Syllabus

CompSci 284C/184C: *Computational Systems Biology*

Eric Mjolsness
Tu-Th 3:30pm-4:50pm, PCB1200, Spring 2020
Office hours: TBD.
Class web site: Canvas

Instructor email: emj@uci.edu

184C vs 284C: Upper-division undergrad vs graduate course. Distinguished mainly by number of HW problems (roughly 1/2) and by expectations for the final project. Same lectures.

284C Computational Systems Biology (4). Computational inference and modeling of gene regulation networks, signal transduction pathways, and the effects of regulatory networks in cellular processes, development, and disease. Introduction of required mathematical, computational, and data handling tools.

Aims of the course: This course aims to give students the capability to *extend*, *create*, and *apply* computational tools for the simulation and analysis of realistically complex biological models; and to put this capability to good use.

Schedule (subject to change based on class progress and interests)!

Week 1: Modeling: dynamics, emergent phenomena, multiple scales in biology. Reaction kinetics: mass action, binding site occupancy, molecular complexes, pathways and feedback. Stochastic vs. deterministic modeling. Software: Computer algebra packages.

Week 2: Small networks and their emergent phenomena. Attractors, nonlinearity, multistability, oscillation. Feedback and information bottlenecks. Statistical Mechanics of molecular complexes, including transcriptional regulation.

Week 3. Computation: process graph translation to model dynamics (deterministic and stochastic). Binding site and state diagrams. Stat mech of reaction networks. Simulation algorithms: ODE solving, stochastic simulation (SSA and its variants and generalizations), hybrid deterministic/stochastic solvers. Analysis of models: Jacobians and linearization; master equation. Metarules for mathematical language translators.

Week 4: Compound networks: graph structure; cell + environment (homeostasis, replication, population biology models; Lineage modeling: branching processes; solvable models; resource limitations; emergent fitness functions); spatially replicated networks (homogeneous + diffusion and/or signaling, heterogeneous, cell division + mechanics); modular regulatory network models.

Week 5: Developmental models. Fixed-geometry spatial patterning; regulated cell growth and division and dynamic geometry; discrete and continuous mechanical models; cell complex representations for geometry.

Week 6: Realistic networks: Metabolism (optimization approaches, enzymatic regulation); transcriptional regulation; signal transduction; intercellular+mechanical models in development. Examples: cell cycle; amino acid synthesis; MAPK signaling, transcriptional regulation in Drosophila development.

Week 7: Computation: simulation (hybrid and heterogeneous dynamics), graph analysis, Markov chains. Spatial models: pattern formation vs. morphodynamics. PDEs and their discretizations. Emerging numerical software such as FEniCS, Cabana, Julia packages. Parameter inference and structure inference algorithms. Data analysis and model reduction applied to simulation results.

Week 8: Extended examples for potential projects (biological, computational, and mathematical). Subcellular cytoskeletal dynamics. Developmental systems: niches, inflation, migration. Plant (*Arabidopsis*) shoot, root, flower, leaf; fruit fly (*Drosophila*) AP, DV, imaginal disk, epithelium, wing. Neural development.

Week 9: More dynamics: statistical mechanics, dynamical systems, stochastic dynamics, model reduction and collective variables.

Week 10: Applied math methods for biology: graphs; stochastic, partial, and delay differential equations; operator splitting; finite element methods; scalable numerical PDE solving by multigrid methods; dynamic graph grammars; tissue growth models.

Requirements

For undergraduates, detailed assignments will be substantially easier.

Assignments will include (a) 4-5 problem sets (done individually) and (b) an oral and written report on a final project, done in a collaborative group with mixed skills and background; attendance is required for all students. The final project will use computational and mathematical tools from this course. Oral report will be at the regularly scheduled final exam time; electronic materials due at 11:59pm that night. PLEASE DO NOT MAKE TRAVEL PLANS IN CONFLICT with the regularly scheduled final exam time that we are using for final project presentations.
Extra credit: 2 points (on the standard scale of 100) are awarded for completing the class evaluation at the end of the quarter.

Textbook, Readings, etc: next syllabus version! (This is V1).