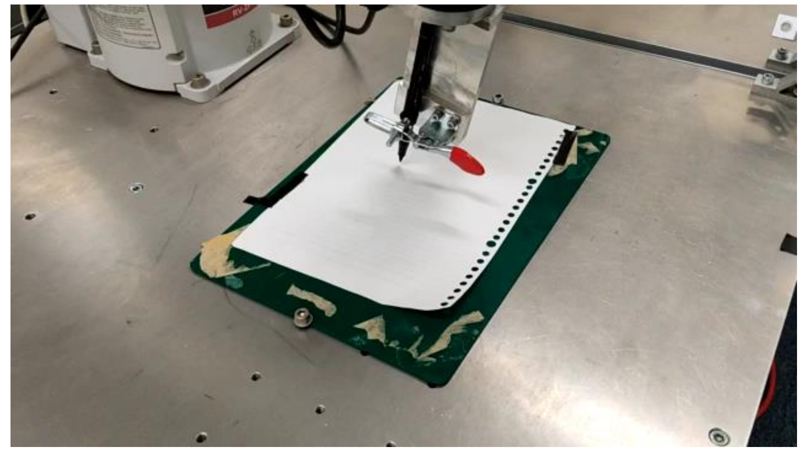


pen

Writing with pen

Writing without pen

Experiment Method (2/3)

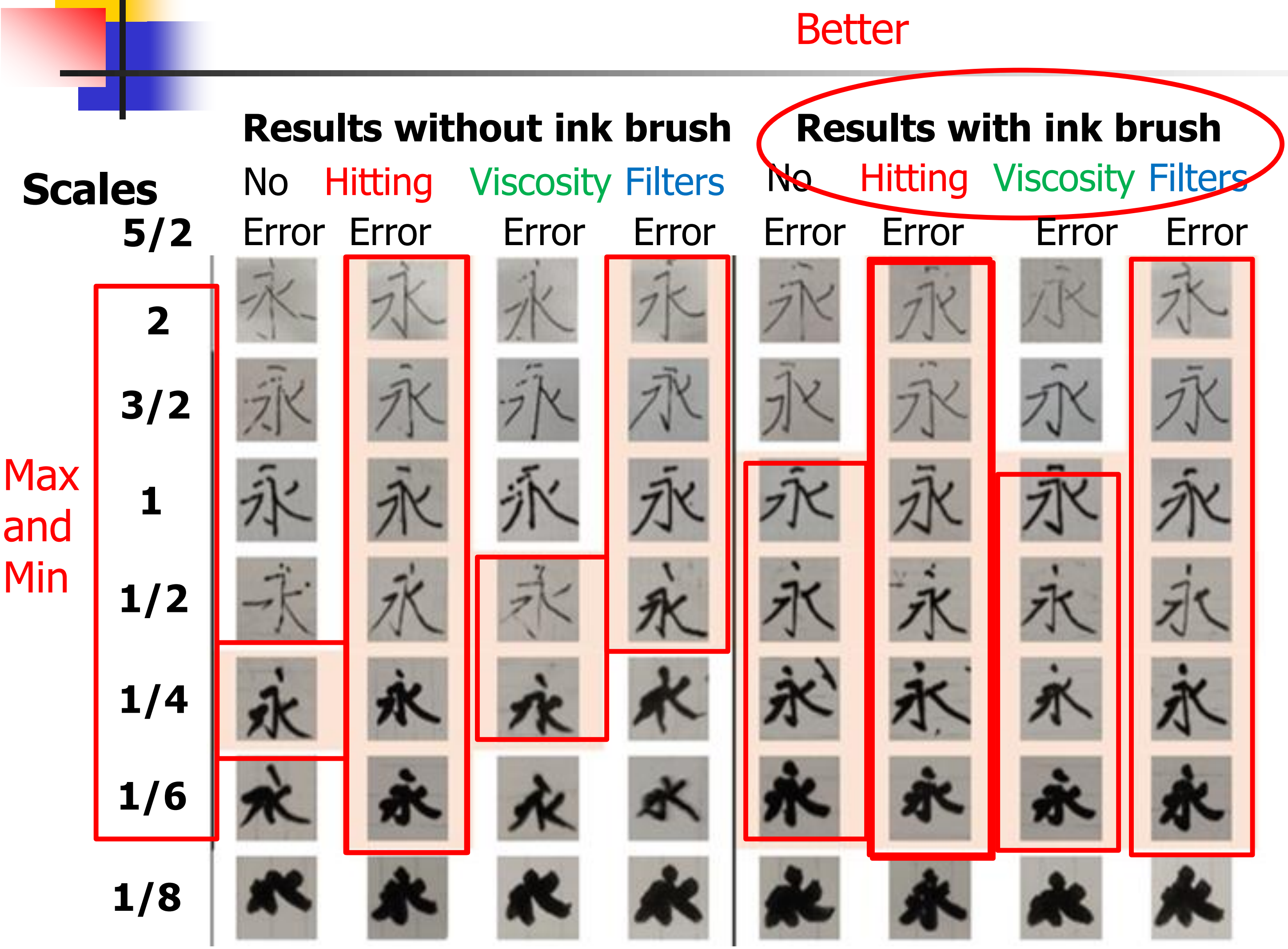


Demo video (without ink brush, $K_{\mathrm{scale}}^{(S)}$=1/2)

Experiment Method (3/3)

- **Wrote the character "永".**
- **Produced a constant delay (called the *additional delay*) for each packet transmitted between the master and slave terminal.**
- **Examined the influence of character size by changing the value of $K_{\mathrm{scale}}^{(\mathrm{S})}$.**
- **Compared among the three types of stabilization control.**
- **Investigated the influence of the network delay under the best stabilization control.**

Experimental Results (1/3)



- No control
- Reaction force control upon hitting
- Stabilization control by viscosity
- Stabilization control with filters

Additional delay=0 ms

The reaction force control upon hitting is the most effective

Experimental Results (2/3)

Results of reaction force control upon hitting (best)

Different *additional delays* and scales

Without ink brush **With ink brush**

Max:2 Min1/6 Max:2 Min1/6

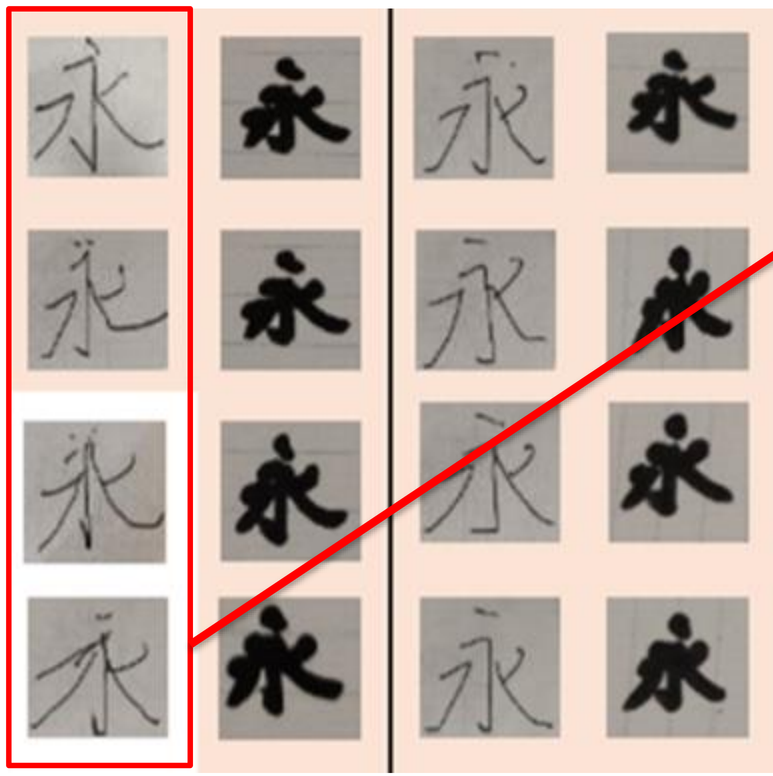
Additional delays

0 ms

100 ms

300 ms

500 ms



As the additional delay increased:

- **Characters became worse**
- **Operation becomes more difficult.**

Conclusion and Future Work

Conclusion

- We investigated the effects of the three types of stabilization control in the remote robot system and made a comparison among them.
- We examined the influence of the network delay.

⬇

- ➢ The reaction force control upon hitting is the most effective.
- ➢ The operation becomes more difficult as the network delay increases.

Future Work

- Deal with other types of cooperative work under the stabilization control.