

CS 357 – Numerical Methods 1

Prof. Mariana Silva

Meeting Mariana



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Education Innovation Fellow**

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Research Area: Computers and
Education

- Started teaching at UIUC Sp 2012
- Taught 10 different courses
- Teaching CS 357 since Sp 2018

My research interests

- Fostering collaborations and group work in the classroom
- Exploration of technological innovations for large-scale teaching
 - Drawing tools in PrairieLearn
 - Incorporate Jupyter notebooks in PrairieLearn workspaces
 - Integrate collaborative learning features in PrairieLearn
 - Developed web-tool to build teams
 - Training and mentoring for innovation and course design
- My most recent professional adventure
 - Co-founded PrairieLearn Inc in 2021

Meet Course Staff

<https://courses.engr.illinois.edu/cs357>

CampusWire

- All communication will happen via CampusWire.
NO EMAILS!
- Check it daily!
- Important course announcements will be pinned.

Office Hours

<https://courses.engr.illinois.edu/cs357/pages/contact.html>

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

Course Website - Syllabus

<https://courses.engr.illinois.edu/cs357/pages/syllabus.html>

PrairieLearn Content

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

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

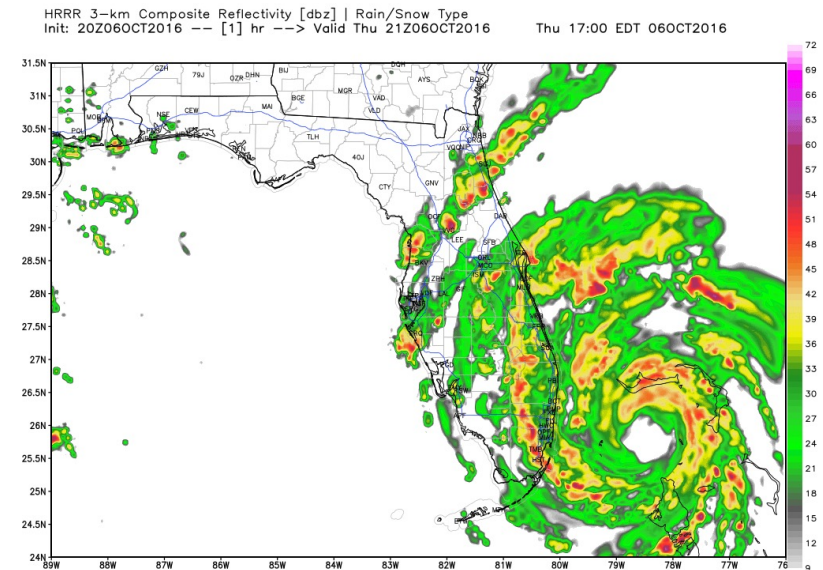
Method = Math + Complexity + Accuracy

Why is this course important?

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



**Explosion of
Ariane 5 in 1996**



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:

$$\pi = 3.1415926535897932384626433832795028841971\dots$$

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

Ultimate Hold'em
DEALER QUALIFIES WITH PAIR OR BETTER

5♣ 4♦

4♣ 9♥ J♥ K♠ 8♥

7♦ K♣

PLAY

TRIPS ANTE = BLIND

BLIND BET
ONLY HIGHEST WIN AWARDED WHEN DEALER IS BEATEN

Royal Flush	500:1
Straight Flush	50:1
Four of a Kind	10:1
Full House	3:1
Flush	3:2
Straight	1:1
All Other	Push

TRIPS BET
ONLY HIGHEST WIN AWARDED BET PAID EVEN IF YOU FOLD

Royal Flush	50:1
Straight Flush	40:1
Four of a Kind	30:1
Full House	8:1
Flush	7:1
Straight	4:1
Three of a Kind	3:1

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

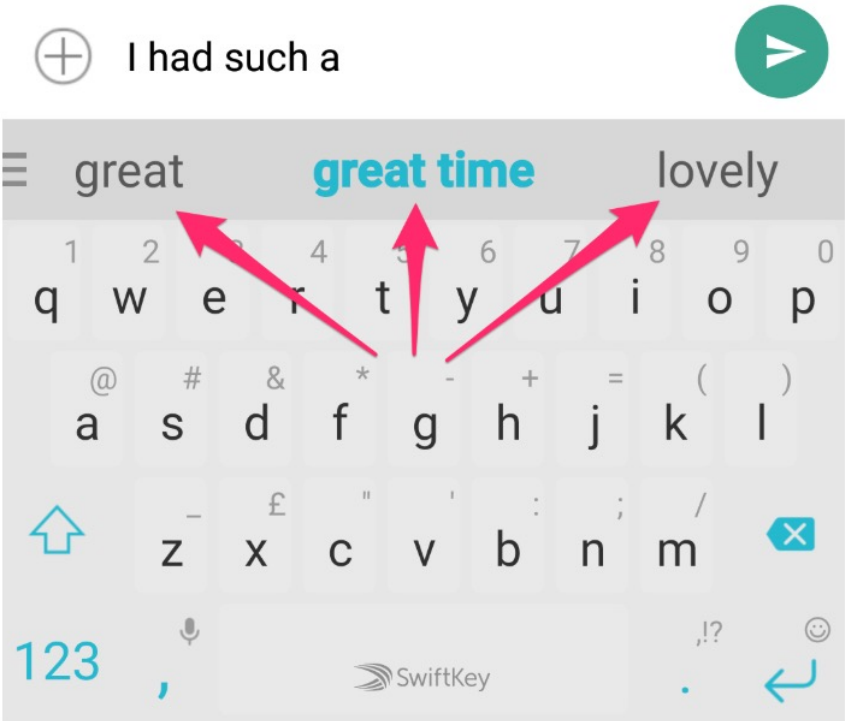
How can we use linear operators to create blurred images? How can we do the inverse process?



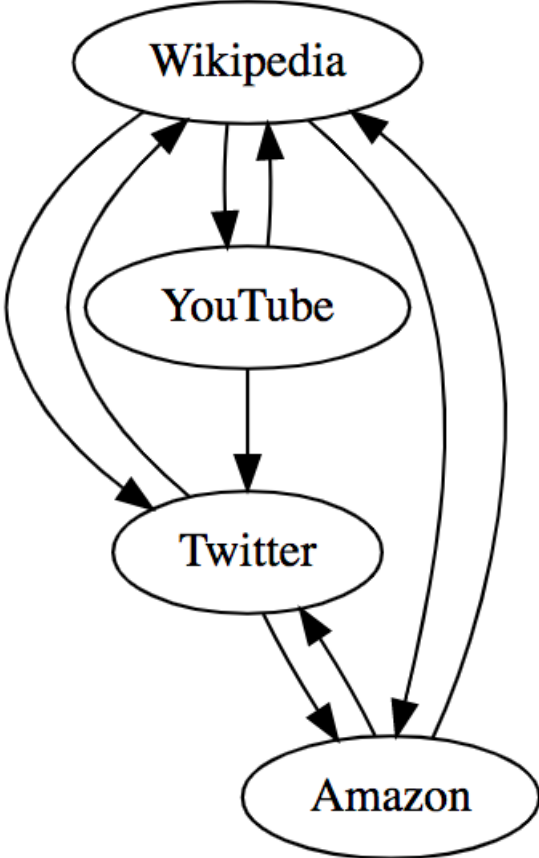
Image credit: <https://datacarpentry.org/image-processing/>

Markov chain

Word prediction

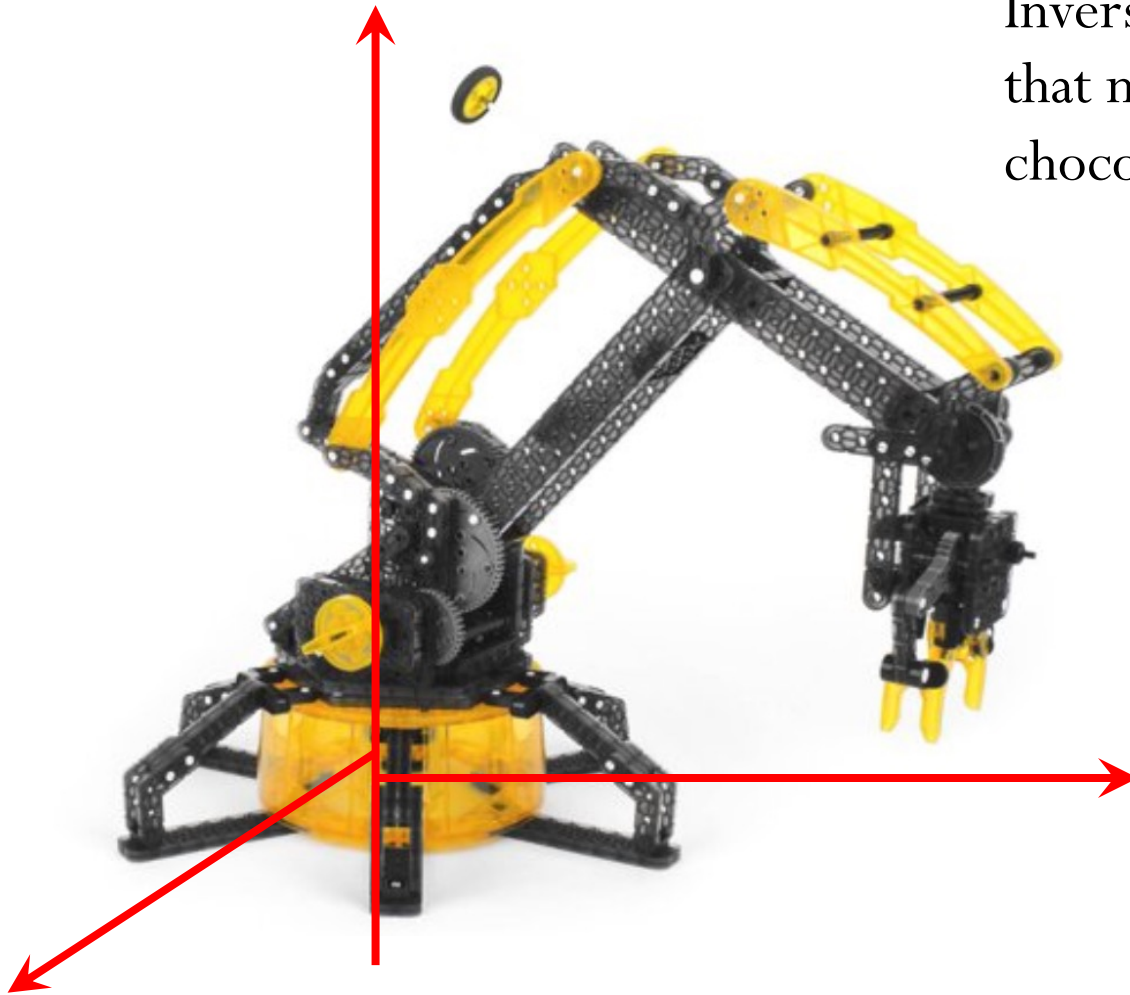


Page Rank



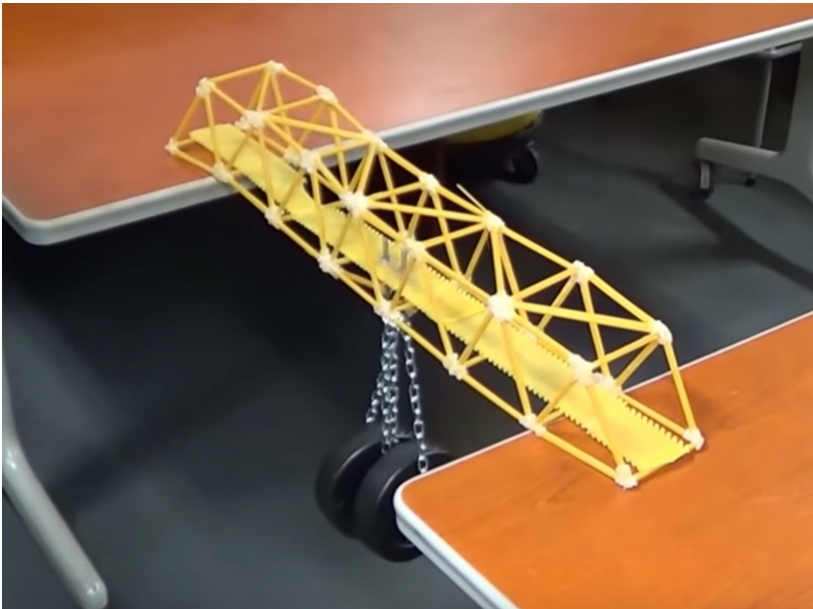
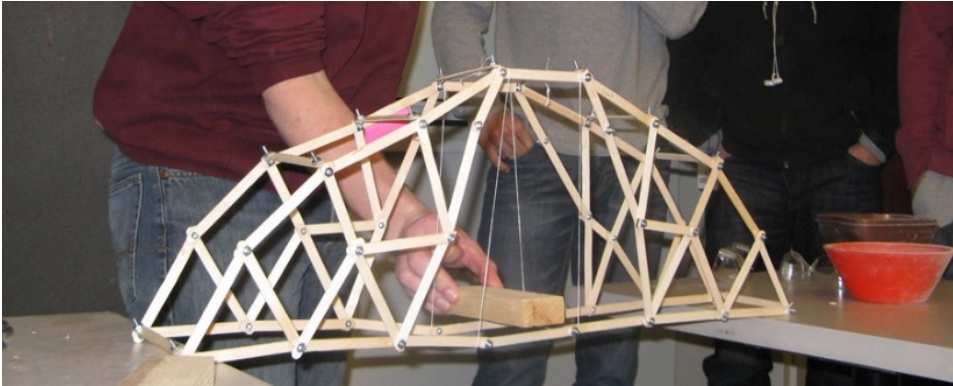
Nonlinear system of equations

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

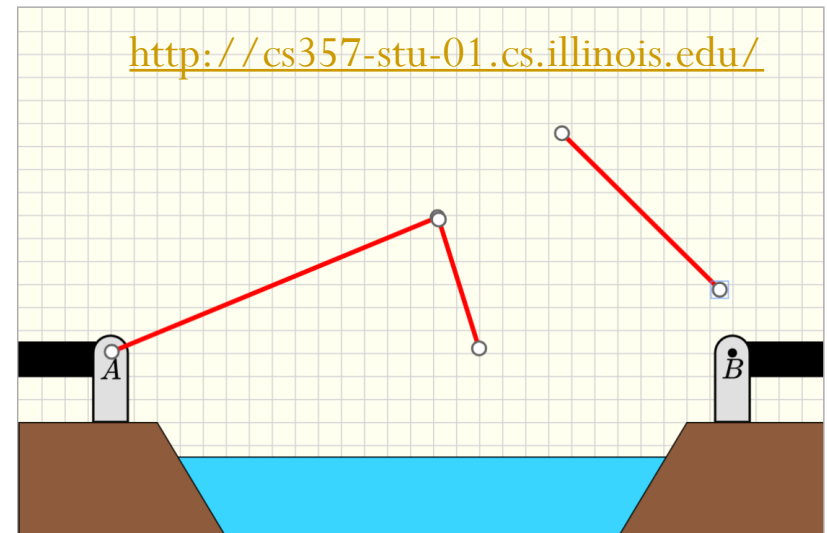
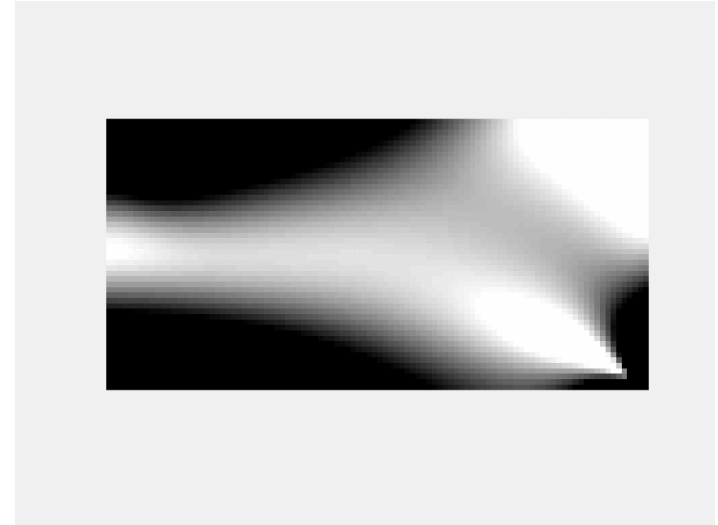


Optimization

Bridge design (high school projects)



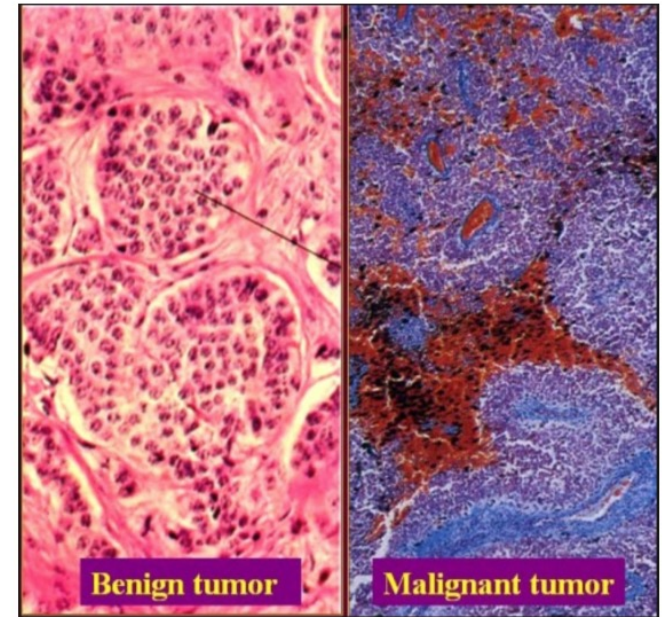
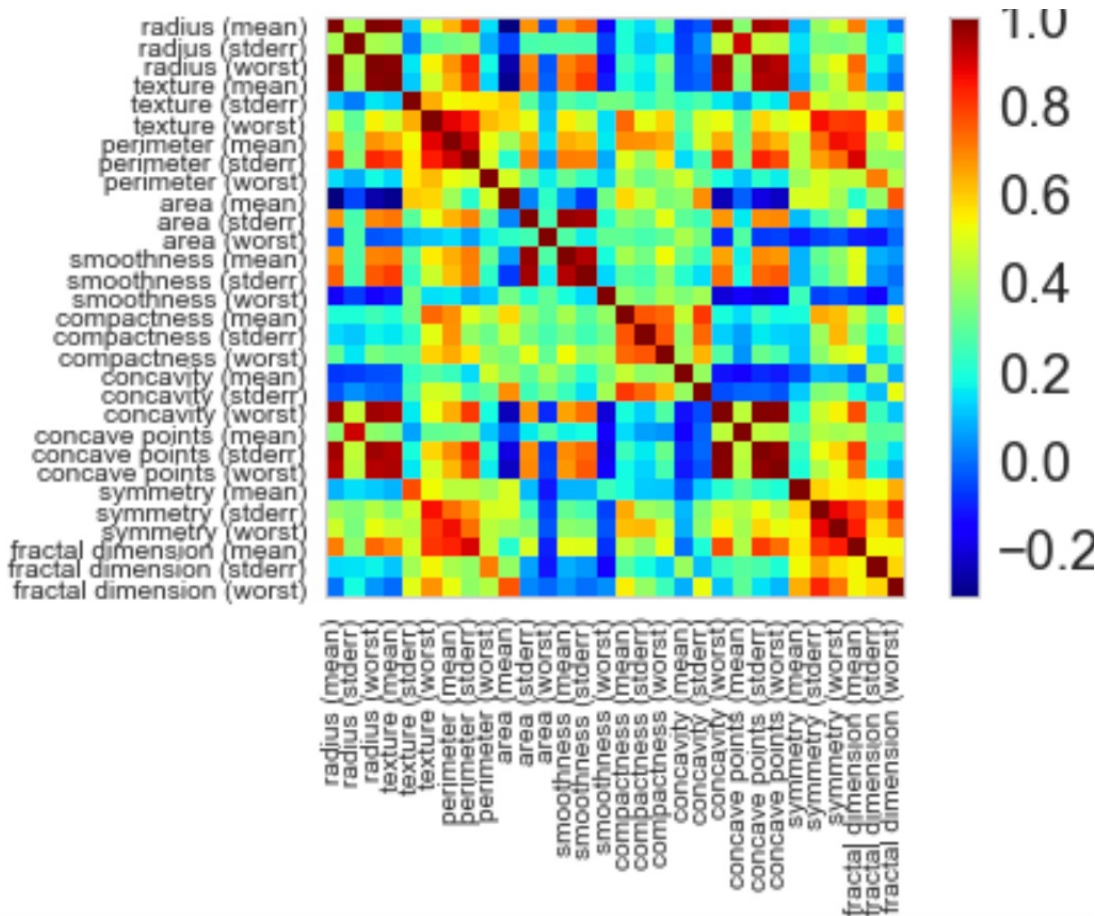
Numerical simulations to find optimized bridge designs



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

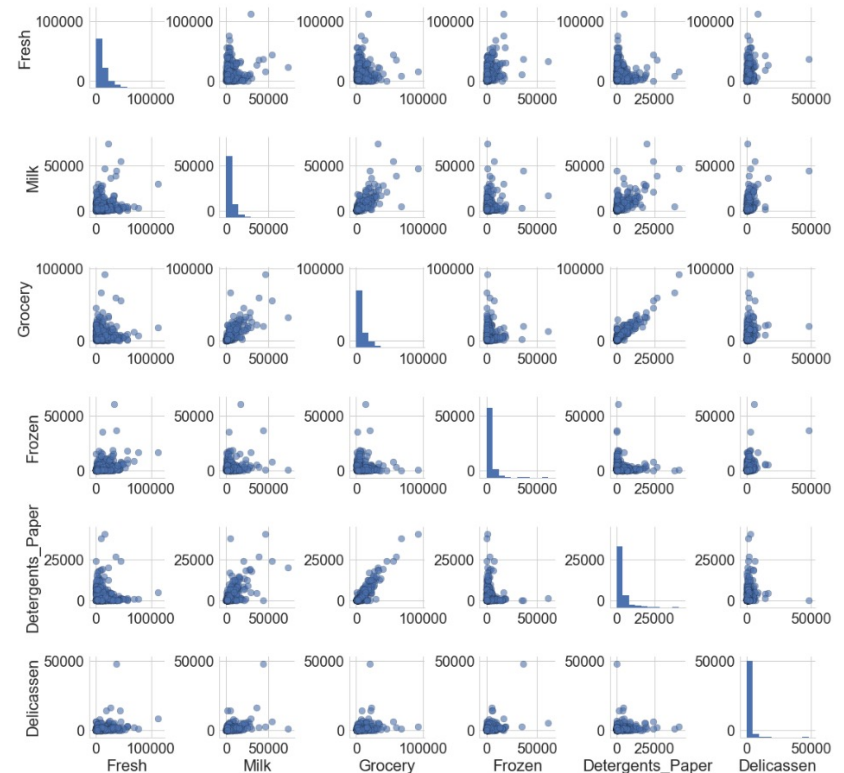
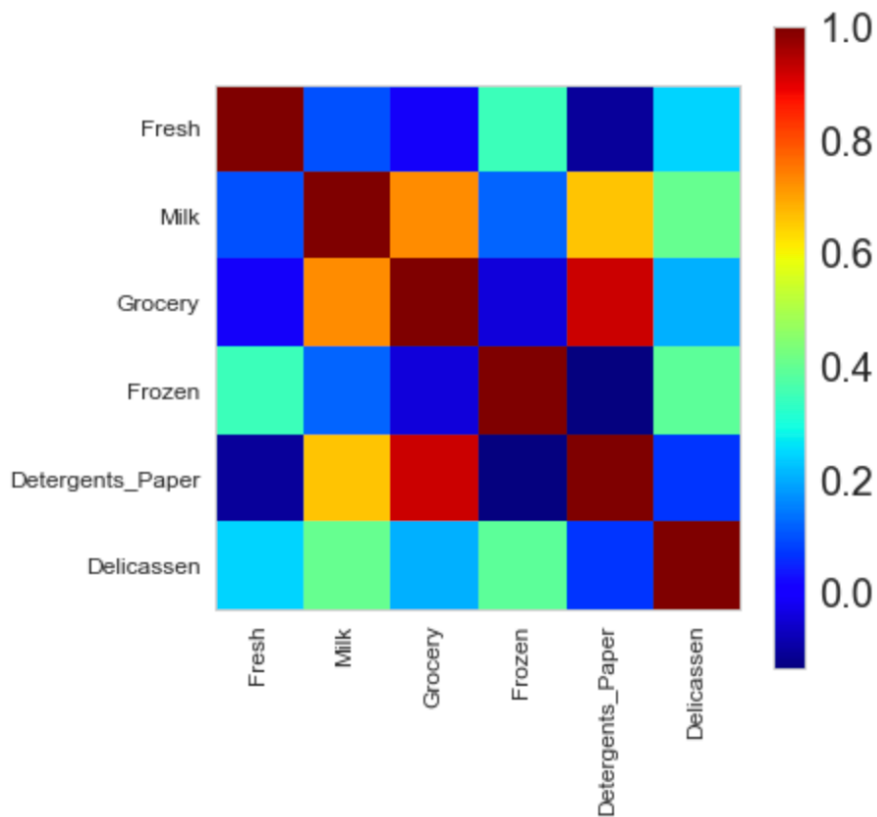
Linear Least Squares

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?



Second day of classes...

In-person support for section M students

1. Grainger Library

- Two TAs will be at the room 404
- Student groups should find tables/seats outside 404: main study area on the 4th floor or any other location at Grainger

2. Siebel Basement

- Two TAs will be at the Tutoring Center
- Student groups should find tables/seats outside of tutoring center: open area of the basement and first floor

3. CIF 35 (~ 12 groups – first come basis)

Assessments

Learning Flow for each Module

1. Complete lectures on Tuesdays and Thursdays as they open
 - Get up to 100% credit by completing them before Tuesday 12pm of the week after they open
 - Get up to 80% credit by completing them before Tuesday midnight of the corresponding quiz week
 - Get up to 50% credit by completing them before last day of classes
2. Complete the Homework
 - Get up to 100% credit by completing them within one week after they open
 - Get up to 96% credit by completing them before Tuesday midnight of the corresponding quiz week
 - Get up to 50% credit by completing them before last day of classes
3. Complete MPs (when available) – similar deadline scheme as HW
4. For additional examples, look at the Demos (not for credit)

Practice Quizzes

1. You are encouraged to start the practice quizzes only after you complete the learning flow above
2. Complete at least one entire practice quiz as if you were taking the quiz (no access to resources, timed, etc). This will give you a good idea of how ready you are.

Week 1

Tue, Jan 17, lecture 1

Syllabus and Intro to Python

Complete your asynchronous lecture today!

L1: Introduction to CS 357 (NOT FOR CREDIT)

L2: Introduction to Python

Also opening today:

HW1: Linear Algebra Review (NOT FOR CREDIT)

HW2: Introduction to Python

Due today:

Thu, Jan 19, lecture 2

Course content + mock group work

Complete your asynchronous lecture today!

L3: Errors, Big-O notation, plots

Also opening today:

HW3: Errors and Big-O

Due today:

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

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

Week 2

Tue, Jan 24, lecture 3

GA1: Working with Python (NOT FOR CREDIT)

Complete your asynchronous lecture today!

L4a: Floating point

Also opening today:

HW4a: Floating point

Q1P: Linear Algebra + Python + Errors

Due today:

HW2: Introduction to Python

Module 2. Python

L2 Introduction to Python

HW2 Introduction to Python

D2 Demo: Additional Python Tutorial

GA 1 Working with Python (NOT FOR CREDIT) 🧑‍🤝🧑 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) 🧑‍🤝🧑

This will be the

GA next Tuesday!

Quiz 1: Modules 1-3

PQ1 Practice Quiz 1: Linear Algebra + Python + Errors (NOT FOR CREDIT)

Q1 Quiz 1: Linear Algebra + Python + Errors

Module 3. Errors and Big-O

L3 Errors, Big-O notation, plots

HW3 Errors and Big-O

D3 Demo: Errors 

Module 2. Python

L2 Introduction to Python

HW2 Introduction to Python

D2 Demo: Additional Python Tutorial

GA 1 Working with Python (NOT FOR CREDIT) 

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	<div style="width: 0%;"><div style="background-color: red; height: 10px; width: 100%;"></div></div> 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

Quiz Schedule

If you are supposed to take the quiz at CBTF

Exams available for reservations			
Action	Exam	First date	Last date
Make a reservation	CS 357 (Sp23): Quiz 1	2023-01-30 00:01:00 (CST)	2023-02-01 23:59:00 (CST)

If you are supposed to take the quiz online with Zoom proctoring

Current and future exam reservations					
Exam	Date	Duration	Type	Location	Accommodations
CS 357 (Sp23): Quiz 1	2023-02-02 12:30:00 (CST)	50 min	Online	Zoom	—

Do not register right now! I will be creating the groups this weekend!

Do you know who Bob Marley is?



Consider studying abroad!



Complexity

Given A, B matrices of size 300×300 , the matrix-matrix multiplication $A \cdot B$ takes 2 seconds.

How long does it take to perform $C \cdot D$, matrices of size 3000×3000 ?

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

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

Course surveys

S1

Select your group (NOT FOR CREDIT)

If you are selecting a group, how did you

- (a) Knew group member(s) prior to tak
- (b) Met group member(s) during first f
- (c) Found group member(s) through c
- (d) Found group member(s) through D
- (e) Found group member(s) through o
- (f) Other

Select all possible options that apply. ?

Creating a group assessment in PL

T1-GA0: Group Activity 0 (not for credit): get started 🧑🏻

Topic1 -GA0: Group Activity 0 (not for credit): get started for CS 357

This is a group assessment.

Group name

e.g. teamOne

Group names can only contain letters and numbers

Create new group

Join code

abcd-1234

Join group

Practice Group Activity