Contact management for a 1D model within a tubular network

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1 General information

Date and duration	6-month internship, starting from February to April 2022
Supervisors	Erwan Kerrien, Pierre-Frédéric Villard
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Applications should be sent to both emails above, including resume, motivation letter, latest grade transcripts.

2 Motivations

A catheter is a long, thin and flexible tube that the medical practitioner nagivates in the vasculature in order to establish a route from the groin to the brain. Thereafter, micro-devices will follow this route to reach the pathological site for stroke treatment. A catheter can be modeled as a 1D model whose geometry is made of points linked with segments, and that mechanically behaves as a Cosserat rod [1]. Many contacts occur between the catheter and the vessel wall during navigation. Such contacts are difficult to simulate in both a fast and reliable way. This internship aims at studying, and implementing a solution for contact management between the catheter and the vessel walls.

3 Sujet

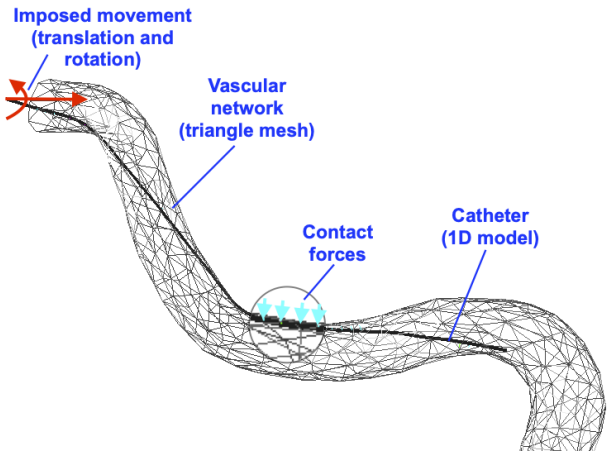

Figure 1 – Contact management between the catheter and the vessel wall

Physics-based modeling is a well-established domain that calls for notions and advanced techniques in physics, mathematics and computer science (e.g. D. James' lessons, that may be old but still are an excellent introduction to these topics [2]). Several forces must be simulated, among which the collision response forces are particular hard, due to their depending on the geometry, that deforms under those very same contact forces. As a consequence, their management – that includes both collision detection and force response computation – depends both on the mechanical solver and the

geometric representation of the objects in contact. In our particular case, the simulation involves a catheter, 1D rod that obeys the Cosserat model, and the vessel wall, expressed as implicit surfaces. Three steps will be taken :

1. Review the state of the art methods to handle contacts between a deforming, dynamic object and a ridig, static structure, with interactive time constraints ([3] is a good recent starting point)
2. Implement a contact management method between the 1D model we designed in our project and vessel walls represented as a discrete mesh (see Figure 1)
3. Design and implement a contact management method between the same 1D model and vessel walls, now represented as implicit surfaces [4]

4 Work environment

This internship is part of the ANR-funded PreSPIN project [5]. This project aims at designing simulation tools to plan and treat ischemic strokes [6]. More specifically, the internship participates in our contribution towards improving the simulation of a catheter [7] within the brain vasculature.

5 Profile

We are looking for candidates pursuing a Master of Science (or equivalent), with excellent skills in applied mathematics, computer science or computational mechanics.

We expect the candidate to be open to other scientific domains, in particular an interest in clinical research and medical applications, and to demonstrate good communication skills.

English or French (with a good level in English) is essential. Software should be developed in C++, but Python proficiency will be appreciated as well.

Références

[1] J. Spillmann. CORDE : Cosserat rod elements for the animation of interacting elastic rods. Thèse de doctorat de l'université Albert Ludwig de Freiburg im Breisgau, 2008. `https://freidok.uni-freiburg.de/fedora/objects/freidok:5775/datastreams/FILE1/content`

[2] D. James. Physically Based Modeling and Interactive Simulation. *Cours du département d'informatique* de Carnegie Mellon University, 2003. `http://www.cs.cmu.edu/~djames/pbmis/spring03.html`

[3] B. Wang et al. A Large-scale Benchmark and an Inclusion-based Algorithm for Continuous Collision Detection. *ACM Transactions on Graphics*, 40(5) :1-16 (No 188), 2021. `https://doi.org/10.1145/3460775`

[4] E. Kerrien et al. Blood vessel modeling for interactive simulation of interventional neuroradiology procedures. *Medical Image Analysis*, 35 :685–698, 2017. `https://hal.inria.fr/hal-01390923/file/medima_20161008.pdf`

[5] `https://project.inria.fr/prespin/`

[6] `https://fr.wikipedia.org/wiki/Accident_vasculaire_cérébral#Ischémique`

[7] `https://fr.wikipedia.org/wiki/Cathéter`