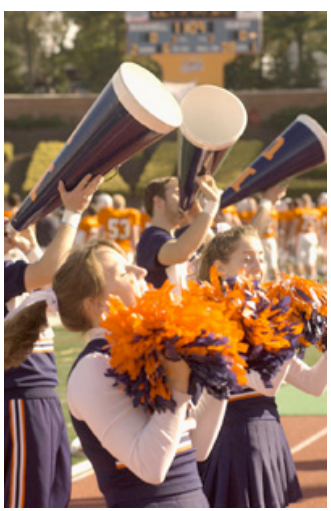
Simulation for the Masses

L. Felipe Perrone <perrone@bucknell.edu>
http://www.eg.bucknell.edu/~perrone
Department of Computer Science
Bucknell University, Lewisburg, PA, U.S.A.




What is **Simulation**?

Who needs Simulation?

- Whoever needs a world that they can fully control and observe.
- Whoever is studying a system so complex that it defies mathematical analysis.
- ...

Uses of Simulation

Training

http://www.firerescue1.com

http://www.x-plane.com/index_pro.html

Uses of Simulation

Games and Movies

Why does "leisure science" need simulation?

Uses of Simulation

Science

- Epidemiology
- Weather
- Political science
- Marketing
- Physics and astronomy
- Chemistry
- Industrial engineering
- Biology, **ecology**
- ...
- Computing systems
  - architecture
  - computer networks

Why does science need simulation?

Uses of Simulation

Science

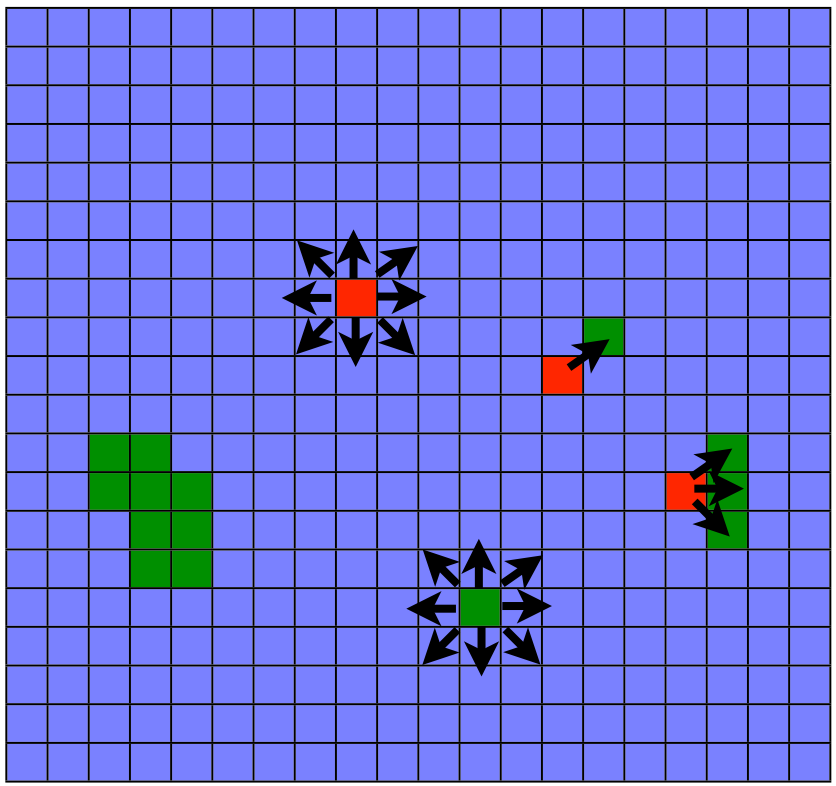
http://www.youtube.com/watch?v=htnh7pBBtrM

"These simulations show the hypothetical spread of a moderately contagious pandemic flu in the United States. Each dot represents a Census tract and changes color from green to red as more people in that tract become infected. The dots change back to green as people recover. With no intervention (top), the pandemic peaks around day 85."

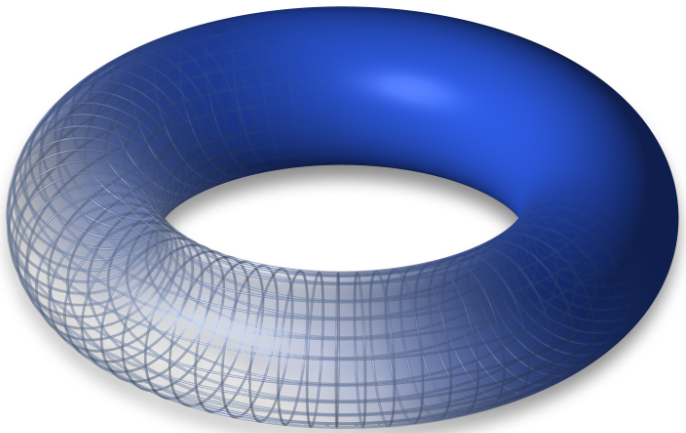
"With the distribution of 10 million doses per week of a vaccine that is poorly matched to the emerging virus (bottom), the pandemic peaks around day 108."

Science or recreation?

WATOR



http://en.wikipedia.org/wiki/Torus



Parameters

- Number of fish
- Number of shark
- Breeding time for fish
- Breeding time for shark
- Starvation time for shark

It's playtime!

Let's see how different parameter settings play out by experimenting with a WATOR simulator:

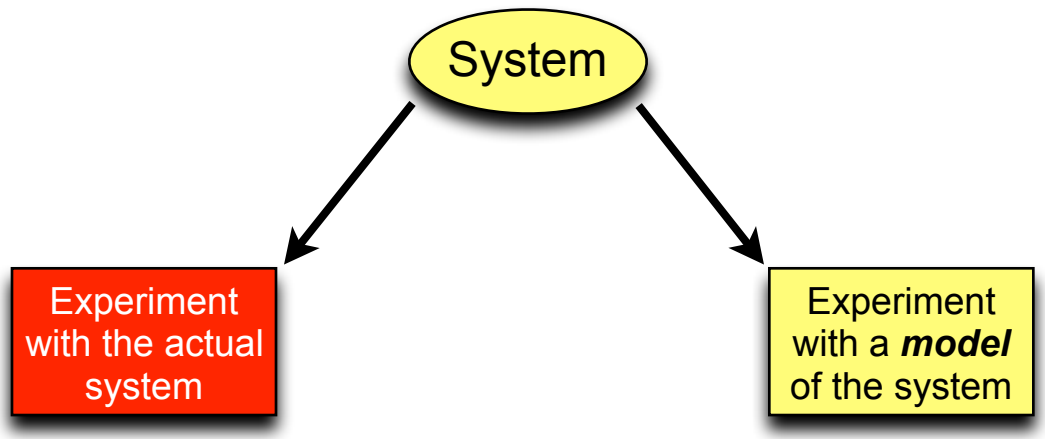
http://www.leinweb.com/snackbar/wator/

Simulation is POWERFUL

- **You** create your custom virtual universe.
- **You** create the laws that govern your own virtual universe.
- You can **fully observe** how things work out in the finest level of detail.

Ways to Study a System

Simulation Modeling and Analysys, Averill M. Law 2007



What's a model?

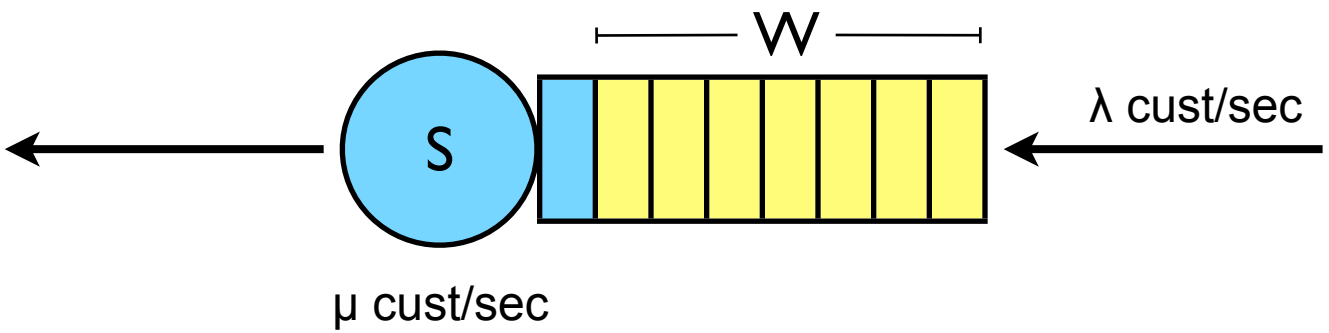
A model is an abstraction. It is the distillation of the essence of the most important features of a system. (Just going for maximum emphasis here.)

Models can be **analytical** or **computational**. Either way, the consist of a state and a function which determines how the state evolves over time.

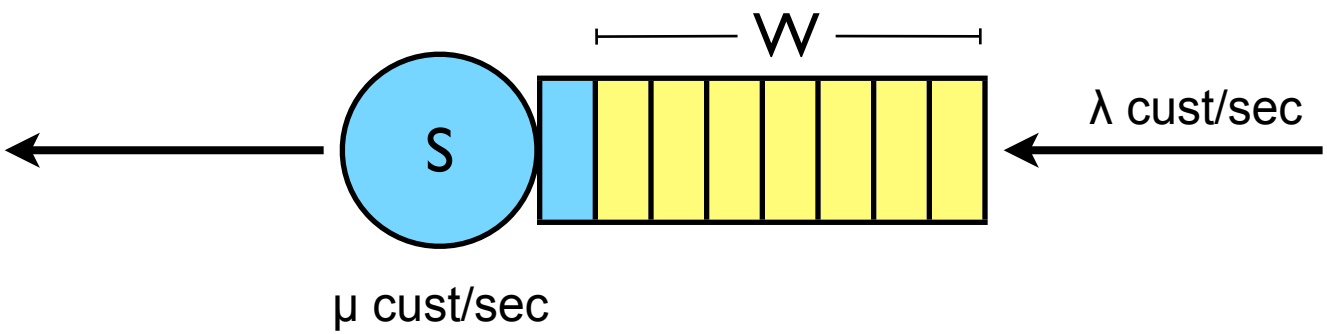
Models need to be **validated**. Computational models need to be also **verified**.

A queueing model

http://zitotalking.wordpress.com/2010/10/25/the-dad-voice-by-chris-zito/



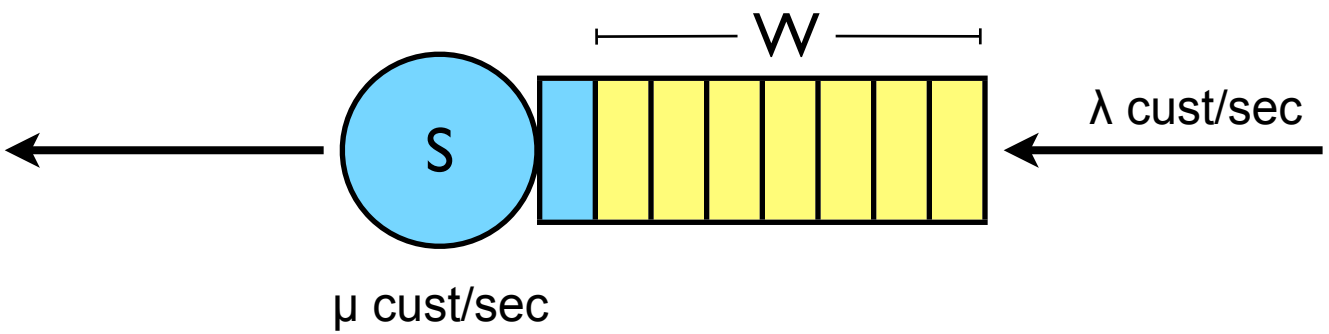
A queueing model



The state of the system at time *t*:

- ***S(t)***, state of the teller (idle or busy)
- ***W(t)***, number of customers waiting

A queueing model

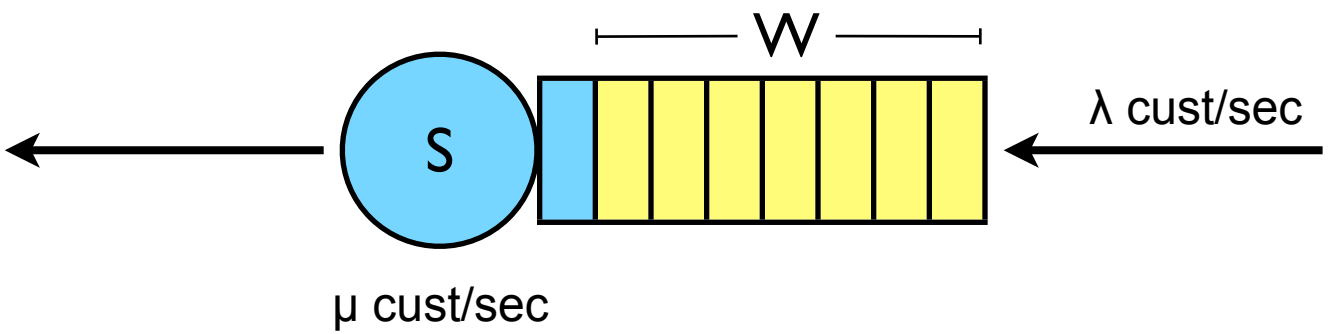


Time?
What is time like in this system?
What time is like in this model?

The state of the system at time *t*:

- *S(t)*, state of the teller (idle or busy)
- *W(t)*, number of customers waiting

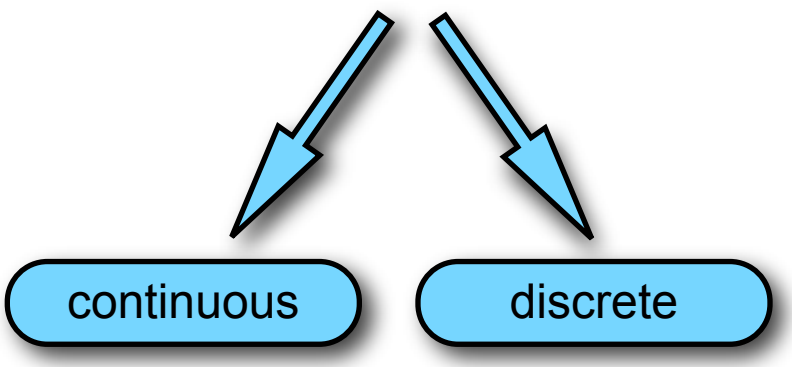
A queueing model



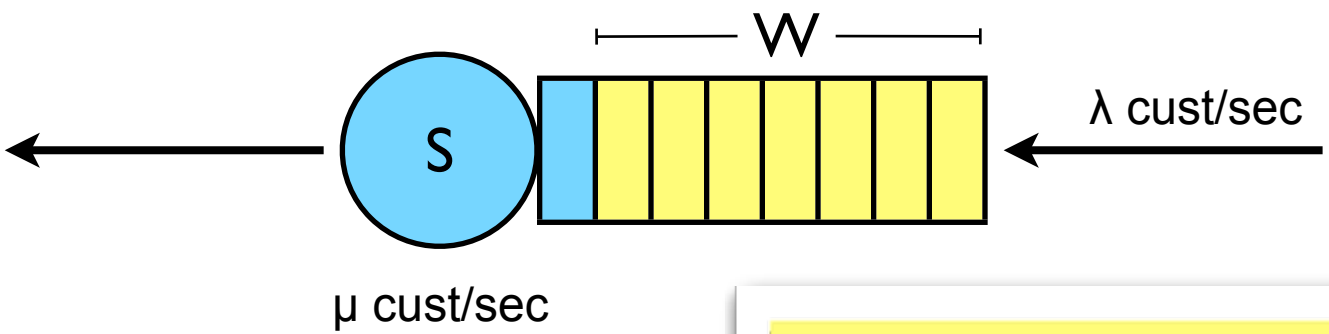
The state of the system at time *t*:

- ***S(t)***, state of the teller (idle or busy)
- ***W(t)***, number of customers waiting

Time?
What is time like in this system?
What time is like in this model?



A queueing model



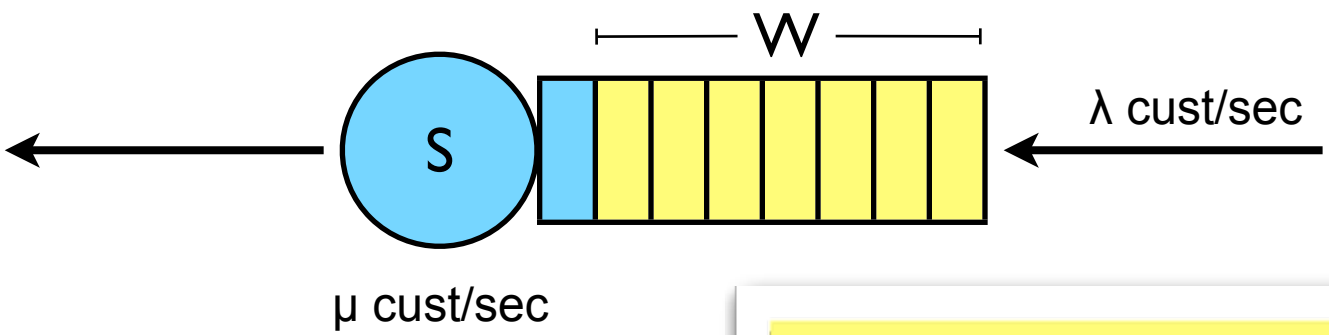
The state of the system at time *t*:

- *S(t)*, state of the teller (idle or busy)
- *W(t)*, number of customers waiting

What do you care to know?

- *W*, the average wait time for a customer
- *L*, the average number of customers
- ...

A queueing model



The state of the system at time *t*:

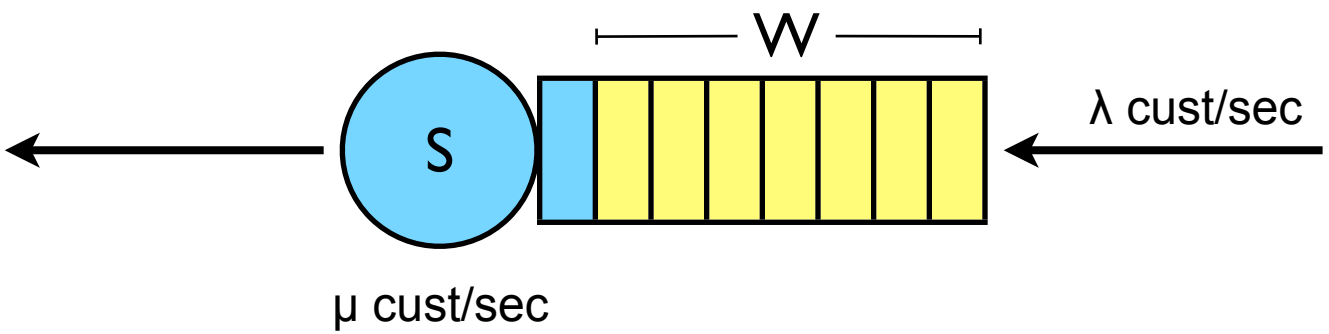
- *S(t)*, state of the teller (idle or busy)
- *W(t)*, number of customers waiting

What do you care to know?

- *W*, the average wait time for a customer
- *L*, the average number of customers
- ...

performance metrics

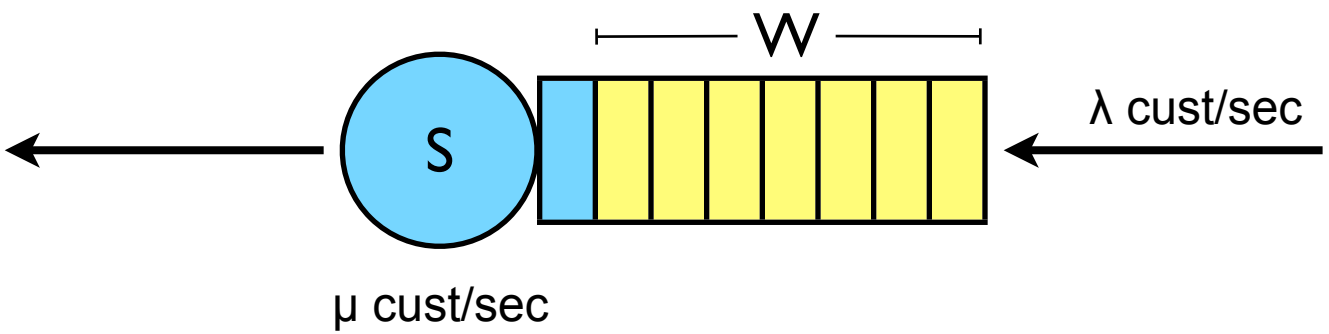
A queueing model



Remember: customers arrive at random times.

If the customer inter-arrival time is *"exponential"* with a constant rate λ and if the service times are also exponential with a constant rate μ, if the service policy is FCFS, what we have is called an **M/M/1** queue.

A queueing model



The **M/M/1** queue is easily solved analytically (that is, with some math).

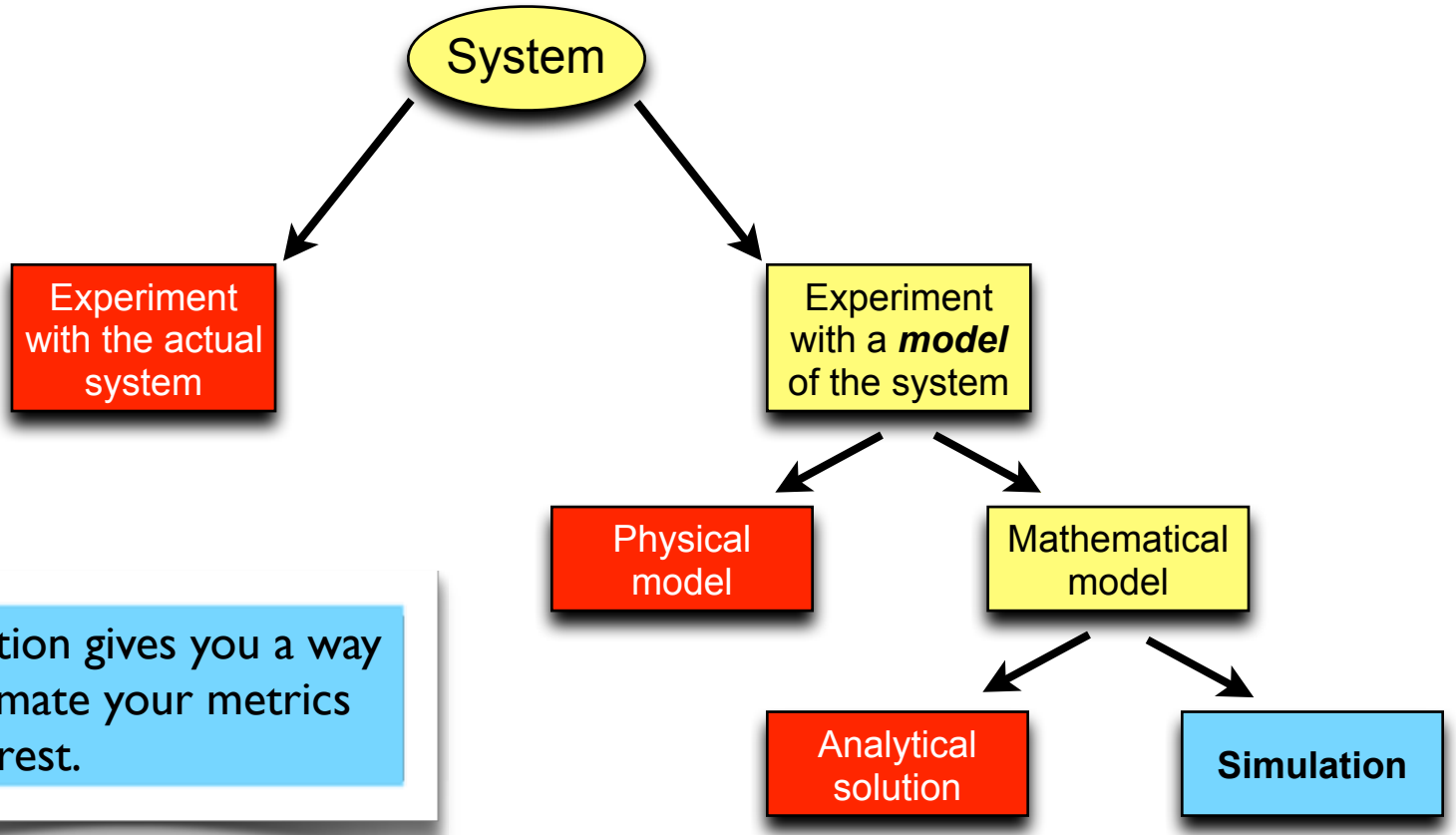
$$L \equiv \frac{\frac{\lambda}{\mu}}{1 - \frac{\lambda}{\mu}} \qquad W \equiv \frac{1}{\mu - \lambda}$$

If easy enough math gives you what you need, you're done.

If the math is really hard, though, you can use simulation.

Ways to Study a System

Simulation Modeling and Analysys, Averill M. Law 2007



Simulation gives you a way to estimate your metrics of interest.

Simulation

- You make **time** advance and compute the function that updates state variables (what makes "things happen"), and the state of the model evolves.
- If you're not just doing something visual, the goal is to produce *samples of metrics* in which you have interest.
- Finally, you use statistical methodology for processing and analyzing output data. This allows you to validate hypothesis you make about the system.

Types of Processes: continuous-time

http://newperspectivesradioshow.wordpress.com/2011/03/26/clock-goes-forward-one-hour-tonight/

Types of Processes: continuous-time

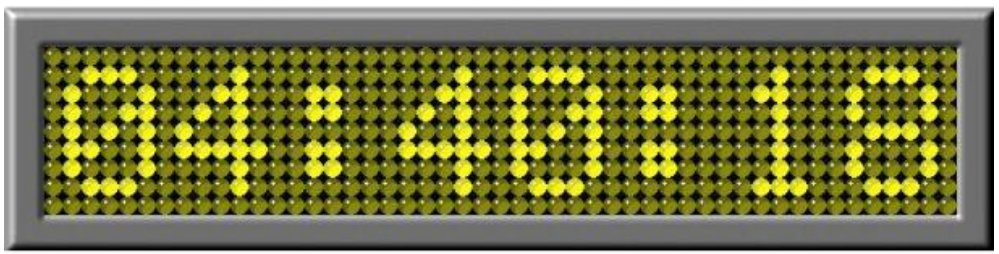
The state of the system evolves with time as we know it.

We can only approximate this with computer simulation.

http://newperspectivesradioshow.wordpress.com/2011/03/26/clock-goes-forward-one-hour-tonight/

Types of Processes: discrete-time

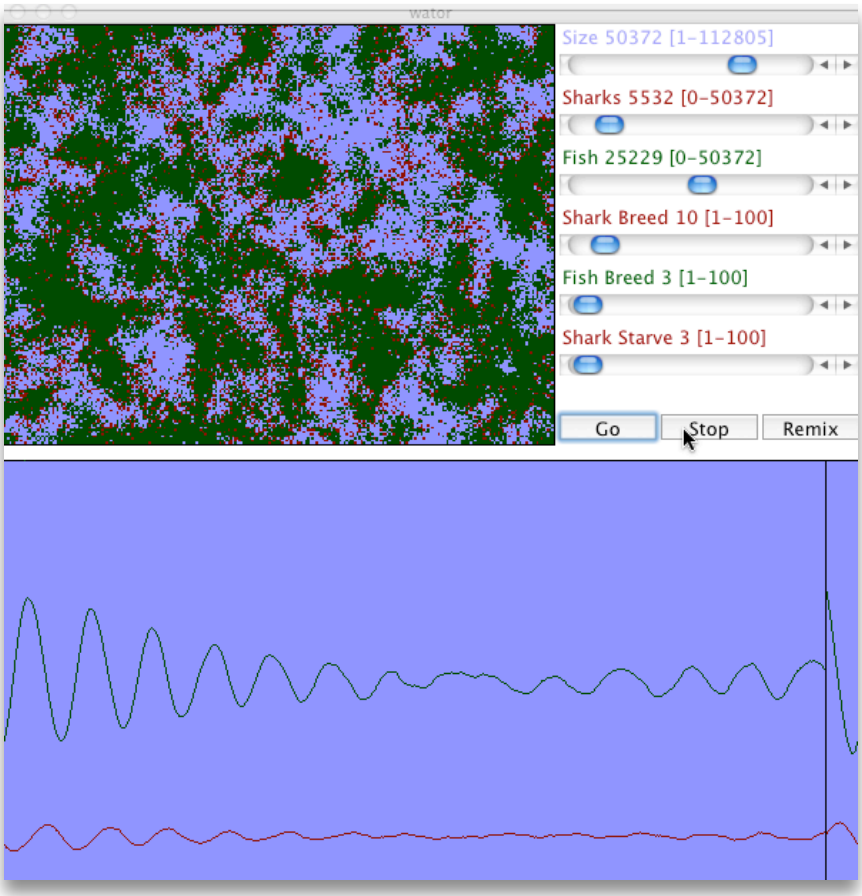
The state of the system evolves in discrete jumps.



The state of the system evolves in discrete jumps.

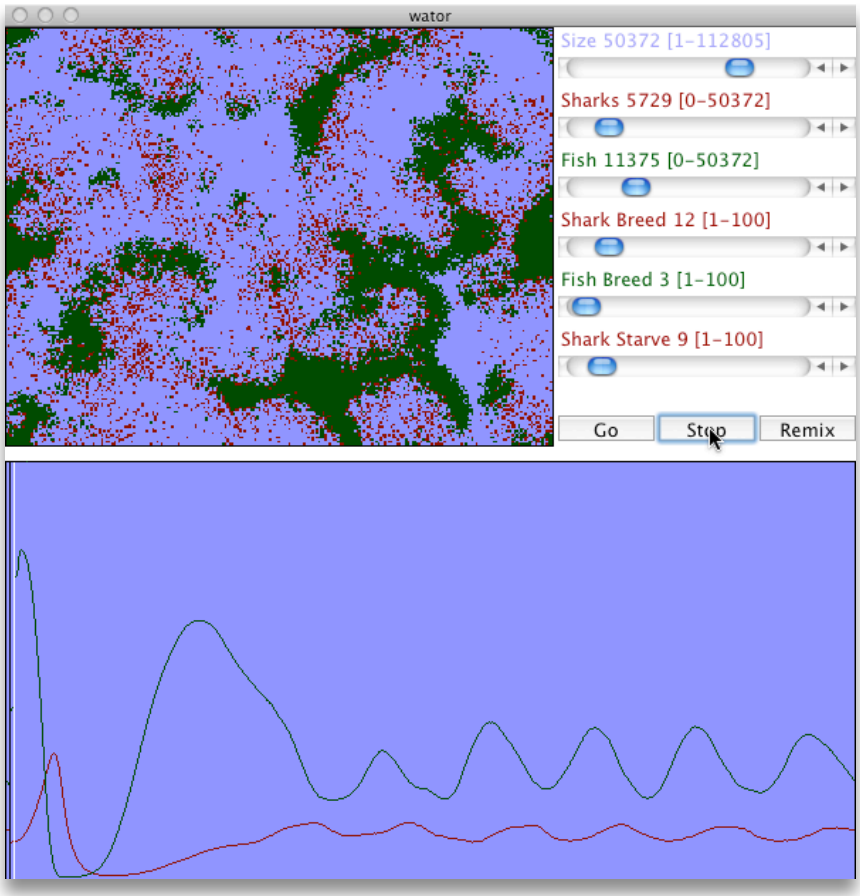
http://downloads.zdnet.com/abstract.aspx?docid=802129

Types of Simulations: steady-state



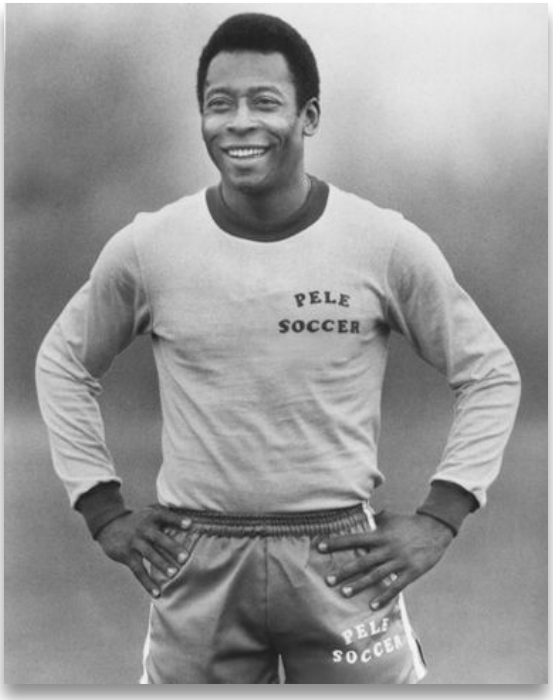
http://www.leinweb.com/snackbar/wator/

Types of Simulations: terminating



http://www.leinweb.com/snackbar/wator/

Types of Simulations: time-driven



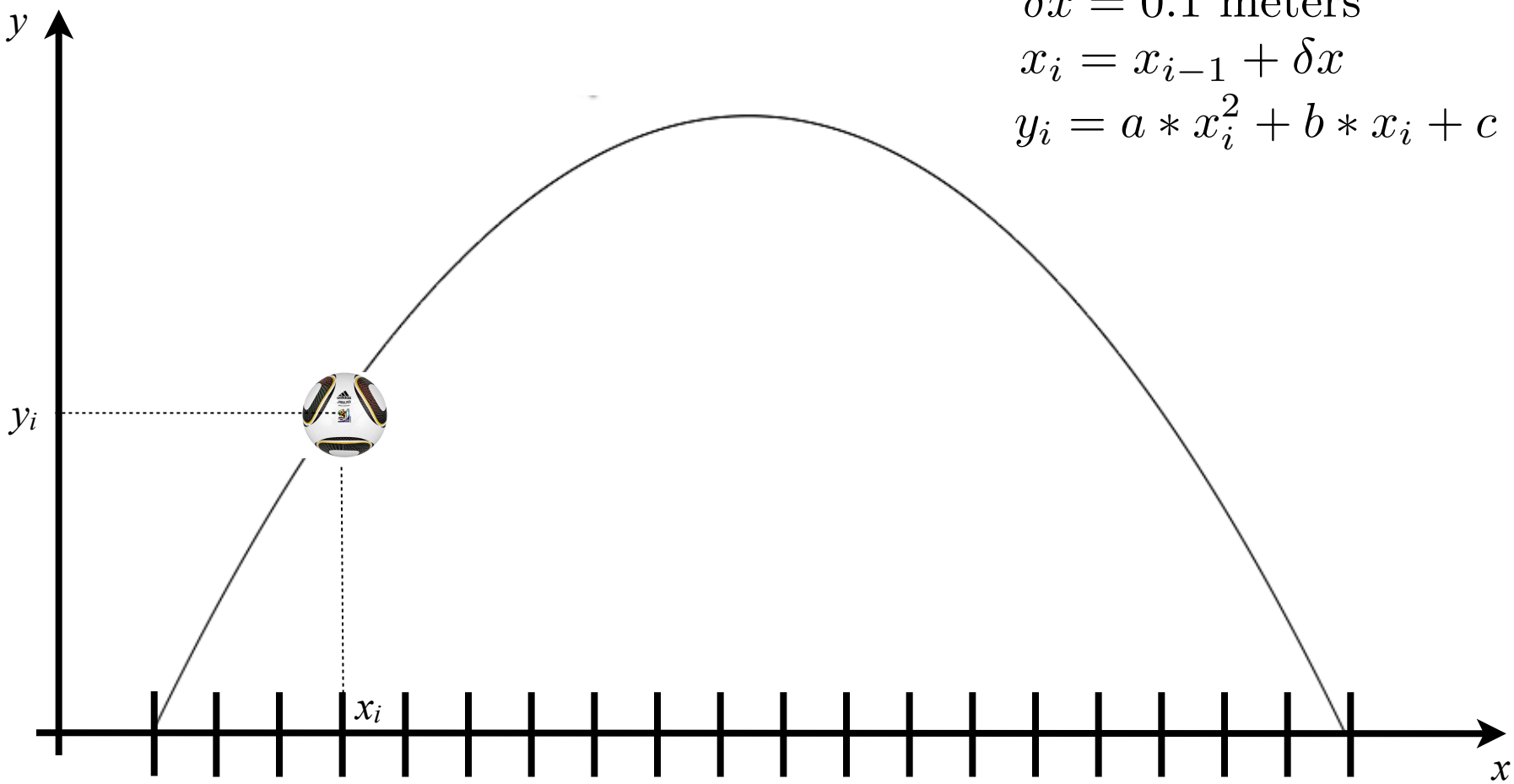
http://www.glogster.com/media/2/3/29/11/3291189.jpg

Goal: to simulate the trajectory of a soccer ball lobbied into the air with a decent amount of physical realism.

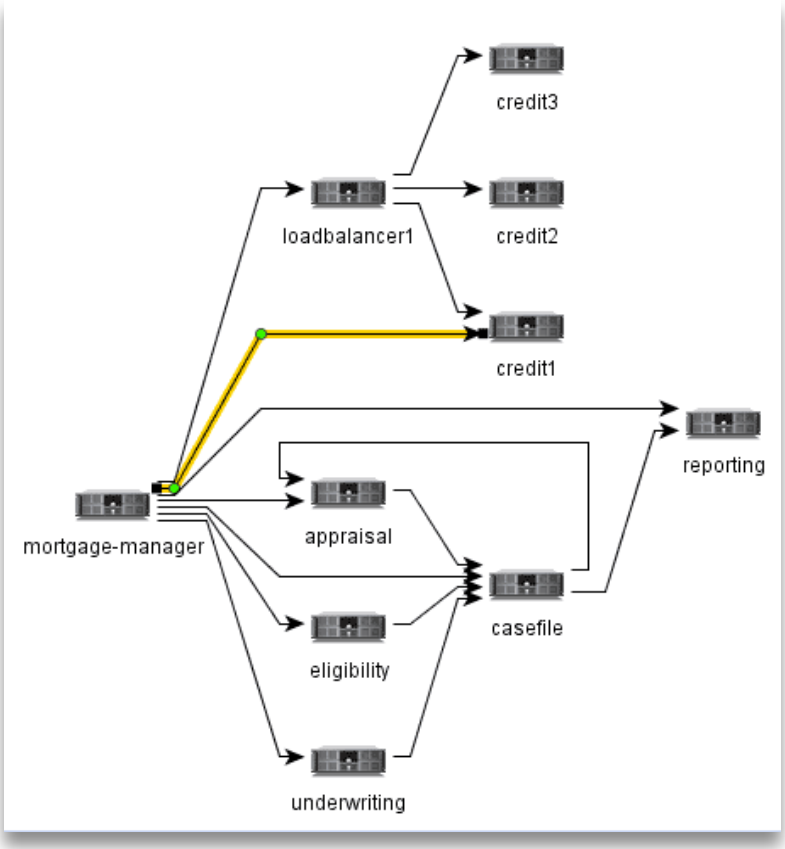
Model: state given by (x,y) coordinates of ball; time advances in discrete steps of δt.

Case study: Simulating Pelé

$$\delta x = 0.1 \text{ meters}$$
$$x_i = x_{i-1} + \delta x$$
$$y_i = a * x_i^2 + b * x_i + c$$



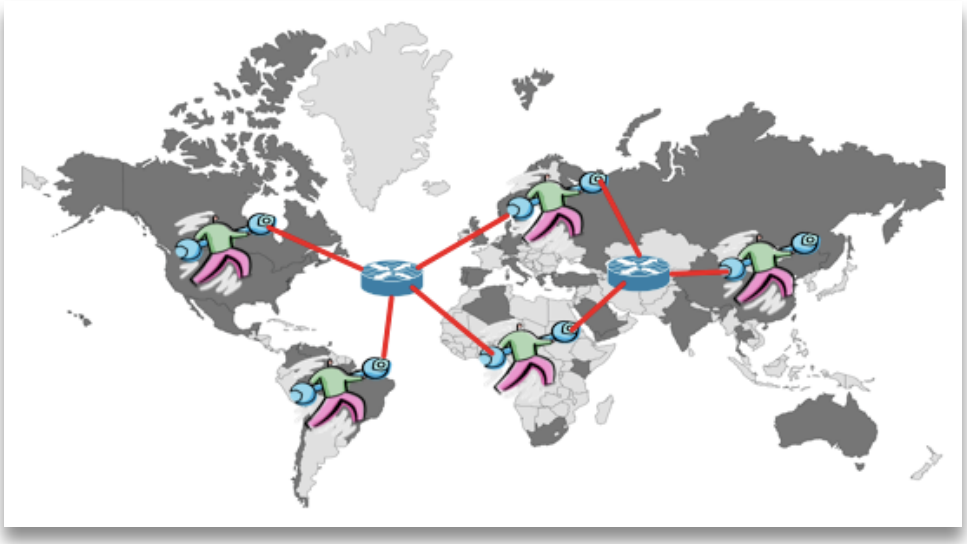
Types of Simulations: discrete-event



http://www.opnet.com/solutions/application_performance/appmapper-xpert.html

- The interesting things (**events**) happen only at discrete, random points in time.
- No reason to simulate the continuous nature of time.
- The state of the system only changes when events happen.
- Events are represented by the arrival of chunks of information called **packets**.
- The state of the system is a set of the states of various queues in components of the system.

Types of Simulations: discrete-event



https://www.primessf.net/bin/view/Public

- Various groups around the world are interested in simulating the global Internet.
- The Internet is almost like a highly complex living organism. In order to understand how it works (we all want good performance), we have turned to simulating it.

In my research, I am interested in studies that involve exploratory, large scale experiments with **network simulation**.

That means: lots of individual simulation runs, lots of data to post-process, to organize and save, and to visualize.

I need help to run experiments and to stay organized.

Network Simulation at Bucknell University

- For several years, we worked with SWAN, a simulator started at Dartmouth College. SWAN provided research opportunities for various undergraduate students (independent studies, honors theses, summer research.
- Currently, we work with ns-3, one of the world's most popular simulators (open source, funded by the NSF).
- Our current project is the Simulator Automation Framework for Experiments (**SAFE**) (funded by the NSF; collaborative work with the University of Washington and Georgia Tech).

Network Simulation at Bucknell University

So far, SAFE has spawned two honors theses (one more on the way), three summer research projects, and several independent studies. Our goals include:

- Making ns-3 simulations easier to execute in a single computer or in multiple networked computers (complete experiments faster).
- Keep the workflow organized so that the scientist has fewer opportunities to make mistakes.
- More details at
  - http://www.eg.bucknell.edu/safe/
  - http://redmine.eg.bucknell.edu/safe

Thanks for your interest!

Questions?