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Fast geometric sensitivity analysis in hemodynamic simulations using a machine learning approach SETHURAMAN SANKARAN, Senior Computational Scientist, LEO GRADY, Vice president, Research and Development, CHARLES TAYLOR, CTO — In the cardiovascular system, blood flow rate, velocities and blood pressure are governed by the Navier-Stokes equations. Inputs to the system such as (a) geometry of arterial tree, (b) clinically measured blood pressure and viscosity, (c) boundary resistances, among others, are typically uncertain. Due to a large number of such parameters, there is a need to efficiently quantify uncertainty in solution fields in this multi-parameter space. We use a machine learning approach to approximate the simulation-based solution. Using an offline database of pre-computed solutions, we compute a map (rule) from the features to solution fields. This is coupled to an adaptive stochastic collocation method to quantify uncertainties in input parameters. We achieve significant speed-up ($\sim$1000 fold) by approximating the simulation-based solution using a machine learning predictor. Bagged decision tree was found to be the best predictor among many candidate regressors (correlation coefficient $\sim$0.92). The sensitivities obtained using machine learning approach has a correlation coefficient of 0.91 with those obtained using finite element simulations. We also calculated and ranked the impact of different inputs such as problem geometry, and clinical parameters. We observed that the impact of geometry supersedes the impact of other variables. Mostly, segments with significant disease in the larger arteries had the highest sensitivities. We were able to localize sensitive regions in long segments with a focal disease using a multi-resolution approach.

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