Multi-fidelity robust controller design with gradient sampling

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Abstract

Robust controllers that stabilize dynamical systems even under disturbances and noise are often formulated as solutions of nonsmooth, nonconvex optimization problems. While methods such as gradient sampling can handle the nonconvexity and nonsmoothness, the costs of evaluating the objective function may be substantial, making robust control challenging for dynamical systems with high-dimensional state spaces. In this work, we introduce multi-fidelity variants of gradient sampling that leverage low-cost, low-fidelity models with low-dimensional state spaces for speeding up the optimization process while nonetheless providing convergence guarantees for a high-fidelity model of the system of interest, which is primarily accessed in the last phase of the optimization process. Our first multi-fidelity method initiates gradient sampling on higher fidelity models with starting points obtained from cheaper, lower fidelity models. Our second multi-fidelity method relies on ensembles of gradients that are computed from low- and high-fidelity models. Numerical experiments with controlling the cooling of a steel rail profile and laminar flow in a cylinder wake demonstrate that our new multi-fidelity gradient sampling methods achieve up to two orders of magnitude speedup compared to the single-fidelity gradient sampling method that relies on the high-fidelity model alone.