Reduced-order models at work: Industry and Medicine

Rapport sur les contributions

ID de Contribution: **28** Type: **Non spécifié**

Hemodynamics examples of reduced order models for clinical applications

mercredi 30 mars 2022 11:20 (50 minutes)

Orateur: Prof. VIGNON-CLÉMENTEL, Irène (Inria Saclay)

ID de Contribution: **29** Type: **Non spécifié**

Some new developments on the non invasive reduced basis method

mercredi 30 mars 2022 10:30 (50 minutes)

The efficient implementation of reduced basis methods relying on a high fidelity discretization method to compute the elements of the reduced basis, requires to enter within the code, offline, so that the online solution can be produced very rapidly. Since this is sometimes impossible, in particular for codes used in industrial framework, we have proposed a Non Invasive alternative where the code is used at two stages : a) offline to build the reduced basis, b) online to, first, compute a coarse approximation using the code with few degrees of freedom (thus more rapidly than with the high fidelity requirement) then by processing this coarse solution to improve the accuracy and fulfil the high fidelity requirement at much mower cost. This method that first appeared with its numerical analysis in [1] for finite element approximations has been generalised in various directions (finite volume, truncation of the domain, different new rectifications) and implemented in a library in the frame of a joined project with large and medium size companies [2].
In this paper I will present some of the new concepts in this drection

[1] Rachida Chakir, Yvon Maday :A two-grid finite-element/reduced basis scheme for the approximation of the solution of parameter dependent PDE. In 9e Colloque national en calcul des structures. ISO 690 Y. (2009, May).
[2] Elise Grosjean : Variations and further developments on the Non-Intrusive Reduced Basis two-grid method, PhD Thesis at Sorbonne Université - 2022

Elise Grosjean and Yvon Maday

Orateur: Prof. MADAY, Yvon (UPMC Paris 6)

ID de Contribution: **30** Type: **Non spécifié**

ROM Closures and Stabilizations for Under-Resolved Turbulent Flows

mercredi 30 mars 2022 13:40 (50 minutes)

In this talk, I will survey reduced order model (ROM) closures and stabilizations for under-resolved turbulent flows. Over the past decade, several closure and stabilization strategies have been developed to tackle the ROM inaccuracy in the convection-dominated, under-resolved regime, i.e., when the number of degrees of freedom is too small to capture the complex underlying dynamics. I will present regularized ROMs, which are stabilizations that employ spatial filtering to alleviate the spurious numerical oscillations generally produced by standard ROMs in the convection-dominated, under-resolved regime. I will also survey three classes of ROM closures, i.e., correction terms that increase the ROM accuracy: (i) functional closures, which are based on physical insight; (ii) structural closures, which are developed by using mathematical arguments; and (iii) data-driven closures, which leverage available data. Throughout my talk, I will highlight the impact made by data on classical numerical methods over the past decade. I will also emphasize the role played by physical constraints in data-driven modeling of ROM closures and stabilizations.

Orateur: Prof. ILIESCU, Traian (Virginia Tech)

ID de Contribution: **31** Type: **Non spécifié**

Field reconstruction using manifold learning and structure-preserving metrics

mercredi 30 mars 2022 14:30 (50 minutes)

The problem of estimating the state of a physical system is ubiquitous in science. However observations are always limited so that the high-dimensional state cannot be observed and the associated mathematical problem is ill-posed. Popular workarounds include dimension reduction and regularization by imposing some structure to the class of elements in which the estimation is sought. We here rely on a purely data-driven approach and learn the map between extended measurements and the nonlinear manifold the state vector lies on. Specifically, we use embedding to address the non-Markovianity of the raw measurements. Combined with multi-kernel learning, it results in high-dimensional measurement features. The state vector nonlinear manifold is approximated and the map from measurement features to the estimated state is the solution to a Sylvester equation. The methodology is illustrated with the estimation of a fluid flow field from a few wall-mounted sensors.

Orateur: Dr MATHELIN, Lionel (LIMSI-CNRS)

ID de Contribution: **32** Type: **Non spécifié**

Use of reduced basis techniques for two-phase flows in porous media

mercredi 30 mars 2022 15:20 (50 minutes)

Orateur: Dr ENCHERY, Guillaume (IFPEN)

ID de Contribution: **33** Type: **Non spécifié**

Quadratic Approximation Manifold for Mitigating the Kolmogorov Barrier in Nonlinear Projection-Based Model Order Reduction

jeudi 31 mars 2022 09:00 (50 minutes)

A quadratic approximation manifold is presented for performing nonlinear, projection-based, model order reduction (PMOR). It constitutes a departure from the traditional affine subspace approximation aimed at mitigating the Kolmogorov barrier for nonlinear PMOR, particularly for convection-dominated transport problems. It builds on the data-driven approach underlying the traditional construction of projection-based reduced-order models (PROMs); is application-independent; is linearization-free; and therefore is robust for highly nonlinear problems. Most importantly, this approximation leads to quadratic PROMs that deliver the same accuracy as their traditional counterparts using however the square root of their dimension. The computational advantages of the proposed high-order approach to nonlinear PMOR over the traditional approach are highlighted for the detached-eddy simulation-based prediction of the Ahmed body turbulent wake flow, which is a popular CFD benchmark problem in the automotive industry. For a fixed accuracy level, these advantages include: a reduction of the total offline computational cost by a factor greater than five; a reduction of its online wall clock time by a factor greater than 32; and a reduction of the wall clock time of the underlying high-dimensional model by a factor greater than two orders of magnitude.

co-author: Joshua Barnett

Orateur: Prof. FARHAT, Charbel (Stanford)

ID de Contribution: **34** Type: **Non spécifié**

Model reduction of convection-dominated partial differential equations via optimization-based implicit feature tracking

jeudi 31 mars 2022 09:50 (50 minutes)

Partial differential equations (PDEs) that model convection-dominated phenomena often arise in engineering practice and scientific applications, ranging from the study of high-speed, turbulent flow over vehicles to wave propagation through solid media. The solutions of these equations are characterized by local features or disturbances that propagate throughout the domain as time evolves or a system parameter varies. Numerical methods to approximate these solutions require stabilization and fine, usually adaptive, grids to adequately resolve the local features, which lead to expensive discretizations with a large number of degrees of freedom. Projection-based model reduction methods tend to be ineffective in reducing the computational cost of such problems due to a slowly decaying Kolmogorov n-width of the solution manifold.

To avoid the fundamental linear reducibility limitation associated with convection-dominated problems, we construct a nonlinear approximation by composing a low-dimensional linear space with a parametrized domain mapping. The linear space is constructed using the method of snapshots and POD; prior to compression, each snapshot is composed with a mapping that causes its local features to align (same spatial location) with the corresponding features in all other snapshots. The parametrized domain mapping is chosen such that the local features present in the linear space deform to the corresponding features in the solution being approximated, effectively removing the convection-dominated nature of the problem. The domain mapping is determined implicitly through the solution of a residual minimization problem, rather than relying on explicit sensing/detection. We provide numerous numerical experiments to demonstrate the effectivity of the proposed method on benchmark problems from computational fluid dynamics.

Orateur: Prof. ZAHR, Mattew (Notre Dame)

ID de Contribution: **35** Type: **Non spécifié**

From handcrafted Galerkin models to automated cluster models

jeudi 31 mars 2022 11:10 (50 minutes)

Reduced-order models (ROM) are of paramount importance for physical understanding, data compression, estimation, control and optimization. Over a century ago, simple dynamical models of coherent structures have been facilitated by stability theory (Orr-Sommerfeld equation 1907) and by vortex models (von K arm an 1911). Data-driven reduced-order modeling of coherent
structures has been pioneered by Aubry et al. (1988) with a celebrated POD model of the turbulent boundary layer. Since then, machine learning [1] has significantly simplified and enriched the spectrum of possibilities for data-driven ROM.
In this talk, we exemplify different ROM approaches for the fluidic pinball [2], the wake flow behind a cluster of three parallel cylinders on an equilateral triangle pointing upstream. The flow may be actuated by rotating cylinders. First, the transition scenario of the unforced fluidic pinball is modeled with a five-mode mean-field Galerkin model. This model comprises successive Hopf and pitchfork bifucations, which are typical for a number of wake flows. Second, a cluster-based network model (CNM) [3, 4] is presented describing the fluidic pinball wake with actuation as free input, employing thousand differently actuated pinball simulations. CNM yields a robust dynamics from a fully automatable procedure. Finally, perspectives of ROM for common tasks of data management are given.
[1] BRUNTON, S. L., NOACK, B. R. & KOUMOUTASKOS, P. 2020 Ann. Rev. Fluid Mech. 52:477–508.
[2] DENG, N., NOACK, B. R., MORZY N SKI, M., & PASTUR, L. R. 2020 Low-order model for successive bifurcations of the fluidic pinball. J. Fluid Mech. 884, A37:1–41.
[3] LI, H., FERNEX, D., SEMAAN, R., TAN, J., MORZY N SKI, M. & NOACK, B. R. 2021 Cluster-based
network model. J. Fluid Mech. 906, A21:1–41.
[4] FERNEX, D., NOACK, B. R. & SEMAAN, R. 2021 Cluster-based network model—From snapshots
to complex dynamical systems. Science Advances (online).

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Orateur: Prof. NOACK, Bernd (Harbin Institute ot Technology, Shenzhen, China)

ID de Contribution: **36** Type: **Non spécifié**

Reduced basis Smagorinsky turbulence models

jeudi 31 mars 2022 12:00 (50 minutes)

Orateur: Prof. CHACÓN, Tomás (Instituto de Matemáticas de la Universidad de Sevilla)

ID de Contribution: **37** Type: **Non spécifié**

TBD

Orateur: Prof. MORBIDUCCI, Umberto (Politecnico di Torino)

ID de Contribution: **38** Type: **Non spécifié**

TBD

jeudi 31 mars 2022 15:00 (30 minutes)

Orateur: Dr BERNARD, Florian (Nurea)

ID de Contribution: **39** Type: **Non spécifié**

Fear and loathing in Aerodynamics: Are ROMs chimeras or game-changers?

jeudi 31 mars 2022 14:30 (30 minutes)

Over the last years promising advances in reduced order modelling and machine learning have been reported by the scientific community.
Within this talk we will try to project (some of) these findings on different industrial settings to discuss their potential.
We will try to make this evaluation using all metrices that are relevant in industry to identify applications where ROMs can have a real impact.

Orateur: Dr TELIB, Haysam (Optimad)

ID de Contribution: **40** Type: **Non spécifié**

TBD

jeudi 31 mars 2022 15:30 (30 minutes)

Orateur: Dr FERTÉ, Guilhem (EDF)

ID de Contribution: **41** Type: **Non spécifié**

Beyond PCA by explicitely taking into account system symmetries

vendredi 1 avril 2022 09:30 (50 minutes)

Linear principal component analysis (PCA) experiences an increase in the dimensionality of the latent space when it is applied to configurations that exhibit symmetries. In this study, we introduce a novel machine learning embedding, which uses spatial transformer networks and siamese networks to account for continuous and discrete symmetries, respectively. This embedding, which we term symmetry-aware PCA, will be applied to three configurations: Burger's equation exhibiting a continuous translation symmetry, flow in sudden expansion, a discrete reflexional symmetry, and Kolmogorov Flow which combines discrete shift-reflect and continuous translation symmetries. We will show a drastic increase in the number of modes required to represent given trajectories.

Simon Kneer, Taraneh Sayadi, Denis Sipp, Peter J. Schmid, Georgios Rigas

Orateur: Prof. SIPP, Denis (ONERA)

ID de Contribution: **42** Type: **Non spécifié**

Tensor methods for high-dimensional problems and model reduction

vendredi 1 avril 2022 10:20 (50 minutes)

We present several contributions related to Tensor methods for high-dimensional problems and discuss how they are inherently related to model reduction.
In particular, we will show several ways to introduce a principle of adaptivity, making tensor representations more suitable to parsimoniously represent certain solutions sets. In the last part of the talk, a contribution on a possible way to exploit a tensor representation in state estimation is presented. In this, we show that variational and sequential state estimation methods can be derived after casting state estimation as an optimal recovery problem, using tensors to have a space-time representation of the solutions set.

Orateur: Dr LOMBARDI, Damiano (Inria Paris)

ID de Contribution: **43** Type: **Non spécifié**

Model order reduction for CFD: state of the art, advances in applications

vendredi 1 avril 2022 11:40 (50 minutes)

Orateur: Prof. ROZZA, Gianlugi (SISSA)

ID de Contribution: **44** Type: **Non spécifié**

POD- and RB-Hierarchical Model Reduction Techniques in a Parametrized Setting

vendredi 1 avril 2022 12:30 (50 minutes)

Different methods have been proposed in the scientific panorama to offer a compromise between modeling accuracy and computational efficiency. Reduced order models represent a widespread solution in such a direction. In this presentation, we focus on the Hierarchical Model (HiMod) reduction technique, which proved to be an effective approach to discretize CFD configurations where a principal horizontal dynamics overwhelms the transverse ones (e.g., when modeling hemodynamics or signal propagation in waveguides). In particular, we address the generalization of the HiMod procedure to a parametrized setting. We propose two alternative approaches, which combine HiMod with Proper Orthogonal Decomposition (POD) and the Reduced Basis (RB) method, respectively. The two strategies will be analyzed and cross-compared in order to identify the associated pros and cons.

Orateur: Prof. PEROTTO, Simona (Politecnico Milano)