New Developments in Reduced Order Modelling
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Abstracts

Adaptive Reduced Order Modelling for steady and unsteady aerodynamics
Marco Fossati, University of Strathclyde
The talk will present an adaptive framework for reduced order modelling of aerodynamic problems involving airfoils and wings. The adaptive framework aims at finding the most accurate ROM approach among a library of methods such that the best accuracy can be achieved while solving a many-query problem. Two different approaches to error estimation will be presented, one based on a direct comparison with a reference solution, and another looking at a residual evaluation of a finite Volume discretization of the Navier-Stokes equations.

Wavelets-based Edge Multiscale Finite Element Method for Helmholtz problems in perforated domains
Guanglian Li, University of Hong Kong
We introduce a new efficient algorithm for Helmholtz problems in perforated domains with the design of the scheme allowing for possibly large wavenumbers. Our method is based upon the Wavelet-based Edge Multiscale Finite Element Method (WEMsFEM) as proposed recently. For a regular coarse mesh with mesh size H, we establish $\mathrm{O}\,(H)$ convergence of this algorithm under the resolution assumption, and with the level parameter being sufficiently large. The performance of the algorithm is demonstrated by extensive 2-dimensional numerical tests including those motivated by photonic crystals.

References
[1] Shubin Fu, Eric Chung and Guanglian Li, An Edge Multiscale Interior Penalty Discontinuous Galerkin method for heterogeneous Helmholtz problems with large varying wave number, to appear, J. Comput. Phys, 2021.
[2] Shubin Fu, Guanglian Li, Richard Craster and Sebastien Guenneau, Wavelets-based Edge Multiscale Finite Element Method for Helmholtz problems in perforated domains, to appear, Multiscale Model. Simul., 2021.

Reduced order methods: state of the art, perspectives and applications in computational fluid dynamics
Gianluigi Rozza, SISSA, Trieste
We provide the state of the art of Reduced Order Methods (ROM) for parametric Partial Differential Equations (PDEs), and we focus on some perspectives in their current trends and developments, with a special interest in parametric problems arising in offline-online Computational Fluid Dynamics (CFD). Efficient parametrisations (random inputs, geometry, physics) are very important to be able to properly address an offline-online decoupling of the computational procedures and to allow competitive computational performances. Current ROM developments in CFD include: a better use of stable high fidelity methods, considering also spectral element method and finite volume discretisations, to enhance the quality of the reduced model too, and allowing to incorporate some turbulent patterns and increasing the Reynolds number; more efficient sampling techniques to reduce the number of the basis functions, retained as snapshots, as well as the dimension of online systems; the improvements of the certification of accuracy based on residual based error bounds and of the stability factors, as well as the guarantee of the stability of the approximation with proper space enrichments. For nonlinear systems, also the investigation on bifurcations of parametric solutions are crucial and they may be obtained thanks to a reduced eigenvalue analysis of the linearised operator. All the previous aspects are very important in CFD problems to focus in real time on complex parametric industrial, environmental and biomedical flow problems, or even in a control flow setting with data assimilation or uncertainty quantification. Model flow problems will focus on few benchmarks, as well as on simple fluid-structure interaction problems and shape optimisation applied to industrial problems.

Physics-driven reduced order models in fluid dynamics

Alexander Wray, University of Strathclyde

Techniques such as optimisation, control and sensitivity analysis often require many computations of a problem. However, solving a problem computationally can often be very expensive, requiring thousands of CPU hours for a single run for many continuum systems. This renders any application requiring multiple runs functionally inaccessible.

A common resolution has been to use reduced order models, which retain the key physics of a system but are dramatically simpler. There are a variety of ways of deriving reduced order models, but here we discuss fluid dynamical systems where the reduction is performed via exploitation of some physical component of the system (typically a separation in length scales). Such models have, for many years, been essentially phenomenological, and agreement with experiment has been hard to achieve. However, in recent years this has begun to change thanks to techniques such as the method of weighted residuals. Here we discuss the recent history of these techniques and their latest developments in the literature. In particular, the same techniques have begun to be used in multi physics situations, allowing for high-speed, high-accuracy modelling of real-world systems.

Finally, we examine the applications of these models to optimal control analysis, and in particular to the control of direct numerical simulations.