Provably Safe and Robust Learning-Based Model Predictive Control

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Controller design faces a trade-off between robustness and performance, and the reliability of linear controllers has caused many practitioners to focus on the former. However, there is renewed interest in improving system performance to deal with growing energy constraints. This paper describes a learning-based model predictive control (LBMPC) scheme that provides deterministic guarantees on robustness, while statistical identification tools are used to identify richer models of the system in order to improve performance; the benefits of this framework are that it handles state and input constraints, optimizes system performance with respect to a cost function, and can be designed to use a wide variety of parametric or nonparametric statistical tools. The main insight of LBMPC is that safety and performance can be decoupled under reasonable conditions in an optimization framework by maintaining two models of the system. The first is an approximate model with bounds on its uncertainty, and the second model is updated by statistical methods. LBMPC improves performance by choosing inputs that minimize a cost subject to the learned dynamics, and it ensures safety and robustness by checking whether these same inputs keep the approximate model stable when it is subject to uncertainty. Furthermore, we show that if the system is sufficiently excited, then the LBMPC control action probabilistically converges to that of an MPC computed using the true dynamics.

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