EPFL

ChE-411

Principles and applications of systems biology

Hatzimanikatis Vassily

Cursus	Sem.	Type
Biotechnology minor	H	Opt.
Computational biology minor	H	Opt.
Computational science and Engineering	MA1, MA3	Opt.
Ing.-chim.	MA1, MA3	Opt.
Life Sciences Engineering	MA1, MA3	Opt.
Physics of living systems minor	H	Opt.
Systems Engineering minor	H	Opt.

Language of teaching	English
Credits	3
Session	Winter
Semester	Fall
Exam	During the semester
Workload	90h
Weeks	14
Hours	**3 weekly**
Lecture	2 weekly
Exercises	1 weekly
Number of positions	

Summary

The course introduces and develops the key concepts from systems biology and systems engineering in the context of complex biological networks. The lectures elaborate on techniques and methods to model and analyze complex biological problems.

Content

The topics of the course include:

- Mathematical and computational analysis of **metabolic reaction networks**
- Analysis of **metabolomics and bioenergetics** data in the context metabolic networks
- Mathematical and computational analysis of **protein expression**
- Methods and technologies for the analysis of **signaling networks**
- Mathematical and computational analysis of **DNA-protein interaction** data
- Interpretation and analysis of **single cell data**
- Mathematical modeling of **spatial effects** in biological systems

Therefore, the course will introduce the following methods:

- Metabolic Flux balance analysis (FBA) (**Linear programming**)
- Thermodynamics based flux balance analysis (TFA) of metabolic networks (**Mixed-integer linear programing).**
- Kinetic models (**Ordinary differential equations**)
- Metabolic control analysis (**Local and global sensitivity analysis**)
- Stochastic simulation algorithm (SSA) and Particle based simulation methods (**stochastic simulation**)
- Parameter estimation for biological systems (**System identification methods**)

Part of the course is a computer laboratory were these methods are applied to characteristic problems.

Keywords

Systems biology, system engineering, metabolic networks, omics-data, thermodynamics, metabolc engineering, stochastic modeling, agent-based modeling, particle-based modeling, parameter estimation.

Learning Prerequisites

Required courses

Analysis I-III, linear algebra, probability and statistics, physical chemistry, programming essentials.

Recommended courses

The building of working groups will make it possible for people with partial knowledge in these fields to contribute depending on their formation.

For deeper understanding into the methods thought in this class we recommend the following courses:

SV courses:
- Dynamical systems in biology BIO-341 (Naef)
- Numerical analysis MATH-251(Deparis)

ChemE courses:
- Dynamics and kinetics CH-310 (Lorenz)
- Biochemical engineering ChE-311(Crelier, Zinn)
- Bioreactor modeling and simulation ChE-320 (Hatzimanikatis)
- Numerical methods ChE-312 (Miskovic, Sivula)

Important concepts to start the course

For the computational exercises, MATLAB® and PYTHON will be the platforms of choice.
An introductory session on and the platforms and software used is part of the course.

Learning Outcomes

By the end of the course, the student must be able to:
- Formulate mass balances of reaction networks
- Solve mass balance equations using linear programing solvers
- Analyze papers on modeling and analysis of biological networks
- Assess / Evaluate alternative methods for the study of biological networks
- Construct kinetic models of biological reactions
- Assess / Evaluate alternative methods for the study of biological networks
- Construct kinetic models of biological reactions
- Create and analyze stochastic models of biological reactions
- Analyze papers on modeling and analysis of biological networks

Transversal skills

- Plan and carry out activities in a way which makes optimal use of available time and other resources.
- Access and evaluate appropriate sources of information.
- Summarize an article or a technical report.
- Demonstrate the capacity for critical thinking
- Negotiate effectively within the group.

Teaching methods

Teaching in classroom, paper reviews, project.

Expected student activities

Presentations and critical analysis of papers.
Project.

Assessment methods

- Exercises (50%)
- Final project presentation (50%)

Supervision

Office hours	Yes
Assistants	Yes
Forum	No

Resources

Bibliography

Bibliography Primary and recommended
A First course in Systems Biology, Eberhard O. Voit 2012.

Systems Biology, By Edda Klipp et al. Wiley-Blackwell 2009.

Fundamentals of Systems Biology: From Synthetic Circuits to Whole-Cell Models, by Markus Covert

Modeling Differential Equations in Biology, by Clifford H. Taubes. Prentice Hall 2000.

An Invitation to Biomathematics, Raina Robeva James Kirkwood Robin Davies Leon Farhy Boris Kovatchev Martin Straume Michael Johnson

Foundations of System Biology, Edited by Hiraoki Kitano. MIT Press 2001

An Introduction to Systems Biology: Design Principles of Biological Circuits, by Uri Alon. Chapman and Hall/CRC 2006.

Computational Modeling of Genetic and Biochemical Networks, by James M. Bower and Hamid Bolouri. Bradford 2004.

Ressources en bibliothèque

- An Introduction to Systems Biology / Alon
- Modeling differential equations in biology / Taubes
- A first course in systems biology / Voitt
- Computational Modeling of Genetic and Biochemical Networks / James
- Foundations of System Biology / Nagasaki
- Systems Biology in Practice / Klipp

Websites

- http://scgc.epfl.ch/telechargement_cours_chimie

Moodle Link

- https://go.epfl.ch/ChE-411