Decoupled Data-based Control (D2C) for Complex Robotic Systems

Doctoral Dissertation Defense

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Abstract

The problem of reinforcement learning (RL) is equivalent to the search for an optimal control policy without the system dynamics information. Most RL techniques search over a complex global nonlinear parametrization with drawbacks in training efficiency and variance. In this dissertation, we propose a decoupled data-based framework to do RL in a more efficient, robust and optimal fashion. The efforts are mainly in three directions: learning to control 1) efficiently and reliably, 2) for high-dimensional nonlinear complex systems with only partial observations, 3) under process and sensing uncertainties. We first propose the decoupling principle that leads to the decoupled data-based control (D2C) framework which designs the open-loop optimal trajectory and the closed-loop feedback law separately to achieve high training efficiency. Its convergence to the global optimum is proved. Simulation results show its advantages in training efficiency, training reliability and robustness to noise over state-of-the-art RL methods. Secondly, D2C is extended to partially observed problems using information state-based autoregressive–moving-average (ARMA) system identification. We show that its solution is the global optimum and satisfies the generalized minimum principle for the partially observed problem. The extended D2C technique allows us to solve the optimal control problem for partially observed, high-dimensional, nonlinear robotic systems. Finally, we prove that in the fully observed case with process noise only, the extended D2C method converges to the global optimum. However, it gives a biased result in the partially observed case with process and measurement noise, where multiple rollouts need to be averaged to recover optimality.

Ran Wang is a PHD candidate in the Department of Aerospace Engineering, working under the supervision of Professor Suman Chakravorty. His research interests are in the areas of optimal control and reinforcement learning. He is employed as a research scientist at Rockwell Automation.