ECE 780-T10: Multivariable Control Systems II

Spring 2019

Department of Electrical and Computer Engineering
University of Waterloo

This course covers advanced topics in linear control theory and multivariable linear time-invariant controller design, and is intended primarily for graduate students in engineering and applied mathematics interested in dynamics and control. The course material is drawn from the broad area of robust control, with an emphasis on modern convex optimization approaches to robust stability/performance certification and optimal controller synthesis. Students will learn the fundamental theoretical concepts underlying robust control theory, and will be exposed to the computational frameworks used for robust stability analysis and robust controller design. Topics (subject to change) include:

(i) historical context and motivation for robust control;

(ii) mathematical essentials: vectors spaces and linear/nonlinear maps on vector spaces;

(iii) input-output LTI systems: signal spaces, rational function spaces, signal and system norms;

(iv) state-space LTI systems: Lyapunov equations, realizations, input-output properties;

(v) linear matrix inequalities (LMIs) and semidefinite programming;

(vi) the Kalman-Yakubovich-Popov (KYP) Lemma and dissipative systems theory;

(vii) the generalized plant framework for feedback control;

(viii) $\mathcal{H}_\infty$ and $\mathcal{H}_2$ performance analysis of control systems;

(ix) statement and solutions of $\mathcal{H}_\infty$ and $\mathcal{H}_2$ control problems;

(x) uncertainty modelling, linear fractional representations of uncertainty;

(xi) robust stability and performance analysis via integral quadratic constraints.

Instructor

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(*Please place "ECE 780 T10" in the subject header of all e-mail correspondence.*)

Course Website and Credit

Units: 0.5

Website: https://ece.uwaterloo.ca/~jwsimpso/multi2/

Prerequisites

Graduate-level LTI systems theory (ECE 682 or equivalent) is strongly recommended. Exposure to optimization theory (e.g., ECE/CO 602 or equivalent) is recommended but is not required.

Lecture and Office Hours

Lectures:

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Office Hours:

- Drop-in or by appointment

Textbook

There is no required textbook for the course. Useful reference material includes

- C. Scherer and S. Weiland. *Linear Matrix Inequalities in Control*, 2015. (Available online)
- G. E. Dullerud and F. G. Paganini. *A Course in Robust Control Theory: A Convex Approach*, Spring, 2000.
- K. Zhou and J. C Doyle. *Essentials of Robust Control*, 1999.
- A. Isidori. *Lectures in Feedback Design for Multivariable Systems*, Springer, 2017.
- S. Boyd, L. El Ghaoui, E. Feron, and V. Balakrishnan. *Linear Matrix Inequalities in System and Control Theory*, SIAM, 1994.

Assignments, Exam, and Evalulation

There will be three to four substantial assignments. Collaboration is permitted, but the submitted work must be your own. Assignments will be graded for completeness, clarity of thought, and clarity of presentation.

The final exam will be a 48 hour take-home final exam, at a date to be determined. Students are expected to work independently on the final exam.

Please familiarize yourself with University of Waterloo's Assignment and Exam Regulations.

$$\textbf{FinalGrade} = (0.5 \times \text{Assignments}) + (0.5 \times \text{Final Exam})$$

Academic Integrity, Discipline, Grievances, and Appeals

In order to maintain a culture of academic integrity, members of the University of Waterloo community are expected to promote honesty, trust, fairness, respect and responsibility. For an overview of academic integrity policies and sanctions, see `here`.

A student is expected to know what constitutes academic integrity to avoid committing an academic offence, and to take responsibility for his/her actions. A student who is unsure whether an action constitutes an offence, or who needs help in learning how to avoid offences (e.g., plagiarism,

cheating) or about rules for group work/collaboration should seek guidance from the course instructor, academic advisor, or the undergraduate Associate Dean. For information on categories of offences and types of penalties, students should refer to Policy 71, Student Discipline. For typical penalties check Guidelines for the Assessment of Penalties.

A student who believes that a decision affecting some aspect of his/her university life has been unfair or unreasonable may have grounds for initiating a grievance. Read Policy 70, Student Petitions and Grievances, Section 4. When in doubt please be certain to contact the department's administrative assistant who will provide further assistance.

A decision made or penalty imposed under Policy 70 (Student Petitions and Grievances) (other than a petition) or Policy 71 (Student Discipline) may be appealed if there is a ground. A student who believes he/she has a ground for an appeal should refer to Policy 72 (Student Appeals).

Disability Policy

AccessAbility Services, located in Needles Hall 1401, collaborates with all academic departments to arrange appropriate accommodations for students with disabilities without compromising the academic integrity of the curriculum. If you require academic accommodations to lessen the impact of your disability, please register with AccessAbility Services at the beginning of each academic term.