Efficient Multi-Physics Approaches Inspired by Aircraft Digital Twin Concepts

The Sir Lawrence Wackett Aerospace and Defence Centre, based at RMIT University, is Australia's leading academic aerospace R&D institution. The Flight Sciences Lab, led by Prof. Pier Marzocca, supports Australian civil and defense R&D initiatives in aircraft design, unsteady aerodynamics, aeroelasticity, structural dynamics and structural health monitoring, with over $15M/year in funding from industry and government agencies. Over the past decade, in partnership with the Australian Defence Science and Technology Group (DSTG), the Flight Sciences Lab have developed the aircraft Operational Loads and Asset Diagnostics (OPERAND) suite, with data-driven and physics-based capabilities that include: High-fidelity and reduced-order aeroservoelastic modelling suite, GPU-native Lattice-Boltzmann CFD code, Prognostics and Health Management software, Flight flutter mode detection tools, Store clearance framework. In this seminar, Prof. Marzocca will provide an overview of the Wackett Centre, OPERAND suite of tools, and of the Flight Sciences group's current research activities.

Recent Efforts in Nonlinear Aeroelastic Reduced Order Models and Computationally Efficient Fluid Dynamic Simulations

Nonlinear aeroelastic ROMs based on ML or AI algorithms can be complex and computationally demanding to train, meaning that for practical aeroelastic applications, the conservative nature of linearization is often favoured. Therefore, there is a requirement for novel NL aeroelastic model reduction approaches that are accurate, simple and, most importantly, efficient to generate. Recently our team has developed novel formulation for the identification of a compact multi-input Volterra series, where Orthogonal Matching Pursuit is used to obtain a set of optimally sparse nonlinear multi-input ROM coefficients from unsteady aerodynamic training data. The novel approach for the identification of OS higher-order polynomial-based aeroelastic ROM significantly reduces the amount of training data needed without sacrificing fidelity. The framework is exemplified using AGARD 445.6 Wing & BSCW benchmark supercritical wing, considering forced response, flutter, and limit cycle oscillation. In recent years, Computational Fluid Dynamics (CFD) solvers incorporating Large Eddy Simulation (LES) turbulence models have gained significant traction. This shift is driven by the exponential growth in computational power, enabling more accurate and detailed simulations of turbulent flows. LES models are particularly attractive due to their ability to resolve large-scale turbulent structures while filtering the smaller scales, providing a balance between accuracy and computational efficiency. Among the various CFD methodologies, the Lattice Boltzmann Method (LBM) has emerged as a robust alternative for fluid flow simulations. Unlike traditional methods that solve the Navier-Stokes equations directly, LBM focuses on the evolution of particle distribution functions on a discrete lattice grid. This approach is inherently compatible with parallel computing, making it highly suitable for modern computational architectures such as Graphics Processing Units (GPUs).

Speaker: Professor Pier Marzocca, Director, Sir Lawrence Wackett Aerospace and Defence Centre. RMIT University, Melbourne, Australia 3000.

About the Speaker:

Professor Pier Marzocca is the Director of the Sir Lawrence Wackett Aerospace and Defence Centre at RMIT University in Melbourne, Australia. He is a Professor in Aerospace Engineering and the Program Leader and Architect of two Joint Chair with the Defence Science and Technology Group, leading the Centre for Advanced Defence Research in Structures and Materials Experimentation, the Joint Defence Chair in Structures and Materials Experimentation, and the Joint Defence Chair of Supersonic Propulsion and Flight Technologies. Prior to these roles, he held the positions of Deputy Dean Research and Innovation, Associate Dean and Chair of the Aerospace Engineering and Aviation Department at RMIT University. Prof Marzocca also served as an Assistant, Associate, and Full Professor in the Mechanical and Aeronautical Engineering Department at Clarkson University in USA, where he currently holds a Research Professor position. He earned his doctoral degree in Aerospace Engineering from Politecnico di Torino, Italy, and worked as a Postdoctoral Researcher and Visiting Assistant Professor in Engineering Science and Mechanics at Virginia Tech under the supervision of Professor Liviu Librescu. With a career spanning since early 90's, Prof Marzocca specializes in multi-physics modelling with expertise in aeroservoelasticity, unsteady aerodynamics, structural dynamics and controls of advanced aerospace systems, including model-based and data driven system identification technique, digital twin/thread solutions, structural diagnostics, prognostics, and load monitoring. Prof Marzocca leads or co-leads numerous research projects, securing over $40 million USD in funding from various government agencies, including the Australian Federal and State Government, Australian Research Council, DST Group, DSI, NSF, AFOSR, ARMY, ONR, DOE, EPA, and NYSERDA, as well as private foundations and industries such as Boeing, BAE Systems, Lockheed Martin, GE, and Pratt & Whitney. Prof Marzocca is a Fellow of RAeS and Associate Fellow of AIAA, and author of over 500 technical papers.