Inverse Problems in Cardiovascular Mathematics

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PROPOSAL

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The impact of Scientific Computing in Cardiovascular Research has remarkably grown in the last 20 years, with applications ranging from image processing (deblurring, segmentation and registration of medical images) to numerical simulations (blood flow, vessels movement, electrocardiology). This growth has been pushed by the increase of computational power (parallel processing, GPU computing) but also by the improvements in the numerical schemes and approximation techniques used in the solution of these challenging problems. This has made possible to bring Mathematics closer to the doctors, providing new tools and new knowledge that can be used to better understand the condition of a patient and hence take more appropriate decisions on the treatment of their diseases.

In order to make Scientific Computing an effective tool for supporting the decision making of doctors (and eventually improve healthcare) it is of paramount importance the assessment of the reliability of mathematical and numerical models in a patient-specific perspective [1]. Even though a work pipeline for numerical simulation on an individual geometry (a specific vessel or the left ventricle) retrieved from medical images is currently well established, there are still several unknown parameters or data required by numerical simulations. They are typically unknown and selected on the basis of non-patient specific criteria. A specific example is the cardiac conductivity as well as the structural parameters for the arterial wall [2].

The precise individual quantification of these parameters is crucial and can take advantage of data obtained by measurement devices. These data generally do not provide a direct estimation of those parameters but can give a patient-specific knowledge to be converted into reliable estimate by means of proper mathematical and numerical techniques of Data Assimilation [3]. A classical example is provided by elastography, where the measurements of displacement induced by a known force applied to a soft tissue lead to an estimation of tissue compliance by solving an inverse elasticity problem [4]. Another case is the compliance of artery estimated by solving an inverse fluid-structure interaction problem [5]. The general framework of Data Assimilation (DA) is the improvement of reliability of numerical models (playing as a sort of background knowledge) by merging simulations and data (that are the foreground knowledge). In the meantime, noise affecting measurements is filtered, with an overall reduction of uncertainty of the numerical process. There are several approaches for performing DA, either based on stochastic arguments or variational formulations [3,6,7].

In a more general perspective, data assimilation leads to the solution of inverse problems. In the last years there is a growing interest in inverse problems in the field of cardiovascular mathematics,
for instance the rigorous definition of optimal therapeutic procedures such as the placement of pacemaker leads in the left ventricle [8,9].

Solution of inverse problems is by themselves challenging because of their intrinsic ill-conditioning features and are even more challenging in the cardiovascular field where the corresponding forward problems are still computationally intensive. A timely solution of inverse problems in cardiovascular mathematics calls therefore for special model reduction approaches (see e.g. [10]).

This minisymposium aims at gathering mathematicians and bioengineers working in the field of inverse problems for cardiovascular diseases following up a similar symposium held at Comp Bio Med 2011 at Mason University (organized by one of the present proponents). The aim is to trigger discussions and exchange of ideas in terms of methods, applications, results with the common goal of making Scientific Computing an operative tool not only for basic research, but also for daily clinical activity.

A list of potential speakers (beyond the organizers) includes J.F. Gerbeau, A. Quarteroni, K. Kunisch, A. Oberai, P. Barbone, A. Figueroa and/or their collaborators.

REFERENCES


