Towards the realistic simulation of whole-body hemodynamics: Decomposition strategies

Gustavo C. Buscaglia,
Depto. Matemática Aplicada e Estatística, ICMC, USP,
13560-970, São Carlos, SP, Brasil
E-mail: gustavo.buscaglia@icmc.usp.br

Jorge S. Leiva
Instituto Balseiro, San Carlos de Bariloche
8400, Río Negro, Argentina
E-mail: leivaj@ib.cnea.gov.ar

Pablo J. Blanco
Laboratório Nacional de Computação Científica
25651–075, Petrópolis, RJ, Brazil
E-mail: pjblanco@lncc.br

Abstract: *Simulations of whole-body hemodynamics is crucial for understanding the interplay among the many components of the circulatory system. However, the best-suited model for each part (heart, arteries, arterioles, capillary bed) is quite specific, implying that a whole-body simulation requires a decomposition strategy that allows for physically different submodels to interact so as to produce the correct dynamics.*

In this presentation, we address decomposition strategies especially tailored to perform this task. They allow for each submodel to be solved separately, in black-box mode, implementing the interactions between subdomains by boundary conditions alone. The fundamental unknowns reside at the interfaces between subdomains, and the proposed methodology takes full advantage of the small number of interfaces in the problems of interest.

An implicit (linear or nonlinear) system of equations is built at each time step, which is solved by effective matrix-free iterative algorithms. Previous algorithms from the literature can be viewed as specific cases of the proposed approach, in which the iterative solver is some variant of Richardson's iterations. Our formulation allows for Krylov-based and quasi-Newton methods to be used, with obvious improvement of performance and robustness.

We begin with a simple application in heat conduction, so as to explain the ideas, and then turn to fluid flow in hydraulic and biological networks, so as to assess the applicability of the method in computational hemodynamics.