6th European Conference on Computational Mechanics (ECCM 6)
7th European Conference on Computational Fluid Dynamics (ECFD 7)
11-15 June 2018, Glasgow, UK

Random-forests for enhancing RANS turbulence models with data: Perspectives for wind-farm modelling

Mikael Kaandorp[1*], **Richard P. Dwight**[1]

[1] Aerodynamics Group, Faculty of Aerospace Engineering, Delft University of Technology, Kluyverweg 1, 2629 HS Delft, The Netherlands, r.p.dwight@tudelft.nl

Keywords: *Turbulence modelling; Reynolds-averaged Navier-Stokes (RANS); Reynolds-stress tensor; machine learning; decision-trees; random-forests; neural networks; wind-farms.*

A novel machine learning algorithm is presented, serving as a data-driven turbulence modeling tool for Reynolds Averaged Navier-Stokes (RANS) simulations. This machine learning algorithm, called the Tensor Basis Random Forest (TBRF), can be used to predict the Reynolds stress anisotropy tensor, guaranteeing Galilean invariance by making use of a tensor basis. By modifying a random forest algorithm to accept such a tensor basis, a robust, easy to implement, and easy to train algorithm is created, with few hyper-parameters which need to be tuned. The individual decision trees in the TBRF are used in a robust outlier filter to improve predictive accuracy, and for uncertainty quantification of the predictions. The algorithm is trained on several flow cases using LES/DNS data, and used to predict the normalized Reynolds stress anisotropy tensor a_{ij} on multiple test flow cases. Results are then propagated with a custom solver implemented in OpenFOAM to yield an improved flow field. Results are compared to a generic random forest, and the Tensor Basis Neural Network (TBNN) from Ling et al. [J. Fluid Mech, 807(2016):155-166, (2016)] on which the TBRF was inspired. Results show that the TBRF algorithm is able to accurately predict the anisotropy tensor for various flow cases, with most of the predictions being realizable and close to the DNS/LES reference data, and that it performs on par with the TBNN algorithm. Resulting mean flows for a flow cases show great resemblance to corresponding DNS and experimental data-sets.

This work serves as a proof-of-concept for inferring unresolved turbulence scales from resolved scale in more challenging settings. In particular, we speculate that the features of turbulent phenomena occurring in far-wakes in wind-farms are ameanable to our approach, provide that sufficient training data is available. A tentative programme to achieve cheap, accurate models of wind-farms with machine-learning is proposed.