CS 357 – Numerical Methods 1

Prof. Mariana Silva

CampusWire

- All communication will happen via CampusWire. NO EMAILS!

- Check it daily!

- Important course announcements will be pinned.

Course Website - Syllabus

PrairieLearn Content

- Lecture
- Workspaces
- Group Activity
- Homework
- Machine Problem
- Practice Quiz

Collaborative Learning

- Complete weekly activity in groups
- Week 1 and 2: randomly assigned groups via Zoom
- Week 3-8: fixed groups
- Week 9-14: fixed groups
- Next class (Thursday) we will talk about group assignment, feedback, and policies

More course logistics

- Office hours start next week (via Zoom)
- Eating is NOT allowed in classroom. You must eat your lunch before or after class.
- Course Survey and Consent Form (Morgan)

PrairieLearn Tour and CBTF Quizzes

Next class

- Course topics
- Use PL for group activity: trial run

Introduction and "Big Idea"

What are…

Numerical Methods ?

Numbers in a computer
(and how computer understands these numbers)

- Mathematical model
  - “algorithms” derived from math ideas to solve equations numerically
- Complexity of the problem
  - Slow vs fast
- Accuracy
  - Accurate vs inaccurate

Method = Math + Complexity + Accuracy

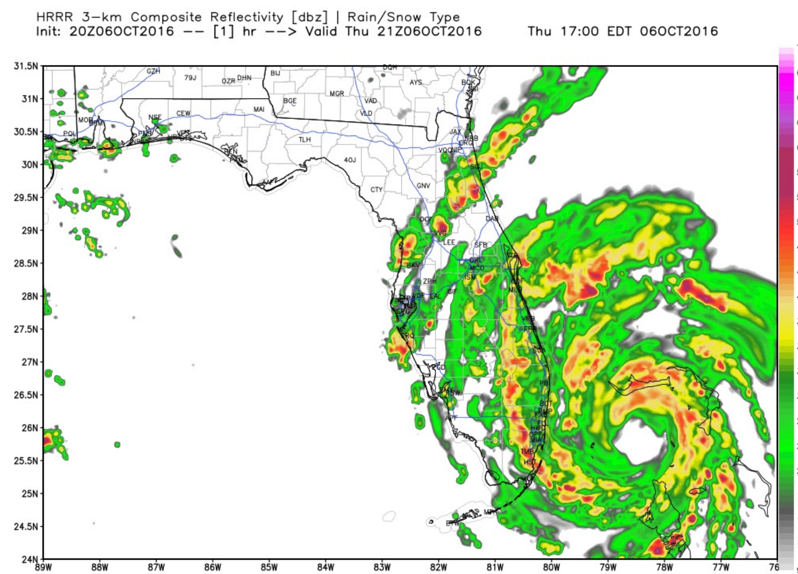
Why is this course important?

Explosion of [Ariane 5](#) in 1996

1. Understanding and reconstruction of known problems
   - Natural disasters
   - Catastrophic failures

2. Prediction of unknown situations
   - Weather conditions
   - Behavior of new materials

3. Optimization of existing problems
   - Image recognition
   - Reduce fabrication costs



Goals for this course

- Understand how numbers are represented in the computer.
- When developing code, you will likely run into numerical errors. What are the sources of these errors?
- How can you avoid numerical errors?
- How can you choose a suitable algorithm for a given application?
- Use existing libraries to solve real applications.

(Numerical) **Method** = **Math** + Complexity + Accuracy

Mathematical model:

What equations can we use to represent our problem?

Accuracy:

Are we getting accurate results?

Why is the method not giving me the correct solution?

Complexity:

How long does it take to solve this problem?

Is it cost-effective?

Your entire CS 357 semester in a few slides!

Are you ready?

Accuracy

- Why a numerical method might not give the right answer?
  - Computers have finite representation of numbers
  - Sometimes the "right answer" cannot be represented in a finite way
  - Example:

$$\pi = 3.14159265358979323846264338327950288419 71\ldots$$

Demo: Waiting for the number 1

```
from time import sleep

x = 0.0

while x != 1.0:
    x += 0.1
    print(repr(x))

    sleep(0.1)
```

What is going to happen when we run this code?

A. Code will stop after printing 11 values for x
B. Code will stop after printing 10 values for x
C. Code will not stop
D. Code will not start

Monte Carlo Methods

Texas Holdem Game: we would like to determine the probability of winning of a given starting hand

Physical experiment
vs
Numerical experiment

Numerical Experiments

- What do we want to know about a numerical experiment?
  1. What questions are we attempting to answer?
  2. What is the outcome of the experiment?
  3. Is it repeatable?
  4. Is the answer accurate?
  5. How long will it take?

Time vs accuracy trade-off

Question: Is running this method (with a certain accuracy) a good use of our time and/or computer resources?

Complexity

How long does it take to solve a problem?

Given A, B matrices of size $m \times m$, the matrix-matrix multiplication $A \cdot B$ takes τ seconds.

How long does it take to perform $C \cdot D$, matrices of size $2m \times 2m$?

```
from time import process_time
import numpy as np
from time import process_time
```

```
n = 2000
A = np.random.randn(n,n)
B = np.random.randn(n,n)

t = process_time()  # store the time
C = A @ B
t = process_time() - t
print(t)
```

```
A = np.random.randn(2*n,2*n)
B = np.random.randn(2*n,2*n)

t2 = process_time()  # store the time
C = A @ B
t2 = process_time() - t2
print(t2)
```

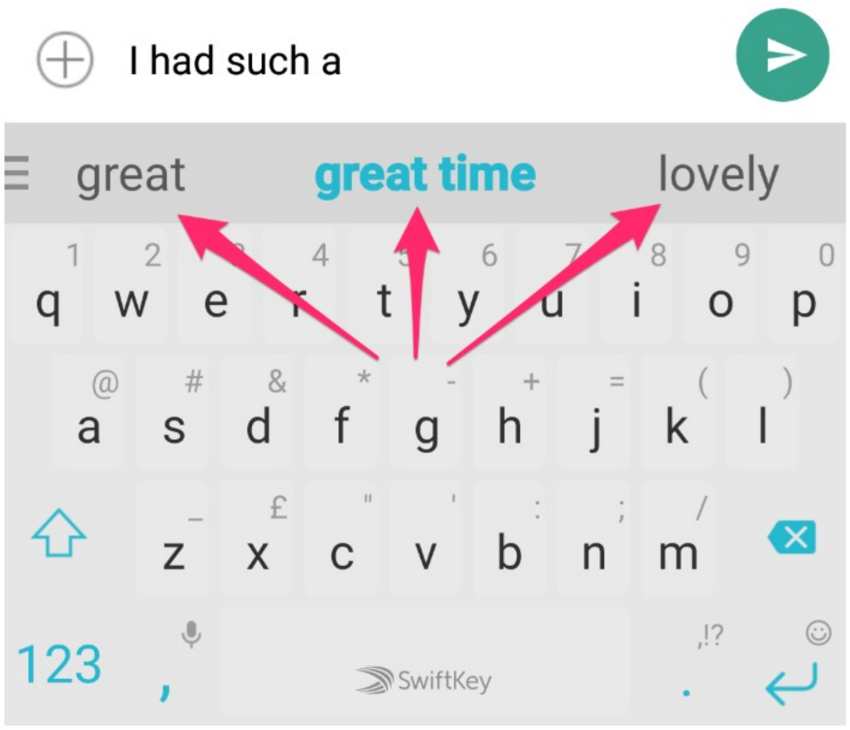
Linear system of equations: Image processing

How can we use linear operators to create blurred images? How can we do the inverse process?

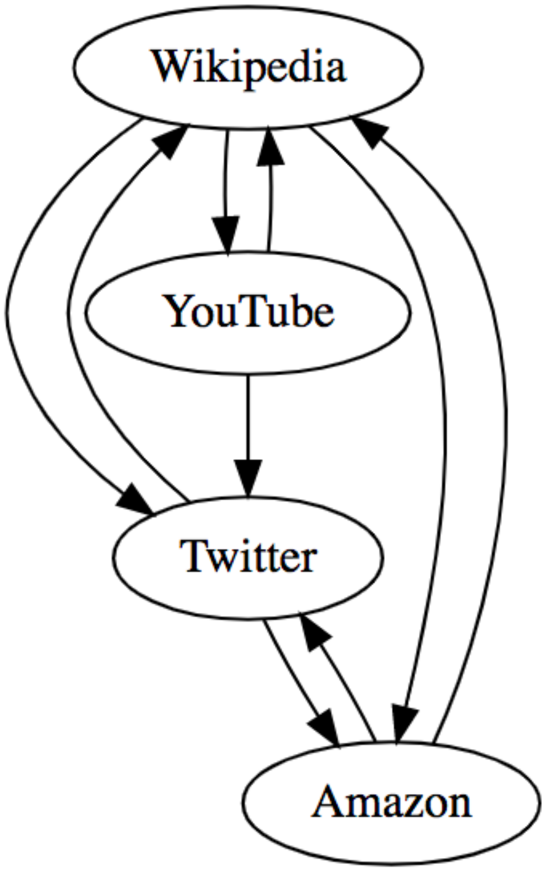
Image credit: https://datacarpentry.org/image-processing/

Markov chain

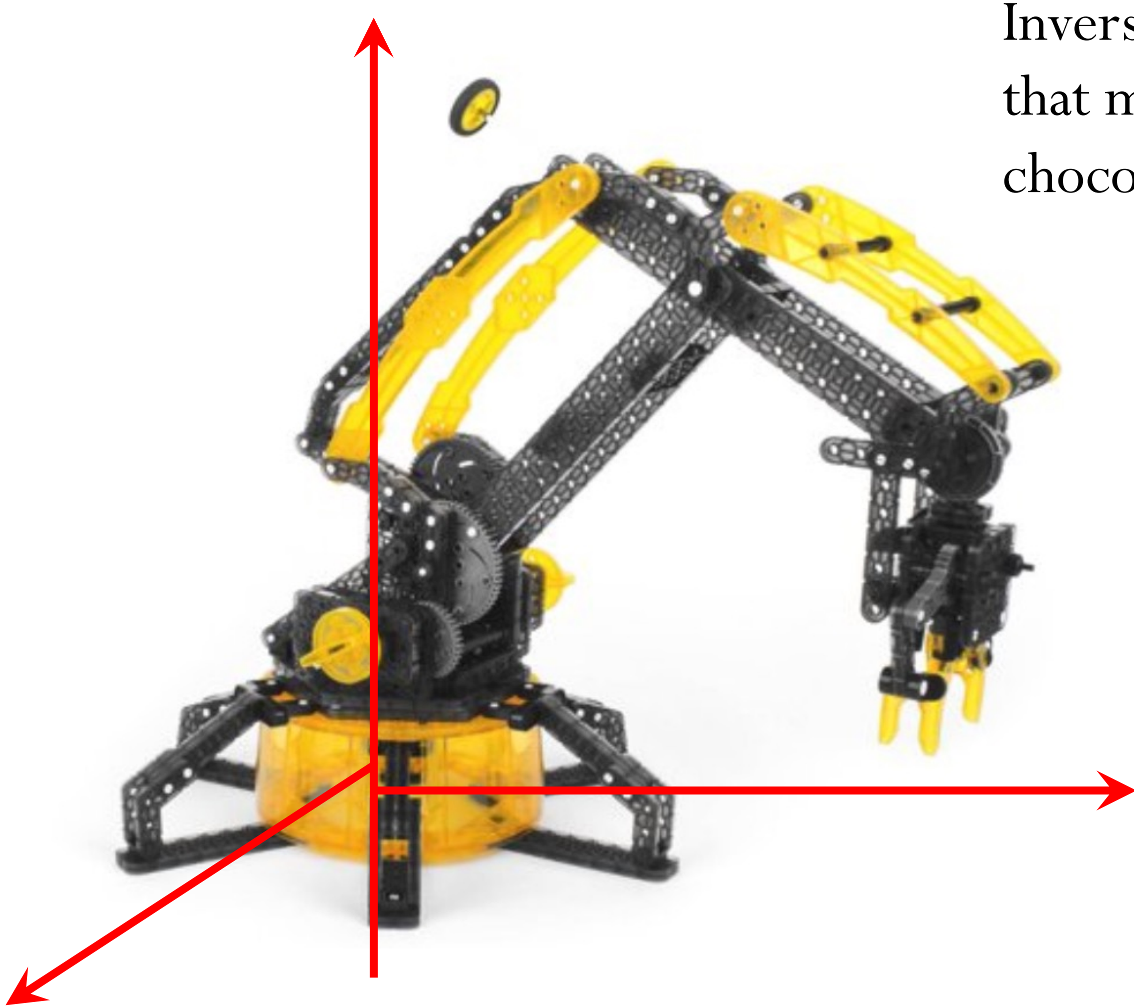
Word prediction



Page Rank



Nonlinear system of equations

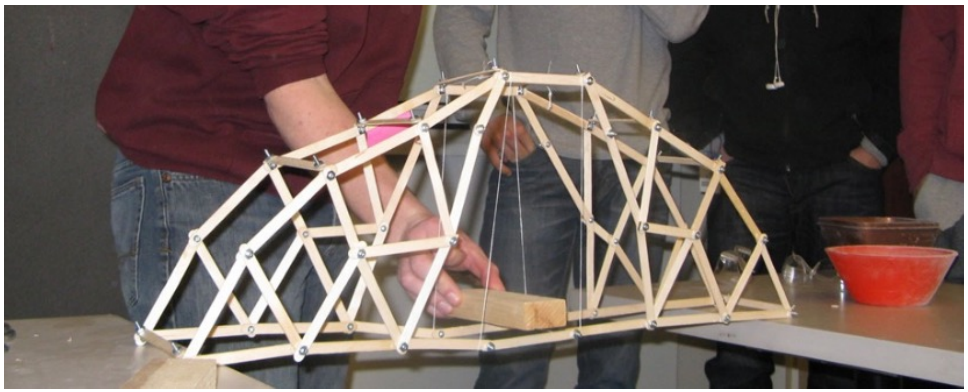


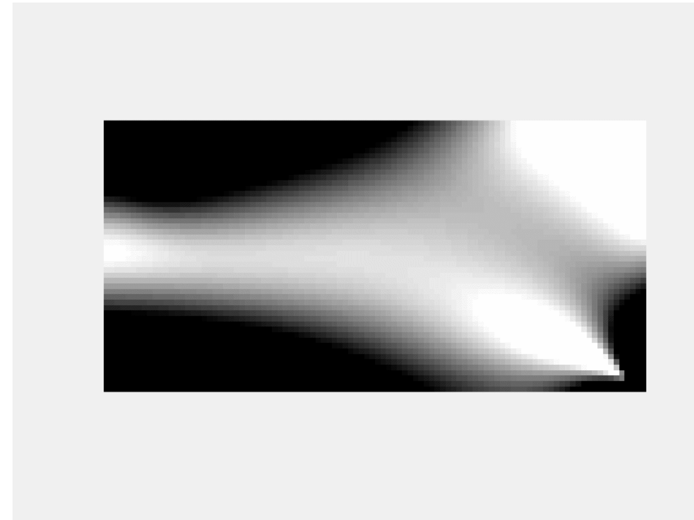
Inverse kinematics: find the angles that make the robotic hand grab a chocolate candy!

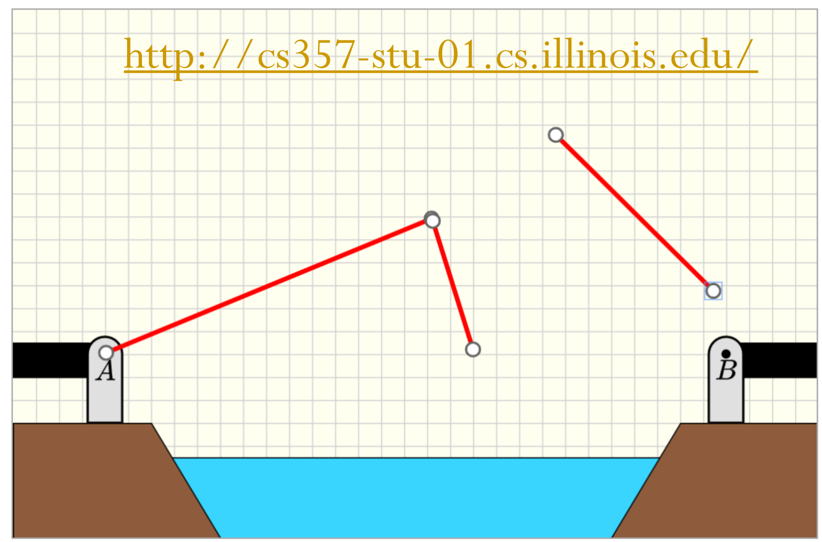
Optimization

Numerical simulations to find optimized bridge designs

Bridge design (high school projects)



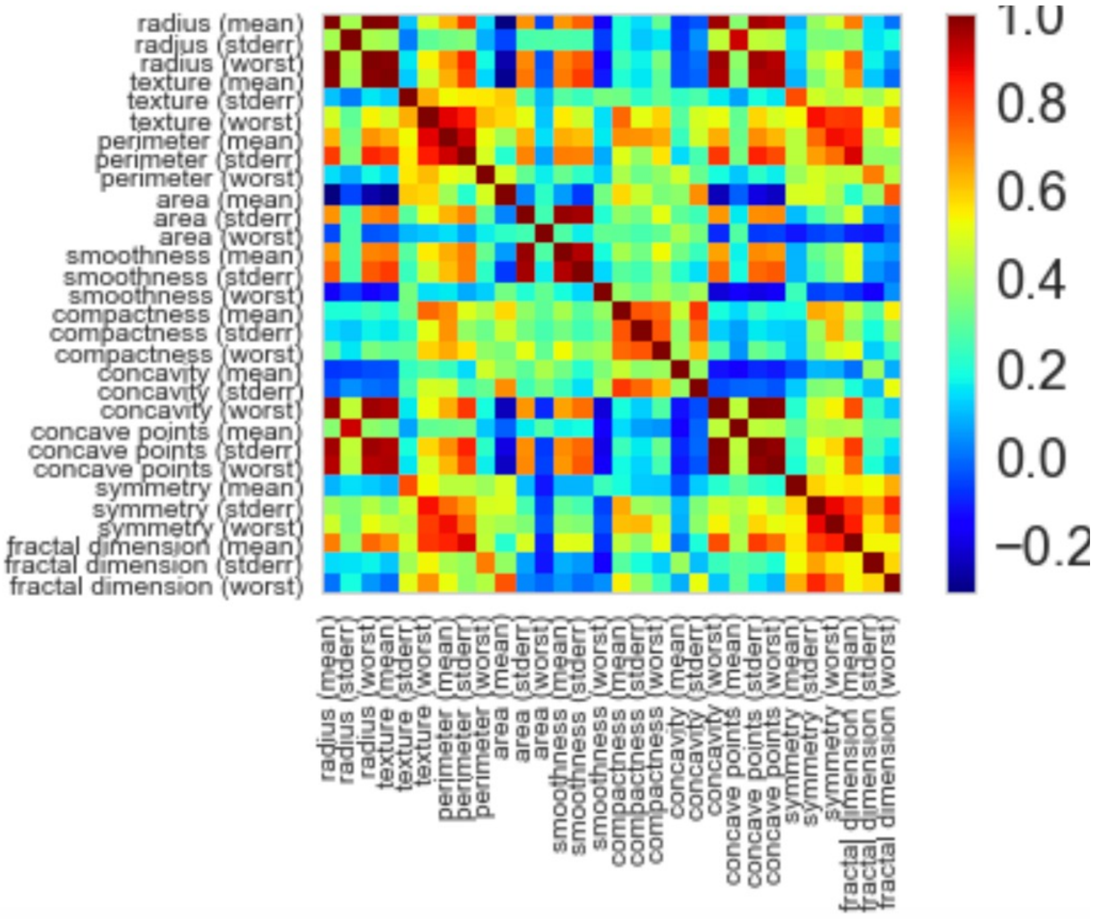


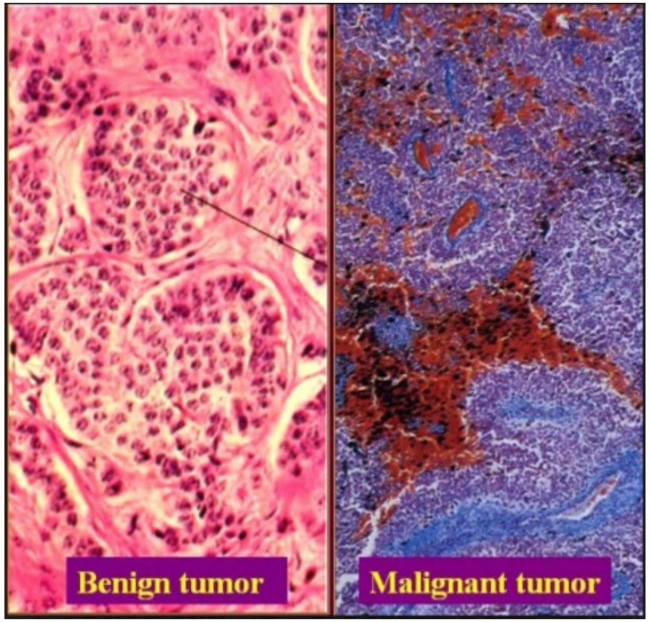


(Tolerance for members to be considered connected is 1/2 square grid.)

Linear Least Squares

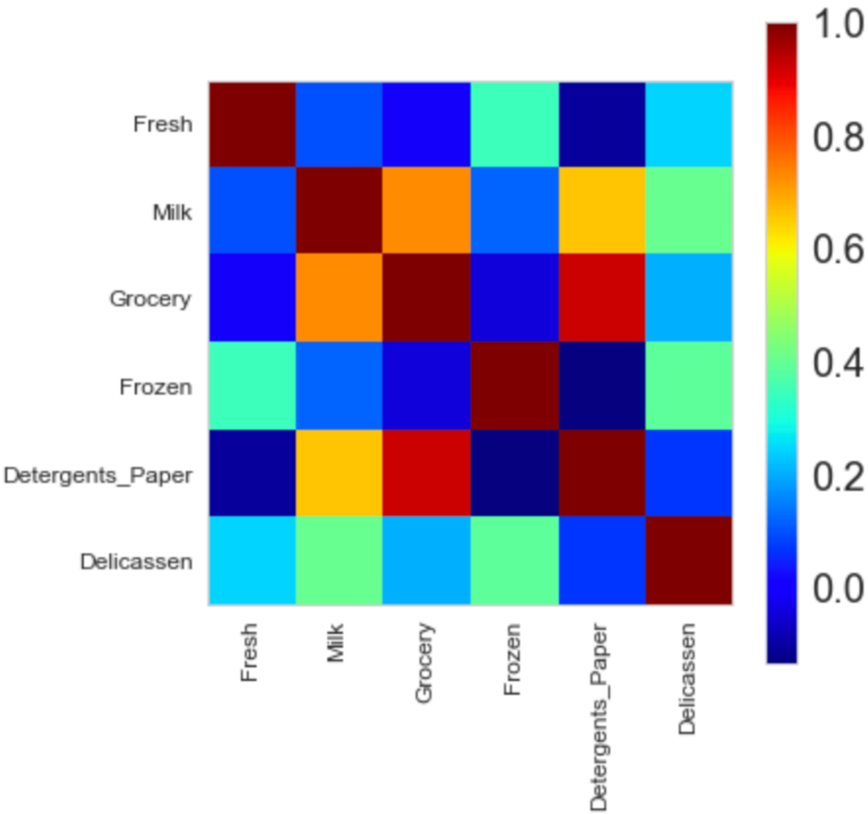
Dataset containing the characteristics of cells for several patients. Can we make predictions if cells are benign or malignant?

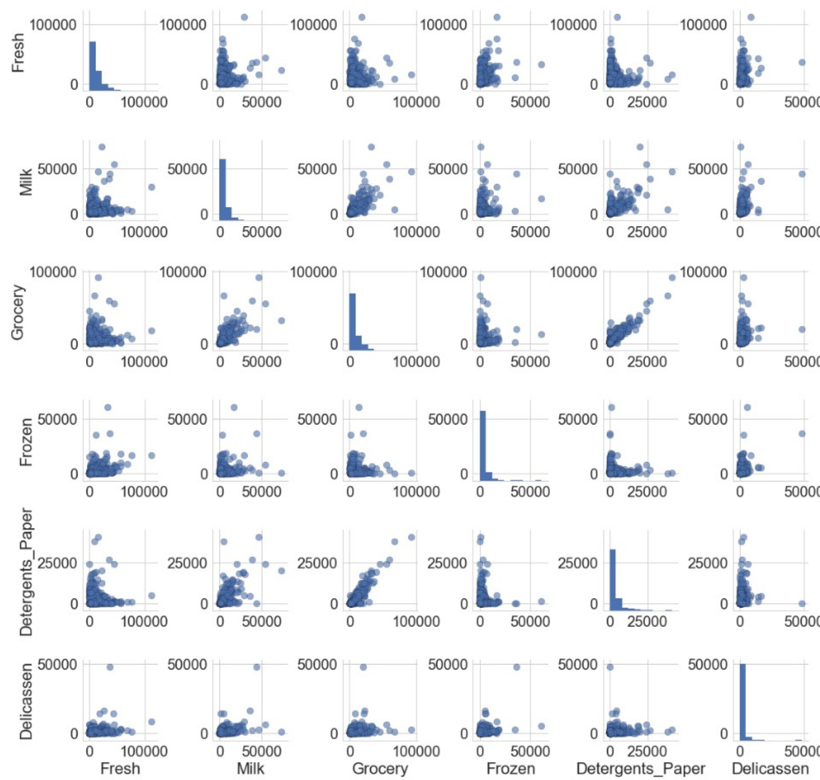




Principal component analysis

Sometimes our dataset has too many features? How can we reduce the feature space and still keep the most important information?





In general lectures and HWs will open at 8am CT Tuesdays and Thursdays.

Usually, Demos will open with the corresponding lectures (sometimes they will appear after the GA)

Week 1

Tue, Aug 23, lecture 1
Syllabus and course content

Complete your asynchronous lecture today!
L1: Introduction to CS 357

Also opening today:
Google form - Course survey and consent (Extra credit)
HW1: Linear Algebra Review

Due today:

Thu, Aug 25, lecture 2
Intro to Python + mock group work

Complete your asynchronous lecture today!
L2: Introduction to Python

Also opening today:
S1: Select your group and time to meet
HW2: Introduction to Python

Due today:

Week 2

Tue, Aug 30, lecture 3
GA1: Working with Python

Complete your asynchronous lecture today!
L3: Errors, Big-O notation, plots

Also opening today:
HW3: Errors and Big-O
Q1P: Linear Algebra + Python + Errors

Due today:

Module 2. Python

L2	Introduction to Python
HW2	Introduction to Python
D2	Demo: Additional Python Tutorial
GA 1	Working with Python

This will be the GA next Tuesday!

Module 1. Introduction

L1	Introduction to CS 357 (not for credit)
HW1	Linear Algebra Review (not for credit)
D1	Demo: Intro to Numerical Methods
GA 0	Get started with GAs (not for credit)
GA00	Workspaces for collaborative learning (not for credit)

L2: Introduction to Python

L2: Introduction to Python

Total points: 0/2 — 0% — Available credit: 100% (Staff override)

Resources: Notes and complete slides

Question	Value	History	Awarded points
Self-guided notebook (no pre-recorded video)			
L2.1. Prerequisite survey	1		0/1
L2.2. Python intro - self-guided notebook	1		0/1

L2.2. Python intro - self-guided notebook

Open the workspace below and complete the IPython notebook.

Open workspace

Select one of the answers below (there is no correct answer):

- (a) I completed the notebook, and I found it helpful.
- (b) I completed the notebook, but I did not find it helpful.
- (c) I did not complete the notebook because I already know how to use Python.
- (d) I did not complete the notebook (for other reasons).

Save & Grade *Single attempt* | Save only

Additional attempts available with new variants

D2: Additional Python Tutorial

D2: Demo: Additional Python Tutorial

Total points: 0/0 0% Available credit: 100% (Staff override)

THIS ASSESSMENT IS NOT FOR CREDIT!

Question	Value	History	Awarded points
D2.1. Basic Python	0		0/0
D2.2. Numpy	0		0/0
D2.3. Matplotlib	0		0/0

For the Mock GA today, you will need to:

- Define Python variables
- Define 1d numpy array
- Perform simple operations with numpy arrays

Course surveys

S1 Select your group (not for credit)

Group selection

We will use the results of this survey to create the groups for at least the first half of the semester **(GA2-7)**. We will give students the opportunity to change groups in the second half of the semester.

If you know 2-3 other students taking CS 357 this semester, and you have agreed to complete the group activities together, you can request to be placed in the same group.

To submit this request, your group must select a group name, so that all members can submit the same answer below:

In the entry field below, enter your group's selection for the **group name**.

group name: ?

Important notes:

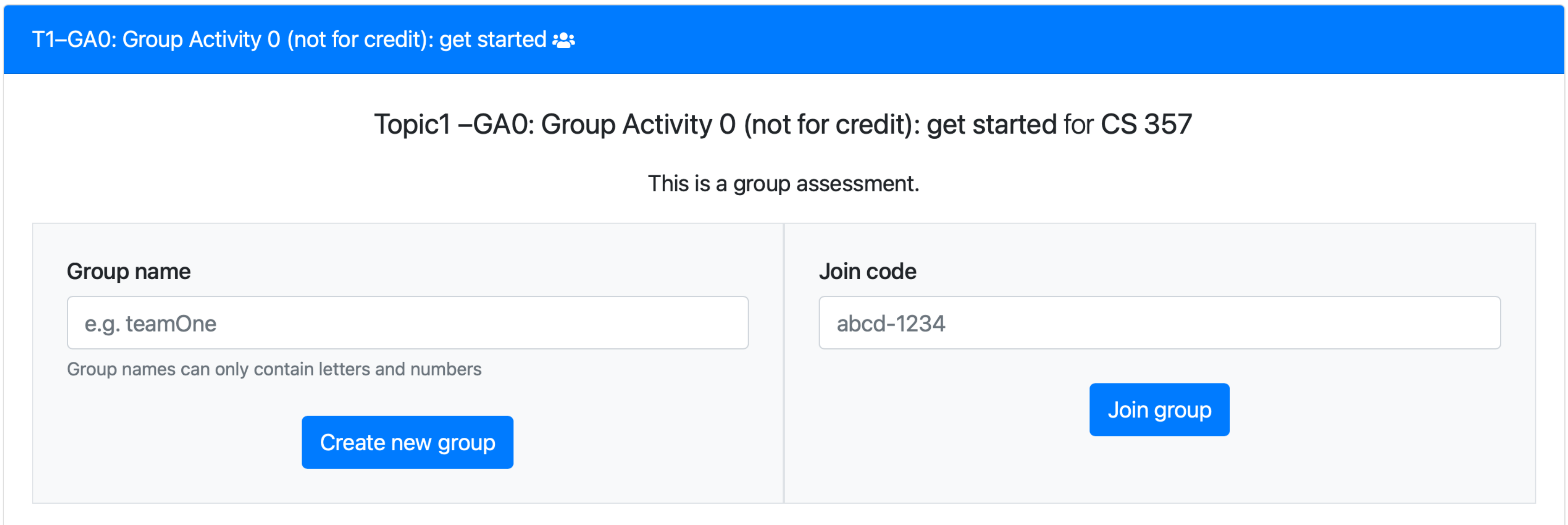
- Every student that enters the same group name will be placed in the same group.
- Make sure you agree on a creative and **unique group name**. For example, you can use the members last names combined. You don't want to be placed in the wrong group by mistake.
- **Groups must have 2-3 students**. If more than 3 students or less than 2 students submit this request using the same group name, ALL these students will be placed in groups at random!
- **Groups can only be formed with students registered in the same section.**

Students who do not submit this survey will be placed at a group at random. Students who are assigned to a random group in section N (online) must attend the Zoom meeting at 12:30pm at least during week 3 (they will be able to make other arrangements at that time).

If you change your mind, you can enter other submissions (by clicking "Save & Grade) until this survey deadline on Friday of week 2. The last submitted answer will be the one used to form the groups. Make sure you triple-check your submission with the other group members!

Save & Grade | Save only | New variant

Creating a group assessment in PL



Practice Group Activity