Improving Turbulence Models and Wall Functions by Using Machine Learning

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Machine Learning (ML) is used for developing wall functions for Large Eddy Simulations (LES). I use Improved Delayed Detached Eddy Simulations (IDDES) in fully-developed channel flow at a frictional Reynolds number of 5 200 to create the database. This database is used as a training set for the ML method. I use Support Vector Regression and Nearest Neighbor(s), both available in Python. The input (i.e. the influence parameters) is $y^+$. The ML method is trained to predict $U^+$. The trained ML model (SVR) is saved to disk and it is subsequently uploaded into the Python CFD code pyCALC-LES. SVR finds a time-averaged regression line. As an alternative I also investigate Nearest neighbor (uploading the database to pyCALC-LES) using Python’s scipy.spatial.KDTree. This method capture the unsteadiness of $U^+$, see Fig. 22 in this report. IDDES is then carried out on coarse – and semi-course – near-wall meshes and the wall-shear stress (using the local $y^+$ and $u^-$) is predicted using the developed ML models. The test cases are channel flow at $Re\tau = 16 000$ and flat-plate boundary layer. I’m currently extending the method to adverse-pressure gradient flows. I have created a number of databases using well-resolved LES in diffuser flows with opening angles $6 \leq \alpha \leq 18^\circ$. The influence parameters are local $u^-$ and $y^+$ as well as the non-dimensionalized pressure gradient, $p^+$. I use Neural Network (pytorch in Python). Finally, I will present some preliminary work on how to use Neural Network (pytorch) in Python to improve the prediction of the Reynolds stresses in non-linear eddy-viscosity and algebraic Reynolds stress turbulence models.

\[pyCALC-LES: \text{a Python code for DNS, LES and Hybrid LES-RANS. M2 Fluid Dynamics[R.1], Chalmers, Gothenburg, 2021.}^{1}\]


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