ES 280: Systems Engineering

Syllabus â€“ August 2018

Harvard School of Engineering and Applied Sciences

Learning Goals

After completing the course, students will be able to:

1. Perform statistical inference calculations to determine the likelihood and significance of experimental data, and design simple experiments to compare prospective treatments.
2. Create models of the dynamics of complex engineering and business systems, using both differential equations descriptions and block-diagram computer simulations. They will understand the role of subsystem interactions (e.g. positive and negative feedback, delays) and be able to recognize the classes of system behavior (e.g. logistic growth, instability, oscillations). They will be able to use these models to explore the relative importance of system parameters and to determine the robustness of model predictions.
3. Design systems that include the interaction of diverse components, using modeling tools to determine relative performance of alternative system configurations and parameter values.

Format and Schedule

- Thirteen meetings from Tues. Aug. 7 through Thurs. Aug. 23, 2018.
- Daily class 9:00 am to noon (lectures, in-class problem solving, hands-on exercises, etc.) in Pierce Hall 301, except for August 9, 10, 13 and 14, which will be in Maxwell Dworkin Room G125.
- Lunch will be provided after class on Wednesday, Aug. 15 and Thursday, Aug. 23.
- Attendance is required for all class meetings.
- Afternoons and evenings will be used for office hours, team meetings, study groups, etc.
- Team project work during the second weekend (Saturday, Aug. 18 and Sun. Aug. 19)

Staff

Instructors

- Robert Howe, Professor of Engineering and Faculty Co-Chair of the MS/MBA Program, Harvard School of Engineering and Applied Sciences (SEAS)
  howe@seas.harvard.edu, 617-877-0930 (mobile), Pierce Hall 323
- Venkat Venkatasubramanian, Professor of Engineering and Co-Director of the Center for the Management of Systemic Risk at Columbia University and Visiting Professor at SEAS, Pierce Hall 120
  venkat@columbia.edu

Teaching Fellows

- Buse Aktas, SEAS doctoral student, buseaktas@g.harvard.edu, Room 312, 60 Oxford St.
- Resmi Suresh, Columbia University - Post-Doctoral scholar, rsm2189@columbia.edu

Evaluation

- Problems sets 40%
- Final Exam 25%
- Team project 25%
- Class participation 10%
  (attendance, team peer evaluations)

Textbook

- **Statistics:** David M. Diez, Christopher D. Barr, and Mine Cetinkaya-Rundel, *OpenIntro Statistics* 3rd Edition. *Free pdf download:* https://www.openintro.org/stat/textbook.php?stat_book=os
- **Business dynamics:** Sterman, J. *Business Dynamics: Systems Thinking and Modeling for a Complex World*, McGraw-Hill /Irwin, 2000. - *purchase*
- **Controls:** Seborg DE, Mellichamp DA, Edgar TF, Doyle III FJ. Process dynamics and control. John Wiley & Sons. *Five copies will be kept in Pierce 301 â€“ please do not remove from classroom!*

Software

- MATLAB will be used in the problem sets to develop simulations - see FAS software downloads http://downloads.fas.harvard.edu/download
- VensimPLE modeling software (free educational version) will be used for modeling complex systems, http://vensim.com/vensim-personal-learning-edition/

Homework Policy

The assignments are intended to provide practice working with key concepts, and hence to prepare for the exam â€“ and eventually, for use in professional life. We thus encourage collaboration and discussion of the course material; however, violations of academic integrity (such as direct copying of othersâ€™ work) will be sanctioned.

An ideal procedure for completing the problem sets is to first complete the assigned reading and review the lecture notes, then work with a group of students to explore the solution methods. Once the group separates, individuals write up their own solutions. This ensures that everyone understands the solution methods and precludes the appearance of plagiarism.

- **You must write up your own problem sets, and acknowledge those you worked with at the top of your solutions.**
- **Problem sets will be due at the beginning of class; no late submissions will be accepted.**

Topics

I. Probability and statistical inference

1. Probability distributions: uniform, binomial, normal; simulation of distributions
2. Inference: z tests, t tests
3. Experimental design; A/B testing
4. Linear modeling/Regression
5. Statistical process control

II. System dynamics and modeling [Following Stermanâ€™s *Business Dynamics*]

1. Introduction
    1. Examples of system dynamics and typical behaviors [chapt. 2,4]
    2. The modeling process [chapt. 3]
2. Causal loop (block) diagram modeling [chapt. 5]
3. Stocks and flows [chapt. 6,7]
4. Feedback and first-order systems [chapt. 8]
5. Logistic growth, positive feedback, delays [chapt. 9,10,11]
6. Instability and oscillation [chapt. 17]
7. Examples: Manufacturing and labor supply chains [chapt. 18,19]
8. Model testing and validation [chapt. 21]
9. Management flight simulators [throughout]

III. Design

1. Design process introduction
2. In-class design exercise
3. Team design project