Fusing multi-electrode signals for Bioelectric Navigation

Project Management and Software Development
for Medical Applications

General Info

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Project Abstract

Catheterization procedures for treatment of diseases of the human vascular system require harmful radiation doses and application of contrast agent to the patient. We are working on a new catheterization concept, "Bioelectric Navigation", which works based on electric sensing of vessel geometry. So far, the concept has mostly explored using a 1-dimensional signal, obtained from one pair of electrodes on the catheter tip. Here, we want to investigate, using a simulation framework, how alternative catheter shapes like basket catheters (Fig. 1) could benefit the localisation of the device.

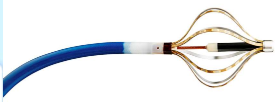

Fig. 1: Intellamap Orion basket catheter from Boston Scientific
(https://www.bostonscientific.com/en-US/products/catheters--mapping/orion.html)

Background and Motivation

In order to successfully treat diseases of the human vasculature, current catheterization procedures require guidance using x-ray radiation, which causes harmful radiation doses, and administration of potentially nephrotoxic contrast agents. A different and novel approach that is being investigated by the CAMP chair is Bioelectric Navigation [1], which relies on electrical sensing of the position inside the human vasculature. Recent works have only explored using standard tube-shaped catheters [2].

In this work, we want to investigate whether using alternative catheter shapes, like basket catheters, can help the localization. The hardware setup is currently under development, but not yet capable of recording signals from many pairs of electrodes in parallel. Thus, this project will explore multi-electrode localization in an FEM-simulation pipeline, where we can quickly change the configuration and number of electrodes to find an optimal setup.

Student's Tasks Description

The student will first spend some time to understand the existing simulation pipeline, which is built based on freely available Elmer and Gmsh software packages. They will extend the existing pipeline with alternative catheter shapes, like the basket shape, and add them to the simulation. Then, they will investigate how the added information from multiple electrodes in a basket shape can be used to more precisely localize a catheter.

Specifically, in this project, we are interested in determining the 3D orientation of the catheter from the simulated measurements using these alternative shapes. Once the simulation is set up, we will experiment on the determination of the 6D position of the catheter in specific locations from the electric signals recorded by the basket. Here, the student will conventional signal analysis and apply small neural network to the low-dimensional signals. While the algorithms will be mostly developed based on the simulated signals, once the electrical setup is ready, the chosen algorithm will be evaluated on one actual recorded dataset.

During the course of this project, the student will learn about tracking of catheters by electrical sensing. They will collect experience on using simulations to iterate through different design ideas. Furthermore, they will strengthen their knowledge on machine learning on low-dimensional signals.

Technical Prerequisites

Knowledge in Python programming is required, as well as applied knowledge in machine learning. Familiarity with signal processing (Fourier transform, correlation, principal component analysis, …) is beneficial. A basic understanding of electrical circuits is not required, but a plus.

References

[1] Sutton, E.E., Fuerst, B., Ghotbi, R. et al. Biologically Inspired Catheter for Endovascular Sensing and Navigation. Sci Rep 10, 5643 (2020).

https://doi.org/10.1038/s41598-020-62360-w.

[2] Maier, H., Schunkert, H. & Navab, N. Extending bioelectric navigation for displacement and direction detection. *Int J CARS* **18**, 1253–1260 (2023). https://doi.org/10.1007/s11548-023-02927-w