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Year 2023	**Summary of Thesis**

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(Title)

Developments of Wire-driven Haptic Glove and Wire-tension Control for Robotic Hand Teleoperation System

Remote robotic operations are utilized in variety of applications, such as assisting in surgery and working in inaccessible or dangerous areas. If various task can be made remotely by using robots, it is expected to improve the task environment and reduce travel costs. The bilateral leader-follower control is one of robot teleoperation methods. The remote follower device is operated by a reader device at the operator's hand. In addition, the haptic information is fed back from the follower side to the reader side. As a result, the operator can obtain the haptic sensation while handling a remote object. This study aims to achieve remote control of a follower robot hand with haptic information. Figure 1 is a schematic diagram of the teleoperation system.

Our laboratory has developed a robot hand with almost same degree of freedom as a human. In this study, we develop a wire-driven haptic glove for operation and exchanging haptic information with the robot hand. The follower robotic hand is controlled by a human hand wearing the leader haptic glove.

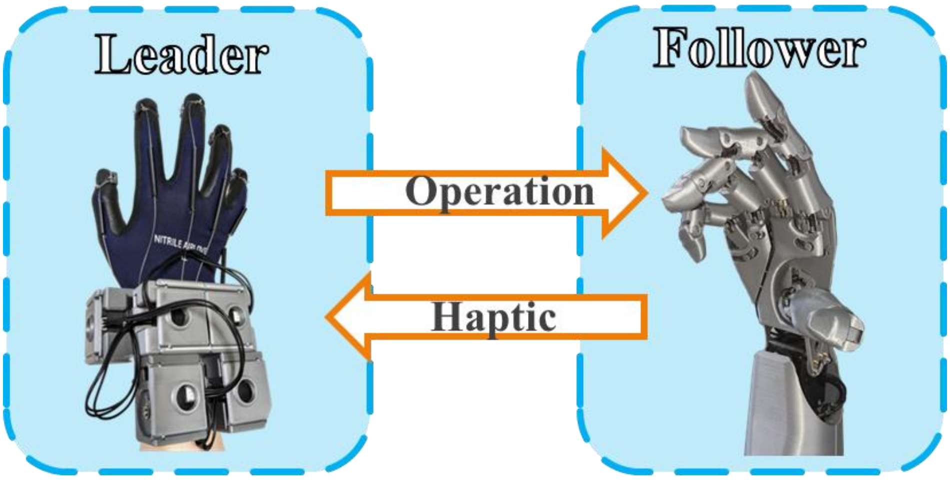

Fig.1 Schematic diagram of bilateral leader-follower control

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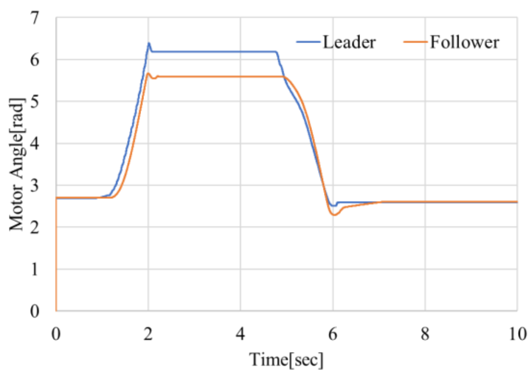
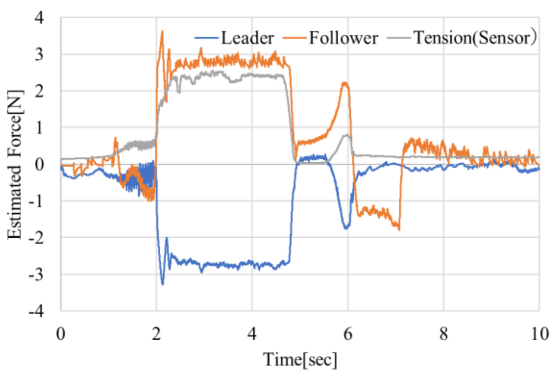
The glove can produce haptic force by wire driven. However, there is possibility that the slack of wire in glove occurs. If the wire is slack, haptic force cannot be produced correctly. In order to eliminate the slack and to avoid the resistance force, a tension control using a high-sensitivity force sensor is developed to keep wire tension small under free motion. In teleoperation of robotic hand, the tension control is enabled when the follower robotic hand is not in contact with the object. When the follower is in contact with the object, bilateral control is enabled instead of tension control. Thus, a motor control in the proposed method combines tension control and bilateral control.

In this paper, we designed a bilateral control system for teleoperation the robotic hand with a wire-driven leader device, and the effect of the control system is evaluated by verification experiment. In the verification experiment, the follower pushes object by leader action winding a wire of the motor pulley in test device. The results of the experiment are shown in Figure 2.

In conclusion, it was confirmed that the follower device can be operated by manipulating the leader device’s wire, and a reaction torque was transmitted to the leader side in contact motion. However, when the direction of direction of the rotation of the motor of follower side changes significantly, an error in the estimated reaction torque occurs, and this error torque is fed back to the leader side. Therefore, there are still points to be improved in the teleoperation system in this study. In the future works, the friction model, the thresholds for switching between wire tension control and bilateral control, and several control gains are required to be adjusted in order to improve the operability and enhance the transparency of force transmission during teleoperation.



(a) Angle response



(b)Force response

Fig2. Bilateral control experiment results

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