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A computational framework for certified reduced basis methods: applications to multiphysics problems

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ABSTRACT

Over the last few years we have been developing an open-source computational framework for certified reduced basis methods [1] based on the Feel++ framework [5]. The latter provides (i) a very wide range of arbitrary order Galerkin methods (fem, sem, cG, dG) in 1D, 2D and 3D (ii) an interface to modern linear algebra framework PETSc/SLEPc and Trilinos and (iii) a language embedded in C++ for Galerkin methods with a syntax following closely the mathematical one. Our recent advances in the former allow to (i) treat a wide range of problems as exercised later, (ii) provide an (almost) automated framework including the use of reduced basis element methods [3, 4], *hp* reduced basis approximations, empirical interpolation method, the successive constraints methods, a posteriori error estimation for linear and non-linear parametrized partial differential equations.

The exposition is organized as follows, first we present the advances in our framework for certified reduced basis methods since [1], in particular in two areas (i) automation of the reduced basis method using a domain specific language [5] and (ii) coupling of the reduced basis methods coupled with domain decomposition methods or multiscale methods. Then we apply our framework to two large multi-physics applications (i) high field magnet design (ii) aerothermal modeling in an airplane cabin. Note that the objective is to identify the bottlenecks in the methodology to be applied to industrial problems. Full results may not be expected but we shall report the scaling issues encountered as well as the intermediary results.

Regarding the first application, the Laboratoire National des Champs Magnétiques Intenses (LNCMI) is a French large scale facility enabling researchers to perform experiments in the highest possible magnetic field (up to 35 T static field). High magnetic fields are obtained by using water cooled resistive magnets (cf. fig. 1) connected with a 24 MW power supply [2]. As to the second application, its purpose is to build reduced order models aimed at replacing some 0D models in the energy control system of an airplane, see fig. 2. The design, optimization or control of these magnets or the energy control system require from an engineering point of view solutions of a multi-physics model involving combination of electro-thermal, magnetostatics, electro-thermal-mechanical and thermo-hydraulics models. It should be noted that these models are non-linear. In practice the parametric and physical spaces induce huge computational costs.

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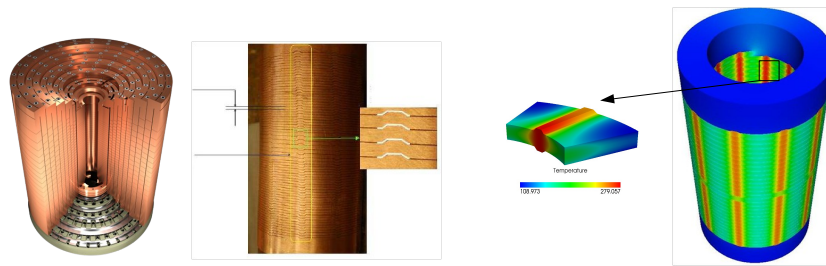


Figure 1: A high field magnet: (left) exploded view; (center) detailed view of the inner part; (right) temperature of the inner part with a zoom on a “turn”.

Global model

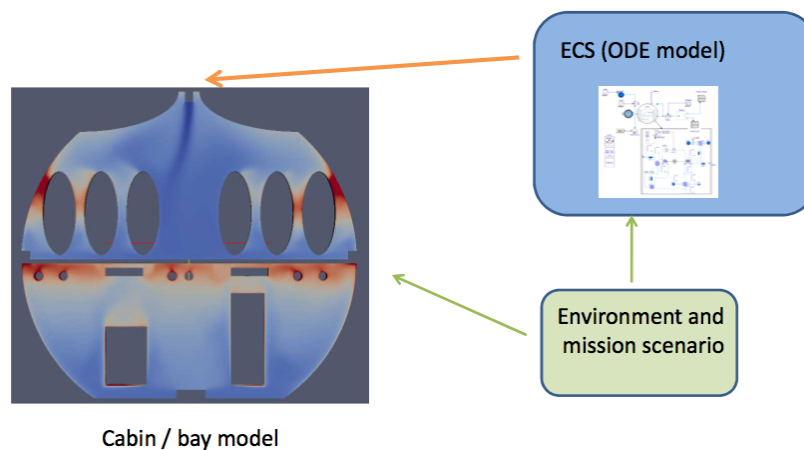


Figure 2: Energy control system in an airplane

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