Data-Based Control Design for Naturally Compliant Fluidic Robotic Joint:
1. Virtual Reference Feedback Tuning (VRFT)
2. Iterative Feedback Tuning (IFT)

Background:
Widespread applications of robots in human environment imply the use of “soft” manipulators, which guarantee safe interaction with a user, followed by the traditional requirements concerning speed and accuracy. A secure way in designing such robot arms is to use naturally compliant actuators known as artificial muscles. A novel fluidic artificial muscle has been developed at IAT/FWBI. It is of revolute type and thus suitable for direct actuation of rotary robotic joints without mechanical transmission, which is necessary when using the linear types of pneumatic artificial muscles. The working principle of the new actuator is analogous to conventional single vane fluidic motor, which consists of two chambers, defined by a fixed and moving vane. An essential difference is in the rotary elastic chambers that replace the rigid chambers of the conventional vane actuator. When pressurized, the chamber expands in meridian direction only and pressure force is transferred to torque by means of the moving vane. The actuator can be operated by oil or gas pressure.

Approach:
Mathematical model of a new actuator is highly nonlinear, with uncertain and time varying parameters. On the other hand, control design can be model-based or data-based. A model-based design can deliver a high performance controller if the implemented model is an accurate description of the plant. Inaccuracies in the model limit the controller performance and may even lead to instability. In data-based control design, the plant modelling step is omitted. Instead, the controller is derived using experimental data.

Project 1:
Virtual Reference Feedback Tuning (VRFT) [1] is a general methodology for the design of feedback controllers when the plant is unknown. Its main features are:
• it is a direct method (no model identification of the plant is needed);
• it can be applied using a single set of data collected from the plant with no need for specific experiments nor iterations.
• VRFT permits to tune a 1 or 2 degree of freedom linear controller within a specified class on the basis of a single set of input/output data collected from an experiment on the plant. The control specifications are assigned via a model-reference discrete time transfer function. Given a single set of input/output data (either collected in open-loop or in closed-loop), the VRFT method can be applied in order to obtain the controller that satisfies the assigned specifications.
• The “design engine” of VRFT is a solver of a model-reference optimization problem. Lack of knowledge of the plant transfer function is compensated for via I/O measurements.

Tasks:
1. Introduction to the VRFT method.
2. Introduction to the toolbox and implementation of the method in Matlab/Simulink.
3. Introduction to the experimental set up.
4. Experimental validation in low level control of a compliant fluidic actuator.

Literature:
http://bsing.ing.unibs.it/~campi/VRFTwebsite/index.html
Project 2
Iterative Feedback Tuning (IFT) is a data-based control approach which aims to optimize the parameters of a feedback controller without the usage of any model for the plant. Feedback design using the IFT approach begins with the definition of a performance criterion. Typically, the criterion simultaneously penalizes the difference between the desired and actual plant output (error) and the input to the plant. Furthermore, the designer selects a controller class of desired complexity with some parameters free to tune, e.g. a PID controller. The objective of IFT is to minimize the criterion by tuning the free controller parameters. The optimization is performed by an iterative method, which requires knowledge of the gradient of the criterion with respect to the controller tuning parameters. The key feature of IFT is the estimation of this gradient directly from the experimental data.

Tasks:
1. Introduction to the IFT method (one Diplom thesis has been just finished).
2. Implementation of the method for 2 degrees of freedom controller.
3. Introduction to the experimental set up.
4. Experimental validation in low level control of a compliant fluidic actuator.

Literature:
