Speaker: Alessandro Veneziani

Title: From the Computer Lab to the Bedside: perspectives and challenges of translational Cardiovascular Mathematics

Abstract:
Mathematical and numerical modelling of cardiovascular problems has experienced a terrific progress in the last years, evolving into a unique tool for patient-specific analysis. However, the extensive introduction of numerical procedures as a part of an established clinical routine and more in general of a consolidated support to the decision making process of physicians still requires some steps both in terms of methods and infrastructures (to bring computational tools to the operating room or to the bedside).

The quality of the numerical results needs to be carefully assessed and certified. An important research line - quite established in other fields - is the integration of numerical simulations and measurements in what is usually called Data Assimilation. A rigorous merging of available data (images, measures) and mathematical models is expected to reduce the uncertainty intrinsic in mathematical models featuring parameters that would require a patient-specific quantification; and to improve the overall quality of information provided by measures. However, computational costs of assimilation procedures - and in particular variational approaches - may be quite high, as typically we need to solve inverse problems, dual and possibly backward-in-time equations. For this reason, appropriate model reduction techniques are required, to fit assimilation procedures within the timelines and the size of patient cohorts usually needed by medical doctors. In this talk, we will consider some applications of variational data assimilation in vascular and cardiac problems and associated model reduction techniques currently investigated to bring numerical simulations into the clinical routine.

For solving incompressible flows in network of pipes we will address hierarchical modeling (HiMod) of the solution of partial differential equations in domains featuring a prevalent mainstream, like arteries. The HiMod approach consists of approximating the main direction of each vessel with finite elements, coupled with spectral approximation of the transverse dynamics. The rationale is that a few modes are enough to a reliable approximation of secondary motion. In addition, modal adaptivity allows to tune the local accuracy of the model. This results in a "psychologically" 1D modeling to be compared with classical approaches based on the Euler equations.

Finally, we will address some more advanced applications of geometrical processing for (a) investigating patient-specific bioresorbable stents; (b) supporting decision making of neurosurgeons in deploying flow diverters for cerebral aneurysms; (c) analyzing patients suffering from aortic diseases like dissection and cardiac insufficiency.