INC 692 Optimal and Robust Control

Semester: 1/2017

Schedule: Th 13.30–16.20 **Classroom:** CB40609

Exams: to be announced

Instructors:

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Course web: https://staff.kmutt.ac.th/~sudchai.boo/Teaching/inc962/

Required pre-requisites:
Control system analysis and design based on transfer functions and state-space models (INC 341 and EEE 600, or equivalent courses)

Course Description:

Optimal regulator problem with finite time horizon, Riccati differential equation, Time-varying and steady state solutions, algebraic Riccati equation, Hamiltonian system. Kalmans identity, phase margin of LQR controllers, spectral factorization, Optimal state estimation, Kalman filter, LQG control, Generalized plant, review of LQG control, Signal and system norms, computing $\mathcal{H}_2$ and $\mathcal{H}_\infty$ norms, Singular value plots, input and output directions, Mixed sensitivity design, $\mathcal{H}_\infty$ loop shaping, choice of weighting filters, Case study: design example flight control, Linear matrix inequalities, design specifications as LMI constraints ($\mathcal{H}_2$, $\mathcal{H}_\infty$ and pole region), Controller synthesis by solving LMI problems, multi-objective design, Robust control of uncertain systems, small gain theorem, representation of parameter uncertainty, Balanced realization and model order reduction.

Learning Outcomes:

- Student will be able to design state feedback and output feedback controllers based on LQR and LQG methods from given system models.
- Student will be able to express design specifications in terms of the $\mathcal{H}_2$ norm and the $\mathcal{H}_\infty$ norm, and to use LMI techniques to design controllers that satisfied the specifications.

- To be able to use the suitable tools of the LMI control toolbox and CVX for Matlab.

Course text: Werner, H., Lecture Notes, "Optimal and Robust Control"

Reference:

- A. Damen and S. Weiland, *Robust Control*, Lecture Notes, TU/e, 2002.
- C. W. Scherer, *Theory of Robust Control*, Lecture Notes, Delft University of Technology, 2001.
- G. E. Dullerud and F. Paganini, *A Course in Robust Control Theory: A Convex Approach*, Springer, 1999.
- J. C. Doyle, B. A. Francis and A. R. Tannenbaum, *Feedback Control Theory*, McMillan, 1992.
- Skogestad, S. and Postlethwaite, I., *Multivariable Feedback Control Analysis and Design*, 2nd Edition, Wiley, 2005.
- Zhou, K. , *Essentials in Robust Control*, Prentice Hall, 1998
- Gu, D.-W., Petkov, P. H. and Konstantinov, M. M., *Robust Control Design with MATLAB*,", Springer, 2013.

Project:
Each graduate student is required to formulate a realistic control problem (preferably related to his/her own research, or otherwise we can help), to do analysis and design for the problem using the course material, to analyze the designed controller in simulation (and in implementation if possible), to give a seminar, and to submit a report. The project should show the usefulness and/or the limitation of multivariable (robust) control theory.

Grading scheme:
Homework: 30% Midterm Exam: 30% Project: 40%

- I reserve the right to modify the grading scheme.

Course Schedule (Tentative)

Week	Topic	Date	Lecturer
1	Overview of the Robust Control Theory	12 Jan 17	Sudchai
2	Classical Control System design	19 Jan 17	Sudchai
3	Introduction to Optimal Control, The Linear Optimal Regulator Problem, The Principle of Optimality, The Hamilton-Jacobi Equation	26 Jan 17	Sudchai
4	The Matrix Riccati Equation, Solution of the Riccati Equation, The Infinite-Time Regulator Problem	2 Feb 17	Sudchai
5	Properties of the Optimal Regulator, The Euler–Lagrange Equations	9 Feb 17	Sudchai
6	State Estimate Feedback, Loss of Robustness and Loop Transfer Recovery	16 Feb 17	Sudchai
7	Midterm Exam	23 Feb 17	
8	Introduction to Robust Control, The Concept of a Generalized Plant – A Review of LQG Control	2 March 17	Sudchai
9	Vector Norms and Induced Norms, The Singular Value Decomposition	9 March 17	Sudchai
10	System Norms, Computing System Norms	16 March 17	Sudchai
11	Design Objectives and Sensitivity Functions	23 March 17	Sudchai
12	Mixed Sensitivity – A Design Example	30 March 17	Sudchai
13	Design Specifications as LMI Constraints, Controller Design Using Linear Matrix Inequalities	6 April 17	Sudchai

Week	Topic	Date	Lecturer
14	LMI Approach to Multi-Objective Design, Design Example: Robust Control of a Power System Stabilizer	13 April 17	Sudchai
15	Model Order Reduction	20 April 17	Sudchai
16	Presentations	27 April 17	Sudchai

Note: All topics and timetable may be changed!