

ORIE 4580/5580: Simulation Modeling and Analysis

ORIE 5581: Monte Carlo Simulation

Fall 2018

Sid Banerjee

School of ORIE, Cornell University

Essential Course Information

- *Instructor*

Sid Banerjee <sbanerjee@cornell.edu>

Office: 229 Rhodes Hall

- *Teaching Assistants*

Chamsi Hssaine <ch822@cornell.edu>

Marc Finzi <maf388@cornell.edu>

Venus Lo <vh18@cornell.edu>

Auston Li <a1884@cornell.edu>

Cean Park <ckp42@cornell.edu>

Eric Wu <ew398@cornell.edu>

Evan Solomonides <egs73@cornell.edu>

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: Kimball B11

- **Recitation Sessions**

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

- **Course Communication:**

Piazza: <https://piazza.com/cornell/fall2018/orie458055805581>

Website: <http://people.orie.cornell.edu/sbanerjee/ORIE4580/orie4580f18.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 S. Ross, 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 11, 7:30pm **Final exam:** December 14, 9:00am

- ORIE 5581 students only do the prelim
- One formula sheet for prelims; two for finals

Component	4580/5580	5581
Clicker responses	4	4
Homeworks	25	35
Project	20	-
Prelim (Oct 11)	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

Clicker Question

Suppose we toss a fair coin 8 times. Which of the following is the 'most likely' observation:

- (a) $H H H H H H H H$
- (b) $H H H H T T T T$
- (c) $T H T H T H T H$
- (d) $T H T T T H T H$
- (e) All seem the same to me...

Clicker Question: Solution

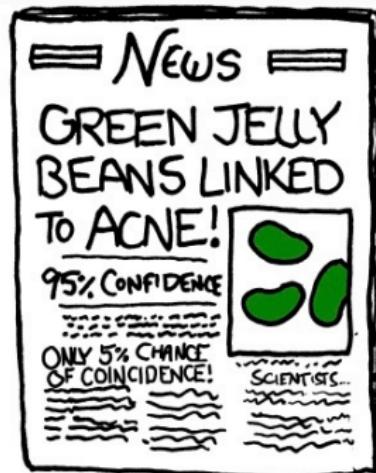
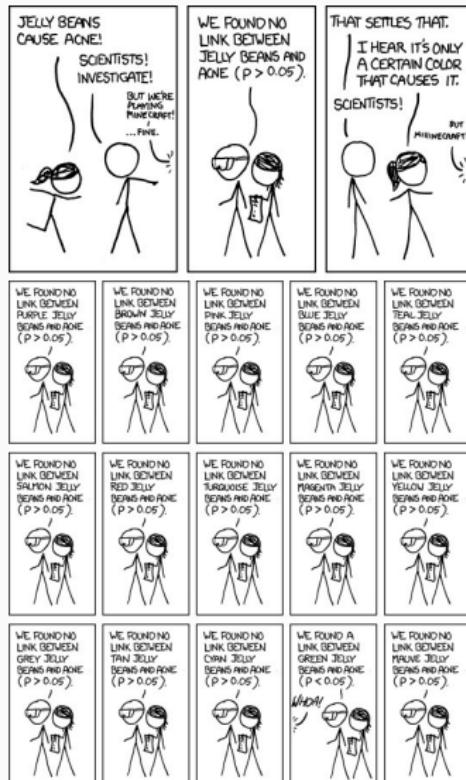
Suppose we toss a fair coin 8 times. Which of the following is the 'most likely' observation:

Why Study Simulation?

Stochastic simulation has four major applications

- **Numerical Computation:** Monte Carlo algorithms for scientific computing
- **Algorithms for massive data:** Sampling, sketching, streaming data, random-walk network algorithms, graphical models, etc.
- **Risk Analysis:** Quantifying and hedging against random 'shocks' in daily life
- **Counterfactual ('What-if') Analysis:** Understanding and optimizing complex systems in-vitro

Understanding randomness and sampling



What are the fundamental misunderstandings here?

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

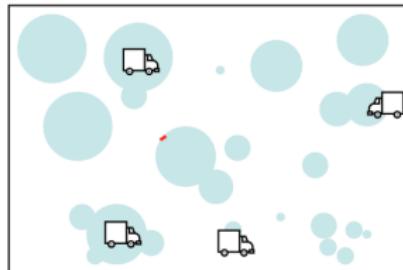
The book Bringing Down the House (made into the movie 21) showed how a team from MIT used card counting (a technique which lets you know when the odds are slightly in your favor) to win big in blackjack in Las Vegas.

- How do slightly favorable odds get turned into big winnings?
- What can go wrong (besides getting caught)?
- Why wouldn't you bet your entire retirement savings or college tuition on one hand?



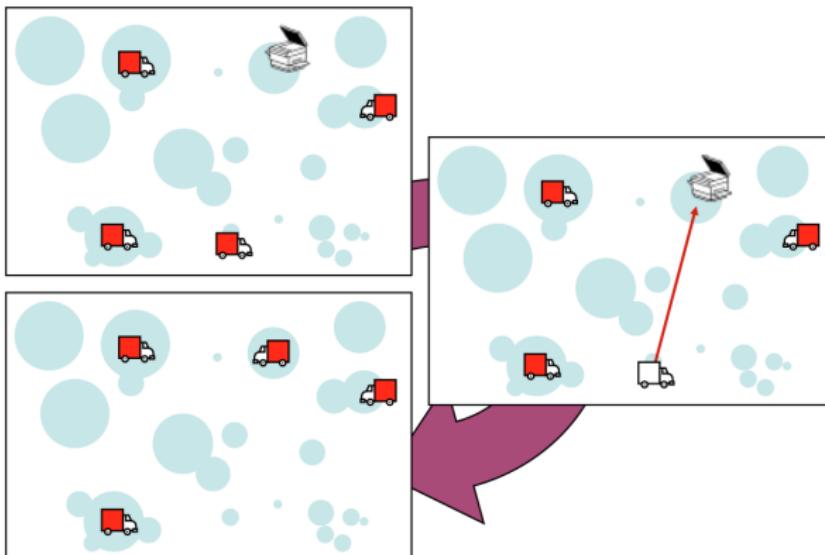
Counterfactual Analysis: System Optimization

- 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

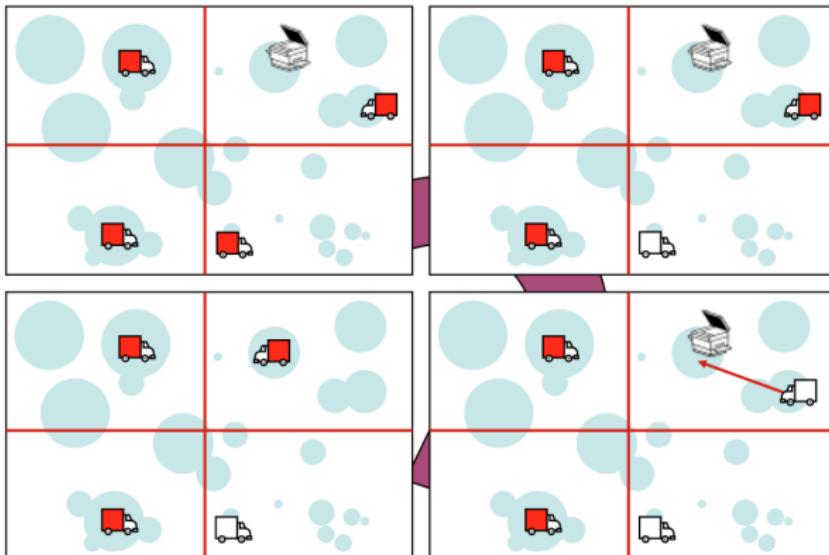
Current Policy



- 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.

...and beyond: Reinforcement Learning

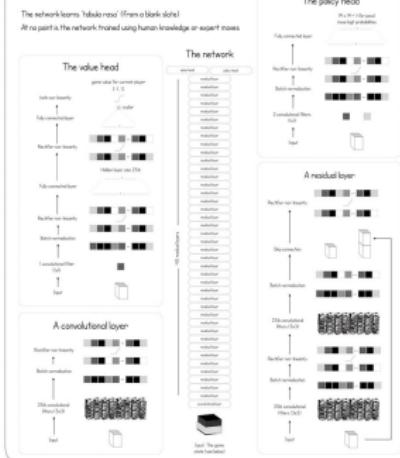
ALPHAGO ZERO CHEAT SHEET

The training pipeline for AlphaGo Zero consists of three stages, executed in parallel



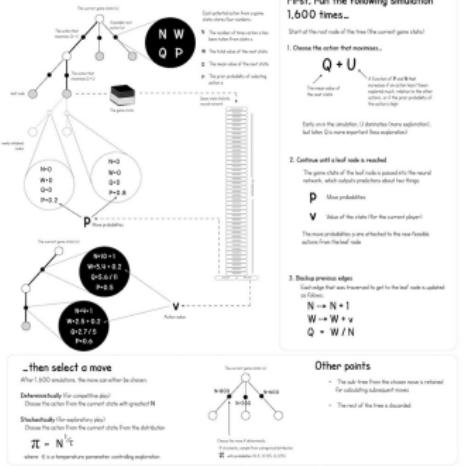
THE DEEP NEURAL NETWORK ARCHITECTURE

How AlphaGo Zero assesses new positions



MONTE CARLO TREE SEARCH (MCTS)

How AlphaGo Zero chooses its next move



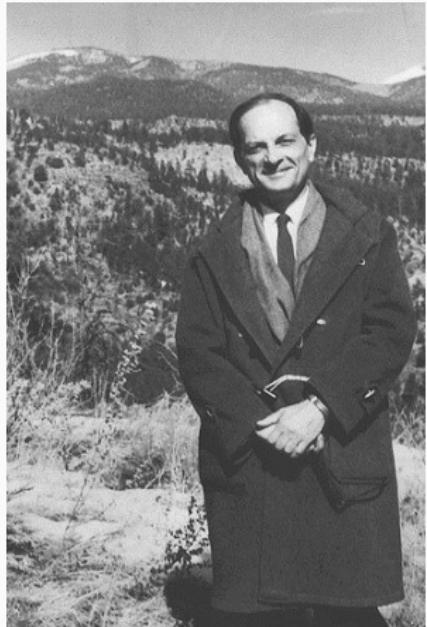
Course Outline

Topics cover simulation analysis, modeling and optimization

Review of probability and statistics	1-2
Basic Monte Carlo Simulation	2
Generating random variables	2
Input modeling	2
Statistical validation	2
Variance reduction and importance sampling	2-3
Review of Markov Chains	1-2
Intro to Discrete-event system simulation	1
Markovian models and queues	2
Modeling in Simio (flipped classroom)	2
Output analysis	2
Comparing systems; ranking and selection	1-2
Verification, validation, project mgmt	1
Simulation and dynamic programming	2

Birth of Monte Carlo Simulation: Ulam in Hospital

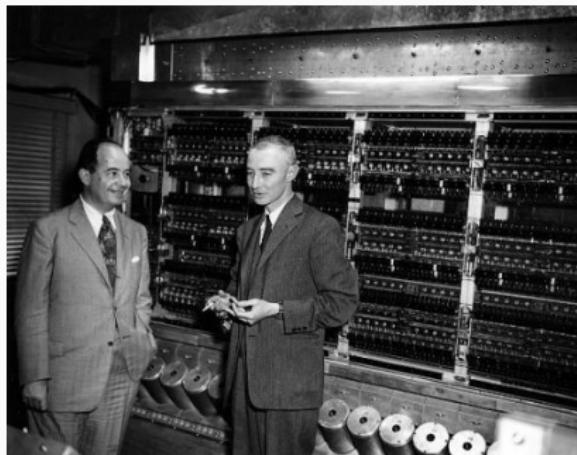
“...in 1946 as I was convalescing from an illness and playing solitaires ... I thought what are the chances that a Canfield solitaire laid out with 52 cards will come out successfully? After spending a lot of time trying to estimate them by pure combinatorial calculations, I wondered whether a more practical 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

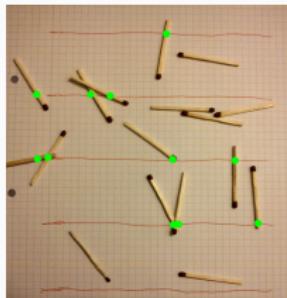


Nicholas Metropolis

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