QoE Assessment of Adaptive Δ-Causality Control in Remote Robot Systems with Force Feedback

Lamin N. Gassama[1], Christian T. Amedayenou[1], Yutaka Ishibashi[1], Pingguo Huang[2], Yuichiro Tateiwa[1]

[1]Nagoya Institute of Technology, Japan
[2]Gifu Shotoku Gakuen University, Japan

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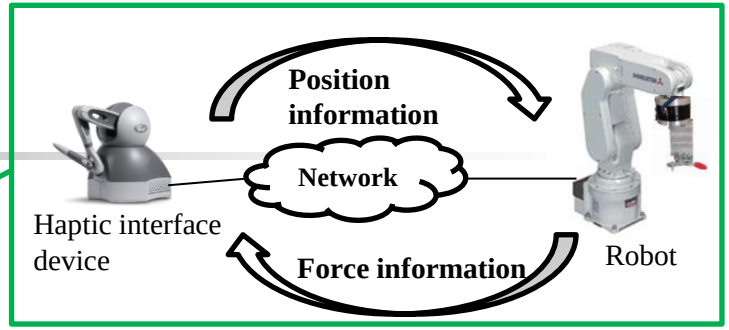
Background (1/2)



Remote robot system with force feedback has its applications in various domains; especially, in situations and environments that are dangerous, unstructured, and under-recognized.

Through a haptic interface device, a user of a system can remotely operate a robot with a force sensor while watching the video.

We can conduct various types of cooperative work efficiently.

Background (2/2)

*1 N. Hameedha *et al.*, MTA, pp. 1-7, Jan. 2022.

*2 K. Kanaishi *et al.*, ICAIT, pp. 94-98, Jan. 2020.

When position/force information is transmitted over a network such as the Internet, which does not guarantee the quality of service (QoS)

Network delay, delay jitter and packet loss

QoE (Quality of Experience) degrade

Instability phenomena occur

QoS control[*1] **+ Stabilization control**[*2]

- Local adaptive Δ-casualty control (LADC)
- Global adaptive Δ-casualty control (GADC)

Previous Work (1/2)

- Investigated the effects of two kinds of Adaptive Δ-casualty control on cooperative work between two remote robot systems with force feedback*1.
  - LADC: Control partially applied to the systems.
  - GADC: Control globally done.
- In LADC, two types of control are introduced.
  - Control between the haptic interface device and robot in each system (LADC-DR).
  - Control between the two robots (LADC-RR)
- GADC is a combination of LADC-RR and LADC-DR.

*1 N. Hameedha *et al.*, MTA, pp.1-7, Jan. 2022.

Previous Work (2/2)

Experimental results [*1] show that:

- **LADC-RR has a more beneficial effect on the cooperative work than LADC-DR.**
- **GADC is the most effective control for the cooperative work.**

Problem

- Effect of the LADC and GADC has not been clarified by QoE assessment so far.

*1 N. Hameedha *et al.*, MTA, pp.1-7, Jan. 2022.

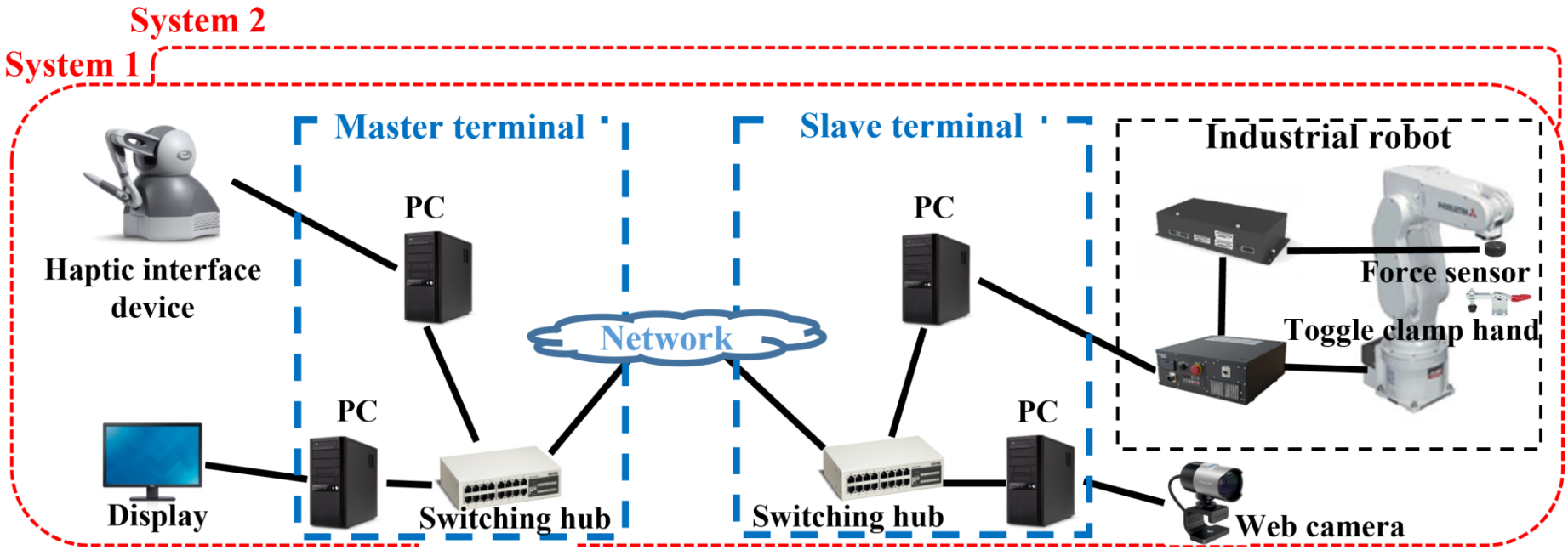
Purpose

This work

- **Investigate the effects of the local adaptive Δ-casualty control between robots on cooperative work between remote robot systems with force feedback by QoE assessment.**

- **Make a comparison between two cases; one case the control is exerted in the systems, and the other case does not exert it (called *NC* here).**

Remote Robot Systems with Force Feedback



Configuration of two remote robot systems with force feedback

Cooperative Work Between Two Robots

- **Through a haptic interface device, a user at the master terminal remotely operates the robot arm while perceiving the force.**
- **The master terminal of each system receives the position information from the haptic interface device every millisecond [*2].**
- **One robot adjusts its position to reduce the force applied to the object according to the force applied to the force sensor [*2] .**
- **Two different users operate the haptic interface devices of systems 1 and 2 while watching videos.**

*2 S. Ishikawa *et al.*, IJCNS, pp. 1-13, Mar. 2021.

Adaptive Δ-Casualty Control

In LADC, we have two types of control.

- **LADC-DR: Control between the haptic interface device and robot in each system.**
- **LADC-RR: Control between the two robots.**

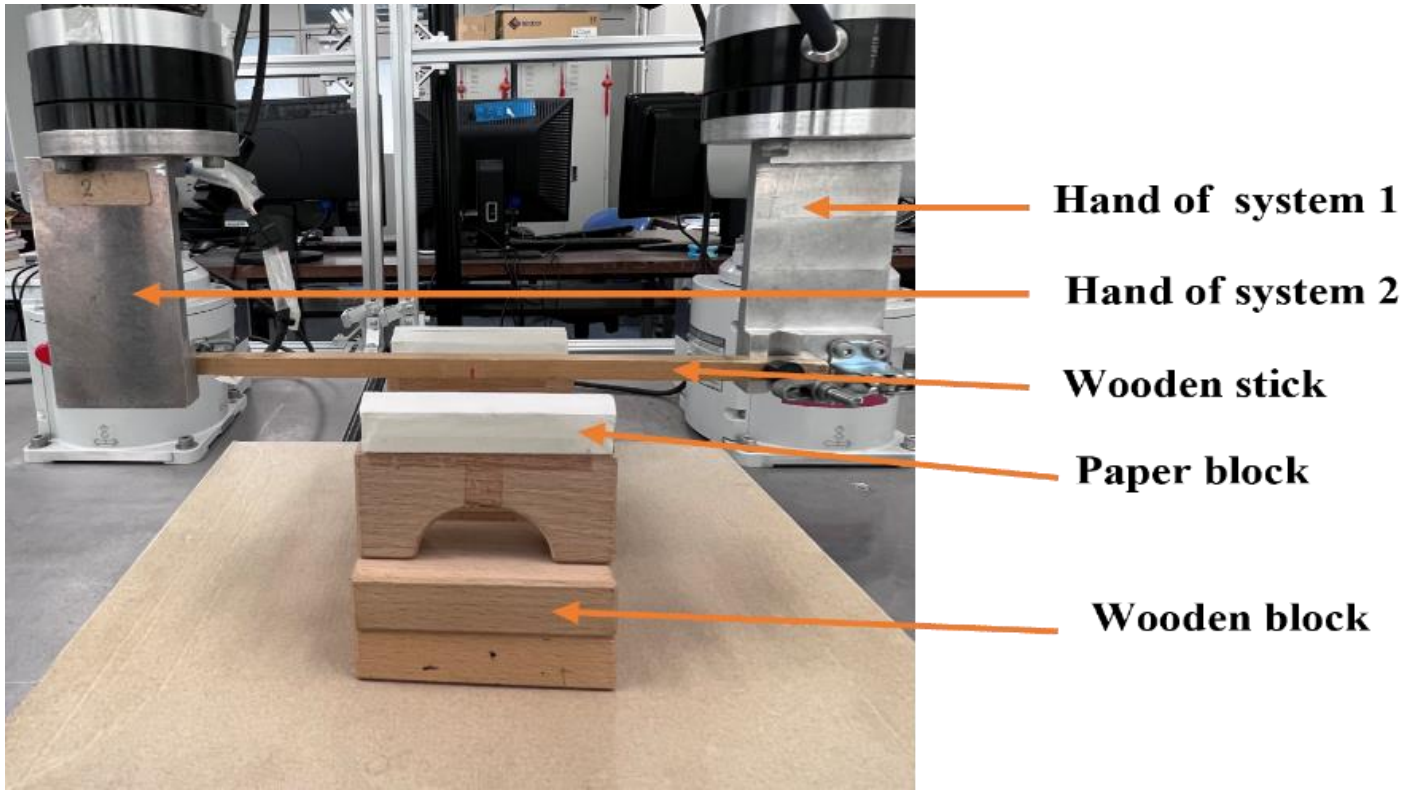
- **LADC-DR: applied to reduce the influence of the difference in network delay between the device and the robot of each system.**
- **LADC-RR: the output timing of the position information is delayed dynamically according to the network delay[*3] between the robots so that both robots move at the same time.**

*3 K. Kanaishi *et al.*, ICAIT, pp. 94-98, Nov. 2020.

Assessment Method (1/3)

- **A network emulator (NIST Net) generates a constant delay (called the network delay here).**
- **Network delay between robots is set from 0 milliseconds (ms) to 200 ms at intervals of 50 ms.**
- **Network delay between the device and the robot was set from 0 ms to 150 ms at intervals of 50 ms.**

Assessment Method (2/3)



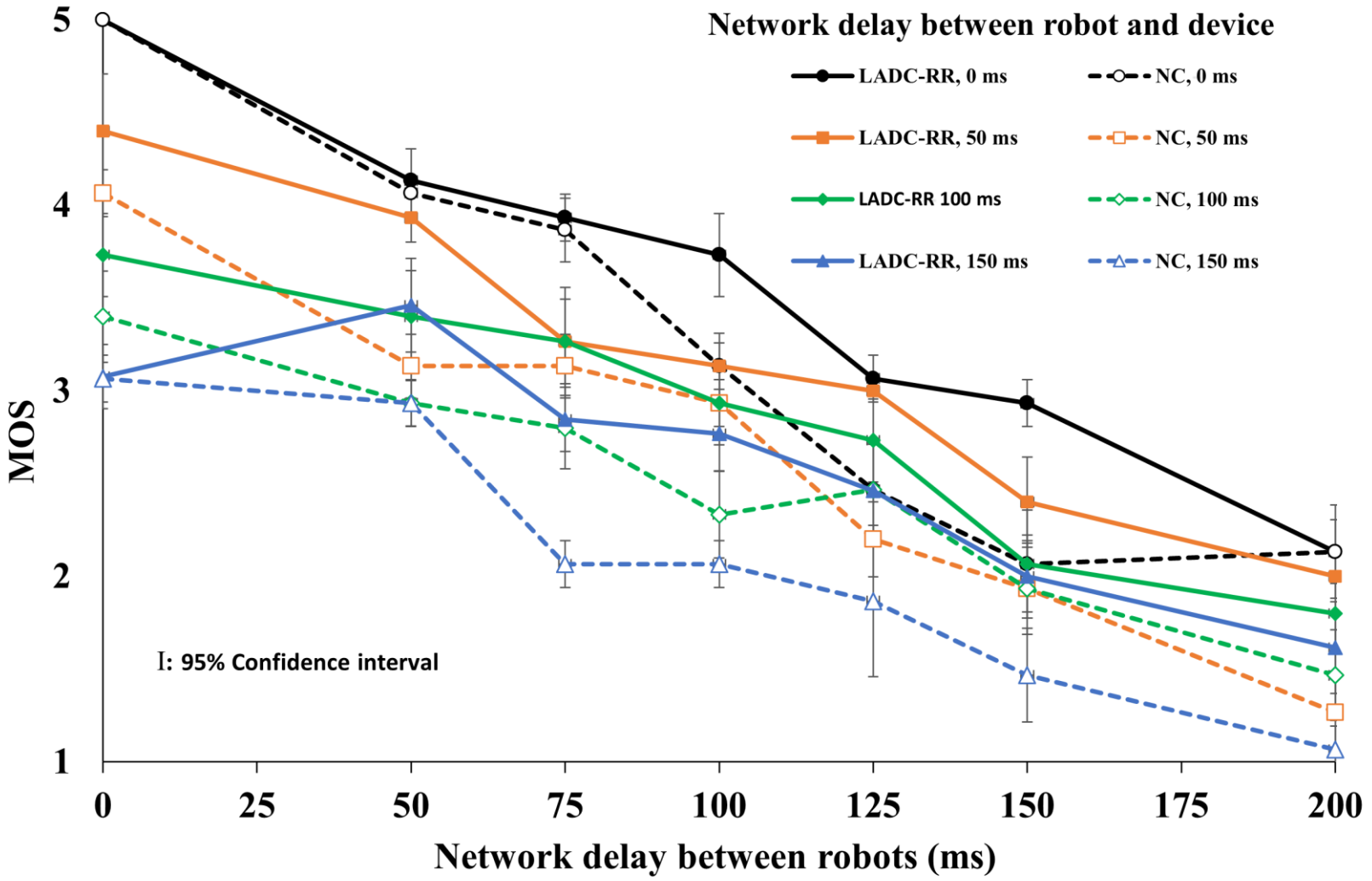
- **The task was to touch each paper front and back with the wooden stick by using the haptic interface device.**

Assessment Method (3/3)

- **Combined 56 stimulus of (LADC-RR and NC) was presented to each subject in random order.**
- **For the standard quality, each subject practice the work of moving the wooden stick three times while watching the video.**
- **The subject was asked to score from (1-5) in terms of the easiness of the operation compared to the standard quality.**
- **Subjects: 15 (12 men and 3 women).**

Score	Impairment
5	Impercitible
4	Perceptible but not annoying
3	Slight annoying
2	Annoying
1	Very Annoying

Assessment Results (1/2)



MOS versus network delay between robots

Experimental Results (2/2)

Network delay (ms)		MOS		Force (N)	
Between robot and device	Between robots	LADC-RR	NC	LADC-RR	NC
0	0	5.0	5.0	0.19	0.19
0	100	3.7	3.1	0.25	0.47
100	0	3.7	3.4	0.18	0.17
100	100	3.0	2.3	0.17	0.53

- The average force tends to become largely suppressed when the network is at 100 ms.
- LADC-RR is more effective compared to NC.

MOS and average force.

Conclusion and Future work

Conclusion

- **We conducted QoE Assessment of the adaptive Δ-causality control in remote robot systems with force feedback.**

We found that the local adaptive Δ-casualty control between robots is more effective compared to No Control.

Future work

- **Conduct the QoE assessment for local adaptive Δ-casualty control between device and the robot and the global adaptive Δ-causality control (GADC).**