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Data- and physics-driven analysis of turbulent channel flows: Insights from DNS and Deep Learning

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Abstract

In this work, data from the literature of direct numerical simulations (DNS) are utilized for data- and physics-driven modelling. The case study refers to the prediction of the time-averaged velocity profiles for turbulent pressure-driven channel flows with friction Reynolds numbers, Re_τ, spanning from 180 to 10049 [1]. Moreover, light is shed on the investigation of logarithmic law and its domain of applicability. By employing unsupervised machine learning (ML) methods, the investigation considers three distinct Re_τ regions: low [180–2021], intermediate [4079–5186], and high [8016–10049], to identify common features that will lead to better understanding of local phenomena and provide more robust conclusions. Next, a deep learning (DL) network constructed with aid of the physics-based DeepXDE library [2] is employed for each region, with two inputs (Re_τ and the dimensionless wall distance y^+) and one output (the dimensionless velocity u^+). The DL model provides accurate predictions when compared to the ground truth DNS data, with slight differences observed due to the inherent resolution and modeling characteristics of each method. Finally, based solely on the DNS data and using an optimization method, we propose values for the logarithmic law constants κ and B ($\kappa = 0.39$ and $B = 4.64$) with a relative error 0.86%, which is in full agreement with the recent fluid dynamics literature.

Keywords: Deep Learning, turbulent boundary layers, direct numerical simulations, logarithmic law

References:

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