Implicit modeling of blood vessels

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Context

This internship is funded by the PreSPIN ANR project. This project aims at designing simulation tools for treatment planning of acute ischemic strokes. The internship focuses on the simulation of a navigating catheter within the blood vessels.

Rationale and objectives

Catheters can be modeled as very long, thin, flexible rods that the physician manipulates to navigate through the vascular tree, which induces multiple contacts between the tool and the vascular wall. These contacts are extremely hard to model. In particular, we have shown (Kerrien et al. 2017) that the usual 3D mesh representation does not allow optimal computation times, and suffers from undesirable border effects. We therefore proposed an implicit surface representation that greatly reduces the contact resolution time and brings the simulation closer to the expected mechanical behavior. The objective of this internship is to design an efficient and robust algorithm to estimate this implicit representation from 3D medical images of any patient.

A preliminary algorithm was designed, but it should be improved, or even redesigned. The following steps are planned:

1. Perform a literature review on implicit surface representations and their estimation from data. The focus will be on radial basis functions to which the current representation is related.
2. Identify limitations and problems of the current optimization algorithm and propose improvements. The algorithms developed for radial basis function networks (Ghosh and Nag 2001; Montazer et al. 2018) will be a source of inspiration.
3. The current representation is a collection of local functions, each of which is separately optimized. Spatial continuity between neighbor functions is thereafter not formally verified. Coupling these models will therefore be studied, as well as its impact on their optimization.

Required skills

We are looking for applicants with excellent skills and knwoledge in computer vision, computer graphics and/or applied mathematics. Software development will be carried out in C++ or Python. A solid practical experience in either one of these languages is expected. Applicants with excellent proficiency in Matlab would also be considered.

An open mind towards related scientific fields, a taste for clinical research and medical applications, good communication skills, and a strong desire to learn and to participate in a scientific project dynamics are also expected.

References

Ghosh, J., and A. Nag. 2001. "An Overview of Radial Basis Function Networks." In *Radial Basis Function Networks 2: New Advances in Design*, edited by Robert J. Howlett and Lakhmi C. Jain, 1–36. Heidelberg: Physica-Verlag HD. https://doi.org/10.1007/978-3-7908-1826-0_1.

Kerrien, Erwan, Ahmed Yureidini, Jeremie Dequidt, Christian Duriez, René Anxionnat, and Stéphane Cotin. 2017. "Blood vessel modeling for interactive simulation of interventional neuroradiology procedures." *Medical Image Analysis* 35 (January): 685–98. https://doi.org/10.1016/j.media.2016.10.003.

Montazer, Gholam Ali, Davar Giveki, Maryam Karami, and Homayon Rastegar. 2018. "Radial Basis Function Neural Networks: A Review." *Comput. Rev. J* 1 (1): 52–74. https://core.ac.uk/download/pdf/322551455.pdf.