Deconvolution-based nonlinear filtering for incompressible flows at moderately large Reynolds numbers: analysis and medical applications

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ABSTRACT

In some applications of cardiovascular numerical modeling, usually related to specific pathologies, blood flow features transition to turbulence. A specific case is the occurrence of dissections in the aorta. A false lumen progressively develops, fed by blood flowing through tiny entry tears where the local velocity significantly increases. The flow in these cases may be accurately computed by Direct Numerical Simulation (DNS), using a sufficiently fine mesh to solve all the scales relevant the dynamics. However, the massive use of numerical simulations in clinics requires high computational efficiency. DNS typically does not meet this requirement. Large Eddie Simulation (LES) models are a viable option to recover computational efficiency without giving up accuracy. Accurate numerical simulations can be obtained for moderately high Reynolds numbers using meshes significantly coarser than required by DNS. This follows from an appropriate surrogate modeling of the small scales not resolved by the mesh. There are several ways for doing this. Some of them are based on physical considerations, others are more oriented to mathematical arguments. Here we stick to the second approach and we pursue a LES modeling based on the concept of non-linear deconvolution filters[1]. We illustrate a method based on a sequence of steps called *Evolve-Filter-Relax* (EFR), where an additional Stokes problem is solved at each time step to incorporate the effects of the small scale into the solution of the grid scale. A relaxation final step yields a stable numerical solution. In this talk we will provide a general introduction to the methodology and its basic mathematical properties[2]. Also, we will present a sensitivity analysis of the solution to the parameters of the method. Finally, the beneficial impact of the LES modeling in terms of computational efficiency (and accuracy preserving) will be assessed on a classical benchmark proposed by the US Food and Drug Administration and on a real patient case with a severe aortic dissection. The last case provides a good evidence of the potential impact of scientific computing on the clinical practice. Joint work with: L. Bertagna (Sandia National Lab, Albuquerque, NM, USA), A. Quaini (Department of Mathematics, University of Houston, TX, USA) L. Rebholz (Department of Mathematics, Clemson University, SC, USA), H. Xu (Georgia Institute of Technology, Atlanta, GA, USA), M. Piccinelli (Emory University, Atlanta, GA, USA) and B. Leshnower (Emory University Hospital, Atlanta, GA, USA). This work is supported by the US National Science Foundation, Project DMS 1620406.

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