Prof. Eugenio OÑATE

International Center for Numerical Methods in Engineering (CIMNE)
Universitat Politècnica de Catalunya (UPC)

Dr. Eugenio Oñate is a Civil Engineer. His activity in the last 35 years has combined an academic career as Professor of Structural Mechanics at the Technical University of Catalonia (UPC), a research career in the field of numerical methods and their application to engineering and the transfer of the results of his research to the industrial sector. His research achievements in the field of numerical methods and software for the analysis and design of structures, fluid dynamics and industrial manufacturing processes are internationally recognized. His scientific contributions and software derived from his research are of particular relevance for solving multidisciplinary problems in the fields of civil, industrial, aerospace, marine and naval engineering, among others.

He has published 306 scientific papers in JCR journals. He has 5.213 citations and a h-index of 37 (Source: Web of Knowledge). He is the chief editor of 3 JCR journals. He is author of 3 text books and editor of 53 books on a variety of topics in computational mechanics (CM). He has organized 52 international conferences on different fields in CM.

He was the founder and Director since 1987 of CIMNE. He was a founder and first president of the Spanish Society of Numerical Methods in Engineering (1989‐2004, www.cimne.com/semni), founder and president of the European Community for Computational Mechanics in Applied Sciences (2000‐2004, www.eccomas.org) and president of the International Association for Computational Mechanics (2002-2010, www.iacm.info).

He has promoted the start-up of several technology-based companies in Spain (www.cimnetecnologia.com).

He has received numerous awards at the international level.

A Physics-Informed Data-Driven Approach for the Simulation of Turbulent Fluid Flows

Eugenio Oñate, Sergio Idelsohn, Juan Gimenez and Norberto Nigro

A new computational model (termed Pseudo-DNS) [1,2] for analysis of incompressible fluid flows with massive instabilities at different scales is presented. It is based on resolving all the flow instabilities at all scales without any additional model, i.e. following the Direct Numerical Simulation (DNS) style. Nevertheless, the computation is carried out at two levels or scales, termed the "coarse" scale and the "fine" scale.

The fine scale simulation is performed on Representative Volume Elements (RVEs) providing the homogenized stress tensor as a function of several dimensionless numbers characterizing the flow. Consequently, the effect of the fine scale instabilities is transferred to the coarse level as a homogenized stress tensor, a procedure inspired by standard multi-scale computational methods used in solid mechanics.

The P-DNS method introduces a new way for the treatment of the flow at the fine scale, simulating not only the coarse scale but also the fine scales with all the necessary detail, but without incurring in the excessive computational cost of the classical DNS method. The transfer of the information of the fine scale to the coarse scale is performed using a physics-based data-driven procedure inspired in AI techniques.

Another interesting aspect of the P-DNS technique is the use of a Lagrangian formulation for convecting the eddies simulated on the fine mesh through the coarse domain.

Several examples showing the applicability of the P-DNS methodology for the simulation of turbulence in homogeneous flows are presented.

References

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[2] Sergio Idelsohn, Juan Gimenez, Norberto Nigro, Eugenio Oñate. "The Pseudo-Direct Numerical Simulation Method for Multi-Scale Problems in Mechanics". *Comput. Methods Appl. Mech. Engrg. 380,113774. doi.org/10.1016/j.cma.2021.113774; (2021).*

Eric Maury
Airbus Technology & Engineering
Head of Environment & Energy - Aircraft Architecture & Integration

Eric Maury has been working at Airbus for the past 25 years within several functions such as Engineering & Techno, Programs Chief engineering and Engine Procurement.
Eric's main field of expertise is around overall aircraft design, aircraft performances and propulsion.
Eric is now overarching the Airbus engineering activities around the new ecosystem challenges related to the decarbonisation strategy (energy, aviation fuel pathways) and their implications on the environment (mainly climate change incl. aviation non-CO2 effects).

Dr. Jos VANKAN
Netherlands Aerospace Centre (NLR)

- current position: principal scientist in NLR's Aerospace Vehicles Division
- has been much involved in recent European initiatives on Hybrid Electric propulsion and other alternative power supply investigations
- involved in a/c concept studies and power train investigations e.g. in Imothep and Novair projects
- also worked on concept design methodologies e.g. for system space allocation and routing optimization
- also involved in technology developments for TP composites manufacturing and assembly techniques like induction welding modelling
- involved in aero-structural modelling and design of composite fan blades for scaled wind-tunnel testing of turbofan engine.

Hybrid-Electric Propulsion Concept Design for Short-Medium Range Aircraft

Ambitious targets for the coming decades have been set for the further reduction of aviation greenhouse gas emissions. Hybrid Electric Propulsion (HEP) concepts can offer potential for mitigation of these aviation emissions. To investigate this potential in an adequate level of detail, the European research project IMOTHEP (Investigation and Maturation of Technologies for Hybrid Electric Propulsion) explores key technologies for HEP in close relation with developments of aircraft mission and configuration. This paper presents conceptual level design investigations on radical HEP aircraft configurations for short-medium range (SMR) missions. In particular, a blended-wing-body configuration with turbo-electric powertrain and distributed electric propulsion is investigated using NLR's aircraft evaluation tool MASS. For the aircraft and powertrain design, representative top-level aircraft requirements have been defined in IMOTHEP and the reference aircraft for the assessment of potential benefits is based on the A320neo aircraft.

Dr. Shuai LI
Chalmers University of Technology
Shuai Li obtained his Ph.D. in Aeroacoustics from Queen's University, Canada. He is currently a postdoc at the Division of Fluid Dynamics, Chalmers University of Technology. He is working with Profs. Lars Davidson and Shia-Hui Peng on the EU Horizon 2020 INVENTOR project addressing aircraft noise reduction with focus on noise mitigation of landing gears (LGs) and high-lift devices (HLDs) by means of innovative designs and noise-control technologies.

On the improvement of acoustic models for aerodynamic noise prediction using Physics-Informed Machine Learning

Shuai Li, Shia-Hui Peng and Lars Davidson

Sustainable Urban Mobility addresses how to design urban transport systems. For example, the vertical take-off and landing (VTOL) aircrafts are promising for urban transportation because they can hover, take off and land vertically without relying on a runway. Although such aircrafts are efficient because their airports are usually located in the city areas, the noise generation raises another issue imminently needed to be solved. An intensive and constant effort towards VTOL aircraft noise reduction is essential, not only through engine noise reduction, but also by addressing the noise generated by the airframe, including landing gears (LGs) and high-lift devices (HLDs). Traditionally, the prediction of aircraft noise relies heavily on the use of Computational Aero-Acoustics (CAA). The most commonly used CAA approach is a hybrid method combining traditional Computational Fluid Dynamics (CFD) simulations and acoustic analogies. Only recently, machine learning in combination with physical constraints, or physics-informed machine learning, gains popularity in inferring flow fields based on a limited amount of physical data (e.g. experiments or direct numerical simulations (DNS)). In this talk, we focus on the improvement of acoustic models using physics-informed machine learning. The improved acoustic models are developed at low Reynolds numbers with DNS data as training data sets. The developed models are then applied to predict aircraft noise in high-Reynolds-number real-world applications.

Prof. Esteban Ferrer
Universidad Politécnica de Madrid (UPM) (ETSIAE School of Aeronautics)

New avenues in Computational Fluid Dynamics

We present the latest developments of our High-Order Spectral Element Solver (HORSES3D), an open source high-order discontinuous Galerkin framework, capable of solving a variety of flow applications, including compressible flows (with or without shocks), incompressible flows, various RANS and LES turbulence models, particle dynamics, multiphase flows, and aeroacoustics. Recent developments allow us to simulate challenging multiphysics including turbulent flows, multiphase and moving bodies, using local p-adaption and fast multigrid time advancement.

In addition, we also present recent work that couples Machine Learning techniques and high order simulations.

Prof. Ramon Codina
Universitat Politècnica de Catalunya (UPC)
International Center for Numerical Methods in Engineering (CIMNE)

Ramon Codina is Professor at the Departament de Resistència de Materials i Estructures a l'Enginyeria (RMEE), in the Universitat Politècnica de Catalunya (UPC). He teaches Structural Mechanics and Continuum Mechanics and his research is concerned with numerical methods in engineering and applied sciences, with particular emphasis on finite element methods in fluid mechanics.

Hybrid Intrusive/ML-based Reduced Order Model for the Optimisation of Aerodynamic Profiles

Ramon Codina, Zulkeefal Dar and Joan Baiges

There are several applications in computational fluid mechanics that require solving many times the flow equations, and one of them is the optimisation of aerodynamic profiles. Considering only shape optimisation problems, the geometry needs to be parametrised and the parameters need to be determined from the minimisation of a cost function, for example the drag. This requires many evaluations of this cost function and, therefore, many solves of the flow equations. A fast numerical solution of the flow problem is thus peremptory, and a means to achieve this is using reduced order models (ROMs). In particular, we propose to use ROMs based on proper orthogonal decomposition (POD) and having a finite element (FE) approximation as full order model (FOM).

POD-based ROMs start from collecting results from the FOM, for example instances of the unknown at different time instants or for different values of the geometric parameters. These are the so-called snapshots. A basis of a reduced space is then constructed, typically from a singular value decomposition (SVD) of the snapshot collection. The dimension of the ROM space is taken much smaller than that of the FOM space. The flow equations are then projected onto the ROM space and solved there, being this solve much cheaper than that of the FOM (sometimes, after the introduction of some hyperreduction techniques).

ROMs that use the FOM equations, as the projected ROMs described, are often called intrusive. In contrast, there are also ROMs purely designed based on existing data of high fidelity and using machine learning (ML) techniques; these are called non-intrusive models. In this work we propose to design a hybrid model, essentially of intrusive type but incorporating a correction term based on ML techniques. The idea is to start from a purely POD-based ROM, projecting the equations onto the ROM space, and then add a nonlinear correction that depends on the ROM unknowns to enhance the final ROM model. This correction is based on the fact that we do have some available high fidelity data, namely, the snapshots. Thus, the correcting term is built as an artificial neural network (ANN) constructed with the snapshots as training set, i.e., considering that the loss function is the norm of the difference between the snapshots projected onto the ROM space and the outputs predicted by the model. The resulting hybrid ROM has a significant higher accuracy than the original intrusive one.

Dr. Domenico Quagliarella
Italian Aerospace Research Centre (CIRA)

Domenico Quagliarella received in May 1988 the MS degree and in July 1993 the Ph.D. in Aerospace Engineering from the University "Federico II" in Naples, Italy. In July 1988, he got a research engineer position at CIRA, where he is currently head of the Multidisciplinary Analysis and Design Group of Fluid Mechanics Department. His research interests are the application of hybrid multi-objective optimization methods to aerodynamic and multidisciplinary design, the use of approximate fitness evaluators for efficiency improvement in optimization, and uncertainty quantification for robust and reliability-based design. He is the author of about 90 international journal and conference papers. He is also editor of five edited books and two special issues of academic journals. He participated in several EU projects, and he also carried out research activity in the framework of "Clean Sky" and "Clean Sky 2" public-private partnerships between the European Commission and the Aeronautical Industry.

Risk Measures for Robust Optimization and Their Efficient Use in Aerodynamic Shape Design

Domenico Quagliarella and Elisa Morales Tirado

We introduce the use of advanced risk functions, initially conceived in financial engineering, in the formulation of robust optimization problems and illustrate their application to robust design problems of aerodynamic shapes. The focus is here on techniques for increasing the computational efficiency of robust optimization processes based on risk functions. In previous work, we have illustrated an intrusive approach based on the gradient computation with the adjoint field to approximate the empirical cumulative distributions for calculating risk functions. In subsequent work, however, we have shown how a non-intrusive approach, based on Gaussian processes, led to comparable results, with a slight advantage on the flexibility of the procedure and

a disadvantage, also slight, in terms of efficiency. In this paper, instead, we want to analyze the performance of a mixed approach, where both the gradient information, calculated intrusively, and the approximation methodology based on Gaussian processes are used simultaneously. In particular, we illustrate the new mixed approximation technique and discuss the differences in terms of efficiency and easiness of implementation compared to the intrusive and non-intrusive ones. This method is then applied to a robust aerodynamic design problem.

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Prof. Nicolas R. Gauger
University of Kaiserslautern (TUK)

- 1998 M.Sc. in Mathematics at Leibniz University Hannover
- 2003 Ph.D. in Applied Mathematics at TU Braunschweig
- 1998-2010 Research Scientist at German Arospace Center (DLR) in Braunschweig
- 2005-2010 Assistant Professor for Applied Mathematics at Humboldt University Berlin
- 2006-2010 Member of DFG Institute MATHEON in Berlin (MATHEON - Mathematics for Key Technologies)
- 2010-2014 Associate Professor for Computational Mathematics at RWTH Aachen
- Since 2014 Full Professor for Scientific Computing and Director of Computing Center (RHRK) at TU Kaiserslautern

Groundbreaking Designs Through Innovative Combination of Methods from Artificial Intelligence and Optimization

Nicolas R. Gauger, Emre Özkaya, Rohit Pochampalli, Guillermo Suarez and Stefanie Günther

The so-called "grey-box modeling" approach cleverly combines insights from simulations ("white-box modeling") on high-performance computing (HPC) architectures with data-driven approaches ("black-box modeling") using artificial intelligence (AI) methods.

As an example, we consider here the so-called "field inversion" method in data-driven turbulence modeling for the Navier-Stokes equations. For the field inversion, classical methods from the area of optimization with partial differential equations are used. Furthermore, in the data-driven part, the training of certain artificial neural networks shows analogies to the optimization for ordinary differential equations. In all approaches, we keep an eye on automation and parallelization on the computing systems to be used.

Prof. Jacques Periaux
CIMNE/UPC

Credit for joint contributions: Gabriel Bugeda, Hong Quan Chen, Yongbin Chen, Roland Glowinski, Luis Felipe González, David Greiner, Dong Seop Chris Lee, Eugenio Oñate, Jordi Pons Prats, O. Pironneau, Mourad Sefrioui, Karkenhalli Srinivas, Tang Zhili, Jin Wang, Eric Whitney, Yao Zheng… among others appearing in joint publications …)
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Abstract:
This lecture reviews chronologically during almost three decades (1994-2022) major improvements of Evolutionary multi objective and multi-disciplinary design optimization (MO & MDO) techniques achieved in terms of efficiency and quality (Hierarchical EAS, Parallel Island EAs, Asynchronous Parallel EAs…).
An increased level of efficiency is due to the hybridization of EAs with Game Strategies (Pareto, Nash, Stackelberg and their coalition) is briefly reported (speed-ups of multi objective optimizers evaluated on simple aeronautical optimisation test problems using friendly design frameworks).
Finally, numerical experiments on real life design applications are chronologically presented (with referenced optimization papers reducing in particular drag impacting $CO2$ on climate change) in Aeronautics (aerofoils, wings, UAV Systems).
It is hoped that these improved methods in evolutionary optimization will provide young scientists and young engineers recently involved in the fields of CFD useful and efficient tools for their future careers in aeronautical research and industrial communities.
More details of this lecture can be found in Ref. [1]

Reference:

[1] J. Periaux, F. González, C.L Dong Seop, Evolutionary Optimization and game Strategies for Advanced Multi-Disciplinary Design, Application to Aeronautics and UAV Design, Intelligent Systems, Control and Automation: Science and Engineering, Springer, 2015.