Lecturer: Alessandro Veneziani (Emory University, Atlanta USA)

Lecture 1:

Title: Reduced Models for the Cardiovascular System: from 3D to lumped parameters.

Abstract:

In this lecture the mathematical process to reduce dimensional complexity of models for hemodynamics and fluid-structure interaction will be addressed. In particular, we will consider the model reduction based on the geometric features of the circulation, with a dimension prevalent over the others. We will introduce 1D models based on the Euler equations and numerical techniques for their solution. Then, we will discuss 0D or lumped models (including simplified models for the heart) based on ordinary differential equations. We will also discuss some more recent developments leading to "psychologically 1D" models, yet not giving up the mathematical description of transversal hemodynamics.

Tutorial 1: Numerical solution of 1D models, fundamentals and networks

Lecture 2:

Title: Geometrical Multiscale Modeling of the Circulatory System.

Abstract:

This lecture follows up the previous one, by illustrating numerical methods for coupling models with different spatial detail (3D/1D/0D). This is particularly important when one wants to have an accurate model of the hemodynamics in a specific region of interest, yet systemic effects are needed in the simulation. The mathematical coupling of different equations is generally nontrivial. It requires to solve "defective" problems, since the most accurate (3D) systems of equations do not receive enough data from the coarsest ones. Reliable managing defective problems can be done in different ways that will be addressed in the lecture (Lagrange multiplier - at either differential or algebraic level, Data Assimilation methods, etc.). The coupling of different models then requires specific - typically partitioned - numerical methods that will be addressed too. Some aspects related to the well posedness analysis of multiscale problems will be covered as well.

Tutorial 2: Numerical solution of geometric multiscale models with partitioned methods (3D/1D, 3D/0D)

Lecture 3:

Title: Data assimilation techniques in computational hemodynamics.

Abstract:

In patient-specific setting, computational hemodynamics models rely on parameters that are difficult or impossible to measure in vivo and in the clinical routine - blood viscosity, cardiac conductivity, etc. A reliable estimation of these parameters can still be based on mathematical techniques. More in general, these techniques can be used for merging numerical models and available measures to provide a patient-specific quantitative analysis for the sake of the clinical practice. In this lecture, we will give a short introduction to different possible approaches, ranging from Kalman filtering techniques to variational methods. A review of the literature in the field will be carried out in the Hands-On session.

Tutorial 2: An example of data assimilation in 2D: variational estimation of cardiac conductivities

Textbooks:

Lecture 1: Chapter 10 of [1]

Lecture 2: Chapter 11 of [1]

Lecture 3: Chapter 6 of [2]

The instructor will also provide notes and slides.

[1] L. Formaggia et al. (eds), Cardiovascular Mathematics, Springer 2009,

[2] T. Bodnar et al. (eds), Fluid-Structure Interaction and Biomedical Applications , Birkhauser 2014.