Estimating High Probability Reachable Sets using Gaussian Processes

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Abstract: We present a method for computing reachable sets and forward invariant sets for systems with dynamics that include unknown components. Our main assumption is that, given any hyperrectangle of states, lower and upper bounds for the unknown components that hold with high probability are available. We then show that this assumption is well-suited when the unknown terms are modeled as state-dependent Gaussian processes. Under this assumption, we leverage the theory of mixed monotone systems and propose an efficient method for computing a hyperrectangular set that over-approximates the reachable set of the system with high probability. We then show a related approach that leads to sufficient conditions for identifying sets that are forward invariant for the dynamics with high probability. These theoretical results lead to practical algorithms for efficient computation of high probability reachable sets and invariant sets. A major advantage of our approach is that it leads to tractable computations for systems up to moderately high dimension that are subject to low dimensional uncertainty modeled as Gaussian Processes, a class of systems that appears often in practice. We demonstrate our results on an example of a six-dimensional model of a multirotor aerial vehicle.

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