Drag reduction in wall-bounded flows using deep reinforcement learning

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We introduce a reinforcement learning (RL) environment to design and benchmark control strategies aimed at reducing drag in turbulent fluid flows enclosed in a channel. The control is applied in the form of blowing and suction at the wall, while the observable state is configurable, allowing to choose different variables such as velocity and pressure, in different locations of the domain. Given the complex nonlinear nature of turbulent flows, the control strategies proposed so far in the literature are physically grounded, but too simple. DRL, by contrast, enables leveraging the high-dimensional data that can be sampled from flow simulations to design advanced control strategies. In an effort to establish a benchmark for testing data-driven control strategies, we compare opposition control, the state-of-the-art turbulence-control strategy from the literature, and a commonly-used DRL algorithm, deep deterministic policy gradient. At a friction Reynolds number of 180, our results show that DRL leads to 43% and 30% drag reduction in a minimal and a larger channel (shown in figure 1), respectively. The DRL strategy outperforms the classical opposition control by around 20 and 10 percentage points, respectively[1].

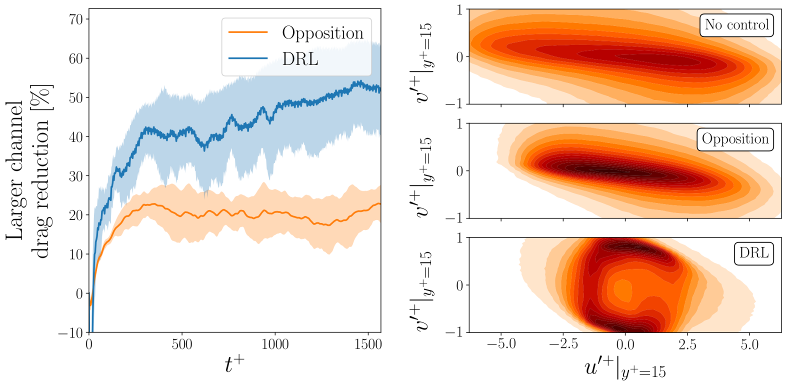

Figure 1: (Left) Drag reduction with respect to the uncontrolled case obtained in the larger channel versus using opposition control. The result is averaged over 6 different initial conditions. (Right) Distribution of the inner-scaled velocity-fluctuation components after the initial transient ($t^+ > 500$) in the streamwise (u) and wall-normal (v) directions, for the uncontrolled case (top), with opposition control (middle) and when using DRL (bottom).

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[1] Guastoni et al., *arXiv preprint 2301.09889, DOI: 10.48550/ARXIV.2301.09889*