Turbulence modeling via deep reinforcement learning

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Turbulence is a highly nonlinear, chaotic, and multi-scale phenomenon. Fully resolved unsteady simulation of turbulent flows is prohibitive due to limitation of computational resource. Based on physical and mathematical insight, many kinds of turbulence models such as large-eddy simulation (LES) and Reynolds-averaged Navier—Stokes simulation have been developed over the last sixty years for practical and industrial applications. However, performance of the models is still not satisfactory. In this study, we propose a turbulence model automatically developed through deep reinforcement learning (DRL), which is free from prior assumption used in supervised learning. We applied DRL to wall modeling of LES in turbulent channel flow, finding a deep neural network mapping instantaneous wall-shear stress from instantaneous off-wall velocity. DRL of turbulent flows is very challenging because spatial dimension of state and action is high and responses of flows are highly delayed. Using deep deterministic policy gradient, an actor-critic algorithm, we automatically modeled the wall shear boundary condition to match the target statistics. As a result, our trained wall model is superior to conventional equilibrium wall model with respect to the target mean and root-mean square profile of velocity.

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References

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