ASEN 6412
Uncertainty Quantification (UQ)

Spring 2020

Class meetings: MW 10:00 AM - 11:15 AM in AERO 232

Instructor:

Alireza Doostan
Smead Aerospace Engineering Sciences, AERO 356
Tel: 303-492-7572
E-mail: doostan@colorado.edu
Office hours: MW noon - 1:30 PM, otherwise by appointment.

Prerequisites:

Prerequisite is a B or better in ASEN 5070, APPM 5520, APPM 5570, ECEN 5612, or equivalent courses with instructor consent.

References:

- R. Smith, Uncertainty Quantification: Theory, Implementation, and Applications, SIAM, 2013
- R. Ghanem and P.D. Spanos, Stochastic Finite Elements: A Spectral Approach, Dover, 1991
- D. Xiu, Numerical Methods for Stochastic Computations: A Spectral Method Approach, Princeton University Press, 2010
- O. P. Le Maitre and O. M. Knio, Spectral Methods for Uncertainty Quantification: With Applications to Computational Fluid Dynamics, Springer Verlag, 2010
- R. Aster, B. Borchers, and C. Thurber, Parameter Estimation and Inverse Problems, Elsevier Academic Press, 2005

Grading:

- Homework (35%)
- Mid-term exam (20%)
- Final project (35%)
- Class attendance/discussion participation (10%)

Some notes:

- Homework problems involve combinations of analytical, numerical, or paper review tasks
- Please answer homework problems as clear and clean as possible. 10% of the homework grade goes to clarity
- No late homework submissions will be accepted unless there is an emergency
- Sharing thoughts on homework problems is encouraged; however, every student must submit his/her homework

Course objectives:

This course will provide an introduction to recent techniques for representation and propagation of uncertainty in PDE/ODE-based systems. Students will be exposed to the state-of-the-art techniques for simulation of random processes as well as numerical solution of stochastic PDEs/ODEs. A number of case studies from computational solid and fluid mechanics will be discussed.

Course content (tentative):

- Review of basic probability: Probability space, random variables, vectors, and processes
- Convergence of random sequences
- Simulation of random variables: Inversion- and rejection-based techniques
- Karhunen-Loeve expansion
- Simulation of Gaussian and non-Gaussian random vectors
- Simulation of Gaussian and non-Gaussian random processes
- Solution of stochastic PDEs/ODEs via Monte Carlo techniques – Standard sampling, Latin Hypercube sampliung, and importance sampling
- Solution of stochastic PDEs/ODEs via Multi-level Monte Carlo technique
- Polynomial chaos and generalized polynomial chaos expansions
- Tensor-product and Smolyak sparse grids
- Solution of stochastic PDEs/ODEs via sparse-grid collocation
- Application of Deep Neural Networks (DNNs) in UQ
- Application of model reduction techniques in UQ (low-rank, sparse, and multi-fidelity) techniques

Some university policies:

Accommodation For Disabilities: If you qualify for accommodations because of a disability, please submit to your professor a letter from Disability Services in a timely manner (for exam accommodations provide your letter at least one week prior to the exam) so that your needs can be addressed. Disability Services determines accommodations based on documented disabilities. Contact Disability Services at 303-492-8671 or by e-mail at `dsinfo@colorado.edu`. If you have a temporary medical condition or injury, see Temporary Injuries guidelines under the Quick Links at the Disability Services website and discuss your needs with your professor.

Religious Holidays: Campus policy regarding religious observances requires that faculty make every effort to deal reasonably and fairly with all students who, because of religious obligations, have conflicts with scheduled exams, assignments or required attendance. In this class, you must let the instructors know of any such conflicts within the first two weeks of the semester so that we can work with you to make reasonable arrangements. See campus policy regarding religious observances for full details.

Policy Regarding Classroom Behavior: Students and faculty each have responsibility for maintaining an appropriate learning environment. Those who fail to adhere to such behavioral standards may be subject to discipline. Professional courtesy and sensitivity are especially important with respect to individuals and topics dealing with differences of race, color, culture, religion, creed, politics, veteran's status, sexual orientation, gender, gender identity and gender expression, age, disability, and nationalities. Class rosters are provided to the instructor with the student's legal name. I will gladly honor your request to address you by an alternate name or gender pronoun. Please advise me of this preference early in the semester so that I may make appropriate changes to my records. For more information, see the policies on classroom behavior and the student code.

Discrimination and Harassment: The University of Colorado Boulder (CU-Boulder) is committed to maintaining a positive learning, working, and living environment. CU-Boulder will not tolerate, both in-class and outside of class, acts of sexual misconduct, discrimination, harassment or related retaliation against or by any employee or student. CU's Sexual Misconduct Policy prohibits sexual assault, sexual exploitation,

sexual harassment, intimate partner abuse (dating or domestic violence), stalking or related retaliation. CU-Boulder's Discrimination and Harassment Policy prohibits discrimination, harassment or related retaliation based on race, color, national origin, sex, pregnancy, age, disability, creed, religion, sexual orientation, gender identity, gender expression, veteran status, political affiliation or political philosophy. Individuals who believe they have been subject to misconduct under either policy should contact the Office of Institutional Equity and Compliance (OIEC) at 303-492-2127. Information about the OIEC, the above referenced policies, and the campus resources available to assist individuals regarding sexual misconduct, discrimination, harassment or related retaliation can be found at the OIEC website.

Honor Code: All students enrolled in a University of Colorado Boulder course are responsible for knowing and adhering to the academic integrity policy of the institution. Violations of the policy may include: plagiarism, cheating, fabrication, lying, bribery, threat, unauthorized access, clicker fraud, resubmission, and aiding academic dishonesty. All incidents of academic misconduct will be reported to the Honor Code Council (honor@colorado.edu; 303-735-2273). Students who are found responsible of violating the academic integrity policy will be subject to nonacademic sanctions from the Honor Code Council as well as academic sanctions from the faculty member. Additional information regarding the academic integrity policy can be found at http://honorcode.colorado.edu.