Spring 2015

BIOS 9134 - Stochastic Processes for Systems Biology

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BIOS 9134: Stochastic Processes for Systems Biology  
Spring 2015

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Class Time: Tuesday, 6:30-9:15 PM  
Location: 2020 Hendricks Hall  
Office Hours: Tuesday: 1:00 - 6:00 PM; and by appointment

Course Description: This course provides the student with an introduction to stochastic processes with emphasis on Markov chains, The Poisson Process, Brownian Motion and other continuous time processes. The theory developed will be used to model and simulate complex biochemical reaction networks and perform network inference given data from the stochastic trajectory of a biological process, typically arising from microarray or next generation sequencing experiments.


References:  


**Dr.P.H. Biostatistics Concentration Competencies:** Upon graduation a student with a Dr.P.H. in Biostatistics will be able to:

1. Demonstrate skills for translating objectives of a public health and biomedical research question into the appropriate biostatistical questions.

2. Design a public health and biomedical investigation in terms of the experimental design, data to be collected to reflect research objectives, number of subjects needed to address the objectives, and specification of appropriate methods for analysis.

3. Develop a theoretical foundation for commonly used topics in inferential statistics such as probability, sampling, discrete and continuous distributions and their moment generating functions, point and interval estimation, likelihood ratio tests, hypothesis testing, and nonparametrics found in advanced analyses of public health and biomedical studies.

4. Compare Bayesian methods to frequentist methods for analyzing data.

5. Evaluate a public health and biomedical research proposal to determine the more appropriate biostatistical analysis methodology, including Bayesian and frequentist approaches.

6. Analyze public health and biomedical data via classical and Bayesian approaches using statistical software packages such as SAS, R/S-plus, and WinBUGS.

7. Develop a protocol for performing meta-analyses of data to be collected to address a question requiring collection of summary data across several sources.

8. Demonstrate use of meta-analytic methods for combining information across public health and biomedical studies.

9. Apply meta-analysis to estimate the sources and magnitude of heterogeneity across public health and biomedical studies.

10. Explain underlying theory in longitudinal data analyses of public health and biomedical studies.

11. Analyze longitudinal data in public health and biomedical studies with appropriate longitudinal data analysis methods.
12. Interpret analytic methods used throughout the literature in biostatistical and public health journals.

13. Interpret results of classical and Bayesian biostatistical analyses so that valid and reliable conclusions regarding a public health and biomedical research question may be drawn from the analyses.

14. Develop new ideas for applying existing biostatistical methods to applications in public health.

15. Develop statistical reasoning skills to work independently on ideas for research in public health and biomedicine.

16. Develop written and oral reports to communicate effectively to research investigators pivotal aspects of a study, including its design, objectives, data, analysis methods, results, and conclusions.

17. Create a collaborative environment for working on written and oral reports and developing critical thinking skills.

**Course Objectives:** At the end of this course, students will be able to complete the following:

1. Explain what a Markov chain is and determine the type of each state in the chain.

2. Define the Markov property.

3. Classify the state space and index set as discrete or continuous.

4. Compute the stationary distribution and limiting behavior of a Markov chain given the transition matrix.

5. Define detailed balance and prove the Metropolis-Hastings algorithm and Gibbs sampler converge to the proper distribution.

6. Explain the connection between the exponential distribution and the Poisson process.

7. Solve problems involving compound Poisson processes.

8. Use Thinning, Superposition, and conditioning to solve Poisson process problems.

9. Compute transition probabilities of some continuous time Markov chains.
10. Determine the limiting behavior of continuous time Markov chains.

11. Define what a Martingale is and have working knowledge of conditional expectation.

12. Define and simulate Brownian Motion.

13. Understand biochemical reaction notation and simulate a biochemical trajectory with R.

14. Write the deterministic ODE given a set of biochemical reactions.


**Computing:** R will be used exclusively in this course.

**Grading Scheme:**
Assignments (assesses competencies 1-17): 30%
Midterm Exam (assesses competencies 1-11): 30%
Final Exam (assesses competencies 1-17): 40%

Note: All exams and assignments will be graded and returned promptly so that students may accurately calculate their grades at any point in time during the semester.

**Grading Scale:**

- **A** 90 - 100%
- **B** 80 - 89%
- **C** 70 - 79%
- **D** 60 - 69%
- **F** 0 - 59%

**Exams:** There will be 2 exams, the midterm exam (Tuesday, March 24) and the final exam (Tuesday, May 5—taken from the university’s 2015 Final Exam Schedule).
**Assignments:** Assignments account for 30% of your course grade. You may work together or individually on these assignments, however each student must submit his/her own assignment and state with whom he/she worked, if applicable.

What does ‘working together’ mean? You are welcome to solve problems and discuss explanations in groups, however it is not acceptable to submit assignments with identical wordings and explanations.

**Schedule of Exams:**
MIDTERM EXAM: Tuesday, March 24
FINAL EXAM: Tuesday, May 5

**Course Outline:**

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<th>Topic</th>
<th>Chapters</th>
<th>Homework</th>
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<tbody>
<tr>
<td>Markov Chain Theory</td>
<td>Notes &amp; Chapter 1(Durrett)</td>
<td>1.1, 1.2, 1.5, 1.6, 1.10, 1.13, 1.32, 1.36, 1.45, 1.48, 1.54, 1.70, 1.72, 1.76(Due Feb. 3)</td>
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<tr>
<td>Weeks 1-3</td>
<td></td>
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<tr>
<td>The Poisson Process</td>
<td>Notes &amp; Chapter 2(Durrett)</td>
<td>2.1, 2.5, 2.6, 2.7, 2.8, 2.10, 2.11, 2.22, 2.24, 2.30, 2.32, 2.34, 2.38, 2.57, 2.58, 2.61(Due March 3)</td>
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<tr>
<td>Weeks 4-6</td>
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<tr>
<td>Continuous Time</td>
<td>Notes &amp; Chapter 4(Durrett)</td>
<td>4.1, 4.2, 4.3, 4.5, 4.6, 4.9-4.13, 4.23, 4.24, 4.25(Due March 24)</td>
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<tr>
<td>Markov Chains</td>
<td></td>
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<td>Weeks 7-8</td>
<td>Notes &amp; Chapter 5(Durrett)</td>
<td>5.1-5.17 (Due April 14)</td>
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<tr>
<td>Martingales</td>
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<td>Weeks 9-10</td>
<td>Notes Chapter 5(Wilkinson)</td>
<td>Exercises 1-7 from Chapter 5(Due April 31)</td>
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<tr>
<td>Markov Processes</td>
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<tr>
<td>Chemical and Biochemical kinetics</td>
<td>Notes &amp; Chapter 6(Wilkinson)</td>
<td>Exercises 2, 5-8 from Chapter 6(Due May 5)</td>
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<tr>
<td>Inference for stochastic kinetic models</td>
<td>Notes &amp; Chapters 9-10(Wilkinson)</td>
<td>Selected Reading</td>
</tr>
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</table>

**Academic Integrity:** Students are expected to follow guidelines outlined in the *Academic Dishonesty* policy found online in the course catalog. Any student found in violation of academic honesty will receive a grade of ‘F’ for the course. It is the student’s responsibility to familiarize him/herself with the student policies and expectations set forth in the online GSU *Catalog*. 
**Plagiarism:** According to the Academic Dishonesty Policy of GSU, Plagiarism includes (but is not limited to):

A. Directly quoting the words of others without using quotation marks or indented format to identify them.
B. Using published or unpublished sources of information without identifying them.
C. Paraphrasing material or ideas without identifying the source.
D. Unacknowledged use of materials prepared by another person or agency engaged in the selling of term papers or other academic material.

If you are accused of plagiarism by a JPHCOPH, the following policy, as per the Judicial Affairs website (http://students.georgiasouthern.edu/judicial/faculty.htm) will be enforced:

**PROCEDURES FOR ADJUDICATING ACADEMIC DISHONESTY CASES**

**First Offense - In Violation Plea**

1. If the professor and the Dean of Students agree that the evidence is sufficient to warrant a charge of academic dishonesty, the professor should contact the Office of Judicial Affairs to determine if this is a first violation of academic dishonesty. The incident will be reported via the following website: http://students.georgiasouthern.edu/judicial/faculty.htm

2. If it is a first violation, the professor should talk with the student about the violation. If the student accepts responsibility in writing and the professor decides to adjudicate the case, the following procedures will be followed:

   a. The student will be placed on disciplinary probation for a minimum of one semester by the Office of Judicial Affairs.

   b. The student will be subject to any academic sanctions imposed by the professor (from receiving a 0 on the assignment to receiving a failing grade in the class).

   c. A copy of all the material involved in the case (Academic Dishonesty Report Form and the Request For Instructor to Adjudicate Form) and a brief statement from the professor concerning the facts of the case and the course syllabus should be mailed to the Office of Judicial Affairs for inclusion in the students discipline record.

**First Offense - Not In Violation Plea (student does not admit the violation)**

If the professor and the Dean of Students agree that the evidence is sufficient to warrant a charge of academic dishonesty, the professor should contact the Office of Judicial Affairs to determine if this is the first or second violation of academic dishonesty. The student will be charged with academic dishonesty and the University Judicial Board or a University Hearing Officer would hear the case. If the student is found responsible, the following penalty will normally be imposed:
a. The student will be placed on Disciplinary Probation for a minimum of one semester by the Office of Judicial Affairs.

b. The student will be subject to any academic sanctions imposed by the professor.

**Second Violation of Academic Dishonesty**

If the professor and the Dean of Students agree that the evidence is sufficient to warrant a charge of academic dishonesty, and if it is determined this is the second violation, the student will be charged with academic dishonesty and the University Judicial Board or a University Hearing Officer would hear the case.

If the student is found responsible, the following penalty will normally be imposed:

a. Suspension for a minimum of one semester or expulsion.

b. The student will be subject to any academic sanctions imposed by the professor.

**NOT RESPONSIBLE FINDING**

When a student is found not responsible of academic dishonesty, the work in question (assignment, paper, test, etc.) would be forwarded to the Department Chair. It is the responsibility of the Department Chair to ensure that the work is evaluated by a faculty member other than the individual who brought the charge and, if necessary, submit a final grade to the Registrar. For the protection of the faculty member and the student, the work in question should not be referred back to the faculty member who charged the student with academic dishonesty.

In the case of a Department Chair bringing charges against a student, an administrator at the Deans level will ensure that the students work is evaluated in an appropriate manner.

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**Attendance Policy & Class Participation**: Due to the nature and structure of this course, class attendance is essential to succeeding in this course. You are responsible for any material covered or distributed in class, including any announcements, so please check with me or your colleagues if you miss class in order to obtain copies of notes or any announcements. Federal regulations require attendance be verified prior to distribution of financial aid allotments. Attendance will not be recorded after this initial period.

Furthermore, I believe it is important to foster student-teacher and student-student interactions within this course, so you will discover that I will ask questions throughout class. Although participation is not a formal part of your final grade, I will use it as a factor if your final grade is on the border between two letter grades. It is noted throughout the semester when you partake in class discussions. If your final course grade is on the border of two letter grades, then class participation will weight your final grade to the next highest letter grade. Otherwise, I do not round final numerical grades to the nearest letter grade.

**Class Etiquette**: Please turn off all cell phones during all class/lab/exam meetings, since ring tones are disruptive to others.
Dates to Remember: To see the important dates see the following website:

University Calendar:
http://students.georgiasouthern.edu/registrar/calendar.htm

and on the Graduate School’s website:
http://cogs.georgiasouthern.edu/importantdates.html

Disclaimer: The contents of this syllabus are as complete and accurate as possible. The instructor reserves the right to make any changes necessary to the syllabus and course material. The instructor will make every effort to inform you of changes as they occur. It is the responsibility of the student to know what changes have been made in order to successfully complete the requirements of the course.

University Writing Center: For those of you who may need assistance with improving your writing for assignments, or for general writing, I encourage you to visit the University Writing Center. To learn more, visit their website:
http://class.georgiasouthern.edu/writingc.