CoCo Seminar Series
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[CoCo/Data Science TAE Joint Seminar]

Simulation, Design and Monitoring for Time-Delay Complex Systems

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Engineering Building H-9 (Knoll-MacDonald Commons / Watson Commons)

Time delay is omnipresent in a variety of natural and man-made complex systems, from interaction of gene circuits for personalized medicine to self-excited vibration in machining processes. Remarkably, time delay could trigger sophisticated dynamic behaviors even in simple or low-order systems, which are largely resistant to conventional classical controllers, particularly considering stability of system dynamics. This present study investigates optimal design and *in situ* monitoring that are imperative for performance optimization and quality assurance of such systems. (1) **Sequential optimal design:** While high-fidelity simulation (e.g., temporal finite element) has generally been adopted to characterize dynamic behaviors of time-delay systems, the daunting computational overhead has made it infeasible to explore large design spaces. Furthermore, the fairly complicated and bumpy manifestation of stability region nullifies most existing design paradigms. On the other hand, the low-fidelity surrogate modeling (e.g., Gaussian process or GP) efficiently emulates high-fidelity simulation, albeit at the expense of accuracy, not ideal to inspect system behavior near the boundary. In this present study, we investigate a novel fusion of high-fidelity simulation and low-fidelity surrogate in a sequential design framework to rapidly locate the stability boundary. At its core, this sequential fusion approach is congruous with the exploration-exploitation trade-off principle: execute the high-fidelity simulation to exploit the vicinity of the estimated boundary and explore the region with high uncertainty as indicated by prediction from GP. (2) ***in situ* monitoring:** Nonetheless, even under the optimal design, process drifts or anomaly could still occur due to exceeding sensitivity to circumstance variations. With the sensing temporal data available, an intrinsic multiplex graph modeling is built, and graph features are extracted for detection of incipient process drift. Application in the optimal design and online monitoring of ultra-precision machining process corroborates the proposed approach.

Dr. Changqing Cheng is an Assistant Professor in the Department of Systems Science and Industrial Engineering at Binghamton University. His research focuses on sensor-based data-driven modeling and control for complex systems, uncertainty quantification, and optimal design.

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