American University of Beirut
Maroun Semaan Faculty of Engineering and Architecture
Department of Industrial Engineering and Management

INDE 504 Discreet Event Simulation

Fall 2023, CRN 11747 , TTh 9:30 AM - 10:45 PM (Bechtel 110).
Lab sessions TTh 11:00 AM - 12:15 AM (IOEC 518)

Instructor
Bacel Maddah
Office: Bechtel 319B
E-mail: bacel.maddah@aub.edu.lb. Office phone: 01 350 000 Ext. 3551.
Webpage: `https://sites.aub.edu.lb/bacel/`
Office hours: Thu 12:30 PM - 2:00 PM.

Lab Instructor
Maysaa Jaafar
Office: SRB 402
E-mail: mj73@aub.edu.lb. Office phone: 01 350 000 Ext. 3569.
Webpage: `http://www.aub.edu.lb/pages/profile.aspx?memberId=mj73`
Office hours: TBA

Course Description and Objectives
Simulation is concerned with developing computer models that mimic the behavior of real systems. This is done through the generation of "random variates" that replicate the statistical properties of a system. Simulation falls under the umbrella of Operations Research. The objective of simulation (like other OR models) is to gain insight into the real system with the ultimate goal of enhancing performance. Simulation is generally used when analytical methods are not effective (i.e., the model cannot be developed with closed-form mathematical expressions). It is also used for validating analytical models. As such, simulation is one of the most popular decision making tools used by analysts in OR and related disciplines. The objective of this course is to introduce the student to the main ingredients of a successful simulation study. Students will learn how to (i) process input data for a simulation model; (ii) develop a simulation model on a computer; and (iii) analyze the output of the simulation. Simulation models will be developed using the simulation software Arena, Python pacakges (e.g. SimPy), and @Risk (Excel add-in). Financial, logistic, manufacturing, and service applications will be emphasized.

Textbooks

1. Banks, J., J. S. Carson, B. L. Nelson, and D. M. Nicol. *Discrete-Event System Simulation*, 5$^{\text{th}}$ Edition. Prentice-Hall, 2009. (BCNN)

2. Kelton, W. David, Randall P. Sadowski and Nancy Zupick. *Simulation with Arena*. 6$^{\text{th}}$ Edition. McGraw Hill, 2014. (KSZ)

Grading

Homework	20%
Lab Exercises	10%
Project	30%
Final Exam	40%

Additional References

1. Law, Averill M. *Simulation Modeling and Analysis.* 5^{th} Edition. McGraw Hill, 2015.
2. Hillier, F. S. and G. J. Lieberman. *Introduction to Operations Research*, 8^{th} Edition. McGraw-Hill, 2004.
3. Ross, S. M. *Introduction to Probability Models*, 8^{th} Edition. Academic Press, 2002.
4. Ross, S. M. *Simulation*, 3^{rd} Edition. Academic Press, 2001.
5. Taha, H. A. *Operations Research: An Introduction.* 8^{th} Edition. Prentice Hall, 2007.

Learning Outcomes

- Identify sources of randomness in a system and utilize probability distributions to model them.
- Develop the successful ingredients of a discrete-event simulation.
- Carry-out input analysis (by hand and via software) to fit probability distributions to real data.
- Understand and analyze the performance of modern random number generators (RNGs).
- Develop algorithms for generating random varietes based on fitted distributions and RNGs.
- Conduct statistical analysis of a simulation output.
- Apply all of the above to design bulletproof system simulations in a process-oriented software environment (Arena).
- Develop knowledge of Python packages to relate simulation and data science.

Tentative Schedule
Topics will be covered according to the following schedule.

1. Course introduction, OR modeling approach, simulation overview. Review of Probability Theory and Random Variables. A primer on queueing theory. Introduction to Arena. Inroduction to Python. (Chs. 1-6 BCNN; Ch 3 KSZ)
2. Introduction to discrete event, Monte Carlo, and process oriented simulation. Hand simulation of a queueing and an inventory system. Introduction to Monte Carlo simulation in @Risk. (Chs. 1-6 BCNN)

3. Input Analysis. Collecting input probability distributions, estimation of parameters, MLE estimators goodness of fit tests, Chi-Square, Kolmogorov-Smirnov. Input Analysis in Arena and ExpertFit. Distribution fitting in Python. (Ch 9, BCNN; Ch 4 KSZ; web resources)

4. Random number generators. Linear congruential generators (mixed and multiplicative), more general combined generators, tests for random numbers. Modeling basic systems with Arena and SimPy (Python). (Ch 7 BCNN; Ch 4 KSZ; web resources)

5. Generating random variates. Methods, inverse transform, convolution, composition methods, acceptance-rejection. Application to well-known distributions and processes, generating from Normal, Gamma and arrival processes. Modeling detailed operations with Arena and SimPy (Python). (Ch 8 BCNN; Ch 5 KSZ; web resources)

6. Output analysis. Statistical estimation, confidence intervals, termination rules, variance reduction technique, comparing multiple system designs. Output analysis in Arena. (Chs. 11-12 BCNN, Ch 6 KSZ)

7. **Class presentation of student projects.** (Thursday, November 30 from 9:30 AM to 12:30 PM).

8. **Final exam** (as scheduled by the registrar's office).

Homework

Homework will be assigned frequently. It will involve conceptual problems from BCNN book and Arena applications from KSZ book. All students are encouraged to solve the homework problems, and to discuss them with each others and the instructor. However, every student must write and submit the homework assignment individually. the output of Arena or Excel spreadsheets. Certain assignments require uploading Arena files. Doing the homework is the best way to excel in this course.

Project

The project involves simulating a real system with complete input analysis, model development in Arena and output analysis with suggestions for improvement. Possible ideas include simulating traffic, parking systems, port and airport operations, computer and communications networks, call centers, supermarket check-out lines, doctor clinics, pandemic diffusion and the effectiveness of intervention policies, emergency rooms, emergency response, construction operations, manufacturing systems, games, or any *interesting* system you find. You should work in groups of three. (If the class size is not divisible by three, the least possible number of groups of size four will be allowed on a FCFS basis.) **A one-page proposal for the project is due on Tuesday October 3, 2023.** In this proposal, you briefly describe the system you want to simulate and the objective of the simulation study. Upon reading your proposals, I will either accept your proposal or ask you to look for another idea. In the last week of classes, you are required to do a 15-minute presentation of your project. You must also submit a written report not exceeding 15 pages, double-spaced, font 12, ample margins, and containing an abstract, an introduction and a conclusion section.

Attendance Policy and Class Management

Attendance will be noted utilizing random sampling.[1] Late arrivals are not allowed. The class door will be closed at 9:30 AM sharpt. So-called “smart” phones are not allowed in class.

Course Website

`https://sites.aub.edu.lb/bacel/inde-504/`

Look for assignments and slides presented in class there. A Moodle page is also there for the lab component of the class.

[1] I'll call on one quarter of the students at random in every session. There is a 25% chance that your name is called in a given session. With approximately 28 sessions in the semester, there is a 98.3% chance that your name will be called more than two times in the whole semeste. So, the probability of missing all sessions and not getting penalized is 1.7%.