Course Notes

Mathematical Models, Spring 2018

Queens College, Math 245

Prof. Christopher Hanusa

`http://qcpages.qc.cuny.edu/~chanusa/courses/245/18/`

What is a model?

A model is an object or concept used to represent something else.
It converts reality to a form we can comprehend.

▶ Reality: How to understand the aerodynamics of an airplane?

What is a model?

A model is an object or concept used to represent something else. It converts reality to a form we can comprehend.

▶ Reality: How to understand the aerodynamics of an airplane?
  Model: Use a **model airplane** or a **computer simulation**.

What is a model?

A model is an object or concept used to represent something else.
It converts reality to a form we can comprehend.

▶ Reality: How to understand the aerodynamics of an airplane?
   Model: Use a **model airplane** or a **computer simulation**.

▶ Reality: Politics flows between left-wing and right-wing ideas.

What is a model?

A model is an object or concept used to represent something else.
It converts reality to a form we can comprehend.

- ▶ Reality: How to understand the aerodynamics of an airplane?
  Model: Use a **model airplane** or a **computer simulation**.
- ▶ Reality: Politics flows between left-wing and right-wing ideas.
  Model: Think of public opinion as a **pendulum**.

What is a model?

A model is an object or concept used to represent something else.
It converts reality to a form we can comprehend.

▶ Reality: How to understand the aerodynamics of an airplane?
  Model: Use a **model airplane** or a **computer simulation**.

▶ Reality: Politics flows between left-wing and right-wing ideas.
  Model: Think of public opinion as a **pendulum**.

A mathematical model is a model involving mathematical concepts.

What is a model?

A model is an object or concept used to represent something else.
It converts reality to a form we can comprehend.

- ▶ Reality: How to understand the aerodynamics of an airplane?
  Model: Use a **model airplane** or a **computer simulation**.

- ▶ Reality: Politics flows between left-wing and right-wing ideas.
  Model: Think of public opinion as a **pendulum**.

A mathematical model is a model involving mathematical concepts.

IN THIS CLASS:
We take real-world situations and represent them using mathematics.

- ▶ Model bike sharing using a **computer simulation**.
- ▶ Model world population by comparing **growth functions**.
- ▶ Model infection rate using **differential equations**.

What is a model?

A model is an object or concept used to represent something else.
It converts reality to a form we can comprehend.

- ▶ Reality: How to understand the aerodynamics of an airplane?
  Model: Use a **model airplane** or a **computer simulation**.

- ▶ Reality: Politics flows between left-wing and right-wing ideas.
  Model: Think of public opinion as a **pendulum**.

A mathematical model is a model involving mathematical concepts.

IN THIS CLASS:
We take real-world situations and represent them using mathematics.

- ▶ Model bike sharing using a **computer simulation**.

- ▶ Model world population by comparing **growth functions**.

- ▶ Model infection rate using **differential equations**.

Then we must **analyze our models** to determine their applicability.

Why should we model?

As scientists, we want to understand how the world works.

observed real-world
behavior

Why should we model?

As scientists, we want to understand how the world works.

observed real-world
behavior

- ▶ What is happening?
- ▶ What are the reasons for the behavior?

Why should we model?

As scientists, we want to understand how the world works.

observed real-world behavior

- ▶ What is happening?
- ▶ What are the reasons for the behavior?
- ▶ How do we convey that our reasoning is plausible?

Why should we model?
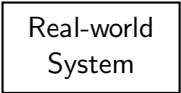
As scientists, we want to understand how the world works.

 $\longrightarrow$ observed real-world
$\rightsquigarrow$
$\longrightarrow$ behavior

▶ What is happening?   (Observation)

▶ What are the reasons for the behavior?   (Hypothesis)

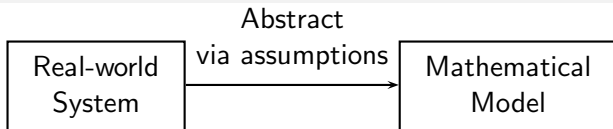▶ How do we convey that our reasoning is plausible?   ("proof")
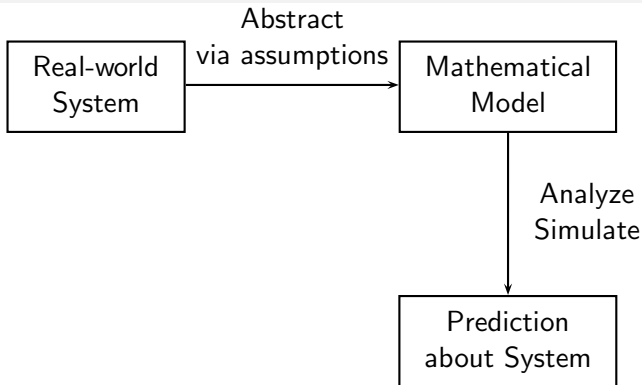
— Use the language of mathematics! —

How do we model?

Real-world
System

How do we model?

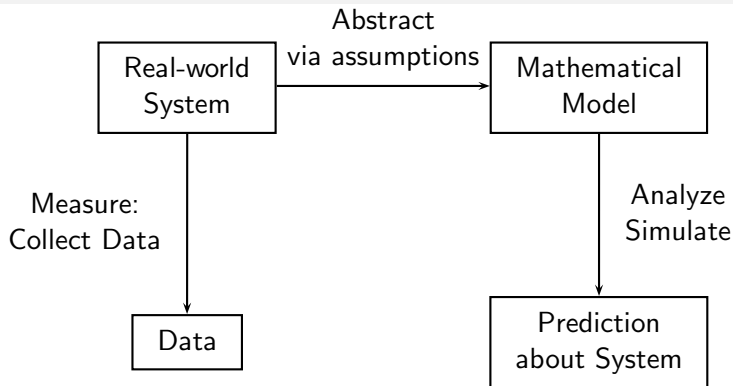Real-world System → Abstract via assumptions → Mathematical Model

▶ Identify the most important variables in a real-world system
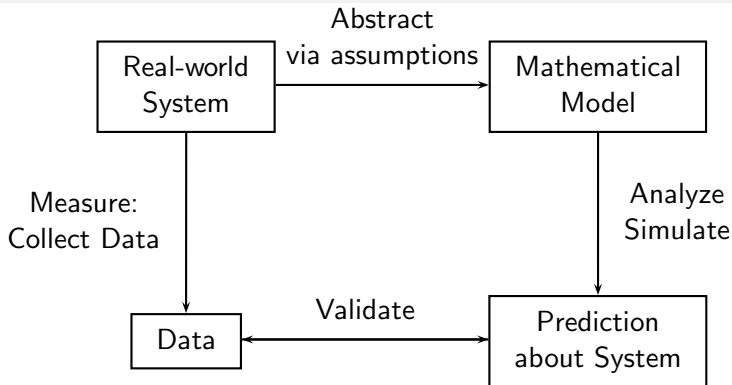
How do we model?

- ▶ Identify the most important variables in a real-world system
- ▶ Analyze the model / Create a computer simulation

How do we model?

- ▶ Identify the most important variables in a real-world system
- ▶ Analyze the model / Create a computer simulation
- ▶ Collect some data from the real world system

How do we model?

- ▶ Identify the most important variables in a real-world system
- ▶ Analyze the model / Create a computer simulation
- ▶ Collect some data from the real world system
- ▶ Validate your model and refine / revise!

A normal day in this class

- Arrive on time & Be ready to participate!

A normal day in this class

- ▶ Arrive on time & Be ready to participate!
- ▶ Discussion of responses to Daily Question, recap.

A normal day in this class

- ▶ Arrive on time & Be ready to participate!
- ▶ Discussion of responses to Daily Question, recap.
- ▶ Introduction to new concepts
  - ▶ Overview of the day, focus on complex concepts

A normal day in this class

▶ Arrive on time & Be ready to participate!

▶ Discussion of responses to Daily Question, recap.

▶ Introduction to new concepts

　　▶ Overview of the day, focus on complex concepts

▶ Tutorials

　　▶ Work through Python notebook or textbook exercises

　　▶ Explore, Take notes in notebook (Save to your email.)

　　▶ Group Project Work

A normal day in this class

In class

- ▶ Arrive on time & Be ready to participate!
- ▶ Discussion of responses to Daily Question, recap.
- ▶ Introduction to new concepts
  - ▶ Overview of the day, focus on complex concepts
- ▶ Tutorials
  - ▶ Work through Python notebook or textbook exercises
  - ▶ Explore, Take notes in notebook (Save to your email.)
  - ▶ Group Project Work

A normal day in this class

Outside class

In class

- ▶ Arrive on time & Be ready to participate!
- ▶ Discussion of responses to Daily Question, recap.
- ▶ Introduction to new concepts
  - ▶ Overview of the day, focus on complex concepts
- ▶ Tutorials
  - ▶ Work through Python notebook or textbook exercises
  - ▶ Explore, Take notes in notebook (Save to your email.)
  - ▶ Group Project Work

Outside class

A normal day in this class

Outside class

In class

Outside class

- ▶ Arrive on time & Be ready to participate!
- ▶ Discussion of responses to Daily Question, recap.
- ▶ Introduction to new concepts
  - ▶ Overview of the day, focus on complex concepts
- ▶ Tutorials
  - ▶ Work through Python notebook or textbook exercises
  - ▶ Explore, Take notes in notebook (Save to your email.)
  - ▶ Group Project Work

- ▶ Learning after class
  - ▶ Finish tutorial, review notes, project work

A normal day in this class

Outside class

▶ Preparing for class
  ▶ Respond to Daily Question, prepare questions.

In class

▶ Arrive on time & Be ready to participate!
▶ Discussion of responses to Daily Question, recap.
▶ Introduction to new concepts
  ▶ Overview of the day, focus on complex concepts
▶ Tutorials
  ▶ Work through Python notebook or textbook exercises
  ▶ Explore, Take notes in notebook (Save to your email.)
  ▶ Group Project Work

Outside class

▶ Learning after class
  ▶ Finish tutorial, review notes, project work

To do well in this class:

▶ **Form good study groups.**
  - ▶ Discuss homework and classwork.
  - ▶ Bounce around ideas, topics, questions.
  - ▶ It helps to have people to talk through things with.

To do well in this class:

- ▶ **Form good study groups.**
  - ▶ Discuss homework and classwork.
  - ▶ Bounce around ideas, topics, questions.
  - ▶ It helps to have people to talk through things with.
- ▶ **Put in the time OUTSIDE class.**
  - ▶ Three credits = 6–9 hours / week out of class.
  - ▶ The work stresses key concepts from class; learning takes time.

To do well in this class:

- **Form good study groups.**
  - Discuss homework and classwork.
  - Bounce around ideas, topics, questions.
  - It helps to have people to talk through things with.
- **Put in the time OUTSIDE class.**
  - Three credits = 6–9 hours / week out of class.
  - The work stresses key concepts from class; learning takes time.
- **Come to class prepared.**
  - Review previous day's notes.
  - Do the homework & work on your projects.

To do well in this class:

▶ **Form good study groups.**
  ▶ Discuss homework and classwork.
  ▶ Bounce around ideas, topics, questions.
  ▶ It helps to have people to talk through things with.

▶ **Put in the time OUTSIDE class.**
  ▶ Three credits = 6–9 hours / week out of class.
  ▶ The work stresses key concepts from class; learning takes time.

▶ **Come to class prepared.**
  ▶ Review previous day's notes.
  ▶ Do the homework & work on your projects.

▶ **Stay in contact.**
  ▶ If you are confused, ask questions (in class and out).
  ▶ Don't fall behind in coursework or homework.
  ▶ I need to understand your concerns.

To do well in this class:

- **Form good study groups.**
  - Discuss homework and classwork.
  - Bounce around ideas, topics, questions.
  - It helps to have people to talk through things with.
- **Put in the time OUTSIDE class.**
  - Three credits = 6–9 hours / week out of class.
  - The work stresses key concepts from class; learning takes time.
- **Come to class prepared.**
  - Review previous day's notes.
  - Do the homework & work on your projects.
- **Stay in contact.**
  - If you are confused, ask questions (in class and out).
  - Don't fall behind in coursework or homework.
  - I need to understand your concerns.

Everything posted online; first one (many parts) due Wednesday.

Software Installation.

Choose a computer. (Remember the number.)
Log On: User: `Student`   —   Password: `Student1`

Install Anaconda Distribution of Python:

▶ Go to the shared documents folder.

▶ Double click on Anaconda installation.

▶ Click on "Install for me only".

▶ Click on Continue / Agree as needed.

Install the package Pint:

▶ In the upper right corner, click the magnifying glass

▶ Type in "Terminal", click enter.

▶ In this window, type `su QCUser`. (I will enter password.)

▶ In this window, type `sudo pip install pint` (+ password.)

Software Installation.

Use GitHub Online:

▶ Create an account at https://education.github.com/

▶ When logged in to GitHub, navigate to
   https://github.com/AllenDowney/ModSimPy.

▶ Get a copy of course documents: Click "Fork" at top right.
   Use the name "ModSimPy" for your repo.

Use GitHub on your computer:

▶ Click on GitHub Desktop in the shared documents folder.

▶ Log in with your GitHub account.

▶ Go to File > "Clone Repository" and enter in your URL.
   Ex: https://github.com/245student/ModSimPy.
   Choose the name "ModSimPy" for the local folder.

Get started with Google Classroom:

Go to your Google Apps for Education account

- ▶ Visit Google Drive at `http://drive.google.com`.
- ▶ Enter your **QUEENS COLLEGE** Email Address.
- ▶ Log in with your CAMS information.
- ▶ Visit Google Classroom at `http://classroom.google.com`
- ▶ Click on the plus sign at the top of the page.
- ▶ Select Join Class and use class code **prcgobx**.
- ▶ Respond to Daily Question: January 29.
- ▶ Look at your groupmates' responses and comment on them.

Start working in a Python notebook!

Open Anaconda Navigator

- ▶ Click on the magnifying glass and type & select Anaconda.
- ▶ Click on "Launch" under "Jupyter Notebook".
- ▶ Navigate to the folder that has your files in it
  (probably `Documents/GitHub/ModSimPy/`)
  and into the folder "code".
- ▶ Click on chapter1.
- ▶ At the top of the screen, click "File > Make a Copy...".
- ▶ Rename this copy to be your name "chap01-XXXXX"
- ▶ Now you can work in the notebook.