Graduate Student Research Seminar

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Synthesizing Controller for Safe Navigation using Control Density Function

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Abstract

Most of the control system applications in robotics and automotive engineering include driving the nonlinear system dynamics from an initial set to a target set while avoiding certain unsafe sets. Safe navigation is a well-known problem in the robotics community, with applications extending to aerospace, unmanned ground vehicles, manufacturing, power systems, etc. We consider the problem of navigating a nonlinear dynamical system from some initial set to some target set while avoiding collision with an unsafe set. We extend the concept of density function to control density function (CDF) for solving navigation problems with safety constraints. The occupancy-based interpretation of the measure associated with the density function is instrumental in imposing the safety constraints. The navigation problem with safety constraints is formulated as a quadratic program (QP) using CDF.

The existing approach using the control barrier function (CBF) also formulate the navigation problem with safety constraints as QP. One of the main advantages of the proposed QP using CDF compared to QP formulated using CBF is that both the convergence/stability and safety can be combined and imposed using the control density function. We also provide an example of an underactuated system in the form of the Dubin car model, where obstacles are only present in the subspace of the system dynamics. Finally, we also show that the density-based safe controller can be combined with a nominal controller for optimal performance by modifying the cost function to include the norm of the difference between the desired safe control and the nominal control.

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