Master's thesis project:

Advanced Teleoperation with Haptic Feedback

Motivation & Background

Programming robots for tasks involving force interaction is difficult, since both the knowledge of the task and the dynamics of the robots are necessary. An **immersive haptic interface** such that the operator can sense and act through the robot can facilitate the programming. Far from being a solved problem, haptic teleoperation is still one of the active topics in robotics research. It is characterized by a high degree of **physical interaction** with the environment, which demands sophisticated control algorithms.

The **non linearty**, along with the **uncertainty of the parameters**, especially friction forces, and communication delays pose a challenge for **stability** and **robustness** of the teleoperation systems. Safety is also paramount if robots are to share their workspace with humans.

Project Description

The project is about the development of a dual-arm haptic system. Two small 6-DOF robotic manipulators are to be used in the setup. However, it is possible to replace one robotic arm with a specialized haptic interface shown in Figure 1b. The user interacts with one of the arms to perform a task by the second one, while feeling the interaction forces. There two main objectives, which can be followed in this order:

- **Reliable Haptic Interface**: The system should remain stable during interaction with a stiff environment. Moreover, similar performance must be obtainable every time the system is in operation. Robustness with respect to model uncertainty and delay can additionally be explored.
- **Enhanced User Experience**: Assuming negligible delays and high enough control bandwidth, linearity has a major impact on the transparency with respect to the task. Moreover, constrained motions, guiding forces and motion scaling can be introduced to assist the user.

Task Overview

The tasks consists of many iterations of implementation, testing, improvement, and documentation. After getting acquainted with the hardware and interfaces, the first step is to implement the algorithm detailed in [1].

(a) UR5e (b) Omega7 haptic device

Figure 1: Hardware available for the experiments

Timeline:

Weeks 1-5: At first, the student should get familiar with the algorithms and tools. First implementation of the algorithm is carried out.

Weeks 6-11: In this part, the work focuses on performance and reliability aspects. Force sensors are to be integrated. For an easier interaction with the robot, a teaching handle is designed.

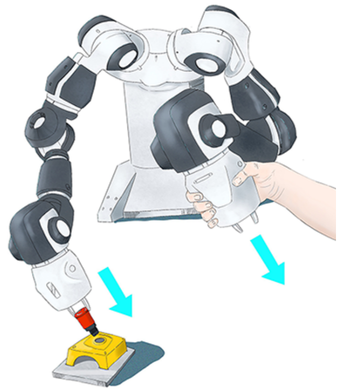

Figure 2: Teaching a task

Weeks 12-16: The focus in this part is the improvement of user experience. The teaching handle is also integrated and tested.

Weeks 17-20: The last part of the project is about packaging of the results and finalizing the report.

Required Skills

The successful completion of this project requires that the student possesses or can easily acquire the following skills:

Mechanics: Basic familiarity with multi-body dynamics, in particular kinematics and dynamics of robots, is required for understanding the algorithms.

Control: A significant part of the work will be the development of algorithms and control laws to be executed by the robot. The student should at least have some basic understanding of nonlinear control, signal processing, and optimization methods.

Programming: For modeling purpose, Matlab or Modelica may be used. However, prototyping is usually done in Python, which could also be tested with the robots. For interfacing with some devices, familiarity with C++ can be necessary.

Outcomes

The student will become proficient in robot **control** and gain significant **hands-on experience** with UR robots. They will advance their knowledge in robot kinematics and **dynamics**. Furthermore, they will have an opportunity to be a member of a highly-skilled team in various aspects of robotics, obtaining **technical** as well as **personal** skills. They will also improve on how to do data analysis, system engineering, programming and scientific writing.

Contact

The project will be carried out at Cognibotics AB located at Ideon Science Park, Scheelevägen 15, SE-22370 Lund, Sweden. For further information, please contact Dr. Mahdi Ghazaei email: mahdi.ghazaei@cognibotics.com.

Further Reading

[1] M. Ghazaei Ardakani, M. Karlsson, K. Nilsson, A. Robertsson, and R. Johansson, "Master-slave coordination using virtual constraints for a redundant dual-arm haptic interface," in *Proc. 2018 IEEE/RSJ Int. Conf. Intelligent Robots and Systems (IROS)*, 10 2018, pp. 8751–8757.

[2] M. Selvaggio, F. Abi-Farraj, C. Pacchierotti, P. R. Giordano, and B. Siciliano, "Haptic-based shared-control methods for a dual-arm system," *IEEE Robotics and Automation Letters*, vol. 3, no. 4, pp. 4249–4256, 2018.

[3] Z. Pasztori, "Master-slave teleoperation with force feedback in hazardous environment," Master's thesis, Universitat Jaume I, 2018, CERN-THESIS-2018-395.