Stabilization Control by Viscosity in Remote Robot System with Haptics

Takafumi Rikiishi\textsuperscript{1}, Yutaka Ishibashi\textsuperscript{1}, Pingguo Huang\textsuperscript{2}, Takanori Miyoshi\textsuperscript{3}, Hitoshi Ohnishi\textsuperscript{4}, Yuichiro Tateiwa\textsuperscript{1}, Kostas E. Psannis\textsuperscript{5}, and Hitoshi Watanabe\textsuperscript{6}

\textsuperscript{1}Nagoya Institute of Technology, \textsuperscript{2}Seijyo University \textsuperscript{3}Toyohashi University of Technology, \textsuperscript{4}The Open University of Japan \textsuperscript{5}University of Macedonia, \textsuperscript{6}Tokyo University of Science

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Outline

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Remote robot systems with haptics have been studied in various fields. It is possible to transmit the information about the shape, weight, texture of an object, and so on by using haptics. It is expected that the efficiency and accuracy of work performed remotely can largely be improved.
The remote robot systems are used over a network like the Internet, which does not guarantee the quality of service (QoS).

- The quality of experience (QoE) may seriously deteriorate.
- The instability phenomenon (e.g., vibrations) may occur.

Network delay, delay jitter, and packet loss
Remote Robot System with Haptics

A method using the phase control filter in combination with the wave filter was applied to the system.

Effects of the method was demonstrated by experiment.
Purpose (2/3)


Remote control system with haptic media and video*2

The viscosity control which dynamically changes the viscosity coefficient according to the network delay was proposed.

The effect of the control was shown by QoE assessment

The effect is not sufficiently investigated for the remote robot system with haptics.
Remote Robot System with Haptics*1

We propose stabilization control by viscosity.

We illustrate the effectiveness of the control by experiment.
Remote Robot System
Industrial Robot

- robot arm
- force sensor
- metal rod
- web camera
Remote Operation

- Position information
- Force information
- Video pictures
Method of Calculation for Reaction Force

\[ F_t^{(m)} = K_{\text{scale}} F_t^{(s)} \]

- \( F_t^{(m)} \): The reaction force outputted at time \( t (>1) \)
- \( F_t^{(s)} \): The force acquired from the slave terminal at time \( t \)

<table>
<thead>
<tr>
<th>Work space (Robot : Geomagic)</th>
<th>force (Robot : Geomagic)</th>
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Robot: industrial robot
Geomagic: haptic interface device

\( K_{\text{scale}} \)
In the stabilization control by viscosity, the instability phenomenon is suppressed by restricting the movement distance of the industrial robot to some extent.

\[ S_t = M_t - C_d(S_{t-1} - S_{t-2}) \]

- \( S_t \): The position vector of the industrial robot
- \( M_t \): The position vector of the haptic interface device
- \( C_d \): Coefficient related to viscosity
A user did work of moving the haptic interface device from side to side along the line (i.e., along the \(x\) axis) of 16 cm length drawn on a paper.

The working time was about 2 seconds.

We selected the value of \(C_d\) from among 0.85, 0.90, 0.95, and 0.99.
We measured the position on the x axis of the haptic interface device, the position on the x axis of the industrial robot, and the reaction force of the haptic interface device.

- The average difference between the position of the haptic interface device and the position of the industrial robot
- The standard deviation of the reaction force of the haptic interface device.
Experiment Results (1/4)

The position on the x axis

\[ C_d = 0.85 \quad \text{and} \quad C_d = 0.90 \]
Experiment Results (2/4)

The position on the x axis

$C_d = 0.95$

$C_d = 0.99$
Experiment Results (3/4)

$\mathcal{C}_d = 0.85$

$\mathcal{C}_d = 0.90$

$\mathcal{C}_d = 0.95$

$\mathcal{C}_d = 0.99$
Experiment Results (4/4)

Additional delay: 200 ms

\( Cd = 0.85 \)

\( Cd = 0.90 \)

\( Cd = 0.95 \)

\( Cd = 0.99 \)
We proposed the stabilization control by viscosity for the remote robot system with haptics. We also investigated the effect of the proposed control by experiment.

We found that the stabilization control by viscosity can suppress the instability phenomenon.
Future Work

➢ We will further investigate the influences of network delay and packet loss under the stabilization control by viscosity.

➢ We will also compare the effects between the stabilization control by viscosity and that using the phase control filter in combinational with wave filter\*1.