SMITH COLLEGE

PICKER ENGINEERING PROGRAM

EGR 301 Spring 2005

Modeling and Simulation of Natural and Engineered Systems

Lecture	TR 9:00-10:20, in EGR 201		
Prerequisites	Physics 210, *corequisites* Math 204, EGR 320		
Professors	Judith Cardell	EGR105b	jcardell@email.smith.edu
	Glenn Ellis	EGR105a	gellis@email.smith.edu
Office Hours	TO BE ANNOUNCED		
Text	**1.** *Introduction to Dynamic Systems: Theory, Models & Applications*, by David G. Luenberger; Wiley, 1979, ISBN 0-471-02594-1		
	2. Additional handouts		

Course Overview and Objectives

The objective of this course is to introduce students to the fundamental theory, mathematics and modeling tools necessary to analyze and simulate natural and engineered systems. The course includes three broad areas of modeling and analysis: that of stationary processes, linear dynamic systems and neural networks. Topics include modeling time series with ARIMA models, applications of artificial neural networks, building state space models for dynamic systems, and performing sensitivity and stability analyses. Students will have the opportunity to apply these tools to model systems in many areas of engineering, including: mechanical, civil, environmental, computer, chemical and electrical engineering. Simple examples of this type of system include systems with masses and springs (mechanical), systems with resistors and energy storage devices (electrical circuits with capacitance and inductance), heat transfer (thermal), capacitors and resistors (fluid systems), energy converting and signal converting devices (mixed systems). More advanced examples of systems that could be analyzed include earthquake ground motion, water and wastewater treatment, financial markets, pendulums, robotic arms, spacecraft, electric power systems, the sustainable use of natural resources, the human body and natural waterways, to mention only a few.

Through the material presented in this course, students will be able to

1. Recognize engineering applications for ARIMA models, input-output and state-space models for linear dynamic systems, and artificial neural networks.
2. Identify time series data in the world around them; fit an ARIMA model to the time series; and apply the model for forecasting and simulation.

3. Identify and define linear dynamic systems in the world around them. Model and predict the behavior of these systems with respect to the system inputs, system evolution and the system outputs.
4. Develop a basic understanding of the concepts of stability and feedback control for linear dynamic systems.
5. Construct, train, and test feed-forward, back-propagation artificial neural networks to learn relationships among variables.
6. Identify both the appropriate applications and the limitations of each model developed.
7. Learn and use modeling tools, including Matlab and associated toolboxes.
8. Present project results, including the problem formulation and analysis method selected, through oral and written formats.

Assignments

The assignments in the course will be a combination of week-long homework sets and two longer, small group projects. There will also be two midterms and final exam.

Homework

All homework solutions must be written on standard engineering paper (or typed and printed when appropriate, *e.g.,* Matlab code and computer plotted results). Students are encouraged to work together to understand the concepts, but each student must work out and hand in her own solutions. All assignments are to be neatly written or typed, and stapled, with your name and date.

Each problem will be evaluated on a 0-10 Guswa© scale as follows:

0	No effort
2	Problem statement written out but not attempted
6	Incomplete attempt
9	Complete attempt, incorrect solution
10	Complete attempt, correct solution

A complete attempt includes identifying what is known, articulating what you are solving, stating any assumptions, properly labeling figures, commenting all computer models/computer code, including units and a reasonable number of significant figures in your answer, and clearly and neatly documenting your progression towards a final result. Homework solutions will be compiled from the solutions submitted by the class – so it is very important that your solutions can be clearly understood by all!

Projects

There are two small group projects during the semester. These projects will be followed by student presentations of the projects to the entire class, with each of these projects contributing 15% to the final grade for the class.

The projects are an opportunity for each student to demonstrate a complete understanding of the topic. In addition to successfully modeling the desired system and completing all parts of the assignment, students must demonstrate a significant depth of understanding of the concepts to receive an A, including, for example, a thorough understanding of the modeling approach, an explanation of both the limitations and appropriate applications of the model and the significance of the results.

Exams
There will be two midterm exams and final exam. The midterms will be available to be taken in the library during a four-day period from Tuesday February 22nd through Friday February 25th, and Tuesday April 12th through Friday April 15th. You will have two hours to complete the midterm. The final will be a take-home exam.

Grading
Grades in this course are designed to represent your achievement of the objectives listed above. The course components that will make up your grade are listed below.

Assignment	Grade Contribution
Homework sets	15%
Class participation	5%
Projects (two total)	30%
Midterm exams (two)	30%
Final exam	20%

Late Policy
All assignments are to be submitted at the beginning of class; late assignments will be penalized at the rate of ***one point per minute*** unless you have requested and received and extension at least 24 hours before the deadline.

Honor Code

The weekly homework assignments that you submit must be your own work. You are encouraged to discuss the problems with your classmates and work on them together, but each student must work out her own solutions. It is not okay to copy answers from another student's homework – doing so is a violation of the Honor Code. Projects will be done in small groups. Exams must be exclusively each student's own work, following the instructions provided with each exam. *Do not hesitate to ask any questions that you may have concerning the honor code!*

EGR 301 Class and Assignment Schedule

Date	Topic	Reading	Assignments
Jan 25	Introduction to course topics; Review of Matlab		
Jan 27	ANN		Project 1 out
Feb 1	ANN		HW 1 due
Feb 3	ANN		
Feb 8	ANN		HW 2 due
Feb 10	ANN		
Feb 15	ANN		HW 3 due
Feb 17	ANN		
Feb 22	Introduction to dynamic systems Chapter 1	Chapter 1	Exam 1: ANN (in library)
Feb 24	Difference equations and applications	Chapter 2: 2.1–2.7	Project 2 out
Mar 1	Differential equations and applications, with time for student sample examples and applications	Chapter 2: 2.8–2.10	HW 4 due
Mar 3	Linear algebra	Chapter 3: 3.1–3.5	
Mar 8	Eigenvectors and values	Chapter 3: 3.6–3.9	HW 5 due
Mar 10	**ANN Presentations**		Project 1 due
Mar 15	***Spring Break***		
Mar 17	***Spring Break***		
Mar 22	State space and state equations, examples and interpretations, eigen-analysis	Chapter 4: 4.1–4.5	
Mar 24	Block diagrams; Outside system examples (2004 text?), Section 10.1 (remaining ch 10 for projects?)	Chapter 4: 4.6, 4.7	HW 6 due
Mar 29	Linear systems: Diagonalization, eigenvectors, equilibrium	Chapter 5: 5.1–5.7	
Mar 31	Linear systems: Stability, oscillation, dominant modes	Chapter 5: 5.8–5.12	HW 7 due
Apr 5	Positive linear systems and examples	Chapter 6: 6.1–6.6	
Apr 7	Concepts of controllability and observability, with feedback	Chapter 8: 8.1, 8.6, 8.7, 8.9	
Apr 12	Stability and linearization only	Chapter 9: 9.1–9.5	**Exam 2:** Dynamic Systems (in library)
Apr 14	ARIMA		
Apr 19	ARIMA		
Apr 21	ARIMA		

Apr 26	ARIMA		HW 8 due
Apr 28	**Dynamic System Presentations**		Project 2 due
	FINAL EXAM DURING	**FINALS WEEK**	