Comparison of Object Movement Methods for Remote Robot Systems with Force Feedback

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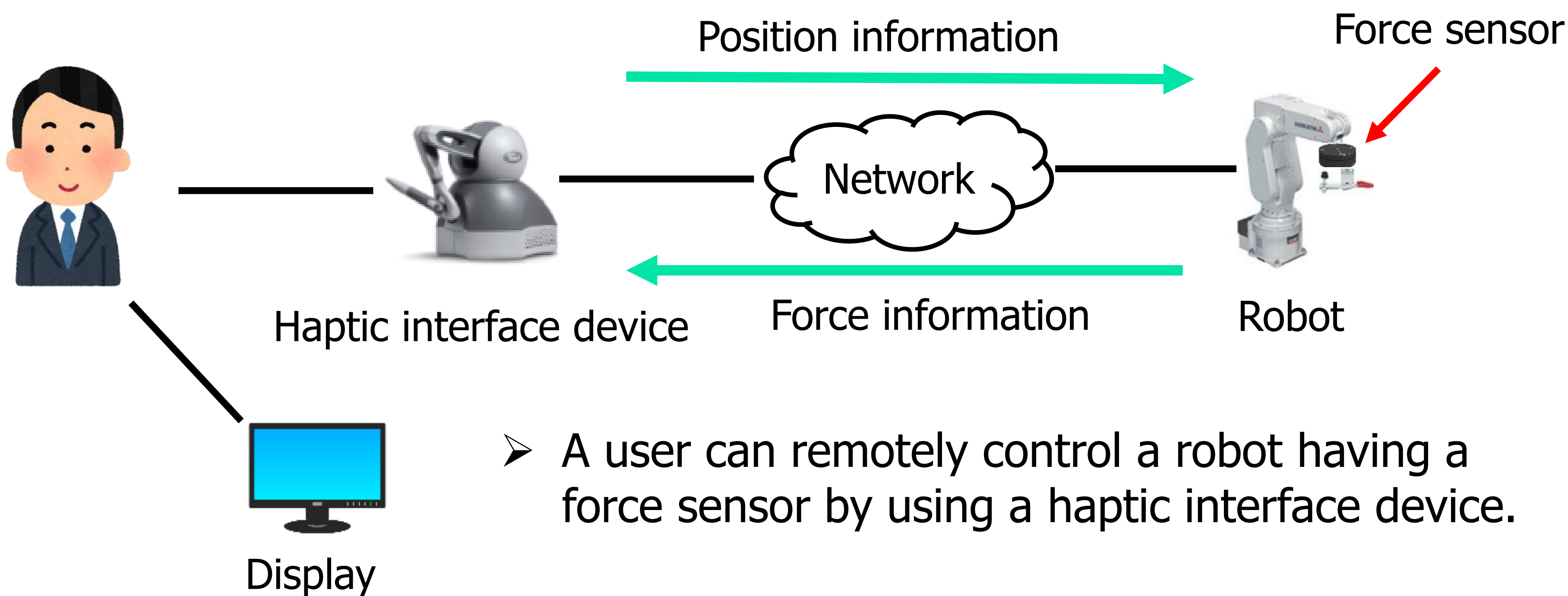
Outline

- Background
- Previous Work
- Purpose of This Work
- Remote Robot Systems with Force Feedback
- Object Movement Methods
- Experiment Method
- Experimental Results
- Conclusion
- Future Work

Background (1/3)

Remote robot systems with force feedback

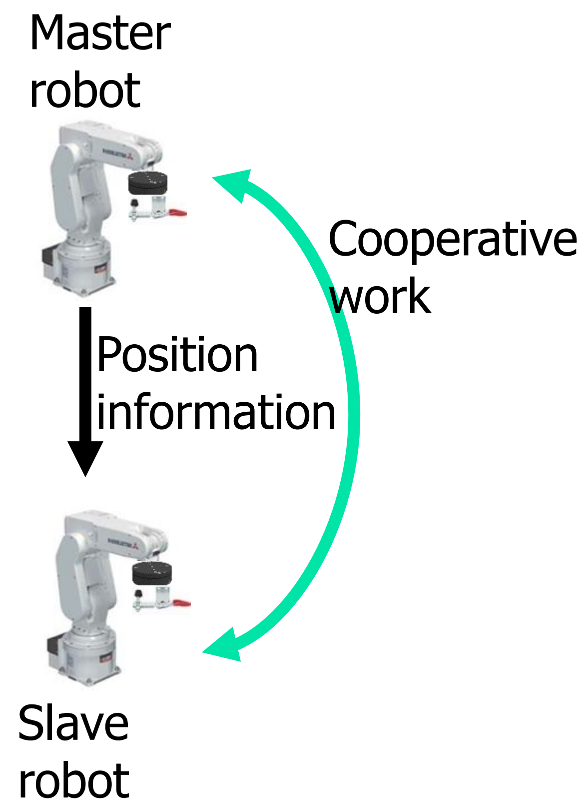


- A user can remotely control a robot having a force sensor by using a haptic interface device.
- It is possible for users to perceive shapes, weights, and softness of remote objects hit/touched by robot arm through haptic interface device (i.e., force feedback).

Background (2/3)

Cooperative work is possible by using multiple remote robot systems.

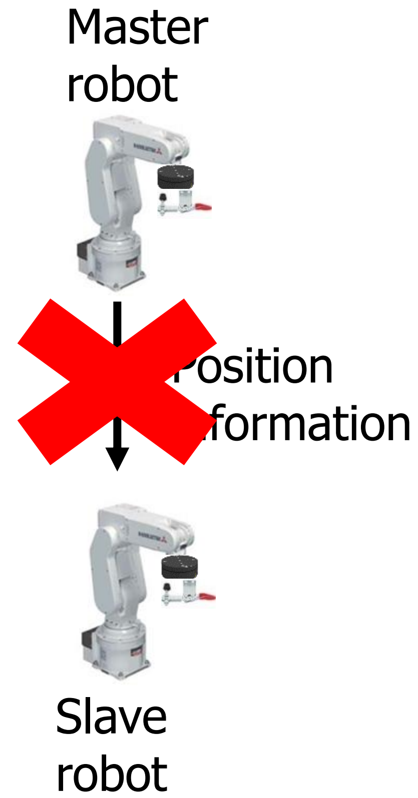
If there is a master-slave relationship between robots, the master robot's position information is transmitted to the slave robots to follow.



Background (3/3)

Network environments are not always good.
Poor network environments may cause various problems.

- Cooperative work between the systems without communication
- Robot movement control using force information



Previous Work

- Cooperative work of carrying an object together between two remote robot systems with force feedback.
- One robot is set to move automatically and the other follows.

Four types of robot movement control using force information

- Position control*1
- Extended position control*2
- Control by exponent*3
- Control by motion equation*4

*1 S. Ishikawa *et al.,* Proc. WSCE. pp. 210-214, Dec. 2019.
*2 S. Ito *et al.,* Proc. ICIET, pp 257-261, Mar 2021.
*3 K. Kanaishi *et al.,* IEICE Technical Report, CQ2021-1, Mar 2021.
*4 Y. Ishibashi *et al.,* Proc. IEEE ICCE-TW. July 2022.

Purpose of This Work

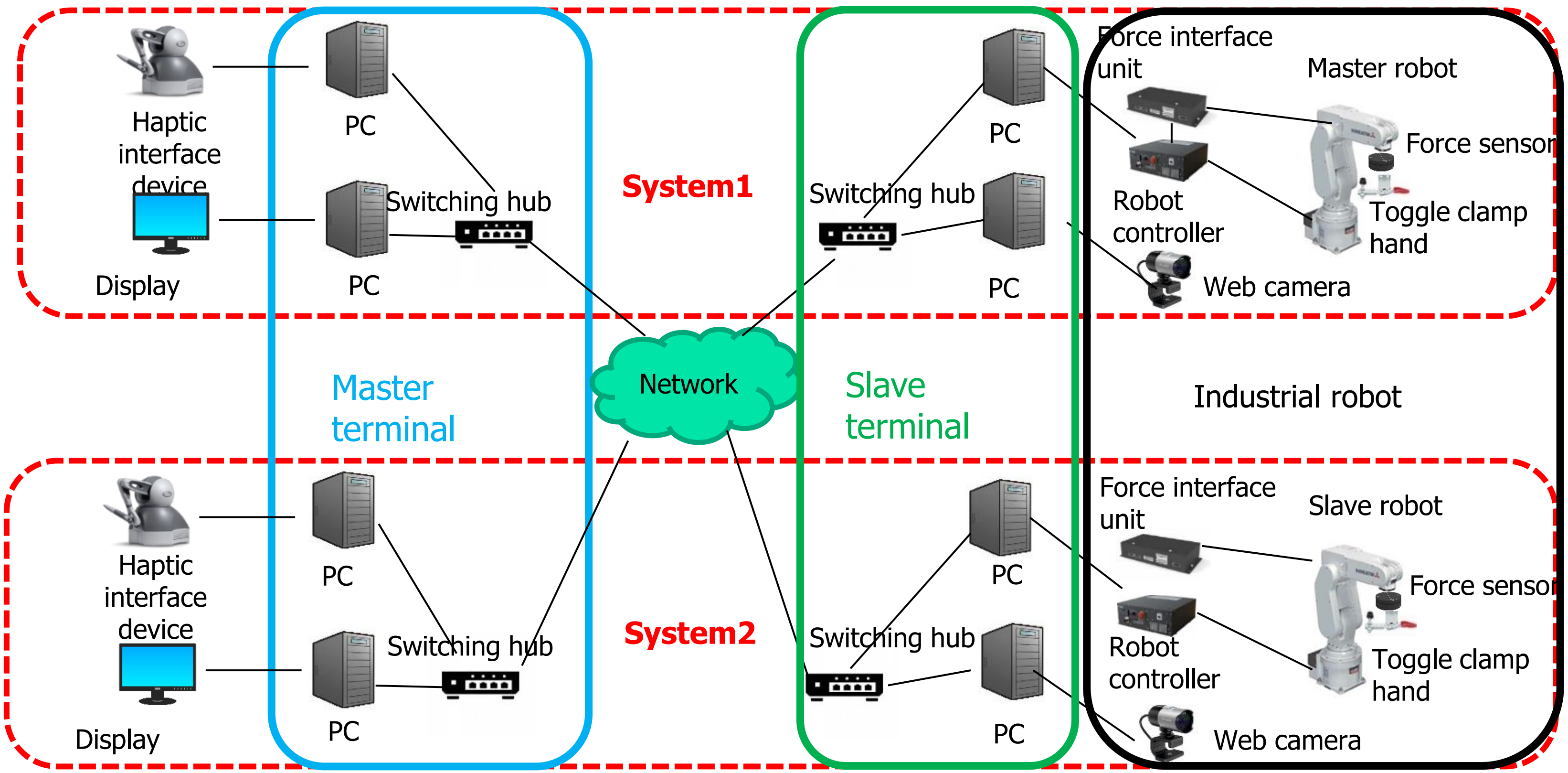
Problems of previous work

The quantitative relationship among the movement methods have not been clarified.

Purpose of this work

We deal with the cooperative work in which carrying the object together, and we compare the four movement methods, remote control by user and human case to clarify their quantitative relations.

Remote Robot Systems with Force Feedback



Object Movement Control (1/4)

*1 S. Ishikawa *et al.,* Proc. WSCE. pp. 210-214, Dec. 2019.

Position control*1

$$\boldsymbol{P}_t = a\,\boldsymbol{F}_t \quad (1)$$

$$a = 1.491 \quad (2)$$

$\boldsymbol{P}_t$: Position adjustment vector
$\boldsymbol{F}_t$: force applied to wooden stick
a : Coefficient (depending on length of wooden stick)

Position control finely adjusts the position of the robot arm in the direction where the force is reduced.

Object Movement Control (2/4)

*2 S. Ito *et al.*, Proc. ICIET, pp 257-261, Mar 2021.

Extended position control*2

$$\boldsymbol{P}_t = K\,\boldsymbol{F}_t \qquad (3)$$

$\boldsymbol{P}_t$: Position adjustment vector
$\boldsymbol{F}_t$: force applied to wooden stick
K: Coefficient (depending on velocity)

Extended position control largely (i.e., not finely) adjusts the position of the robot arm to that of the other robot arm.

Object Movement Control (3/4)

*3 K. Kanaishi *et al.*, IEICE Technical Report, CQ2021-1, Mar 2021.

Control by exponent*3

$$\boldsymbol{P}_t = 20\,v \times (1.01)^n \qquad (4)$$

$\boldsymbol{P}_t$: Position adjustment vector
v: Movement velocity of the robot arm(mm/ms)
n: Number of position adjustments

Control by exponent respond more quickly to sudden position changes by increasing the position change exponentially.

Object Movement Control (4/4)

*4 Y. Ishibashi *et al.*, Proc. IEEE ICCE-TW, July 2022.

Control by motion equation*4

$$\boldsymbol{P}_t = 0.9\,\boldsymbol{P}_{t-1} + 0.279\,\boldsymbol{F}_t \qquad (5)$$

$\boldsymbol{P}_t$: Position adjustment vector
$\boldsymbol{F}_t$: Sensed force

Control by motion equation using motion equation and time and distance formulas is proposed to use force information efficiently.

Experiment Method (1/4)

- Carrying a wooden stick was moved 40 mm forward and 80 mm backward.

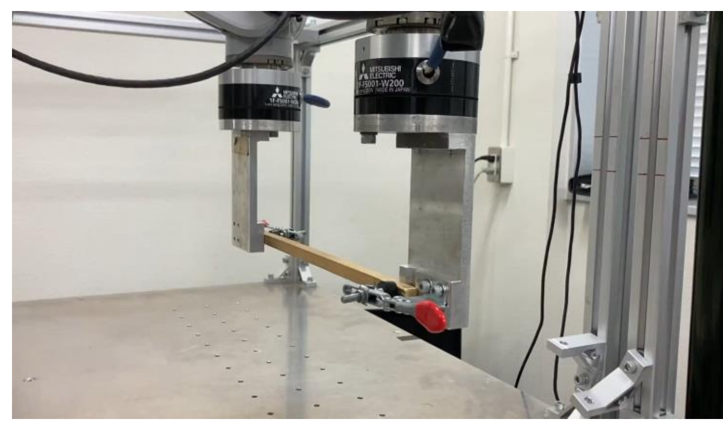
- There are two types of cases: robot-robot case using two robots and human-robot case human instead of one robot.

- One robot is moved automatically that is set to 8 mm/s, 16 mm/s, 24 mm/s, 32 mm/s.

Experiment Method (2/4)

robot-robot case

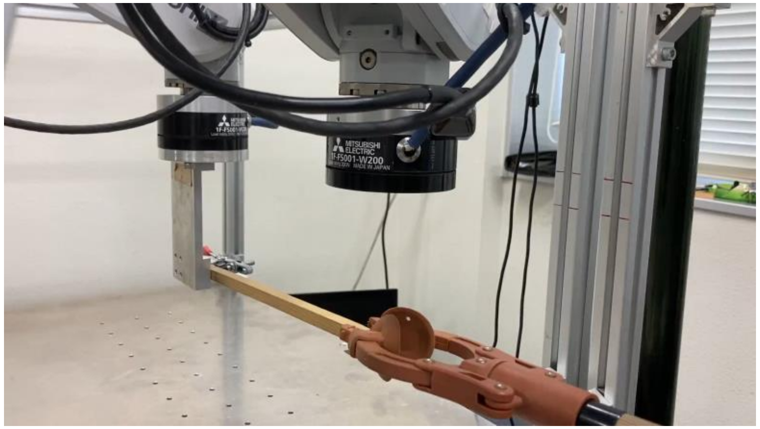
- Two robot arms grasp the wooden stick.
- One robot is set to move automatically.
- The other follows it by movement control or remote control by the haptic interface device.



Experiment Method (3/4)

human-robot case

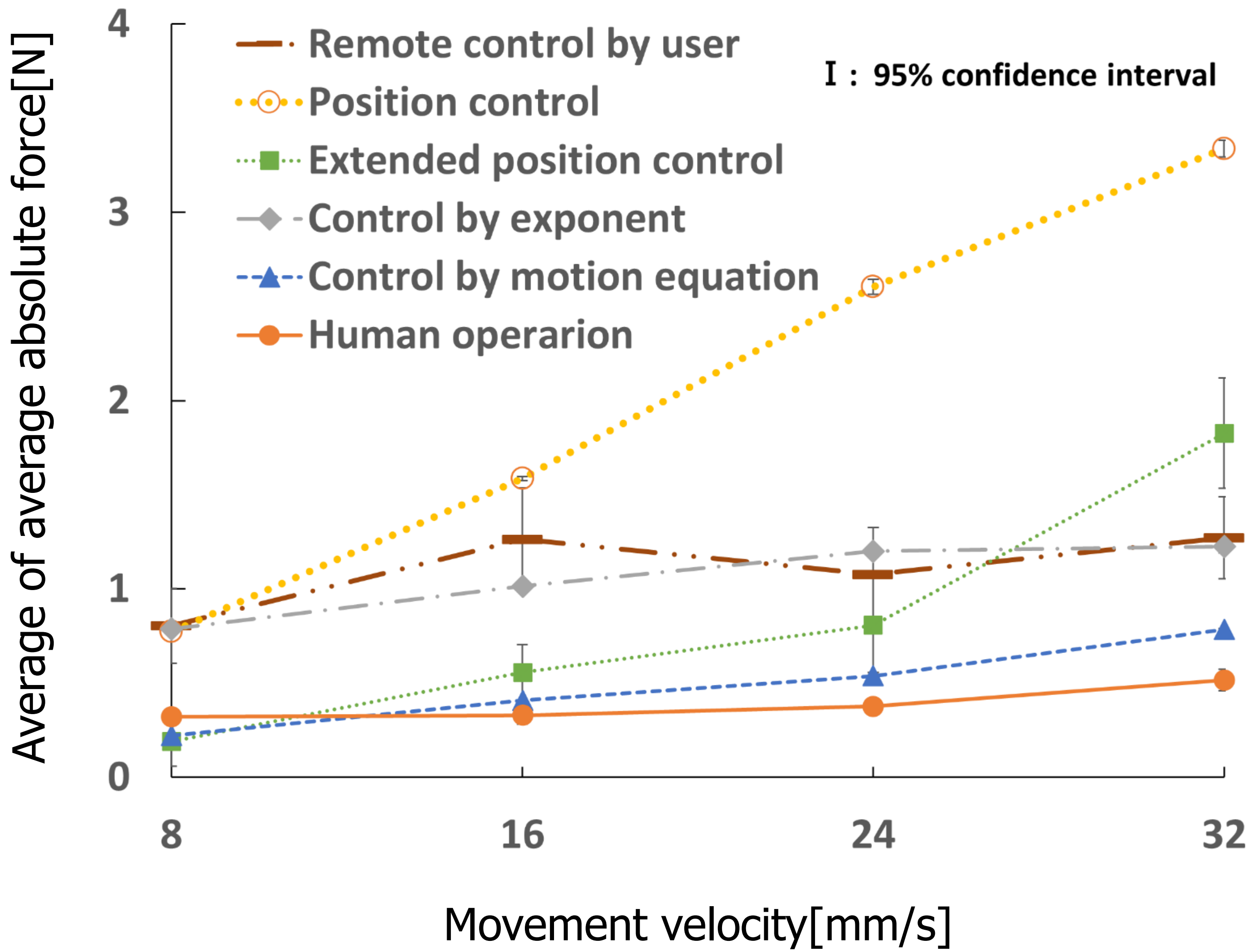
- Human grasps a wooden stick with a reacher instead of the robot while looking at the movement of the other robot directly.



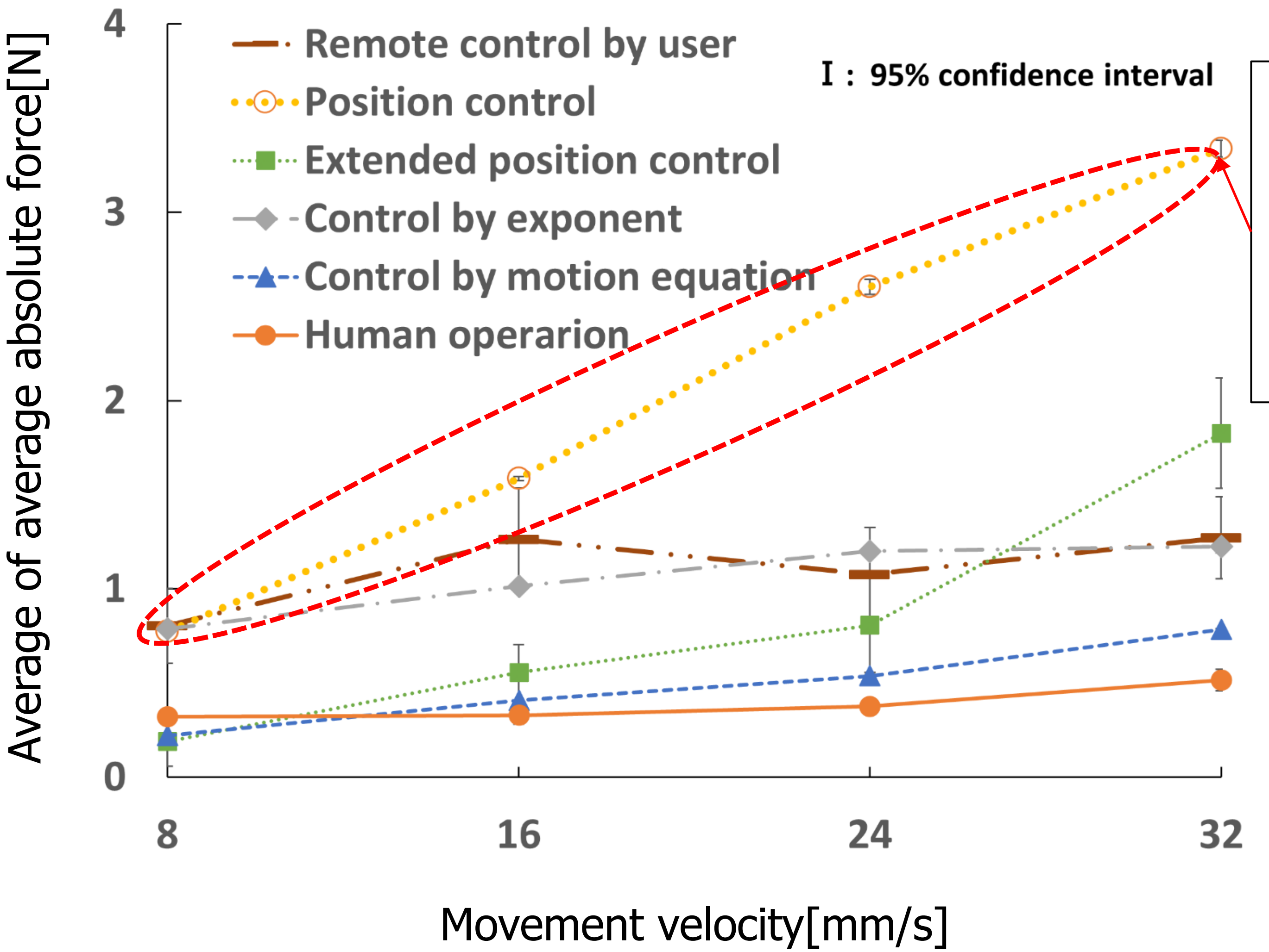
Experiment Method (4/4)

- Comparison of four types of robot movement control, remote control by user and human operation.
- Perform each experiment ten times and find the average of the force and the average of the maximum.

Experimental Results



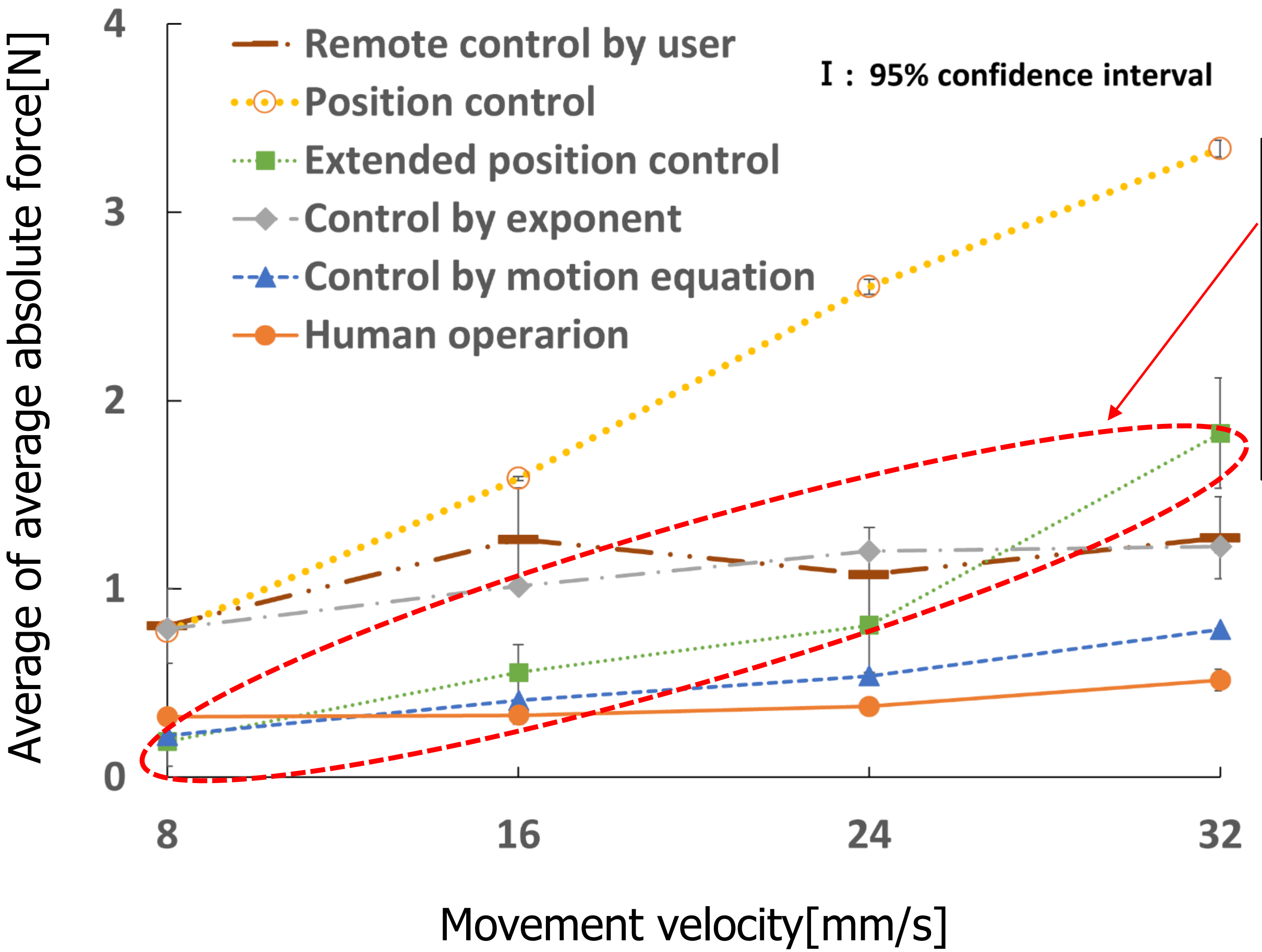
Experimental Results



Position control

Average increases significantly as the movement velocity becomes larger.

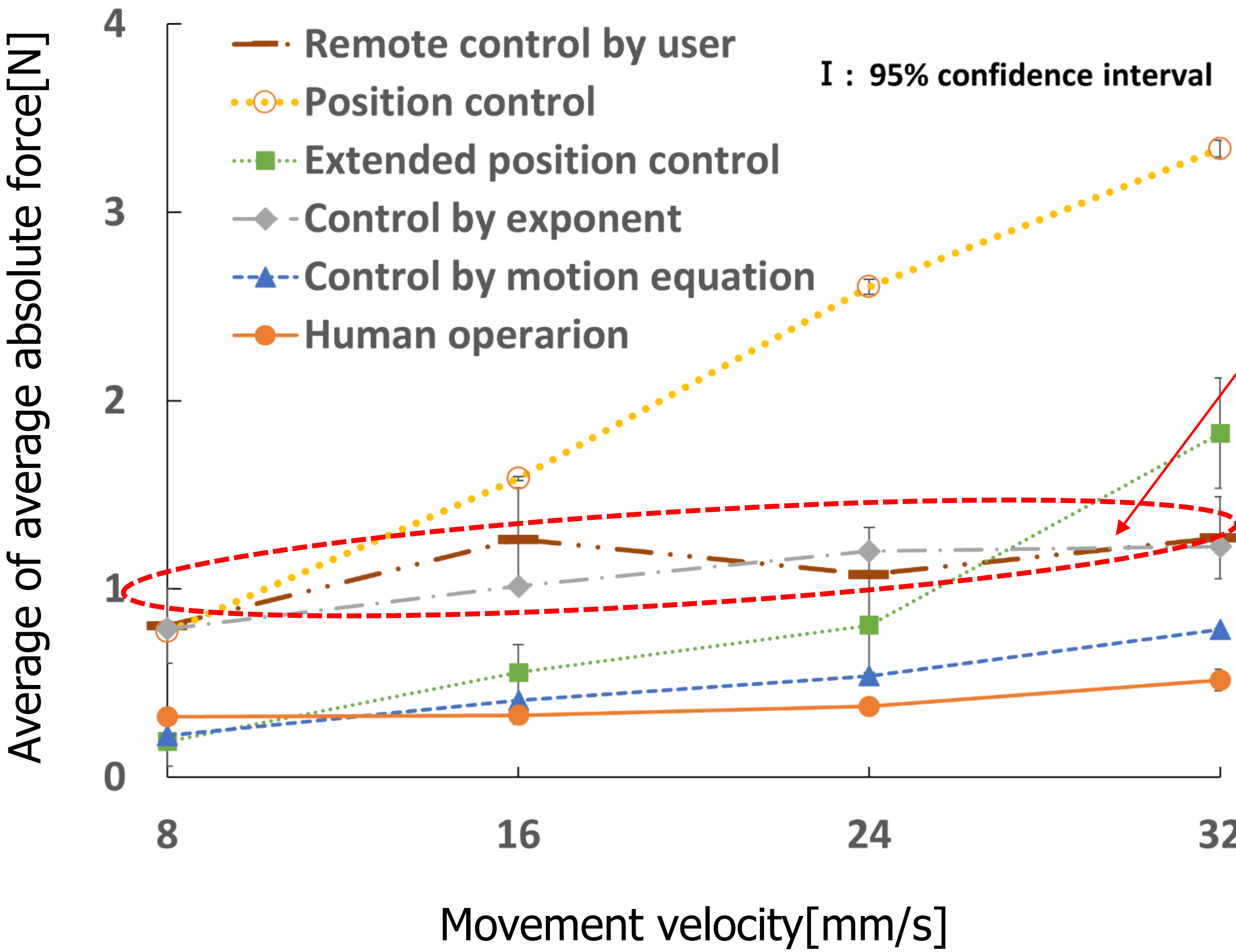
Experimental Results



Extended position control

Average is smaller than position control.

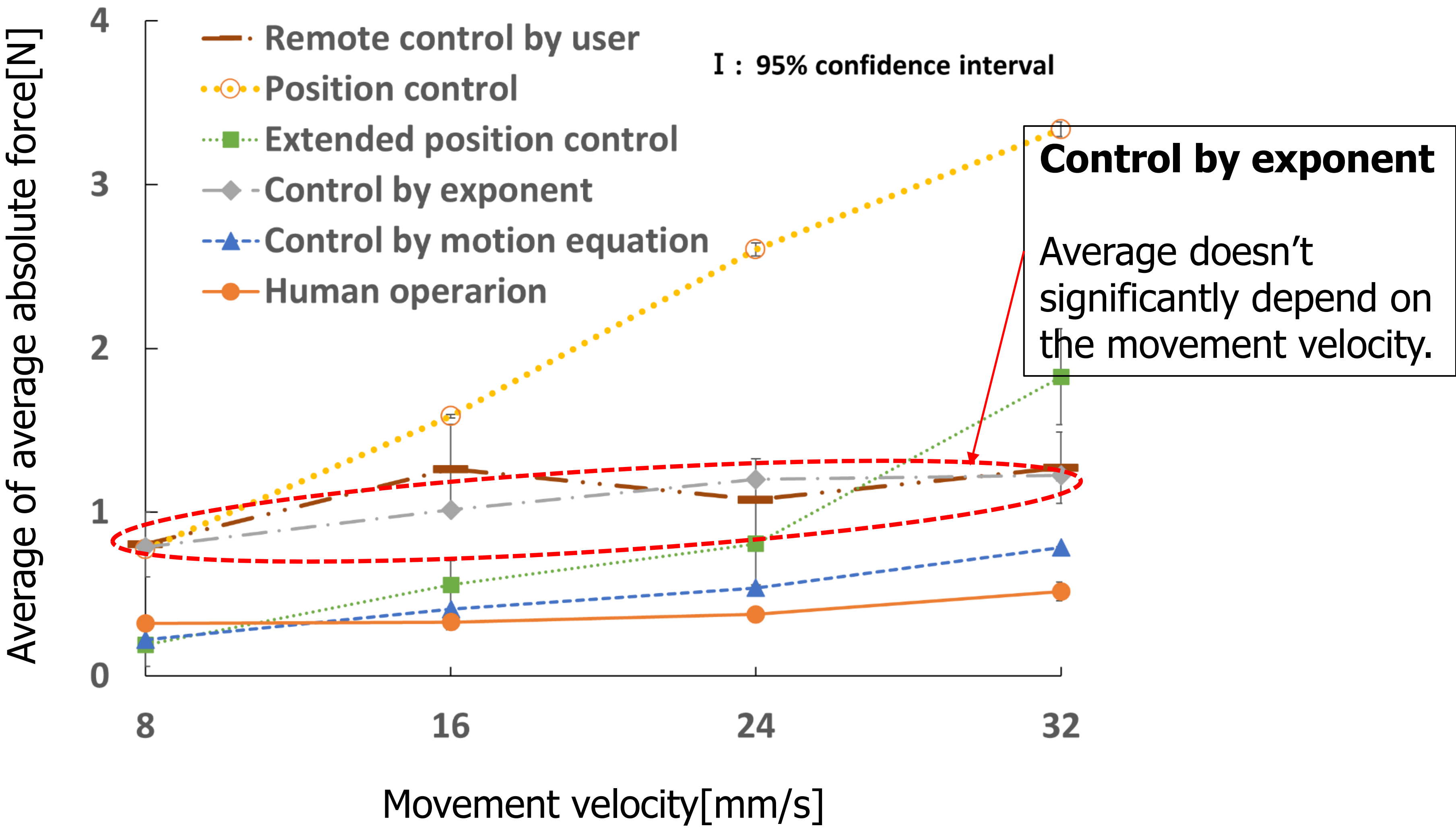
Experimental Results



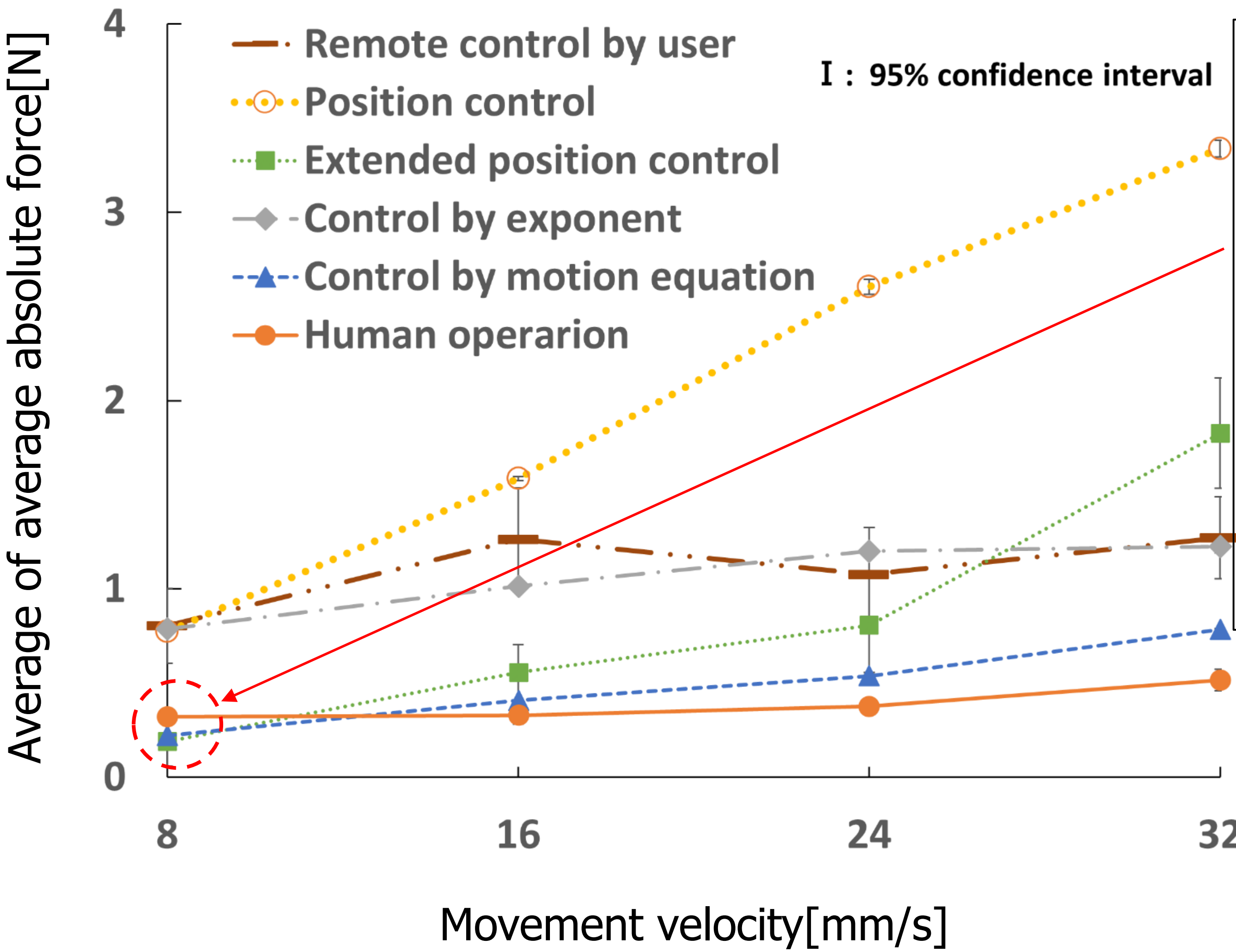
Remote control by user

Average doesn't tend to increase as the movement velocity becomes larger.

Experimental Results



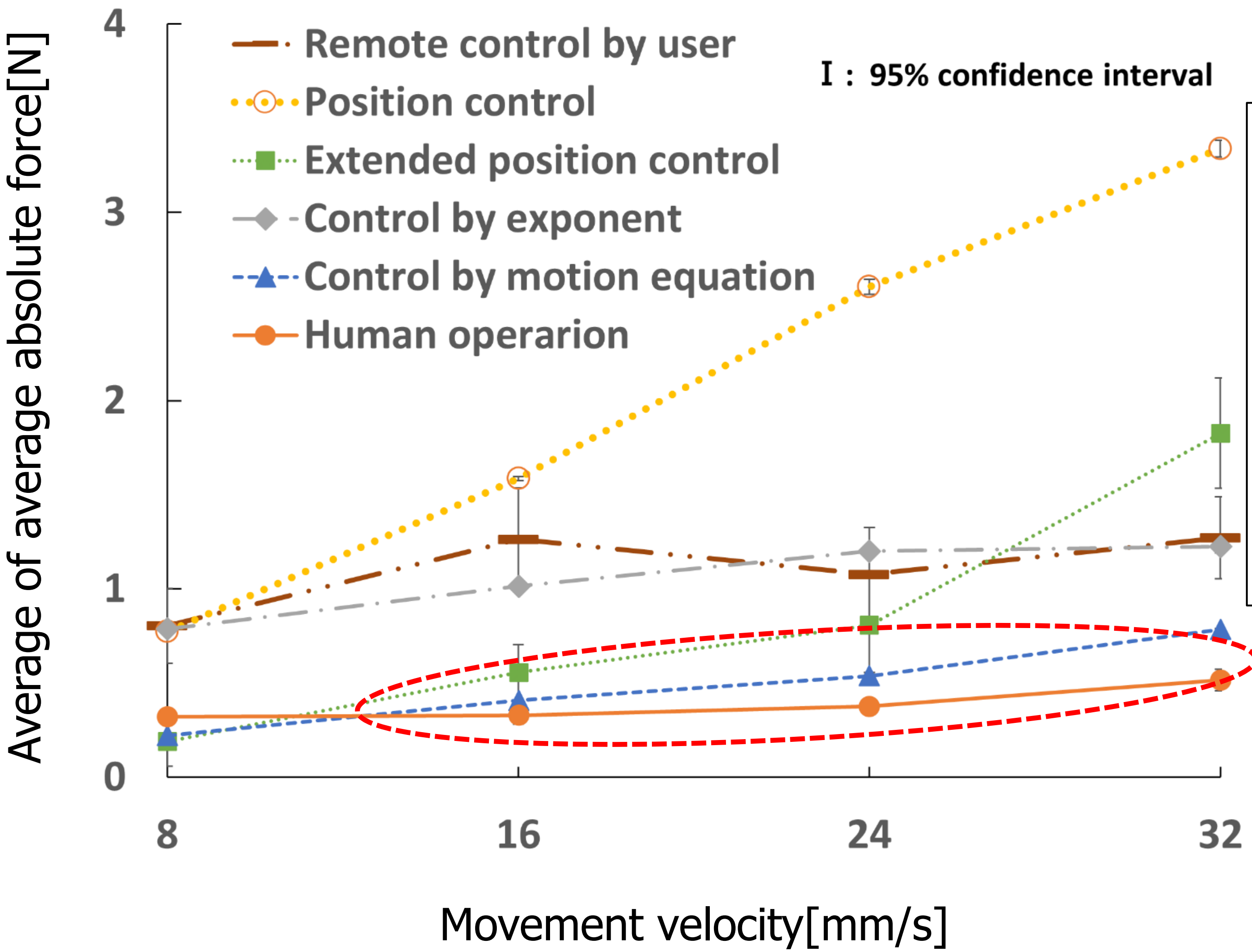
Experimental Results



Extended position control and Control by motion equation

When the movement velocity is less that about 16 mm/s, averages are smaller than human operation.

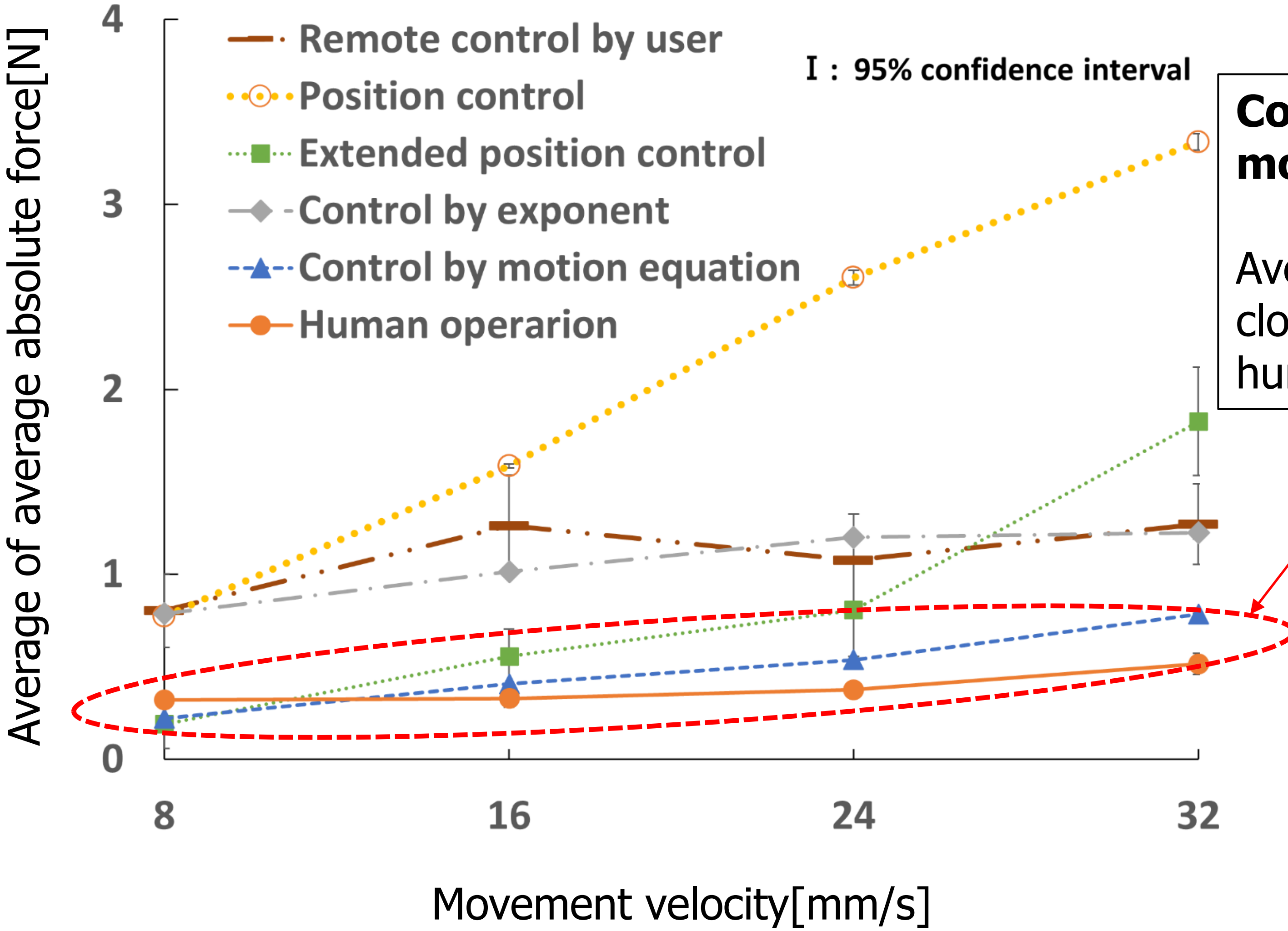
Experimental Results



Human operation

When the movement velocity is larger than or equal to about 16 mm/s, average are the smallest

Experimental Results



Control by motion equation

Average is the closest to the human operation.

Conclusion (1/2)

Comparison of six movement methods in cooperative work of carrying an object between two remote robot systems with force feedback by experiment.

- Position control increases significantly as the movement velocity becomes larger.
- Extended position control are smaller than position control.
- Control by exponent and remote control by user don’t significantly depend on the movement velocity.

Conclusion (2/2)

- Human operation can suppress the force more largely as the movement velocity increases.

- Control by motion equation is the closest to human operation.

Future Work

- Plan to improve the control by motion equation so that the robot can behave the human when the movement velocity is high.

- Also need to study switching control between two cases depending on whether communication environments between two robots are good or not.