Haptic Gripper with Adjustable Inherent Passive Properties

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Abstract. This paper describes the design and implementation of an experimental teleoperation setup with adjustable inherent properties for both the master and the slave interface. With this setup certain aspects of biological inspired teleoperation can be explored. The system consists of two identical 1 degree of freedom devices with structural stiffness adjustable between 0.2 and 100 N/mm and a relative damping adjustable between 0 and 1.

1 Introduction

Teleoperators with haptic feedback gain in popularity, from underwater operations [1] and nuclear inspection robots [2] to nanomanipulators [3] and surgery stations[4].

The current design of teleoperator slave robots is focused on precise sensors, stiff structures and fast controllers. This approach results in high haptic performance [5], but makes the system sensitive, potentially dangerous and expensive. Moreover this results in high frequency instability in contact with hard environments. To achieve stability in contact with a wide range of impedances, controller-simulated damping and stiffness are introduced, either with constant damping [6], a passivity observer/controller [7], or by adapting the closed loop dynamics [8].

An alternative design is found in biological systems. The slenderness and stability of a human arm stands in a bright contrast to industrial robots. The two most important differences in the constitution of a robotic arm and a human arm are the control principles and the actuator properties.

There have been numerous studies that show that it is possible to make robotic machines that function in a similar way as the biological systems, e.g. *biorobotic* machines [9]. It has been suggested that biorobotic manipulators can achieve higher performance than traditional robots for certain tasks [10]. Our research intends to investigate to which extent these methods can improve teleoperation.

This paper describes an experimental setup for 1-degree of freedom (dof) teleoperation where the biorobotic principles can be implemented, tested and evaluated. Preliminary results suggest that contact stability can be improved thanks to the inherent mechanical properties, even with a very simple controller.

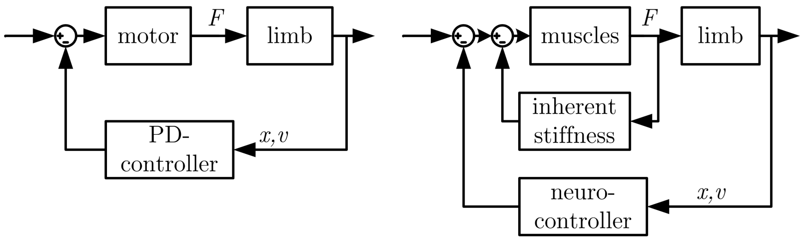

Fig. 1. Traditional robot motion controller (*left*) and a biological motion controller (*right*)

2 Biorobotics for teleoperation

A teleoperation system can be seen as an extension of the human body. The interface with the operator - the master - should reproduce the characteristics of the remote environment. The remote slave robot on the other hand represents the operator's hand. The difference in stiffness for the master and the slave introduces a hard-soft asymmetry which has important implications for the dynamics of the system. We believe that a sensitive and stable system can be achieved using the biorobotic principles for control and actuation.

The control principles used in a biological system is based on a completely mechanical, thus fast, inner loop and a slow outer neural feedback loop with an effective bandwidth of 1-10 Hz, see Fig. 1. This neural control loop is much slower than a robotic controller, which typically has a bandwidth of 1-10 kHz. The biological neuro-controllers are furthermore nonlinear, in contrast to the common linear robotic PD controllers.

The actuator systems found in biological systems, muscles and tendons, have characteristic inherent mechanical stiffness and damping [11]. The most popular actuator for robotics, the electric motor, has very different inherent properties, but is easy to control thanks to the linear current/torque relationship.

3 Design Requirements

To explore the influence of intrinsic properties of haptic hardware, it shall be possible to adjust the stiffness and damping between the end effector and the actuator, see Fig. 2 for a schematic overview of the experimental setup.

Two setups are built to form a teleoperation system. The focus of our research is grasping of small objects between the index finger and the thumb, which dictates ranges of motion and force. The required range of motion is set to 50 mm. As mentioned in [12] the maximum force humans can apply with the index finger for short periods of time is about 50 N. Tests showed that significant levels of discomfort are encountered after only 10 minutes at grasp levels of only 25% of the maximum force. Based on this information a continuous force of 10 N, and a peak of at least 50 N are required for the setup.