EE593, “Multivariable Control,”
E. Jonckheere
Fall 2014

Synopsis

This course is meant to be the first advanced control course after the foundational EE482, “Linear Control Systems” and the fundamental state-space theory EE585 course, “Linear Systems Theory.” It emphasizes two main points: (i) the multivariable aspects of control when there are many sensors and many actuators and (ii) the robustness aspects, guaranteeing proper operation of the control system under model uncertainty. Here, the robustness aspects are incorporated in the multivariable aspects, as the uncertainty will be represented as a (structured) feedback around a “nominal” plant, giving the plant extra sets of inputs and outputs in addition to actuator inputs and sensor outputs, hence promoting the “multivariable aspects.” The classes will also emphasize the “architectural” aspects of feedback control by taking power grid as probably the best example of a very large-scale control system and reviewing the recent control challenges paused by quantum control, where the architecture is unconventional to say the least. The class will also provide a flavor of the thriving field of “networked control system” by going over the graph decomposition of a highly interconnected feedback system for stability analysis.

Instead of the traditional Linear-Quadratic-Gaussian (LQG) approach, the fundamental design tool will be the modern H^∞ approach, known to endow the resulting design with much better robustness properties than the LQG design. The H^∞ design equations will be derived from a bounded real lemma argument developed by the instructor[1] and that obviates the need for hard analysis.

Class scheduling:

Tue & Thu, 2:00-3:20; DEN, OHE 100C

Instructor:

E. Jonckheere, EEB 306, (213) 740-4457; jonckhee@usc.edu, http://eudoxus2.usc.edu

[1] Ian R. Petersen, Brian D.O. Anderson and Edmond A. Jonckheere, ``A first principles solution to the nonsingular H^∞ control problem,'' *International Journal on Robust and Nonlinear Control*, vol. 1, pp. 171-185, 1991.

Textbook:

Kemin Zhou and John C. Doyle, *"Essentials of Robust Control."* Prentice Hall, Upper Saddle River, NJ, 1998. ISBN 0-13-525833-2.

http://www.amazon.com/Essentials-Robust-Control-Kemin-Zhou/dp/0135258332

As the review says, the book is very concise (too concise?) and the instructor will supplement the formal textbook with papers posted on the blackboard, which will be reading assignments with homework questions.

Office hours:

Tue & Thu 3:30-5:30 p.m.

Teaching assistant:

Eugenio Grippo; egrippo@usc.edu; office hours: TBA

Prerequisites:

EE482, *"Linear Control Systems"* and EE585, *"Linear System Theory"*

Format:

	Weights in %
One homework every 2 weeks	**25%**
One midterm	**35%**
One final	**40%**
Total:	**100%**

Schedule:

Week/month	**Topics**	**Textbook chapters**
August 2014	Fundamental concept of multivariable system as a corollary of availability of a great many cheap sensors/actuators. Concept of uncertainty as difficulty to represent real-life systems with mathematical models compounded by inaccuracies of actuators/sensors, especially when used in great quantity in a cost conscientious manner. Parameter	Chap. 1

	variation viewed as uncertain feedback. Concept of robustness as a mean of a feedback control system to mitigate the various uncertainties.	
September 2014	Various control system architectures, emphasizing specifications to be achieved despite uncertainties. Various modeling of uncertainties (multiplicative, additive, structured, unstructured). Notion of input loop matrix, output loop matrix, input sensitivity matrix, output sensitivity matrix, input complementary sensitivity matrix, output complementary sensitivity matrix.	Chap. 6, 8
September 2014	Balanced model reduction and robustness against truncation error.	Chap. 7
October 2014	Algebraic foundation of multivariable transfer matrix: Smith-McMillan form. Stability concepts for multivariable systems. Internal stability. Parameterization of stabilizing controllers. (Robust) multivariable Nyquist criterion. Horowitz template. Notion of structured/unstructured multivariable stability margin. Multivariable phase and gain margins.	Chap. 2, 5, 10 + supplemental material
October 2014	Further architectural features in multivariable ("networked") systems: the Callier-Desoer graph decomposition for stability analysis.	Supplemental material
November 2014	Linear-Quadratic foundation of robust multivariable control: Linear-Quadratic regulator; Algebraic Riccati Equation, Bounded real lemma, H^∞ design.	Chap. 12-14 + supplemental material
December 2014	Modern applications: voltage stability in multi-generator, multi-load power grid, quantum control, stability of TCP-IP protocol. Choices will have to be made, depending on students' interests.	Supplemental material