Syllabus MAE 207 – Uncertainty Quantification (Spring 2021)

Synopsis: Today's models for complex systems are often in form of partial differential equations (PDEs) with a large state dimension, and many parameters (e.g., material constants, viscosities in flows, boundary conditions, etc.) that are only measurable and known up to some variance. The field of uncertainty quantification is concerned with understanding and recognizing this uncertainty in the models we use, and therefore takes a stochastic/statistical perspective. This course is an introduction to uncertainty quantification and will cover both basic and advanced methods to dealing with uncertainties in simulation. We will start with basics in statistical modeling and the central limit theorem, then cover Monte Carlo sampling techniques and Sensitivity analysis (Sobol indices), move towards Polynomial Chaos expansions, Stochastic Galerkin methods and then also cover dimensionality reduction through Principal Component Analysis. The last part of the course covers the thinking of Bayes' Theorem and the related Bayesian sampling methods (e.g., Markov Chain Monte Carlo).

- Course Coordinator: Prof. Boris Kramer (<u>bmkramer@ucsd.edu</u>)
- Teaching Assistant:
 Ms. Liezl Maree (<u>Imaree@ucsd.edu</u>)
- Class schedule: Tu/Th 8:00a 9:20a PST (San Diego Time)
- **Zoom Class Info**: Before the first class, you need to register at: <u>https://ucsd.zoom.us/meeting/register/tJYtf-</u> <u>2pqD0oH9ZKL1UKUtuu6qOG30i02-Vu</u> (Password: UQ-S21) Once registered, you can use <u>https://ucsd.zoom.us/j/92084166252</u> every time to join class. Class sessions will be also recorded and made available to students asynchronously (available in Canvas within 24h of recording).
- Zoom office Hours: Fr 8a 9.30a (Prof. Kramer) https://ucsd.zoom.us/j/92268964380
- **Prerequisites:** Good knowledge of Linear Algebra.
- **Software:** MATLAB/Python will be used as the standard computing environment and proficiency is required. You can get a Total Academic Headcount (TAH) license (free for students) from <u>https://matlab.ucsd.edu/student.html</u> and install MATLAB on your own computer.

E-mail communication: In an e-mail to instructor or TA please put "MAE207" first in the subject line.

Textbooks/Materials: We will draw topics from a wide range of journal articles and several textbooks. The books below are excellent resources, but not strictly required.

- 1. Smith, Ralph C.: Uncertainty Quantification: Theory, Implementation, and Applications. SIAM (2013), https://my.siam.org/Store/Product/viewproduct/?ProductId=24973024
- 2. Owen, Art: Monte Carlo theory, methods and examples. Free pdf: <u>http://statweb.stanford.edu/~owen/mc/</u>
- 3. Sivia, D.S. and Skilling, J.: Data Analysis: A Bayesian Tutorial, OUP Oxford, 2nd edition, 2006.
- Robert, Christian P., and Casella, George: Monte Carlo Statistical Methods, Springer, 2004, (free link to chapters) <u>https://link.springer.com/book/10.1007/978-1-4757-4145-2</u>
- 5. Sarkka, Simo: Bayesian Filtering and Smoothing, Cambridge University Press, 2013 https://doi.org/10.1017/CBO9781139344203

Homework: This is a very important part of this course. There will be about 3-4 homework assignments. You can work together on homework problems, but your final write up must be your own work, done independently. Late assignments within 24h of due date will be graded but the points reduced by 50%. Assignments past 24h of the deadline will get zero points..

Term Project: Various potential subjects for term project will be provided. However, students are strongly encouraged to propose their own ideas for a term project, that would connect/apply uncertainty quantification to their research area. Approval for term project proposals is not automatic. A clear connection to the class material needs to be established and the work cannot be work that the student already gets 299 ("Research") credit for

by their advisor. Details of the term project requirements and expectations will be discussed during the quarter. Teams of two students are also possible, but the project scope will then be more comprehensive than just a single student project.

Grading: Homework 50% Term Project 50% A 90% will guarantee an A-, 80% a B-, 70% a C- and 60% a D. Re-grade requests need to be made within 48h of the return of the assignment. Appeals outside of this time frame will not be considered.

Missing a graded assignment: If <u>for a documented reason</u> you cannot turn in your homework, then the remaining N-1 homework results will determine your homework grade. If <u>for a documented reason</u> you cannot participate in the final project, the instructor reserves the right to assess your grade based on an oral exam.

Academic Integrity is expected of everyone at UC San Diego. This means that you must be honest, fair, responsible, respectful, and trustworthy in all of your actions. This is especially relevant now that we hold our classes and exams online. Dishonesty will not be tolerated because it undermines learning and the University's ability to certify students' knowledge and abilities. You can learn more about academic integrity at academicintegrity.ucsd.edu.

Copyright: My lectures and course materials, including PowerPoint presentations, tests, outlines, and similar materials, are protected by U.S. copyright law and by <u>University policy</u>. I am the exclusive owner of the copyright in those materials I create. You may take notes and make copies of course materials for your own use. You may also share those materials with another student who is enrolled in or auditing this course. You may not <u>reproduce, distribute or display (post/upload)</u> lecture notes or recordings or course materials in any other way — whether or not a fee is charged — without my express prior written consent. You also may not allow others to do so. If you do so, you may be subject to student conduct proceedings under the UC San Diego Student Code of Conduct. Similarly, you own the copyright in your original papers and exam essays. If I am interested in posting your answers or papers on the course web site, I will ask for your written permission.

Last Updated: March 23, 2021. The course coordinator reserves the right to change the syllabus at any time.