Kinodynamic RRT*: Optimal Motion Planning for Systems with Linear Differential Constraints

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Abstract

We present Kinodynamic RRT*, an incremental sampling-based approach for asymptotically optimal motion planning for robots with linear differential constraints. Our approach extends RRT*, which was introduced for holonomic robots [8], by using a fixed-final-state-free-final-time controller that exactly and optimally connects any pair of states, where the cost function is expressed as a trade-off between the duration of a trajectory and the expended control effort. Our approach generalizes earlier work on extending RRT* to kinodynamic systems, as it guarantees asymptotic optimality for any system with controllable linear dynamics, in state spaces of any dimension. Our approach can be applied to non-linear dynamics as well by using their first-order Taylor approximations. In addition, we show that for the rich subclass of systems with a nilpotent dynamics matrix, closed-form solutions for optimal trajectories can be derived, which keeps the computational overhead of our algorithm compared to traditional RRT* at a minimum. We demonstrate the potential of our approach by computing asymptotically optimal trajectories in three challenging motion planning scenarios: (i) a planar robot with a 4-D state space and double integrator dynamics, (ii) an aerial vehicle with a 10-D state space and linearized quadrotor dynamics, and (iii) a car-like robot with a 5-D state space and non-linear dynamics.