Simulation

- Useful
  in science, industry, government
  for prediction & understanding systems,
  the environment, physical processes
- Popular
  in entertainment, games, virtual reality
- Crucial in networking
  to evaluate protocols, discover bottlenecks
- networking
  used in large simulations, as enabler
  of parallel & distributed simulation

Types of Simulation

- continuous time vs discrete time
- output final result vs online behavior
- analytic vs approximated by computation
- random (Monte Carlo) vs deterministic
- time-stepped vs event-driven

Simulation Fundamentals

Simulation Time

usually a number representing the progress of time in the physical system being simulated.

Note: simulation time can run faster or slower than "real" physical time

(example: simulate 100,000 years of climate change)

Simulation State

represent all interesting attributes of the simulated system using variables $(x, y, z, \dots)$. The collection of all such variables is the <u>state</u>.

Note: technically, state is a function of the simulation time.

Initial state: values of variables at time t_0.

EXAMPLE OF SIMULATION

① Earlier homework on birth events simulated by a coin toss

② Time-stepped simulation of Lotka-Volterra equations that model two species predator-prey "Foxes & Rabbits"

Differential Equations model the rates of growth / decline in population of each specie

Simulation State: (R, F)

R: number of rabbits

F: number of foxes

$$\frac{dR}{dt} = aR - bRF$$

$$\frac{dF}{dt} = cbRF - eF$$

} "coupled" equations

How to Simulate ?

- Start with some initial state, e.g.

$$(R, F) = (5000, 45)$$

- Use the "$\frac{\Delta R}{\Delta t}$" interpretation of $\frac{dR}{dt}$

and approximate the <u>system trajectory</u> using some granularity for Δt.

Simulation time is

$$t_0 \quad t_1 \quad t_2 \quad \ldots \quad t_k$$

where $t_i = t_{i-1} + \Delta t$

and $t_0 = 0$.

$$(R_0, F_0) = (5000, 45)$$

$$R_{i+1} = a R_i - b R_i F_i$$

$$F_{i+1} = c b R_i F_i - e F_i$$

Record

$(R_0, F_0)\ (R_1, F_1)\ (R_2, F_2) \ldots$

as output of the simulation.