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EDITORIAL

Guest Editorial to the special issue: Computational mathematics aspects of flow and mechanics of porous media

State-of-the-art computational methods in the mechanics and flow in porous media

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Abstract
This Special Issue contains a series of fourteen papers that resulted from the Lorentz workshop in Leiden in the period of May 22–25 in 2018.

1 From the guest editors

In May 22–25 in 2018, we enjoyed the hospitality of the Lorentz Institute at the University of Leiden in the Netherlands. The workshop lasted a week and brought together computational porous media scientists from all over the world. We had great talks given by expert colleagues, but also a nice social programme, where we sailed in the Lake District near Leiden while we enjoyed a nice Indonesian dinner on the boat. We are very grateful to the Lorentz foundation and to the Leiden University. We are also grateful to prof Kees Oosterlee, who initiated and co-organised the event. We further acknowledge our sponsors: The University of Leiden, the Lorentz Center, the Center of Mathematics and Informatics (CWI) in Amsterdam, The Delft Centre of Computing in Science and Engineering (DCSE), The Netherlands Science Foundation (NWO), the NWO cluster of Nonlinear Dynamics in Natural Sciences (NDNS+), and the Royal Dutch Academy of Sciences (KNAW). The sponsors enabled us to invite scientists, and to pay the accommodation for everyone and the flight for some of them. In particular, we enjoyed the presence of prof Mary Wheeler from the University of Texas at Austin.

It was undoubtedly a great event with many well–known experts in porous media flow and mechanics. This special issue comprises some of the contributions that were presented in this workshop. We are proud to present fourteen papers. This special issue contains a large variation of papers, with modelling contributions, rigorous mathematical studies, and numerical methodologies. There is a clear trend in porous media research towards the (numerical) analysis and solution of poro-mechanical models. This type of models gives rise to saddle–point problems, which need a careful assessment in terms of the inf–sup condition, as well as in terms of stabilization in order to preserve properties like monotonicity and discrete maximum principles for the (finite–element) numerical solutions. Another important issue is the iterative solution of the resulting algebraic systems in cases of saddle–point problems that result from Biot–type poro–elastic problems. These iterative procedures entail domain decomposition techniques combined with Krylov subspace methods and multigrid methods. This is a state–of–the–art research direction in flow and mechanics in porous media.

Currently, many researchers are interested in the coupling of multi–dimensional problems. One may think of the interaction between cracks and bulk porous media. In these systems, one treats the cracks as manifolds or curves through a porous medium. Elasticity, as well as, transport properties such as diffusion coefficients often have a completely different order of magnitude in cracks and bulk porous media. In this sense a lot of interest has been triggered in the solution of partial differential equations with

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source terms that only act on points, lines and surfaces (with 'zero measure').

Classical applications of porous media models are in simulating sub–surface flows, with applications in oil and gas recovery, CO_2–sequestration, and thermal storage. A relatively recent application is in living porous media, such as in brain tissues, or in tumors. These applications result into multi–physics problems in which numerical and modelling challenges results due to nonlinear couplings between several sub–model equations. In these living tissues, plasticity (permanent deformations), tissue growth or contraction, combined with flow through microchannels is crucially important in the modelling. Here, possibly the morpho-elastic models could be helpful. There is a clear tendency in porous media modelling (mechanics and transport) studies towards biological applications. The current issue also contains some of these applications.

Since many of these calculations contain input parameters that are hard to measure, and at least are varying from case to case, uncertainty is an important matter to deal with. Hence parameter sensitivity analysis of the models becomes crucially important. To this end, clever (multi level) Monte Carlo methods are used to estimate the impact of uncertainty to the solution. The uncertainty necessitates the prediction of likelihoods that particular scenarios occur, rather than just showing one sample run of a simulation. Of course, the assessment of uncertainty requires running of multiple simulations, and therewith efficiency of sample runs is indispensable. Another reason why computational efficiency is crucially important is to feed the computations from a Bayesian parameter variation into neural networks. This brings in the need of high-performance computing on supercomputer infrastructures, in particular for three dimensional problems. Artificial intelligence (AI) could be used to produce fast results that may be needed in engineering or medical platforms.

Concluding, poro-mechanical modelling and its applications require efficient, robust, reliable numerical models and sound physical models. This is needed for each sample run, and also for the quantification of uncertainty, where in the last case, one should also strive for clever Monte Carlo techniques. This Special Issue contains all these aspects. We invite the reader to enjoy this set of seriously peer–reviewed papers. If you are not yet involved in modelling porous media, then, feel welcome to join this nice community. We finally thank all the contributors for sharing their wonderful work.