UNIVERSITÀ
DEGLI STUDI DI MILANO-BICOCCA

COURSE SYLLABUS

Clerkship 6

2021-4-H4102D027

Aims

The course aims at developing a basic understanding of computational hemodynamics, i.e. the task of predicting the blood flow behavior in the cardiovascular system by means of numerical simulations. In synthesis computational hemodynamics provides approximate solutions of the Navier-Stokes equations, that is the system of partial differential equations governing fluid flow under the assumption of fluid as a continuum. The final goal is to learn how to set up a numerical simulation and understand the simulation outputs.

Contents

1) The continuum mechanics approach.

2) Navier-Stokes equations in integral form: a system of conservation laws.

3) Solving the Navier-Stokes equations with the control volume method.

4) Solving the Navier-Stokes equations with numerical simulations: imposition of boundary conditions, interpretation of numerical results.

6) Using computational hemodynamics as a tool to study pathology.

Detailed program

A control volume can be defined as a region of interest where we want to describe the flow behavior and quantify

the interactions between the flow and the body surfaces the flow comes into contact with.

The control volume method consists in applying conservation laws, i.e. conservation of mass, balance of linear momentum and balance of energy, to the region of interest. By introducing suitable simplifying assumptions the differential equation system can be rewritten as a system of algebraic equations that can be solved for average quantities at the control volume boundaries: e.g. flow of mass, momentum and energy through the control volume boundaries, forces and mechanical power exerted at the control volume boundaries. The control volume method is not capable of providing quantitative information regarding the flow behavior within the control volume but is a valuable tool for supporting the setup of numerical simulations. Moreover it provides useful insight on widely employed Finite Volumes formulations.

Numerical simulations predict the flow behavior within the control volume by numerically solving a boundary value problem based on the Navier-Stokes equations, i.e. the system of conservation laws supplemented with suitable boundary and initial conditions. Accordingly, a sufficient amount of information regarding average quantities at the control volume boundary needs to be prescribed. The imposition boundary conditions is crucial for the well-posedness of the boundary value problem and for the success of the simulation

The concepts of convergence rate, mesh independence and computational cost will also be discussed in order to provide a complete overview of the field.

Prerequisites

Understanding of the physical phenomena described by the Navier-Stokes equations.

Teaching form

Teaching of basic concepts and practical sessions utilizing software tools.

Textbook and teaching resource

Handwritten notes will be provided.

Semester

First Semester

Assessment method

Oral exam with questions targeting the basic concepts.

Office hours

Contact by e-mail