Ph.D. DISSERTATION DEFENSE

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Title:	Robust Controller Design and Performance Evaluation via Statistical Learning and Optimization
Chairperson:	Dr. Serban Sabau, Department of Electrical and Computer Engineering, Charles V. Schaefer, Jr. School of Engineering and Science
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ABSTRACT

Within the last few years, modern statistical and algorithmic methods led to new solutions for classical control problems, such as the Linear Quadratic Gaussian problem.

The first part of this dissertation addresses the end-to-end sample complexity bound for learning the H2 optimal controller (the Linear Quadratic Gaussian (LQG) problem) with unknown dynamics, for potentially unstable Linear Time Invariant (LTI) systems. The robust LQG synthesis procedure is performed by considering bounded additive model uncertainty on the coprime factors of the plant. The closed-loop identification of the nominal model of the true plant is performed by constructing a Hankel-like matrix from a single time-series of noisy finite length input-output data, using the ordinary least squares algorithm from Sarkar et al. (2020). Next, an $H\infty$ bound on the estimated model error is provided, and the robust controller is designed via convex optimization, much in the spirit of Boczar et al. (2018) and Zheng et al. (2020a), while allowing for bounded additive uncertainty on the coprime factors of the model. The conclusions are consistent with previous results on learning the LQG and LQR controllers.

The second part of this dissertation addresses the end-to-end sample complexity bound for learning in closed loop the state estimator-based robust H2 controller for an unknown (possibly unstable) Linear Time Invariant (LTI) system, when given a fixed state-feedback gain. The results are built from Ding et al. (1994) to bridge the gap between the parameterization of all state-estimators and the celebrated Youla parameterization. Refitting the expression of the relevant closed loop allows for the optimal linear observer problem given a fixed state feedback gain to be recast as a convex problem in the Youla parameter. The robust synthesis procedure is performed by considering

bounded additive model uncertainty on the coprime factors of the plant, such that a min-max optimization problem is formulated for the robust H2 controller via an observer approach. The closed-loop identification scheme follows Zhang et al. (2021), where the nominal model of the true plant is identified by constructing a Hankel-like matrix from a single time-series of noisy, finite length input-output data by using the ordinary least squares algorithm from Sarkar et al. (2020). Finally, an H_∞ bound on the estimated model error is provided, as the robust synthesis procedure requires bounded additive uncertainty on the coprime factors of the model.

The last part of this dissertation will be about the Quadratically Constrained Quadratic Programming (QCQP) problem. The nonconvex QCQP is still an open problem in operation research nowadays, I tried to give a general algorithm by nonconvex polyhedral approximation of the feasible set. A large number of parallel computing threads are needed for this purpose. Comparing to conventional Semi-Definite Relaxation (SDR) algorithms, my method costs far more computational resources, but always gives a feasible solution.