UNIVERSITÀ DI TRENTO
Dipartimento di Matematica

DOTTORATO

CYCLE 35th
ORAL DEFENCE OF THE PHD THESIS

Thursday 4 May 2023 – at 9.00 am

Department of Mathematics
Seminar Room 1

The event will take place in presence and online through the ZOOM platform.
To get the access codes please contact the secretary office

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PhD Student in Mathematics

Numerical methods for computationally efficient and accurate blood flow simulations in complex vascular networks: Application to cerebral blood flow

Abstract:
It is currently a well-established fact that the dynamics of interacting fluid compartments of the central nervous system (CNS) may play a role in the CNS fluid physiology and pathology of a number of neurological disorders, including neurodegenerative diseases associated with misaccumulation of waste products in the brain. Mathematical modeling and fluid dynamics simulations can contribute to the definition of a quantitative and comprehensive approach for the description of flow and transport in the brain parenchyma, and the interaction of intracranial fluids. In this context, we will focus on the modeling of one of the main components of this interacting cerebral fluids dynamics, blood flow, with emphasis on cerebral blood flow dynamics and, in particular, the venous haemodynamics.
In the first part of the talk, we will present a novel modeling and computational framework developed to construct hybrid networks of coupled 1D and 0D vessels and, thus, perform computationally efficient and accurate blood flow simulations in highly complex vascular networks, such as cerebral networks. Starting from a 1D model and a family of nonlinear 0D models for blood flow, with either elastic or viscoelastic tube laws, this methodology is based on (i) suitable coupling equations ensuring conservation principles; (ii) efficient numerical methods and numerical coupling strategies to solve 1D, 0D and hybrid junctions of vessels; (iii) model selection criteria to construct hybrid networks, which provide a good trade-off between accuracy in the results and computational cost of simulations. We will show how the proposed hybrid network solver becomes crucial to gain computational efficiency when solving networks and models where the heterogeneity of spatial and/or temporal scales is relevant, still ensuring a good level of accuracy in the predicted results.
Thereafter, in the second part of the presentation, we will deal with the modeling and simulation of cerebral blood flow, with focus on the venous side. We will introduce a methodology that, departing from the high-resolution MRI data obtained from a novel in-vivo microvascular imaging technique of the human brain, the MICRO method, allows to reconstruct detailed subject-specific cerebral networks of specific vascular districts which are suitable to perform blood flow simulations. We will describe the main steps of the proposed processing pipeline for the extraction and calibration of networks of vessels from the MRI data employed. Then, by performing blood flow simulations on the MRI-derived venous networks, we will validate the methodology and assess the ability of such networks to predict physiologically reasonable results in the corresponding vascular territories. We will show that it is feasible to extract cerebral vascular networks from the MICRO imaging data, setting the basis for detailed blood flow simulations from subject-specific data.

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CONTATTI
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