

# A Non-Intrusive Coupling prototype for ABAQUS: implementation, demonstration & prospects

S. Guinard<sup>1</sup>, M. Hamadi<sup>2</sup>, J.-C. Passieux<sup>3</sup>, and R. Bouclier<sup>4</sup>

<sup>1</sup>*Airbus SAS, XRXF, Toulouse, France*

<sup>2</sup>*Airbus Operations SAS, ESCRNS, Toulouse, France*

<sup>3</sup>*Institut Clément Ader, Université de Toulouse, INSA-UPS-Mines d'Albi-ISAE-CNRS, Toulouse, France*

<sup>4</sup>*Institut de Mathématiques de Toulouse, Université de Toulouse, INSA-Toulouse, Toulouse, France*

July 21, 2017

## Abstract

Non-Intrusive Coupling Techniques (NICT) [1, 2] aim at simulating the behaviour of large and complex structures: investigate local structural non-linearities, while avoiding any human intervention on existing global models. Though existing numerical technologies may already afford the coupling of different structural models (sub-modelling), they still remain penalizing in terms of operability, and/or valid only within limited domains where local non-linearities do not affect the global behaviour significantly.

Exploratory investigations of a variety of coupling capabilities offered by NICT (FEM/X-FEM [3], determinist/stochastic [4], 2D-1D/3D [5], domain decomposition [6], FEM/NURBS [7]) have been achieved within ANR funded project ICARE, 2013-2016. The joined efforts of ICARE's partners have resulted in NICT's implementation and documentation in openSource FEM software code-aster (<http://www.code-aster.org>).

As an additional industrialization effort and dissemination towards AIRBUS stress analysis community, AGI has derived a prototype for ABAQUS, based on co-simulation features, specific developments and adapted meshing strategy. For demonstration purpose, specific needs of civil aircraft structural engineering have been addressed: shell to solid, linear orthotropic elasticity to damage and failure of composite materials. Attention was paid to consider models actually representative of day-to-day stress analysis exercises, which involve geometrical complexity, large number of dofs, mixture of element types (shell, connectors & solid), imposed kinematical constraints. A critical source of local non-linearity was considered: damage and failure of composites, captured through adapted solid meshes at local scale (discretization at meso-constituents scale, plies & interfaces) and relevant constitutive models ([8] & ABAQUS Example Problems Guide §1.4.6).

## References

- [1] L. Gendre, O. Allix, P. Gosselet, and F. Comte. Non-intrusive and exact global/local techniques for structural problems with local plasticity. *Computational Mechanics*, (44):233–245, 2009.
- [2] J.-C. Passieux, A. Gravouil, J. Rhétoré, and M. C. Baietto. Direct estimation of generalized stress intensity factors using a three-scale concurrent multigrid X-FEM. *International Journal for Numerical Methods in Engineering*, 85(13):1648–1666, 2011.
- [3] J.-C. Passieux, J. Réthoré, A. Gravouil, and M.-C. Baietto. Local/global non-intrusive crack propagation simulation using a multigrid X-FEM solver. *Computational Mechanics*, 52(6):1381–1393, 2013.
- [4] A. Nouy, F. Pled, and M. Chevreuril. A multiscale method for semi-linear elliptic equations with local uncertainties and non-linearities. *Submitted*, 2017.
- [5] G. Guguin, O. Allix, P. Gosselet, and S. Guinard. On the computation of plate assemblies using realistic 3D joint model: a non-intrusive approach. *Advanced Modeling and Simulation in Engineering Sciences*, 3(16), 2016.
- [6] M. Duval, J.-C. Passieux, M. Salaün, and S. Guinard. Non-intrusive coupling: Recent advances and scalable nonlinear domain decomposition. *Archives of Computational Methods in Engineering*, 23(1):17–38, 2016.
- [7] R. Bouclier, J.-C. Passieux, and M. Salaün. Development of a new, more regular, mortar method for the coupling of NURBS subdomains with a NURBS patch: Application to the non-intrusive local enrichment of NURBS patches. *Computer Methods in Applied Mathematics and Engineering*, (316):123–150, June 2017.
- [8] P. Linde, J. Pleitner, H. De Boer, and C. Carmone. Modelling and simulation of fiber metal laminates. In *ABAQUS Users' Conference*, 2004.