Human Perception of Force in Cooperation between Remote Robot Systems with Force Feedback

Qin Qian\textsuperscript{1}  Daiki Osada\textsuperscript{1}  Yutaka Ishibashi\textsuperscript{1}
Pingguo Huang\textsuperscript{2}  Yuichiro Tateiwa\textsuperscript{1}

\textsuperscript{1}Nagoya Institute of Technology,  \textsuperscript{2}Seijoh University

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Remote robot systems with force feedback have been actively researched. A user remotely controls a robot having force sensors by operating a haptic interface device.

It is possible for the user to know the shape, weight, and softness of a remote object because he/she can perceive the reaction force from the object through the haptic interface device.

The efficiency and accuracy of work can largely be improved.
When remote operation is performed over the Internet, which does not guarantee the quality of service (QoS)

Network delay, delay jitter and packet loss

QoE (Quality of Experience) degradation

◆ QoS (Quality of Service) control

To carry out QoS control efficiently

Human perception of force (i.e., shape, weight, and softness of a remote object) should be clarified.
Purpose (1/2)

Previous work

Influences of weight change on human perception of weight by using a haptic interface device in a networked virtual environment were investigated by QoE assessment*1.

- Humans start to perceive the absolute weight changes heavier than about 20 gf (about 0.2 N).

- Investigation of human perception of force in a real environment is necessary.
- Human perception of force has not sufficiently been clarified so far.
We carry out QoE assessment on human perception of force in collaborative work between two remote robot systems with force feedback.

We examine the influence of the length of wooden stick on human perception of force direction.
Two Remote Robot Systems with Force Feedback

User side
- Key input
- Haptic interface device
- Subject side
- Position information
- Force information
- Woodens stick

System 1
- PC for haptic interface device
- Switching hub
- Network
- PC for industrial robot
- Switching hub
- Force interface unit
- Force sensor
- Robot controller
- Toggle clamp hand
- Wooden stick
- Robot arm

System 2
- Master terminal
- Slave terminal
- PC for haptic interface device
- PC for industrial robot
- Robot controller
- Electric hand
The two robot arms grasp both ends of a wooden stick (width 10 mm × height 10 mm × lengths 300 mm and 600 mm) with the toggle clamp hand and the electric hand.
User side:

- The user moved only one side (robot arm 1) of the wooden stick in one direction of front and back, left and right, and up and down with key input.

- Distances to move

<table>
<thead>
<tr>
<th>Length</th>
<th>Direction</th>
<th>front-back</th>
<th>left-right</th>
<th>up-down</th>
</tr>
</thead>
<tbody>
<tr>
<td>300 mm</td>
<td></td>
<td></td>
<td>0.01 mm ~ 0.16 mm</td>
<td></td>
</tr>
<tr>
<td>600 mm</td>
<td>0.06 mm ~ 0.48 mm</td>
<td>0.01 mm ~ 0.16 mm</td>
<td>0.06 mm ~ 0.66 mm</td>
<td></td>
</tr>
</tbody>
</table>

- The moving distance and moving direction were selected in random order per subject.
Subject side:

- Each subject just held the stylus of the haptic interface device and pressed the button as shown on the right figure.

- Each subject was asked to select one answer from among the following three answers:
  1. “I can perceive the force and know the moving direction” (he/she was asked to say the moving direction)
  2. “I can perceive the force but do not know the moving direction”
  3. “I cannot perceive any force”

- We calculated the percentage of correct answers (i.e., the force was perceived and the correct moving direction was answered).
Assessment Results (1/4)

- Percentage of correct answers [%]
- Moving distance [mm]

Front-back direction
- Front
- Back
- Line symmetry

Left-right direction
- Left
- Right
- Line Asymmetry

Up-down direction
- Up
- Down
- Line Symmetry
Assessment Results (2/4)

Point symmetry

- Force [N]
- Moving distance [mm]
- Average of maximum reaction force
- Average of average reaction force

Front-back direction

Front

Back

Left-right direction

Front

Right

Left

Up-down direction

Down

Up
Assessment Results (3/4)

- Front-back direction
  - Line Symmetry
  - Front
  - Back

- Left-right direction
  - Line Symmetry
  - Right
  - Left

- Up-down direction
  - Line Asymmetry
  - Down
  - Up
Assessment Results (3/4)

Front-back direction

- Front
- Back

Left-right direction

- Right
- Left

Up-down direction

- Down
- Up
Assessment Results (3/4)

Front-back direction

- Back
- Front

Left-right direction

- Right
- Left

Up-down direction

- Down
- Up
Assessment Results (4/4)

The Gravity is applied to the haptic interface device. To hold the device.

Force perception in the up direction is harder than other directions.
Influences of Length of Stick

Conclusion

• We carried out QoE assessment to investigate to what extent humans can accurately perceive the force direction by using a haptic interface device in the remote robot system with haptics.
• We investigated the influence of the length of wooden stick on the human perception of the force direction.

Humans can perceive the force correctly as the force is equal or greater than about 0.2 N excluding the up direction. (This is almost the same as result that humans start to perceive the absolute weight changes heavier than about 20 gf *1)
• The human perception of the force hardly depends on the length of the wooden stick.
Future Work

- Assessment of force perception by using grasped sticks with various length or softness
- Study on QoS control by using human perception of force