# High Performance Model-Order-Reduction Methods in Computational Multi-Scale Simulations of Non-Linear Materials

**J.Oliver[†*], J.A. Hernández[†], A.E. Huespe[‡] and M. Caicedo[†]**

[* †]Technical University of Catalonia (UPC)/CIMNE
Campus Nord UPC, Edifici C-1, c/Jordi Girona 1-3, 08034 Barcelona, Spain
xavier.oliver@upc.edu

[‡]CIMEC – INTEC-Universidad del Litoral
Predio CONICET, Santa Fe, Argentina
ahuespe@intec.unl.edu.ar

## ABSTRACT

The unwavering quest for new high-performance materials poses, in turn, unprecedented challenges to devise and develop new modeling tools able to predict, within reasonable accuracy, the mechanical behavior of such materials by taking into account phenomena operating on vastly different scales. Since traditional phenomenological approaches fall clearly short in describing such scale interactions, in recent years a new paradigm, in computational mechanics, has emerged to address this issue: computational multiscale modeling (CMM). [1]. There is wide consensus that one of the major factors that hinder exploitation of CMM technology in practical engineering contexts is the enormous computational cost associated to multiscale simulations. Thus, even with the dizzying speed of today's computers, solution of large structural systems (bridges, nuclear pressure vessels, airplane fuselages, etc.) with accurate resolution of microstructural fields becomes impractical.

To attempt to drastically diminish the computational burden associated with multiscale simulations, the approach followed in this work is the incorporation of model reduction techniques (ROM) into CMMs. However, in its standard form reduced basis methods suffer from an important limitation when handling non-linear problems: though they reduce notably the number of degrees of freedom --- and thus the pertinent equation solving effort ---, the computational cost associated to the evaluation of the internal forces and jacobians at quadrature points remains the same. Therefore, standard reduction methods only prove effective in dealing with micro-cells whose constituents are assumed to obey simple constitutive laws (typically linear elasticity) and they are completely inefficient for the highly non-linear dissipative materials case. In order to overcome this problem, in this work we use the more sophisticated projection methods [2], combined with interpolatory/least-square reconstruction schemes for the stress field at the microscopic unit-cell. This combination is here termed *high-performance model reduction method* (HP-ROM). To the best of the authors' knowledge, this research activity has not yet penetrated into the specific field of computational multiscale modeling, and the present work is thereby intended to take a first step in this direction, by exploring and addressing the challenges that may arise in applying these nascent (HP-ROM) techniques to multiscale modeling.

## REFERENCES

[1] Fish, J. Multiscale Methods: Bridging the Scales in Science and Engineering. Oxford Univ Pr, 2009.

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