University of Victoria | Graduate Studies

Notice of the Final Oral Examination
for the Degree of Master of Applied Science

of

CHANGXIN LIU

BEng (Hubei University of Science and Technology, 2013)

"Robust Model Predictive Control and Scheduling Co-design for Networked Cyber-physical Systems"

Department of Mechanical Engineering

Tuesday, February 19, 2019
9:00 A.M
Engineering Office Wing
Room 430

Supervisory Committee:
Dr. Yang Shi, Department of Mechanical Engineering, University of Victoria (Supervisor)
Dr. Daniela Constantinescu, Department of Mechanical Engineering, UVic (Member)

External Examiner:
Dr. Hong-Chuan Yang, Department of Electrical and Computer Engineering, UVic

Chair of Oral Examination:
Dr. Dzifa Dordunoo, School of Nursing, UVic

Dr. David Capson, Dean, Faculty of Graduate Studies

Abstract

In modern cyber-physical systems (CPSs) where the control signals are generally transmitted via shared communication networks, there is a desire to balance the closed-loop control performance with the communication cost necessary to achieve it. In this context, aperiodic real-time scheduling of control tasks comes into being and has received increasing attention recently. It is well known that model predictive control (MPC) is currently widely utilized in industrial control systems and has greatly increased profits in comparison with the proportional-integral-derivative (PID) control. As communication and networks play more and more important roles in modern society, there is a great trend to upgrade and transform traditional industrial systems into CPSs, which naturally requires extending conventional MPC to communication efficient MPC to save network resources.

Motivated by this fact, we in this thesis propose robust MPC and scheduling co-design algorithms to networked CPSs possibly affected by both parameter uncertainties and additive disturbances.

In Chapter 2, a dynamic event-triggered robust tube-based MPC for constrained linear systems with additive disturbances is developed, where a time-varying pre-stabilizing gain is obtained by interpolating multiple static state feedbacks and the interpolating coefficient is determined via optimization at the time instants when the MPC-based control is triggered. The original constraints are properly tightened to achieve robust constraint optimization and a sequence of dynamic sets used to test events are derived according to the optimized coefficient. We theoretically show that the proposed algorithm is recursively feasible and the closed-loop system is input-to state stable (ISS) in the attraction region. Numerical results are presented to verify the design.

In Chapter 3, a self-triggered min-max MPC strategy is developed for constrained nonlinear systems subject to both parametric uncertainties and additive disturbances, where the robust constraint satisfaction is achieved by considering the worst case of all possible uncertainty realizations. First, we propose a new cost function that relaxes the penalty on the system state in a time period where the controller will not be invoked. With this cost function, the next triggering time instant can be obtained at current time instant by solving a min-max optimization problem where the maximum triggering period becomes a decision variable. The proposed strategy is proved to be input-to-state practical stable (ISpS) in the attraction region at triggering time instants under some standard assumptions. Extensions are made to linear systems with additive disturbances, for which the conditions reduce to a linear matrix inequality (LMI). Comprehensive numerical experiments are performed to verify the correctness of the theoretical results.