

Recommender Systems Lecture 1

Summer 2022 (Dr. Karthik Mohan)

Univ. of Washington, Seattle

June 24 2022

Instruction Team

- Instructor - Dr. Karthik Mohan (Amazon, Meta, Faculty at ECE)
- TA - Jinlin Xiang (CV, Incremental Learning, Neuro AI Lab, PhD student ECE)



Motivation for Recommender Systems

- ① Where you have a web based product sales, you need recommendations
- ② Top companies deploy simple to sophisticated recommendation systems depending on their needs
- ③ Recommendations drives sales, revenue and customer base (e.g. Amazon)
- ④ Example: Amazon, Walmart, Facebook, YouTube, Twitter and so many more!
- ⑤ Scalability issues are rampant and bring in interesting solutions to Recommender systems ↗ Company with 10MM customers with 500K products
- ⑥ The course will discuss real case-studies and help students get hands on in thinking about building scalable recommender systems
- ⑦ The course will be focused on concepts and practical aspects of recommender systems. Hence all assessments will be through conceptual assignments programming assignments and mini-projects hosted on Kaggle.

Week by Week Break Down (Tentative)

Week	Lecture Material	Assignment
1	Intro to Recommender Systems	Sambazon case study
2	Recommender System <u>Baselines</u>	Shopify case study
3	Matrix Factorization methods	Twitter case study
4	Matrix Factorization methods	Twitter case study
5	Deep Learning based recommendations	Walmart case study
6	<u>ML Pipeline for Recommender systems</u>	Amazon case study
7	<u>Real-time Recommendations</u>	Amazon Fresh case study
8	Diversity and Relevance	Final Project
9	Scaling Recommender systems	Final Project
10	Special Topics <i>Final Presentation</i>	Final Project

Summer

Final Presentation

Logistics

- Lectures on Monday and Wednesday 4 pm pst

Logistics

at 6PM

- Lectures on Monday and Wednesday 4 pm pst
- Monday lecture is in-person and Wednesday is online.

[July 5 - 12 → Travel → Px- Recorded for all lectures
(2 Lectures)]

Logistics

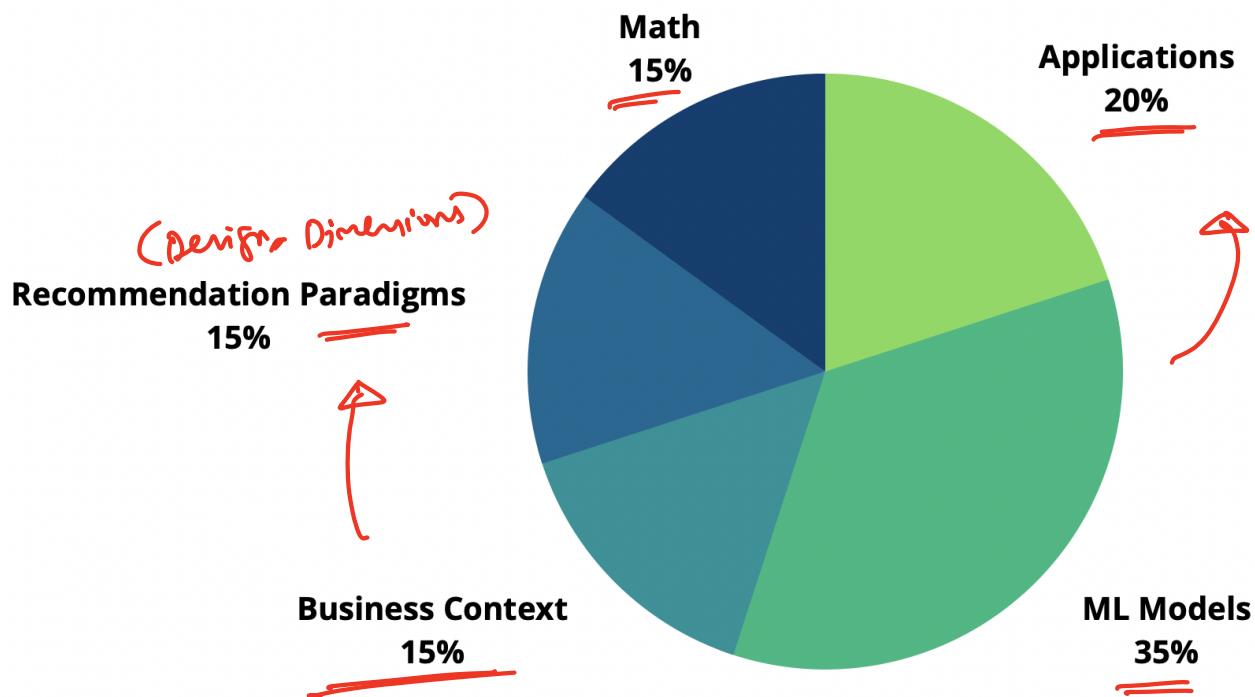
- Lectures on Monday and Wednesday 4 pm pst
- Monday lecture is in-person and Wednesday is online.
- **TA Quiz Section:** Saturday/~~Sunday~~

 
TA Quiz Section: Saturday/~~Sunday~~
Recap material / For assignment

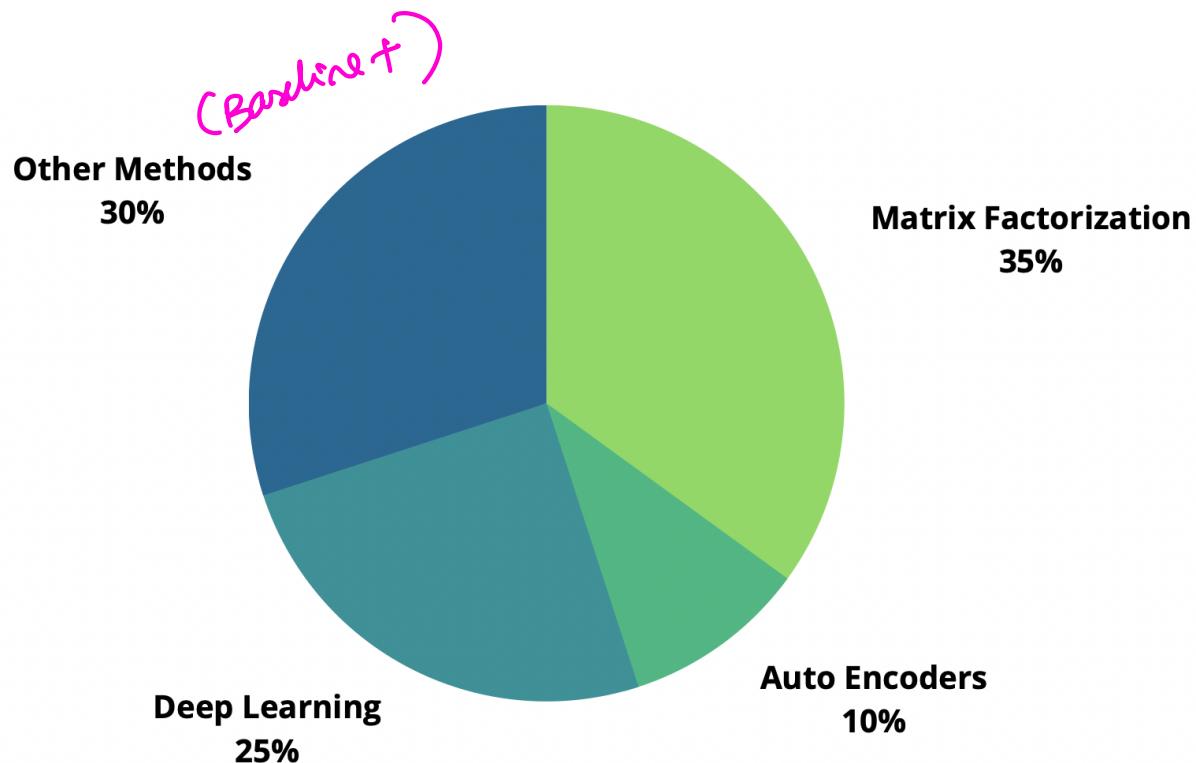
Logistics

- Lectures on Monday and Wednesday 4 pm pst
- Monday lecture is in-person and Wednesday is online.
- **TA Quiz Section:** Saturday/Sunday
- **TA Office Hours:** Tu 4-5 PM PST | Zoom
- **Karthik Office Hours:** Monday 5 pm, EEB M258
5-6

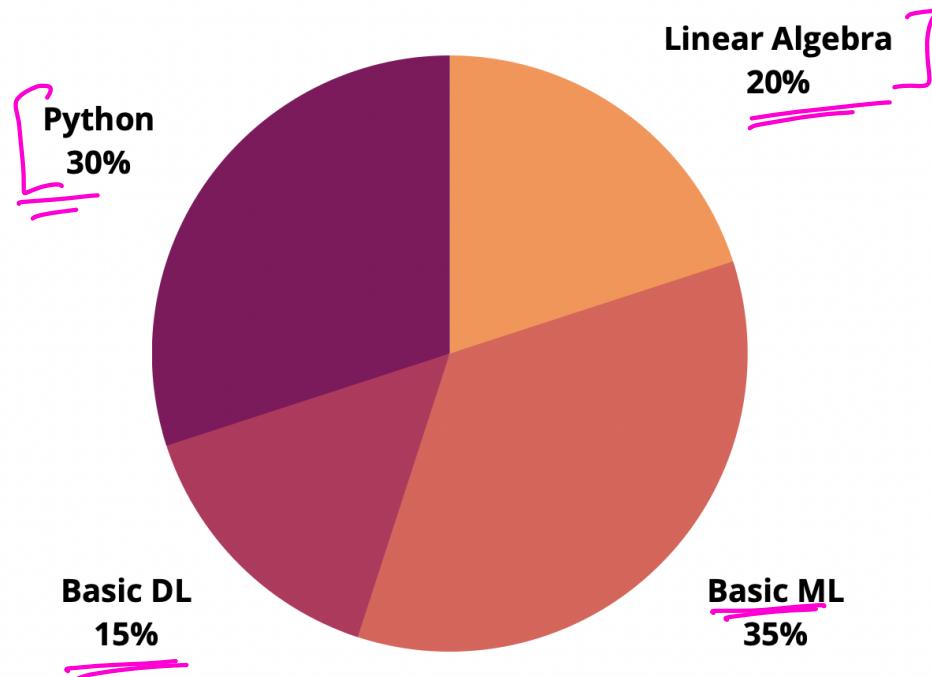
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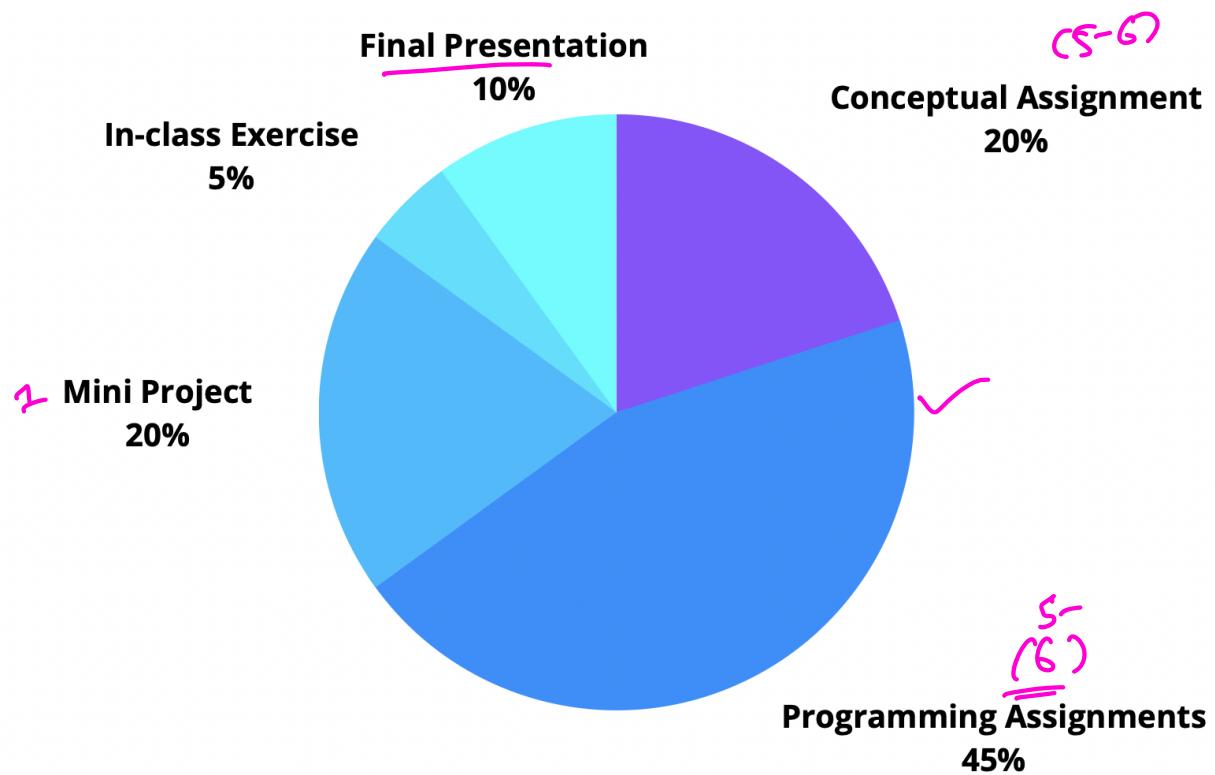
ML Methods



Pre-requisites



Assessments



Real World Recommender System Examples

Amazon Recommendations

Recommended for you, Thomas



Literature & Fiction
62 ITEMS



Exercise & Fitness Equipment
8 ITEMS



Health, Fitness & Dieting Books
37 ITEMS



Tableware
12 ITEMS



Prime Video – Unlimited Streaming for
Prime Members
12 ITEMS



Coffee, Tea & Espresso
98 ITEMS



Biographies & Memoirs
17 ITEMS



Engineering Books
7 ITEMS

Amazon Recommendations

Get Ready for Summer ›

Shop by Department -

Your Amazon.com Today's Deals Gift Cards Sell Help

Industrial & Scientific

Industrial & Scientific

Industrial & Scientific Safety Janitorial & Facilities Food Service Education Material Handling Materials Fabrication Fasteners Filtration

Amazon Best Sellers

Our most popular products based on sales. Updated hourly.

Any Department Industrial & Scientific Additive Manufacturing Products 3D Printers 3D Printing Materials 3D Printer Parts & Accessories 3D Scanners

Best Sellers in 3D Printers

1. XYZprinting Da Vinci 1.0 3D Printer ★★★★☆ (474) Click to see price 2 new

2. FlashForge 3d Printer Creator Pro, Me... ★★★★☆ (235) \$1,349.00 2 new from \$1,349.00

3. ROBO 3D R1 Fully Assembled 3D Printer ★★★★☆ (100) \$799.99 7 new from \$796.00

4. LulzBot Mini Desktop 3D Printer ★★★★☆ (22) \$1,275.00

5. XYZprinting Da Vinci Jr. 1.0 3D Printer ★★★★☆ (8) \$189.99

6. 3doodler 2.0 3d Printing Pen + Free T... \$189.96

More to Explore in 3D Printers

Hot New Releases See More

XYZprinting Da Vinci 1.0 3D Printer \$349.99

3doodler 2.0 3d Printing Pen \$189.98

XrZprinting Da Vinci 1.1 P... \$699.99

Top Rated See More

The MakerGear M2 \$1,775.00

FlashForge 3d Printer Creat... \$1,349.00

LulzBot Mini Desktop 3D Prin... \$1,350.00

Most Wished For See Top 100

Gillette Subscription \$10.25

Gillette Fusion ProGlide \$10.25

YouTube Recommendations

The screenshot shows the YouTube desktop interface with a sidebar on the left and a main content area with three recommended video feeds.

Sidebar:

- Home
- Trending
- Subscriptions
- Library
- History
- Watch later
- Purchases (2)
- Zoe
- Show more

SUBSCRIPTIONS:

- AI Jazerra Eng... (1)
- AI and Games
- Apple
- Ariana Grande
- Avril Lavigne
- B2 Dance Group
- B.C.&Lowy
- Show 54 more

TWICE Recommended channel for you (84)

- [KPOP IN PUBLIC CHALLENGE] TWICE - FEEL SPECIAL [BOYS VS GIRL] 3:33 B2 Dance Group 234K views • 3 days ago (91)
- [KPOP IN PUBLIC CHALLENGE] TWICE(트와이...) 4:12 B2 Dance Group 320K views • 10 months ago (90)
- [KPOP IN PUBLIC CHALLENGE] TWICE(트와이...) 3:34 B2 Dance Group 1.1M views • 5 months ago (85)
- TWICE - YES or YES Dance Cover | Ellen and Brian 4:13 Ellen and Brian 936K views • 11 months ago (73) ← Attention Score

NBC Sports Recommended channel for you (71)

- Usain Bolt's last race ends in disaster, photo finish | NBC... 7:49 NBC Sports 1.3M views • 1 week ago (78)
- USA dominates in first mixed 4x400 relay, Allyson Felix... 9:10 NBC Sports 1.3M views • 1 week ago (75)
- Stunning upset in historic women's 400m world... 9:23 NBC Sports 818K views • 1 week ago (71)
- Simone Biles: the GOAT wins her 5th world title by record... 9:29 NBC Sports 190K views • 12 hours ago (69)

Rock Music - Topic Recommended channel for you (70)

- BOHEMIAN RHAPSODY 4:12 Queen 1.1M views • 1 week ago (78)
- LIVE AID 4:12 Queen 1.1M views • 1 week ago (75)
- Elton John 4:12 Elton John 1.1M views • 1 week ago (71)
- Shania Twain 4:12 Shania Twain 1.1M views • 1 week ago (69)

Shopify Recommendations

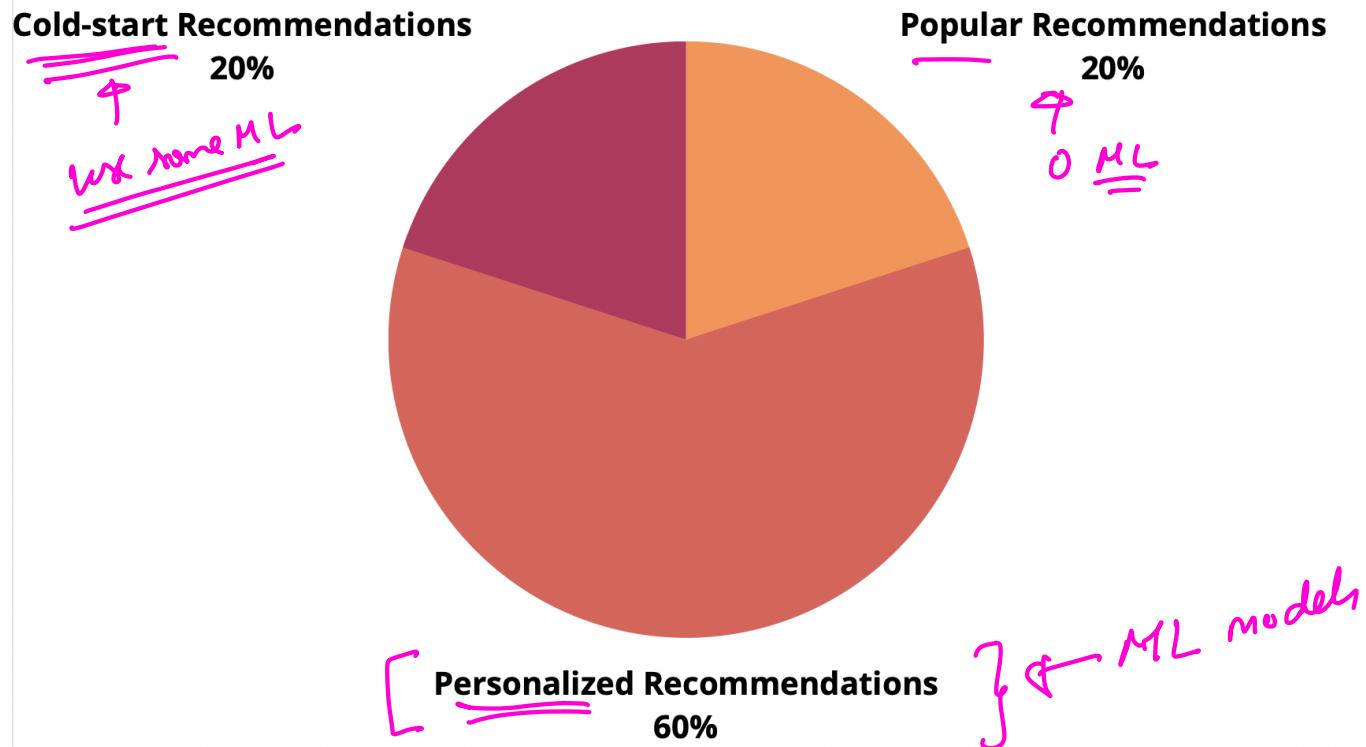
The screenshot displays the WISER AI platform interface for Shopify, featuring several recommendation modules:

- Smart Cart Drawer Upsell:** Shows a product card for "Shredded Two Tone Denim (Jet Black)" with a "Check out" button.
- You May Also Like:** A grid of four items: "Knee Sussen Charcoal Tee", "Knee Sussen White Tee", "Knee Sussen Coal Long Sleeve Tee", and "Knee Sussen White Long Sleeve Tee". Each item has an "ADD TO CART" button.
- Frequently bought together:** A grid of three items: "Knee Sussen Ash Zip-up Hoodie", "Knee Sussen Charcoal Tee", and "Knee Sussen White Tee". Each item has an "ADD TO CART" button.
- You Might Also Like:** A grid of three items: "Boys Graphic Print Sweater", "Dapper Holiday V-neck Set (3pc)", and "Boys Graphic Print Sweater". Each item has an "Add to Cart" button.
- Integration:** Shows compatibility with various platforms: PageFly, Loox, Judge.me, All Reviews, Yotpo, and Back in Stock.
- Performance Metrics:** Three cards showing performance: "30% Increase in Customer Engagement", "22% Increase in Average Order Value", and "17% Increase in Conversions".

Personalized Recommendations

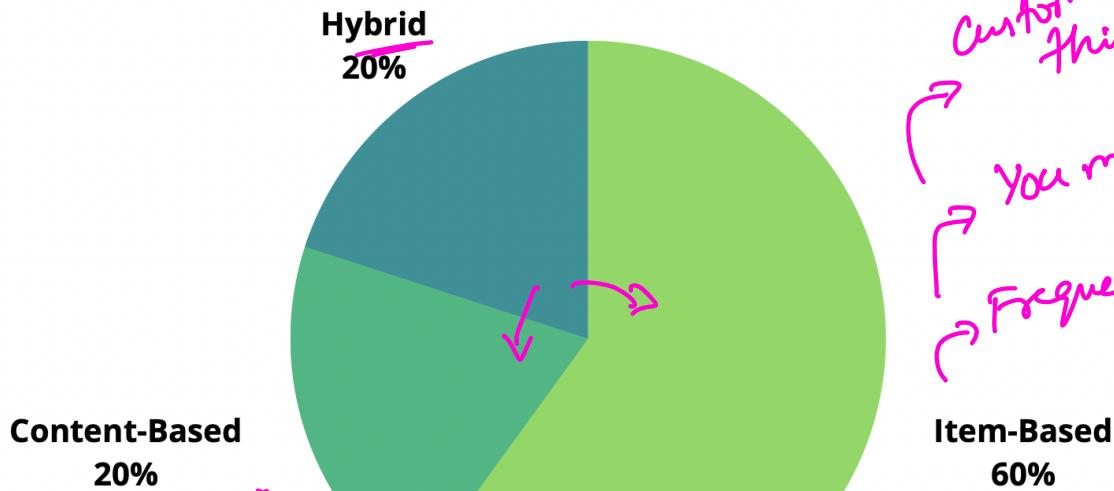
Introduction to Recommender Systems

Recommender Types



Recommenders

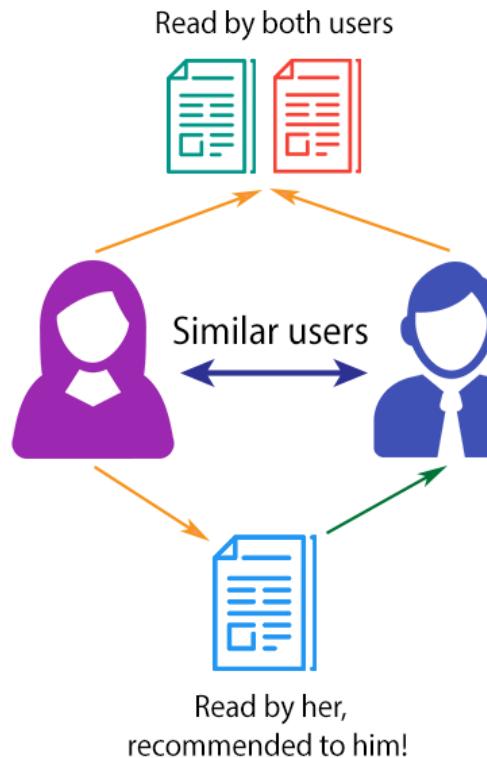
(ML Model)



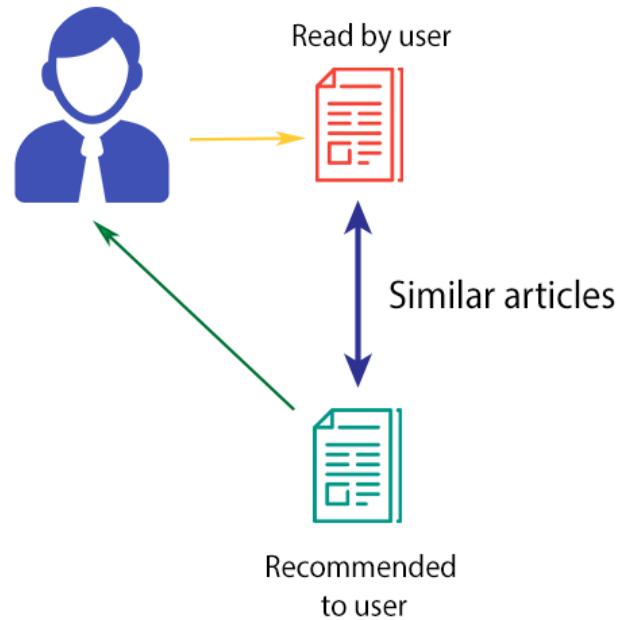
Customers who bought this also...
You may also like
Frequently bought together
↳ shaving kit

Collaborative filtering

COLLABORATIVE FILTERING



CONTENT-BASED FILTERING



Item based recommendations

amazon.com

Recommended for You

Amazon.com has new recommendations for you based on items you purchased or told us you own.

LOOK INSIDE!

[Google Apps Deciphered: Compute in the Cloud to Streamline Your Desktop](#)

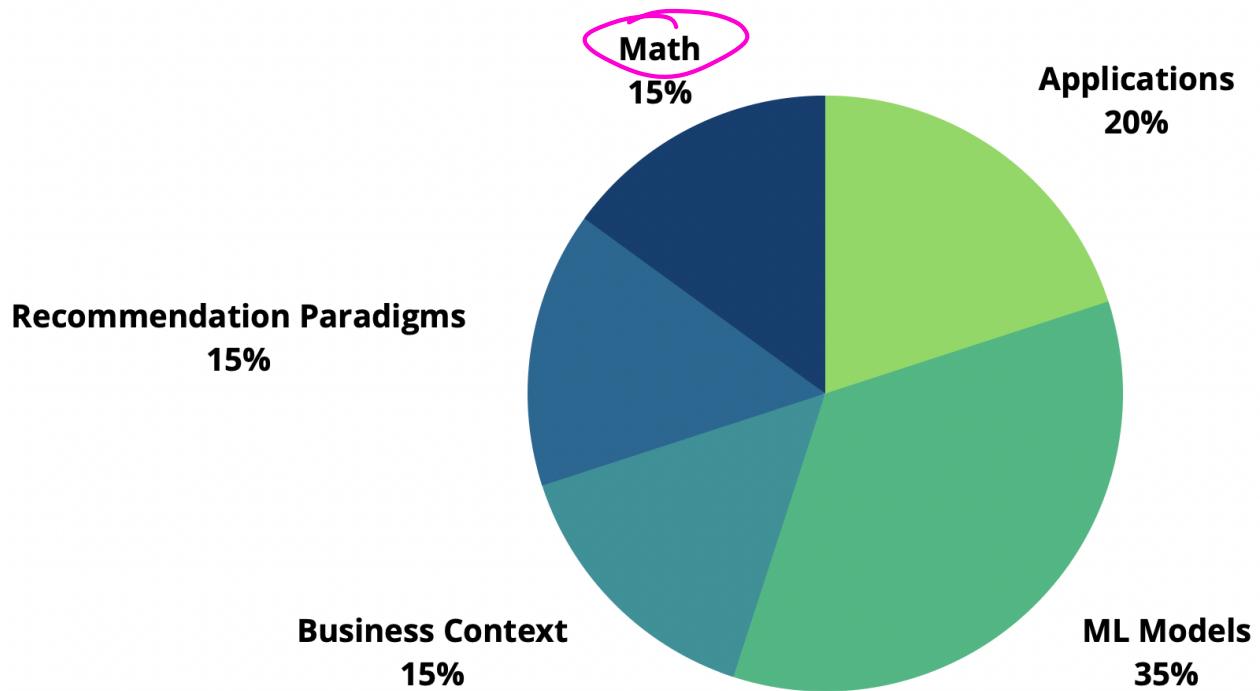
LOOK INSIDE!

[Google Apps Administrator Guide: A Private-Label Web Workspace](#)

LOOK INSIDE!

[Googlepedia: The Ultimate Google Resource \(3rd Edition\)](#)

Content



Linear Algebra Background

Linear Algebra & Matrix

1. Scalar

$$d \in \mathbb{R}$$

\hookrightarrow scalar

$$d = 5 \xrightarrow{\text{Integer}}$$

$$d = 0.3 \xrightarrow{\text{float}}$$

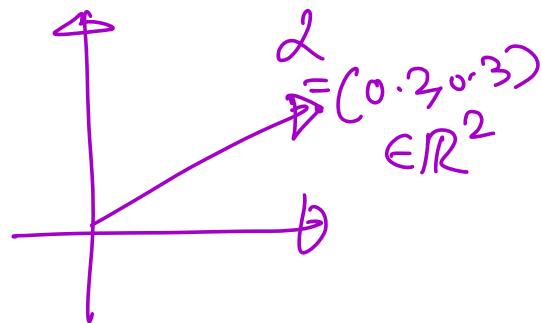
$$d = -0.2$$

$$p = 0.7 \rightarrow \text{prob} = 0.7$$

\hookrightarrow scalar

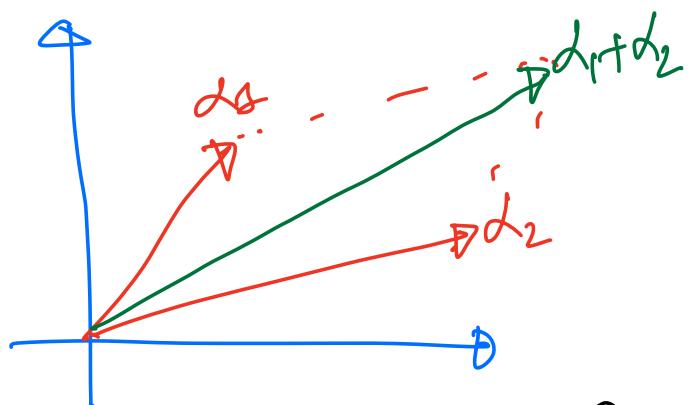
2. vector

$$\vec{d} = \begin{bmatrix} d_1 \\ d_2 \\ d_3 \\ \vdots \\ d_d \end{bmatrix} \xrightarrow{\text{array}} \mathbb{R}^d \xrightarrow{\text{dimension of vector}}$$



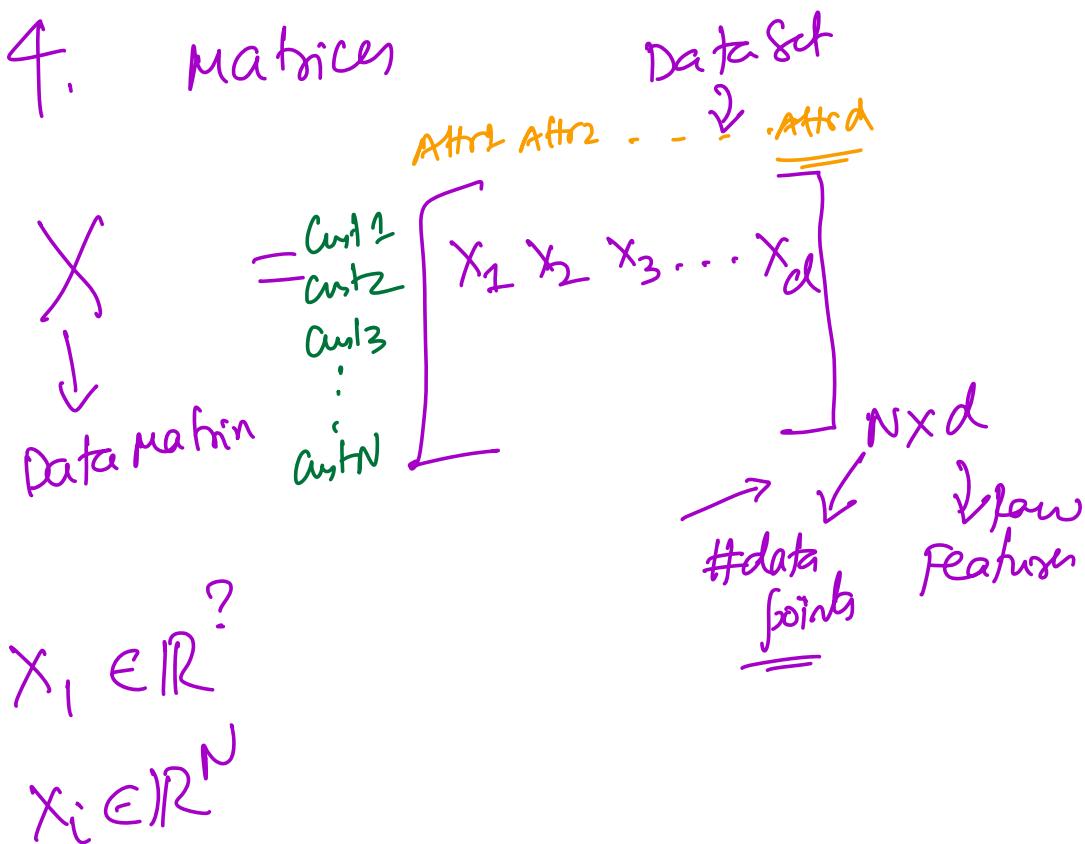
b. Vector Arithmetic

$$d_1, d_2 \in \mathbb{R}^d$$
$$d_1 + d_2 = \begin{bmatrix} d_{11} + d_{21} \\ d_{12} + d_{22} \\ \vdots \\ d_{1d} + d_{2d} \end{bmatrix} \in \mathbb{R}^d$$



$$\beta d \in \mathbb{R}^d = \begin{bmatrix} \beta d_1 \\ \beta d_2 \\ \vdots \\ \beta d_d \end{bmatrix} \in \mathbb{R}^d$$

4. Matrices



$$X = [x_1 \ x_2 \ x_3 \ \dots \ x_d]$$

$$Y = [y_1 \ y_2 \ y_3 \ \dots \ y_d]$$

$$X+Y = [x_1+y_1 \ x_2+y_2 \ x_3+y_3 \ \dots \ x_d+y_d]$$

Adding by Columns

5. Matrix multiplication

$$X \quad Y$$

$$XY = ?$$

$$\begin{bmatrix} -x_1^T \\ -x_2^T \\ \vdots \\ -x_n^T \end{bmatrix} \begin{bmatrix} \cdot \\ y_1 \\ y_2 \\ \vdots \\ y_d \end{bmatrix} = \begin{bmatrix} x_1^T y_1, x_1^T y_2, \dots, x_1^T y_d \\ \vdots \\ \vdots \\ x_n^T y_1, x_n^T y_2, \dots, x_n^T y_d \end{bmatrix}$$

$\therefore x_1^T \rightarrow \begin{bmatrix} \cdot \\ y_1 \\ y_2 \end{bmatrix} = x_1^T y_2 \in \mathbb{R}$
scalar

6. Matrix - vector multiplication

$X \cdot y \rightarrow \mathbb{R}^d$
 $\hookrightarrow \mathbb{R}^{N \times d}$
 $\hookrightarrow \text{Data Matrix}$

1.

$$\begin{bmatrix} -x_1^T \\ -x_2^T \\ \vdots \\ -x_N^T \end{bmatrix} y = \begin{bmatrix} x_1^T y \\ x_2^T y \\ \vdots \\ x_N^T y \end{bmatrix} \in \mathbb{R}^N$$

2.

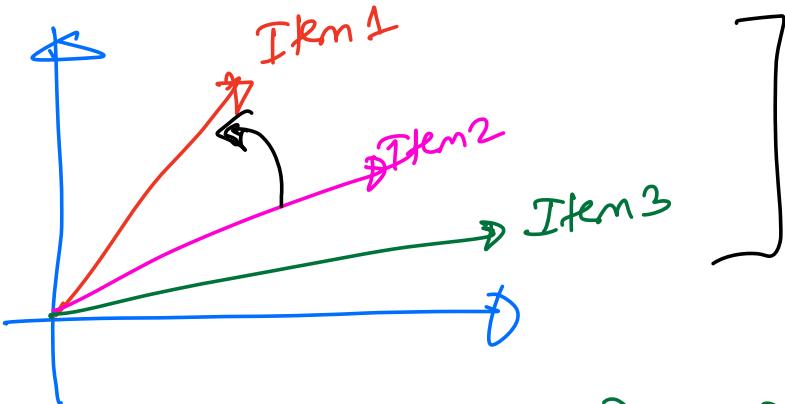
$$\begin{bmatrix} x_1 & x_2 & \dots & x_d \end{bmatrix} y = x_1 y_1 + x_2 y_2 + \dots + x_d y_d \in \mathbb{R}^N$$

$$X_{N \times d} \quad y_{d \times 1} \rightarrow (XY)_{N \times 1}$$

$$y_{m \times n} \quad X_{n \times d} \rightarrow (YX)_{m \times d}$$

7. Dot products

↳ Item-Item Similarity
 (Frequently Bought Together)



$\text{Dot}(\text{Item}1, \text{Item}2) > \text{Dot}(\text{Item}1, \text{Item}3)$

\nparallel
 \downarrow
 I purchased this

$$\mathbf{I}_1 \in \mathbb{R}^d$$

$$\mathbf{I}_1 \cdot \mathbf{I}_2 = I_{11}I_{21} + I_{12}I_{22} + \dots + I_{1d}I_{2d}$$

$$\mathbf{I}_2 \in \mathbb{R}^d$$

$$\mathbf{I}_1 = \begin{bmatrix} I_{11} \\ I_{12} \\ \vdots \\ I_{1d} \end{bmatrix} \quad \mathbf{I}_2 = \begin{bmatrix} I_{21} \\ I_{22} \\ \vdots \\ I_{2d} \end{bmatrix}$$

$$\mathbf{I}_1 \cdot \mathbf{I}_2 = \mathbf{I}_1^T \mathbf{I}_2$$

Normalizing dot product \Rightarrow Correlation Similarity!!

$$-1 \leq \frac{\mathbf{I}_1 \cdot \mathbf{I}_2}{\|\mathbf{I}_1\| \|\mathbf{I}_2\|} \leq 1$$

8. Norms

Magnitude of a vector or a matrix!

$$\text{Vector norm} \quad \|I\|_2 = \sqrt{(I_{11})^2 + (I_{12})^2 + \dots + (I_{1d})^2}$$

$$\text{Matrix norm} \quad \|X\|_F = \sqrt{\sum_{ij} (x_{ij})^2}$$

Appln.:- 1) Cosine Similarity

2) Convergence of a ML algorithm

$$\theta^t \quad \theta^{t+1}$$

$$\frac{\|\theta^{t+1} - \theta^t\|_2}{\|\theta^t\|_2} \leq \epsilon$$

3) Distance between cluster centers

Similarity \rightarrow Dot products

Distance \rightarrow Norms of difference of vectors

9. Next Lecture

- SVD?
- Eigen DeCompr.

} Adv.-Matrix
Operation

10.

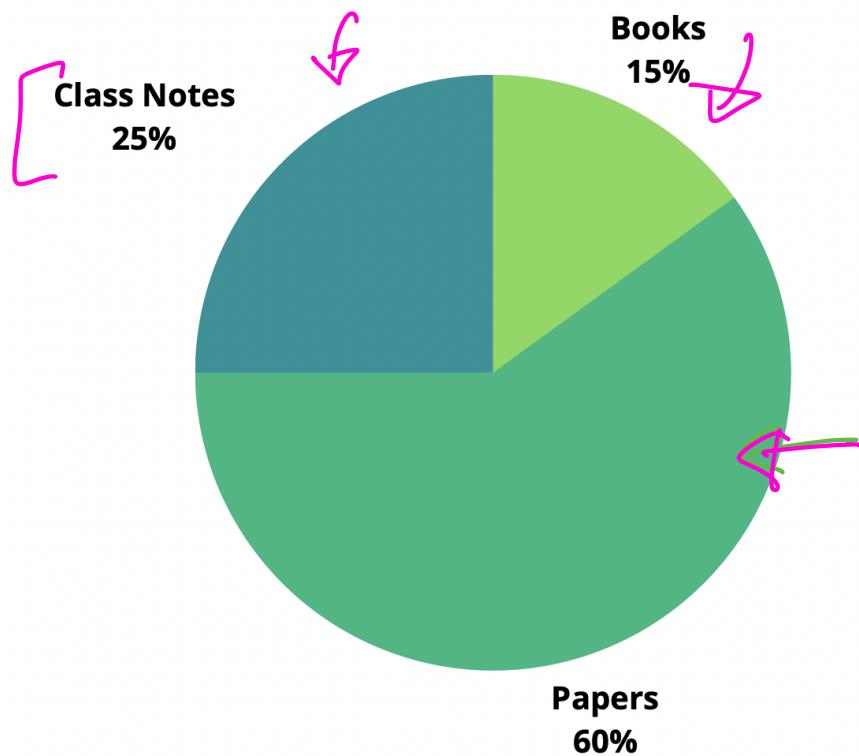
Gradient Arithmetic

- Back propagation
- Gradient Composition.

Assignment 1

- ① **Programming Assignment:** Python and Numpy module coverage for Linear Algebra + Coverage on metrics and feature extraction
- ② **Conceptual Assignment:** Concepts on Linear and Matrix Algebra

Reference materials



Independent Study Credits

Next Lecture

on Monday, 6PM in person!

- More Linear Algebra and ML Background
- Baseline models for Recommender Systems

Join Discord!! (check Email)