ECE 515 ***Control System Theory and Design*** Fall, 2009

Sean Meyn
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Tuesday & Thursday, 9:30 - 11:00
253 Mechanical Engineering Bldg

This is a fundamental graduate-level course on the modern theory of control of dynamical systems, building upon a first-level course in control such as ECE 486. State space techniques are emphasized in the analysis of dynamical systems and in the synthesis of control laws meeting given design specifications. The course also develops some mathematical tools required for further study in control and communication.

To follow the course, some familiarity with vector spaces and matrix algebra is strongly recommended. Some of this material will, however, be reviewed during the course in proper contexts.

The course TA is *Yu (Robin) Ru*, yuru2@illinois.edu.

Office hours Sean Meyn: Tuesdays, 4:30–5:30 p.m.
Yu Ru: Wednesdays, 4:00-5:00 p.m., *all in 154 CSL*

Exams, homework, and grading Approximately eight homework sets will be assigned, to be handed in at the beginning of class on the date due. They will be graded and returned the following week. *Late homework cannot be accepted.*

There will be two evening midterm exams, October 14 and November 18, 7:00 - 8:30 p.m. You will be allowed *one* sheet of notes ($8\frac{1}{2} \times 11$; both sides) in the first exam, and *two* in the second. Otherwise, the exams are closed-book and closed-notes.

Tentative grading scheme: Homework problems will count 20%, the two midterm exams $2 \times 25\%$, and the final will count 30% towards the final grade in the course.

In addition to the University-wide scheduled holidays, class is cancelled on

Tuesday, September 15
Thursday, October 1 Allerton Conference `http://www.csl.uiuc.edu/allerton/`

References

Main reference:

Lecture Notes on Multivariate Control and Optimization

Available for sale in room 243 of Everitt Lab (IEEE office)
10am–4pm Monday–Friday (during the first few weeks).

The following textbooks are on reserve in the Engineering Library.

- C-T Chen, *Linear System Theory and Design*, Holt, Rinehart and Winston, Inc., 1984.
- Brogan, W.L., *Modern Control Theory*, Prentice Hall, 1991.
- B.D.O. Anderson and Moore, J.B., *Linear Optimal Control*, Prentice Hall, 1990.

In case that isn't enough....

▷ Kwakernaak, H. and R. Sivan, *Linear Optimal Control Systems*, Wiley, 1972.
▷ Wiberg, D.M., *State Space and Linear Systems*, Schaum's Outline, McGraw Hill, 1972.
▷ Athans, M. and Falb, P.L., *Optimal Control*, McGraw Hill, 1966.
▷ Cruz, J.B., Jr., *Feedback Systems*, McGraw Hill, 1972.
▷ Cruz, J.B., Jr., *System Sensitivity Analysis*, Dowden, Hutchinson & Ross, 1973.
▷ Frank, P.M., *Introduction to System Sensitivity Theory*, Academic Press, 1978.
▷ Rosenbrock, H.H., State Space and Multivariable Theory, Wiley, 1970.
▷ Kailath, T., *Linear Systems*, Prentice Hall, 1980.
▷ Bellman, R.E., *Matrix Analysis*, 2nd ed., McGraw Hill, 1968.
▷ Bryson, A.E. and Ho, Y.C., *Applied Optimal Control*, 2nd ed., Blaisdell, 1979.

Course Outline

I. Modeling and Analysis of Control Systems

1 Linear and nonlinear state space models
2 Linear algebra and linear operators
3 State transition matrix and solutions of linear state equations

II. Structural Properties of Control Systems

1 Stability (Lyapunov, Input-Output)
2 Stability tests for linear systems
3 Controllability
4 Observability

Exam 1 *Wednesday October 14, 7:00–8:30 p.m., 165 EL*

III. Feedback Controller Design

1 Role of feedback in controller design
2 Stabilization and eigenvalue placement by state and output feedback
3 Full-order and reduced-order observers
4 Tracking, disturbance rejection, and the Internal Model Principle

Exam 2 *Wednesday November 18, 7:00–8:30 p.m., 165 EL*

Fall break *November 21—29*

IV. Optimal Feedback Control

1 Dynamic optimization: Dynamic programming and the HJB equation
2 Specialization to linear systems with quadratic cost (LQ).
The Riccati equation
3 Infinite horizon problems and steady-state analysis
4 Minimum principle for continuous-time systems.
Application to Q-learning

Final Exam *Friday December 11, 8-11am.*