INTRODUCTION TO SCIENTIFIC MODELING

UNM CS 365
Fall Term, 2014
Mon/Wed 1:00 - 2:50 pm
Centennial 1026

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Office Hours: Mon. 3:00 - 5:00; Wed. 10:00 - 12:00
Web site: http://cs.unm.edu/forrest/classes/cs365-2014/

Textbook:
Selected Readings
Getting Started With MatLab
Recommended Secondary Sources
http://www.complexityexplorer.org/online-courses/11
Networks M. E. J. Newman, Oxford 2010

Course Description:

CS 365 will focus on using the computer as a laboratory for understanding the world around us. We will study and develop computational models of complex systems, study different modeling techniques, learn how to design simulation experiments, and how to analyze results. Data analysis will include simple curve fitting, looking for power laws, testing for goodness of fit, and interpreting the results of experiments. We will explore these topics in the context of compelling interdisciplinary examples, including: predator-prey models from ecology, evolutionary computation, simple games such as the Prisoner’s Dilemma, artificial life and machine learning.

Course Assignments and Grading:

The course will consist of lectures and class discussions based on assigned readings and online lectures. There will be a moderate amount of reading (plan on one or two readings per week), three or four programming projects, and one or two exams. Grades will be based on programming assignments and exercises (~ 40%), exams (~ 40%), and class participation (~ 20%).

The official programming language for the course will be MatLab, which provides built in plotting, curve fitting routines, and other useful packages. Some assignments will be most easily completed using MatLab, and access to introductory tutorials will be provided for those who are new to MatLab. However, you are free to use your favorite programming language if you choose. Some programming experience is expected as a pre-requisite, and you will be responsible for writing and debugging your own computer programs.
Collaboration, online help and academic honesty

Programming is often a collaborative endeavor, but in this class you are expected to develop code for assignments independently and hand in only your own work. Students are encouraged to help each other with concepts from class, but they are not allowed to copy any part of another students code. In other words, students may help each other by communicating in English, but not by communicating computer programs or snippets of computer programs. You are strongly encouraged to seek help from the instructor to clarify assignments, algorithm design and tips on writing up lab reports, although you are expected to debug your own code. You are responsible for documenting all code that you do not write yourself, for example, open source code that you use in one of your assignments. Any code, images, or text that is obtained online and modified, must be cited. The original code and web address must be provided in the program comments and lab report when it is turned in. If you end up collaborating with another student, the details of the collaboration must be documented in program comments and lab reports. Any student caught copying code from any source and presenting it as his or her own will be failed and reported to the University for cheating. Any student who is unclear whether something is cheating should ask the instructor.

Course Topics

Introduction (1 week)
Topics:
  General course introduction, MatLab resources
  “What is a model?” What can models teach us about the natural and engineered world?
  How do we evaluate the quality of a model?
  Modeling approaches: Continuous and discrete methods
Readings:
  Mitchell preface, Ch 1, Ch 14 (p 209-212 only)
  C. Hall and J. Day “Revisiting the limits to growth”
  P.J. Denning “Computing is a natural science”
  MatLab Tutorial. Download software from http://it.unm.edu/download

Modeling Case Studies (2 weeks)
Assignment 1: To be announced
Topics:
  Malware on the Internet
  Networks in nature and technology
  Agent-based and dynamical models of Influenza
  Modeling ant foraging strategies
Readings:
  Mitchell, Ch 2
  Mitchell, Ch. 15 - 16
  Mitchell, Ch. 9

Cellular automata and agent-based models (2 weeks)
Assignment 2: To be announced
Topics:
  1-dimensional cellular automata
The game of life
Extensions and applications

Readings:
- Mitchell Ch. 10
- Wolfram *A New Kind of Science* Ch. 8 (available from http://www.wolframscience.com/nksonline/toc.html)
- Axelrod: Agent-based modeling as a bridge between disciplines

**Simulation Underpinnings** (1 week)

Topics:
- Random numbers
- Discrete event vs. discrete time simulations
- Validation issues
- Reproducible results

Readings:
- To be announced

**Data Analysis and Scaling Laws** (3 weeks)

**Assignment 3: To be announced**

Topics:
- Statistical distributions and testing for statistical significance
- Data collection and analysis
  - Graphing
  - Curve fitting
  - Maximum Likelihood Estimation
- Power laws
- Scaling laws in nature
- Complex networks

Readings:
- Review Mitchell Ch. 15-16, Mitchell 17
- Newman Ch. 8
- Sibly, Borwn, and Kodric-Brown *Metabolic Ecology*, Ch. 24 (Beyond Biology)

**Midterm**

**Predator/Prey Models and epidemics** (2 weeks)

Topics:
- Brief introduction to dynamical systems and chaos
- Lotka-Volterra systems
- Individual-based modeling of predator/prey systems
- SIR models

Readings:
- Review Mitchell Ch. 2
- G. Flake *The Computational Beauty of Nature* Ch. 12
- Newman *Networks* Ch. 17, pp. 627 - 641
Optimization methods (2 weeks)
Assignment 4: To be announced
Topics:
  Search spaces, random search, hillclimbing
  Genetic algorithms
  Applications
Readings:
  Mitchell Ch. 5, 6, 9, 18
  G. Flake *The Computational Beauty of Nature* Ch. 20

Game Theory and Modeling Social Systems (1 week)
Topics:
  Non-zero sum games and the Iterated Prisoner’s Dilemma
  Hawks and Doves
Readings:
  Mitchell Ch. 14 (213-224)
  G. Flake *The Computational Beauty of Nature* Ch. 17
  R. Axelrod and D. S. Bennet *A Landscape Theory of Aggregation*
  T. Maurer and R. Morgus *Tipping the scale: An analysis of global swing states in the Internet governance debate*

Bayesian Models (1 week)
Topics:
  Bayes Rule
  Computing with Bayes Rule
  Applications
Readings:
  E. Charniak “Bayesian Networks Without Tears”
  T. Mitchell *Machine Learning* Ch. 6, McGraw Hill, 1997

Review and catchup (1 week)
Readings:
  H. Simon “The architecture of complexity”