CSCI 202 Research Methods

Modeling and Simulation

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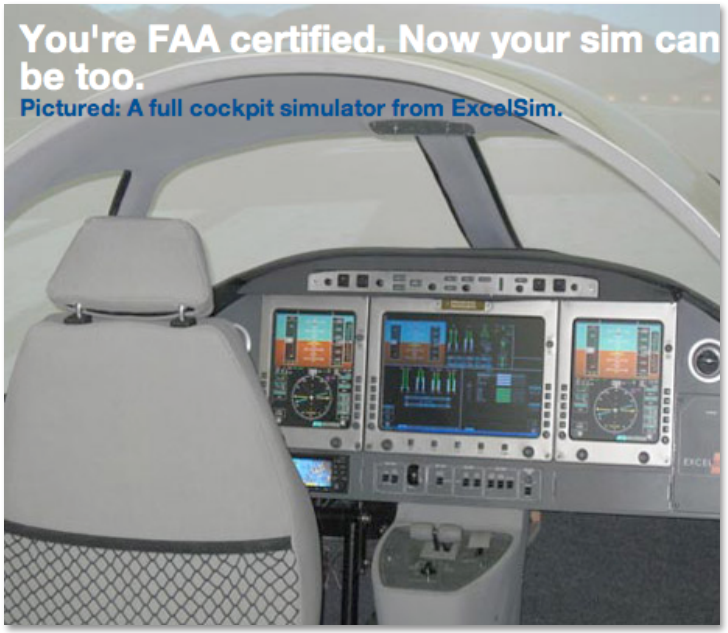
What is simulation?

Who needs simulation?

- Whoever may benefit from experimenting with a system.
- Whoever needs a system that they can fully control and observe.
- Whoever is studying a system so complex that it defies mathematical analysis.

For example: Training



For example: Games and movies

For example: Science

- Epidemiology
- Weather
- Marketing
- Physics
- Astronomy
- Chemistry
- Industrial engineering
- Management
- Biology
- Ecology
- Communications
- Electronics
- Computing
  - Architecture
  - Networks
  - …

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For example: Epidemiology

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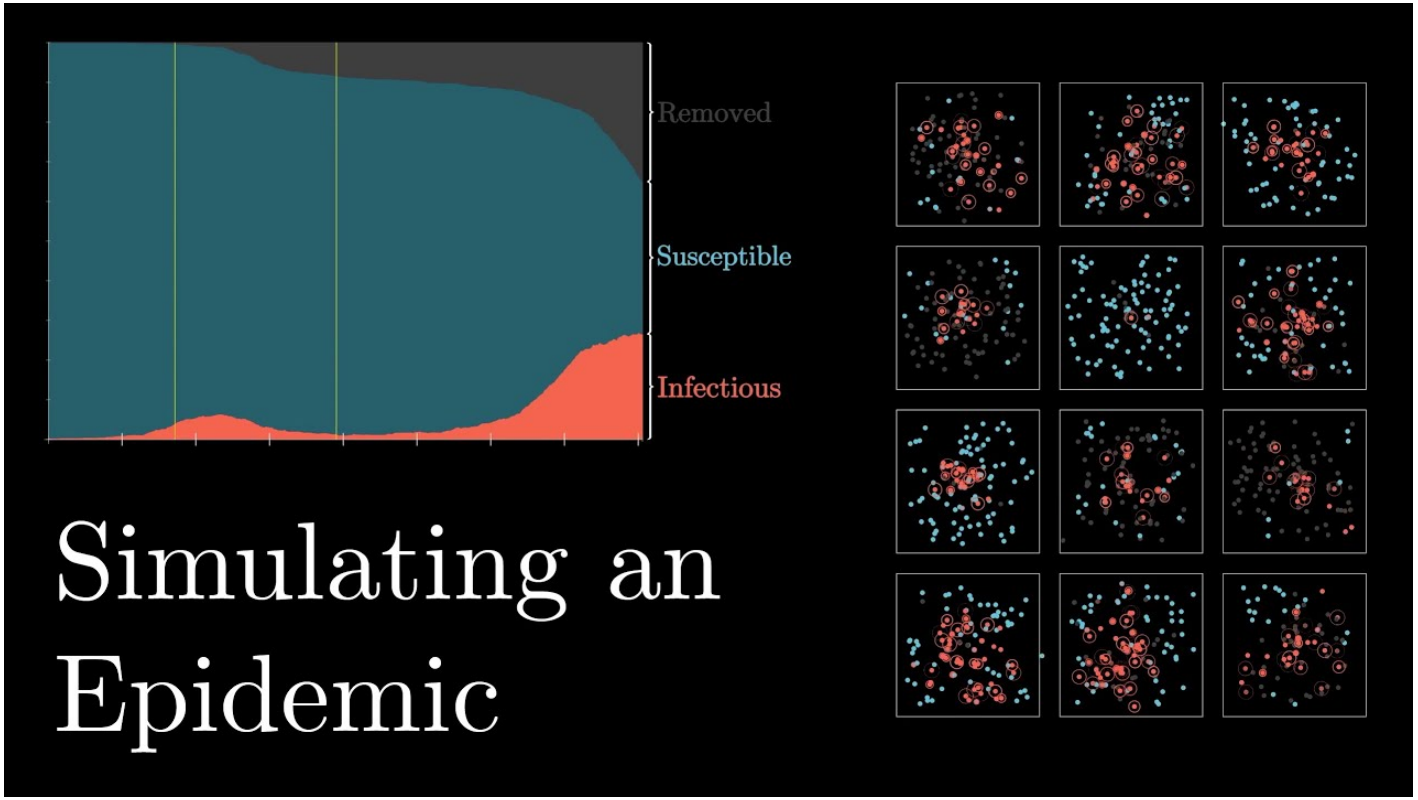
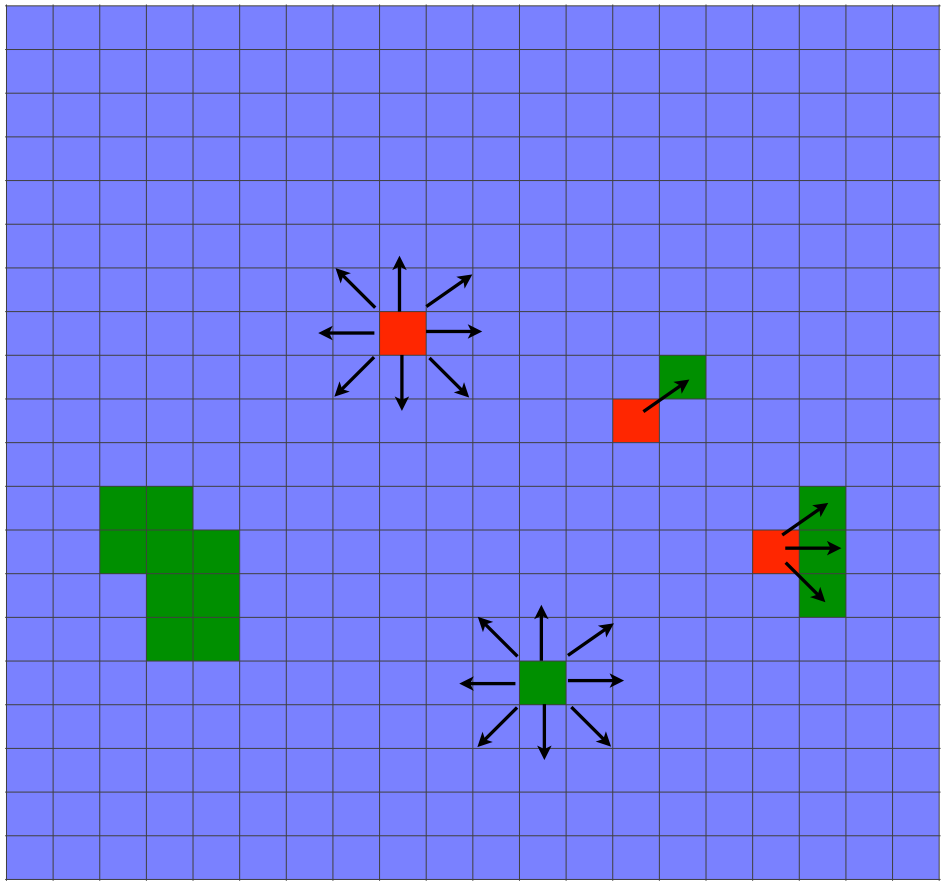
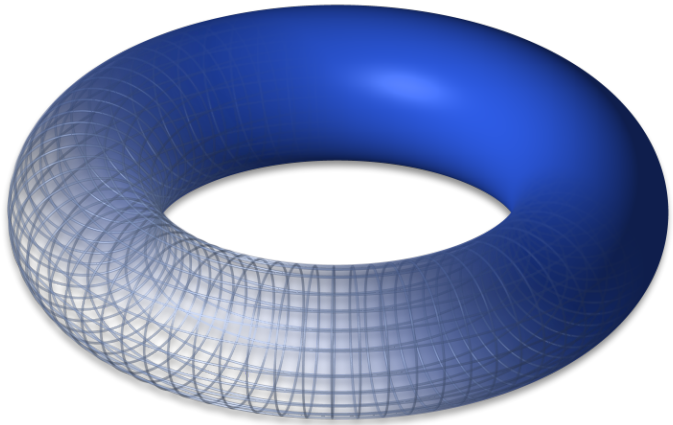


For example: WATOR





Parameters

- Initial number of fish
- Initial number of shark
- Breeding time for fish
- Breeding time for shark
- Starvation time for shark

For example: WATOR

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

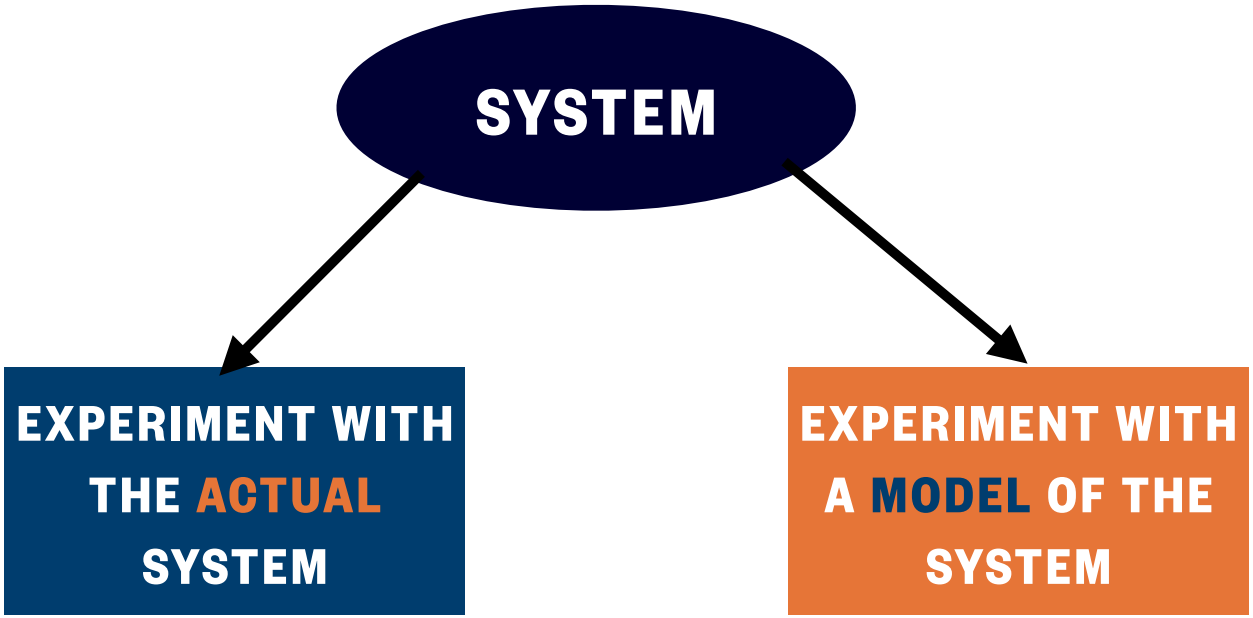
https://www.cheesygames.com/wator/

https://www.hydrus.org.uk/wator.html

Simulation is power

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

Ways to study a system



What is a model?

A model is an **abstraction**. It is the distillation of the essence of the most important features of a system.

What is a model?

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

What is a model?

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

What is a model?

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Let's model something simple

- What represents the state of the system?
- What are the possible states of the system?
- What changes the state of the system?

A static model

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A dynamic model

A dynamic model

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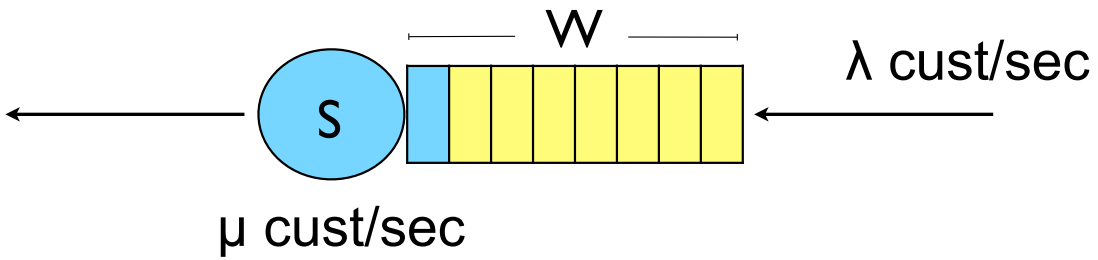

The state of the system at time *t*:

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

A dynamic model

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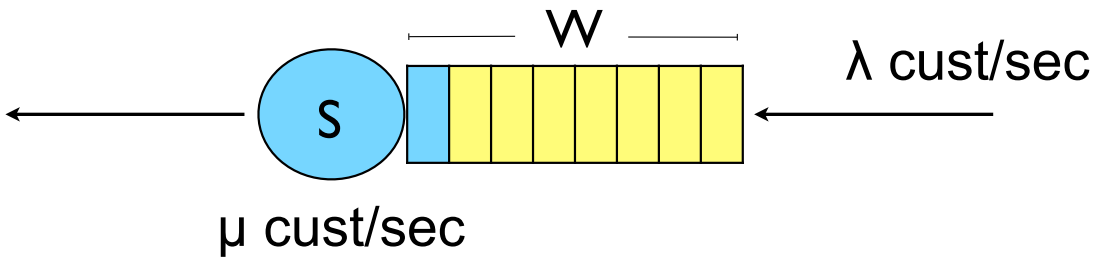

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Time? What's time?

A dynamic model

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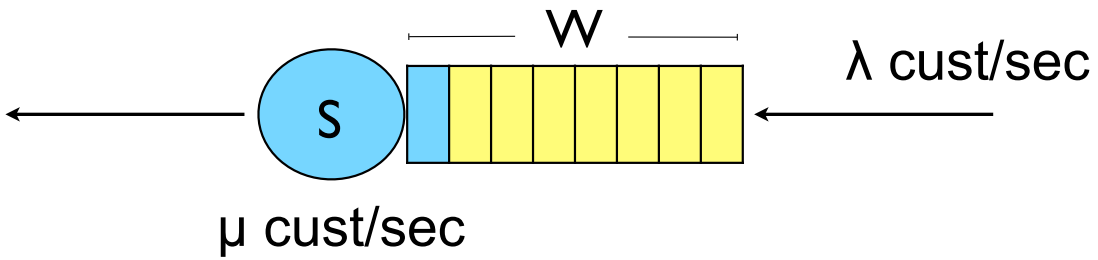

The state of the system at time *t*:

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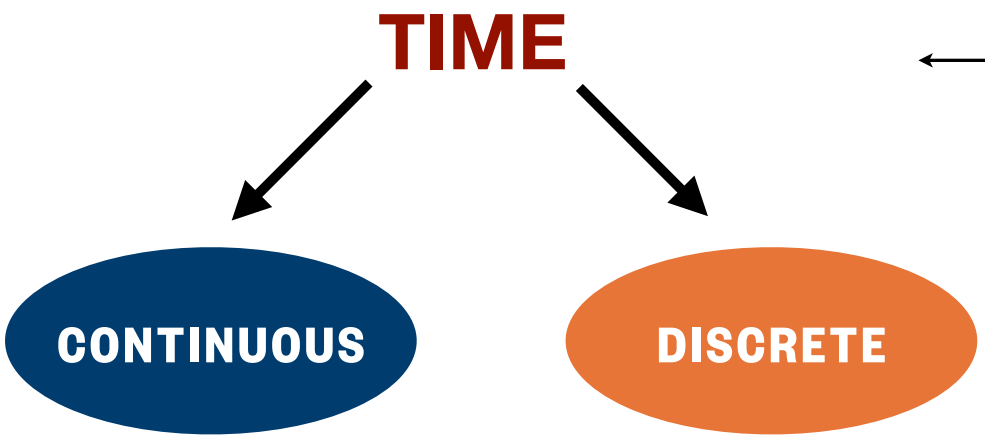
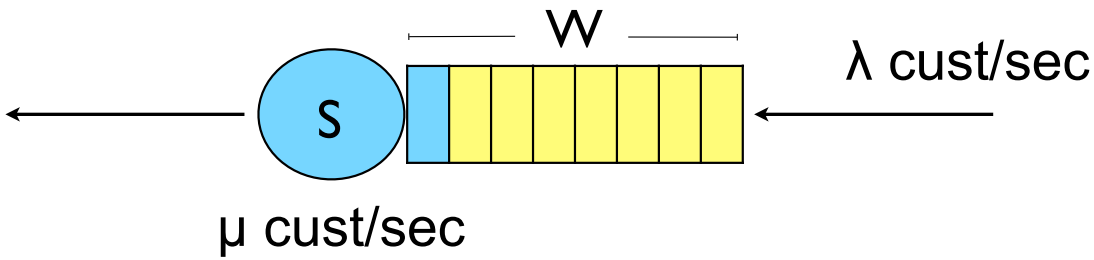
How does time evolve?

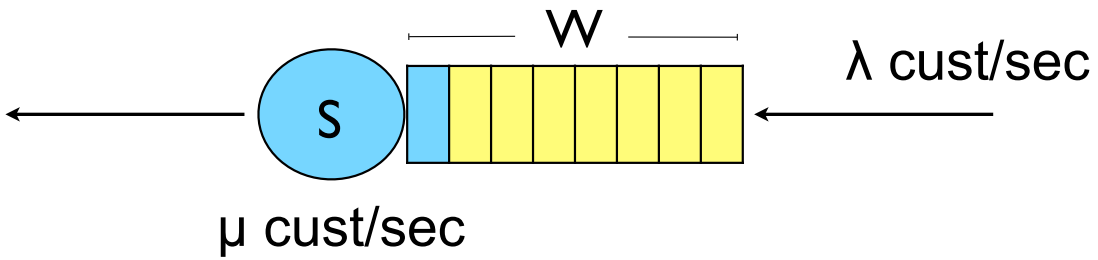
A dynamic model





A dynamic model

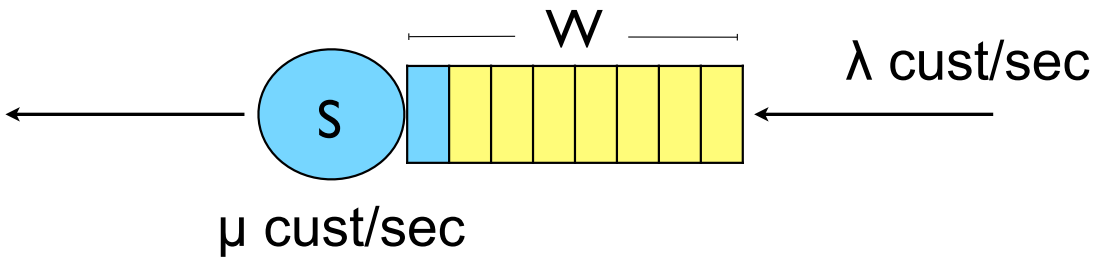
What do you want to know about this system?



A dynamic model

Average wait time for a customer (W)

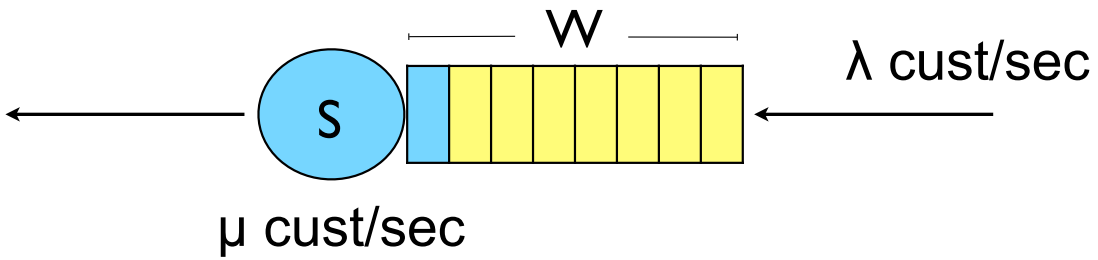
Average number of customers in the system (L)



A dynamic model

How do you characterize the time between customer arrivals?

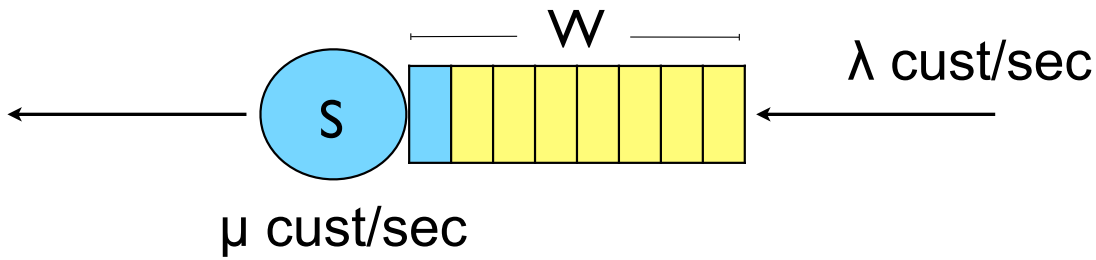
(interarrival time)



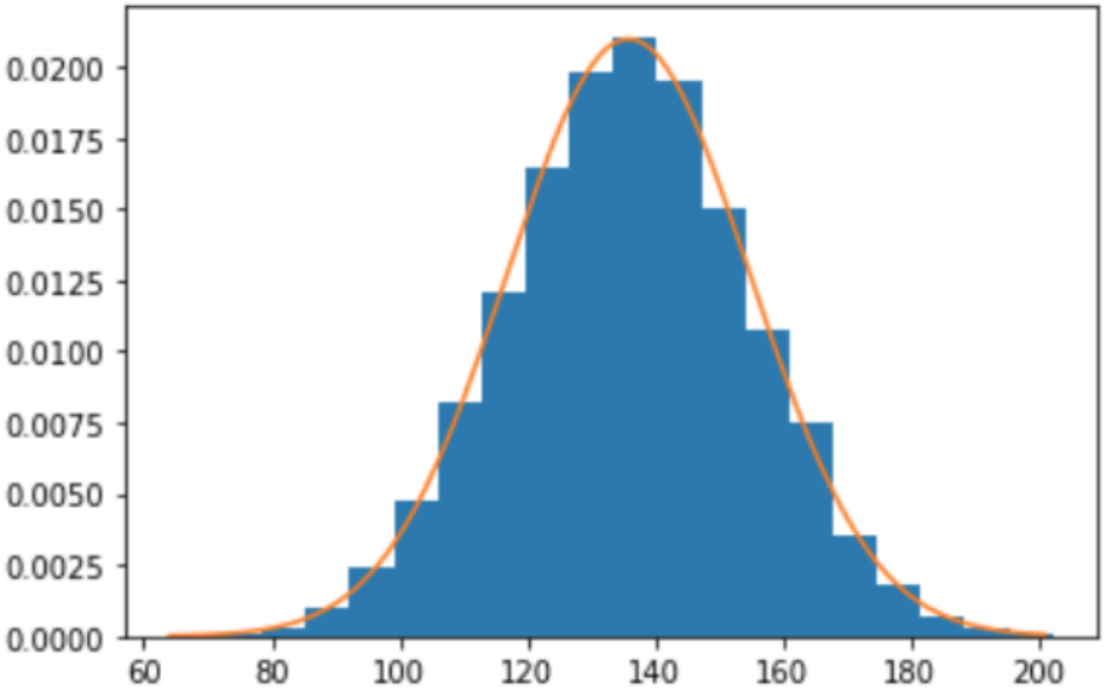
A dynamic model

How do you characterize the time it takes to serve a customer?

(service time)



Random variates



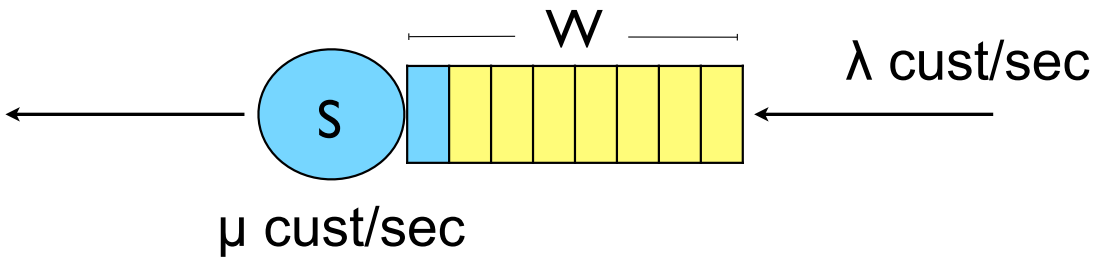
Discrete

or

Continuous

A queueing model

This one can be modeled and solved analytically

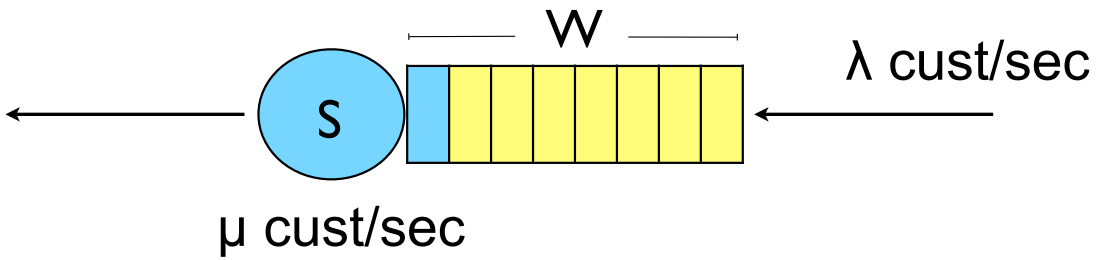


If easy enough math gives you what you need, you're done.

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

A queueing model

This one can be modeled and solved analytically



$$L = \frac{\frac{\lambda}{\mu}}{1 - \frac{\lambda}{\mu}}$$

$$W = \frac{1}{\mu - \lambda}$$

M/M/1

Markovian arrivals

A queueing model

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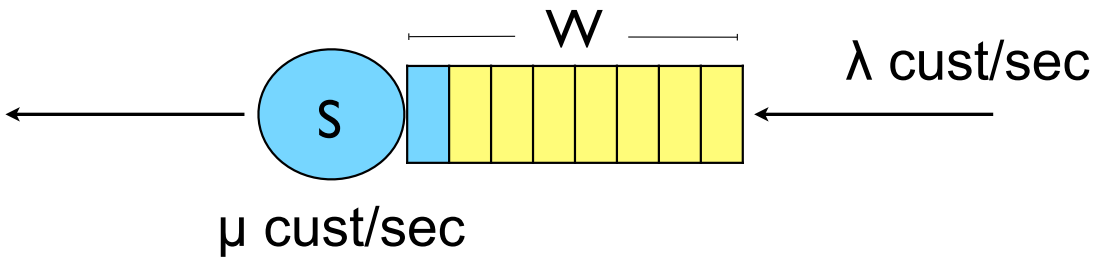

$$L = \frac{\frac{\lambda}{\mu}}{1 - \frac{\lambda}{\mu}}$$

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M/M/1

Markovian service times

A queueing model

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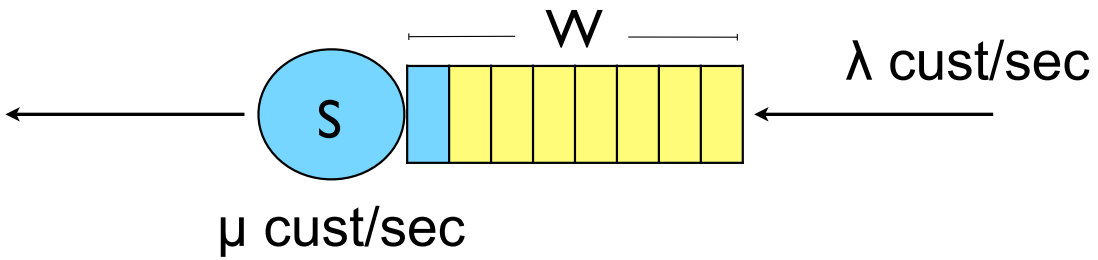


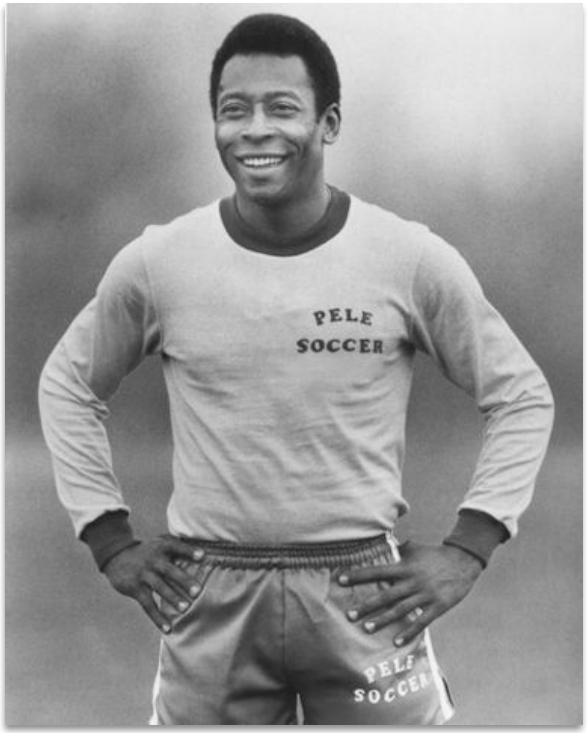
$$L = \frac{\frac{\lambda}{\mu}}{1 - \frac{\lambda}{\mu}}$$

$$W = \frac{1}{\mu - \lambda}$$

M/M/1

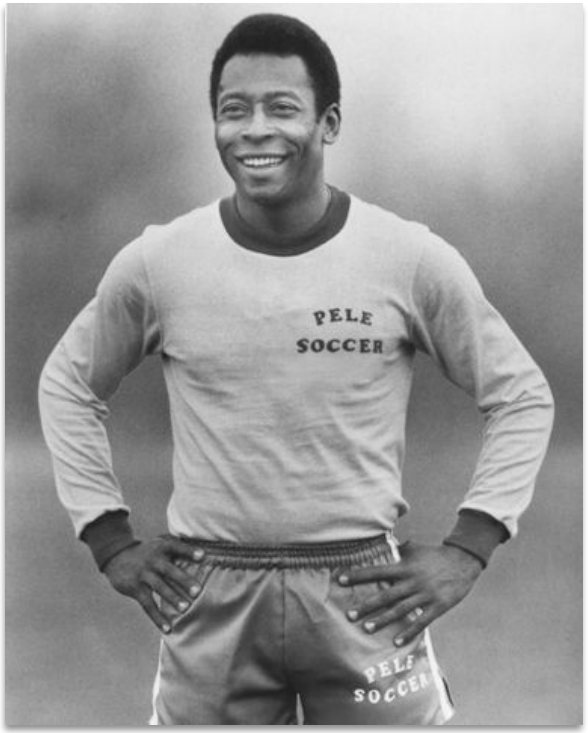
1 server

Another dynamic model



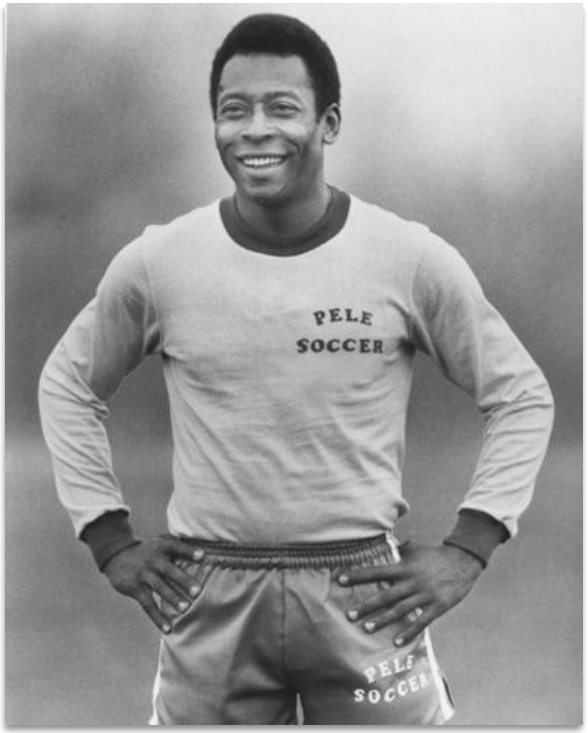
Goal: to simulate the trajectory of a soccer ball lobbied into the air with *physical realism*.

Another dynamic model



Model: the state is given by the coordinates *(x(t),y(t))* of the ball at a specific time *t.*

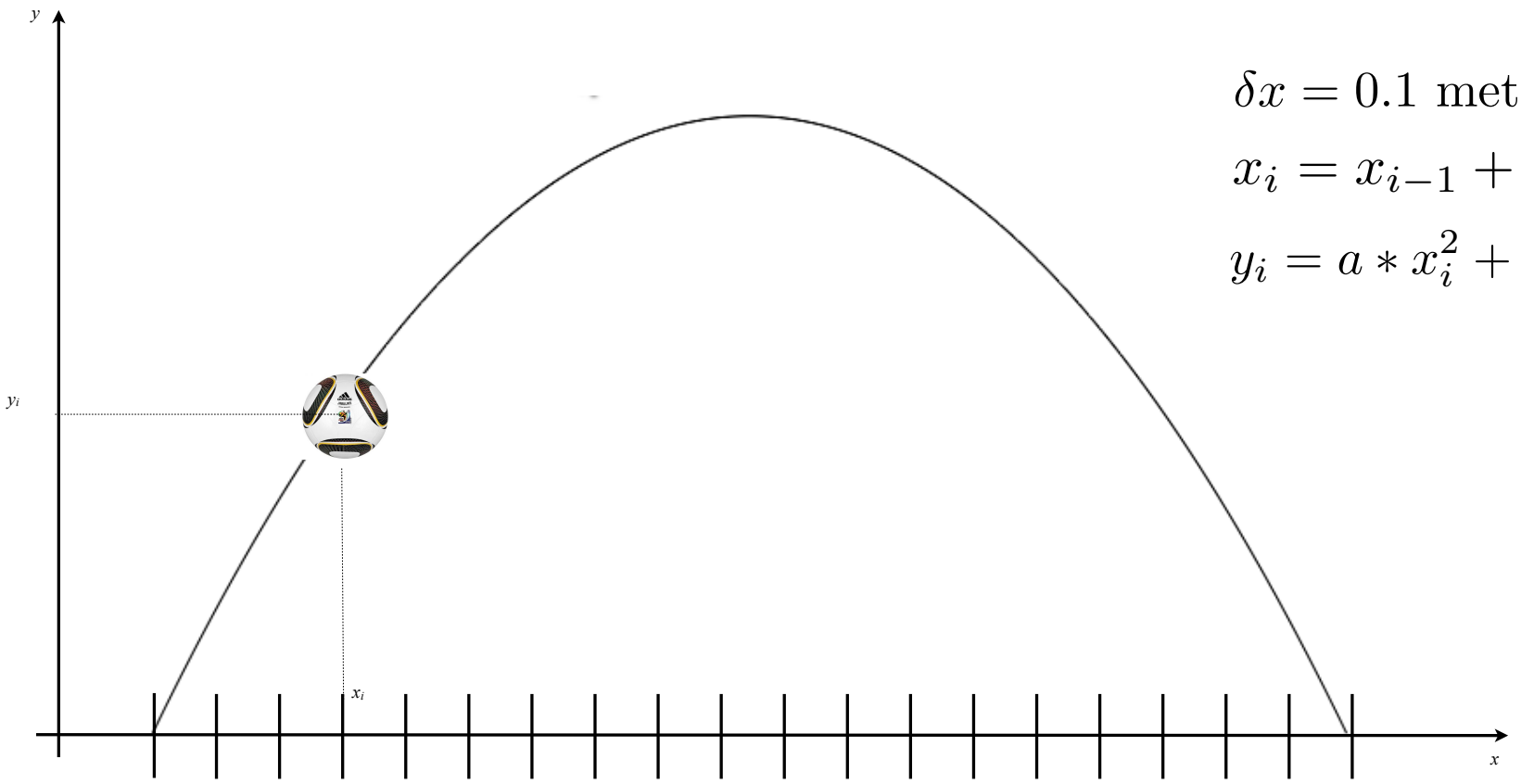
Another dynamic model



Model: the state is given by the coordinates *(x(t),y(t))* of the ball at a specific time *t.*

BIG Question:
How does time advance?

Another dynamic model



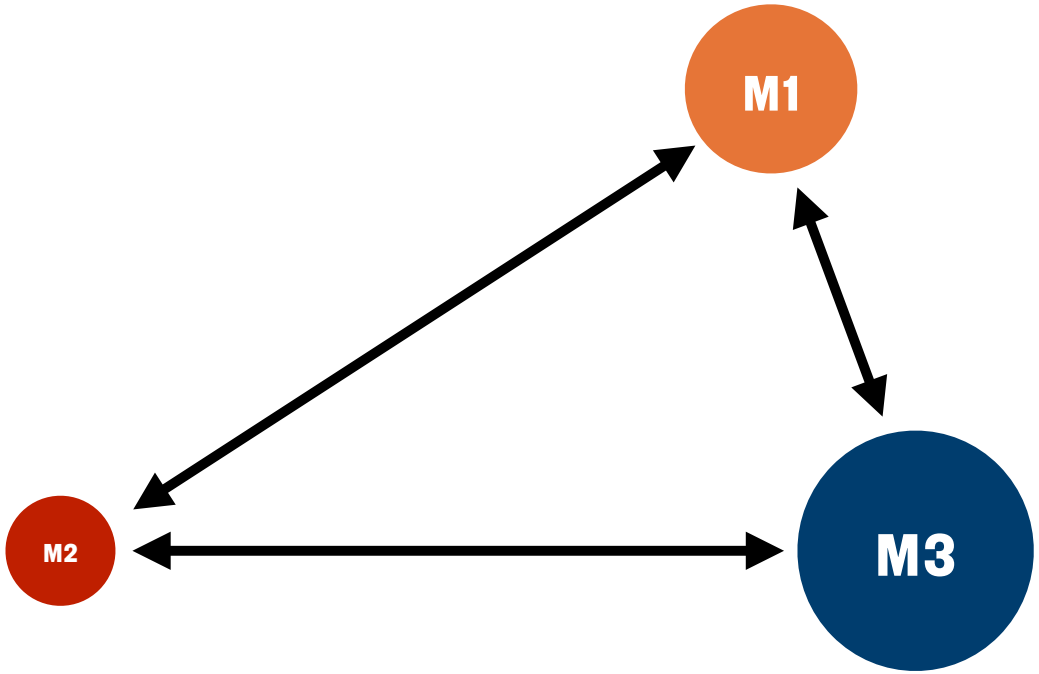
$$\delta x = 0.1 \text{ meters}$$

$$x_i = x_{i-1} + \delta x$$

$$y_i = a * x_i^2 + b * x_i + c$$

Yet another dynamic model

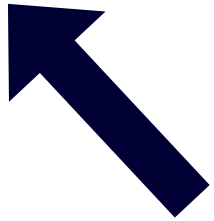
Three-body Problem



A static model

Predicting profits for furniture sales

Simulation Model for Special Promotion Furniture Sale				fixed by contract
				input data
Stock ordered (S):	3000			calculated data
Unit cost for stock (C):	$175.00			
			Distribution Parameters	
			Lower	Upper
Demand within first 8 weeks (V):	2667		500	3500
Sales within first 8 weeks (V):	2667			
Initial price (R):	$251		200	300
Sales after first 8 weeks (S-V):	333			
Discount (D):	0.2			
Sale price (R*D):	0.5			
Profit (P):	$144,343			
Note: Google Sheets refresh on browser reload command				



Time has no bearing on this model

A static model

Predicting profits for furniture sales

This one is on Moodle:

Spreadsheet simulation