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ESCUELA TÉCNICA SUPERIOR INGENIERÍA AERONÁUTICA Y DEL ESPACIO
UNIVERSIDAD POLITÉCNICA DE MADRID
Plaza Cardenal Cisneros, 3
28040 Madrid, España
☏: (+34) 91 067 5544

NORTHWESTERN POLYTECHNICAL UNIVERSITY (China)

TECHNICAL CONFERENCES BY:

Prof. Jiaqing Kou
Prof. Weiwei Zhang

(abstracts and bios below)

DATE: **Monday, June 2nd.**

TIME: **10:00h**

PLACE: **Salón de Actos (Building A)**

Additionally for Chinese students in Spain: **HOW TO JOIN NPU**
TIME: **09:00h**
PLACE: Salón de Actos

Organised by
Prof. Esteban Ferrer in collaboration with the Office of International Affairs-ETSIAE-UPM
(Oficina de Movilidad)

Application of Data-Driven Knowledge Discovery in Turbulence Modeling and Aerodynamic Modeling

[1,2]Weiwei Zhang*; [1,2]Xuxiang Sun; [1,2]Zhongxin Yang; [1,2]Xianglin Shan; [1,2]Zijie Shi; [1,2]Wenbo Cao ; [1,2]Jiaqing Kou; [1,2]Yilang Liu; [1,2]Chuangqiang Gao;

[1]*School of Aeronautics, Northwestern Polytechnical University, Xi'an, 710072, China*

[2]*International Joint Institute of Artiffcial Intelligence on Fluid Mechanics, Northwestern Polytechnical University, Xi'an, 710072, China*

Abstract

Artificial intelligence (AI) provides a new research paradigm for the development of fluid mechanics. Based on data, AI can not only provide a black box representation of complex fluid systems through deep learning, but also provide new opportunities for knowledge discovery of fluid mechanics, such as symbolic regression method and sparse identification of governing equations. This presentation highlights our team's recent advancements in data-driven knowledge discovery for fluid mechanics and related engineering applications. Our first focus involves the discovery of generalizable corrections to the conventional mixing length model and the construction of a new algebraic turbulence model. By progressively training on increasingly complex flows (channel DNS and flat plate LES data), we obtained machine-learned corrections for inner-layer physics, outer-layer physics, and pressure gradient physics. These machine-learned corrections are then validated against a wide range of attached flows, most of which are outside the training dataset, and the results are favorable. This work addresses the generalizability issue in the context of symbolic regression. The second aspect of our work focuses on the discovery of turbulence generation term of Spalart-Allmaras (SA) model for separation flow. Based on the data assimilation of two flow fields, the turbulent transport equation of high-Re separation flow was constructed by using the symbolic regression method. Then, the high-precision simulation of high-Re separation flow with variable configurations and variable flow condition was realized, and the error was reduced by 2-10 times compared with the standard SA model, while the calculation accuracy of the attached flow was consistent with that of the standard SA. The third aspect of our work addresses scaling function learning, a sparse aerodynamic data reconstruction method for generalizing aircraft shapes. The scaling parameters learning (SPL) method was proposed to learn the correlation function of aerodynamic data, and the unified low-dimensional manifold of aerodynamic force change with free flow state of different aircraft shapes was discovered, so that the nonlinear aerodynamic modeling of variable states can be realized with very small samples (3-5) for the new configuration. The last aspect of our work focuses on the discovery of a data-driven blunt body flow-induced vibration model. With a limited amount of vibration response data, a customized wake oscillator model can be constructed. Additionally, a low-dimensional model describing the amplitude as a function of structural damping, mass ratio, and Reynolds number is derived based on a small set of experimental data. The research shows that compared with the black-box deep learning driven solely by big data, the dual integration of "data" + "knowledge" is a clear direction for the development of industrial artificial intelligence, with inherent interpretability and trust. Data can make up for the limitations of knowledge, replace or improve classical models (e.g., turbulent models), and knowledge can make up for the sparsity of data and solve few-shot machine learning in engineering. This report serves as a demonstration of AI4fluid research, and can be expanded in other fields.

Keywords: Data-driven, knowledge discovery, symbolic regression, machine-learned turbulence model, manifold dimensionality reduction

Wei-Wei Zhang is Prof in Northwestern Polytechnical University. He research on AI for aerodynamics and aircraft design, including unsteady aerodynamics, aeroelasticity, turbulence modeling, and digital twin flight. He has received the National Excellent Youth Fund (2016) and Chang Jiang Scholars Award (Distinguished Professor, 2019) of the Ministry of Education. He has published over 100 articles in premier international journals. He is now Vice Chairman of the China Aerodynamics Society and Associate Editors of 10 premier international and domestic journals.

Enhancing Flow Stability through Aerodynamic Shape Optimization for Airfoils and Bluff Bodies

[1,2]Jiaqing Kou; [1,2]Hao Yuan; [1,2]Wengang Chen; [1,2]Yiming Gong; [1,2]Chuangqiang Gao; [1,2]Weiwei Zhang

[1]*School of Aeronautics, Northwestern Polytechnical University, Xi'an, 710072, China*

[2]*International Joint Institute of Artificial Intelligence on Fluid Mechanics, Northwestern Polytechnical University, Xi'an, 710072, China*

Abstract:

Flow instability commonly exists in natural phenomena and engineering systems. Typical examples include the von Kármán vortex shedding behind bluff bodies, flow separation on airfoils at large angles of attack, and transonic buffet on airfoils, etc. Such instabilities give rise to force fluctuations, structural vibrations, and acoustic noise. To suppress flow instability, a number of flow control techniques have been developed. However, due to the lack of prior knowledge and theoretical guidance, designing flow control techniques often leads to strong disturbances and requires extensive trial and error with respect to control parameters. This results in low design efficiency and limits their applicability in engineering practice. To enhance the stability of unsteady flow past complex shapes and develop effective flow control strategies, we propose several stability-based aerodynamic shape optimization frameworks. Our research mainly includes three parts: 1) An adjoint-based shape optimization design is developed to reduce the fluctuation of lift coefficient. The vortex shedding has been suppressed and the onset angle of attack of transonic buffet has been delayed. 2) The Jacobian-free global stability analysis is developed to formulate the shape optimization design framework considering the constraint of transonic buffet. The lift and drag characteristics of the optimized airfoil are enhanced and the buffeting is effectively suppressed, thereby expanding the flight envelope. 3) An aerodynamic shape optimization framework based on resolvent analysis is proposed to optimize the geometry while minimizing the resolvent gain of the flow past a cylinder at the subcritical Reynolds number. Through shape optimization, the flow separation is delayed and the vortex shedding are suppressed at higher Reynolds numbers. In the future, to enhance the proposed techniques, reduced-order modeling and efficient gradient-based optimization algorithms will be further developed. The framework is expected to be applied to engineering problems with higher Reynolds number and higher complexity, such as wings and full aircraft.

Keywords:

Global Stability Analysis, Flow Control, Aerodynamic Shape Optimization, Separated Flow, Resolvent Analysis

Bio:

Jiaqing Kou is currently a Professor in School of Aeronautics, Northwestern Polytechnical University. His research interest includes complex flow simulation and artificial intelligence for unsteady aerodynamics. He obtained B. Eng. and M. Eng. degrees in 2015 and 2018 from NPU, and PhD degree (Premios Extraordinarios de Doctorado) in 2022 from ETSIAE-UPM (Universidad Politécnica de Madrid), under the Marie-Curie framework ASIMIA. He received the Alexander von Humboldt Postdoctoral Fellowship at the RWTH Aachen University (2022), and the National Excellent Youth Fund Overseas in China (2023). He has published over 50 papers in leading international journals and is an associate editor of Aerospace Science and Technology.