USC Dornsife

Modeling dynamics of biological systems

Units: 4.0

Spring 2-3:20 Tuesdays and Thursdays

Location:

Instructor: Prof. Naomi Levine
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Instructor: Prof. Andrew Hires
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Course Description

As our ability to study the full complexity of biological systems has increased, quantitative and computational tools have become increasingly essential for facilitating our understanding of these systems. From numerical simulations of ion channels to ecosystem dynamics to processing huge datasets, quantitative biological tools have truly become a fundamental aspect of biological sciences. This course will provide a foundation for quantitative biology and cover an overview of key topics including: ecological models, disease models, population models, evolution models, machine learning, attractor dynamics, cortical microcircuits, and neuronal population dynamics. The course will be based in MATLAB and provide students with fundamentals in developing and coding models of dynamic systems.

Learning Objectives

Students will develop a foundation in statistics, models, and computation analyses targeted for biological research. They will also become proficienct in MATLAB, a powerful computational tool for quantatiative biology. The course will include hands-on exercises to teach students how to build their own models of dynamic biological systems and will culminate in a final project. Specifically, during the first half of the class, a portion of each class will be devoted to basic programing concepts which will provide the students with the necessary skills to complete an independent research project during the second half of the class.

Recommended Preparation: AB calculus; suggested reading MATLAB Primer (Timothy Davis, 8th edition

Required Readings: No single text is required. Rather readings will be provided from:

Mathematics for the Life Sciences, 2014, Bodine, Lenhart and Gross (MLS)
Population Ecology -- Vandermeer, John H. and Goldberg, Deborah E. (electronically available through USC libraries)
Chaos: Making a New Science ,James Gleick

In addition, other journal articles will be assigned and provided on Blackboard

Technological Proficiency and Hardware/Software Required

This course will use MATLAB as a platform to provide examples for topics discussed during the lectures and for problem sets.

Description and Assessment of Assignments

Assignments will be in the form of weekly problem sets which will require the students to create and run MATLAB scripts related to the topics discussed during the week's lecture.

All students will complete a final project for the class worth 20% of their grade. This project will expand upon one of the problem sets or topics in the class. Each student will meet with one of the instructors to discuss potential project ideas in week 10 and will turn in a brief description of the project topic. The project will be graded based on the project proposal, the MATLAB code generated for the project, a 2 page description of the research and results, and a 15 mintute presentation to the class.

Grading Breakdown

Assignment	Points	% of Grade
Problem sets (x12)	100 pt x 12	80
Final Project	200 pts	14
Final Project presentaion	50 pts	3
Participation	50 pts	3
TOTAL	**1500**	**100**

Assignment Submission Policy

Problem sets must be submitted by Monday at noon (11:59 am PST). Maximum credit will be reduced by 10% for every day the assignment is late unless the student has obtained prior approval from the instructor.

Course Schedule: A Weekly Breakdown

	Topics/Daily Activities	Readings	Assignment due	Prof
T Jan 9	Introduction MATLAB: Introduction	MLS Ch. 1		NL/AH
Th Jan 11	Stats: Probability distributions MATLAB: matrices, find function, hist function	MLS Ch. 2		NL
T Jan 16	Stats: Linear regressions and correlation analyses MATLAB: plotting	MLS Ch. 3	Problem Set #1 (Distributions)	NL
Th Jan 18	Stats: Quantifying diversity and MDS MATLAB: reading in data			NL
T Jan 23	Stats: PCA and Association network models MATLAB: for loops	Journal article (Furhman)	Problem Set #2 (Diversity)	NL
Th Jan 25	Ecology: Population Dynamics MATLAB: functions	PopEco Ch. 1		NL
T Jan 23	Ecology: Lokta-Voltera MATLAB: global variables	PopEco Ch. 8	Problem Set #3 (PCA analysis)	NL
Th Feb 1	Ecology: NPZ models MATLAB: ODE solver	PopEco Ch. 7		NL
T Feb 6	Emergent complexity: Conway's game of life	Article (Gardner)	Problem Set #5 (Infection Dynamics)	AH
Th Feb 8	Emergent complexity: Mandelbrot & Julia set	Article (Fredriksson)		AH
T Feb 13	Emergent complexity: Butterfly Effect and Attractor Dynamics	Journal (Levine)	Problem Set #7 (Random Walk)	AH
Th Feb 15	Emergent complexity: Oscillatory dynamics	Journal (Elowitz 2000)		AH
T Feb 20	Ecology: Evolutionary theory models MATLAB: interactive code	Journal article (Collins)	Problem Set #6 (Emergent complexity)	NL
Th Feb 22	Ecology: Animal movement models MATLAB:	Journal article (Moorcroft)		NL
T Feb 27	Ecology: Infection dynamics MATLAB: building a model	PopEco Ch. 7	Problem Set #4 (Lokta-Volterra)	NL
Th Mar 1	Ecology: Random Walk Models MATLAB: logicals (if statements)	TBD		NL

T Mar 6	Neurological models: Animal behavior & detection theory	*Detection Theory* (Ch1,2)	Problem Set #8 (Attractors)	AH
Th Mar 8	Neurological models: Psychometric vs. neurometric models	Journal (Hecht)		AH
Spring Break				
T Mar 20	Neurological models: Single neuron representations	Journal (Hires)		AH
Th Mar 22	Neurological models: Neural circuits	Journal	Final project topic selection due	AH
T Mar 27	Deconvolving signals: Indicators of calcium and neurotransmitters MATLAB: image processing I	Journal article (Chen)	Problem Set #9 (single neuron coding)	AH
Th Mar 29	Deconvolving signals: The ground truth problem MATLAB: image processing II	Journal article (Pnevmatikakis)		AH
T Apr 3	Deconvolving signals: Dimensionality reduction MATLAB: image processing III	Journal article (Cunningham & Yu)	Problem Set #10 (calcium deconvolution)	AH
Th Apr 5	Deconvolving signals: Neuronal population dynamics MATLAB: image processing IV	Journal article (Peron)		AH
T Apr 10	Ecosystem models (Terrestrial, Marine) MATLAB: netcdf format, structured arrays		Problem Set #11 (population decoding)	NL
Th Apr 12	Agent based models (IBMs) MATLAB: generate movies	Journal article (Ji)		NL
T Apr 17	Current research in QBio: How does the brain decide?	Journal (Shadlen vs. Latimer)	Problem Set #12 (IBM)	AH
Th Apr 19	Current research in QBio: The role of epigenetics in microbial evolution			NL
T Apr 24	Student Presentations			NL/AH
Th Apr 26	Student Presentations			NL/AH
Finals week			Final project due	

References

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Cunningham JP, Yu BM. Dimensionality reduction for large-scale neural recordings. Nat Neurosci. 2014;17(11):1500-9.

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Statement on Academic Conduct and Support Systems

Academic Conduct

Plagiarism – presenting someone else's ideas as your own, either verbatim or recast in your own words – is a serious academic offense with serious consequences. Please familiarize yourself with the discussion of plagiarism in *SCampus* in Section 11, *Behavior Violating University Standards*https://scampus.usc.edu/1100-behavior-violating-university-standards-and-appropriate-sanctions/. Other forms of academic dishonesty are equally unacceptable. See additional information in *SCampus* and university policies on scientific misconduct, http://policy.usc.edu/scientific-misconduct/.

Discrimination, sexual assault, and harassment are not tolerated by the university. You are encouraged to report any incidents to the *Office of Equity and Diversity* http://equity.usc.edu/ or to the *Department of Public Safety* http://capsnet.usc.edu/department/department-public-safety/online-forms/contact-us. This is important for the safety whole USC community. Another member of the university community – such as a friend, classmate, advisor, or faculty member – can help initiate the report, or can initiate the report on behalf of another person. *The Center for Women and Men* http://www.usc.edu/student-affairs/cwm/ provides 24/7 confidential support, and the sexual assault resource center webpage sarc@usc.edu describes reporting options and other resources.

Support Systems

A number of USC's schools provide support for students who need help with scholarly writing. Check with your advisor or program staff to find out more. Students whose primary language is not English should check with the *American Language Institute* http://dornsife.usc.edu/ali, which sponsors courses and workshops specifically for international graduate students. *The Office of Disability Services and Programs* http://sait.usc.edu/academicsupport/centerprograms/dsp/home_index.htmlprovides certification for students with disabilities and helps arrange the relevant accommodations. If an officially declared emergency makes travel to campus infeasible, *USC Emergency Information http://emergency.usc.edu/*will provide safety and other updates, including ways in which instruction will be continued by means of blackboard, teleconferencing, and other technology.