ABE 6933: Stochastic modeling in ecology and hydrology

FALL 2019, 3 credit hours

Time & Location: Mondays—Period 5 (11:45 AM - 12:35 PM)
Wednesdays—Period 5-6 (11:45 AM - 1:40 PM)
Frazier Rogers Hall 283

Pre-requisites: MAC2312 or equivalent
Basic calculus and college-level probability courses

Instructor: Rachata Muneepeerakul, PhD
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Frazier Rogers Hall 227; Office Hours: by appointments

Graduate Teaching Assistants (email, office hours and location): N/A

Course Description

Stochastic modeling is introduced through a problem-based approach. Selected papers are studied in depth; derivation of their main results unpacked. Examples include stochastic models of biodiversity, soil moisture, and rainfall. Students pick stochastic models to study for final projects. Students enjoy deeper understanding from unpacking these otherwise seemingly mysterious results.

Learning Objectives:

Upon completion of this course, students will be able to:

- Unpack and explain the derivations of the basic results of stochastic models
- Apply the analytical techniques discussed in class to solve problems in other stochastic models
- Articulate the effects of stochastic fluctuation on the resulting dynamics based on the analysis of stochastic models

Assessment and Evaluation:

The final grade breakdown: Class participation: 15% | Assignments: 55% | Final project: 30%

Final grade will be rounded to the nearest integer; 85.5 will be rounded to 86.

91-100 = A | 86-90 = A- | 81-85 = B+ | 76-80 = B | 71-75 = B- | 66-70 = C+ | 61-65 = C |56-60 = C- | 51-55 = D+ | 46-50 = D | 41-45 = D-| 0-40 = E

Textbooks: None

Tentative Weekly course schedule:

Week	TOPIC*
1	**Basic concepts in probability theory:** random variables, expected value, variance, probability mass function (PMF), probability density function (PDF); Properties of selected standard random variables (binomial, exponential, Gaussian)
2	**Basic concepts** continued: Moment generating function (MGF) **Examples of simple stochastic processes:** Markov chain, 1st-order autoregressive (AR) model
3	***Leigh, EG Jr.* (2007)—Neutral theory of diversity:** Relative species abundance (RSA)
4	RSA (cont'd); Probability of two random individuals belonging to the same species (*F*)
5	*F* under spatial settings; Generating function of the branching process
6	***Rodriguez-Iturbe et al.* (1999)—Soil moisture dynamic:** Introduction and intuitive understanding of the process; Marked Poisson process; Memorylessness of exponential pulses; loss function
7	Combining the discussed elements; Derive forward Kolmogorov equation
8	Solve forward Kolmogorov equation for steady-state probability density function for soil moisture; Crossing properties
9	**Wiener process:** Introduction; Forward & backward Kolmogorov eqs; First passage time (FPT)
10	First passage time (FPT) ***Rodriguez-Iturbe et al.* (1987)—Rectangular pulse models of rainfall:** Introduction; Derive expected value and variance of the process
11	Moment generation function of the rainfall process *PROJECT PROGRESS REPORTS*
12	Derive autocorrelation coefficient, PDF of the number of active rain cells
13	Neyman-Scott process: Introduction; Derive expected value, variance, autocovariance
14	*PROJECT PROGRESS REPORTS* *WORKSHOPS TO HELP WITH FINAL PROJECTS*
15	TBD*
16	**FINAL PROJECT PRESENTATIONS**

* The schedule is tentative. Actual schedule would depend on progress and interest in class.

Assignments

Assignments are usually due within 1-1.5 weeks after the date they are assigned.

HW	Will be assigned in week	Brief description*
1	2	State problems of your interest Calculate expected value and variance of a random variable Analyze 1st-order autoregressive model of annual stream flow
2	4	Memo on *Leigh* (2007)** Calculate the probability that two random selected individuals belong to the same species in a neutral model Analyze a property of moment generating function
3	7	Memo on *Rodriguez-Iturbe et al.* (1999)** Derive statistics of a compound Poisson random variable Derive the probability density function (pdf) for a marked Poisson process with a constant loss function Compile potential papers for your project
4	9	Derive steady-state probabilities of different states in a random telegraph process Derive the autocovariance of Wiener process
5	11	Memo on *Rodriguez-Iturbe et al.* (1987)** Derive the pdf of the number of active rain cells in a rectangular pulse model of rainfall

* The assignment descriptions are based on a recent offering and are subject to change.

** For memos, please refer to the papers in Sample Readings below. The papers to be discussed in class may change based on the class interests.

For the final project, students will form groups based on their common interest. Each group will select, with the instructor's guidance and approval, a stochastic modeling paper in their field, in which some basic results of the stochastic model are reported the derivation of those results are omitted or unclear. The group's main task is to work out the detailed derivation of these results and report to the class. Throughout the semester, each group will present 2 or 3 progress reports to inform the instructor and the class on where they are and, importantly, what difficulty they are facing in deriving the results in their selected paper, so that the instructor can provide assistance in a timely manner. These progress reports are designed to keep the group's work on track and are not worth any points.

Sample Readings:

(Notes: we would likely *not* have time to cover all papers listed below; we may cover them in a different order; and we may even switch to different papers, depending on the interest and progress of the class.)

Leigh , E.G. Jr. 2007. Neutral theory: a historical perspective. *Journal of Evolutionary Biology* **20**: 2075-2091.

Volkov, I., J.R. Banavar, S.P. Hubbell, & A. Maritan. 2003. Neutral theory and relative species abundance in ecology. *Nature* **424**: 1035-1037.

McKane, A.J., D. Alonso, & R. V. Solé. 2004. Analytical solution of Hubbell's model of local community dynamics. *Theoretical Population Biology* **65**: 67-73.

Chave, J. & E.G. Leigh Jr. 2002. A spatially explicit neutral model of β-diversity in tropical forests. *Theoretical Population Biology* **62**: 153-166.

Rodriguez-Iturbe, I., A. Porporato, L. Ridolfi, V. Isham, & D.R. Cox. 1999. Probabilistic modeling of water balance at a point: the role of climate, soil and vegetation. *Proceedings of the Royal Society, London, A* **455**: 3789-3805.

Laio, F., A. Porporato, L. Ridolfi, & I. Rodriguez-Iturbe. 2001. Mean first passage times of processes driven by white shot noise. *Physical Review E* **63**, 036105.

Leigh , E.G. Jr. 1981. The average lifetime of a population in a varying environment. *Journal of Theoretical Biology* **90**: 213-239.

Rodriguez-Iturbe, I., D.R. Cox, & V. Isham. 1987. Some models for rainfall based on stochastic point processes. *Proceedings of the Royal Society, London, A* **410**: 269-288.

Grades and Grade Points

For information on current UF policies for assigning grade points, see http://gradcatalog.ufl.edu/content.php?catoid=10&navoid=2020#grades

Attendance and Make-Up Work

Requirements for class attendance and make-up exams, assignments and other work are consistent with university policies that can be found at: http://gradcatalog.ufl.edu/content.php?catoid=10&navoid=2020#attendance.

Online Course Evaluation Process

Student assessment of instruction is an important part of efforts to improve teaching and learning. At the end of the semester, students are expected to provide feedback on the quality of instruction in this course using a standard set of university and college criteria. These evaluations are conducted online at https://evaluations.ufl.edu. Evaluations are typically open for students to complete during the last two or three weeks of the semester; students will be notified of the specific times when they are open. Summary results of these assessments are available to students at https://evaluations.ufl.edu/results.

Academic Honesty

As a student at the University of Florida, you have committed yourself to uphold the Honor Code, which includes the following pledge: *"We, the members of the University of Florida community, pledge to hold ourselves and our peers to the highest standards of honesty and integrity."* You are expected to exhibit behavior consistent with this commitment to the UF academic community, and on all work submitted for credit at the University of Florida, the following pledge is either required or implied: "*On my honor, I have neither given nor received unauthorized aid in doing this assignment*."

It is assumed that you will complete all work independently in each course unless the instructor provides explicit permission for you to collaborate on course tasks (e.g. assignments, papers, quizzes, exams). Furthermore, as part of your obligation to uphold the Honor Code, you should report any condition that facilitates academic misconduct to appropriate personnel. It is your individual responsibility to know and comply with all university policies and procedures regarding academic integrity and the Student Honor Code. Violations of the Honor Code at the University of Florida will not be tolerated. Violations will be reported to the Dean of Students Office for consideration of disciplinary action. For more information regarding the Student Honor Code, please see: http://www.dso.ufl.edu/sccr/process/student-conduct-honor-code.

Software Use:

All faculty, staff and students of the university are required and expected to obey the laws and legal agreements governing software use. Failure to do so can lead to monetary damages and/or criminal penalties for the individual violator. Because such violations are also against university policies and rules, disciplinary action will be taken as appropriate

Services for Students with Disabilities

The Disability Resource Center coordinates the needed accommodations of students with disabilities. This includes registering disabilities, recommending academic accommodations within the classroom, accessing special adaptive computer equipment, providing interpretation services and mediating faculty-student disability related issues. Students requesting classroom accommodation must first register with the Dean of Students Office. The Dean of Students Office will provide documentation to the student who must then provide this documentation to the Instructor when requesting accommodation

0001 Reid Hall, 352-392-8565, www.dso.ufl.edu/drc/

Campus Helping Resources

Students experiencing crises or personal problems that interfere with their general well-being are encouraged to utilize the university's counseling resources. The Counseling & Wellness Center provides confidential counseling services at no cost for currently enrolled students.

Resources are available on campus for students having personal problems or lacking clear career or academic goals, which interfere with their academic performance.

- *University Counseling & Wellness Center, 3190 Radio Road, 352-392-1575,* www.counseling.ufl.edu/cwc/
  Counseling Services
  Groups and Workshops
  Outreach and Consultation
  Self-Help Library
  Wellness Coaching
- *Career Resource Center,* First Floor JWRU, 392-1601, www.crc.ufl.edu/