Linear Multivariable Control

Catalogue Description

A state space investigation of multi-input multi-output control design problems from the geometric perspective. The course will detail the theory and design algorithms needed for a solution to the state feedback eigenvalue assignment problem, the disturbance decoupling problem with and without internal stability, the output stabilization problem, and the tracking (or regulator) problem with internal stability.

Prerequisites: ECE 602 (Lumped System Theory) or equivalent

Course Information

Lecture: SL 109 TR 6:00 – 7:15 pm

Instructor: Sarah Koskie

Office Hours: tbd, or by appointment, in SL 164F

Email: skoskie@iupui.edu

Objectives: Students will become familiar with the basic concepts and methods of linear multivariable control and be able to apply them appropriately to the analysis and design of control systems. They should become comfortable using the literature to identify and implement refinements to these procedures as needed.

Text: W.M. Wonham, *Linear Multivariate Control: A Geometric Approach* (third edition), Springer, 1985, (ISBN: 978-0-387-96071-5). Some lecture notes will also be provided.

Prerequisite: ECE 602 or equivalent. Students should be comfortable with matrix and vector algebra.

Grading: Homework 100%

Homework Assignments/Exams

There will be approximately seven homework assignments during the course of the semester. Homework assignments will be announced in class and posted on the web. Homework will not be graded, but will offer the student an opportunity to verify that he/she has mastered the material of the corresponding section before the midterm and final exams. Students are encouraged to discuss the homework with the instructor and with fellow students.

Exams may be take-home or in class, depending on the preference of the majority of students in the class. If exams are take-home, they will be due in class on the assigned date, which will be announced in class and posted to the course website.

Homework/take-home exams may be submitted as pdf files by email before class. Please do not send obscure formats, zipped files, or extremely long files.

- Late papers will NOT be accepted.
- Work submitted should be the student's own.
- All necessary steps towards obtaining the solution, as well as any MATLAB code, must be included in the writeup for full credit.

Students are allowed, even encouraged, to work on the assignments in small groups, but each student must hand in an individual set of answers, which must be his/her own work. Students may discuss the problems but should not work jointly on them. Discussions should be noted, e.g. "John and I compared approaches to this problem because we found our results surprising; but after considering the alternatives decided that we both had the right approach." or "I kept getting a negative number for an answer and Jane suggested I check whether I forgot to whiten the data, which I had. I fixed this and got the answer indicated." or "John and Jane and I couldn't see how to approach this and Jean suggested . . . which yielded a successful approach." Each student must write his/her own Matlab code where needed.

Students are referred to the code of student conduct at
`http://life.iupui.edu/dos/code.htm.`

Detailed Course Outline / Syllabus

Controllability and spectral assignability: (4 lectures)

Conditions under which closed loop system eigenvalues can be reassigned are discussed. Then, once the theory has been understood, the process of designing state feedback controls to achieve eigenvalue reassignment will be discussed and Matlab will be used to implement and test such controllers.

Disturbance decoupling problem (DDP): (5 lectures)

A practical controller design should ideally prevent deterministic disturbance inputs from having any influence on the controlled output of the system. Theory and application of disturbance-decoupling controllers will be discussed as will the conditions under which they can be designed. Matlab will be used to implement and test control designs.

Output stabilization problem (OSP): (5 lectures)

One common control objective is to use control inputs to bring output error to zero within an appropriately short time. Theory and design of state feedback to stabilize specified output variables will be discussed. Controllers will be implemented and tested in Matlab.

Disturbance Decoupling with Internal Stability: (6 lectures)

In these lectures we revisit the disturbance decoupling problem with the objective of requiring also that the system remain internally stable. Theory will be applied and tested by designing, implementing and testing controllers in Matlab.

Tracking and regulation: (5 lectures)

An alternative control objective to simply driving controlled output to a constant value is the goal of achieving zero tracking error in following a specified trajectory. Tracking controllers will be tested in simulation using Matlab.

Balanced Model Reduction: (3 lectures)

The use of the matrix Lyapunov equation in model reduction strategies will be investigated. Model reduction and its effect on controller design and performance will be investigated and results tested in Matlab.

LQ Control: (3 lectures)

Linear Quadratic (LQ) control constitutes one of the simplest optimal control strategies, and as such is an important topic in any control course. We will discuss existence and uniqueness of solutions, the role of the matrix Riccati equation, and controller limitations. Controllers will be implemented and tested in Matlab.

Bibliography

The following references are relevant to various portions of the material to be presented in this course and will be consulted as appropriate.

- *Multivariable Control Systems: An Engineering Approach* by P. Albertos and A. Sala, Springer, 2004.
- *Linear Controller Design: Limits of Performance* by Stephen P. Boyd and Craig H. Barrett, Prentice-Hall, 1991.
- *Linear Systems* by Thomas Kailath, Prentice Hall, 1996.
- *Mathematical Control Theory* (second edition) by Eduardo D. Sontag, Springer, 1998.
- *Multivariable feedback design* by J. M. Maciejowski, Addison-Wesley, 1989.
- *The Theory of Matrices* by Felix R. Gantmacher, (two volumes), American Mathematical Society, 1960.
- *Essentials of Robust Control* by K. Zhou and J. C. Doyle, Prentice-Hall, 1998.
- *Linear System Theory* by Wilson J. Rugh, Prentice Hall, 1996.