Enhanced Robot Position Control Using Force Information for Mobile Robots

Influence of Obstacles on Cooperative Work

Yutaka Ishibashi† Pingguo Huang‡ Kostas E. Psannis*

† Nagoya Institute of Technology, Japan
‡ Gifu Shotoku Gakuen University, Japan
* University of Macedonia, Greece

The 4th World Symposium on Communication Engineering (WSCE 2021), Nov. 25-28, 2021
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
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\textsuperscript{*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

\textsuperscript{*1} K. Kanaishi \textit{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

System 1
- Master terminal
- Slave terminal
- Network
- Web camera
- Haptic interface device
- Force interface unit
- Robot controller
- Robot arm
- Toggle clamp hand

System 2
- Industrial robot
- Force sensor

Remote Robot Systems with Force Feedback
Work of Carrying Object

- Robot arm 2
- Force sensor
- Toggle clamp hand
- Wooden stick

- Robot arm 1
- Force sensor
- Toggle clamp hand

(x, y, z axis)
Calculation of Reaction Force*2

\[ F_{t}^{(m)} = K_{\text{scale}} F_{t-1}^{(s)} \]

- \( F_{t}^{(m)} \): Reaction force outputted at master terminal at time \( t (> 0) \) (ms)
- \( F_{t}^{(s)} \): Force sensed at slave terminal at time \( t \) (ms)
- \( K_{\text{scale}} \): Scale multiplied to \( F_{t-1}^{(s)} (=0.5)^{*2} \)

Calculation of Robot Arm Position

\[ S_t = M_{t-1} + V_{t-1} \quad (|V_{t-1}| < V_{\text{max}})^3 \]

\[ S_t: \] Position vector of robot arm at time \( t (> 0) \)

\[ M_t: \] Position vector of haptic interface device received from master terminal to slave terminal at time \( t (> 0) \)

\[ V_t: \] Velocity vector of robot arm at time \( t (> 0) \)

\[ V_{\text{max}}: \] 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

\[ \vec{S}_t = S_t + P \]

\[ P_z = aF_z \]

\[ a = 4.82 \times 10^{-2} l_{\text{opt}} \]

\[ l_{\text{opt}} = 2.01 \times 10^{3.34 \times 10^{-2}L} \]

\( \vec{S}_t \): Position vector of robot arm at time \( t \) under control

\( S_t \): Position vector of robot arm at time \( t \)

\( P \): 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 cm) of wooden stick*4

Enhanced Robot position Control Using Force Information

\[ P_z = \alpha F_z \quad (|F_z| < 0.7\text{N}) \]

\[ P_n = \pm 0.01 \times 1.2^n \quad (|F_z| \geq 0.7\text{N}) \]

\( P_z \): 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
- Distance: ±10 mm, ±30 mm
- Velocity: ±0.14 mm/ms

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

Conventional control

- Position [mm]
- Time [sec.]
  - Constant distance: -30 mm
  - Robot arm 1
  - Robot arm 2

- Force [N]
- Time [sec.]
  - Constant distance: -30 mm
  - Robot arm 1
  - Robot arm 2
Experimental Results (Drop: -30 mm) (2/4)

Enhanced control

**Position [mm]**

<table>
<thead>
<tr>
<th>Time [sec.]</th>
<th>Constant distance: -30 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Robot arm 1</td>
</tr>
<tr>
<td>1</td>
<td>Robot arm 2</td>
</tr>
</tbody>
</table>

**Force [N]**

<table>
<thead>
<tr>
<th>Time [sec.]</th>
<th>Constant distance: -30 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Robot arm 1</td>
</tr>
<tr>
<td>1</td>
<td>Robot arm 2</td>
</tr>
</tbody>
</table>
Experimental Results (Raise: 30 mm) (3/4)

Conventional control

![Graph showing position and force over time for Robot arm 1 and Robot arm 2 with constant distance of +30 mm.](image)
Experimental Results (Raise: 30 mm)  

Enhanced control

Constant distance: +30 mm

Position [mm]

Time [sec.]

Force [N]

Constant distance: +30 mm

Time [sec.]
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