Improving Blood Flow Simulations Using Known Data

T. Guerra[1], J. Tiago[2]

[1]Escola Superior de Tecnologia do Barreiro do Instituto Politécnico de Setúbal, Barreiro, Portugal

[2]Instituto Superior Técnico da Universidade de Lisboa, Lisboa, Portugal

Abstract

Numerical simulations applied to blood flow together with the imaging processing advances are a powerful tool in the prevention and treatment of some diseases. The inclusion of real data in the numerical blood flow simulations allow us to obtain more realistic and accurate results. The techniques that use known data in the simulations are named by Data Assimilation (DA) in the literature. In this work we solve a variational DA problem to numerically reconstruct the blood flow circulation inside a real artery deformed by a saccular aneurysm.
We use COMSOL Multiphysics® to model the blood flow using the stationary Navier-Stokes equations. The geometry representing the real artery is obtained from medical images and imported to COMSOL Multiphysics®. The data to be used in the DA process is generated by solving the forward problem, with realistic parameters and boundary conditions. We then use the Optimization Module to define a cost function to be minimized. The cost function essentially measures the misfit between the data and the solution at several sections of the artery. The misfit considers velocity and Wall Shear Stress (WSS) measurements. We include the WSS since it is an important indicator to predict vascular diseases which is highly sensitive with respect to the geometry. Figure 1 illustrates this. We also include a regularizing term to avoid numerical spurious minima. The control variable corresponds to the inlet profile at the inlet boundary.

To check the robustness of this DA approach, we test it for data that was obtained with the different inlet profiles represented in Figures 2 and 3. We also consider different parameters in the definition of the cost function so that the influence of the different components of the cost can be understood.

The work here presented gives an automatic approach to obtain realistic blood flow simulations representing the reconstruction of the blood flow profile from partially available measurements. If successfully adapted to time dependent models, it may be a useful tool for predictions in medical practices. As for time dependent simulations the vessel wall can no longer be considered rigid, therefore, the next stage should include the fluid-structure interaction between the blood and the vessel.

Reference

A. Gambaruto, J. Janela et al, Sensitivity of hemodynamics in a patient specific cerebral aneurysm to vascular geometry and blood rheology, Mathematical Biosciences and Engineering, 8, 409-423 (2011);

J. Cebral, M. Castro et al, Characterization of cerebral aneurysms for assessing risk of rupture by using patient-specific computational Hemodynamics models, American Journal of Neuroradiology, 26, 2550-2559 (2005);

M. D'Elia, M. Perego et al, A variational data assimilation procedure for the incompressible Navier-Stokes equations in Hemodynamics, Journal of Scientific Computing, 52, 340-359 (2012).

Figures used in the abstract

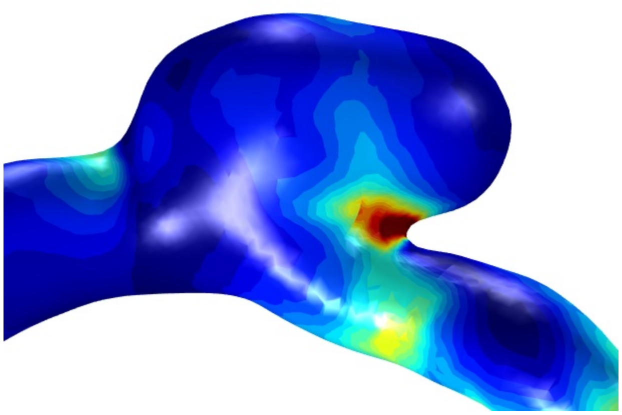

Figure 1

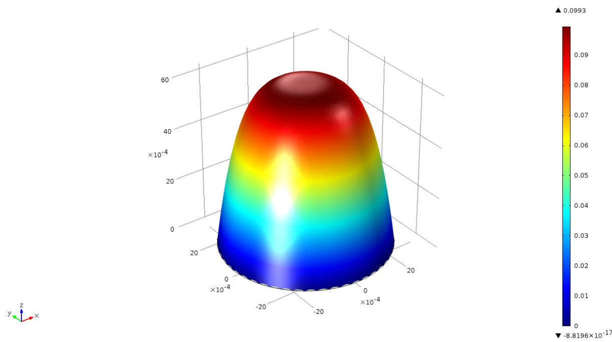

Figure 2

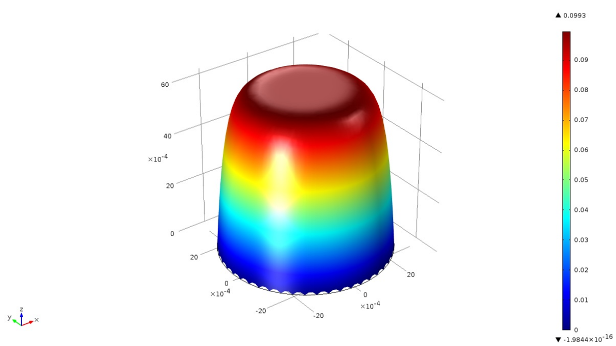

Figure 3