**Georgia Institute of Technology / Department of Biomedical Engineering**

**BMED 3520 Biomedical Systems and Modeling**

**Instructors:** Eberhard Voit, Peng Qiu

**Credit:** 3

**Prerequisites:** BMED 3100 AND MATH 2403

**Text Book:** Voit, E.O.: *A First Course in Systems Biology*. Garland Science, New York, NY, 2012

**Description**

The course introduces BME students to the field of computational systems biology. It covers all typical aspects of biomathematical modeling, including: the choice of a modeling framework from among alternative approaches; the design of interaction diagrams; the identification of variables and processes; the design of systems models; standard methods of parameter estimation; the analysis of steady states, stability, sensitivity and gains; numerical evaluations of transients; phase-plane analysis; and the simulation of representative biomedical scenarios. All theoretical concepts are exemplified with applications.

**Objectives and Expected Outcomes**

This course consists of a weekly overview lecture, a problem solving session, and a homework discussion and recitation session. The overarching objective is to equip students with solid basic knowledge of different types of mathematical and computational modeling approaches and their applications to solving biomedical problems. By the end of the course the students should:

1. Understand the basic strengths and limitations of quantitative modeling

2. Have acquired a basic skill set for designing and implementing quantitative models of biomedical systems

3. Have mastered standard techniques of steady-state and dynamical analysis

4. Understand how to apply different modeling tools to the analysis of dynamical systems in biomedicine

**Instructional Format**

Four hours each week are scheduled for the class. The weekly one-hour overview lecture on Monday presents a high-level discussion of the topics to be studied during the week. The session on Tuesday begins with a brief question-and-answer period followed by hands-on projects and team-based problem solving. The session on Thursday reviews and explains details of the topics to be learned during the week in a question-and-answer manner and includes, if desired, a discussion of homework problems. The primary weekly assignment is the reading and understanding of selected text from the book. Secondary assignments consist of exercises from the book or uploaded to T-square.

Homework may be done and submitted in groups of up to four individuals. Three semester exams and one final exam assess each student’s mastery of the materials discussed in class.

**Grading:**

Weekly assignments and quizzes 15%

Three exams 20% each

Final exam 25%

**Topical Outline**

Week 01: Introduction, why modeling

Week 02: Type of models (dynamic/static, discrete/continuous, etc)

Week 03: Modeling process (SIR model, ODE models)

Week 04: Static network models (Graph, Stoichiometry)

Week 05: Discrete models (Recursive models, Markov chain)

Week 06: Continuous models (Linearization, Generalized mass action, S-system)

*Midterm exam 1*

Week 07: Standard methods of analysis (Steady state, stability, sensitivity)

Week 08: Parameter estimation (Grid search, Gradient, Stochastic search)

Week 09: Gene and protein networks (modeling of lac operon, gene network)

Week 10: Metabolic systems (Enzyme-catalyzed reactions, Michaelis Menten)

*Midterm exam 2*

Week 11: Spring Break

Week 12: Bistability, hysteresis, MAPK cascade

Week 13: Population models (Lotka-Volterra, Agent-based simulation)

Week 14: Personalized medicine and drug development

Week 15: Synthetic biology (Flux analysis, Elementary model analysis)

*Midterm exam 3*

Week 16: Models of the heart, Frontiers of Systems Biology

Week 17: Final exam