Project title: Digital Twin for a Multi-Field Controlled Soft Catheter

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Aim of the Project

We will develop a digital description of a soft catheter made of active hydrogels that can be controlled from the inside and which is subject to external bio-chemical influences. This will be done using approaches from robotic control and multi-field continuum theory.

Project Description

Steerable catheters enable a wide range of minimally invasive, clinical procedures, including coronary and neurological interventions. To date, catheters are typically fabricated from traditional, passive polymers such as PTFE and nylon which are inherently flexible and as such, can be actuated via cables or tendons to generate motion. However, an entirely new approach to this is to use micro-manipulators made of soft, electro-active materials, such as hydrogels. Hydrogels are highly biocompatible and have been employed in the context of catheterisation for enhancing traditional devices through coatings to improve patient comfort. Despite that, the use of hydrogels as structural building blocks or actuation mechanisms for new types of medical devices and particularly catheters is still in its infancy. This is partially due to the complexity of modelling the response of hydrogels under thermal and mechanical loading conditions and the resulting control challenges.

The use of hydrogels as actuators has mostly been limited to very simple shapes, such as linear actuators (so-called artificial muscles [Bar-Cohen, “Electroactive polymer actuators as artificial muscles.” Potential and challenges, PM 98 (2004)]) or cantilever setups. This is because these kinds of investigations mostly focus on the active material’s behaviour and actuation performance and not on the solution of specific manipulation tasks.

The project proposed here aims to solve more complex problems suitable for catheters, through a digital-twin-enabled design and control methodology. Specifically, it aims to build a detailed mechanical models of the hydrogel structure, and its thermo-mechanical interaction with its environment suitable for enabling the data-driven control of deformations. Such a system would, for instance, enable shape adaptation and swelling, for targeted drug delivery in catheters customised to individual patients.

The project arises from a small pilot project funded under the TransCampus scheme, in which a simple hydrogel beam that can react to local heat gradients was modelled. Here, we propose a design with a deformable backbone to provide structural support embedded in hydrogel that can react to local heat gradients and controlled from the inside using thin heating wires. In addition an outer hydrogel structure will be employed to locally release drugs. The digital twin methodology will be taken to design, model and build this new hydrogel-based manipulator: due to its complex form and local reaction, the self-sensing and adequate reaction cannot be adequately predefined. Instead, the model must be represented, e.g., by using machine-learning based blackbox models or simplified analytical models with just-in-time capabilities.

Requirements:

Strong background in robotic control, basic knowledge of Finite-Element analysis in multi-field problems, basic knowledge in biochemistry.