Editorial: Advanced materials modeling combining model order reduction and data science

Chady Ghnatios, Anaïs Barasinski, Elias Cueto

frontiers | Frontiers in Materials

TYPE Editorial
PUBLISHED 11 January 2023
DOI 10.3389/fmats.2022.1096233

Check for updates

OPEN ACCESS

EDITED AND REVIEWED BY
Douglas Soares Galvao,
State University of Campinas, Brazil

*CORRESPONDENCE
Chady Ghnatios,
✉ chady.ghnatios@ensam.eu

SPECIALTY SECTION
This article was submitted to Computational Materials Science, a section of the journal Frontiers in Materials

RECEIVED 11 November 2022
ACCEPTED 28 December 2022
PUBLISHED 11 January 2023

CITATION
Ghnatios C, Barasinski A and Cueto E (2023), Editorial: Advanced materials modeling combining model order reduction and data science.
Front. Mater. 9:1096233.
doi: 10.3389/fmats.2022.1096233

Editorial: Advanced materials modeling combining model order reduction and data science

Chady Ghnatios[1,2]*, Anais Barasinski[3] and Elias Cueto[4]

[1]PIMM Lab, Arts et Metiers Institute of Technologie, CNRS, HESAM University, 151 Boulevard de l'Hopital, Paris, France, [2]Department of Mechanical Engineering, Notre Dame university Louaizé, Keserwan, Lebanon, [3]Universite de Pau et des Pays de l'Adour, E2S UPPA, CNRS, IPREM, Pau, France, [4]Aragon Institute of Engineering Research, Universidad de Zaragoza, Zaragoza, Spain

KEYWORDS

digital twins technologies, data-driven materials modeling, model reduction applications in materials forming, digital twins of materials and processes, machine learning of materials models

Editorial on the Research Topic
Advanced materials modeling combining model order reduction and data science

Materials modeling has always been a challenging issue. Many complexities rise in such modelings, like non-linear material behavior, complex physics, and large deformation, coupled with multiphysics phenomena. Moreover, materials often exhibit rich behavior in response to thickness, hindering the use of classical simplifications, and imposing the need for an extremely refined mesh when using classical simulation techniques. Model reduction techniques appeared as a suitable solution to alleviate computational time. Many applications and material-forming processes benefit from the advantages offered by model reduction techniques including solid deformation, heat transfer, and fluid flow. Moreover, the recent development in data-driven modeling has opened novel possibilities in materials modeling. In fact, a correction or an update of the simulation using data modeling has led to the formation of the so-called "digital twin" models, improving the simulation with data-driven modeling. Data-driven modeling of materials for which current models are inaccurate also became possible through the use of machine learning algorithms.

The problem of efficiently building digital twins in the framework of materials manufacturing processes and materials modeling is thus, nowadays, a topic of increasing interest. Recent advances in digital twin technologies use experimental results to correct the simulation, but also to include their variability in the running simulation when a ground truth cannot be defined experimentally. This Research Topic addresses the recent developments in model reduction techniques, data-driven modeling, and digital twins technologies along with their applications in materials modeling and materials forming processes.

In Victor Champaney et al., the authors tackle the problem of non-trivial interpolations, which arise, for example, when critical points in a curve, an elastic-plastic transition point, for instance, shifts location. To address an efficient solution to the problem, several methodologies are shown, coupling model reduction techniques and surrogate modeling. Moreover, surrogates that quantify and propagate uncertainties by delivering statistical bounds for the predicted curves are shown. Several applications are shown, featuring examples of classical mechanics of materials problems.

Optimization of scaffolds for tissue engineering, applied in bone regeneration problems, is tackled in Muixí et al. In this work, the authors use a coupled hyper-reduction technique and principal component analysis to create surrogate modeling of the designed scaffolds. Further, the surrogate modeling is leveraged in an inverse problem, thus identifying the process parameters and optimizing these parameters for the best scaffold material as desired outputs.

Since material observation is often partial, with partially observable data and expensive measurements which lead to data scarcity, data completion and modeling of partially observable data become a must, especially when manipulating data in the mechanics of materials. Therefore, in Victor Champaney et al., the authors tackle the modeling of partially observable data, using time evolution as the solution. In fact, taking into consideration previous input/output combinations would incorporate all the missing variables, or at least their effects, on the output. The problem is showcased in classical linear and non-linear Kelvin-Voight material models. On the other hand, data completion is tackled in Aublet et al., where an artificial intelligence-assisted data completion method is derived. The proposed data-augmentation technique is desirable for digital twinning assisted by artificial intelligence, especially when performing non-linear model reduction. The proposed method preserved similarities in terms of the validity domain of reduced digital twins. The method is leveraged to train a ROM-net with two showcased applications, one of them including a mechanical component undergoing cyclic loading at high temperature, with the aim to characterize or predict its life expectancy.

Author contributions

CG, AB, and EC contributed in writing the manuscript. CG wrote the first draft of the manuscript. CG, AB, and EC wrote different sections and reviewed the manuscript.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note