Effects of Robot Position Control Using Force Information in Remote Robot Systems with Force Feedback

Comparison between Human-Robot and Robot-Robot Cases

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Outline

- Background
- Problem and Purpose
- Remote Robot Control Systems with Force Feedback
- Cooperative work
- Robot Position Control Using Force Information
- Experiment Method
- Experimental Results
- Conclusions and Future Study

Background (1/3)

Remote robot systems with force feedback have actively been studied.

It is possible for users to feel the shape, softness, surface smoothness, and weight of a remote object by using haptic interface device (i.e., force feedback).

The efficiency and accuracy of cooperative work are expected to be largely improved.

Background (2/3)

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

Network delay, delay jitter and packet loss

- **Degradation of QoE (Quality of Experience)**
- **Instability phenomena**

QoS control and stabilization control

Background (3/3)

Robots should outperform or behave generally like humans.

It is necessary to make a comparison between humans and robots.

The quantitative relationships between humans and robots have not been sufficiently clarified so far.

Problem

*1 S. Ishikawa *et al.*, Proc. WSCE, Dec. 2019.

Previous Study*1

- Cooperative work (carrying an object together) was performed under the robot position control using force information.
- The robot position is adjusted to reduce the force applied to the object under the control.

  - ✓ The optimal value of position adjustment is obtained.
  - ✓ The force applied to the object becomes small at the optimal value.

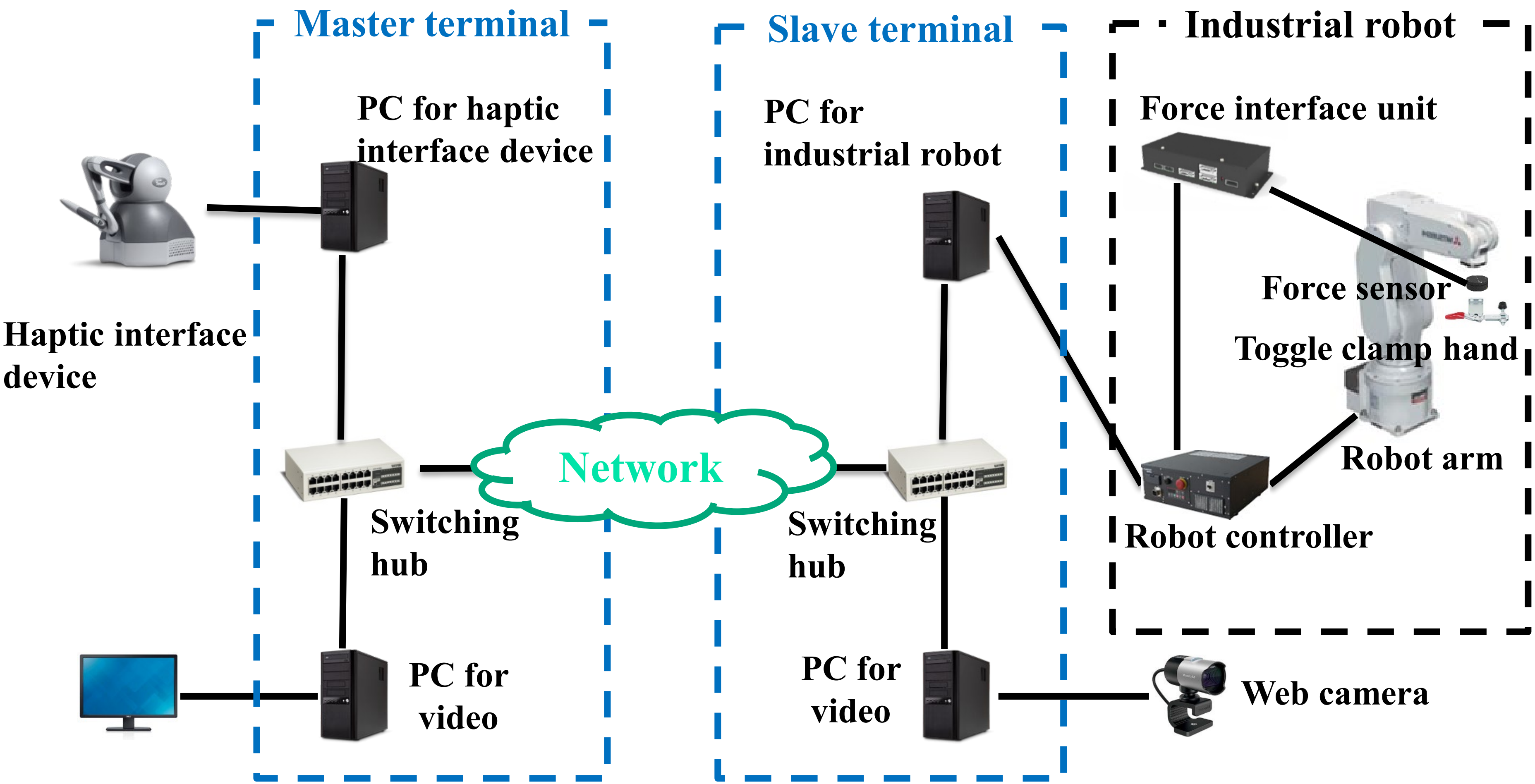
The comparison between humans and robots has not been made sufficiently so far.

Purpose

This Study

- We perform cooperative work (carrying object together) under the robot position control using force information.
  - ✓ Between human and robot (*human-robot case*)
  - ✓ Between two robots (*robot-robot case*)
- We compare the force applied to the object for the work between the two cases.
- In the robot-robot case, we also handle the following two cases.
  - ✓ Case in which the control is carried out in both systems
  - ✓ Case in which the control is performed in only one system

Remote Robot System with Force Feedback

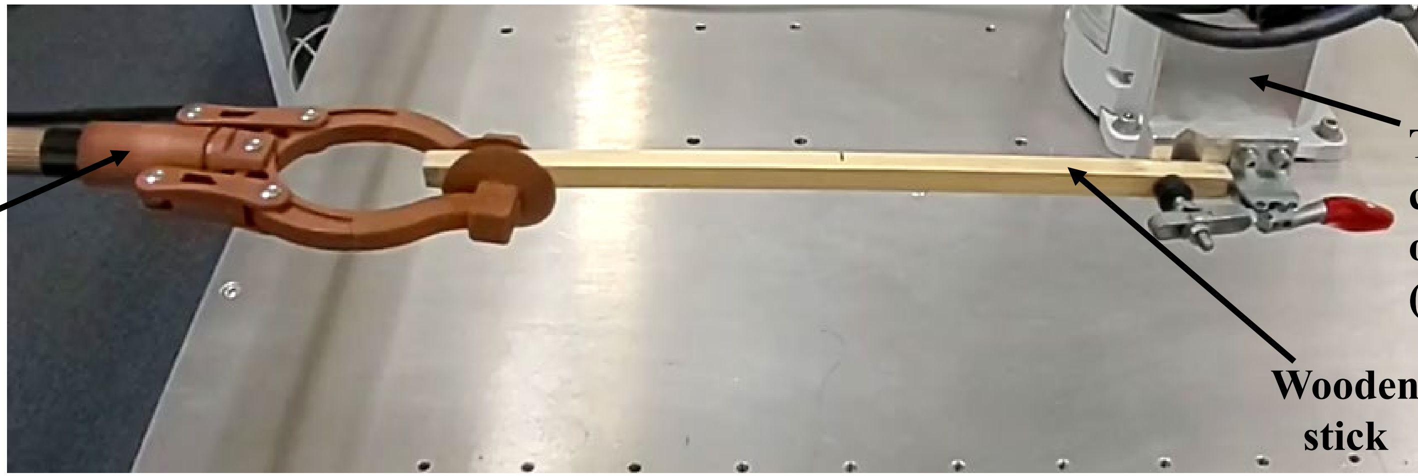


We use two systems in the robot-robot case.

Cooperative Work

*2 P. Huang *et al.*, IJCNS, July 2019.

Reacher (human)



Toggle clamp hand of system 1 (robot)

Slave terminal (human-robot case)

- **We handle cooperative work in which a wooden stick is carried out together in the human-robot and robot-robot cases.**
- **To avoid instability phenomena (vibrations), we carry out the stabilization control with filter[*2] and disable the movement of each robot arm in the left-right and up-down directions (y and z axes) for each system.**

Robot Position Control Using Force Information[*3] (1/2)

*3 Y. Ishibashi *et al.*, Proc. ICCAR, Apr. 2019.

We move the robot arm in the direction where the force applied to the stick is reduced as follows:

$$\widehat{\boldsymbol{S}_t} = \boldsymbol{S}_t + \boldsymbol{P}$$

$\widehat{\boldsymbol{S}_t}$: **New position vector of robot arm at time** $t(> 0)$

$\boldsymbol{S}_t$: **Position vector of robot arm calculated by haptic interface device at time** $t(> 0)$

$\boldsymbol{P}$: **Position adjustment vector**

Robot Position Control Using Force Information (2/2)

When a wooden stick is held by two robot arms, we move the one robot arm by *P*, and measure the force applied to the stick[*4].

$$P_x = a_x F_x$$

P_x: **Movement distance of the robot arm at x axis**

F_x: **Force vector sensed by force sensor at x axis**

a_x: **Function of length l of the wooden stick [*1]**

$$a_x = 4.82 \times 10^{-2} l - 1.16$$

We can calculate the difference in the position vector between the two robot arms from the force applied to the stick with length of l [cm].

***1 S. Ishikawa *et al.*, Proc. WSCE, Dec. 2019.**
***4 Q. Qian *et al.*, Proc. ICCC, Dec. 2018.**

Experiment Method (1/4)

- **We conducted cooperative work as carrying the stick together in three cases:**
  - **Human-robot case**
  - **Robot-robot case when the control is carried out in both systems**
  - **Robot-robot case when the control is carried out in only one system**

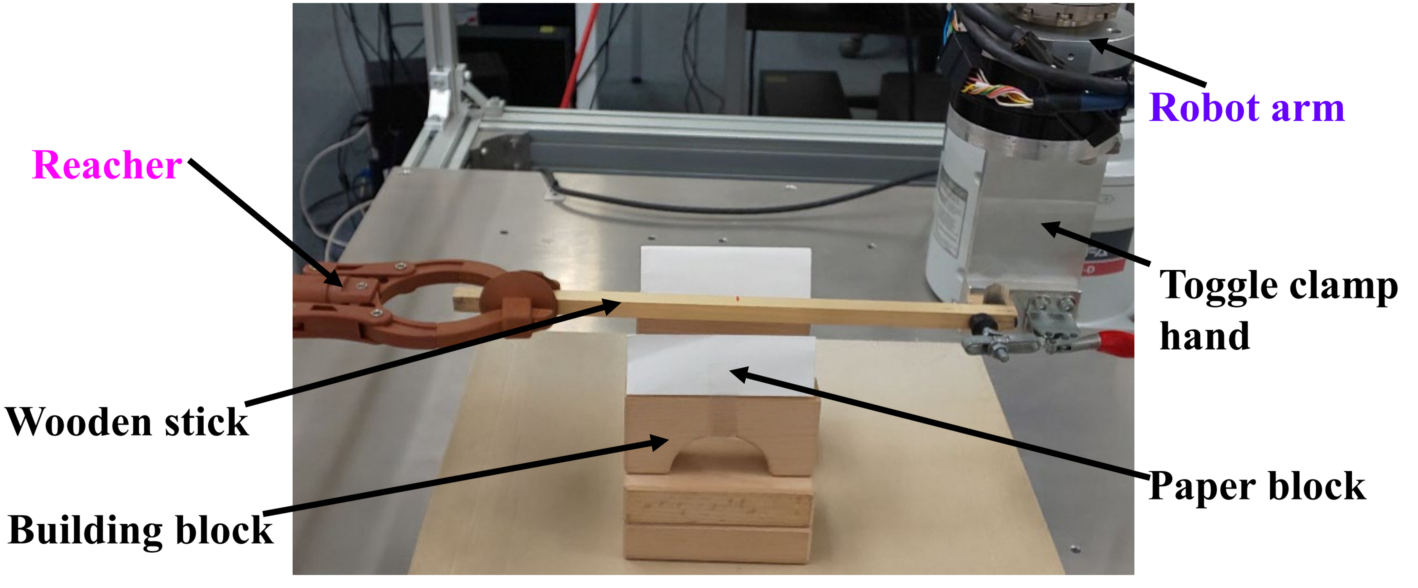
- **Used wooden stick:**
  1 cm × 1 cm × 30 cm **(height × width × length)**

- **To move the stick at almost the same, building blocks and paper blocks were piled up ahead and behind the initial position of the stick.**

Experiment Method (2/4)

Human-robot case

- The **human** used a reacher to carry the stick.
- The robot arm followed **automatically** the human under the robot position control using force information.

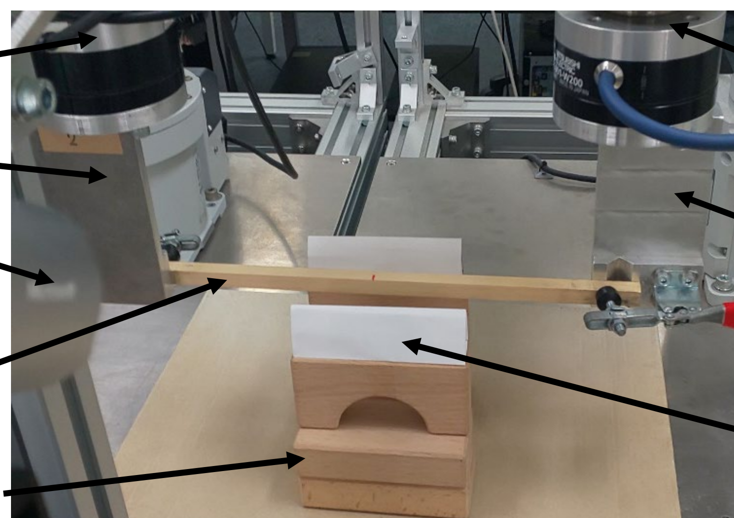


Slave terminals

Experiment Method (3/4)

Robot-robot case

- **The user remotely operated the robot arm (in *system 1*) manually with the haptic interface device.**
- **The other robot arm (in *system 2*) followed automatically the robot arm in system 1 under the robot position control using force information.**



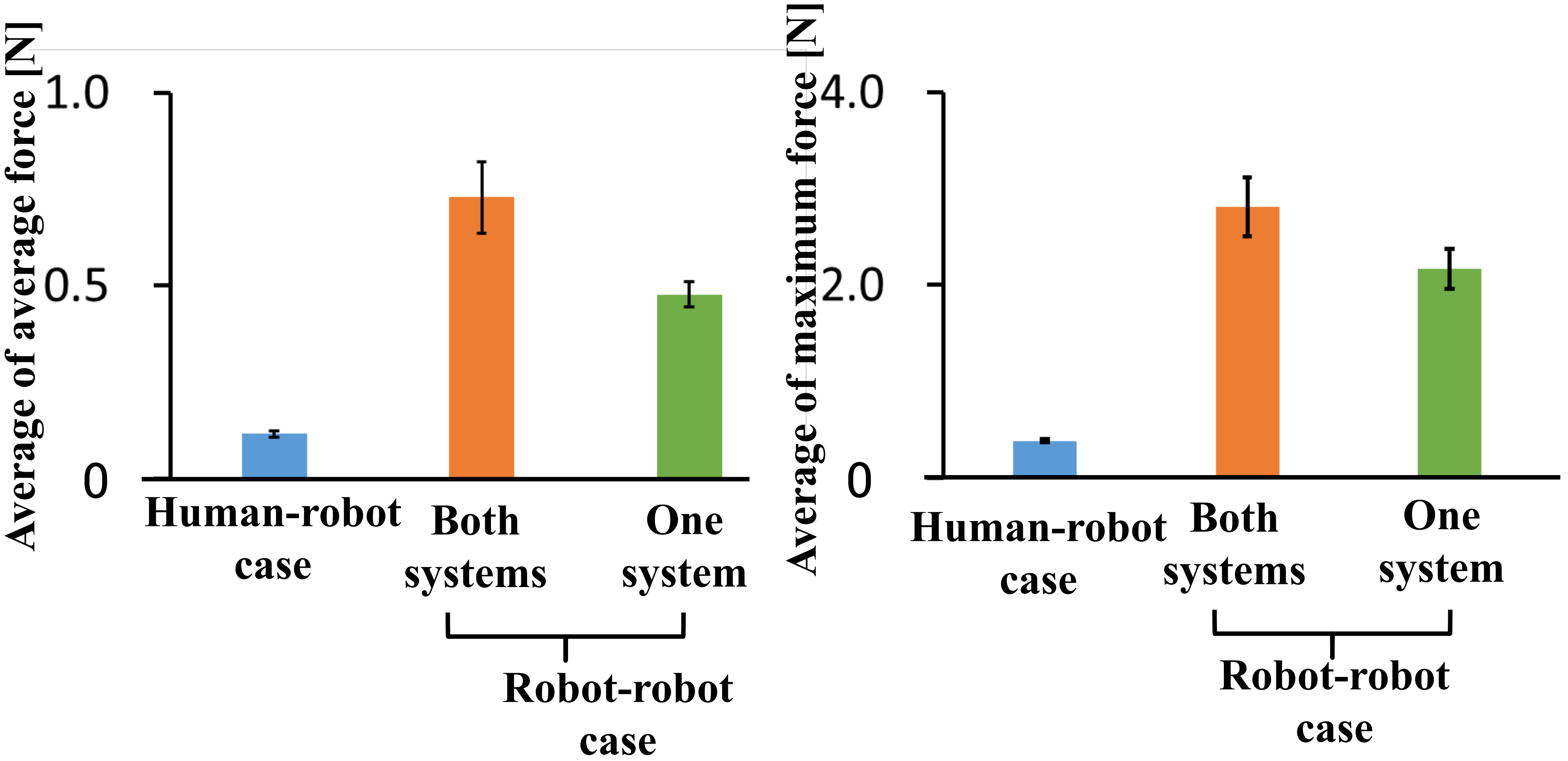
Slave terminals

Experiment Method (4/4)

- **In three cases, the work was performed 10 times in random order.**
- **We measured the force applied to the stick during the work and obtained the average and maximum of the 10 times (called *the average of average force* and *the average of maximum force*).**

Experimental Results

I: 95% confidence interval



Conclusion and Future Study

Conclusion

- We compared the effects of the robot position control using force information between human-robot and robot-robot cases.

➡ The force applied to the object in the human-robot case is smaller than that in the robot-robot case.

Future Study

- Use other kinds of sticks with different lengths and materials
- Improve the flexibility of robots and suppress the force applied to the stick in robot-robot case