Effect of Neural Network on Robot Position Control Using Force Information

Yifei Zhang [†] , Pingguo Huang[‡] , Yutaka Ishibashi[†] ,
Takashi Okuda[††] , Kostas E. Psannis[†††]

† Nagoya Institute of Technology, ‡ Gifu Shotoku Gakuen University,
†† Aichi Prefectural University, ††† University of Macedonia (Greece)

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Background (1/2)

Remote robot systems with force feedback have actively been researched.

We can feel the shape, softness, surface smoothness, and weight of a remote object touched/hit by a remote robot with a force sensor through a haptic interface device (i.e., force feedback).

↓

The efficiency and accuracy of work can largely be improved.

Background (2/2)

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

↓ Network delay, delay jitter and packet loss

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

→

- QoS control
- Stabilization control

↓ In order to enhance the efficiency of QoS control

We use big data, cloud computing, and AI (Artificial Intelligence) technologies.

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

Previous Work (1/2)

- Two remote robot systems with force feedback are used to handle cooperative work of moving an object together.
- The robot position control using force information as QoS control is applied to the systems [*1].
- Examined the effectiveness of the control by experiment.

- **The control is effective.**
- **There is the optimal value for position adjustment according to the force and the length of the object.**
- **The optimal value is also dependent on the material of the object.**

* 2 X. Wang *et al*., Proc. ICNCC, Dec. 2020.
* 3 X. Wang *et al*., Proc. ICCE-TW, Sep. 2021.

Previous Work (2/2)

- They apply the big data, cloud computing, and AI technologies to the robot position control using force information as QoS control for the remote robot systems with force feedback [*2].
- The optimal model of the neural network is investigated, and the effect of the model is examined by simulation [*3].

- **The technologies are effective.**
- **The optimal model of the neural network is three layers.**
- **The numbers of neurons in the input layer, hidden layer, and output layer are set to 2, 25, and 1, respectively.**

It is important to investigate the effect of the model by experiment but it has not been carried out.

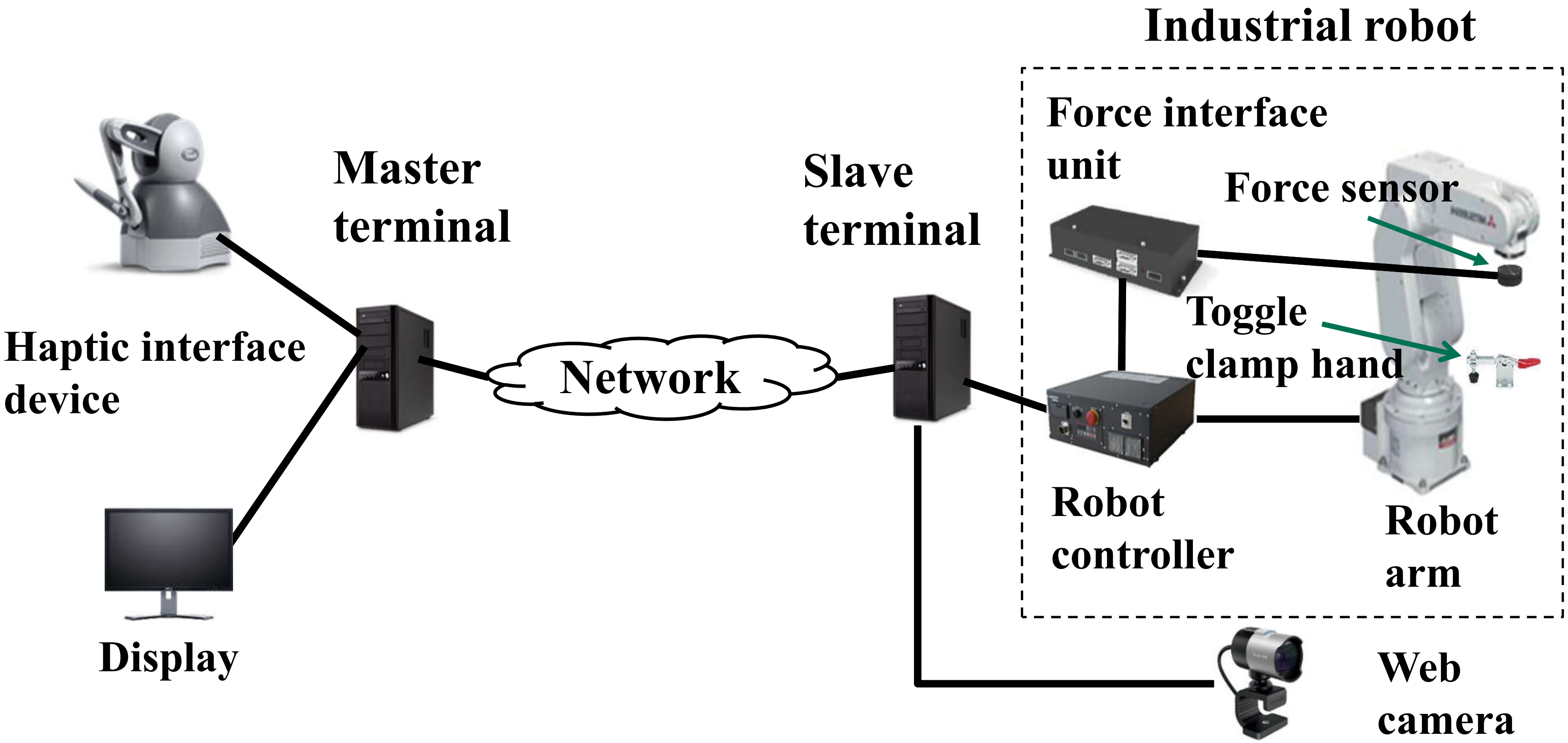
Purpose

This work

- **We implement the neural network model for the robot position control using force information in the remote robot systems with force feedback.**

- **We examine the effect of the model by experiment.**

Remote Robot System with Force Feedback



We use the two systems (called System 1 and System 2) in our experiment.

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

Reaction Force

Reaction force outputted at master terminal

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

$\boldsymbol{F}_t^{(\mathrm{m})}$: Reaction force is output at master terminal at time t (>0)

$\boldsymbol{F}_t^{(\mathrm{S})}$: Force received from slave terminal at time t

K_{scale} : Coefficient (0.33*1) multiplied to force received from slave terminal

*4 K. Suzuki *et al.*, Proc. GCCE, Oct. 2015.

Robot Position

Position of robot arm

$$\boldsymbol{S}_t = \begin{cases} \boldsymbol{M}_{t-1} + \boldsymbol{V}_{t-1} & (\text{if } |\boldsymbol{V}_{t-1}| \le V_{\max}) \\ \boldsymbol{M}_{t-1} + V_{\max} \dfrac{\boldsymbol{V}_{t-1}}{|\boldsymbol{V}_{t-1}|} & (\text{otherwise}) \end{cases} \quad (2)$$

$\boldsymbol{S}_t$: Position vector of robot arm at time t (> 0)

$\boldsymbol{M}_t$: Position vector of haptic interface device received by slave terminal from master terminal at time t

$\boldsymbol{V}_t$: Velocity of robot arm at time t

$V_{\max}$: Maximum movement velocity (5mm/ms[*4]) of robot arm

Robot Position Control Using Force Information (1/2)

- The robot position control using force information finely adjusts the robot position to reduce the force applied to the wooden stick which we use as an object in experiment.
- The adjusted position vector $\hat{\boldsymbol{S}}_{\boldsymbol{t}}$ of the robot arm at time t (> 0) is obtained by the following equation.

$$\hat{\boldsymbol{S}}_t = \boldsymbol{S}_t + \boldsymbol{P} \qquad (3)$$

$\boldsymbol{S}_t$: Position vector obtained by Eq. (2)

$\boldsymbol{P}$: Position adjustment vector

Robot Position Control Using Force Information (2/2)

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

Calculation method of $\boldsymbol{P}_x$ [*1] (x-axis of $\boldsymbol{P}$)

$$\boldsymbol{P}_x = a_x \boldsymbol{F}_x \qquad (4)$$

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

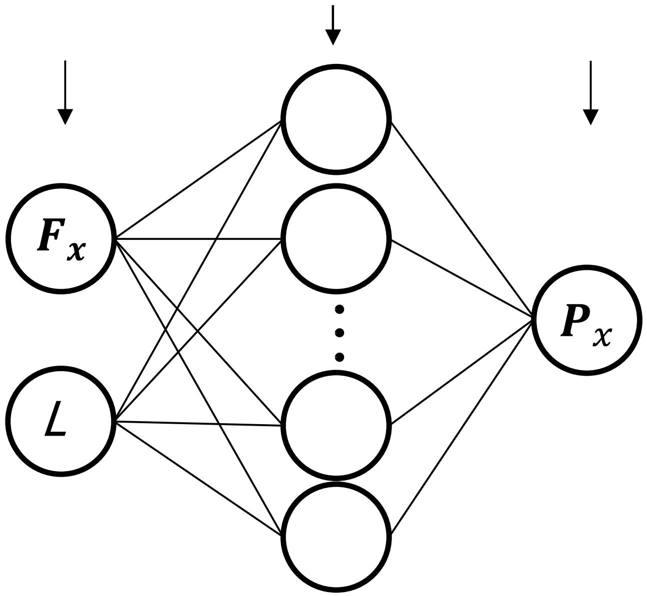
$\boldsymbol{F}_x$: Force in x-axis

$$a_x = 4.82 \times 10^{-2} l_{opt} - 1.16 \qquad (5)$$

l_{opt}: Optimal value for $\boldsymbol{P}_x$

Neural Network Model

Layer	Input Layer	Hidden Layer	Output Layer
Neuron number	2	25	1



We use python language and Keras library to implement the three-layer neural network model.

Experiment Environment

Neural Network Setting

	F_x (N)	L (cm)	l_{opt} (cm)	P_x (mm)
Training data	-6 ~ 6	30	55	Calculated by Equations
		40	76	
		60	150	
Validation data		25, 35, 45		

Experiment Method (1/3)

To examine the effect, we compare the experimental results when the wooden stick length *L* are 25 cm, 35 cm, and 45 cm in the following cases.

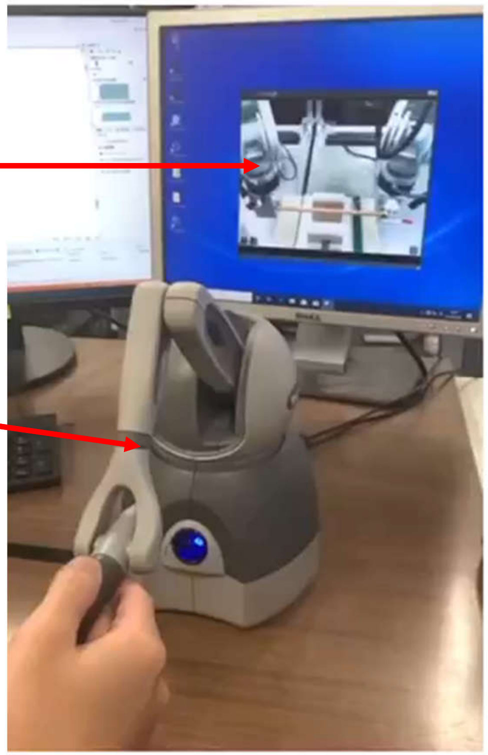
- **Neural network control (NN)**
- **Equations: Calculate by Equations of robot position control using force information**
- **No control (NC)**

In the case where we use Equations, we use the optimal value of the similar length of the wooden stick which we had gotten.

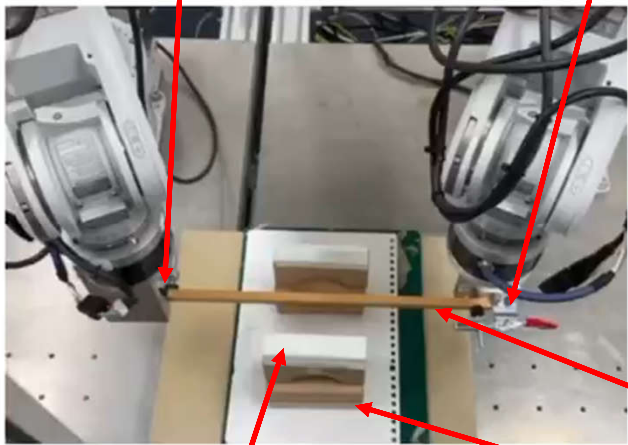
Length of wooden stick *L* (cm)	25	35	45
Similar length *L* (cm)	30	30,40	40,60

Experiment Method (2/3)

The robot arm of system 1 is operated automatically at a constant velocity, and the robot arm of system 2 is operated manually with haptic interface device.



(a) Each master terminal



(b) Two robot arms

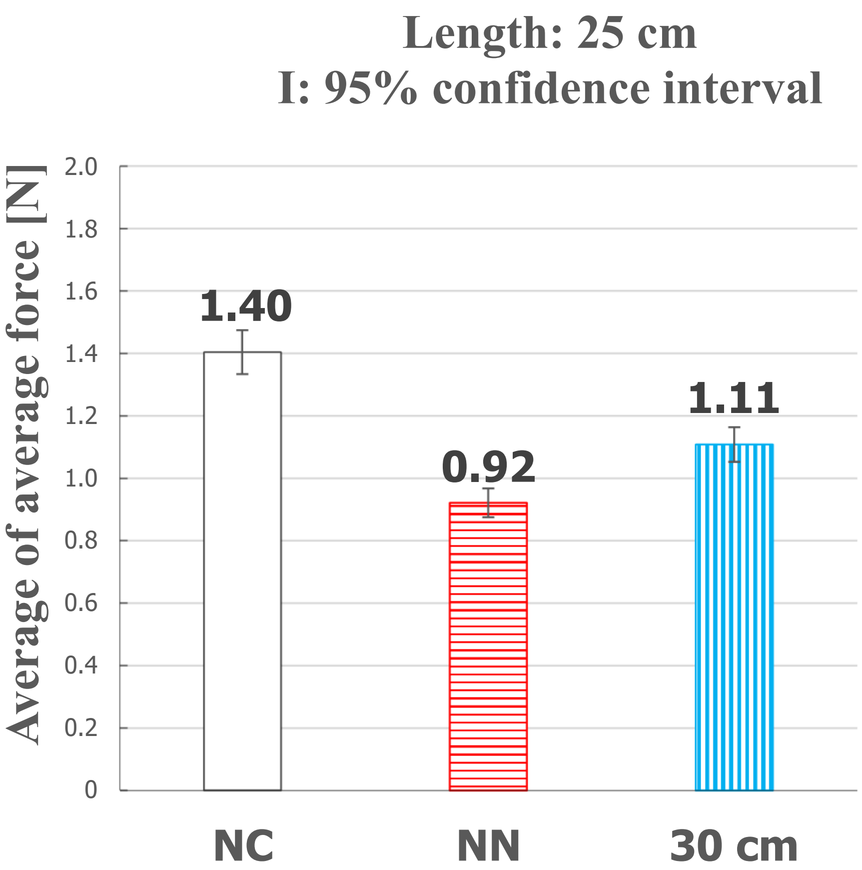
Experiment Method (3/3)

The operation was performed 10 times for each case.

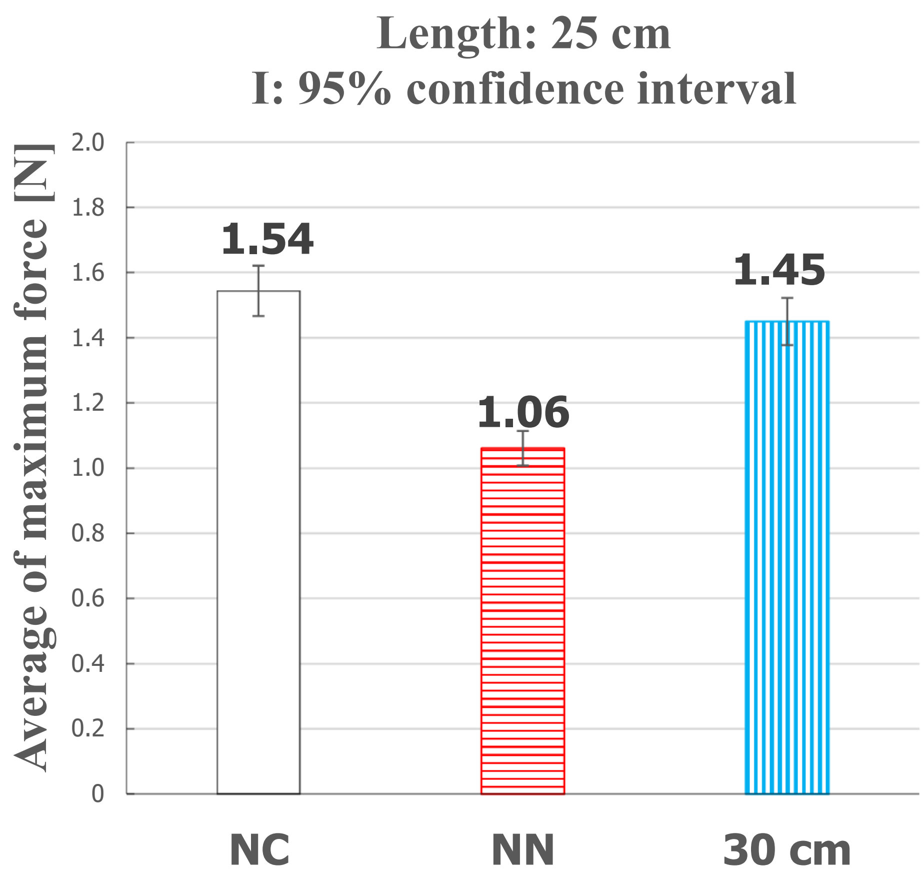
Performance measure:

- **Average of average force : the averages of the average forces applied to the wooden stick during the 10 operations.**
- **Average of maximum force: the averages of the maximum forces applied to the wooden stick during the 10 operations.**

Experimental Results (1/3)

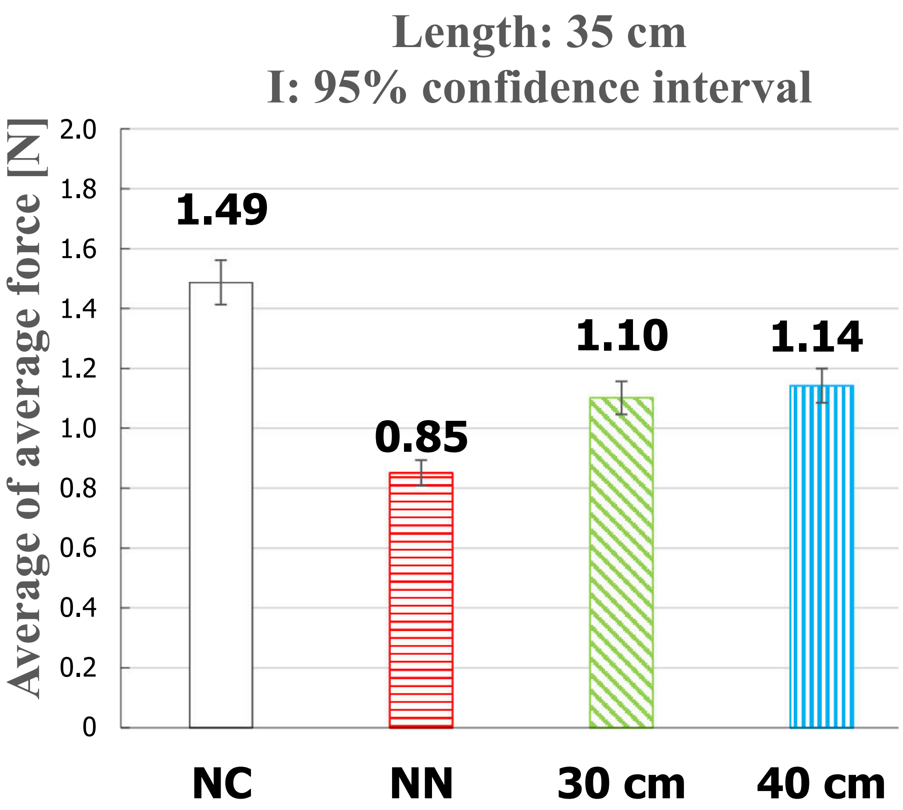


(a) Average of average force

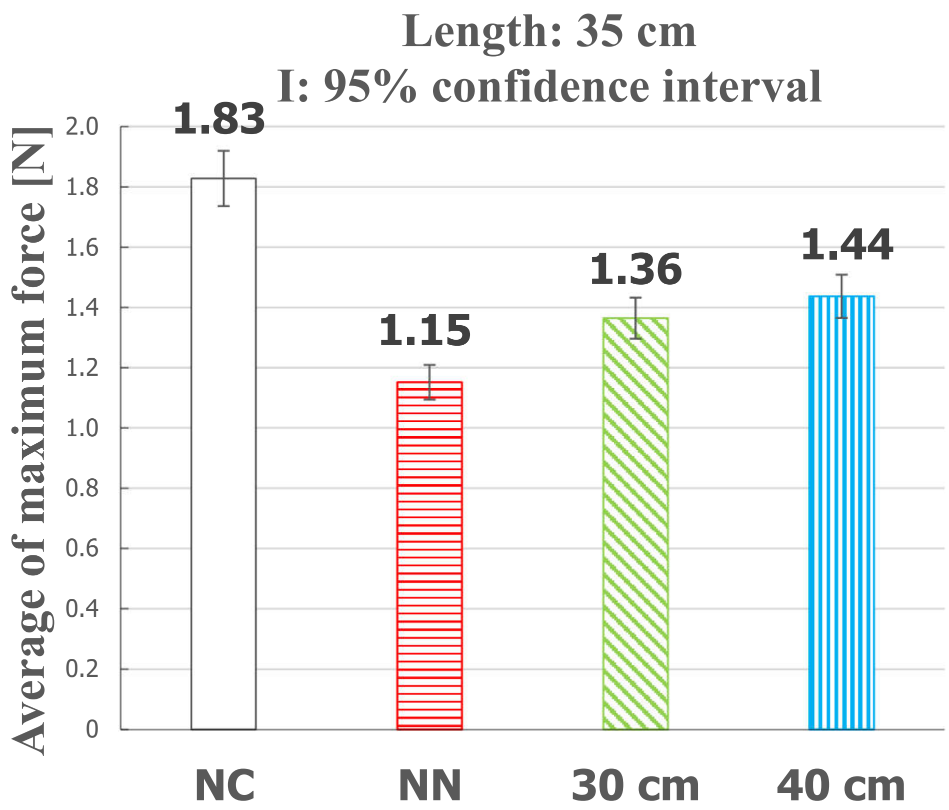


(b) Average of maximum force

Experimental Results (2/3)

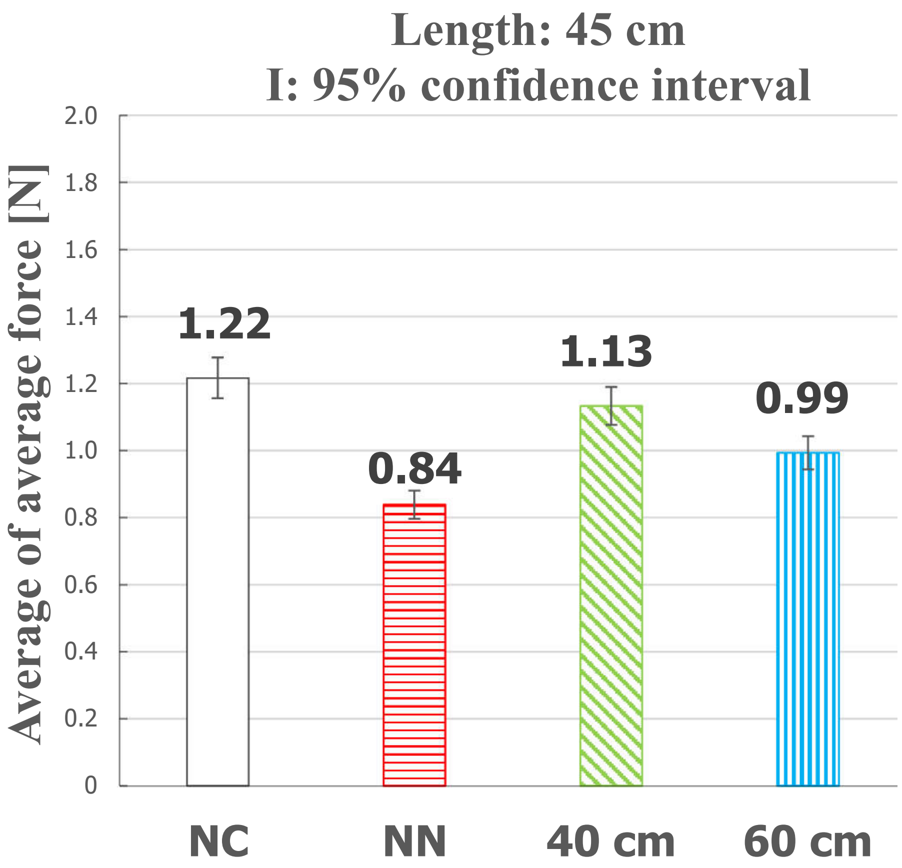


(a) Average of average force

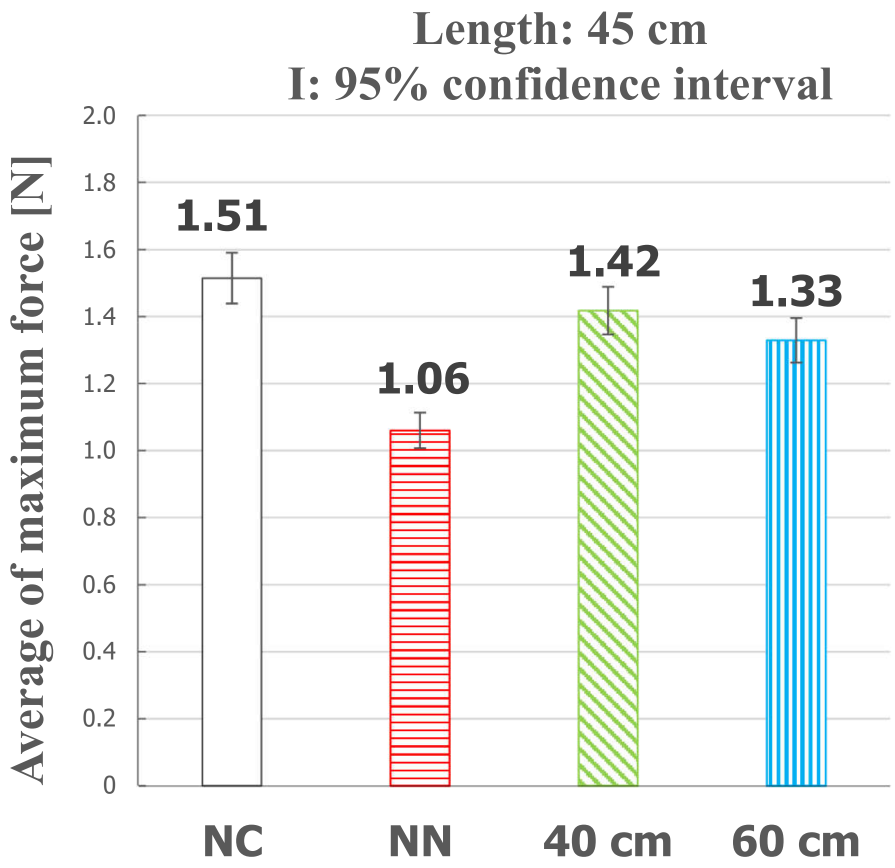


(b) Average of maximum force

Experimental Results (3/3)



(a) Average of average force



(b) Average of maximum force

Conclusions and Future Work

Conclusions

- We investigated the effect of a neural network model for the robot position control using force information in remote robot systems with force feedback by experiment.
- Experimental results illustrated that the neural network model is effective.

Future Work

- We will deal with other factors that affect the effect of the neural network on the robot position control using force information.