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Physics-informed data based neural networks for two-dimensional turbulence

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Turbulence remains a problem that is yet to be fully understood, with experimental and numerical studies aiming to fully characterize the statistical properties of turbulent flows. Such studies require huge amount of resources to capture, simulate, store and analyse the data. In this work, we present physics-informed neural network (PINN) based methods to predict flow quantities and features of two-dimensional turbulence with the help of sparse data in a rectangular domain with periodic boundaries. While the PINN model can reproduce all the statistics at large scales, the small scale properties are not captured properly. We introduce a new PINN model that can effectively capture the energy distribution at small scales performing better than the standard PINN based approach. It relies on the training of the low and high wavenumber behaviour separately leading to a better estimate for the full turbulent flow. With 0.1% training data, we observe that the new PINN model captures the turbulent field at inertial scales leading to a general agreement of the kinetic energy spectra upto eight to nine decades as compared with the solutions from direct numerical simulation (DNS). We further apply these techniques to successfully capture the statistical behaviour of large scale modes in the turbulent flow. We believe such methods to have significant applications in enhancing the retrieval of existing turbulent data sets at even shorter time intervals.