YS3 INDAM Young Scientists Seminars Series on Reduced Order Modelling

SISSA, International School for Advanced Studies, Trieste, Italy

Wednesday October 8, 2014 Room A-133
(SISSA, Via Bonomea 265, Trieste)

14:30 Gianluigi Rozza, *welcome and presentation of EU-MORNET initiatives within COST, European Cooperation in Science and Technology, www.eu-mor.net*

14:45 Laura Iapichino, University of Konstanz, Germany
"Reduced Basis Method for solving PDEs with large number of parameters"
SISSA mathLab seminar

15:30 Lorenzo Zanon, RWTH Aachen, Germany
"The Reduced Basis Method for Nonlinear Elasticity"

16:15 Break

16:45 Francesco Ballarin, MOX-Politecnico di Milano, Italy
"Reduced Order Models for patient-specific haemodynamics of coronary artery bypass grafts"

17:30 Angela Scardigli, Optimad-Politecnico di Torino, Italy
"POD Reduced-Order Modelling applied to Aerodynamic Shape Optimization"

18:15 Conclusive remarks

Main contact: Gianluigi Rozza, SISSA mathLab, grozza@sissa.it

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SISSA, International School for Advanced Studies, Trieste, Italy
Thursday October 9, 2014 Room A-005
(SISSA, Via Bonomea 265, Trieste)

9:45 Alberto Sartori, CESNEF-Politecnico di Milano, Italy
"Reduced Order Models for Nuclear Engineering: Breaking the Wall of Point-Wise Kinetic"

10:30 Paolo Pacciarini, MOX-Politecnico di Milano, Italy
"A discontinuous Galerkin Reduced Basis Element method for elliptic problems"

11:15 Break

11:45 Giuseppe Pitton, SISSA mathLab, Trieste, Italy
"Recent advances on reduced order modelling for viscous and thermal flows in parametrized settings: focus on stability and bifurcations"

12:30 Filippo Salmoiraghi, SISSA mathlab, Trieste, Italy
"Reduced Basis Isogeometric Boundary Element Methods for the real-time simulation of flows around parametrized NACA airfoils"

13:15-14:30 Lunch break

14:30 Round table: *Scientific computing software development and libraries for Reduced Order Modelling in HPC.*

15:15 Conclusive remarks

Main contact: Gianluigi Rozza, SISSA mathLab, grozza@sissa.it

Abstracts

Laura Iapichino, University of Konstanz, Germany

“Reduced basis method for solving PDEs with large number of parameters”

Often a physical model is represented by a set of partial differential equations (PDEs) where some parameters or parametric functions describe physical quantities (like source terms, boundary conditions, material properties) and/or geometrical configuration, so that the system solution is parameter dependent. The reduced basis method is a reduced order technique suitable to solve parametric partial differential equations and, compared with classical numerical methods, requires a significant lower computational time by maintaining a certain level of the solution accuracy.
The presented model reduction paradigms are particularly indicated for solving problems that involve a large number of parameters (due to large parametrized computational domains) and/or distributed parameter functions and when a considerable number of solution evaluations is required in real-time for many different values of the parameters.
In particular, the reduced basis method is proposed in conjunction with domain decomposition techniques and optimal control theories. The combination of these frameworks becomes a very effective tool for applications since we have the possibility to deal with complex geometrical configurations, obtained as composition of simpler geometries deformable through suitable parametric transfinite maps, and with distributed parameter functions, which are prohibitive with the classical reduced basis method.
Some numerical results show the effectiveness and the advantages of the proposed approaches.
Joint work with Alfio Quarteroni, Gianluigi Rozza and Stefan Volkwein.

Lorenzo Zanon, RWTH Aachen, Germany

"The Reduced Basis Method for Nonlinear Elasticity"

Although many elastic phenomena undergo small deformations and can be described by the linearized form of the equilibrium equations, problems involving large displacements exhibit a nonlinear behavior and require an exact geometric treatment. So far, the literature on model order reduction for nonlinear elasticity based on the Finite Element (FE) Method is largely related to the Proper Orthogonal Decomposition (POD). This, on the one hand, allows substantial savings of computational time for highly nonlinear problems (e.g., viscoelasticity, plasticity) without a significant loss of precision; on the other hand, POD does not provide the tools to efficiently treat parametrized systems. Therefore, we consider here the reduced basis (RB) method and discuss issues and challenges in its application to nonlinear elasticity.
One example is a buckling problem for different 2D and 3D parametrized geometries. The first step consists in solving a linear elastic problem for an arbitrary load; the second in the identification of the critical load through an eigenvalue problem. Even though the choice of the RB functions and the quality of the approximation can only be verified through a non-rigorous estimator or a comparison with the "truth" FE solution, we will show that the RB method allows, in the online phase, for a drastic reduction of computational time as well as for a quick parameter-identification procedure.
Another example focuses on a finite deformation problem characterized by large strains, where the parameters correspond to the material constants. The initial choice of a linear St.Venant material constitutive law is justified by the fact that it still introduces a (polynomial) nonlinearity in the tangential stiffness matrix. More complex nonlinearities introduced by physically realistic constitutive relations (e.g., Ogden, Neo-Hooke) will affect in a similar way the affine parameter dependence of the system, thus compromising the efficient offline-online decomposition. In the RB context, an approximation technique such as the Empirical Interpolation Method allows us to deal with such a difficulty. We therefore present numerical results for a model problem, investigating the computational benefits of the reduced dimensionality.
Joint work with Karen Veroy.

Francesco Ballarin, MOX-Politecnico di Milano, Italy

"Reduced Order Models for patient-specific haemodynamics of coronary artery bypass grafts"

In this talk we present a POD-Galerkin reduced order model (ROM) to simulate the haemodynamics of coronary artery bypass grafts. In the first part of the talk the POD-Galerkin ROM will be summarized, with a focus on stability properties of the ROM and a two-level POD for unsteady problem. Afterwards, the proposed ROM is applied to some patient-specific cases of coronary artery bypass grafts, for clinically relevant physical (inlet flow rates) and geometrical (stenoses severity, anastomoses geometry) parameters. A clinical discussion of the resulting flow patterns will conclude the talk.
Joint work with Elena Faggiano, Sonia Ippolito, Andrea Manzoni, Alfio Quarteroni, Gianluigi Rozza and Roberto Scrofani.

Angela Scardigli, Optimad-Politecnico di Torino, Italy

"POD Reduced-Order Modeling applied to Aerodynamic Shape Optimization"

We propose a hybrid low-order/high-order method based on a domain decomposition approach, in order to reduce the computational cost of aerodynamic shape optimization. The main idea is to split the domain of interest in two subdomains and to use different approximation methods in each of the two subdomains. In particular, the canonical CFD solver is used within a crucial region, whereas in the rest of domain we use a semi-empirical model based on Proper Orthogonal Decomposition (POD). The effectiveness of this approach is tested on large-scale problems, i.e. car aerodynamics, and it is employed successfully in a surrogate-based global optimization procedure.

Alberto Sartori, CESNEF-Politecnico di Milano, Italy

"Reduced Order Models for Nuclear Engineering: Breaking the Wall of Point-Wise Kinetic"

Control of a nuclear reactor core is an important and difficult task. The neutron behavior is described by a set of coupled non-coercive parabolic PDEs. Moreover, in order to develop an efficient control tool, the simulation time must be very short, possibly a real-time capabilities is required. The point-wise kinetics has been the common approach employed for control oriented studies. However, the development of innovative nuclear reactor concepts, such as Gen IV reactors, requires more advanced simulation tools. In this venue, Reduced Order Models could be the turning point for control-oriented studies thanks to their fast running simulation time and the capabilities of dealing with parametrized PDEs in efficient and reliable way. Moreover, ROMs could be also a bridge between the world of control and world of design of a nuclear reactor core.

Paolo Pacciarini, MOX-Politecnico di Milano, Italy

"A discontinuous Galerkin Reduced Basis Element method for elliptic problems"

We propose a new discontinuous reduced basis element method for the approximation of parametrized elliptic PDEs in partitioned domains.
The method is built upon an offline stage (parameter independent) and an online (parameter dependent) one. In the offline stage we build a non-conforming (discontinuous) global reduced space as a direct sum of local basis functions built independently on each subdomain. In the online stage, for a given value of the parameter, the approximate solution is obtained by ensuring the weak continuity of the fluxes and of the solution itself thanks to a discontinuous Galerkin approach. The new method extends and generalizes the methods introduced by L. Iapichino, G. Rozza and A. Quarteroni [Comput. Methods Appl. Mech. Engrg. 221/222 (2012), 63–82] and by L. Iapichino [PhD thesis, EPF Lausanne, 2012]. We also propose a two-level preconditioner for the online problem which exploits the pre-existing decomposition of the domain and is based upon the introduction of a global coarse finite element space.
A rigorous a posteriori error estimation strategy is currently under investigation. Further developments will concern the extension of the method to more general problems, e.g. the Stokes problem, in which some stabilization techniques may be needed to guarantee the stability of the method.

Giuseppe Pitton, SISSA mathLab, Trieste, Italy

"Recent advances on reduced order modelling for viscous and thermal flows in parametrized settings: focus on stability and bifurcations"

Some recent developments of reduced order modelling in computational fluid dynamics for viscous incompressible flows will be discussed.
The main topics will deal with the use of combined ROM techniques currently available, efficient sampling procedures, inf-sup pressure stabilization for ROM approaches, error bounds. Spectral elements method is used for basis generation.
Some emphasis will be given to the stability of flows and steady and Hopf bifurcations.

Filippo Salmoiraghi, SISSA mathlab, Trieste, Italy

"Reduced Basis Isogeometric Boundary Element Methods for the real-time simulation of flows around parametrized NACA airfoils"

In this talk I will present a Reduced Basis (RB) method relying on Isogeometric Analysis (IGA) for the rapid and reliable evaluation of PDE systems characterized by complex geometrical features. At the current state of the art, this is the first case of coupling between RB and IGA methods. The construction of the RB method exploits an Isogeometric Boundary Element Method (IGA-BEM) as the high-fidelity technique, allowing a direct interface with Computer Aided Design (CAD) tools. For the selection of the reduced basis functions we adopt both the Proper Orthogonal Decomposition (POD) and a Greedy algorithm. A suitable empirical interpolation method (EIM) ensures an efficient offline/online decomposition between the construction and the evaluation of the RB method. As a proof of concept, I will consider the real-time simulation of potential flows past airfoils, parametrized with respect to the angle of attack and the NACA number identifying their shape. I will provide a validation of the results with respect to experimental data and reference numerical codes, showing in both cases a very good agreement.