Evaluation and Learning Curves of Motion- and Force-based Haptic Input Devices in Telemanipulation: A Work-in-Progress Study*

Timo Markert[1,2], Sebastian Matich[1], Jonas Pfannes[1], Andreas Theissler[3], and Martin Atzmueller[2]

***Abstract*— The factory of the future as well as robot-assisted surgery (RAS) make use of telemanipulation systems to enable remote control by human operators. Accuracy, intuitive handling, and short task completion times are of highest priority. In this work-in-progress study, two haptic input devices are considered for telemanipulation: An off-the-shelf 3 degrees of freedom (DoF) motion-based device is compared to a custom rigid stick with 6 DoF force/torque (F/T) sensing capabilities. Three tasks which mimic relevant maneuvers for assembly and RAS are performed by 24 subjects. Preliminary results show that operating with the force-based device is particularly intuitive for novices. Observing the learning curves of our long-term study, we conclude that sleep reveals to be crucial in memorizing sensory impressions. Thus, a training period of several days is recommendable for teleoperation systems.**

I. Introduction and Methods

Teleoperation scenarios in industrial applications and RAS make use of a vast variety of input devices, such as haptic interfaces, joysticks, 3D mice, and rigid-link manipulators [1]. Their quality, intuitive handling and effectiveness are of highest priority for expert hapticians [2]. Also, learning characteristics have to be investigated to derive required training times for novices. Both, performance metrics as well as learning curves, are systematically investigated in this study for two conceptually different haptic input devices.

A robot manipulator is remotely controlled by human operators using a Novint Falcon, an off-the-shelf 3 DoF motion-based delta structure (force-feedback disabled), and a custom rigid stick with a built-in sensor strcuture for measuring 6 DoF forces and torques (Fig. 1). An overview of the sensor design is given in [3]. The three rotational DoF are disabled for our experiments. In a first study, 24 subjects perform three tasks which mimic relevant maneuvers for assembly and RAS w.r.t. task performance and execution time: (1) pick-and-place, (2) peg-in-hole, and (3) precise movement. In a second study, three subjects carry out the tasks over a longer period of time to investigate learning characteristics and long-term effects.

II. Preliminary Results and Future Work

Our preliminary results indicate, that the force-based device provides high usability with low task execution times, especially for novices. Learning curves of our long-term study underline, that sleep reveals to be crucial in memorizing sensory impressions [4]. Training for a period of several days is recommendable for teleoperation systems (Fig. 2).

The outcome of the performed tasks may still depend on factors that are related to the input type. Therefore, we aim to match controller architecture and bandwidth for a fair comparison of both device classes in future work.

*The authors acknowledge the financial support by the Bavarian State Ministry for Economic Affairs, Regional Development and Energy (StMWi) for the Lighthouse Initiative KI.Fabrik, phase 1, grant no. DIK0249.

[1]T. Markert, S. Matich, and J. Pfannes are with Resense GmbH, Klingenberg, Germany. Corresponding author: timo.markert@resense.io.

[2]T. Markert and M. Atzmueller are with Osnabrück University, Osnabrück, Germany. M. Atzmueller is also with the German Research Center for Artificial Intelligence (DFKI), Osnabrück, Germany.

[3]A. Theissler is with Aalen Univ. of Applied Sciences, Aalen, Germany.

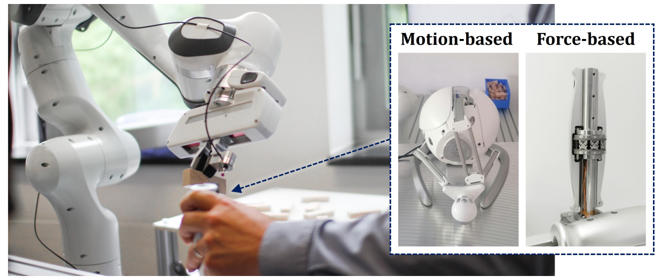

Fig. 1. **Haptic input devices.** In this work-in-progress study, 24 subjects evaluate two different input devices, i.e., an off-the-shelf motion-based device and a rigid stick with 6 DoF F/T output, for telemanipulation.

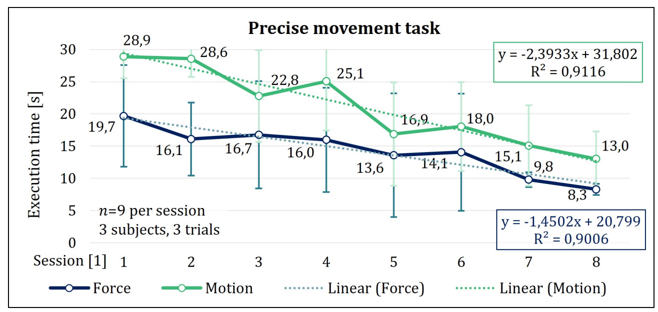

Fig. 2. **Learning curves.** Preliminary results of our long-term study show, that execution times for both input devices can be significantly reduced by more than 50% within only a few days. The steep learning curve in the most difficult precise movement task is particularly remarkable.

References

[1] G. S. Giri, Y. Maddahi, and K. Zareinia, “An application-based review of haptics technology,” *Robotics*, vol. 10, no. 1, p. 29, 2021.

[2] F. Fazlollahi, H. Seifi, K. MacLean, and K. J. Kuchenbecker, “How do expert hapticians evaluate grounded force-feedback devices?,” *IEEE World Haptics Conference (WHC)*, p. 341, 2021.

[3] T. Markert, S. Matich, E. Hoerner, A. Theissler, and M. Atzmueller, “Fingertip 6-axis force/torque sensing for texture recognition in robotic manipulation,” *2021 IEEE 26th International Conference on Emerging Technologies and Factory Automation (ETFA)*, 2021.

[4] B. C. Clawson, E. J. Pickup, A. Ensing, L. Geneseo, J. Shaver, J. Gonzalez-Amoretti, M. Zhao, A. K. York, F. R. Kuhn, K. Swift, J. D. Martinez, L. Wang, S. Jiang, and S. J. Aton, “Causal role for sleep-dependent reactivation of learning-activated sensory ensembles for fear memory consolidation,” *Nature communications*, vol. 12, no. 1, 2021.