Multi-Layered Control of A Bilateral Haptic Telemanipulation Setup using Collaborative UR10e Robots

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***Abstract*— This article discusses the design of a telemanipulation system providing haptic feedback for remote sensing of textured surfaces to improve and test vibrotactile actuator design. The system includes two UR10e Collaborative robots, each with a vibrotactile end-effectors for providing accurate texture-emulation. The system is designed with multilayered control, including local supervisors for managing operation modes and data transfer, and a system-wide supervisor that is responsible for managing the behavior of the local supervisor units and the data transfer between them.**

I. Introduction

Haptics is a sensory experience that involves touch, movement, and their mechanical interaction [1]. When working on tactile actuator design [4] and doing research on its design requirements, a test-bed-environment to control and modify mechanical properties during interaction is required: an ideally transparent telemanipulation system. These are widely known and have many potential applications, including the remote sensing of textures using robot telemanipulation [3]. However, beside accurate emulation of the feeling of texture with actuators with adequate capabilities, additionally force impedance control is essential to define the boundaries of motion to the operator and to create an immersive experience. One significant challenge in this application is the transparency of data transmission from the primary source of motion, the operator, to the environment and back. This issue can be addressed by dividing the primary system into multiple subsystems, each operating independently and receiving only the necessary information from the network [2]. This approach ensures that the transfer of data between subsystems is as fast as possible without losing any critical information, improving the transparency of the haptic feedback.

II. Multilayered Control

The telemanipulation system consists of two UR10e Collaborative robots, each of which has an end-effector for actuator-design-studies, connected. The end-effector is an aluminum pen enclosed in a compartment that is designed to isolate its vibration from the robot movement. It is considered a mass-spring system that vibrates perpendicular to the textured surface. The robot unit is responsible for handling the motion sensing and actuation with a force/torque sensor, an IMU, and Forward Kinematics, while the end effector unit is used for resembling a tactile interaction perception controlled by another IMU sensor. Each robot unit has an H_2/H_∞ impedance control loop for synchronizing the motion impedance. The secondary vibrotactile end effector has a vibration control loop, while the primary will be used to capture the vibration of the texture. In the final stage, each robot and end effector unit will have a local supervisor responsible for managing the operation modes and data transfer from and to the kinesthetic and vibrotactile control loops. The local supervisor is a state machine that passes through the reference signals to their corresponding feedback loops and ensures that safety margins are not exceeded. On the other hand, the system supervisor is a consensus based controller that coordinates the states of each agent in the system by sending each agent their reference trajectory.

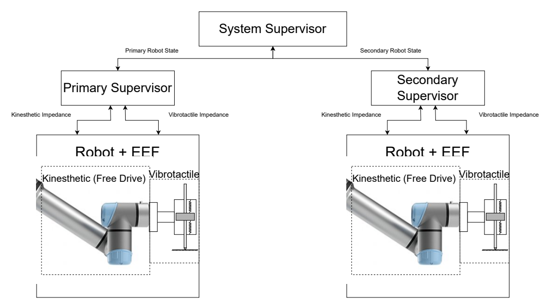

Fig. 1. A diagram showing the Multilayered Control Structure

III. Current Status

The current status for the project involves implementing several components. The implementation of kinesthetic H_2/H_∞ impedance control for the UR10e collaborative robots, the implementation of the vibrotactile control loop and the implementation of the robot/end effector supervisor as well as the system-wide supervisor, which will manage the behavior of the robot supervisor units.

References

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