Mathematical Modeling for the Circulatory System
Models, Equations, Applications
March – May 2017
Università degli Studi di Verona
Syllabus

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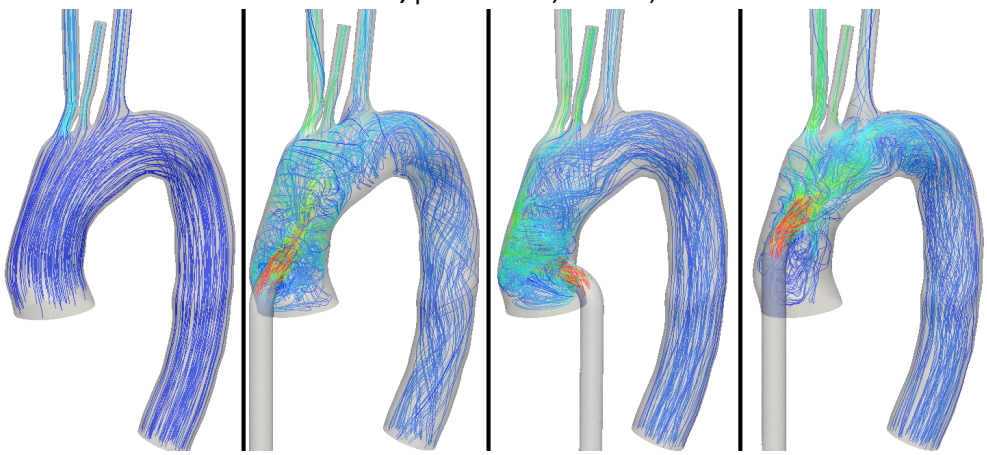

Motivations

Numerical models have been recognized since decades to introduce a relevant added value to cardiovascular research, both for understanding physiopathology and for designing new devices and therapies. The predictive nature of mathematical models, solved by numerical tools on high performance computing architectures, opens significant and somehow revolutionary perspectives with a potential impact on clinical practice too. For instance, a surgical operation like the Left Ventricular Assisted Device (see the picture), consisting in an external graft added to the ascending aorta to replace the functionality of a malfunctioning valve, may be carried out in different ways (for the position of the anastomosis). Numerical tools may quantitatively assess the impact of the different options on the hemodynamics and eventually on the success of the surgery. This course intends to provide some fundamental concept of modeling the circulation, covering: the introduction of equations and initial/value problems relevant to the description of dynamics of interest; the methodological aspects for their numerical solution. Also, the course will cover medical image processing, a key step for the patient-specific modeling. Finally, lectures will be offered by biomedical engineers and clinicians who will provide the "end-user" perspective of numerical modeling for cardiovascular diseases, including new entrepreneurial opportunities coming from cloud computing and computer aided clinical trials.

Textbook: L. Formaggia, A. Quarteroni, A. Veneziani, Cardiovascular Mathematics, Springer 2009

Additional notes will be indicated by the lecturers.

Grading: Students will have the option to do a small project/research with a final report or to work on a paper selected by the instructors and do an oral presentation in June 2017.

Schedule

A. Veneziani (Math)

March 6th: Introduction to the Cardiovascular System, Motivations, Blood as a fluid, Rheology, Flow regimes, Structure, Fluid-Structure Interaction

March 7th: Numerical Modeling of Blood Flow – Numerical simulation of incompressible fluids with finite elements, Time advancing methods (projection and segregation schemes), Treatment of Defective Boundary Conditions, Numerical Fluid-Structure Interaction

March 9th: An Introduction to Data Assimilation in Cardiovascular Modeling. Recall of stochastic filtering techniques (Kalman filtering). Variational Data Assimilation techniques. Showcases in fluid dynamics and electrocardiology.

March 9th: Hands On session in Computer Lab (2 hrs) with FreeFem++

L. Antiga (Bioeng)

Mar 24th: Vascular Modeling ToolKit: a tool for patient specific image processing, geometrical modeling, meshing and computations.

G.K. Ricciardi (Clinician)

Apr 7th: Bridging mathematical modelling and clinical scenarios using MR imaging and Angiography - State of the art in diffusion based brain connectivity and cerebrovascular modelling by computational fluid dynamics

F. Auricchio (Bioeng)

Apr 21st : An advanced example of computer aided clinical trial: the iCardioCloud Project

M. Marrocco-Trischitta (Clinician)

May 15th : Geometrical classification of aortic arches and its impact in clinics

E. Toro (Math)

May 22nd: Reduced models for the Cardiovascular System, 1D models, 0D models

May 23rd: Geometrical Multiscale Modeling of the Circulation – coupling of 1D-0D models, 3D-1D models

L. Emili (Entrepreneur)

May 25th : Software infrastructures for *in silico* Clinical Trials