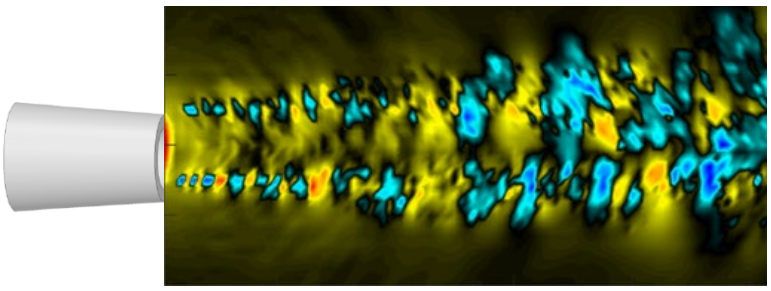
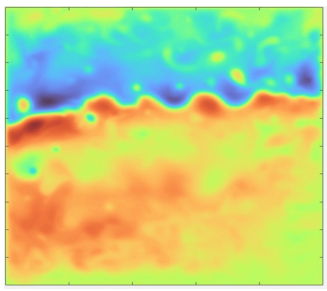
Machine Learning Applications in Turbulent Flows





Overview

While remaining as one of least understood topics, turbulence is observed in every branch of fluid mechanics from aerodynamics to environmental flows. What makes the analysis of turbulent flows complicated is the variety of spatial and temporal scales that exist in such flow regimes. It is specifically challenging for machine learning algorithms to deal with wide-spectrum nature of turbulent signals and differentiate between the deterministic and stochastic components in such data sets. Hence, applying machine learning methods to turbulent flows systems not only pushes the limits of scientific machine learning but also can be insightful in discovering new structures from such complex data sets and accelerate the conventional flow simulations.

This workshop is designed to familiarize the participants with basic machine learning tools that can be applied to turbulent flow simulations. These methods aim at reducing the complexity of turbulent flow simulations in space and time, uncovering key dynamic features in such flow regimes and reconstructing the flow field for predicting the behaviour of these systems beyond the simulation time with a lower computational cost.

The workshop is designed for target audience of PhD students and postdocs and participants should be familiar with MATLAB and Python as a prerequisite.

Agenda

- **9:00-9:30** Introduction

  Prof. Sergey Karabasov

- **9:30-10:45**

  Decomposition of time-space data using Proper Orthogonal Decomposition (POD) and Spectral Proper Orthogonal Decomposition (SPOD)
  Dr Elnaz Naghibi

- **10:45-12:00**

  Time series reconstruction using Neural Networks and Transformers
  Dr Nick Zang

- **12:00-13:15**

  Dynamical system analysis using Sparse Identification of Nonlinear Dynamics (SINDy) and Modified Permutation Entropy (MPE) method
  Dr Vasily Gryazev, Dr Elnaz Naghibi

Presenters

Prof Sergey Karabasov

Sergey Karabasov is Professor of Computational Modelling at Queen Mary, University of London. He holds PhD in mathematical modelling from Moscow Lomonosov State University and Full Doctorate of Science (Habilitation Degree) from the Moscow Keldysh Institute of Applied Mathematics for his work on hybrid and direct models in computational aeroacoustics. Prior to joining Queen Mary in 2012, Sergey was a Royal Society University Research Fellow in Cambridge University Engineering Department developing hybrid methods for computational aeroacoustics. He is an Associate Fellow of the AIAA elected for career-long work in high-speed flow aeroacoustics for jet engines and rotor noise and a Fellow of the Royal Aeronautical Society. Over the years, Sergey's research has been supported by UK Research Councils, European Commission, the Royal Society of London, and leading aerospace companies. More recently, Sergey has been working on developing data-driven reduced order models for engineering applications including high-speed and bioengineering flows based on Machine Learning. In 2023 he served as a guest editor for the Research Topic “Computational Modelling of Cardiovascular Hemodynamics and Machine Learning” of Frontiers in Cardiovascular Medicine.

Dr Elnaz Naghibi

Elnaz Naghibi is a senior lecturer in Mechanical Engineering in University of East London. Her research interests lie in applied mathematics by developing analytical and semi-analytical solutions to idealised models of engineering and natural systems. Her main research focus is on studying interactions of mesoscale oceanic currents and the Earth’s rotational variations through developing reduced-order and data-driven models.

Dr Nick Zang

Nick Zang is currently a senior lecturer in aerospace engineering at Queen Mary University of London. His research primarily focuses on experimental aerodynamics and aeroacoustics, and the development of advanced experimental techniques applicable to new aerial vehicle configurations. In more recent years, taking advantages of a range of experimental databases, he has developed a strong interest in aeroacoustic modelling of lifting surfaces, propellers, wind turbines as well as full vehicular configurations using machine-learning-based algorithms, such as Autoencoders, Transformers and Kolmogorov-Arnold Network and their variants. He has chaired thematic sessions on propeller noise in International Congress of Sound and Vibration (2024 - present) and on machine learning in fluids in ICTAM 2024. Over the years, his research has been supported by EPSRC, Horizon Europe, InnovateUK and aerospace industries across UK.

Dr Vasily Grayzev

Vasily Gryazev is a Lecturer in Aerospace Systems at Brunel University of London. He previously held the role of a Senior Aeroacoustics Research Engineer at Dyson (2022–2024) and held a postdoctoral role at Queen Mary University of London (2020–2022). His research covers computational fluid dynamics, aerodynamics and aeroacoustics, focusing on modern modelling approaches and the integrated use of numerical and experimental evidence to predict and analyse turbulent flows, particularly those with strong acoustic signatures.

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