MATH564
Mathematical Modeling in the Life Sciences

Course syllabus

Times	TuTh 11:00AM-12:15PM, Phillips 381
Instructor	Sorin Mitran
Office hours	M 1:00-2:00PM, Tu 1:00-2:00PM, Chapman 451
Assistant	Ziqin He
Office hours	

(*The instructor reserves the right to make changes to the syllabus. Any changes will be announced as early as possible.*)

This course is intended as an introduction to the application of quantitative mathematical methods to the life sciences, a field that both finds new uses for traditional mathematical techniques (e.g., differential equations) and suggests novel approaches (e.g., machine learning). Through specific biological examples, the course will introduce a variety of mathematical modeling techniques and computational programming approaches as specified in the lesson plan below.

Course goals

Students will be exposed to mathematical modeling techniques commonly used in the life sciences, their implementation using a variety of software systems, and standard procedures for analysis and validation. A non-exhaustive list of the mathematical approaches includes: function approximation, differential and difference equations, combinatorics, stochastic calculus, algebraic-integro-differential systems, linear approximation, model reduction, deep neural networks.

Upon course completion students:

- will be able to choose appropriate mathematical models for various problems arising in the life sciences;
- will be able to use software environments for solving mathematical models arising in biology;
- will draft a manuscript describing a quantitative life science problem, the mathematical approach, solution, and analysis of results.

Course policies

- Homework is to be submitted electronically through Canvas. Homework is intended as a gradual introduction to specific mathematical approaches and accounts for 40% of the course grade. Late homework is not accepted.
- Mastery of the mathematical techniques is verified in a final examination accounting for 20% of the course grade.

- The main goal of the course is to develop the quantitative modeling skills required for drafting a scientific manuscript on a some problem within the life sciences of interest to a student. This is accomplished through a course project carried out in five phases, and accounting for remaining balance of 40% of the course grade.

- Students must bring their CCI-compliant laptop to all classes. All coursework is carried out using software tools for carrying out mathematical modeling, drafting of homework and course project.

- Honor code. Unless explicitly stated otherwise, all work is individual. You may discuss various approaches to homework problems with students, instructors, but must draft your answers by yourself.

Grading

Required work

- Homework: 10 assignments x 4 points = 40 points.
- Final Examination: 5 questions x 4 points = 20 points. (May 5, 12:00-3:00PM)
- Project: 5 phases, 40 points.
  - Bibliographic research: 5 points
  - Formulation of mathematical model: 10 points
  - Analysis of mathematical model solution: 10 points
  - Presentation of manuscript: 10 points
  - Review of another student's manuscript: 5 points

Mapping of point scores to letter grades

Grade	Points	Grade	Points	Grade	Points	Grade	Points
		B+	86-90	C+	71-75	D+	56-60
A	96-100	B	81-85	C	66-70	D-	50-55
A-	91-95	B-	76-80	C-	61-65	F	0-49

Course materials

Course topics

MOD. Introduction to mathematical modeling and software

LSQ. Least squares, linear and nonlinear dependence and regression.

ROC. Rates of change, differential and finite difference equations.

PRB. Probability

POP. Population models

AGE. Aging models

DIF. Diffusion, random movements

TRN. Transport in biological organisms

SYN. Synapses and neural models

MOL. Biomolecules

SIR. Epidemiological models

GEN. Genomics

PHL. Phylogenitic models

LUC. Last universal common ancestor

PRJ. Project presentation

Textbooks

In contrast to well-established topics such as calculus, there is no set curriculum for mathematical biology. The course will loosely follow the topics within *Mathematical Biology* by Ronald Shonkwiler and James Herod, freely accessible through the UNC library. Additional topics will be considered from the following sources. In all cases, modernized mathematical formulations are presented in class slides.

- *Mathematical Models in Biology* by Leah Edelstein-Keshet
- *An Invitation to Mathematical Biology* by David Costs and Paul Schulte
- *Topics in Mathematical Biology* by Karl Peter Hadeler
- *Modeling and simulation in medicine and the life sciences* by Frank Hoppensteadt and Charles Peskin
- *Mathematical Biology* by James Murray
- *Mathematical Biology: Looking Back and Going Forward* by Philip Maini
- *Introduction to Mathematical Biology* by Ching-Shan Chou and Avner Friedman

- *The Mathematics of Life* by Ian Stewart

Class slides

Presentation slides used in class discussion will be provided on this website. Textbook sections covered in each class are indicated in parantheses. Each week, theoretical concepts are presented in about two thirds of class time, with the remaining third used as a recitation, with exercises and practical applications that prepare students to draft the current homework.

Week	Date	Topic			
01	01/08	MOD		L01 (pp.1-10)	
02	01/15	LSQ	L02 (pp. 17-36)	L03 (pp. 52-57)	Homework01
03	01/22	POP	L04 (pp. 85-105)	L05 (pp. 107-127)	Homework02
04	01/29	AGE	L06 (pp. 128-135)	L07 (pp. 141-161)	Homework03
05	02/05	DIF	L08 (pp. 163-178)	L09 (pp. 178-185)	Homework04
06	02/12	TRN	L10	L11	Project
07	02/19	SYN	L12 (pp. 201-213)	Snow day	Homework05
08	02/26	SYN	L13 (pp. 214-227)	L14	
09	03/05	PRJ	paper.tm	bib	paper.pdf
10	03/19	MOL	L15	L16	Homework06
11	03/26	SIR	L17	L18	Homework07
12	04/02	PHL	L19	L20	Homework08
13	04/09	LUC	L21	L22	Homework09
14	04/16	LUC	L23	L24	Homework10
15	04/23	PRJ	Project defense	-	-

Homework

Homework generally consists of exercises from the textbook. Exercises similar to the homework assignment are solved in class, guided by Instructor. Reading the homework solutions is an important part of the course. Pay particular attention to how to succintly and correctly present mathematical answers.

UNC stylesheet for Mathematica notebooks: UNC.nb.

Nr.	Issue Date	Due Date	Topic	Problems	Solution
01	01/16	01/24	LSQ	Homework01	Solution01
02	01/27	02/04	POP	Homework02	Solution02
03	02/04	02/14	POP	Homework03	Solution03
04	02/11	02/21	DIF	Homework04	cancelled
05	02/25	03/07	SYN	Homework05	Solution05
06	10/02	10/09	SYN	Homework06	Solution06
07	10/09	10/16	MOL	Homework07	Solution07
08	10/16	10/23	SIR	Homework08	Solution08
09	10/19	10/26		Homework09	Solution09
10	10/26	11/02		Homework10	Solution10

Course project

The project is meant to navigate the typical process of preparing a scientific manuscript for publication: background research, problem formulation and solution, statement of conclusions. The course final examination will consist of reading another student's manuscript and presenting a critique similar to the peer review procedure. The course project is graded by the Instructor.

Phase	Start Date	Due Date	Templates
Bibliographic research	08/24	09/23	biblio.bib, introduction.tm
Problem formulation	10/05	10/14	methods.tm
Solution, conclusions	10/12	10/26	results.tm
Manuscript submission		11/06	paper.tm
Peer review	11/17	11/24	review.tm

Project models: AntibodyTransport.tm AntibodyTransport.pdf DiscreteSImodel.tm DiscreteSImodel.pdf

NeuronSignalModel.tm NeuronSignalModel.pdf

Final Examination

The final examination considers the first steps in constructing a mathematical model to study a problem in biology. It is open book and you are welome to use course notes, textbooks, online resources, search engines and generative tools. A sample first two set of questions are considered during class to gain familiarity with the biological background. During the scheduled examination, four additional questions are considered that involve applying mathematical models similar to those considered in previous case studies during the course.

Final Examination

Software

Modern software systems allow efficient, productive formulation and solution of mathematical models. A key goal of the course is to familiarize students with these capabilities, by presentation of two applications:

1. TeXmacs, a public domain scientific editing platform, used to draft the course project manuscript. Follow instructions on the TeXmacs website to install the software.

2. Mathematica, a commerical symbolic, numerical, and graphical computation package, available through a UNC site license, used to carry out computations and draft homework. Follow these UNC instructions to install the software.

Software tutorials

Software usage is introduced gradually in each class, so the first resource students should use is careful, active reading of the material posted in class. In particular, carry out small tasks until it becomes clear what the software commands accomplish. Some additional resources:

- TeXmacs
    - http://www.texmacs.org/tmweb/help/tutorial.en.html

  - https://www.youtube.com/watch?v=mlcqGRv7xhc

- Mathematica
  - http://www.wolfram.com/language/fast-introduction-for-math-students/en/
  - http://www.wolfram.com/wolfram-u/catalog/gen005/
  - http://www.wolfram.com/language/fast-introduction-for-programmers/en/