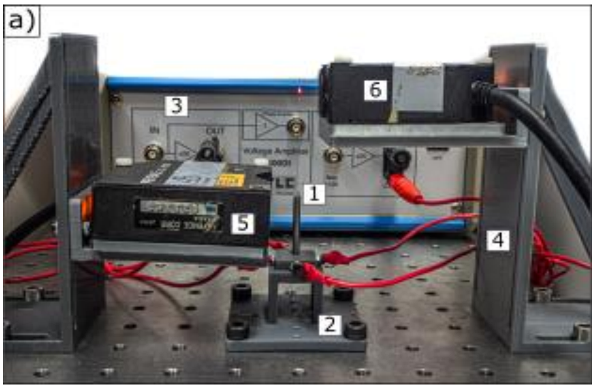
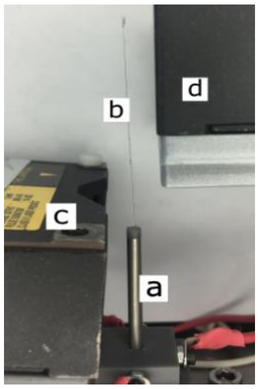
Energy based control of flexible optical fiber using the port Hamiltonian framework

Context

The AS2M department of FEMTO-ST Institute, specialized in microrobotics and micro-mechatronics investigate since more than 10 years on the design, modeling, fabrication, and control of microsystems and microrobots. Various systems have been achieved for micro-assembly and biomedical applications with smart actuators, sensors, and in a small volume. In addition, different methods were developed for improving the performances of microrobotics systems: feedforwards, closed-loop control through H infinity, predictive control, sliding mode, energy shaping, etc.

In the framework of computer-assisted surgery, the continuum robots have shown their ability to reach some areas difficult to access. They can be categorized in terms of their structural design and actuation strategy [1]. In this project, we have developed a piezoelectric actuated optical fiber for the scanning tasks [2]. The main challenge of this project is the boundary control problem of the optical fiber with high flexibility, strong nonlinear behaviors and the multi physical fact of the interconnection with the piezoelectric tube actuator.





Left figure: 1. Piezoelectric tube actuated optical fiber; 2. Support base; 3. Voltage amplifier; 4. Sensors bases; 5&6. Displacement sensors. Right figure: a. Piezoelectric tube actuator; b. Optical fiber; c&d. Displacement sensors (the same as 5&6 in left figure)

Work plan

The **main objective** of this work is to develop the **control design method** for a scanning continuum robot with an actuated base. This continuum robot consists of an optical fiber rod and a piezoelectric tube actuator. This optical fiber continuum robot exhibits large deformations, highly flexibility and nonlinear behaviors that will be described using Cosserat rods [1,2]. To deal with the large deformations, high flexibility and nonlinearities involved in Cosserat rods, the port Hamiltonian framework will be investigated during the internship. The port Hamiltonian formulation is particularly well-adapted for the modeling and the control of nonlinear multi-physical systems [3] such as electro-mechanical systems. It is based on the principle of conservation of energy and exhibits the system's passivity properties and provides a clear physical interpretation of control design strategies. Different energy-based control methods have been proposed for 1-D distributed parameter port Hamiltonian, like the control by interconnection via Casimir invariants [4], the structure preserving observer-based controller [5], and Hamiltonian LQG controller [6]. In this internship, the control design for the port Hamiltonian Cosserat rod model will also be investigated.

Internship time schedule

The internship starts from February/March 2022 and end on July 2022, the time planning of the internship is following:

1. The intern will first have to do a solid literature review on dynamic modeling of Cosserat rod and energy-based control PHS formulations with the help of the project team. It will be based on the previous internship (Spring 2021)
2. The validation of PHS Cosserat rod model needs to be proceeded both on simulation and experimental setup of the optical fiber.
3. The intern needs to propose an energy-based control design method to control the tip of the optical fiber using the PHS formalism and validate on the experimental setup.

Implementation and supervision team

This master internship will take place in the AS2M department of FEMTO-ST institute in Besançon and be supervised by Dr. Yongxin Wu (MACS team), Prof. Yann Le Gorrec (MACS team) and Dr. Kanty Rabenorosoa (Micro and Nano Robotics team).

Application

The following candidate profiles are expected for this internship: Automatic control, mechatronics, Robotics, etc. The candidate can send his CV, a cover letter, and transcript of grades the last two years by email to Dr. Yongxin Wu yongxin.wu@femto-st.fr and Kanty Rabenorosoa rkanty@femto-st.fr. The application of the internship will be closed at the mi-December 2021.

Bibliography

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