Accepted Manuscript

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PII: S0045-7825(17)30669-2
DOI: https://doi.org/10.1016/j.cma.2017.09.032
Reference: CMA 11626

To appear in: *Comput. Methods Appl. Mech. Engrg.*

Received date : 2 June 2017
Revised date : 21 September 2017
Accepted date : 26 September 2017

Please cite this article as: M. Duval, A. Lozinski, J.C. Passieux, M. Salaün, Residual error based adaptive mesh refinement with the non-intrusive patch algorithm, *Comput. Methods Appl. Mech. Engrg.* (2017), https://doi.org/10.1016/j.cma.2017.09.032

Residual error based adaptive mesh refinement with the non-intrusive patch algorithm

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Abstract

This paper deals with the introduction of mesh refinement techniques within the non-intrusive patch process. For this, an *ad hoc* residual based explicit error estimator is built, which is adapted to a multi-scale solution, associated with those non-intrusive mesh refinement technique. Moreover, to reduce the global cost of the process, one introduces an estimate of the convergence error of the non-intrusive algorithm, which allows to reduce the number of iterations. This method is discussed and illustrated on various numerical examples.

Keywords: Multiscale, Finite Elements, Non-intrusive coupling, Error estimation, Mesh refinement

1. Introduction

It exists a wide variety of applications in which a given finite element mesh may not be locally fine enough in order to take into account some localized phenomena. In such a case, when pre-processing with mesh adaptation is either not possible or hardly feasible, several numerical methods still allow to carry on an analysis guaranteeing a sufficient accuracy. For instance, if the vectorial space generated by the finite element discretization is too poor to well take into account local scale phenomena (crack for instance), then the model can be enriched using the eXtended Finite Element Method [Moës *et al.* 1999] or, in a more general context, the Generalized Finite Element Method [Strouboulis *et al.* 2001; Kim & Duarte 2015]. Another efficient way for bridging different scales is to rely on multigrid algorithms [Rannou *et al.* 2009; Passieux *et al.* 2011], which allow for relevant computations while keeping a reasonable computational cost. Nevertheless, setting up an enriched finite element model or making use of a multigrid solver requires to use an *ad-hoc* software. While remaining very efficient, such methods may not be suited to all situations, especially if one uses a software which does not support such features.

Then a flexible and efficient solution is to rely on an iterative algorithm with patches of finite elements [Glowinski *et al.* 2005; Rezzonico *et al.* 2007; Pironneau & Lozinski 2011], which is based upon the wider class of Schwarz algorithms [Gander 2008]. Such methods rely on separate finite elements models and solvers. A patch of finite elements is used to "zoom" the solution provided by a global scale model, without modifying it. Then, in its non-intrusive version [Gendre *et al.* 2009; Duval *et al.* 2016], the patch algorithm can be used regardless of the used software and the underlying class of solver for each scale.

The main idea of this paper is to join together non-intrusive patch algorithm and mesh refinement. A major advantage is that it allows to confine mesh refinement to a restricted area, defined at the beginning of the procedure. Then, this area, our "patch", may be refined classically, in a h and/or p manner and several times, fully independently from the mesh, model and operators of the global domain, its coupling to the patch being driven by the non-intrusive algorithm.

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