CS/ECE/ME 532
Matrix Methods in Machine Learning

Spring 2021

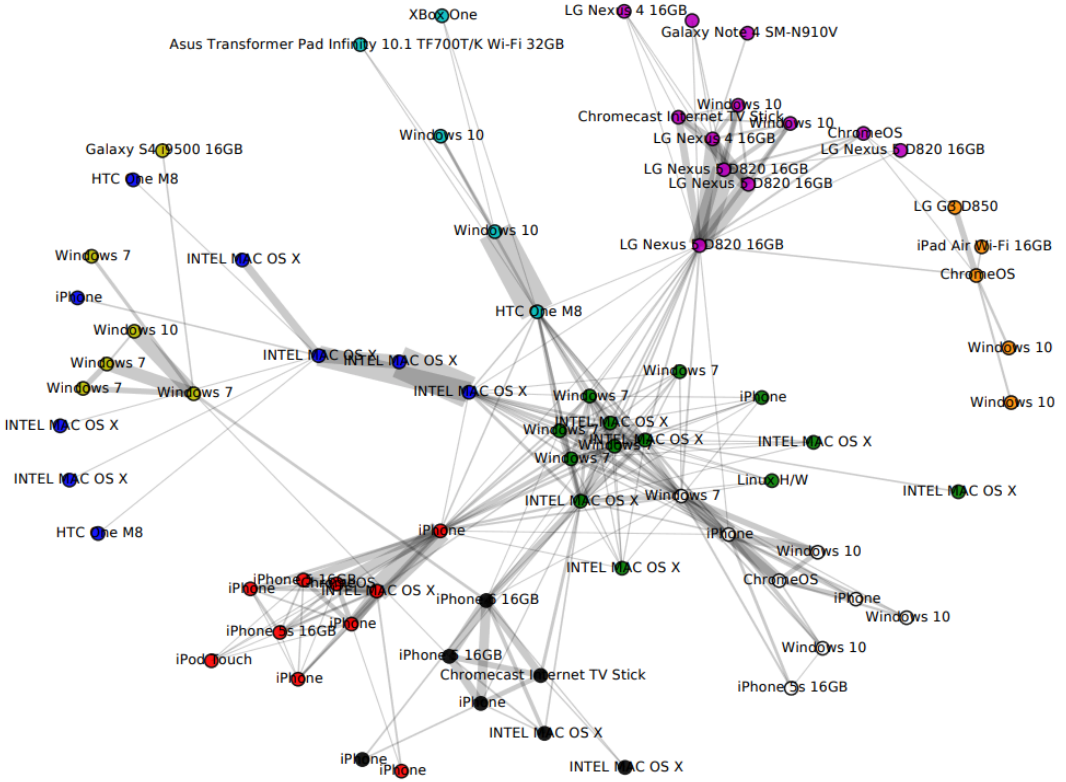
Today

- Introductions
- Motivation
- Course Logistics
- Period 1 Activity – due 11:59 PM today!

Professor Malloy

mmalloy@wisc.edu, 3615 EH

- Joined UW and Electrical and Computer Engineering in 2019
- 8 years in industry, machine learning, signal processing and data science to improve targeted advertising
- Taught 532 in fall 2019 and spring 2020
- Spent good portion of the weekend cross country skiing

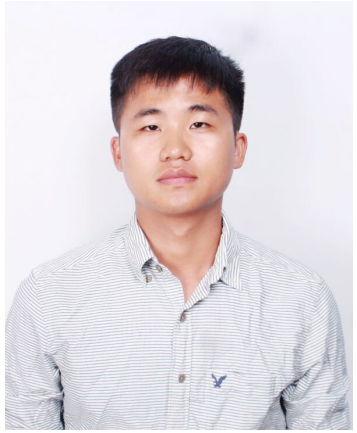


Professor Van Veen

bvanveen@wisc.edu, 3546a Engineering Hall

- Created most of the course videos!
- Last taught 532 in fall
- Research interests in machine learning and signal processing for biomedical applications

Jianwei Ke



- Ph.D. Student in Electrical Engineering
- Research in Computer Vision and Image Processing
- TAed 532 in Spring/Summer/Fall 2020
- Enjoys ice fishing and jogging

Emad Sadeghi

- PhD Student in Electrical Engineering
  - Interested in Machine Learning and Optimization
  - Got his BS and MS degrees here at UW Madison
- First time TAing for ECE 532 but have TAed for CS 524, 726 and 760 before
- Enjoys photography, cooking, and tennis

Ruisu Zhang

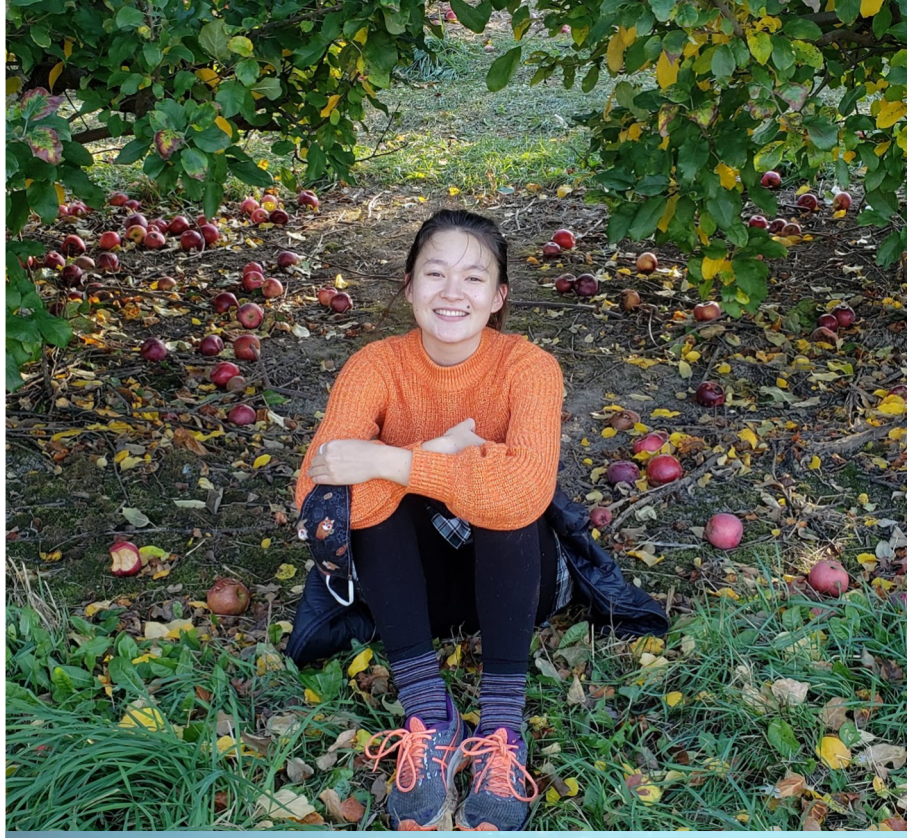
- Senior in Computer Science and Psychology
- Took 532 in spring 2020, with Prof. Malloy
- Fun fact: I used to want to be a therapist, but now I’m interested in Machine Learning and Artificial Intelligence and will go for graduate study.

Angelique

Senior in Electrical Engineering and Computer Science

I took 532 in Summer 2020

I enjoy being outside, sewing, and painting



Matrix Completion

- Users rate movies with 1-5 stars

- How can we predict if a user will like a movie they haven't rated?

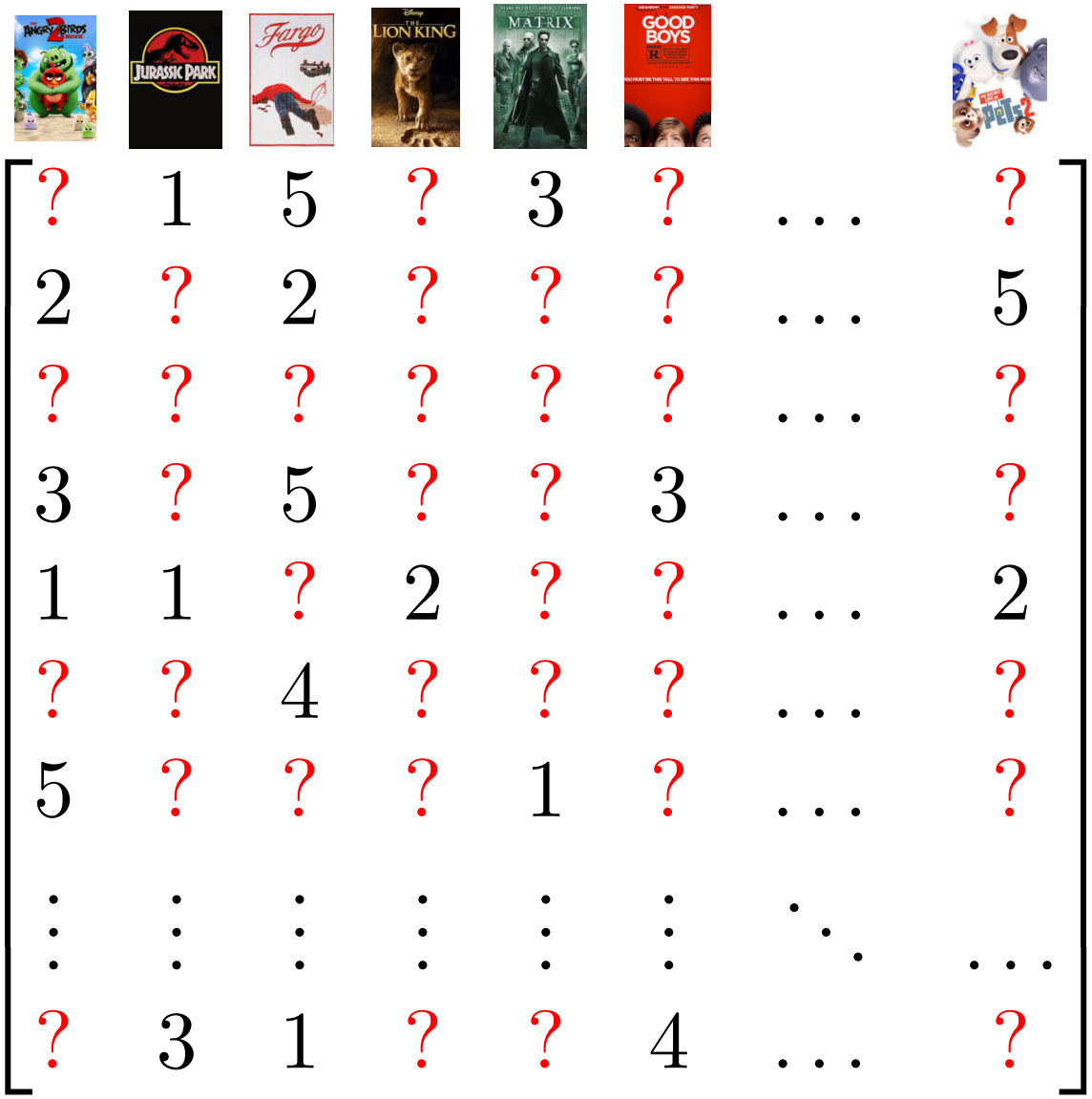
Netflix offered $1M cash prize to improve ratings predictions.

- We'll learn how to do this in Unit 4 with *iterative singular value thresholding.*

- All about finding ***patterns*** in data.

Movies →

Users ↓

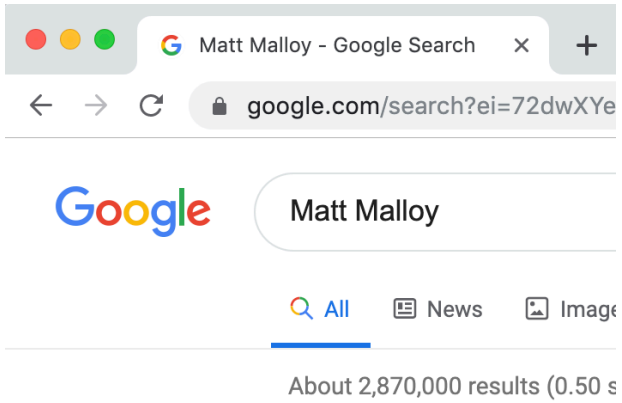


$$\begin{bmatrix} ? & 1 & 5 & ? & 3 & ? & \dots & ? \\ 2 & ? & 2 & ? & ? & ? & \dots & 5 \\ ? & ? & ? & ? & ? & ? & \dots & ? \\ 3 & ? & 5 & ? & ? & 3 & \dots & ? \\ 1 & 1 & ? & 2 & ? & ? & \dots & 2 \\ ? & ? & 4 & ? & ? & ? & \dots & ? \\ 5 & ? & ? & ? & 1 & ? & \dots & ? \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \ddots & \vdots \\ ? & 3 & 1 & ? & ? & 4 & \dots & ? \end{bmatrix}$$

Google's PageRank Algorithm

- How does Google order search results?

PageRank.



1. Create a matrix with a 1 if page *i* links to page *j*.
2. Scale the columns so they add to 1.
3. Solve an eigenvalue problem.

The vector that corresponds to the largest eigenvalue gives us the ranking.

We'll learn the algorithm and why it works in Unit 4.

Webpage →

Webpage ↓

$$\begin{bmatrix} 0 & 1 & 1 & 0 & 0 & 0 & \dots & 0 \\ 1 & 0 & 1 & 0 & 0 & 0 & \dots & 1 \\ 1 & 0 & 0 & 0 & 1 & 1 & \dots & 0 \\ 0 & 0 & 1 & 0 & 0 & 1 & \dots & 0 \\ 1 & 0 & 0 & 0 & 0 & 0 & \dots & 1 \\ 0 & 0 & 0 & 0 & 0 & 0 & \dots & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & \dots & 0 \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \ddots & \dots \\ 0 & 1 & 0 & 0 & 0 & 1 & \dots & 0 \end{bmatrix}$$

Course Logistics

'Active Learning course' - you watch lecture videos on your own time, work problems together in class

1. Video Lectures (5-15 minutes each)
   - Each video lecture is followed by a graded quiz
   - Due evening before class

2. Classroom activities (Tu/Th in class)
   - Due at 11:59 PM on the same day
   - Groups assigned randomly, rotated every 4—5 weeks

3. Assignments
   - ~9, Due on assigned day (usually Sunday) at 11:59PM

4. Unit Quizzes – in class
   - Feb 9, March 2, March 25, April 15, and April 29

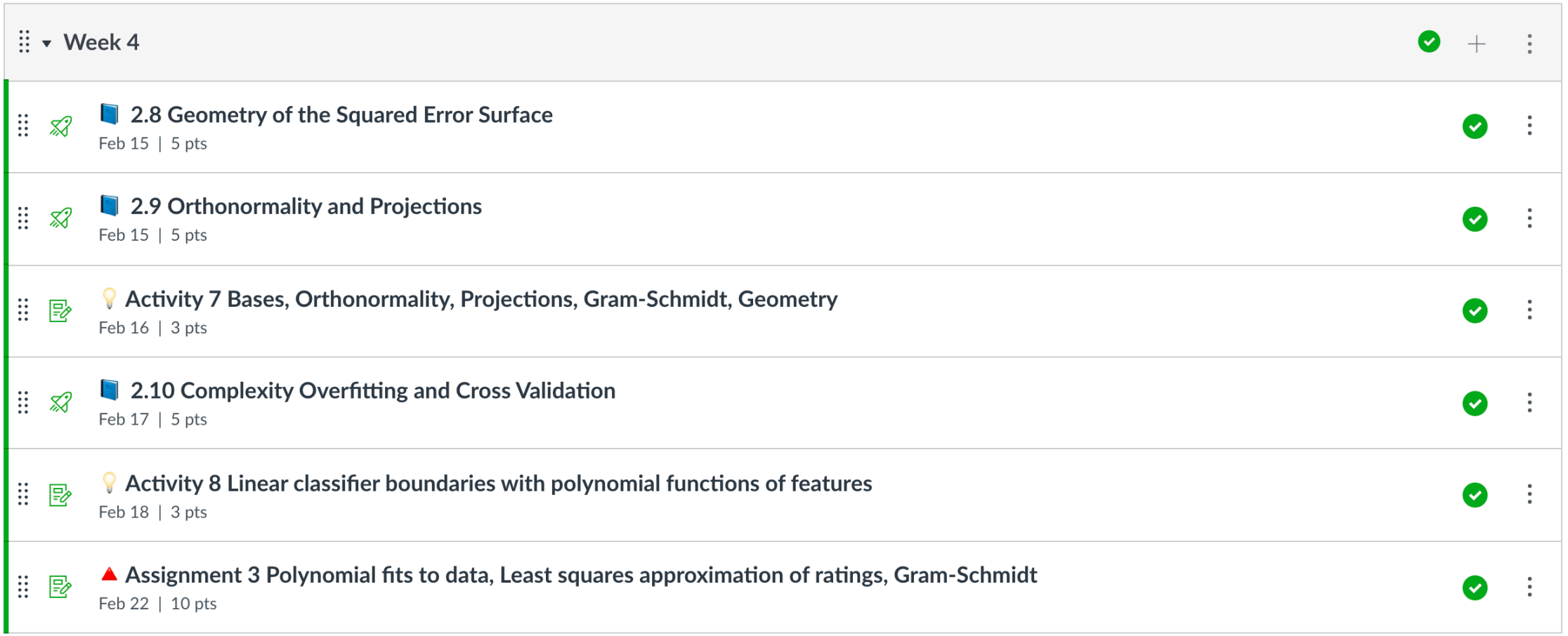
5. Integrative Summary Assignments

Assignment	Percent of Final Grade
Video Quizzes (drop lowest 6 scores)	10
Activities (drop lowest 3 scores)	25
Assignments (drop 1 lowest)	25
Unit Quizzes (1st: 2%, 2—4th: 6%, 5th : 5%)	25
Integrative Summaries (Units: 2.2%, Course: 4%)	15
Total	100

Late work:

Deadline are hard deadlines, and there are no exceptions (after the first week). Late work will reduced by 50% if submitted before grading, and will receive a zero if submitted after grading.

Typical Week



Getting Help

1. Classroom sessions. Don’t be afraid to ask questions!
2. Office hours – scheduled and by appointment
3. Piazza - for all content questions
   ** This is a joint forum with graduate sections. Please use [Sec 001] tag if you have section-specific questions.
4. Email - only for personal questions

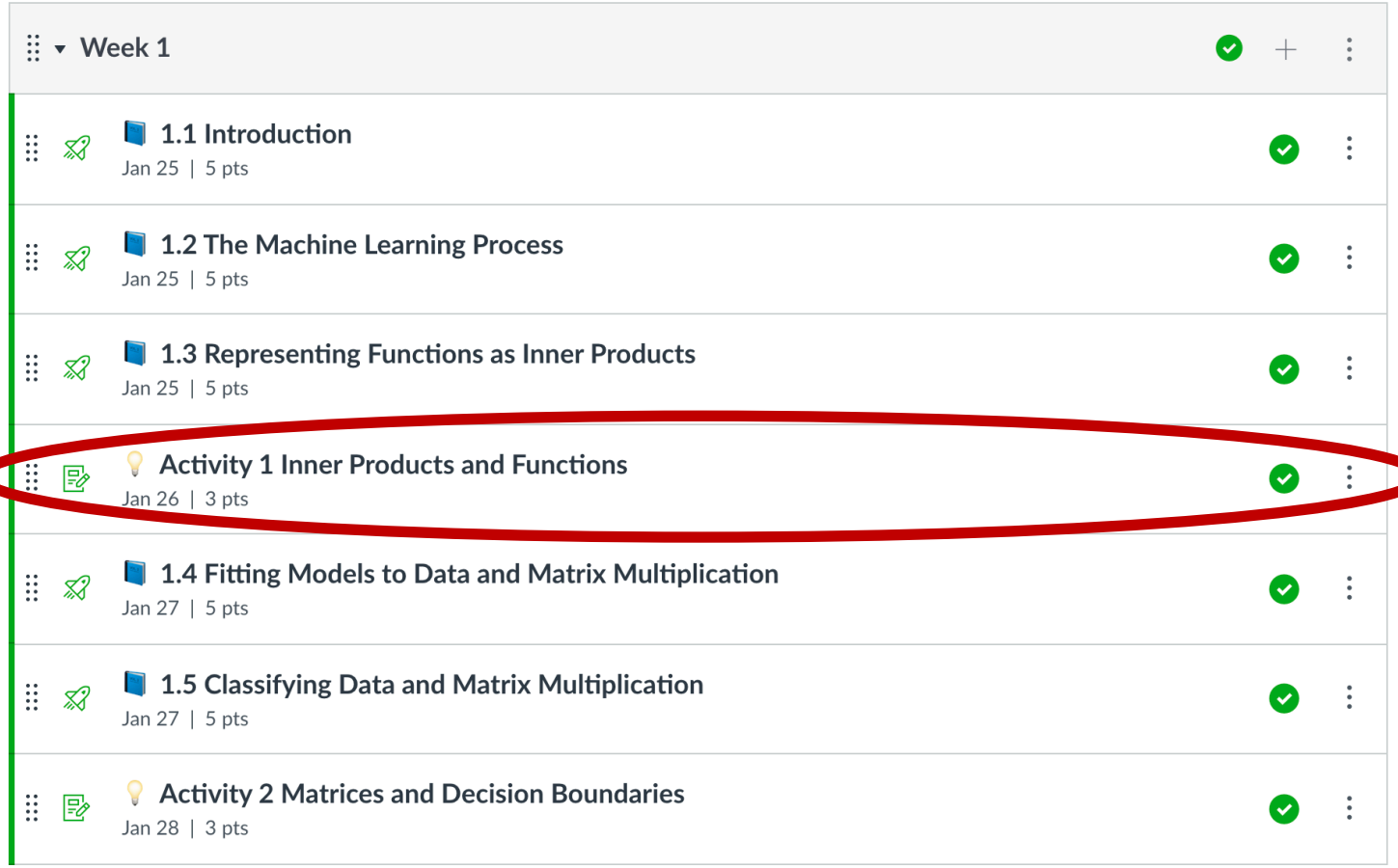
Get help early and often!

Warning

This class can be very challenging if:

1. You don’t have enough time (10+ hours many weeks).
2. You haven’t been exposed to linear algebra in the past.
3. You aren’t comfortable coding/scripting to solve math problems.

Today


Week 1
1.1 Introduction
Jan 25 | 5 pts
1.2 The Machine Learning Process
Jan 25 | 5 pts
1.3 Representing Functions as Inner Products
Jan 25 | 5 pts
Activity 1 Inner Products and Functions
Jan 26 | 3 pts
1.4 Fitting Models to Data and Matrix Multiplication
Jan 27 | 5 pts
1.5 Classifying Data and Matrix Multiplication
Jan 27 | 5 pts
Activity 2 Matrices and Decision Boundaries
Jan 28 | 3 pts

Period 1 Activity Notes

Notes

If you finish the activity, move on to the videos for next time.

vectors are column vectors by default

$$\boldsymbol{w}^T\boldsymbol{x} = \begin{bmatrix} w_1 & w_2 & \dots & w_n \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ \vdots \\ x_n \end{bmatrix} = w_1x_1 + w_2x_2 + \cdots + w_nx_n$$

Usual way to think about multiplying matrices

$$\boldsymbol{A}\boldsymbol{x} = \begin{bmatrix} 1 & 2 & 3 \\ 4 & 5 & 6 \end{bmatrix} \begin{bmatrix} 7 \\ 8 \\ 9 \end{bmatrix} = \begin{bmatrix} 1\cdot 7 + 2\cdot 8 + 3\cdot 9 \\ 4\cdot 7 + 5\cdot 8 + 6\cdot 9 \end{bmatrix} = \begin{bmatrix} 50 \\ 122 \end{bmatrix}$$

Inner dimensions must agree

$$\boldsymbol{A} \in \mathbb{R}^{2\times 3}$$
$$\boldsymbol{x} \in \mathbb{R}^{3\times 1}$$

$$2 \times 3, 3 \times 1$$

$$\boldsymbol{A}\boldsymbol{x} \in \mathbb{R}^{2\times 1}$$

$$\begin{bmatrix} 1 & 2 & 3 \\ 4 & 5 & 6 \end{bmatrix} \begin{bmatrix} 7 \\ 8 \\ 9 \end{bmatrix} = 7\begin{bmatrix} 1 \\ 4 \end{bmatrix} + 8\begin{bmatrix} 2 \\ 5 \end{bmatrix} + 9\begin{bmatrix} 3 \\ 6 \end{bmatrix} = \begin{bmatrix} 50 \\ 122 \end{bmatrix}$$

another way – weighted sum of the columns of first matrix