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► To cite this version:

Floriane Wurtzer, Pierre-Alain Boucard, Pierre Ladevèze, David Néron. A first illustration of a multimodel strategy for coupled multiphysics problems. VII ECCOMAS Young Investigators Conference, Jun 2023, Porto, Portugal. hal-04143008

HAL Id: hal-04143008

<https://hal.science/hal-04143008>

Submitted on 27 Jun 2023

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A first illustration of a multimodel strategy for coupled multiphysics problems

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Abstract: This contribution proposes a suitable framework for the multimodel simulation of strongly coupled multiphysics problems based on the non-incremental LATIN-PGD method. This strategy relies on introducing an interface between physics, which can be seen as a generalization of the geometrical interfaces between substructures found in domain decomposition. Therefore, the different physics only communicate through this interface (where the coupled equations are satisfied), whereas the monophysical equations are solved separately for each physics. This separate treatment allows using different kinds of models for both physics. A first implementation in the case of strongly coupled 3D thermo-mechanics is presented herein and deals with coupling a full order model (FOM) with a simplified one (reduced order (ROM) or even analytical). The choice of the accommodation space in which these different models communicate is specifically discussed.

Keywords: multiphysics, strong coupling, multimodel, model order reduction, LATIN-PGD

1 Introduction

Since the operation of most modern industrial systems involves interactions between multiple physical phenomena (e.g., mechanical, thermal, electromagnetic), their high-fidelity simulation requires taking their multiphysical behavior into account. In the case of strong coupling, i.e., when all phenomena significantly influence each other, the simulation must address the problem in a coupled way. Commonly used approaches are divided into direct monolithic resolution (treating all physics simultaneously) and partitioning strategies (the physics are treated sequentially but still communicate at each time step) [1]. The presented work focuses on an alternative partitioning method based on the non-incremental LATIN-PGD solver, including the powerful Proper Generalized Decomposition (PGD) ROM technique.

Coupling several physics implies choosing their associated models. Indeed, it may be relevant to couple different types of models [2] (e.g., simplified/fine model, data-based/finite element (FE) model). This contribution proposes a first illustration of a multimodel strongly coupled multiphysics simulation within the framework provided by the LATIN-PGD solver.

2 The LATIN-PGD method

It is a non-incremental iterative approach initially developed for nonlinear evolution problems [3]. In order to deal with multiphysics problems, the method relies on extending the notion of material interface between substructures to an interface between physics on which the physics will interact [4]. The strategy is based on three ingredients:

The first one consists in separating the governing equations into two sets: the linear mono-physical but possibly global equations (set \mathbf{A}_d) and the local but coupled equations (set $\mathbf{\Gamma}$).

The second idea involves using search directions in a two-stage iterative algorithm to build intermediate solutions belonging to \mathbf{A}_d and $\mathbf{\Gamma}$ alternatively until a sufficient level of convergence has been reached. Thus, each iteration consists of first solving a local in space but coupled system (within the so-called coupled stage) and then solving a global linear system for each physics (during the decoupled stage). Therefore, the simultaneous treatment of both a global and a coupled problem is avoided.

The third one takes advantage of the non-incremental nature of the method, meaning that an approximation of the solution over the whole domain and the entire time interval is provided at each iteration. It is, therefore, highly relevant to apply efficient model reduction techniques based on the PGD to reduce the computational costs of the decoupled stage.

3 First application

The presented method is applied to a strongly coupled 3-dimensional thermo-mechanics problem. First, both physics are solved with standard FE models associated with a PGD decomposition during the decoupled stage. Then, the multimodel aspect is tackled by replacing the FE solution with a simplified model for one of the physics. Special attention is paid to the accommodation of these models on the interface between physics (i.e., where the coupled equations are solved).

4 Conclusions

This work presents a framework adapted for the multimodel simulation of strongly coupled multiphysics problems based on the non-incremental LATIN-PGD solver. The key feature of this approach is the concept of interface between physics. A first illustration is given by coupling a simplified model to a fine one in order to solve a strongly coupled 3D thermo-mechanics problem. First results are very promising in terms of modularity.

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