Computational Cell Biology
CS/Biology/GBCB 5424

Home Department: Computer Science

I -- Catalogue Description

Use of mathematical models (nonlinear ordinary differential equations and stochastic processes) and simulation algorithms to explore the complex feedback circuits that control the behavior of living cells. Concepts and techniques from dynamical systems theory, bifurcation analysis, numerical methods, SBML (systems biology makeup language) and Matlab programming. Applications in gene regulatory networks, cell cycle control, circadian rhythms, cell signaling. Pre: MATH 5515 (3H, 3C)

Course Number: 5424 (BIO 5424, GBCB 5424)
ADP TITLE: Computational Cell Biology

II - Learning Objectives

After successfully completing this course, the student will be able to:

- Apply up-to-date modeling and simulation techniques to a realistic problem of current interest in life science;
- Analyze and construct models of cellular biological systems, determine parameters, run simulations, compare simulation results with experimental data, and improve the model;
- Assess the strengths and limitations of mathematical modeling for answering important questions about mechanisms underlying living cells.

III - Justification

Systems biology is a rapidly growing field which seeks to integrate biological data to understand how biological systems function. By studying the relationships and interactions among various parts of a biological system, the systems biologist hopes to develop a useful and informative model of the system as an integrated whole. For such an interdisciplinary area, it is necessary for students to have fundamental knowledge in multiple areas of biological sciences, mathematics and computer science. Current courses offered by these departments provide some of the necessary ideas and methods, but an interdisciplinary, hands-on computational modeling course, such as the one proposed here, is necessary for the professional development of many graduate students in programs such as computer science, biological sciences and GBCB (Genetics, Bioinformatics, and Computational Biology).

The course is appropriately placed at the 5000 level because it requires a maturity and a level of research interest that can be assumed for graduate students. Furthermore, it has another 5000 level course (Math 5515) as a prerequisite.

IV - Prerequisites and Corequisites

The prerequisite (MATH 5515, Mathematical Methods for Modeling and Simulation of Biological Systems) introduces fundamental mathematical theories and methods related

to differential equations and mathematical modeling, which provides necessary background for this course.

V - Texts and Special Teaching Aids

Modeling and simulation in molecular cell biology is a new topic in scientific research, and useful textbooks that cover all aspects of this course are not yet available. Thus a required textbook is omitted. Students will be provided with required and recommended reading lists drawn from textbooks and the original literature. Suggested textbooks include

- Fall, Christopher, Eric S. Marland, John M. Wagner and John J. Tyson (eds.). COMPUTATIONAL CELL BIOLOGY. vii, New York: Springer Verlag, 2005, 488.
- Klipp, Edda, Ralf Herwig, Axel Kowald, Christoph Wierling and Hans Lehrach. SYSTEMS BIOLOGY IN PRACTICE: CONCEPTS, IMPLEMENTATION AND APPLICATION. v, Weinheim:Wiley-VCH, 2005, 486.
- Uri Alon, AN INTRODUCTION TO SYSTEMS BIOLOGY: DESIGN PRINCIPLES OF BIOLOGICAL CIRCUITS. Boca Raton: Chapman & Hall/CRC, 2006, 301.

VI - Syllabus

- Introduction of modeling and simulation 7%
- Ordinary differential equations and stochastic processes 10%
- Dynamic systems, bifurcation theory 20%
- Numerical methods 20%
- Systems Biology Markup Language (SBML) and Matlab 8%
- Models in systems biology (35%)
    1. gene regulation network 5%
    2. cell cycle 5%
    3. basic positive and negative feedback gene circuits 5%
    4. toggle switch model 5%
    5. gene oscillator model 5%
    6. circadian rhythm 5%
    7. noise in a single cell 5%

100%

VII - Old (current) Syllabus

Not applicable

VIII - Core Curriculum guidelines

Not applicable