Direct and inverse modeling in hemodynamics

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Fluid-structure interaction is an important phenomenon in large arteries like the aorta. The numerical algorithms used in this field have been considerably improved during the last decade (see *e.g.* [2] for a brief overview). Although some significant modeling issues still remain — like prestress in the wall, external tissue support [5], *etc.* — the state-of-the-art coupling algorithms allow for efficient forward simulations.

In this talk, we will mainly address the inverse problem: given a set of measurements — typically provided by medical imaging — estimate the state and the parameters of the system. This step is absolutely necessary to make numerical simulations usable in clinical practice.

Inverse problems can be addressed through a variational method, *i.e.* minimizing a least square criterion which includes observation error and regularization. One of the main difficulties of this approach lies in the evaluation of the gradient, generally based on an adjoint problem. In this presentation, another family of methods will be considered: the sequential filtering, which consists of improving the model prediction using the measurements at every observation time step. Classical Kalman filtering is not tractable for distributed systems, but some effective sequential procedures have been recently introduced for mechanical systems in [4, 3] and are the basis of the proposed approach [1]. The resulting algorithm can easily be run in parallel, making the total time needed for the estimation similar to the duration of a sequential direct computation.

We illustrate our methodology with the estimation of the artery wall stiffness from artery wall displacements. We also show preliminary results about the estimation of the proximal Windkessel resistance, which is an important parameter for fluid boundary conditions in hemodynamics.

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References

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