Impedance control with force feedback

Assistant: Giulia Ramella

One of the most common control methods for human-robot interaction is impedance control. However, non-linearities may affect the performance of our controllers when deployed on the real hardware. To mitigate these effects, this specialization project uses an additional force sensor to acquire the interaction force between the human and the paddle. The interaction force is used in the impedance controller to create an impedance controller with force feedback. The goal is to improve the compensation of non-linearities, and the impedance range that we can render. The difference in the range can be investigated by obtaining K-B plots and comparing them to the ones obtained with the “simple” (open-loop) impedance controller in Lab 3. An additional fun force transmission problem can also be implemented with this force-feedback setup.

In your report, you have to present the concept of adding a force sensor at the interaction point between human and robot (end-effector), and the required calibration. Then, you have to show your implementation of the impedance controller with force feedback and discuss the differences with the simple impedance controller. You also have to motivate the placement of the sensor as close as possible to the output.

References:

- “Closed-loop Force Control for haptic Simulation of virtual environments”, Carignan and Cleary, 2000
- “High-Fidelity Rendering of Virtual Objects with the ReHapticKnob –Novel Avenues in Robot-Assisted Rehabilitation of Hand Function”, Metzger, Lambercy, Gassert ,2012
- "A Review of Algorithms for Compliant Control of Stiff and Fixed-Compliance Robots," Calanca, Muradore and Fiorini, 2016
- "Impedance and Interaction Control", Hogan and Buerger, 2005
- "On the Z-width limitation due to the vibration modes of haptic interfaces," Gil, Puerto, Díaz and Sánchez, 2010
- "Stability and Performance Limits of Interaction Controllers." Newman, 1992

EMG control

Assistant: Mouhamed Zorkot / Giulia Ramella

The aim of this specialization project is to design and implement a control strategy allowing a user to control the haptic paddle through the contraction of a muscle, sensed via surface electromyography (EMG). Your task is first to get familiar with the physiological principles underlying surface electromyography. You will then set up the hardware (EMG electrodes and an instrumentation amplifier board) and implement signal processing and low-level control allowing the muscle activity to be mapped to either position or torque generated by the haptic paddle. You can then explore the user interaction under each of these mapping schemes. In your report, you will give a brief introduction to EMG, discuss the selected signal processing steps and the potential of this control method in prosthetics and other fields.

References:

- “Surface Electromyography: Detection and Recording”, C. De Luca, DelSys Incorporated, 2002
- “Assistive Control System Using Continuous Myoelectric Signal in Robot-Aided Arm Training for Patients After Stroke”, Song et al., IEEE TNSRE, 2008
- “Evaluation of EMG pattern recognition for upper limb prosthesis control: a case study in comparison with direct myoelectric control”, Resnik et al., Journal of NeuroEngineering and Rehabilitation, 2018

Design of framework for teleoperation between two haptic displays

Assistant: Aiden Xu

Teleoperation represents the control of a machine (often times a robot) from a remote location. In cases where the teleoperator, or input device, is also a robot, the teleoperator is known as the "master" robot and the teleoperated robot is known as the "slave" robot. The aim of this project is to design and implement a control framework that allows the user to handle one Haptic Paddle (the master) and operate on a remote environment or with another human operator via a second Haptic Paddle (the slave). If the master is a force feedback manipulator, such as the Haptic Paddle, then the user can "haptically" feel the remote environment of the slave via the master. Your tasks will involve:

- Design and implement a haptic teleoperation scheme;
- Establish both a one-way communication (one paddle is the master, and one the slave), as well as a bimodal communication (tele-interaction) in which the two paddles are both master and a slave grounded through their environment or user;
- Investigate the effect of time delays introduced in your control loop between master and slave (communication delay)
- In your presentation you will give a brief introduction to teleoperation, present the haptic environments that you explored with the haptic paddle (one-way communication), the teleoperation modes you experienced (bimodal communication) and discuss the parameters that affect stability.

References:

- K. J. Kuchenbecker and G. Niemeyer, "Modeling induced master motion in force-reflecting teleoperation", ICRA, 2005.
- P. Mitra and G. Niemeyer, "Model-mediated telemanipulation", IJRR, 2008.
- N. A. Tanner and G. Niemeyer, "Improving perception in time-delayed telerobotics", IJRR, 2005.

Electronic skin and thermal feedback

Assistant: Jonathan Louis Muheim

In this specialization project, you will implement a sensory feedback loop to restore the perception of temperature in amputee individuals. The input of the system is a custom sensor that mimics the thermal response of the human skin and integrates a temperature sensor. The goal will be to copy the measured temperature on a thermal display that can cool down or heat up its surface.

As a first step, you will characterize the sensor's ability to measure changes in temperature and calibrate it to imitate human skin. You will then implement a closed-loop controller for the thermal display. Finally, the goal will be to validate your set-up in a real-time task (e.g., touching different materials or objects at different temperatures).

References:

- "A Review of Non-Invasive Sensory Feedback Methods for Transradial Prosthetic Hands", Stephens-Fripp, Alici and Mutlu, IEEE Access, 2018.
- "Miniaturized Flexible Temperature Sensor", Moser and Gijs, Journal of Microelectromechanical Systems, 2007.
- "Flexible temperature sensors: A review", Kusubasoglu and Bahadir, Sensors and Actuators A: Physical, 2020.
- "Development of a Feedback Device of Temperature Sensation for a Myoelectric Prosthetic Hand by Using Peltier Element", Ueda and Ishii, Proceedings of the 2016 International Conference on Advanced Mechatronic Systems, 2016.