DEPARTMENT OF MECHANICAL ENGINEERING
WILLIAM MAXWELL REED SEMINAR SERIES

"Robust and Secure Control of Cyber-Physical Systems"

Mohammad Naghnaeian, Ph.D.
Postdoctoral Associate, Massachusetts Institute of Technology

Abstract: Cyber-Physical Systems (CPS) are engineered systems with integrated physical and computational capabilities. In this presentation, I will touch upon some of the control theoretic tools that can be used to tackle some of the pressing issues in the control synthesis of CPS, focusing on resilience to component failure and intermittent communication, decentralized control implementation, and security. Linear Switched Systems (LSS) can be used to model discontinuities due to component failure, sudden change of operating conditions, intermittent communication, including variable computational and communication delay. Therefore, in the first part of the talk, I focus on LSS and present a new framework for analysis and control synthesis of LSS. This approach is based on a combination of state space operator descriptions and the Youla parametrization and provides a unified way to check stability, stabilizability and to synthesize stabilizing controllers that guarantee a near optimal closed-loop gain for LSS, and in fact for linear time varying systems, in any $l\infty$ induced norm sense. Such a controller provides a robust performance with respect to the above-mentioned discontinuities. By specializing to the l_∞ case, I show that the computations can be cast as a linear program and hence they are tractable. Next, I focus on decentralized control design for CPS. As many modern large-scale CPS are composed of interconnected subsystems that are usually spread over a large geographic area, designing a centralized controller is often impractical. I talk about the shortcoming of some of the existing decentralized control synthesis methods and then propose a unified way to synthesize stably realizable robust optimal controllers with respect to any input-output measure of performance, e.g., $l1$, $l2$, or l_∞ induced norms. One can use this approach to optimally solve structured problems if and only if they are stably realizable. Finally, I focus on the security of CPS. I model the attacks on actuators and sensors as additive and unbounded disturbances and examine, from an input-output perspective, the exact conditions under which such attacks can be stealthy. I show the pivotal role of unstable zeros and poles of the physical plant and argue that the sampled-data (SD) nature of a CPS may introduce more vulnerabilities into the system. In the SD control scheme, to ensure good intersample behavior, the rate of the sample and hold mechanism has to be high enough. However, high sampling rate can lead to unstable zeros that can be exploited by an attacker to remain stealthy while damaging the physical plant. As one way of fixing this vulnerability, a dual rate sampling approach, a special case of multirate sampling, is proposed. We show that dual rate control is sufficient to remove all the vulnerabilities to stealthy actuator attacks. I will conclude the talk with a vehicle routing problem in a transportation network, where most of the issues raised so far appear, showing preliminary results and discussing future work.

Bio: Mohammad Naghnaeian is a postdoctoral associate at Massachusetts Institute of Technology under the advisement of Domitilla Del Vecchio. He received the M.Sc. in Mathematics and Mechanical Engineering from the Southern Illinois University, and the Ph.D. in Mechanical Engineering from the University of Illinois, Urbana-Champaign, in May 2016 under the supervision of Petros Voulgaris. His research interests lie in the broad area of control and optimization. In particular, he is interested in developing the theoretical foundations to tackle pressing issues in the control of cyber-physical systems as well as systems and synthetic biology.

Date: Friday, Feb. 23 **Time: 3PM**
Place: CB 122 **Contact: Dr. Alexandre Martin 257-4462**

Meet the speaker and have refreshments
Attendance open to all interested persons

College of Engineering

DEPARTMENT OF MECHANICAL ENGINEERING
UNIVERSITY OF KENTUCKY
LEXINGTON, KENTUCKY