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Design of a bilateral position/force master slave teleoperation system with non similar robots

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Desired topic: synchronization under control

In this research a bilateral master slave teleoperation system with two non similar robots is designed and investigated through simulations and experiments, see Figure 1. Both robots are fully characterized kinematically and dynamically. Dynamical identification is done using frequency response methods. Transfer functions are fitted through the frequency response data to obtain the system transfer function matrices. These matrices are used to design a bilateral master slave teleoperation system, where the slave robot imitates the position and orientation of the master robot whereas the master is imitating the reaction force applied to the slave when it is in contact with an environment. Controllers for both robots are developed to ensure high performance on the total system, that yields transparency of the teleoperation scheme.

Figure 1: Schematic diagram of the master - robot teleoperation system

The master controller consists of two parts, namely a PI force controller that controls the force feedback and an internal model controller that compensates for the master robot dynamics. The master robot dynamics should be compensated so that an operator, handling the master robot, actually does not feel this robot. The slave controller also uses a PI force controller to ensure that the force, which is applied by the operator to the master robot, is also applied to the environment by the slave robot. The second part of the slave controller is a position controller tuned with the slave robot transfer functions so that high performance can be reached.

At this point the robots are not provided with force sensors, thus virtual environments are considered to numerically calculate the reaction forces when one of the robots is in contact with these environments. The first type of virtual environment uses an impedance model which represents the environment as a mass-spring-damper system, especially useful for modeling soft environments that can be penetrated. The second type is based on holonomic constraint model, which is useful for modeling rigid environments whereas penetration is impossible. With both models the robots can move tangent to the environment while applying force to it. For simulation purposes an operator is designed as a PID position and force controller so that it can generate torques on the master robot to move it along smooth desired trajectories that are designed using Bezier polynomials.

Experimental results shows good convergence on the position and force errors between the master and slave robots, that concludes high transparency of the overall teleoperation system. This property is particularly of interest for haptic applications, which is considered as further work. Furthermore convergence errors guaranties synchronization between the master and slave robot in both position and applies force.