MIE1613H: Stochastic Simulation (Winter 2024)

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- Office hours: By appointment
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- Lectures: Tuesdays, 6-9PM, Room: BA 2165

Course description and prerequisites

This course is a graduate level introduction to modelling and analysis of stochastic dynamical systems using computer simulation. The course provides a rigorous yet accessible treatment of the probability and statistical foundations of simulation, and covers programming simulation models in a lower-level language (Python). Throughout the course, concepts and methods are illustrated using various examples from different application areas. In particular, applications to service and financial engineering are emphasized. More specifically, the following topics are covered:

- **Probability and Statistical Foundations of Simulation:** Law of Large Numbers; Central Limit Theorem; Large Deviation; Statistical estimation of expected value, probability, and quantiles; Quantifying estimation error using confidence intervals; Maximum Likelihood Estimation; Method of Moments; Bootstrap; Bias-Variance tradeoff.
- **Simulation Programming:** Programming discrete-event simulation models using object oriented programming in Python.
- **Simulation Methodology**: Input modelling; Random variate generation; Input uncertainty; Output analysis; Design of experiments; Comparing alternative scenarios; Importance Sampling; Variance Reduction.
- **Simulation Optimization:** Common Random Numbers (CRN); Sample Average Approximation (SAA); Ranking and selection; gradient estimation for continuous simulation optimization.

Students are expected to have a strong background in undergraduate-level probability and statistics, and be familiar with a general purpose programming language. Familiarity with stochastic processes would be helpful but not required. Students are required to use Python for the homework and project.

Textbook and other resources

- Textbook (required):
  - – Nelson, Barry, and Pei Linda. Foundations and methods of stochastic simulation: A first course. Second edition. Springer Science & Business Media, 2021. (Available online at https://link.springer.com/book/10.1007/978-3-030-86194-0). See also the textbook's website including slides and code: http://users.iems.northwestern.edu/ nelsonb/IEMS435/ [very helpful]
- Masterclass: Ranking & Selection for Simulation Optimization by Barry L. Nelson.
  - – Available at: http://users.iems.northwestern.edu/ nelsonb/RSMasterclass.html
- Supplementary references:
  - – Botev, Z., Keller, A., Lemieux, C., & Tuffin, B. (Eds.). Advances in Modeling and Simulation: Festschrift for Pierre L'Ecuyer, 2022. Springer Nature. (Available online at: https://link.springer.com/book/10.1007/978-3-031-10193-9)
  - – Asmussen, Soren, and Peter W. Glynn. Stochastic simulation: algorithms and analysis. Springer Science & Business Media, 2007. (Available online at https://link.springer.com)
  - – Glasserman, Paul. Monte Carlo methods in financial engineering. Springer Science & Business Media, 2003. (Available online at http://library.utoronto.ca)

Evaluation

- 30% Homework (two homework assignments; see table on next page for tentative due dates)
- 35% Project (Assigned by January 28st; Proposal due by March 11; final report deadline to be announced; Preliminary presentations on April 1th and if needed April 8th) The project is intended to give you the opportunity to apply the methods and ideas from the course to your own research r application area of interest, or explore other advanced topics in simulation modelling or simulation optimization and/or their integration with other methodologies.

- 35% Exam (In-class, closed book; tentatively on March 25th)
- Class and Piazza participation is strongly recommended

Tentative course schedule

Date	Topic	Homework/Project
Jan 7	Intro to stochastic simulation	
Jan 14	Simulation examples (1)	
Jan 21	Simulation examples (2)	
Jan 28	Programming in Python Sim	
Feb 4	A framework for simulation modelling and analysis Simulation input - input modelling and estimation	Homework 1 Due
Feb 11	Simulation input - random variate generation	
Feb 18	**Reading week (no class)**	
Feb 25	Simulation output, Design of simulation experiments	
March 4	Simulation optimization - Intro, CRN, SAA	Homework 2 Due
March 11	Simulation optimization - ranking and selection	Proposals due
March 18	Simulation optimization - gradient estimation	
March 25	Exam	
April 1	Student presentations	
April 8	Student presentations (tentatively)	