Enhanced Robot Position Control Using Force Information for Mobile Robots

Influence of Obstacles on Cooperative Work

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Outline

- ✓ Background
- ✓ Previous Work and Problem
- ✓ Purpose
- ✓ Remote Robot Systems with Force Feedback
- ✓ Enhanced Robot Position Control Using Force Information
- ✓ Experiment Method
- ✓ Experimental Results
- ✓ Conclusions and Future Work

Background

Remote robot systems with force feedback

A user operates a remote robot having a force sensor with a haptic interface device while watching video.

- ✓ The user can perceive force when the robot touches/hits an object (i.e., force feedback).
- ✓ Remote work can be conducted at locations where humans cannot enter easily.
- ✓ Degradation of QoE (Quality of Experience) and stability owing to network delay, delay jitter, and packet loss

QoS control and stabilization control

Previous Work

Two remote robot systems with force feedback*1

✓ Adaptive Δ-causality control

➡ Mitigate influence of network delay

✓ Robot position control using force information

➡ Suppress large force applied to object

Problem

Not handle mobile robots

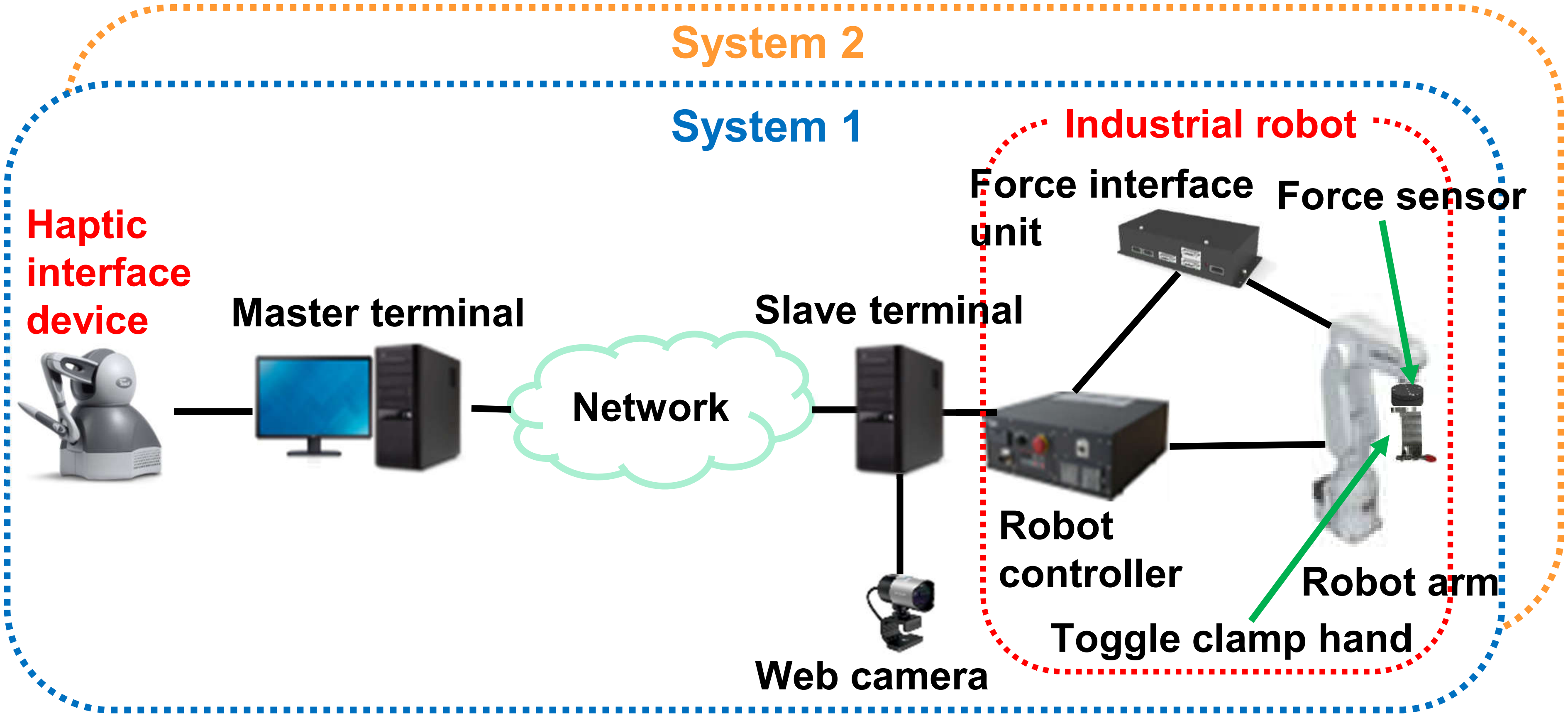
*1 K. Kanaishi *et al.*, ITE 70th Anniversary Convention, Dec. 2020.

Purpose

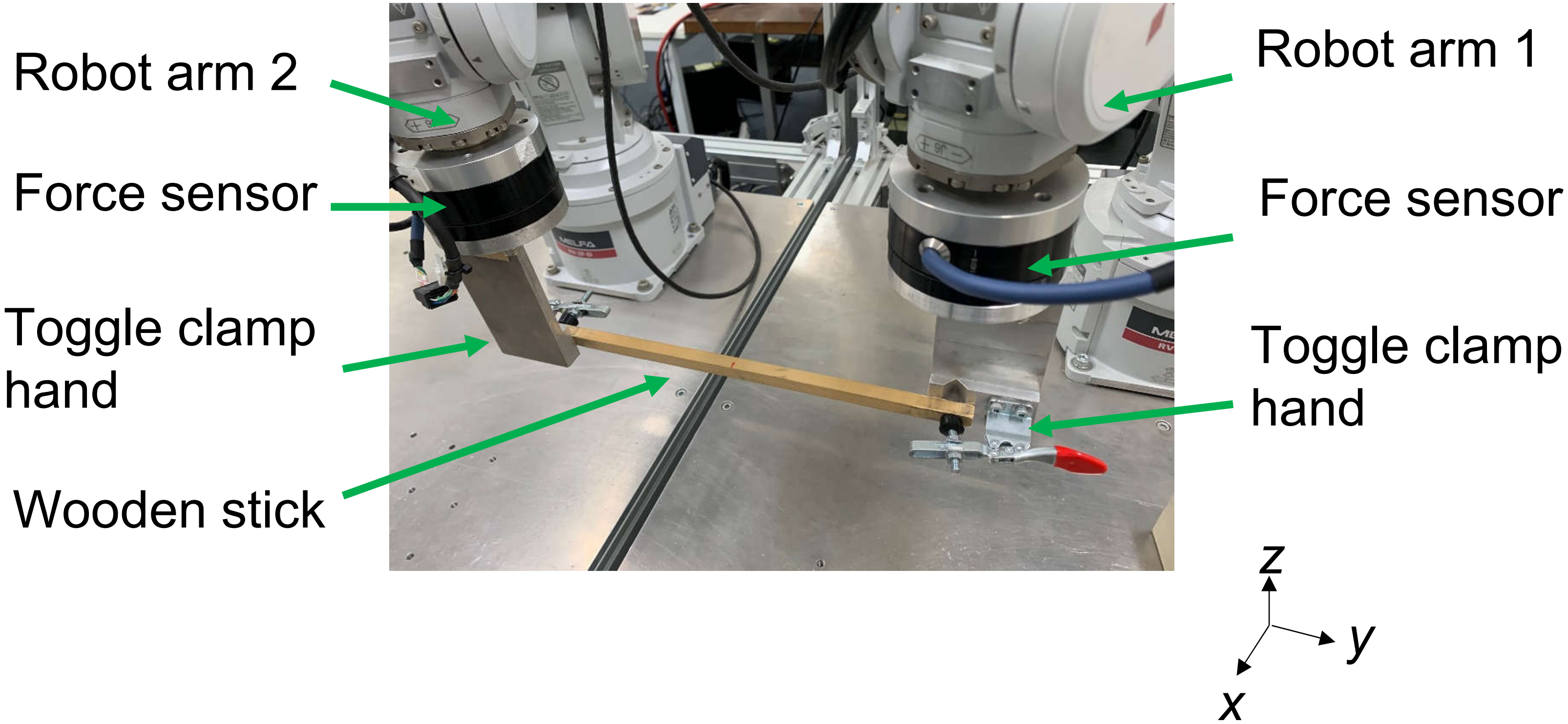
To operate mobile robots remotely → Obstacles

- ✓ Enhance robot position control using force information considering mobile robots
- ✓ For sudden position changes in up-down directions

Remote Robot Systems with Force Feedback



Work of Carrying Object



Calculation of Reaction Force[*2]

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

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

$\boldsymbol{F}_t^{(\mathrm{s})}$: Force sensed at slave terminal at time $t\ (\mathrm{ms})$

K_{scale}: Scale multiplied to $\boldsymbol{F}_{t-1}^{(s)}$ (=0.5)[*2]

*2 K. Kanaishi *et al.*, Proc. ICTCE, pp. 34-38, Nov. 2019.

Calculation of Robot Arm Position

$$\boldsymbol{S}_t = \boldsymbol{M}_{t-1} + \boldsymbol{V}_{t-1} \quad (|\boldsymbol{V}_{t-1}| < V_{\max})^{*3}$$

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

$\boldsymbol{M}_t$: Position vector of haptic interface device received from master terminal to slave terminal at time $t\ (> 0)$

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

$V_{\max}$: Maximum velocity of robot arm (=5 mm/ms)

*3 Y. Toyoda *et al.*, IJMERR, vol. 9, no. 9, June 2020.

Conventional Robot position Control Using Force Information

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

$$P_z = aF_z$$

$$a = 4.82 \times 10^{-2} l_{\mathrm{opt}}$$

$$l_{\mathrm{opt}} = 2.01 \times 10^{3.34\times10^{-2}L}$$

$\widehat{\boldsymbol{S}_t}$: Position vector of robot arm at time t under control

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

$\boldsymbol{P}$: Position adjustment vector to reduce force applied to object

P_z: Position adjustment value on z-axis (in vertical direction)

a: Coefficient for length L $(= 30\ \mathrm{cm})$ of wooden stick[*4]

*4 S. Ishikawa *et al.*, IJCNS, vol. 14, no. 1, Mar. 2021.

Enhanced Robot position Control Using Force Information

$$P_z = aF_z \qquad (|F_z| < 0.7\text{N})$$

$$P_n = \pm 0.01 \times 1.2^n \qquad (|F_z| \geq 0.7\text{N})$$

P_z: Position adjustment value on z-axis (in vertical direction)

P_n : The n-th position adjustment value (every 3.5 ms) ($n \geq 0$)

Experiment Method

Emulation of mobile robots

System 1

- ✓ Move robot arm 1 automatically in front-back (x-axis) direction
- ✓ Raise or drop robot arm 1 automatically by constant distance in vertical (z-axis) direction

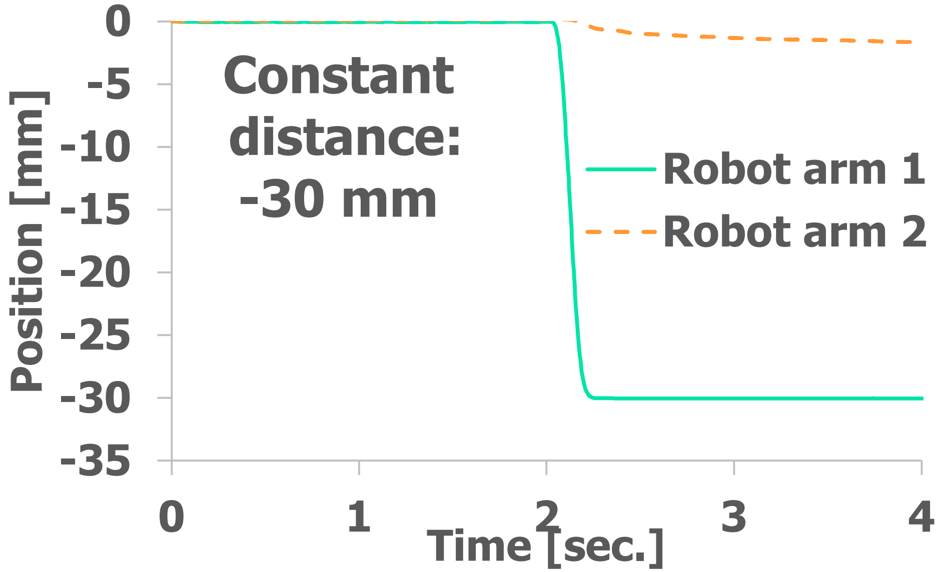
System 2

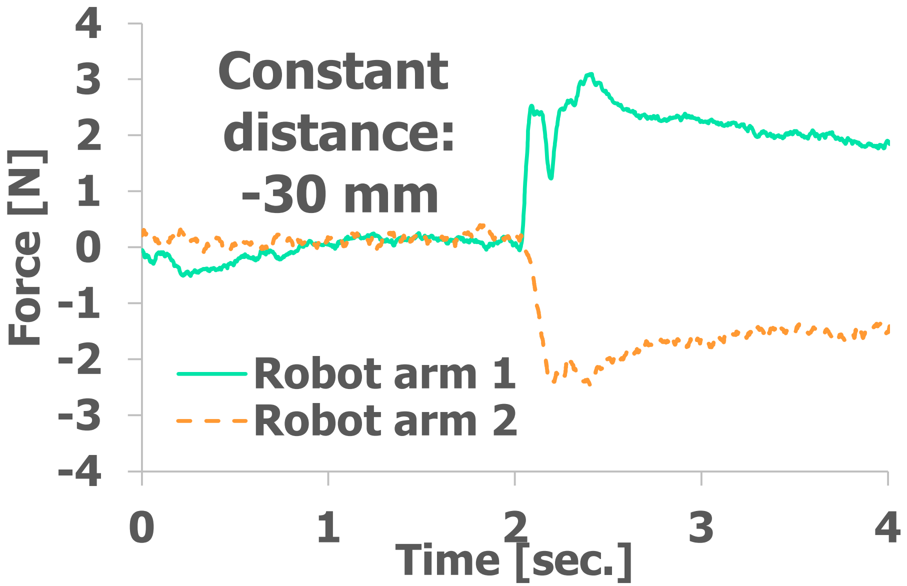
- ✓ Apply enhanced control/conventional control
- ✓ Move robot arm 2 only under control in vertical (z-axis) direction
- ✓ Move robot arm 2 manually in front-back (x-axis) direction

- ✓ Distance: ±10 mm, ±30 mm
- ✓ Velocity: ±0.14 mm/ms

Experimental Results (Drop: -30 mm) (1/4)

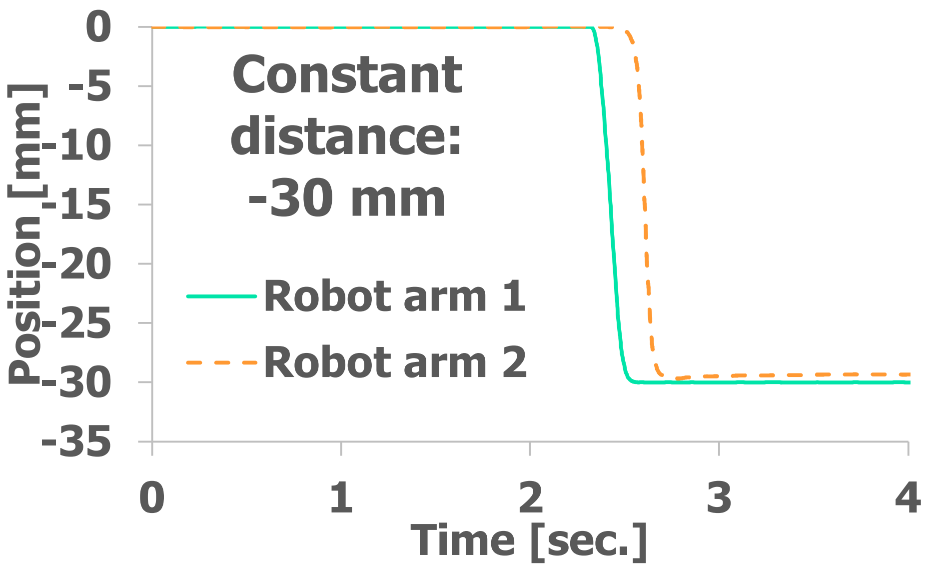
Conventional control

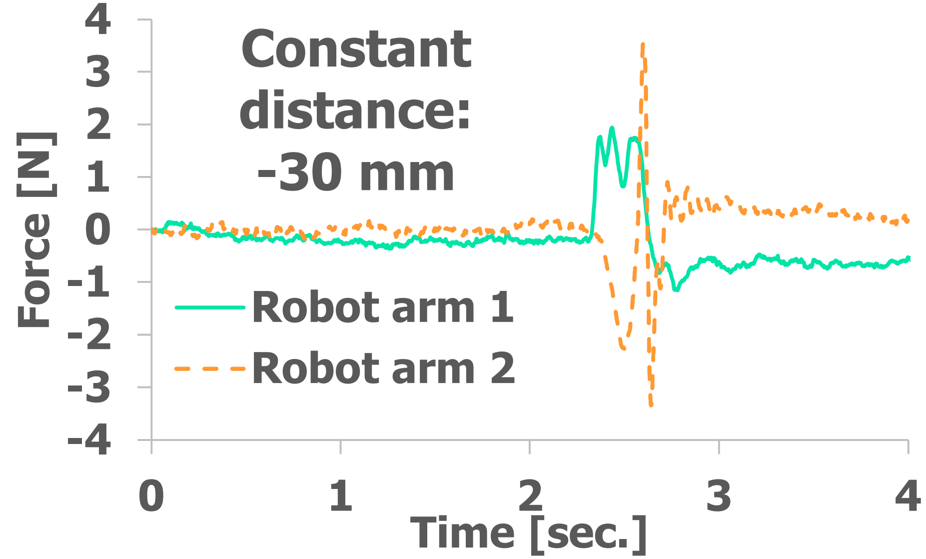




Experimental Results (Drop: -30 mm) (2/4)

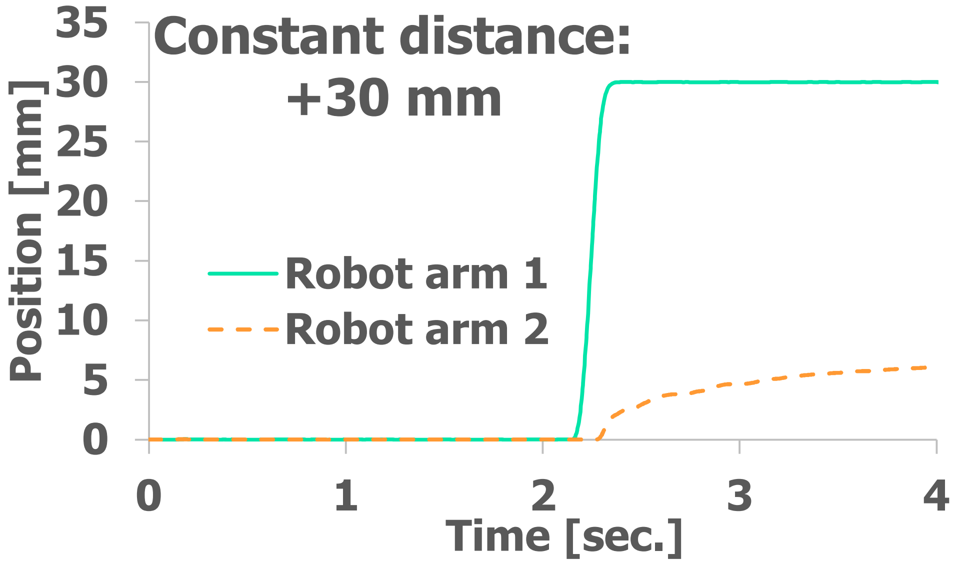
Enhanced control

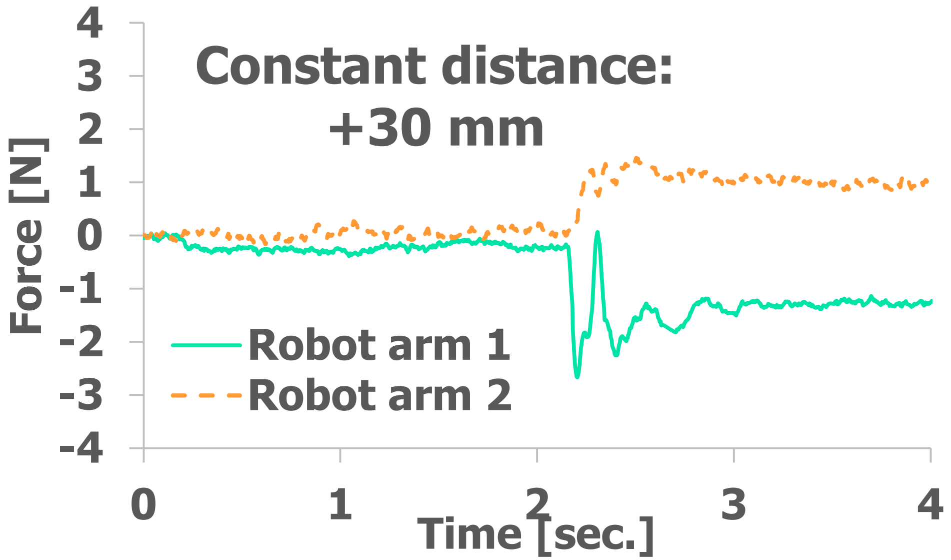




Experimental Results (Raise: 30 mm) (3/4)

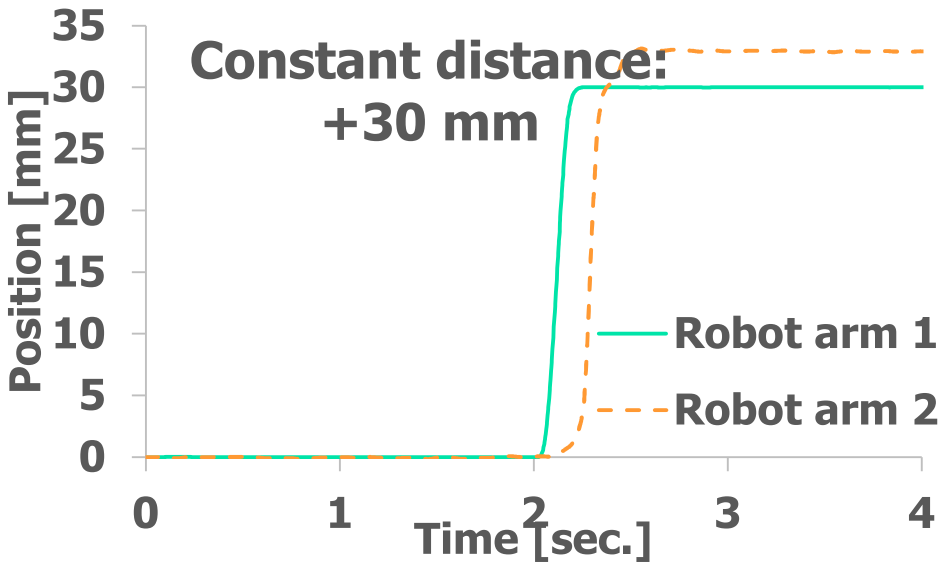
Conventional control

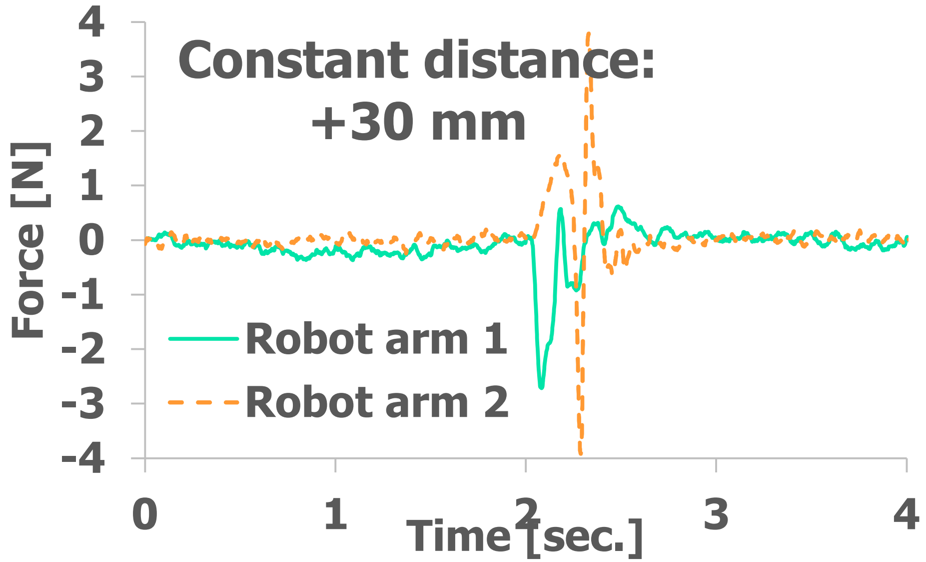




Experimental Results (Raise: 30 mm) (4/4)

Enhanced control





Conclusions

- ✓ Enhanced robot position control using force information by taking account of mobile robots
- ✓ Examined effect of the enhanced control by experiment

➡ Possible to suppress large force applied to object for sudden large position change

Future Work

- ✓ To reduce position differences after the position change
- ✓ Study methods to avoiding obstacles