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Mechanical and Aerospace Engineering Department
The University of Texas at Arlington

SET-THEORETIC FRAMEWORKS FOR ONLINE OPTIMIZATION, ESTIMATION, AND CONTROL

By

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Abstract

This research is primarily focused on developing online frameworks, which are suited to real-time implementation, for performance optimization, estimation, and control of dynamical systems using set-theoretic concepts and/or having set-theoretic interpretations. First, two perturbation-based extremum seeking control schemes, based on the classical setup and equipped with novel adaptation laws for the perturbation signal amplitudes, are proposed for general single input single output nonlinear systems. The proposed schemes are able to extremize steady-state system output in a practical asymptotic sense, i.e., the system is driven to an arbitrarily small set centered at the true optimal steady-state operating point. The next development involves a semi-analytical model for avian-scale (or bird-scale) forward flapping flight. Results generated through this model indicate optimal characteristics of force generation in the unique range of Strouhal numbers used by birds for cruising. Then, constructive arguments are provided leading up to a hypothesis which postulates that birds use some form of online optimization for converging to this unique range during a flight. The hypothesis is investigated using one of the proposed extremum seeking control schemes as the optimization framework.

Furthermore, a novel set-membership state estimation algorithm using state dependent coefficient parameterization for discrete-time nonlinear systems is developed, and it requires solutions to two semi-definite programs (which are convex optimization problems). A linear variant of this estimator is considered in the context of leader-follower multi-agent synchronization. A distributed protocol design is proposed that makes the agents closely follow a leader's trajectory. Finally, model predictive control is applied to synthesize lateral acceleration commands of missiles for planar engagements. The guidance problem is converted into a recursive algorithm that does not require target acceleration information and involves solving for strictly convex quadratic programs. Detailed simulation results are used to both illustrate the theoretical results and verify the hypothesis.