



Cooperative Work among Humans and Robots in Remote Robot Systems with Force Feedback

Comparison between Human-Robot and Robot-Robot Cases

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INTRODUCTION

➤ Background

- ✓ Remote robot systems with force feedback have been actively researched.
- ✓ Various types of cooperative work among multiple remote robot systems with force feedback can be conducted.

High efficiency and accuracy of work are expected.

➤ Problems

Robot should outperform or behave like humans. We need to make a comparison of the efficiency of work performed between a human and a robot (i.e., **human-robot**) and that between two robots (**robot-robot**).

- ✓ Such a comparison has not been made sufficiently so far.
- ✓ The efficiency of work in the human-robot case has not been clarified yet.

➤ This work

- ✓ Handle hand delivery of an object as cooperative work between a human and a moving robot arm of the remote robot system with force feedback
- ✓ Compare the efficiency of the work with that in the cooperative work between a robot arm and a moving robot arm

EXPERIMENT METHOD

➤ Three cases

- ✓ **Human-robot**
(human-robot case)
- ✓ **Robot-robot without control**
(robot-robot case without the position follow-up control)
- ✓ **Robot-robot with control**
(robot-robot case with the position follow-up control)

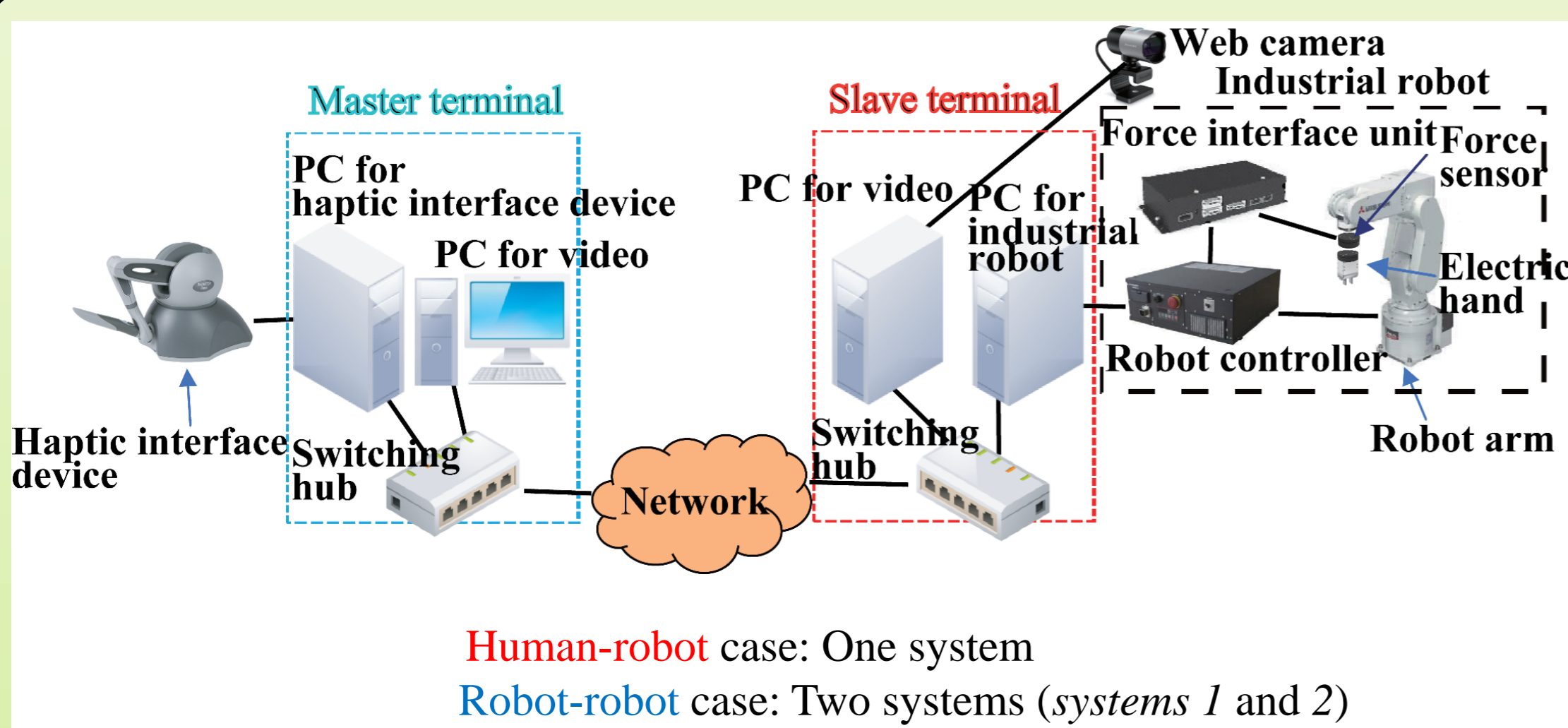
➤ Two types of hand delivery

- ✓ **Work A**
A human or user uses a reacher or operates a robot arm to **receive** a wooden stick of 30 cm from the other robot arm.
- ✓ **Work B**
The human or user uses the reacher or operates the robot arm to **pass** the stick to the other robot arm.

➤ Performance measure

- ✓ **Average time of hand delivery**
The average time from the moment the electric hand or the reacher is closed until the instant the stick is hand-delivered.
- ✓ **Force**
The force in the directions of the x-axis (front-back), y-axis (left-right), and z-axis (up-down) detected by the force sensor.

REMOTE ROBOT SYSTEM with FORCE FEEDBACK



POSITION FOLLOW-UP CONTROL

- ✓ The position follow-up control can be carried out in the robot-robot case.
- ✓ A position near the location of the hand delivery (called the **target position**) is determined from the current position information of the robot arm 1 (i.e., the robot arm of system 1).
- ✓ The robot arm 2 (the robot arm of system 2) is automatically moved to the target position.
- ✓ The hand delivery is performed in combination with automatic and manual operations after robot arm 2 has reached the target position.

CONCLUSION and FUTURE WORK

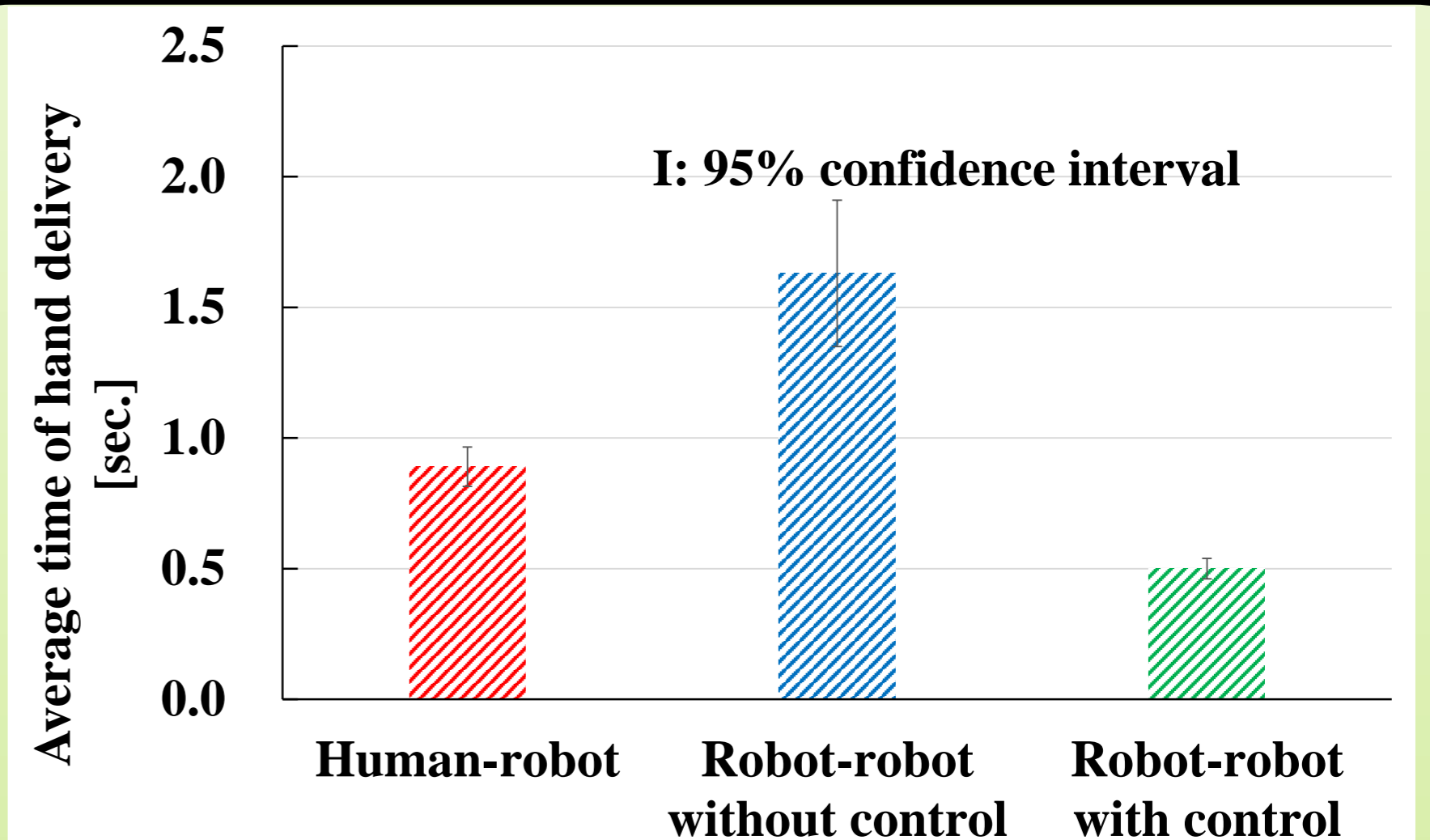
➤ Conclusion

- ✓ The work efficiency can be improved, and the force can greatly be suppressed under the position follow-up control.
- ✓ The force in the robot-robot case with the control is somewhat larger than that in the human-robot case.

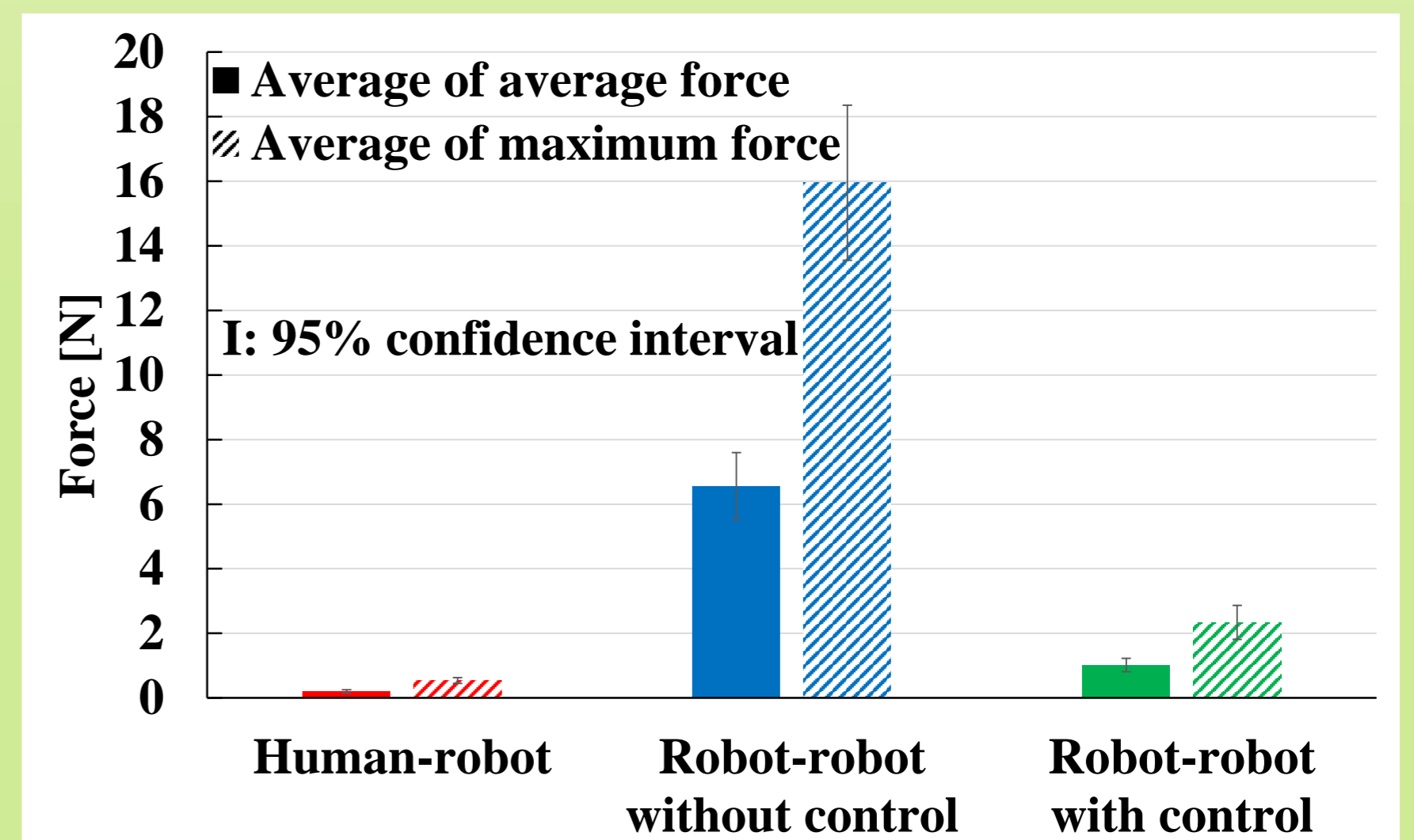
➤ Future work

Suppress the force applied to object when performing the hand delivery in the robot-robot case

EXPERIMENTAL RESULTS



Result 1: Average time of hand delivery in work A.



Result 2: Force of robot arm 1 in x-axis (front-back) direction in work A.

Results of work B are almost the same as those of work A

CONTACT INFORMATION

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