Simulation: Overview and Taxonomy

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Outline

1. Computer Simulation

2. Categorizing Simulations

3. A Couple Examples

Simulation

simulation The imitative representation of the functioning of one system or process by means of the functioning of another [i.e., a computer program]. (Merriam Webster)

- often applied to dynamic processes
- method of understanding and predicting the behavior of real processes
- based on mathematical models (ignore some details)
  - often include many interacting components
- distinct from but often connected to visualization
- fundamental to research in many disciplines (e.g., Computational Science)

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A Taxonomy of Simulation

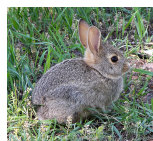How can we categorize simulations?

Dimensions

- timing of change
- randomness
- data organization

Timing

How does the simulation reflect the passage of time?

- steady-state
- dynamic
  - continuous
  - discrete
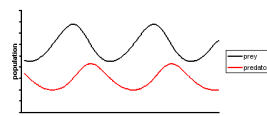   - time-stepped
    - event-driven

Wikimedia:
Rabbit in montana.jpg (left), and
Coyote by Rebecca Richardson.jpg (right)

steady state

- ignores time, finds balance
- E.g.: 5 coyote, 200 rabits

dynamic

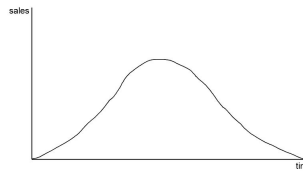- system evolves over time

Wikimedia Commons:
Volterra lotka dynamics.PNG

Timing

How does the simulation reflect the passage of time?

- steady-state
- dynamic
  - continuous
  - discrete
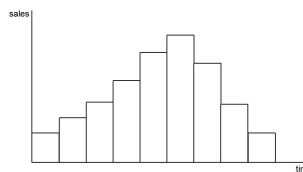   - time-stepped
    - event-driven

Continous

Wikimedia: Continuous simulation graph.jpg

changes occur continuously (time is a real number)

Discrete

Wikimedia: Discrete event simulation graph.jpg

changes at discrete points in time (time is an integer)

Timing

How does the simulation reflect the passage of time?

- steady-state
- dynamic
  - continuous
  - discrete
    - time-stepped
    - event-driven

time-stepped

Time intervals are regular. The simulation is organized with loop, such that each iteration represents the passing of a fixed amount of time.

event-driven

Time intervals are irregular. Updates are associated with events, which are scheduled in advanced. Usually implemented with a priority queue.

Example: http://www.youtube.com/watch?v=Y8XMP_44PRU

Randomness

Simulations may be *deterministic* or *stochastic*.

Deterministic

The result of the simulation depends only on the input. Some deterministic systems are chaotic and produce unpredictable results.

Stochastic

The result of the simulation is based on random values chosen according to some distribution.

Data Organization

Simulations of physical phenomena tend to be either *grid-based* or *meshfree*.

grid-based (a.k.a. stencil codes)

- Data is associated with discrete cells at particular locations in a grid.
- Updates occur to each cell based on its previous state and those of its neighbors.
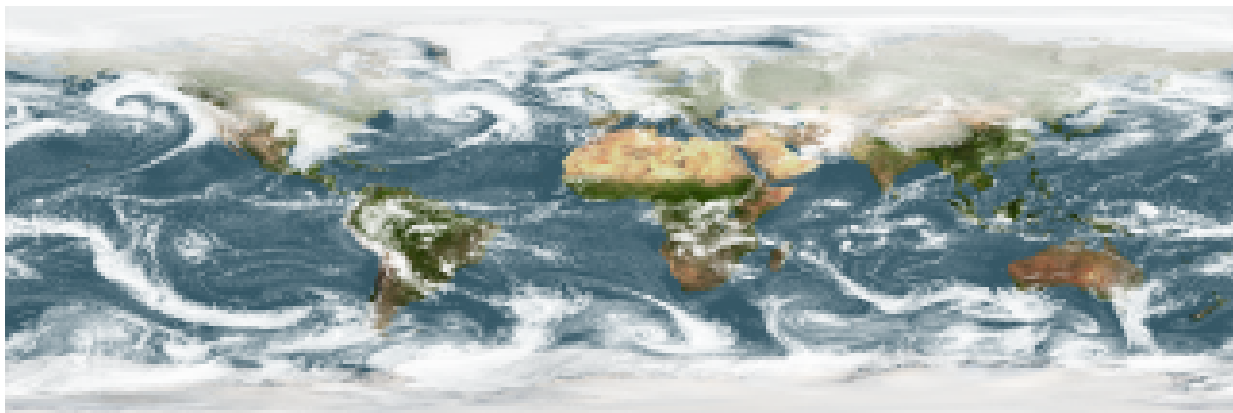
meshfree

- Data is associated with individual particles.
- Updates look at each pair of particles.
- More expensive than grid-based.

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Climate Modeling

NASA/Goddard Space Flight Center Scientific Visualization Studio — GEOS-5 Modeled Clouds — http://svs.gsfc.nasa.gov/goto?3723
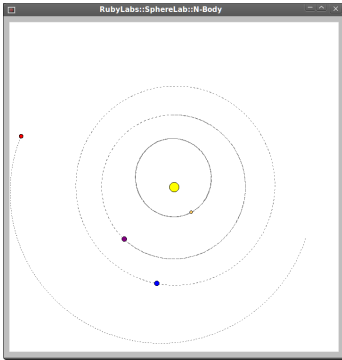
Categorization

Time-stepped or event-driven?

- 30 minutes time steps (mostly)

Grid-based or meshfree?

- 5-km per grid cell

N-Body Simulation

- time-stepped
  or
  event-driven?
- grid-based or
  meshfree?

irb commands

```
include SphereLab
b = make_system(:solarsystem)
view_system(b[0..4], :dash => 1)
365.times {update_system(b, 86459)}
```

update code

```
def step_system(bodies, dt)
  nb = bodies.length
  for i in 0..(nb-1)
    for j in (i+1)..(nb-1)
      Body.interaction(bodies[i], bodies[j])
    end
  end
  bodies.each do |b|
    b.move(dt)
    b.clear_force
  end
end
```

Summary

- a computer simulation is a computation process that models some other system
- usually applied to dynamic processes
- discrete simulation:
  - time-stepped
  - event-drivent
- deterministic vs. stochastic
- grid-based vs. meshfree