ORIE 4580/5580: Simulation Modeling and Analysis

ORIE 5581: Monte Carlo Simulation

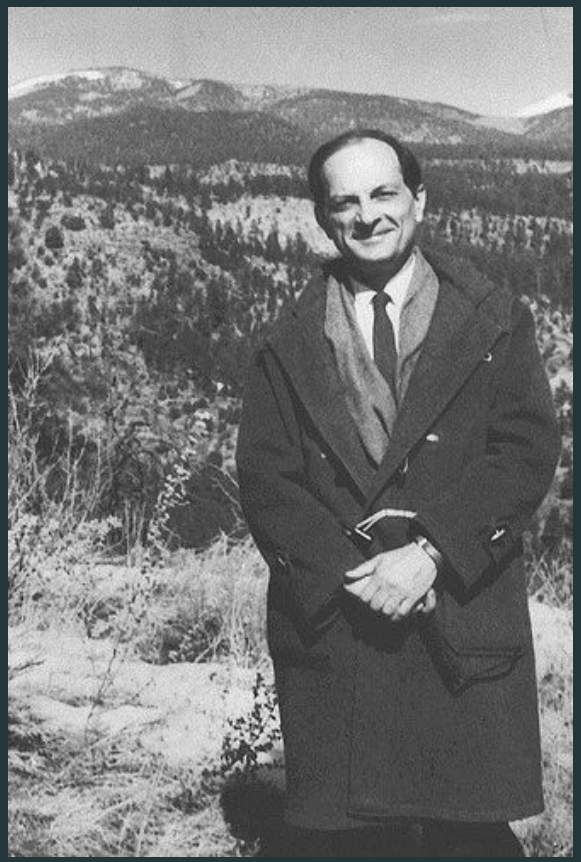
Unit 16: Wrap up

Sid Banerjee

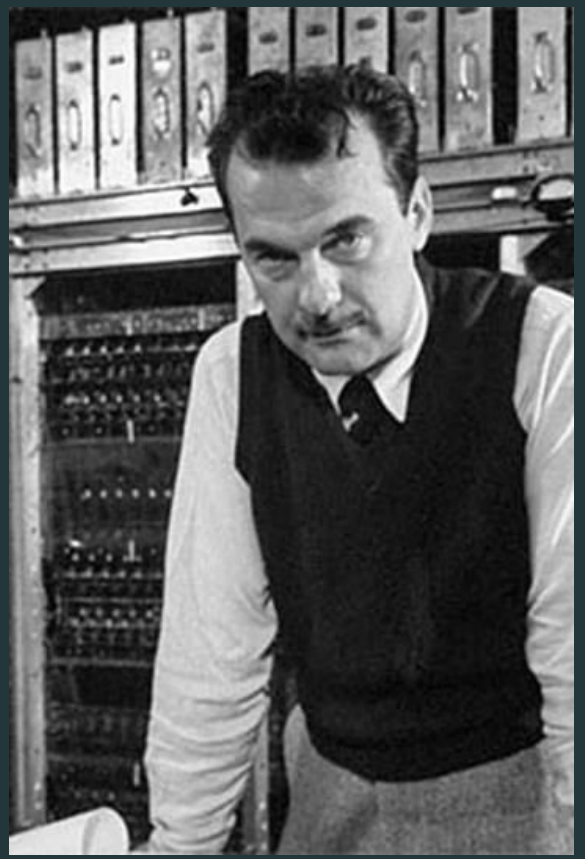
School of ORIE, Cornell University

Monte Carlo simulation

John von Neumann



Stanislaw Ulam



Nicholas Metropolis

why study simulation?

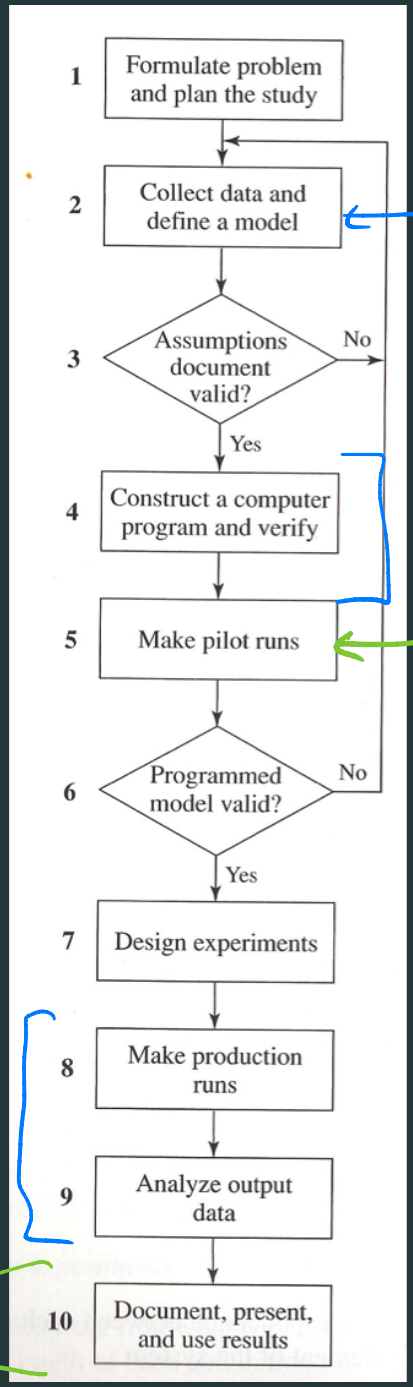
stochastic simulation has four major applications

data science

- **numerical computation**: used for estimating difficult integrals for scientific computing purposes Monte Carlo
- **algorithms for massive data**: sketching, streaming data, random-walk network algorithms, graphical models, etc.

- risk analysis: quantifying/hedging against random 'shocks' in daily life
- 'what-if' analysis: understanding/optimizing complex systems in-vitro

modeling



use data to set model params

Coding

deciding # of replications
deciding where to sample
deciding what policies make sense
etc.
debugging / testing

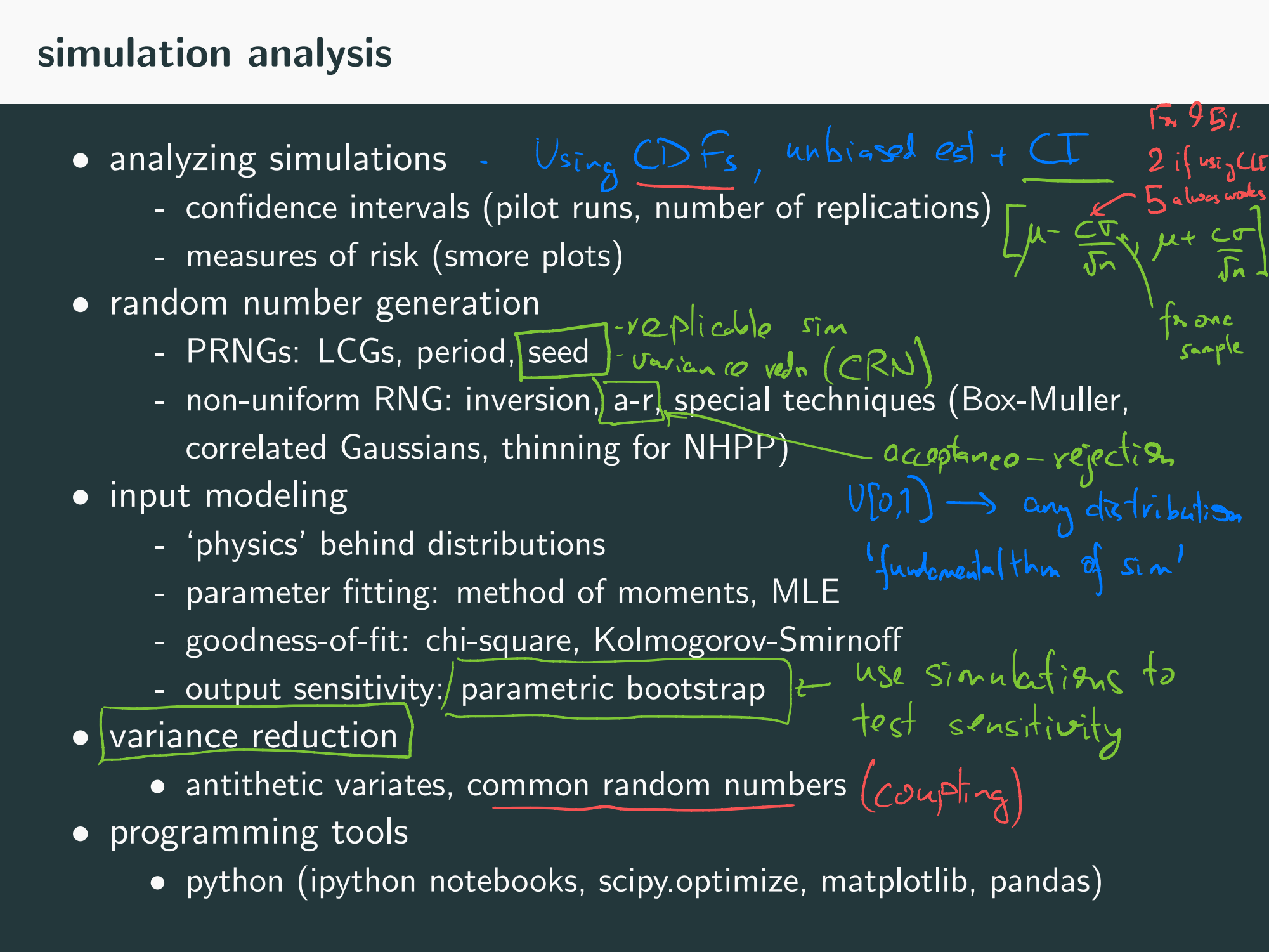
(bootstrap) sensitivity
CI

writing reports

the simulation flow-chart

simulation analysis

- analyzing simulations
  - confidence intervals (pilot runs, number of replications)
  - measures of risk (smore plots)
- random number generation
  - PRNGs: LCGs, period, seed
  - non-uniform RNG: inversion, a-r, special techniques (Box-Muller, correlated Gaussians, thinning for NHPP)
- input modeling
  - 'physics' behind distributions
  - parameter fitting: method of moments, MLE
  - goodness-of-fit: chi-square, Kolmogorov-Smirnoff
  - output sensitivity: parametric bootstrap
- variance reduction
  - antithetic variates, common random numbers
- programming tools
  - python (ipython notebooks, scipy.optimize, matplotlib, pandas)



simulation modeling

- discrete-event simulation (less covered)
  - simulation clock, event lists
- queueing models (stoch processes – conservation laws)
  - physics of queues (stability, flow-balance, Little's law)
  - Markovian queueing models ($a/b/c$ queues)
- Markovian simulation models
  - exponential rvs, Poisson processes; memorylessness ← modeling tool
  - complex models: phase-type distributions, complex state-space
- output analysis
  - terminating simulations, steady-state simulations, warm-up, replication-deletion, batch means
- comparing alternative systems
  - common random numbers, union bound
  - subset selection

and beyond...

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- Model 'information' - information theory
- optimization and simulation
  - simulation optimization for large number of parameters - decision theory
  - using simulation models for control
    (markov decision processes, approximate methods)
  - reinforcement learning - MDP without knowing the model
- markov-chain monte carlo
  - generating from complex distributions
  - example: generating spanning trees

- Bayesian ML