Mechanical Engineering Doctoral Defense

Passive and Active Model Discrimination Algorithms for Constrained Uncertain Systems with Applications to Set-Valued Intent Identification and Fault Detection

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Abstract

Autonomous systems inevitably must interact with other surrounding systems; thus, algorithms for intention/behavior estimation are of great interest. This thesis dissertation focuses on developing passive and active model discrimination algorithms (PMD and AMD) with applications to set-valued intention identification and fault detection for uncertain/bounded-error dynamical systems. PMD uses the obtained input-output data to invalidate the models, while AMD designs an auxiliary input to assist the discrimination process.

First, PMD algorithms are proposed for noisy switched nonlinear systems constrained by metric/signal temporal logic specifications, including systems with lossy data modeled by (m,k)-firm constraints. Specifically, optimization-based algorithms are introduced for analyzing the detectability/distinguishability of models and for ruling out models that are inconsistent with observations at run time.

On the other hand, two AMD approaches are designed for noisy switched nonlinear models and piecewise affine inclusion models, which involve bilevel optimization with integer variables/constraints in the inner/lower level. The first approach solves the inner problem whose parametric solution using mixed-integer parametric optimization, whose solution is then included when solving the outer problem/higher level, while the second approach (suboptimally) moves the integer variables/constraints to the outer problem in a manner that retains feasibility and recasts the problem as a tractable mixed-integer linear programming (MILP).

Moreover, AMD algorithms are proposed for noisy discrete-time affine time-invariant systems constrained by disjunctive and coupled safety constraints. To overcome the issues associated with generalized semi-infinite constraints due to state-dependent input constraints and disjunctive safety constraints, several constraint reformulations are proposed to recast the AMD problems as tractable MILPs.

Finally, partition-based AMD approaches are proposed for noisy discrete-time affine time-invariant models with model-independent parameters and output feedback to leverage information about the parameters and output measurements that are revealed at run time. Specifically, algorithms with fixed and adaptive partitions are proposed, where the latter improves on the performance of the former by allowing the partitions to be optimized. The partitioning the operation region allows us to solve the problem as a sequence of offline MILPs and to construct partition trees that can be used a 'look-up table' to determine the optimal input depending on revealed information at run time.

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