BI 410/510 Advanced modeling in biology
University of Oregon

- Syllabus -

Stilianos Louca

Spring 2020

Contents

Note: This syllabus has been adjusted to address the restrictions related to COVID-19.

1 Instructors

Lead instructor: Stilianos Louca, PhD, Assistant Professor.
Email address can be found at www.loucalab.com.
Office hours: Tuesdays at 15:30–16:30, via Zoom.

Teaching assistant: Phillip (Fill) Staley, PhD student
Office hours via Zoom:

- Wednesdays at 14:00–15:00,
- Thursdays at 15:30–16:30,
- Fridays at 13:00–14:00.

2 Schedule

Online lecture: Tuesdays and Thursdays, 14:00–15:20, via Zoom.
First lecture is on March 31, 2020. Last lecture is on June 4, 2020.

Online computer lab: Mondays, 14:00-15:50, via Zoom.
First lab is on April 6, 2020. Last lab is on June 1, 2020.

Online mid-term exam: Oral examinations (30 min) during week of May 4–8, 2020, via Zoom. Times will be scheduled individually for each student.

Online final exam: Oral examinations (30 min) during week of June 8-12, 2020, via Zoom. Times will be scheduled individually for each student.

Holidays observed: Monday, May 25, 2020. No computer lab will occur on that day.

3 Zoom instructions

All lectures, computer lab sessions, office hours and oral examinations will be done online via Zoom. Lectures and computer labs will be held as Zoom group meetings hosted by the lead instructor (see meeting ID in Section 2). Office hours will be held as Zoom private meetings (see personal meeting ID in Section 1). Students are strongly encouraged to familiarize themselves with Zoom prior to the course. Instructions for installing Zoom and joining a Zoom meeting can be found here:
`https://service.uoregon.edu/TDClient/2030/Portal/KB/ArticleDet?ID=101392`

When joining a Zoom meeting please keep in mind that, depending on your settings, your audio might be muted and/or your video might be off. Please join all meetings with video turned on (audio is optional). If you'd like to ask a question during the lecture and computer lab, please behave as in a normal class – either raise your hand and/or discretely draw the instructor's attention by voice (remember, everyone in the meeting can hear you). Please avoid using the Zoom text-chat function during the lecture and lab, since it distracts from the main conversation and requires additional attention by the instructor.

4 Target audience

The course targets junior and senior biology undergraduate students and graduate students with a strong interest in mathematical methods, but could also be of interest to students in physics, mathematics and environmental sciences. Indeed, students from other disciplines will find that many of the mathematical techniques taught are also applicable to problems in their own field.

5 Course contents

The following topics will be covered, roughly in this order and as time permits.

- Differential equation models and introduction to dynamical systems theory: Formulation, steady states, periodic trajectories, coordinate transformations, linearization theorem.
- Numerically simulating differential equation models in forward time.
- Numerically fitting differential equation models to data via maximum-likelihood as well as weighted least squares.
- Linear differential equations: Eigenvalues, normal modes, matrix-exponential representation of solutions, diagonalization and Jordan normal form, asymptotic stability concepts.
- Forced linear systems, impulse response function, transfer function, Fourier transform of input (forcing) and output (response).
- Vector autoregression models, maximum-likelihood fitting, simulation and forecasting, autocovariance function, power spectral density.

To some students the math may appear to be somewhat abstract. For example, most of the theory is formulated for n-dimensional systems, thus allowing application to a wide range of realistic problems. Mathematical proofs as well as programming tasks are common components of the course. Application of the theory will be demonstrated using examples from across the field of biology, although examples may be somewhat biased towards ecology and epidemiology. Population genetics models are not discussed in this course.

A lot of the material is presented along with mathematical proofs, a practice that some students may not necessarily be familiar with. Providing a "proof" simply means that a rigorous explanation is given for a particular statement. This has a two-fold educational reason. First, seeing the *reason* for a specific mathematical statement facilitates its apprehension, as the task shifts from that of *memorization* to one of *understanding*. Second, a central aspect of modeling is to make quantitative predictions through deductive reasoning that can then be tested experimentally. When an experiment contradicts the prediction of a model it is essential to know whether the experiment really contradicts the model, or whether the model itself is accurate but the prediction itself was erroneously deducted through sloppy (aka. “handwavy”) arguments. Being accustomed to the art of mathematical proof (that is, clear deductive reasoning) is a skill that any serious modeler must have.

6 Prerequisites

Highly recommended prerequisites for this course are:

- Familiarity with multivariate calculus (multivariate integrals, partial derivatives, basic differential equations).
- Basic linear algebra (matrixes, eigenvectors, systems of linear equations).
- Basic probability and statistics (common distributions, especially normal and Poisson, conditional probabilities, density and cumulative distribution function).
- Familiarity with complex numbers.
- Basic experience with computer programming (any language).
- Basic knowledge of biology (e.g., entry college level).

Students lacking some of this background might still succeed in this course with (potentially considerable) additional effort. Students lacking most of this background will probably find this course to be very challenging. Prerequisite courses listed on the university website may be omitted upon instructor approval.

7 Material

Website: Unless otherwise mentioned, material (reading assignments, homework assignments, announcements etc) will be posted on the UO Canvas course page. Students should check for announcements and assignments posted on Canvas at least every 2-3 days; students may also choose to set up automated email notifications in Canvas.

Reading material: The full reading material for this course will be provided for free as a self-contained “lecture notes” document for personal use by the students. Students should download the latest version of this document at least once a week, since material might be added or modified throughout the course. Students lacking some of the prerequisites mentioned in Section 6 will need to look into catching up on that material through other sources, e.g. through wikipedia, books etc., although some brief introductions will also be provided as appendixes in the lecture notes.

Software: The course includes examples and homework assignments in MATLAB, a widely used software for scientific computations. The provided code examples assume MATLAB 2019a or later. Students may in principle choose to use an alternative software to MATLAB for their homework assignments (e.g., R or python), however this is discouraged and no advice/instructions will be provided specific to that alternative software. Macs at the Price Science Commons & Research Library have MATLAB installed, and students can use those to work on their homework assignments depending on current UO restrictions due to COVID-19. Students are strongly encouraged to install MATLAB on their own computers. The University of Oregon provides MATLAB licenses for students at: software.uoregon.edu

Copyright and privacy protection: Do not share or post online any of the course material, including lecture notes, assignments and official solutions, or recordings of online Zoom meetings.

8 Assignments

Weekly assignments will be posted on Canvas and will be **due on the Friday of the following week at noon**. Late assignments will not be accepted in the absence of proper justification. If you anticipate a delay in your assignment delivery and in the presence of justification please contact the lead instructor well ahead of the deadline. Students are responsible for checking notifications and assignments posted on Canvas in time.

Assignments must be uploaded to Canvas in PDF file format. Only PDF files will be accepted; please do not upload your assignments in Word document format. Students are encouraged to learn and use LaTeX for their assignments, a free and widely used software for writing scientific (especially mathematical) documents. Alternatively, students may choose to complete their assignments on paper and upload scanned PDFs to Canvas, provided that these are clearly legible.

Students are expected to do most of the homework on their own. Consultation and collaboration with peers is permitted, but every student should fully understand the solutions produced and must individually write up their computer code and report. Assignments are graded individually. Assignments must be clearly legible and must adhere to common professional standards (e.g., proper axes labeling, thorough reasoning, proper writing, legibility, etc).

9 Grading

All homework and exam scores are counted on a percentage scale. The final grade G will be calculated on a percentage scale using the following formula: $G = 0.2 \cdot H + 0.8 \cdot E$, where H is the average score from the homework assignments (averaged over all assignments) and E is determined by the mid-term and final examination scores, as follows. If the final exam score is greater than the mid-term exam score, then E is equal to the final exam score. If the final exam score is equal to or less than the mid-term exam score, then E is equal to a weighted average of the two exam scores, with the mid-term exam weighting 30% and the final exam weighting 70%. Mid-term and final exams will be oral examinations performed through Zoom. There will be no opportunities for extra credit and no grade bumps.

Letter grade: The following rubric will be used to convert the final grade G from a percentage scale to a letter scale.

Percentage (P)	Letter
$97\% \leq P \leq 100\%$	A+
$93\% \leq P < 97\%$	A
$90\% \leq P < 93\%$	A-
$87\% \leq P < 90\%$	B+
$83\% \leq P < 87\%$	B
$80\% \leq P < 83\%$	B-
$77\% \leq P < 80\%$	C+
$73\% \leq P < 77\%$	C
$70\% \leq P < 73\%$	C-
$67\% \leq P < 70\%$	D+
$63\% \leq P < 67\%$	D
$60\% \leq P < 63\%$	D-
$0\% \leq P < 60\%$	F

10 Attendance

Attendance will not be checked during the course and will not be taken into consideration for the grade. It is ultimately the student's responsibility to stay up to date with the material taught and homework assignments.

11 Disabilities and other issues

If there are aspects of this course that result in unfair barriers to your participation, please let us know as early as possible. You may also contact Accessible Education Services in 164 Oregon Hall, by phone at 541-346-1155 or via email at uoaec@uoregon.edu.

Students having trouble participating in this course due to internet connectivity issues or other related issues (e.g., time zone differences, no access to a computer) should send an email to the lead instructor or to uoadvising@uoregon.edu.

Students may request to borrow a Chromebook laptop from the University of Oregon, as described here:
https://service.uoregon.edu/TDClient/2030/Portal/Requests/ServiceDet?ID=42589

Students may also access the UO virtual computer lab, which provides various Windows software, including MATLAB, remotely:
https://service.uoregon.edu/TDClient/2030/Portal/Requests/ServiceDet?ID=42572

Students having trouble installing MATLAB on their computer should contact CASIT as soon as possible (https://casit.uoregon.edu).