

ELEC4631

Continuous time Control System Design

COURSE INTRODUCTION-Session 1, 2009

Course Staff

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Consultations

Students are encouraged to use the open consultation hour rather than contact by email; students may seek consultation with the course convener at other times by appointment.

Course details

Credits: The course is 6 Units of Credit; expected workload is 10-12 hours per week throughout the 12 week session.

Contact hours: The course consists of 2 hours of lectures per week, 1 hour of tutorial per week and 3 hours of laboratory sessions per week.

Check the website <http://alpha400.ee.unsw.edu.au/elec4631/> for updated schedule.

- Tutorials start in Week 2.
- Laboratory starts in Week 2.
- Consultation sessions start in Week 3.

Course Details

Context and aims

In recent years, modern systems and control have found numerous interesting applications in broad areas of automatic control, signal processing, communication, economics, finance, circuit analysis, mechanical and civil engineering, aeronautics, navigation and guidance etc. The purpose of this course is to provide students very basic concepts and problem solutions of modern systems and control that are useful for the mentioned applications.

The course will:

- a. further enhance students understanding of simple as well as more complex continuous time control systems
- b. introduce students to state-space representation of control systems
- c. help students understand the importance of system state and measurement

- d. familiarise students with the controllability and stability concept of linear systems;
- e. give students an understanding of basic analysis and synthesis of control systems
- f. provide opportunities for students to gain practical experience in the use of computer design and analysis tools such as Matlab and Simulink

Relation to other courses

This course encourages a continuing exploration of control system analysis and synthesis. It provides an introduction to concepts of state space representation of control systems. In undertaking this course, knowledge and experience are drawn from the third year control system course and second year courses in mathematics.

Pre-requisites: This course builds on the Year 3 course in Control System which introduced concepts of transfer functions.

Assumed knowledge: It is assumed that the students have a good computer literacy.

Learning outcomes

After the successful completion of the course, the student will be able to

1. demonstrate the ability to analyse simple to moderately complex control system using Lyapunov theory
2. demonstrate intuition of the uncertainty effects on the system performance
3. demonstrate the ability to synthesis systems by convex optimization methodology

Teaching strategies

The course consists of the following elements: lectures, tutorials, laboratories, and assignments:

Lectures

The lectures provide the students with explanation of the core material in the course. Numerous examples of analysis and design of simple to moderately continuous time dynamical systems using are discussed in order to convey their qualitative understanding. Students are expected to attend the lectures and prepare themselves for them.

Tutorials

The tutorials enable students to analyze and design control systems. Students are expected to attend the tutorials and are expected to attempt to solve given tutorial questions before attending the tutorial.

Laboratories

The laboratories provide the students with hands-on experience to design, analyse and stimulate control systems. Students will also learn how to use of Matlab for system analysis and synthesis. Students must come prepared for the laboratory sessions.

Assessment

- Final examination (65%) - The final examination is a standard open-book three hours written examination. The examination will test knowledge and understanding of all major aspects covered in the course.
- Laboratory assessment (15%) - after completing each simulation experiment, your work will be assessed by the laboratory demonstrator.
- Midterm test (20%): the first week after the session break. It is also open-book.

1 Course Schedule

W1: Introduction and overview

W2: Basic mathematical tools

- symmetric matrices and their eigenvalues
- quadratic forms and basic inequalities
- positive semi-definite matrices and norms
- singular value decomposition

W3: Linear systems with inputs and outputs (MIMO systems)

- Autonomous linear systems: definition, linear circuit examples and other motivations (higher order systems, linearization near equilibrium or along trajectory)
- MIMO systems: definition, transfer matrix, impulse and step response, mass-spring-damper example, interconnect circuit example, DC gain matrix, dual system

W4: State and state-space of MIMO systems

- State concept: causality and state, change of coordinate and standard form
- Understanding concept thru aircraft dynamics and bat's flight

W5: controllability and state transfer

- State transfer, reachable set, controllability matrix and examples
- Minimum energy input problem
- Reachability Gramian

W6: Linear quadratic regulator

- LQR problem: finite horizon and infinite horizon
- Dynamic programming solution and Hamilton-Jacobi equation
- Riccati equations and their solutions

W7: Invariant sets, conservation, and dissipation

- Invariant sets and examples
- Conserved quantities and derivative of function along trajectory
- Dissipated quantities for dynamical systems

W8: Basic Lyapunov theory

- Stability definitions
- Lyapunov functions and Lyapunov stability theorems
- A converse Lyapunov theorem

W9: Linear quadratic Lyapunov theory

- The Lyapunov equation and stability condition
- Lyapunov integral and cost-to-go function
- Monotonicity of Lyapunov equation
- Lyapunov equation of controllability and observability Grammians

W10: Lyapunov theory with inputs and outputs

- Systems with inputs and outputs
- Reachability bounding
- Bounds on RMS gain
- Bounded real lemma
- Feedback synthesis via control-Lyapunov functions

W11: Linear matrix inequalities and the S-procedure

- Linear matrix inequality and semi-definite programming
- S-procedure for quadratic forms and quadratic functions
- Analysis of Lur'e system via quadratic Lyapunov functions

Textbooks

- Two courses EE263 "Introduction to linear dynamical systems" and EE363 "Linear Dynamical Systems" of Stanford University (US). All info is available at web sites: <http://www.stanford.edu/class/ee263/> and <http://www.stanford.edu/class/ee363/>
- G.C. Goodwin et al., *Control system design*, Prentice Hall, 2001