Effect of Robot Position Control Using Force Information

Human versus Robot with Force Sensor

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Outline

- **Background**
- **Problem and Purpose**
- **Remote Robot System with Force Feedback**
- **Master-Slave System**
- **Robot Position Control Using Force Feedback**
- **Experiment Method**
- **Experimental Results**
- **Conclusion and Future Work**

Background (1/2)

Remote robot systems with force feedback have actively researched.

Force feedback makes users feel information such as the shape, hardness, and weight of each object touched with robot arms by using haptic interface devices.

- **It is possible to perform operation more accurately.**
- **We can perform various types of collaborative work among multiple remote robot systems with force feedback.**

Background (2/2)

When force information is transmitted over a network which does not guarantee the quality of service (QoS) like the Internet

Network delay, delay jitter, and packet loss

Quality of Experience (QoE) may seriously be damaged.

QoS control & stabilization control

Problem

*1 Y. Hara *et al.* , NetGames, Nov. 2012.

*2 K. Kanaishi *et al.,* ICTCE, Nov. 2019.

Previous study

Cooperative work of carrying an object by using the two robot systems with master-slave relation to the adaptive Δ-causality control*1, which adjusts the output timing of position information between the systems, as QoS control*2

Problem

Communication between the two robots is sometimes difficult, for example, when a disaster happens. In such a case, because the control cannot be exerted, we need other techniques (e.g., robot position control using force information).

Purpose (1/2)

To move a robot arm flexibly and delicately like a human so as not to apply too large force to an object carried together by the two robot arms

Making a comparison between human and robot is needed.

However, such a comparison has not been carried out sufficiently so far.

Purpose (2/2)

This study

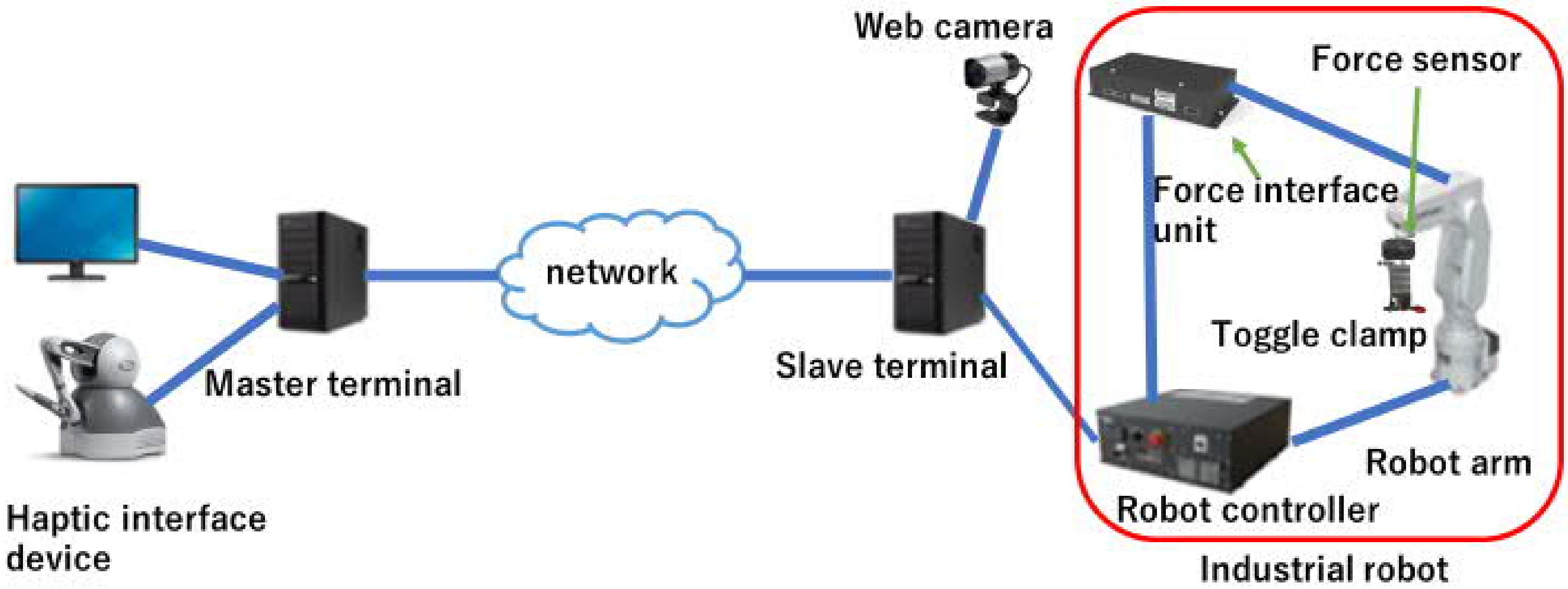
・Enhancement of the robot position control using force information, which was previously proposed, to follow the other robot arm automatically.

・Comparison between the following two cases:

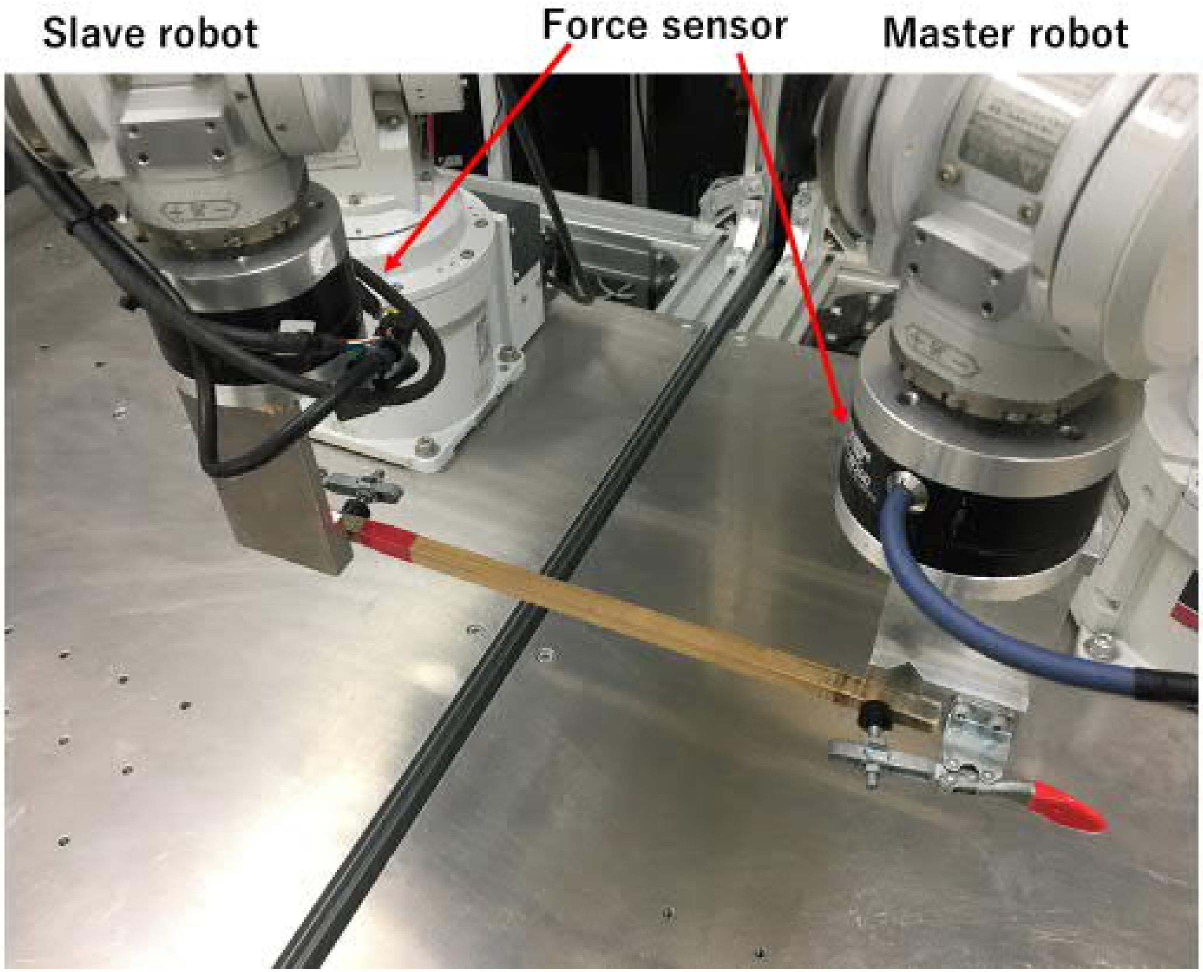
- ✓ **Human-robot case**: A human and a robot arm carry the object together.
- ✓ **Robot-robot case**: The two robot arms carry the object together.

・Examine the influence of the movement velocity of the object on the control.

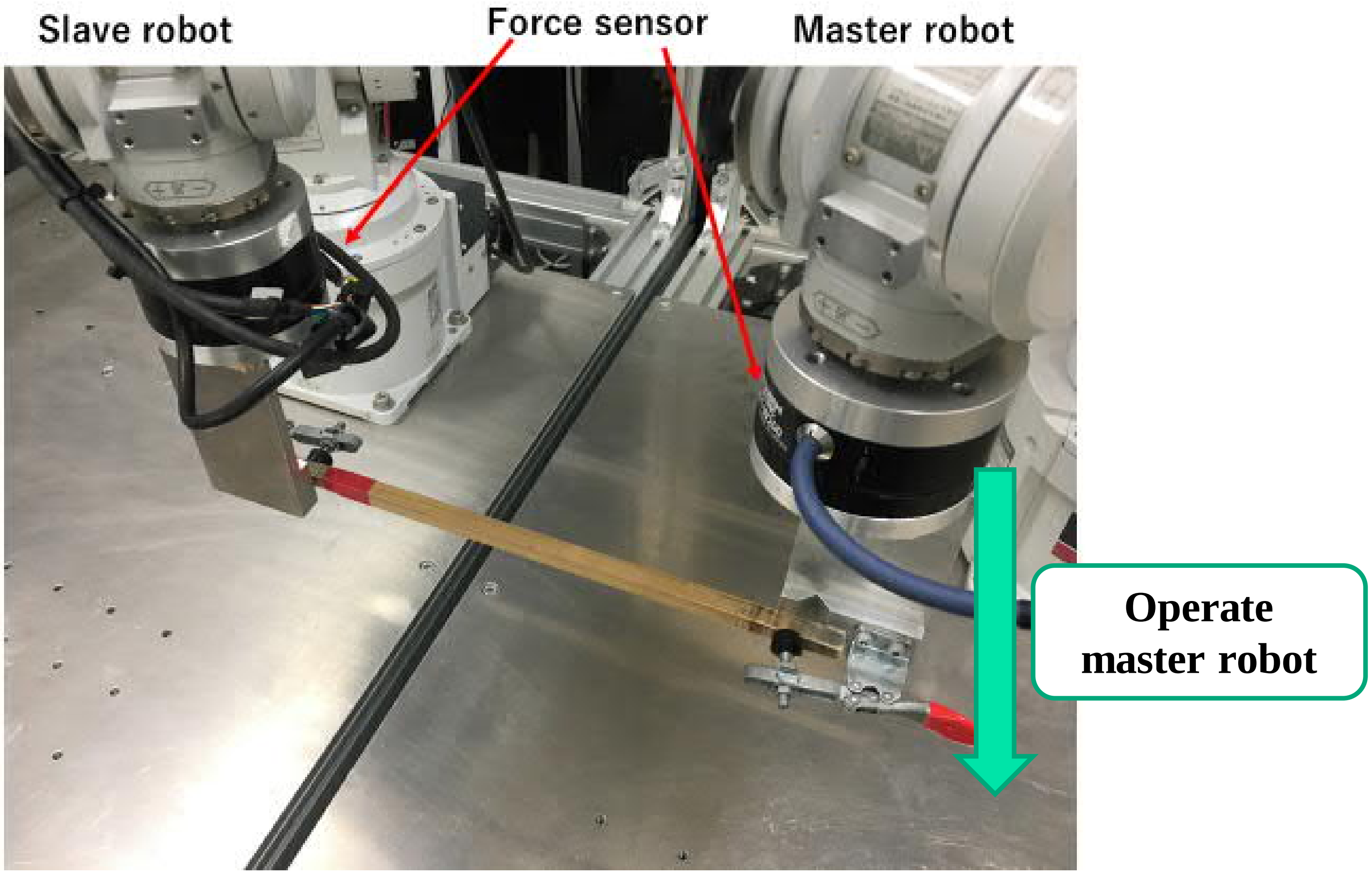
Remote Robot System with Force Feedback



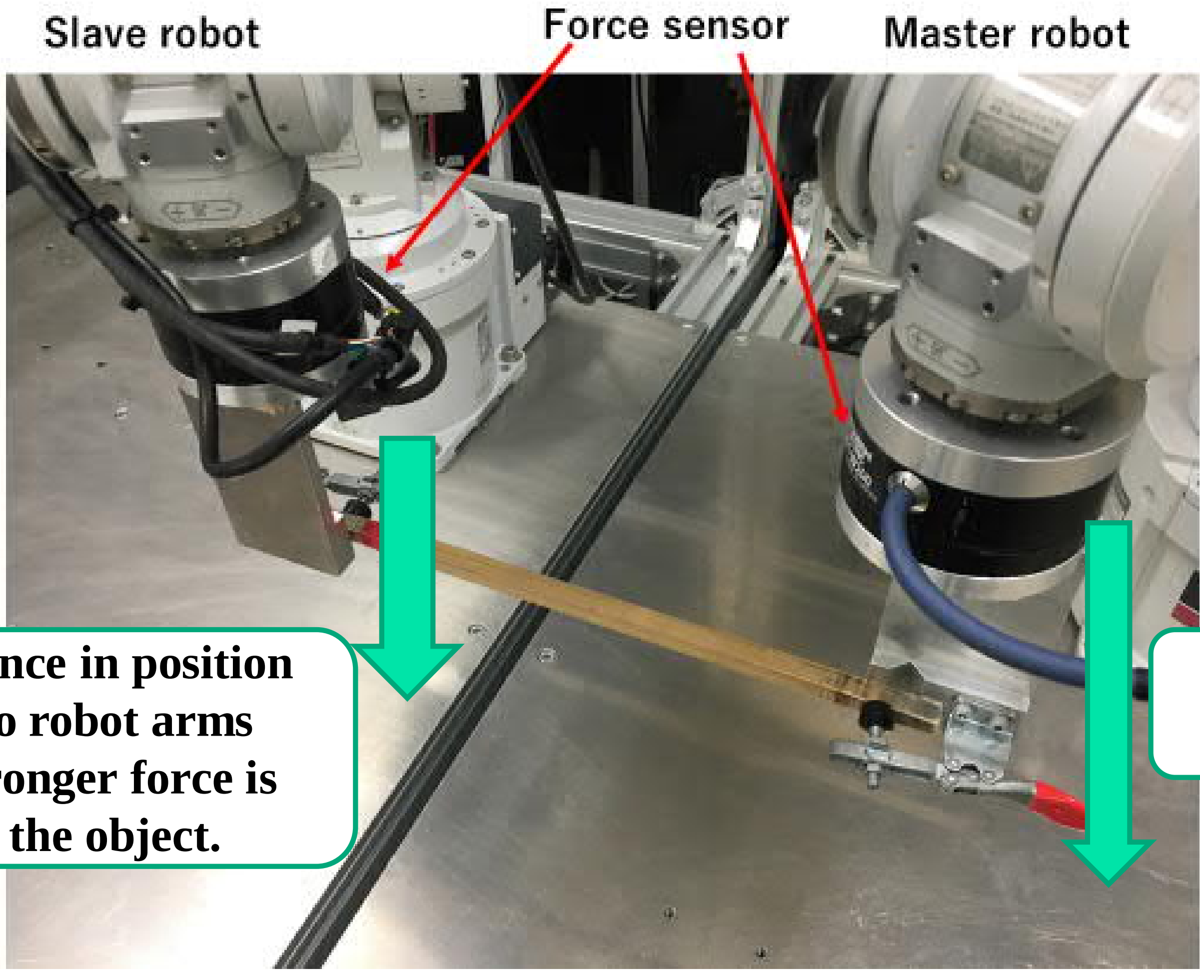
Master-Slave System



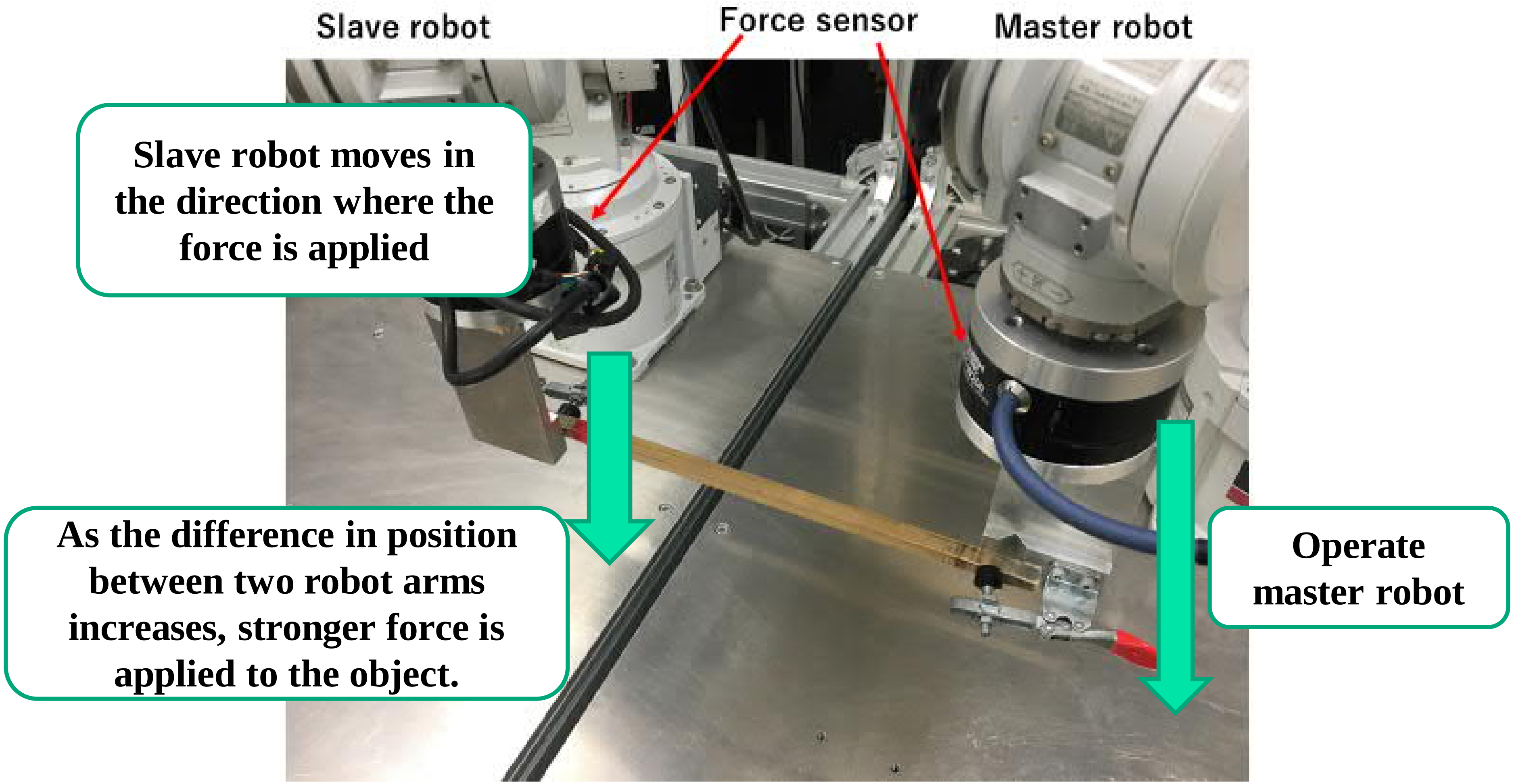
Master-Slave System



Master-Slave System



Master-Slave System



Robot Position Control Using Force Information

$$\boldsymbol{P}_t = K\,\boldsymbol{F}_t$$

$\boldsymbol{P}_t$: Position adjustment vector of robot arm at time *t* (ms)

$\boldsymbol{F}_t$: Force applied the object at time *t* (ms)

K : Coefficient multiplied by the force applied to the object

The original control finely adjusts the robot position in the direction of reducing the force applied to the object.

Enhancement

⇨ **By changing the value of *K*, we make the slave robot arm follow the master one.**

Enhancement of Robot Position Control Using Force Information

$$\boldsymbol{P}_t = K \boldsymbol{F}_t$$

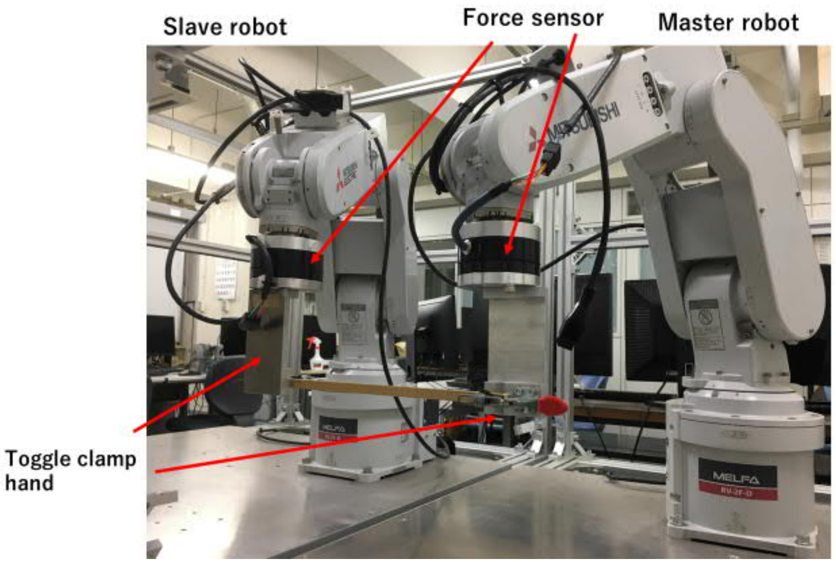
Finding the optimum value of K by a preliminary experiment

Robot-robot case

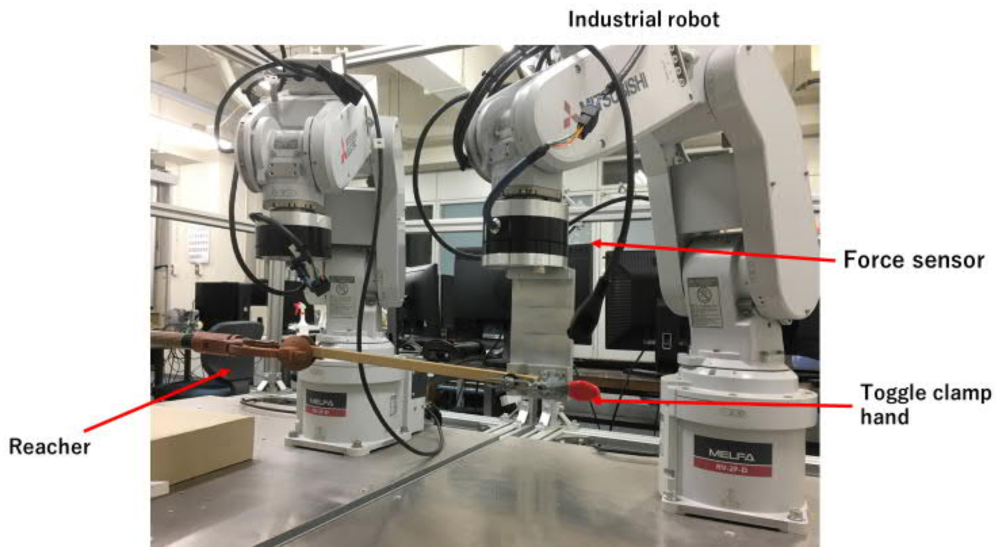
Velocity (mm/sec.)	Optimum value of K
8	3.0
16	2.0
24	2.0
32	1.5

Experiment Method

Cooperative work: Carrying an object (a wooden stick) together in the two cases

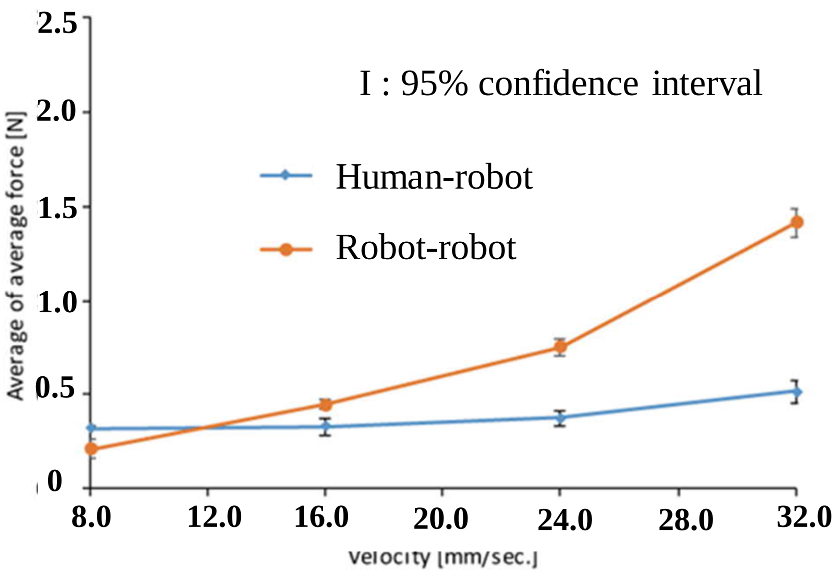


Robot-robot case

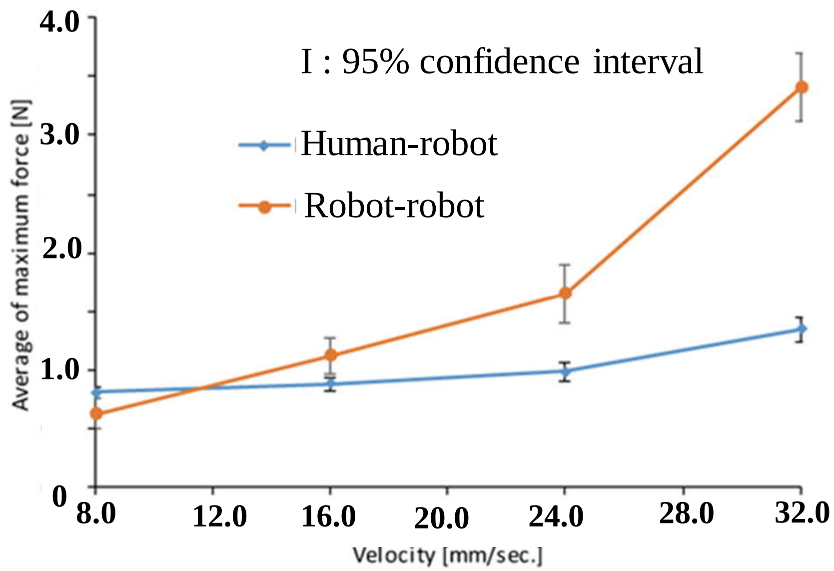


Human-robot case

Experimental Results (1/2)



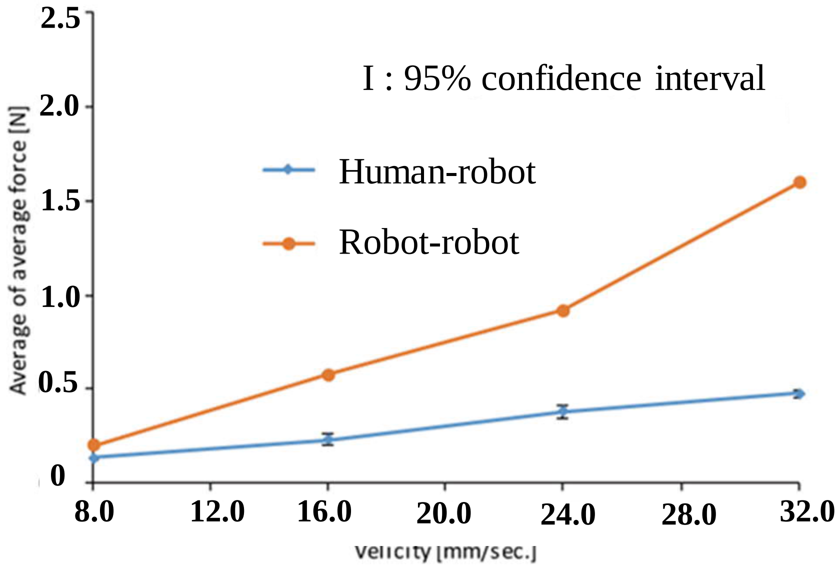
Average of average force



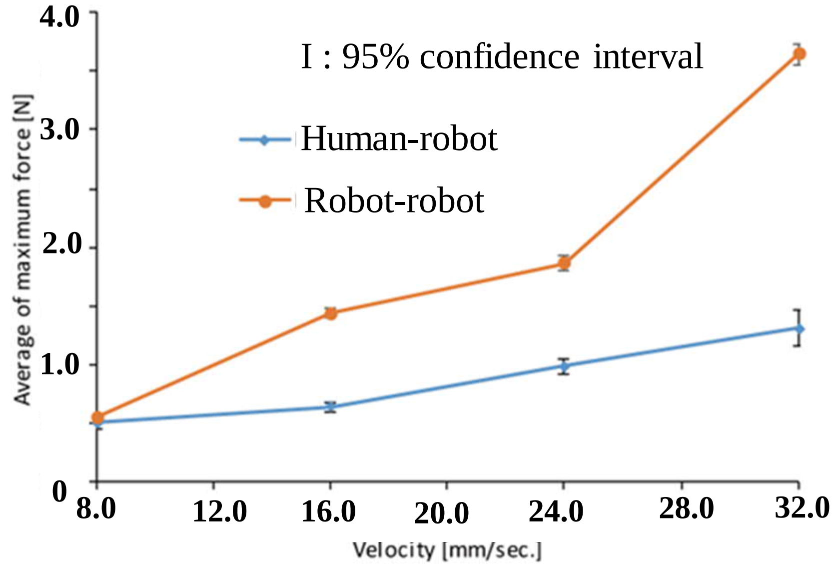
Average of maximum force

Human is slave in human-robot case
(K = 6.1 when the velocity is 8 mm/sec.).

Experimental Results (2/2)



Average of average force



Average of maximum force

Human is master in human-robot case
(K = 6.1 when the velocity is 8 mm/sec.).

Conclusion and Future Work

Conclusion

We made a comparison between the human-robot and robot-robot cases for cooperative work of carrying an object together by using the two remote robot systems with force feedback

・When the velocity is small, the robot-robot case has smaller force applied to the object than the human-robot case.
・As the velocity increases, the force in the robot-robot case becomes much larger than that in the human-robot case.

Future Work

Study how to reduce the force applied to the object in the robot-robot case.