Probabilistic Methods for Model Validation
Doctoral Dissertation Defense

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Abstract

This dissertation develops a probabilistic method for validation and verification (V&V) of dynamical systems with uncertainties. Existing systems-control literature on model and controller V&V make structural assumptions *either* on the dynamics (e.g. linear, semi-algebraic), *or* on the uncertainty (e.g. set valued, first few statistical moments). These results aim to *invalidate* or *falsify* a model. In this work, an axiomatic framework for model validation is proposed in probabilistically relaxed sense, which instead of simply invalidating a model, seeks to quantify the "degree of validation". To develop this framework, novel algorithms for uncertainty propagation are proposed for both deterministic and stochastic nonlinear systems. These algorithms are demonstrated for risk assessment in Mars entry-descent-landing, and for nonlinear estimation. Next, the V&V problem is formulated in terms of the Monge-Kantorovich optimal transport, naturally giving rise to a metric on the space of probability densities. The resulting computation leads to solving a linear program at each time of measurement availability, and computational complexity results for the same are derived. The framework is demonstrated for nonlinear robustness verification of F-16 flight controllers. Frequency domain interpretations for the proposed framework are derived for linear systems, and it is shown that the optimal transport map can be used for automatic model refinement.

Abhishek Halder is a PhD candidate in the Aerospace Engineering Department working under the supervision of Professor Raktim Bhattacharya. His research interests are in the areas of systems and control theory. He is seeking employment related to his areas of interest.