

Title: Improving turbulence control through explainable deep learning

Abstract:

In this work we first use explainable deep learning based on Shapley explanations to identify the most important regions for predicting the future states of a turbulent channel flow. The explainability framework (based on gradient SHAP) is applied to each grid point in the domain, and through percolation analysis we identify coherent flow regions of high importance. These regions have around 70% overlap with the intense Reynolds-stress (Q) events in two-dimensional vertical planes. Interestingly, these importance-based structures have high overlap with classical turbulence structures (Q events, streaks and vortex clusters) in different wall-normal locations, suggesting that this new framework provides a more comprehensive way to study turbulence. We also discuss the application of deep reinforcement learning (DRL) to discover active-flow-control strategies for turbulent flows, including turbulent channels, three-dimensional cylinders and turbulent separation bubbles. In all the cases, the discovered DRL-based strategies significantly outperform classical flow-control approaches. We conclude that DRL has tremendous potential for drag reduction in a wide range of complex turbulent-flow configurations.

Bio:

Dr. Ricardo Vinuesa is an Associate Professor at the Department of Engineering Mechanics, KTH Royal Institute of Technology in Stockholm. He is also Lead Faculty at the KTH Climate Action Centre. He studied Mechanical Engineering at the Polytechnic University of Valencia (Spain), and he received his PhD in Mechanical and Aerospace Engineering from the Illinois Institute of Technology in Chicago. His research combines numerical simulations and data-driven methods to understand, control and predict complex wall-bounded turbulent flows, such as the boundary layers developing around wings and urban environments. Dr. Vinuesa has received, among others, an ERC Consolidator Grant, the TSFP Kasagi Award, the MST Emerging Leaders Award, the Goran Gustafsson Award for Young Researchers, the IIT Outstanding Young Alumnus Award, the SARES Young Researcher Award and he leads several large Horizon Europe projects. He is also a member of the Young Academy of Science of Spain.