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A reduced order modeling for uncertainty propagation in the coupled biomechanical model of bone–implant healing process

David Dureisseix, Béatrice Faverjon, Anthony Gravouil

Univ Lyon, INSA-Lyon, LaMCoS, CNRS UMR 5259, F-69621, Villeurbanne, France

Abstract

Uncertainty quantification is a useful approach for robust design and prediction in numerical simulation of engineering problems. Indeed, once a reliable model is available, it can be subjected to variability or lack of knowledge on one or several input parameters, considered as random variables. The model output is then also a random variable and the user is therefore interested in obtaining stochastic information on this model prediction.

Biomechanical problems are prone to such uncertainty, eventually with a large dispersion on the input parameters. The target problem is herein a transient chemical poromechanical coupled problem of parabolic non-linear convection-diffusion-reaction [1] serving to predict the bone healing around an implant. The goal is to provide a tool for implant design and a help to surgical decision. In this contribution focus is on the case where the deterministic model is considered as a black box: the stochastic analysis should therefore be non-intrusive. Amongst non-intrusive approaches, Monte Carlo simulations and polynomial chaos expansions with collocation [2] are reference approaches. The inputs are given with their cumulative density functions (cdf), and we wish to build the cdf of the output quantity of interest (QoI).

A reduced order model (ROM) can serve as reducing the cost of the overall analysis. Its efficiency is strongly related to the capability of the QoI to be represented in a smaller subspace. This ability can be improved for geometrical input parameters using a morphing approach. We therefore propose to couple ROM with geometric morphing and stochastic analysis, and assess the effectivity of the approach on the bone healing problem, both from an accuracy and efficiency points of view.

References

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