ORIE 4580/5580: Simulation Modeling and Analysis

ORIE 5581: Monte Carlo Simulation

Fall 2017

Sid Banerjee

School of ORIE, Cornell University

Essential Course Information

- *Instructor*

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  Office: 229 Rhodes Hall

- *Teaching Assistants*

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  Office hours: To be announced on Piazza

Essential Course Information (contd.)

- **Lectures**

  Course Number: ORIE 4580

  Class time: TR 1:25am-2:40pm

  Class location: Hollister B14

- **Recitation Sessions**
  1. Monday 12:20-2:15, 571 Rhodes Hall
  2. Monday 2:30-4:25, 571 Rhodes Hall
  3. Friday 11:15-1:10, 571 Rhodes Hall
  4. Friday 2:30-4:25, 571 Rhodes Hall
- **Course Communication**:

  Piazza: `https://piazza.com/cornell/fall2017/orie45805580combined`

  Website: `http://people.orie.cornell.edu/sbanerjee/ORIE4580/orie4580f17.html`

Course Resources

- **Course notes**: Will be uploaded on Piazza before class – you are encouraged to bring copies to annotate them.
- **iClicker** or iClicker App: Required - see course webpage for full details.
- **Textbook and References** The suggested textbook for the course is A. M. Law, Simulation Modeling and Analysis. For recommended reading, see syllabus. Other references are available on the course website.
- **Software** (Suggested) The assignments in the first half can be done in any high-level language; we recommend using Python and iPython/Jupyter notebooks.
  For the second half of semester, we will use a commercial simulation package, Simio.
  Both software will be available in Rhodes 453/571.

Homeworks

Weekly homework assignments (6 for ORIE 5581, 10 for the rest).

- All homework solutions must be submitted online on CMS. Students encouraged to *typeset* their solutions
- Homeworks due on Thursdays at 1pm (before class).
- **Collaboration**: You may do the homework individually or in pairs. Pairs must submit a single solution with both of your names and netids on the solution.
- **Late submissions and drops**:
  4 late days across homeworks (at most 2 late days per hw).
  ORIE 4580/5580 students can drop 2 lowest homework grade.
  (ORIE 5581 students can drop *one lowest grade*).

Grading

Prelim: October 12, 7.30pm **Final exam**: December 8, 2:00pm

ORIE 5581 students only do the prelim. For the prelim you may bring one sheet of notes; for the final you can bring in two sheets.

Component	4580/5580	5581
Clicker responses	4	4
Homeworks	25	35
Project	20	-
Prelim (Oct 12)	20	61
Final	30	-
Course Eval	1	-

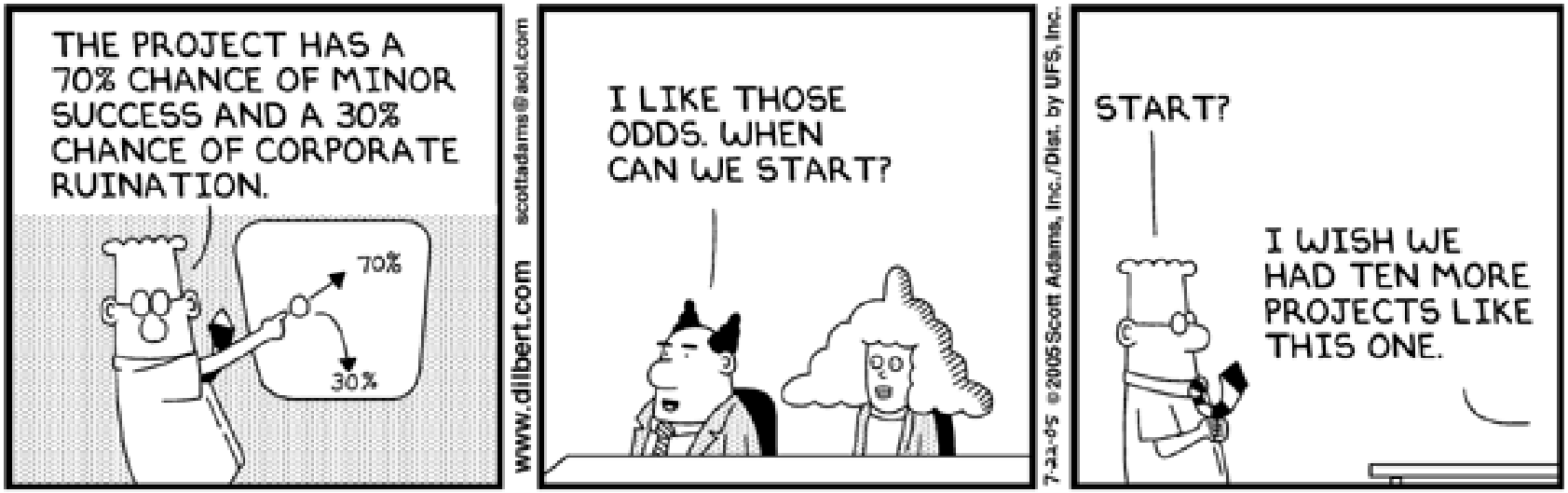
- Must get a $\approx 50\%$ in the final exam to pass this course
- Clicker response: Points are for participation, not correctness
- ORIE majors must get a grade of C or better for graduation

Why Study Simulation?

Stochastic simulation has four major applications

- **Numerical Computation**: Used for estimating difficult integrals for scientific computing purposes
- **Algorithms for massive data**: Sketching, streaming data, random-walk network algorithms, graphical models, etc.
- Risk Analysis: Quantifying and hedging against random 'shocks' in daily life
- 'What-if' Analysis: Understanding and optimizing complex systems in-vitro

Risk Analysis: Choosing Projects



What are the fundamental misunderstandings here?

- The project has a 70% chance of success. Why not try?
- Why not increase the chance of a success by doing 10?

Risk Analysis: Playing Blackjack

The book Bringing Down the House (made into the movie 21) showed how a team from MIT used card counting (a technique which lets you know when the odds are slightly in your favor) to win big in blackjack in Las Vegas.

- How do slightly favorable odds get turned into big winnings?
- What can go wrong (besides getting caught)?
- Why wouldnt you bet your entire retirement savings or college tuition on one hand?

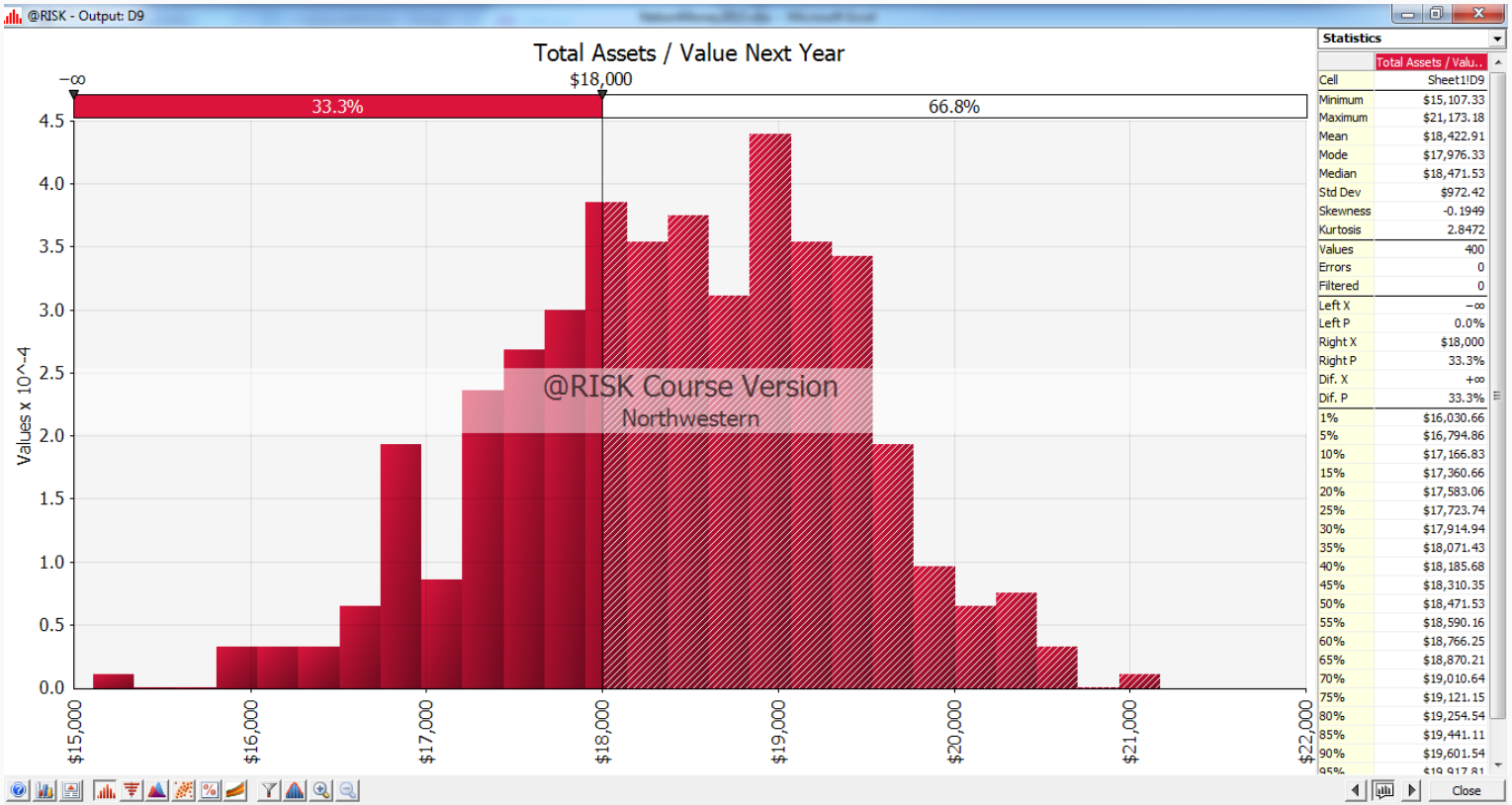
Risk Analysis: Why it Matters

- Most people do not understand risk.
  - Long-run vs. one-shot risk
  - A single project vs. a portfolio of projects
  - Correlated vs. independent risks

  What are the fundamental misunderstandings here?
- Of the people who understand risk, many fewer can quantify it; fewer still can explain it to 'most people'.
- If you can understand, quantify & explain risk, then you can hedge against it.

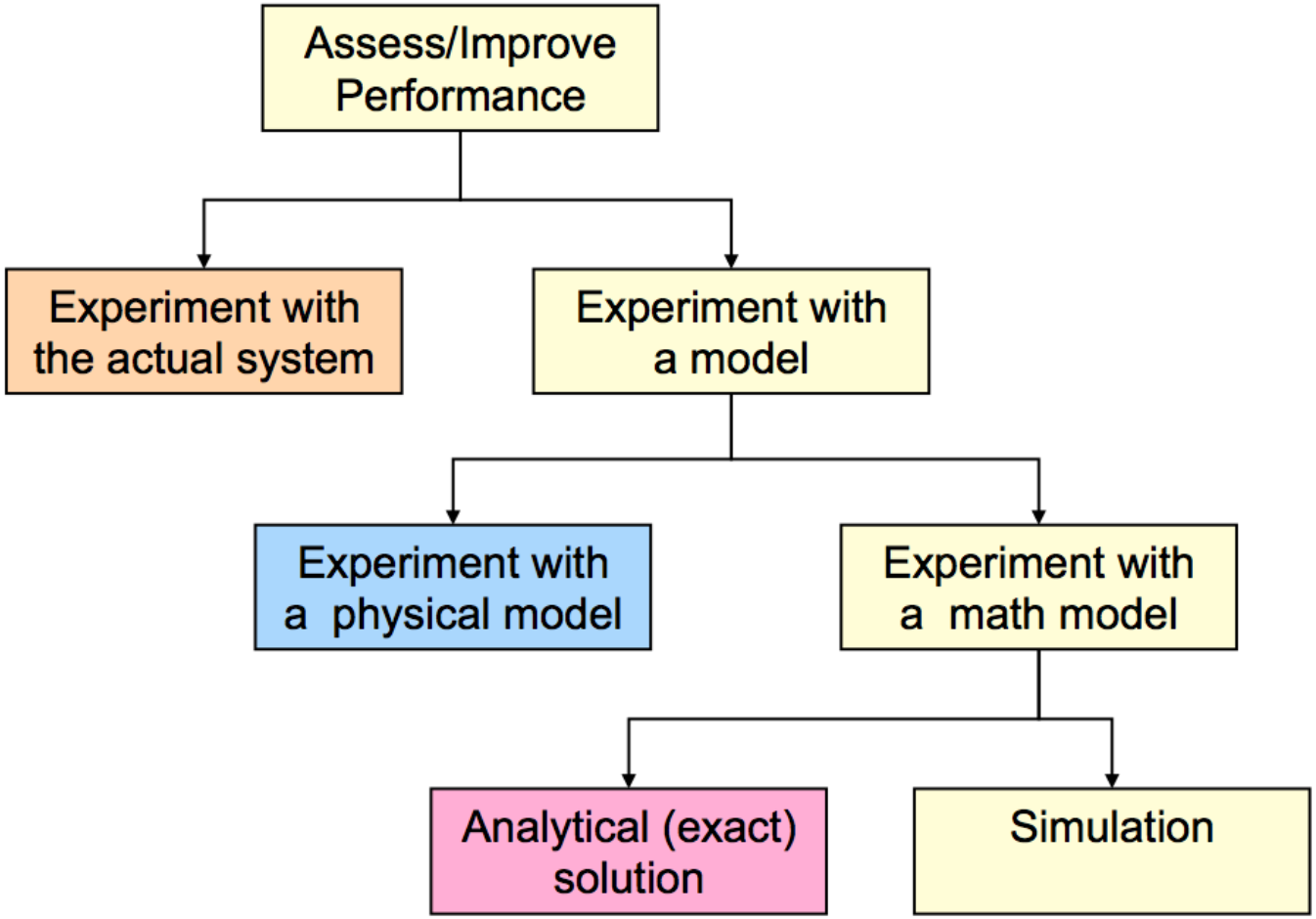
Risk Analysis: Tools

Monte Carlo simulation: systematic way to analyze risk



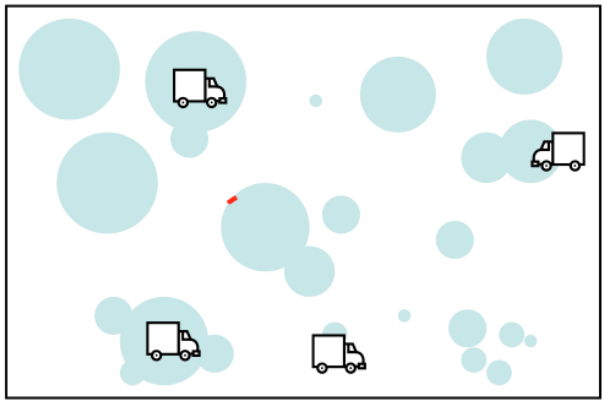
Counterfactual Analysis: System Optimization

Assessing and Improving System Simulation

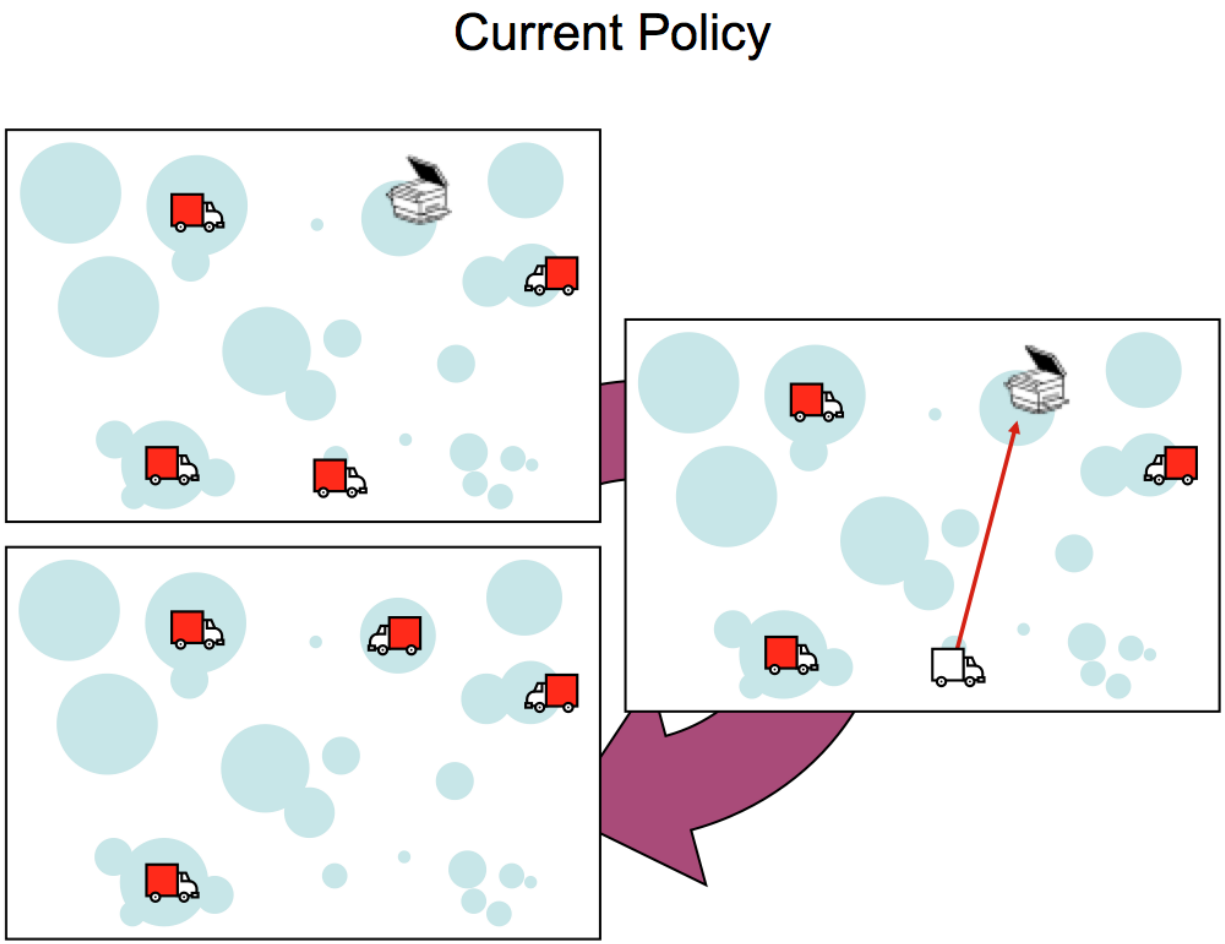


Counterfactual Analysis: System Optimization

- You are responsible for maintaining copiers dispersed throughout the city.
  - 24 customer locations, fleet of 4 repair trucks.
  - Each copier breaks every 2000 hours, on the average.
  - 1.5 hours to fix a copier, on the average.
  - Time to move between customer locations.
  - Each customer location has 30-50 copiers.



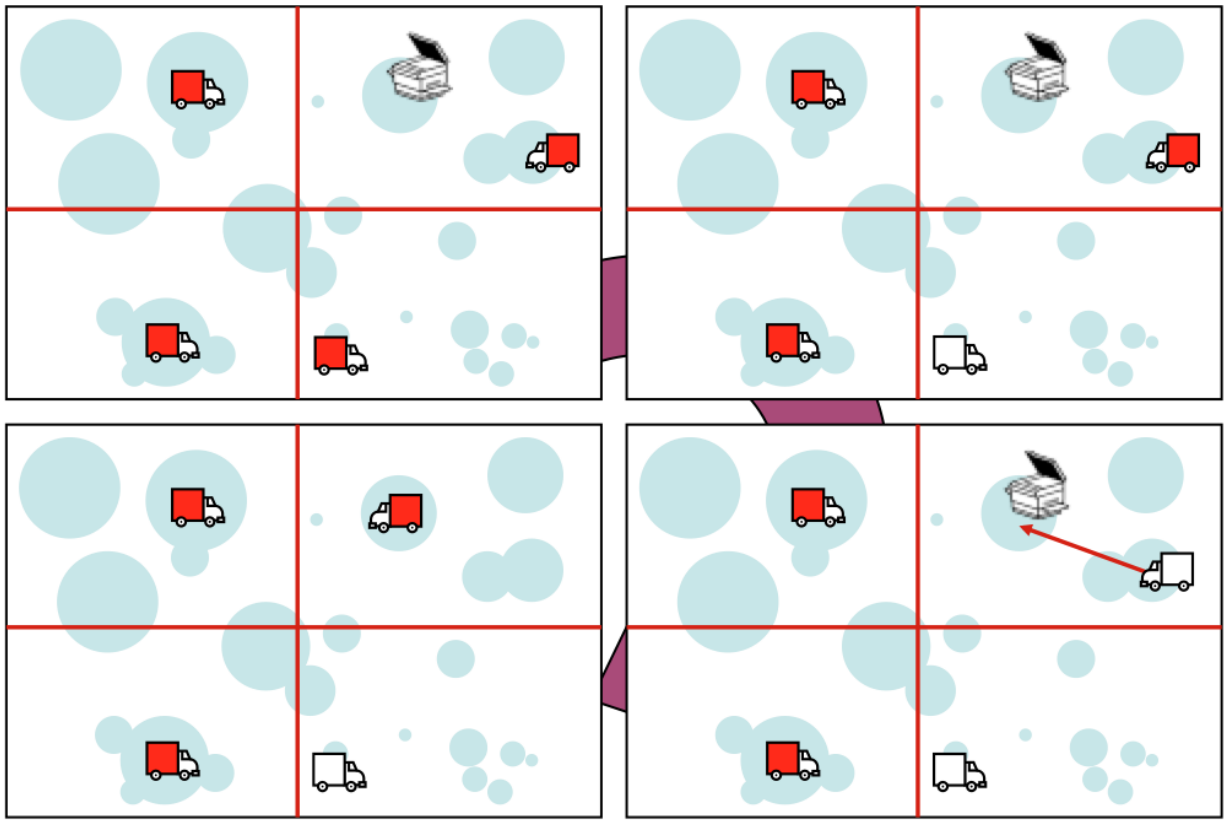
Counterfactual Analysis: System Optimization



- Serve each customer request by the closest available truck.

Counterfactual Analysis: System Optimization

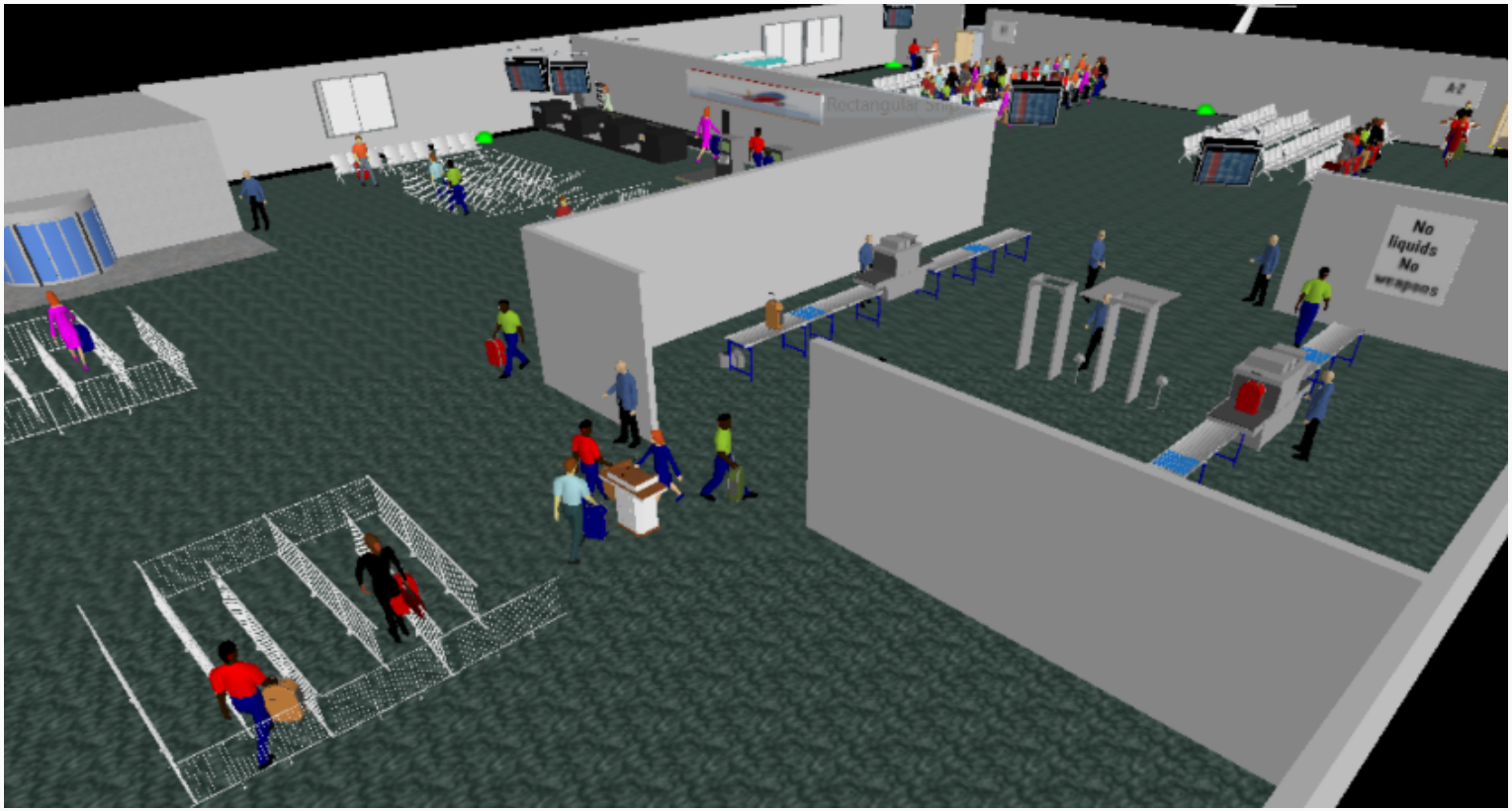
Alternative Policy



- Partition into 4 regions and allocate one truck to each region.
- Serve the requests in a region by the truck allocated to that region.

Discrete Event Simulation

We will simulate systems in Simio (`https://www.simio.com`)

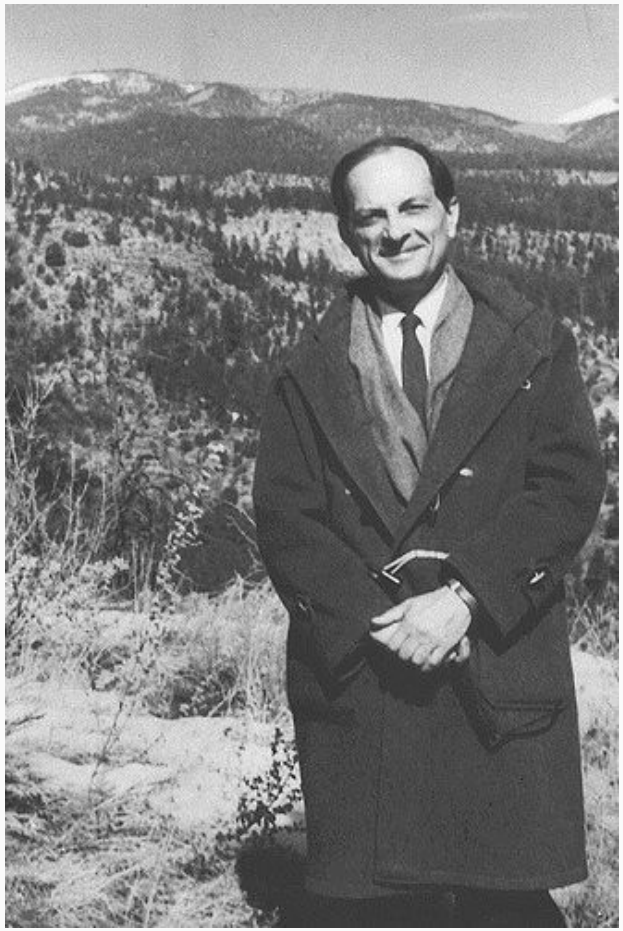


Course Outline

Review of probability and statistics	1-2
Basic Monte Carlo Simulation	2
Uniform random variable generation	2
Non-uniform random variable generation	2-4
Estimation and input modeling	2-3
Variance reduction	2-3
Intro to discrete-event system simulation	1
Modeling in Simio (flipped classroom)	4
Output analysis	2-3
Comparing alternative systems	2
Verification, validation, project mgmt	1
Other topics (MCMC, rare events, etc.)	time permitting

Birth of Monte Carlo Simulation: Ulam in Hospital

"...in 1946 as I was convalescing from an illness and playing solitaires ... I thought what are the chances that a Canfield solitaire laid out with 52 cards will come out successfully? After spending a lot of time trying to estimate them by pure combinatorial calculations, I wondered whether a more practical method than "abstract thinking" might not be to lay it out say one hundred times and simply observe and count the number of successful plays. This was already possible to envisage with the beginning of the new era of fast computers, and I immediately thought of problems of neutron diffusion and other questions of mathematical physics..."



Stanislaw Ulam

Monte Carlo Simulation at Los Alamos

Progress in Monte Carlo simulation was driven in the early years by the development of the MANIAC computer at Los Alamos National Labs by John von Neumann and Nicholas Metropolis.

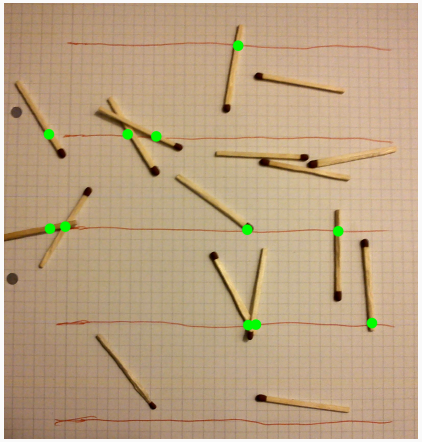
John von Neumann

Nicholas Metropolis

An Even Older Simulation!

Although Ulam first formalized Monte Carlo simulation, similar ideas had been used even before. The most famous early example of simulation is the 18th century Buffon's Needle Problem

- Throw matches of length 1 on horizontal grid with lines at distance 1
- Compute $\hat{X} = 2 \times D/C$, where D =number dropped, and C =number which touch line



Comte de Buffon

See Numberphile Video for more details