
# Simulation using Python

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# What is Simulation?

- **Simulation** is an imitation of some real system, state of affairs, or process
  - Collection of methods to mimic behavior

- **Computer simulation**
- is an attempt to model a real-life situation on a computer for purpose of either understanding the behavior of the system or of evaluating various strategies for the operation of the system

# When to use Simulation?

- To quantify the stochastic behavior
- To understand dynamic behavior of system
- To experiment with new designs or policies before implementation
- To understand system response to changes in inputs, information & environment
- To verify / reinforce analytic solutions

# How do we carry out simulation?

- By Hand!
- Programming in general purpose languages
  - Flexible, familiar
  - Easier to grasp DES concepts
  - C, C++, JAVA, Python
- Simulation Languages/ packages
  - Can build models quickly
  - Graphics and animation provided
  - Help for data collection/ analysis
  - E.g.: Anylogic, Arena, ProModel, Flexsim, …

# Steps in Simulation Study

1. Determine the goals and objectives
2. Build a conceptual model
   - How comprehensive should the model be?
   - What is important? What is dynamic?
3. Convert into a specification model
   - Define variables, parameters, inputs & outputs
   - Draw flowcharts, may involve pseudo codes
4. Convert into a computational model
   - A computer program. Using a simulation package or general purpose language?
5. Verification
   - Did we build the model right?
6. Validation
   - Did we build the right model?

Typically an iterative process

# Steps in Simulation Studies (contd.)

7. Design Simulation Experiments
   - What parameters to be varied, maybe combinatorial
8. Make simulation runs
   - Record initial conditions, statistical outputs
   - Decide on number of replications
9. Analyze outputs
   - Use **proper statistical techniques**.
10. Make decisions
    - Infer from results
11. Document Results

# Background needed

- Basic knowledge of probability & statistics.
- Algorithms and a bit of programming.

# Numpy.random package

- It has functions for sequences, integers and real-valued distributions
  - Random variable generator: Mersenne Twister * Period is 2**19937-1. * It is one of the most extensively tested generators in existence.
  - utility : uniform within range
  - sequences : pick random element, pick random sample , pick weighted random sample , generate random permutation
  - distributions on the real line: Uniform, triangular, normal, lognormal, exponential, gamma, beta, Weibull, multivariate, Poisson, etc
- Let's learn using example scenarios

# Example scenarios

- 1a: Roll a die 10 times
- 1b: Roll a pair of dice N times and plot the histogram of the sum obtained.
- 1c: Toss a fair coin 10 times
- 1d: Toss an unfair coin 10 times (P{H}=0.8)
- 1e: Sample 3 balls from a box with 5 red and 3 blue balls without replacement
- 1f: Randomly shuffle a list of students
- 1g: Sample from probability distributions
  - RANDOM, UNIFORM, EXPONENTIAL, etc
  - Visualise the samples
  - Simple probability exercises
  - SEED
- 1h: Central limit Theorem

# iPython notebooks

- Partially filled iPython workbook are shared via chat
- Download the SimPython1-class.ipynb file ..
  - Open in your desktop using Jupyter
  - -or- upload in YOUR gdrive and open using Google colab.

# Monte Carlo Simulation

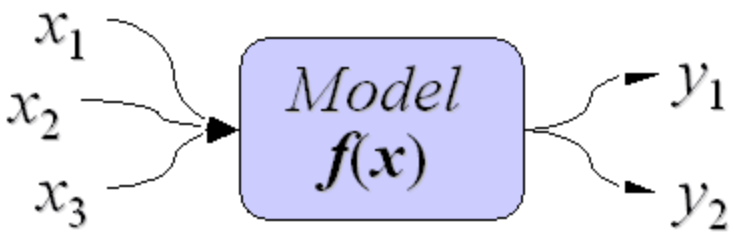
- Any simulation that uses random numbers
  - Very broad, includes all stochastic simulations

More restrictive definition

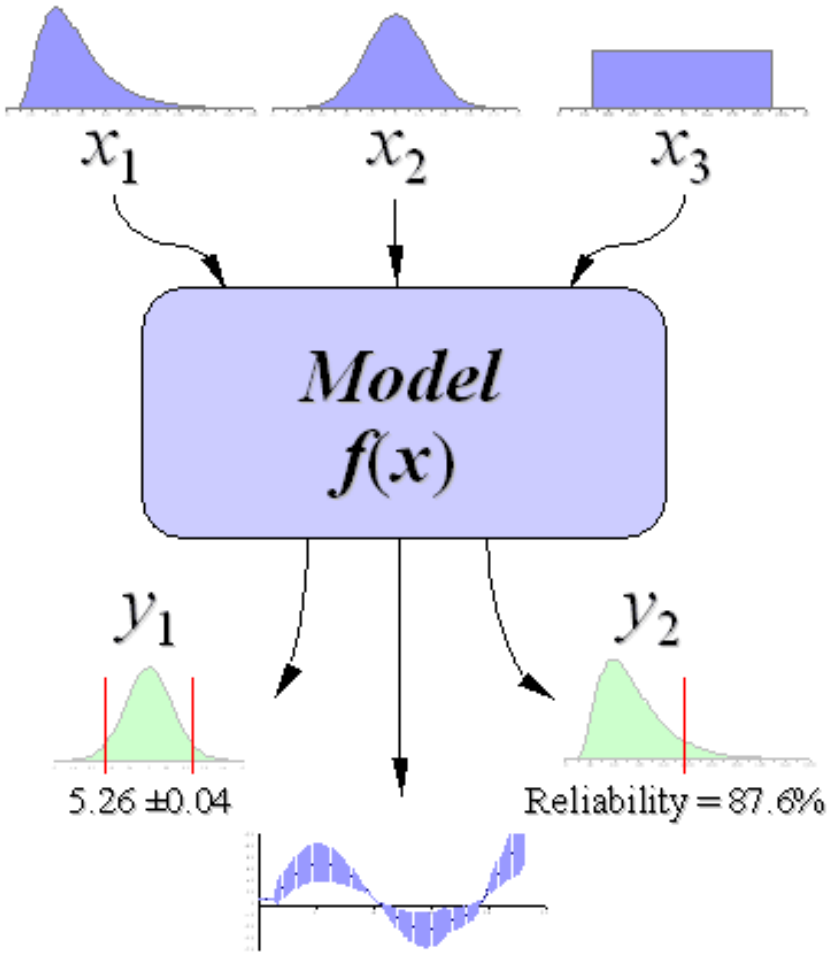
- Monte Carlo is a scheme employing random numbers, i.e. U(0,1) random variates, which is used for solving certain stochastic or deterministic problems where the passage of time plays no role!
  - Monte Carlo simulations are *static* rather than dynamic

# MCS basics

- Deterministic model maps a set of input variables to a set of output variables




- Stochastic uncertainty propagation



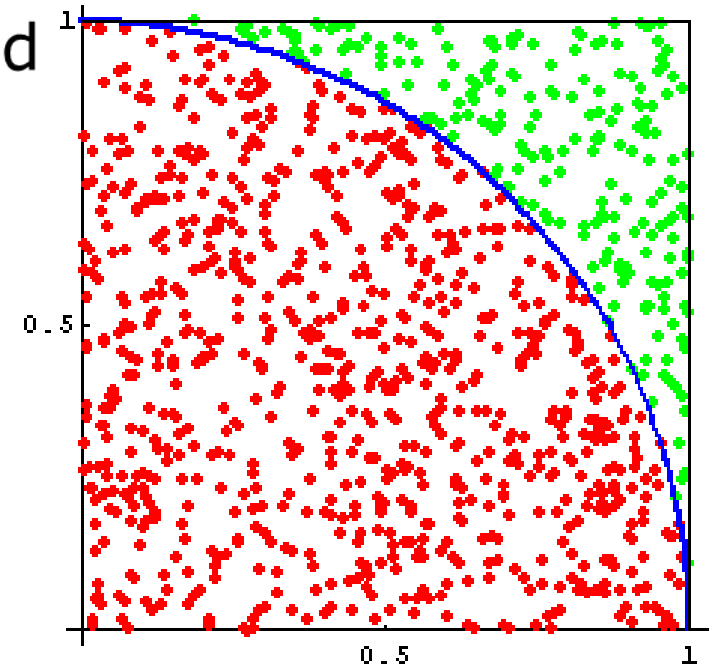

Source:
http://www.vertex42.com/ExcelArticles/mc/MonteCarloSimulation.html

# MCS Scenarios

- Estimate PI
- A rat in a trap (Markov chain example)
- Project planning

# Example PI: Compute value of $\pi$

- Consider a quarter-circle inscribed inside a unit square
- $\text{Area}_{\text{quarter-circle}} = \Pi/4$
- $\text{Area}_{\text{square}} = 1$
- $\text{Area}_{\text{region}} \sim$ Points inside region
  - $\Pi$ = 4*points in circle/ Total points




- Set-up a MCS to compute $\pi$.
  - Generate $(x, y)$ coordinate where $x, y \in [0,1]$
  - If $(x^2 + y^2 < 1)$ then
    - Count point inside quarter-circle
  - Repeat above two steps $n$ times.
  - $\tilde{\pi} \approx 4 * points\ in\ circle/n$

Compute $\pi$ for various values of $n$