COURSE DESCRIPTION
CS482/IE413 Computer Simulation
Spring 2024 In Person: MW 3PM-3:50PM, MW 4PM-4:50PM DCL 1310
***** Tentative*****

Instructor: Sheldon H. Jacobson, Siebel Center 3224
Office Hours: Monday via zoom, after class until 440PM. Send an email to shj@illinois.edu to let me know you are planning to come to office hours. It takes me around five minutes to activate the link.
Professor Jacobson's Course Zoom Link:
https://illinois.zoom.us/j/87378686620?pwd=ZU5UUTljOGdlZ045YVE0Y0FUOVFrZz09

(Passcode: 121212)

Teaching Assistant (TA): Kiera Dobbs
Office Hours: (TBD)
Course Email: cs482.ie413@gmail.com
Text: "*Discrete Event System Simulation* (any edition) by Banks, Carson, Nelson, Nicol (Prentice Hall). This book contains much of the material covered in the second and third parts of the course. You are not required to purchase it, but it is useful for those who like to have a textbook.
Canvas: Course material will be available on the course Canvas web site.

Zoom Etiquette: Please use your video during all zoom calls with myself, and the TAs (if they ask).

Course Objective: This course is intended to be an introduction to and survey of data analysis in discrete event simulation. By the end of the course, you should have a fundamental understanding of discrete event simulation modeling, with an eye on how to apply data analysis methodologies to solve problems in system design and evaluation using simulation. The course is structured to educate and train you in the practice and philosophy of discrete event simulation and the associated data analysis. Designing simulation models is an art; data analysis in simulation models is a science.

Prerequisites:
Knowledge of Python
- You will do programming in this course.
- General programming concepts will not be taught in this course.

Introduction to Probability and Statistics, or equivalent (essential)
Introduction to Operations Research, or equivalent (helpful, though not required)
NOTE: You must have the Probability and Statistics prerequisite to take the course.
- If you earned a B+ or higher in the Probability and Statistics course, you should be prepared to take this course.
- If you earned a B in the Probability and Statistics course, you may need to thoroughly review their material, since all their material will be assumed to be known.
- If you earned a B- or lower in the Probability and Statistics course, you will likely find this course extremely difficult and may wish delaying taking the course at this time. This is based on past experience.

The **proficiency exam** posted on Canvas will provide you with a tool to assess the prerequisite knowledge needed to be successful in this course. If you did not perform well on this test, please speak with me during my office hours. If you do not speak with me by 29 January 2024, I will assume that you scored well on the proficiency exam and are comfortable with the prerequisite material.

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ISE Undergraduates: The ISE department has created a simpler version of this course for IE undergraduates (IE371) who are not prepared for a rigorous course on simulation modeling and analysis.

General Topics:

System and Simulation Modeling	(4-5 weeks)
Generation and Data Analysis of Random Numbers	(3-4 weeks)
Statistical Analysis of Simulation Output Data	(3-4 weeks)

See the end of this syllabus for a more detailed breakdown of course topics.

Groups: Your assignments and final project will be done in groups of one, two, or three, which you are responsible for forming on your own. Send an email to cs482.ie413@gmail.com with a list of your group members, including NetIDs, no later than 2:59:59 p.m. CST, 25 January 2024, and CC all group members. **If we do not receive an email from you by this date/time with all the requisite information, then by default you will work on your own**. Each group member is responsible for the well-being of their group activities, for finding a way to work with the other members in their group, and for any document(s) that they submit or presentations that they make. Therefore, be involved to avoid unexpected surprises. Also, if information is obtained that the effort made by a group member is problematic, differential grades may be assigned for the assignments and/or the project. If one or more group members drop the course, the remaining group member(s) will constitute the group; groups cannot be merged under such circumstances. However….

Group Pivot: After the third assignment, you can choose to leave your group. This decision should be communicated to the TAs and your other group member(s) no later than 2:59:59PM CST, 28 February 2024 (via email to cs482.ie413@gmail.com, and CC the remaining group members). If you leave your group, you will work alone on the fourth and fifth assignments and the project.

Course Project: There is a final course project worth 35% of your final grade. Your project group is responsible for designing its own project. Submit a one-page summary of your proposal for approval (the sooner the better) via email to cs482.ie413@gmail.com. Do not begin your project until it has been approved. Allow up to one week for your project to be approved. The final project submission must be submitted on Canvas no later than **2:59:59 p.m. CST, 24 April 2024**. Follow the project guideline sheet to prepare your project final report and to create a YouTube video of your project. Note the late policy for the final project submission on the project guideline sheet (which will be posted on Canvas). The project can be done with any computer language or simulation software package.

Assignments: You will be given five assignments during the semester (with the n^{th} assignment worth n% towards your final grade, n = 1,2,3,4,5). You should do the homework assignments in the same group as your project group and prepare one assignment for the entire group (note the Group Pivot described above). You must prepare all your assignments during the semester with this group. Assignments must be received by 2:59:59 p.m. CST on the designated due dates and should be submitted on Canvas; late assignments cannot be accepted, under any circumstances and for any reason. When a simulation is required in an assignment, you may use any computer language or simulation software package.

Exams: There will be two exams (the first exam will be in early March, the second exam will be held in April.) There will be no final exam during the final exam period. Each exam will be weighted 25% towards your final grade. Exams will only be given during the designated time windows.

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If you feel that you deserve additional credit on your exam, write an explanation on separate pieces of paper where and why you deserve more points, how many additional points you deserve, and return the explanation, with your exam, to the course email address given above within 48 hours of when the exam is first returned. Note that if you hand your exam back to be regraded, return the entire exam, since the entire exam may be regraded, including the questions that you specifically asked to be regraded. Exams should not be altered or written on once returned to you. Any alterations of an exam handed back for regrade may result in penalties.

If you miss both exams, you will earn a failing grade in the course.

If you miss one exam, the points for the missed exam(s) will be added to your project grade. This means that if you miss one exam, your project with be worth 60% of your final grade. If you exercise this option, you must also complete the project by yourself (with the remaining group members completing their project together on their own). You can continue to submit any remaining assignments with your group.

Final Grades: Final grades are determined based on absolute breakpoints (there is no curving):
Undergraduate students:

84%->100% =A range, 74%->83.999% =B range, 67%->73.999% =C range, 60%->66.999% =D range

Graduate students:

84%->100% = A range, 74%->83.999% = B range, 67%->73.999% = C range.

A final total score below 60% will earn a failing grade in the course for undergraduate students, and below 67% will earn a failing grade in the course for graduate students.

Classes Times: In-person lectures may be as much as 90 minutes. Lab sessions devoted to the simulation software will be scattered throughout the semester during lecture times.

Graduate students (4 credits) versus undergraduate students (3 credits): Graduate students may have additional questions on one or both of their exams.

Class Attendance: You are not required to attend lectures. Experience has shown that students who stay engaged also perform better in the course. Also, stay tuned-in to the Canvas course page for announcements.

Cell Phones: As a courtesy to others, during in-person lectures, please put your cell phone in silence mode or off during all classes, to limit disruptions that affect other students.

General Comments:

- Lectures do not match the book and its presentation very closely. There are a number of concepts covered in the book that I will not cover, and vice versa. Therefore, it is in your best interest to attend, since you will be responsible for all the material covered in the lectures.
- Do not leave the final project until just before it is due. As material is covered in the course, you will incorporate this information into your project sequentially. This hands-on experience with a comprehensive simulation model will make understanding the course material much easier.
- The work you hand in on your exams should be your work alone. The work that you hand in as part of a group should be the group's work alone. Any violations of this policy will result in penalties for all individuals involved, even if they are not aware of such activities.

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- If you are having problems with the course, come and discuss the situation with me as soon as possible. It is very difficult to find solutions in mid-April, while feasible plans can be identified in early February.
- **Students requiring DRES accommodations**: Please contact me no later than 7 February 2024 to discuss your situation. If I do not hear from you within this time frame, I will assume that you do not require any extra accommodations and have chosen to opt out of any such accommodations.
- The exams are designed to test your understanding of simulation concepts, while the assignments and final project provide you with the experience to perform hands-on simulation modeling and data analysis. Therefore, the best way to prepare for exams is to follow what is being presented in the lectures, work through the assignments and the project example, and listen to what I emphasize.
- If the material seems too abstract or unrelated to the real-world, then I have probably forgotten to tell you something. Ask where or how the material can be applied.
- Discrete event simulation is typically applied in manufacturing and queueing-like systems, such as those found in the service, telecommunication, computer networking, or transportation industries; examples of these types will be used.
- Have fun! Simulation is an open-ended discipline. You can make it as interesting as you choose.

TOPICS TO BE COVERED

General Introduction to Simulation (3 Hours):
- Why simulate?
- Steps in a simulation study
- Definitions (system, entities, attributes, hierarchy, laws, policies, ...)

(Objectives: * Identify when and where to use simulation
* Explain the steps in a simulation study
* Identify the components of simulated systems)

Discrete Event Simulation Models (6 Hours):
- Events, states
- Structure of simulation programs, linked lists, event list management
- Model validation and verification
- Simultaneous events and event priorities
- Dynamic versus static models
- Relation to queueing models

(Objectives: * Identify the building blocks of simulation models
* Describe how to build a simulation model
* Describe how to execute a simulation model
* Explain how to check the validity of a simulation model
* Explain how to verify that simulation model code accurately represents the simulation model
* Explain how to set event execution priorities
* Explain the difference between dynamic and static models
* Explain the relationship between simulation models and queuing models)

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Event Graphs (5 Hours):
- Structure of event graphs (nodes, arcs)
- Event graph reduction
- Examples
  (Objectives: * Explain what an event graph is
  * Construct event graphs of simulation models
  * Explain how event graphs can be reduced)

Pseudo Random Number Generators and Data Analysis (PRNG) (5 Hours):
- Desirable properties, Bad and good methods
- Linear congruential generators (LCG)
- Analyzing PRNG data for uniformity and independence
  (Objectives: * Explain why PRNGs are needed in simulation models
  * Describe and explain desirable properties of PRNGs
  * Distinguish between good and bad PRNGs
  * Construct good LCGs, and analyze their data to assess their quality
  * Describe statistical tests for uniformity & independence, and apply such tests to data sets)

Non-Uniform Random Number Generation (5 Hours):
- Why are they needed?
- Driving a simulation
- Choosing input distributions
- Random Number Generation Methods and Analysis
  - Method of Inversion
  - Acceptance/Rejection Method
  - Special properties (Erlang, Poisson, Poisson Processes, …)
  - Discrete distribution methods (Alias, Marsaglia, …)
  - Normal random variates
  (Objectives: * Explain why non-uniform random number generation is needed
  * Explain what it means to drive a simulation model
  * Explain how to choose an input distribution, and perform statistical test to assess whether the distribution is correct
  * Describe and implement various methods of transforming U[0,1] values to more general distributions)

Statistical Analysis of Simulation Output Data Analysis (6 Hours):
- Classical versus non-classical statistics
- Terminating versus steady state simulations
- Initial transient data problem (initialization bias, Welch's method)
- Confidence interval and variance estimation (tradeoffs)
  - Method of Replication, Method of Batch Means, Regeneration Method
  (Objectives: * Explain why simulation output data analysis cannot directly use classical statistics
  * Distinguish between terminating and steady state simulations

* Explain the initial transient data problem for steady state simulations, and apply a statistical method to address it
* Compute mean, variance, and confidence interval estimators for terminating and steady state simulation output data)

Variance Reduction Techniques (VRT) (3 Hours):
- Correlation induction in simulation output data streams
- Common random numbers (CRN) and Antithetic random numbers (ARN)
- Control variates

(Objectives:
* Explain why VRT are needed
* Describe how and when to use CRN and ARN
* Describe how to define a control variate
* Explain how to check whether a variance reduction is likely to occur)

Monte Carlo Simulation (2 Hours):
- Definition and Application

(Objectives:
* Explain what a Monte Carlo simulation experiment is
* Explain how and when Monte Carlo is applied
* Apply statistical methods using Monte Carlo simulation data)