[Computation and Control in Biological Systems]

Term: [Fall]
Credits: [2]
Class Hours: [32] (Teaching Hours: [32], Lab Hours: [#], Practice Hours: [#])

Course Coordinator

Name	Fangzhou Xiao	Contact Info	xiaofangzhou@westlake.edu.cn
Office Address	E1-321	Office Hours	1 hour per week

Course Instructor(s) [List all other instructors here. Add more blanks if needed.]

Name #1	Zibo Chen	Name #2	
Contact Info	chenzibo@westlake.edu.cn	Contact Info	
Name #3		Name #4	
Contact Info		Contact Info	

Course Description [Shall include course introduction, prerequisites, etc.]

Biological organisms exhibit many fascinating behaviors, from magical transformation of matter via thousands of steps of metabolic reactions, to robust homeostasis adapting to rapidly shifting environments, to survival and growth that balances persistence in extreme conditions and all-out ventures into opportunistic moments of rich nutrients, to dominance and terraforming of surroundings to its own advantage. Such complex behaviors involving lots of interacting components demand a rigorous and quantitative way of reasoning, like how we reason about complex engineered machines. In this course, we introduce and master tools of reasoning from three different schools of thought pondering about life: physics, system, and industry. Physics asks what life is as an object. System asks how life works as a machine. Industry asks how life could be useful as a tool. These three schools of thought have distinct origins, approaches to analysis, and goals. They shape how we think about life forms. The tools we learn from them span a wide range, from order of magnitude estimate to design of a single protein molecule, from Markov chains to control systems, from simple reasoning based on central dogma to whole-genome models. By the end of the course, you will be able to integrate these tools and perspectives into a cohesive whole and have the confidence to reason about any biological problem thrown at you, from single molecules to populations of organisms. No background needed, but an exuberant love for biology is mandatory.

Learning Objectives

- To understand and master the tools of analysis in quantitative synthetic biology.
- To formulate problems encountered in synthetic biology into forms analyzable using the tools in quantitative synthetic biology.
- To get familiar with the theoretical background and technical aspects underlying the tools.

Learning Resources

- No background knowledge is needed, as anything necessary to understand the materials will be covered in the lectures. The following references are just for your general interest.

- For general background on modeling of biological circuits, a nice (and free!) reference is Richard Murray's book "Biomolecular Feedback Systems" (most relevant are the first 3 chapters): http://www.cds.caltech.edu/~murray/BFSwiki/index.php/Main_Page
- Of course another good general reference is Uri Alon's book on systems biology:
- https://www.amazon.com/Introduction-Systems-Biology-Mathematical-Computational/dp/1439837171/ref=pd_sbs_1?pd_rd_w=wdYPy&pf_rd_p=ed1e2146-ecfe-435e-b3b5-d79fa072fd58&pf_rd_r=JDGW416B0FACJD43JFET&pd_rd_r=bad2f030-2484-4414-bd96-e0da217b5971&pd_rd_wg=m5v3i&pd_rd_i=1439837171&psc=1
- A very good course with abundant online materials: biocircuits.github.io
- Cell biology by the numbers, by Rob Phillips. Available online: book.bionumbers.org
- Nonlinear dynamical systems and Chaos by Steven Strogatz.

Assessments and Grading [Each criterion can be weighted freely totaling 100%.]

Assessment Criteria	Percentage
Attendance	20
Presentation on homework	80

Grade	Assessment Standard
A	90-100%
B	80-89%
C	70-79%
D	60-69%
F	0-59%

Course Policies

- **Academic Integrity & Collaboration**: How is the policy motivated by the positive dimensions of academic integrity? What is and is not permitted with respect to collaboration and/or outside assistance for each type of graded work in your course?
- **Late-work/Make-up work policy**: Will you accept late work? If so, up until when? Will you deduct points for late work, and if so, how many? Will you require any sort of documentation?
- **Mobile Devices:** Are there times when having a mobile device would benefit student learning? If you have a zero-tolerance policy for mobile devices, how will you enforce it?

Course Schedule

Roughly one homework each week. It will not be graded, but students will be asked to present on their solution to last week's homework problems in class.

The course will run for 11 weeks, 3 course hours (45 min per course hour) each week. With 2 course hours of lecture, and 1 course hour of student presentation on previous week's homework problems.

Week	Theme/Topic	Instructor(s)	Assignments
1	Cell biology by the numbers, dimensional analysis, separation of time scales.	Fangzhou Xiao	None
2	Chemical reaction networks, chemical master equation, rate equation	Fangzhou Xiao	Student Presentation

3	ODE and phase plane analysis and simulation, Stability analysis and adaptation	Fangzhou Xiao	Student Presentation
4	Gillespie algorithm and stochasticity	Fangzhou Xiao	Student Presentation
5	Energy and equilibrium physics (kinetic proofreading), Markov chain	Fangzhou Xiao	Student Presentation
6	Evolution and neutral theory (demand theory)	Fangzhou Xiao	Student Presentation
7	Flux balance analysis (metabolic engineering), bioenergetics and metabolism	Fangzhou Xiao	Student Presentation
8	PROTEIN DESIGN! HANDS ON!!!! Nupack, Rosetta, Fold it.	Zibo Chen	Student Presentation
9	Population and spatial heterogeneity -- PDE and population CME	Fangzhou Xiao	Student Presentation
10	Combinatorial regulation and holistic analysis (promiscuous interactions), ROP	Fangzhou Xiao	Student Presentation
11	Growth dynamics, proteome partition, diauxie, upshift/downshift	Fangzhou Xiao	Student Presentation