

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 state.

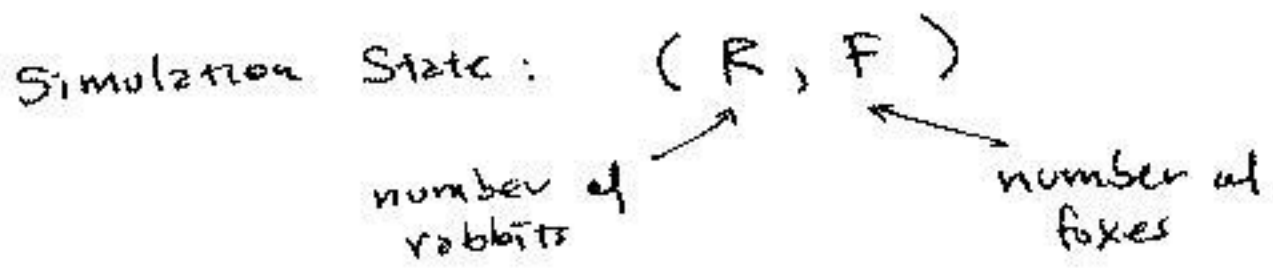
Note: technically, state is a function of the simulation time.

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



$$\left. \begin{aligned} \frac{dR}{dt} &= aR - bRF \\ \frac{dF}{dt} &= cbRF - eF \end{aligned} \right\} \text{"coupled" equations}$$

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 system trajectory using some granularity for Δt .

Simulation time is

$$t_0 \quad t_1 \quad t_2 \quad \dots \quad t_k$$

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

$$\text{and } t_0 = 0.$$

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

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

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

Record

$$(R_0, F_0) \quad (R_1, F_1) \quad (R_2, F_2) \quad \dots$$

as output of the simulation.