

# 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 10M+ 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 programming assignments and mini-projects<sup>2</sup> hosted on Kaggle. *conceptual assignments*

# Week by Week Break Down (Tentative)

Week	Lecture Material	Assignment
1	✓ Intro to Recommender Systems	Sambazon case study
2	Recommender <u>System Baselines</u>	Shopify case study
3	Matrix Factorization methods	Twitter case study
4	Matrix Factorization methods	Twitter case study
5	Deep <u>Learning</u> 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
<del>10</del>	Special Topics	Final Project

Summer

→ Final Presentation

# Logistics

- Lectures on Monday and Wednesday 4 pm pst

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- Monday lecture is in-person and Wednesday is online.

at 6PM  
→

[ July 5 - 12 → Travel → Pre-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~~

*1-2 PM*

*↓*

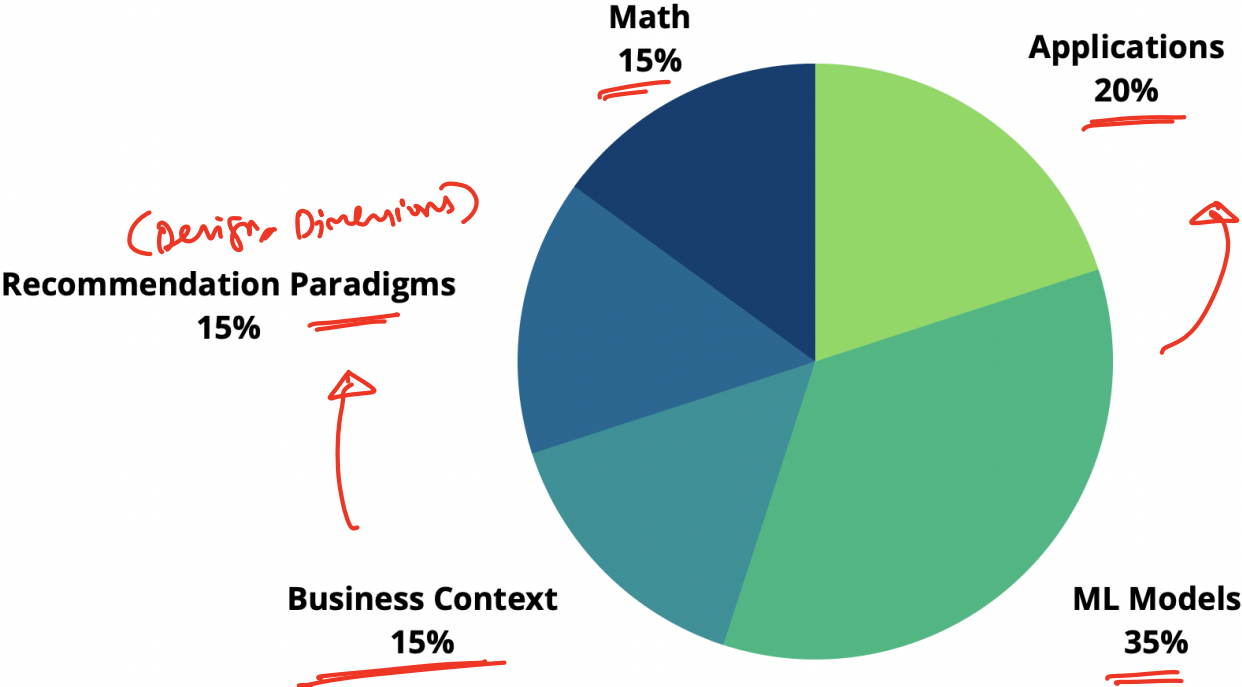
*Recap material / For assignment*

# Logistics

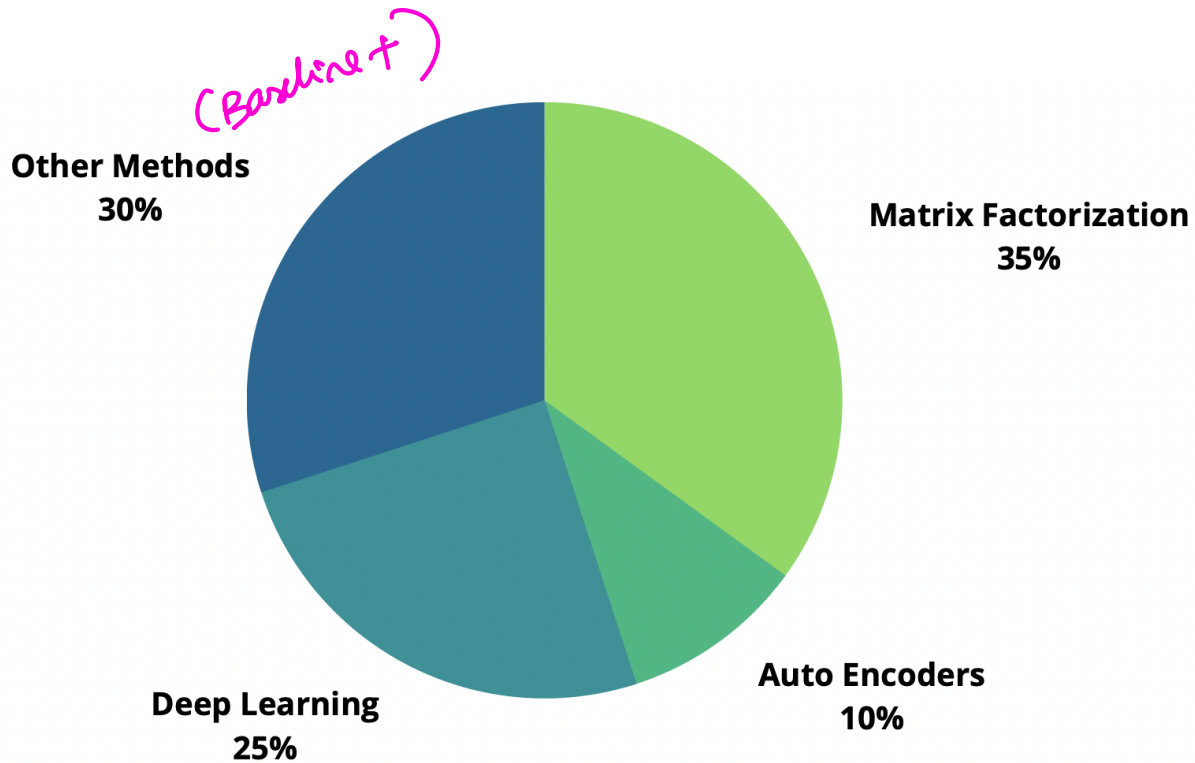
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- Monday lecture is in-person and Wednesday is online.
- **TA Quiz Section:** Saturday/Sunday
- **TA Office Hours:** Tu 4-5 pm PST | Zoom
- **Karthik Office Hours:** Monday ~~6~~ pm, EEB M258  
5-6



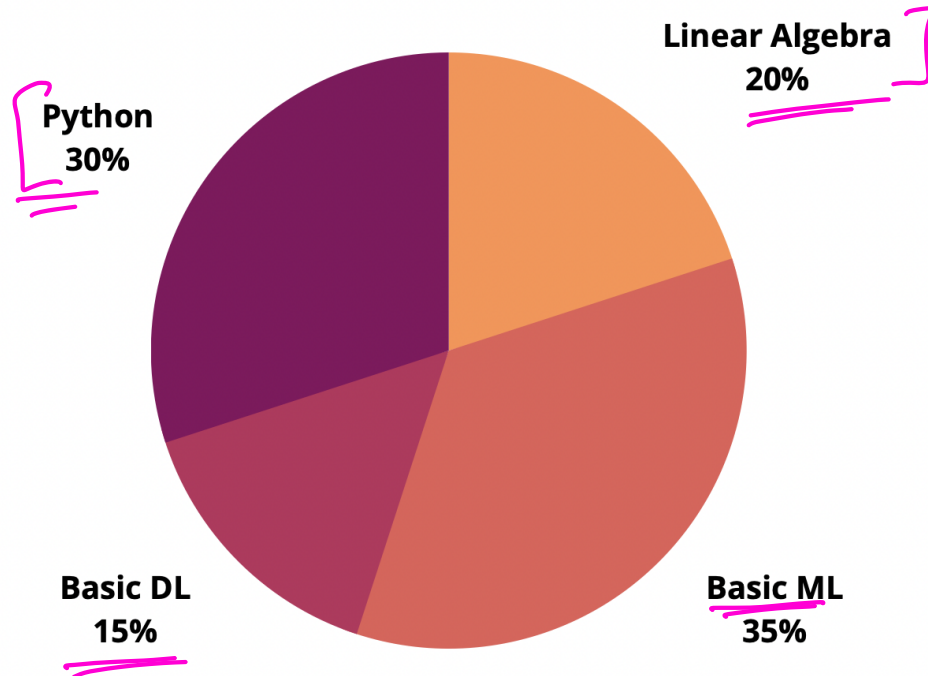
# Content



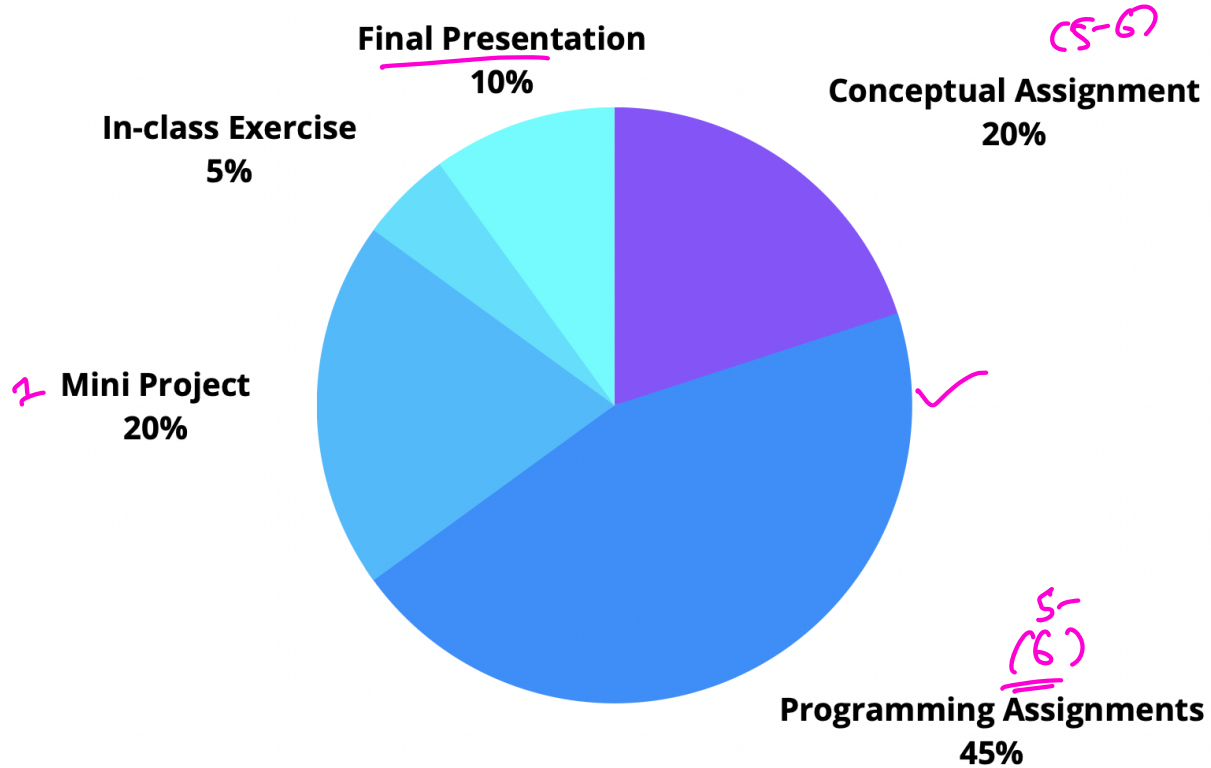
# ML Methods



# 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

The screenshot shows the Amazon.com website for the Industrial & Scientific department. The top navigation bar includes the Amazon logo, a search bar, and links for 'Get Ready for Summer', 'Hello, Sign in Your Account', 'Try Prime', 'Wish List', and 'Cart'. Below the navigation bar, there are links for 'Shop by Department' and 'Your Amazon.com Today's Deals Gift Cards Sell Help'. The main content area is titled 'Amazon Best Sellers' and features a sidebar with navigation links for 'Any Department', 'Industrial & Scientific', 'Additive Manufacturing Products', '3D Printers', '3D Printing Materials', '3D Printer Parts & Accessories', and '3D Scanners'. The main product grid is titled 'Best Sellers in 3D Printers' and displays six items in a 2x3 grid. To the right, there are three sections: 'More to Explore in 3D Printers', 'Hot New Releases', and 'Top Rated', each with a 'See More' link. The 'Most Wanted For' section is also visible at the bottom right.

**Amazon Best Sellers**  
Our most popular products based on sales. Updated hourly.

**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...  
★★★★☆ (225)  
\$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)
- 5.** XYZprinting Da Vinci Jr. 1.0 3D Printer  
★★★★☆ (8)
- 6.** 3oodder 2.0 3d Printing Pen + Free 7...  
\$189.98

**More to Explore in 3D Printers** [See More](#)

**Hot New Releases** [See More](#)

- XYZprinting Da Vinci Jr. 1.0... \$349.99
- 3oodder 2.0 3d Printing Pe... \$189.98
- XYZprinting Da Vinci 1.1 R... \$699.99

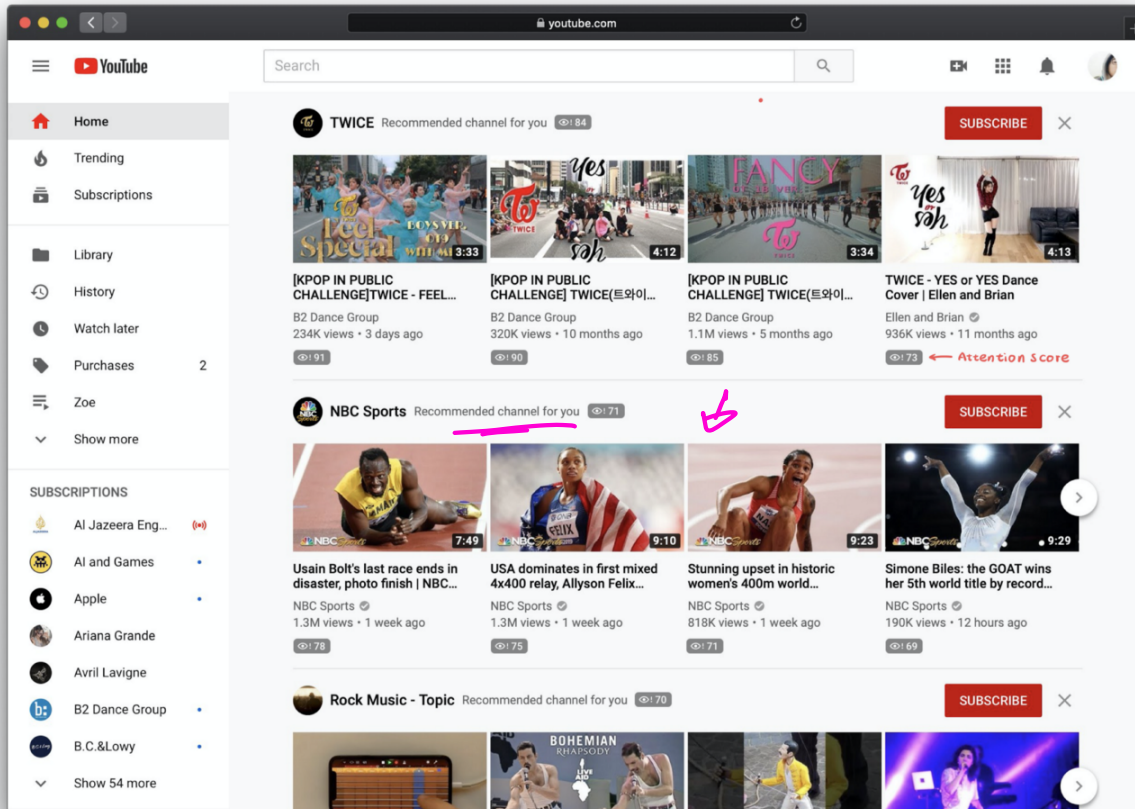
**Top Rated** [See More](#)

- The MakerGear M2 \$1,775.00
- FlashForge 3d Printer Creat... \$1,349.00
- LulzBot Mini Desktop 3D Pri... \$1,300.00

**Most Wanted For** [See Top 100](#)

- FlashForge 3d Printer Creat... \$1,349.00
- XYZprinting Da Vinci Jr. 1.0 3D Printer \$1,349.00
- 3oodder 2.0 3d Printing Pen \$189.98

# YouTube Recommendations





# Shopify Recommendations

**WISER AI**

Integration

- WISER
- Popsyfy
- Loox
- Judge.me
- All Reviews
- Yotpo
- Back in Stock

**Smart Cart Drawer Upsell**

ZIMMOR

Shredded Two Tone Denim (set Black)

**You May Also Like**

- Two Tone Cargo Shorts
- Basic White Long-Sleeve
- Two Tone Mesh Zip Hoodie

**You may also like**

- Xhoo Sunsets Charcoal Tee
- Xhoo Sunsets White Tee
- Xhoo Sunsets Long Sleeve Tee
- Xhoo Sunsets White Long Sleeve Tee

**Frequently bought together**

- Xhoo Sunsets Ash Zip-up Hoodie
- Xhoo Sunsets Charcoal Tee
- Xhoo Sunsets White Tee

Total price: \$45.07

**You Might Also Like**

- Step Graphic Print Sweater
- Disruptor Fleece Vest Set
- Step Graphic Print Sweater

**30% increase in Customer Engagement**

**22% Increase in Average Order Value**

**17% Increase in Conversions**

*Personalized Recommendations*

# Introduction to Recommender Systems

# Recommender Types

Cold-start Recommendations

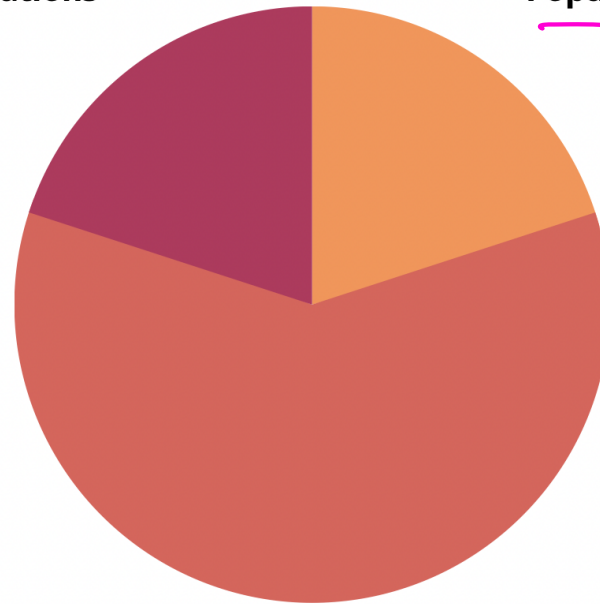
20%

↑  
use some ML

Popular Recommendations

20%

↑  
0 ML



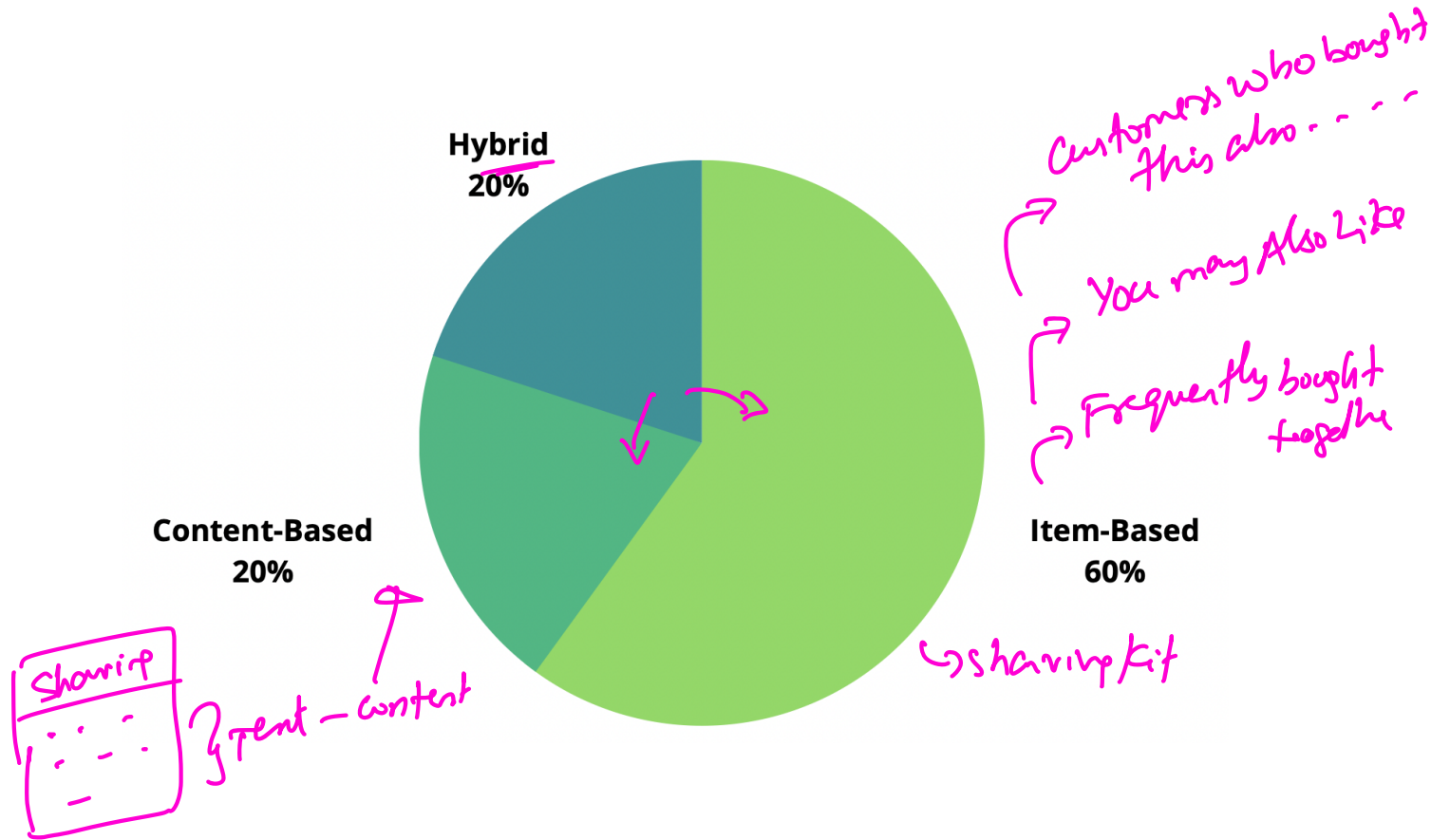
Personalized Recommendations

60%

} ← ML models

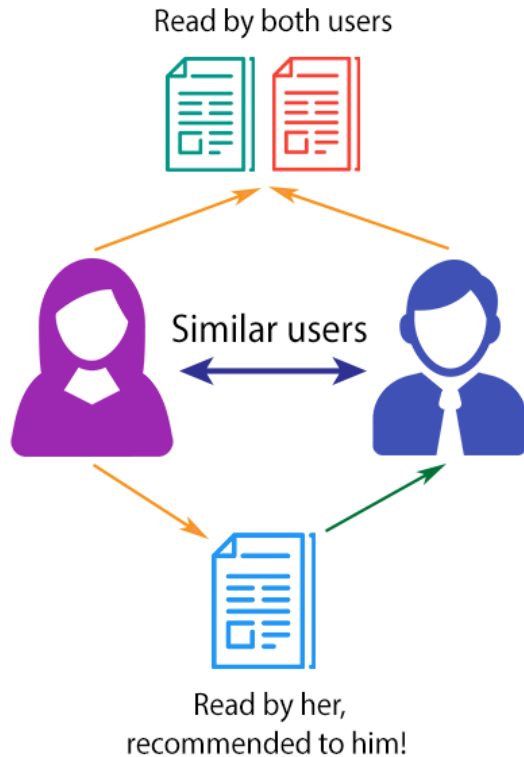
# Recommenders

(ML Models)

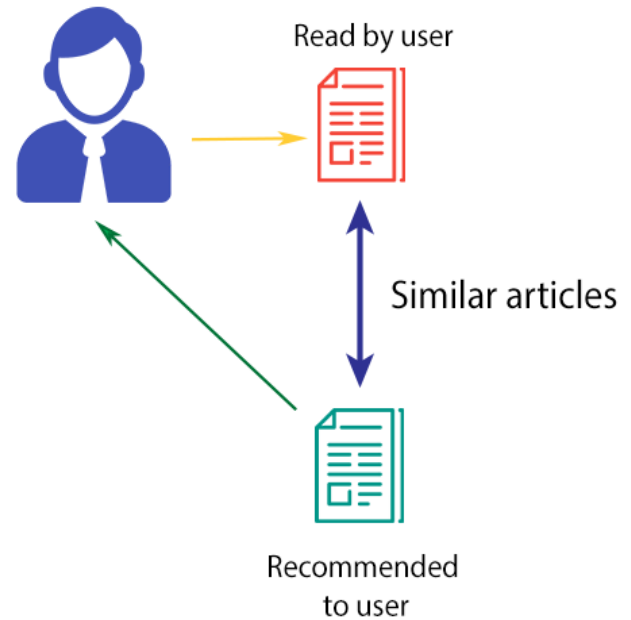


# Collaborative filtering

## 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.



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

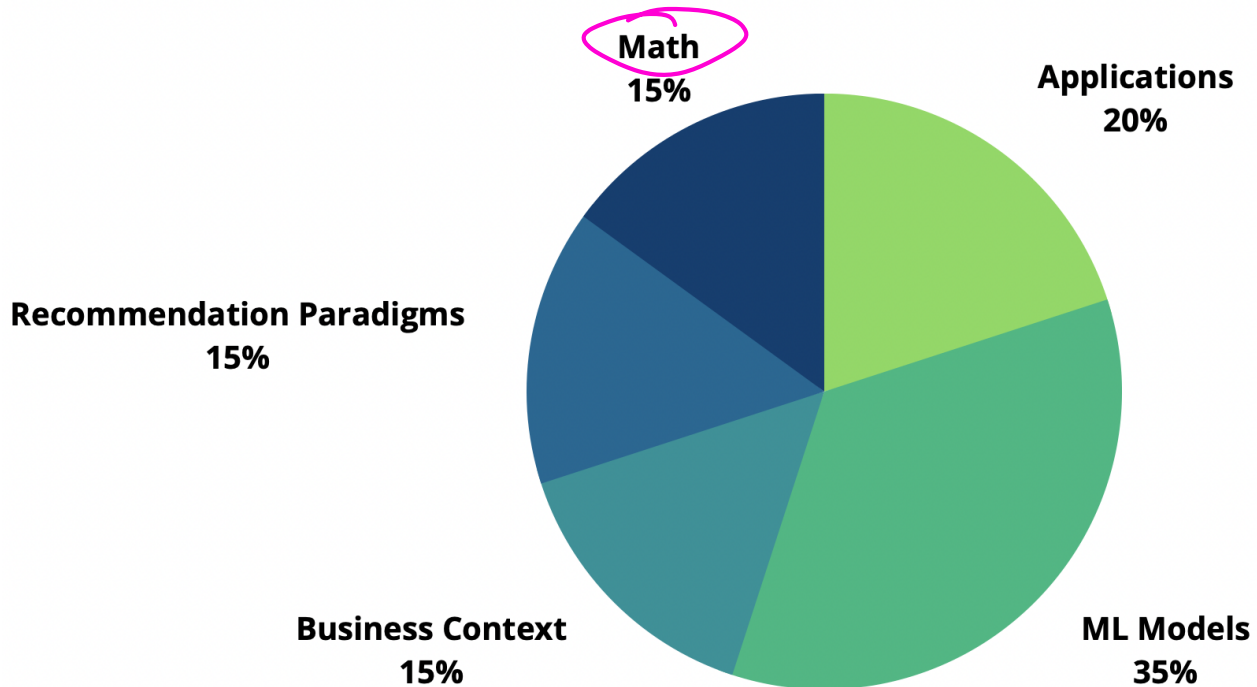


[Google Apps Administrator Guide: A Private-Label Web Workspace](#)



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

# Content



# Linear Algebra Background



# Linear Algebra Matrix

1. Scalars

$\alpha \in \mathbb{R}$   
↳ scalars

$\alpha = 5 \rightarrow \text{Integer}$

$\alpha = 0.3 \rightarrow \text{Float}$

$\alpha = -0.2$

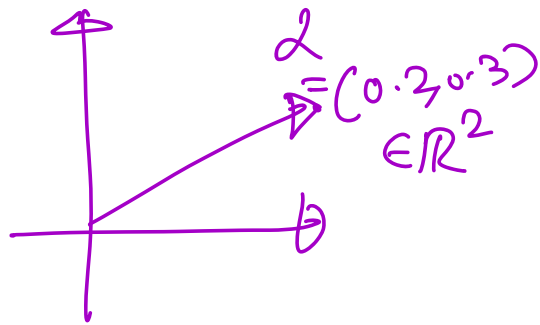
$p = 0.7 \rightarrow \text{prob} = 0.7$   
↳ scalars

2. Vectors

$$\vec{\alpha} = \begin{bmatrix} \alpha_1 \\ \alpha_2 \\ \alpha_3 \\ \vdots \\ \alpha_d \end{bmatrix}$$

↳ Array

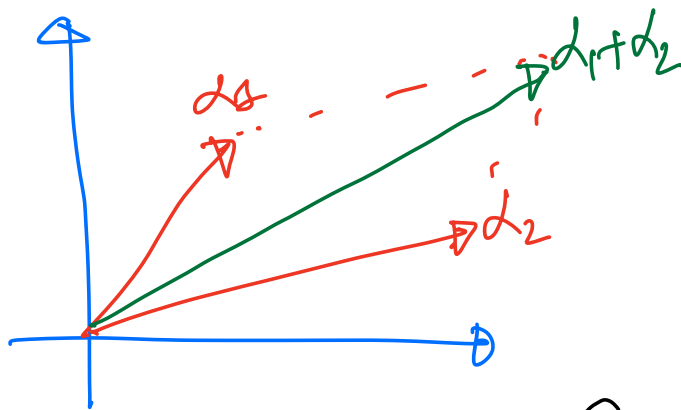
$\in \mathbb{R}^d \rightarrow \text{dimension of vector}$



## 2. vectors arithmetic

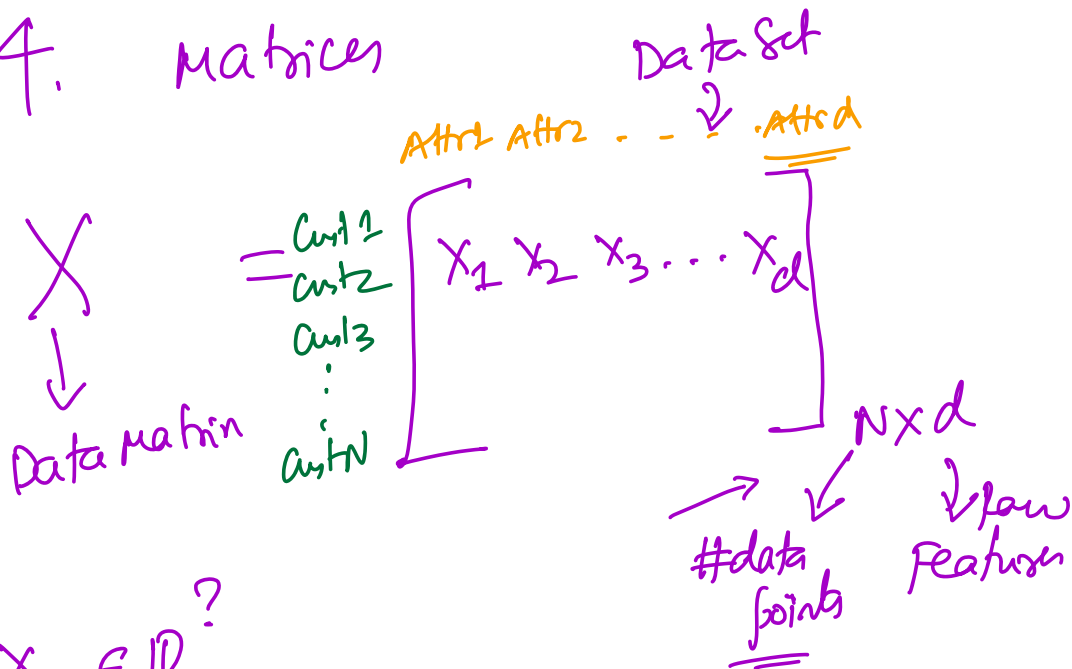
$$d_1, d_2 \in \mathbb{R}^d$$

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



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

# 4. Matrices



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

$$X_i \in \mathbb{R}^N$$

$$X = [X_1 \ X_2 \ X_3 \ \dots \ X_d]$$

$$Y = [Y_1 \ Y_2 \ Y_3 \ \dots \ Y_d]$$

$$X+Y = [X_1+Y_1 \ X_2+Y_2 \ X_3+Y_3 \ \dots \ X_d+Y_d]$$

Adding by Columns

## 5. Matrix multiplication

$$X \quad Y$$

$$XY = ?$$

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

$$\begin{bmatrix} \cdot \\ \cdot \\ \cdot \\ \cdot \end{bmatrix} x_i^T \begin{bmatrix} \cdot \\ \cdot \\ \cdot \\ \cdot \end{bmatrix} = x_i^T y_2 \in \mathbb{R}$$

↳ scalar

## 6. Matrix-vector multiplication

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

1. 
$$\begin{bmatrix} \text{---} x_1^T \text{---} \\ \text{---} x_2^T \text{---} \\ \vdots \\ \text{---} x_N^T \text{---} \end{bmatrix} y = \begin{bmatrix} x_1^T y \\ x_2^T y \\ \vdots \\ x_N^T y \end{bmatrix}$$

$$\hookrightarrow \mathbb{R}^N$$

2. 
$$\begin{bmatrix} x_1 & x_2 & \dots & x_d \end{bmatrix} y = x_1 y_1 + x_2 y_2 + \dots + x_d y_d$$

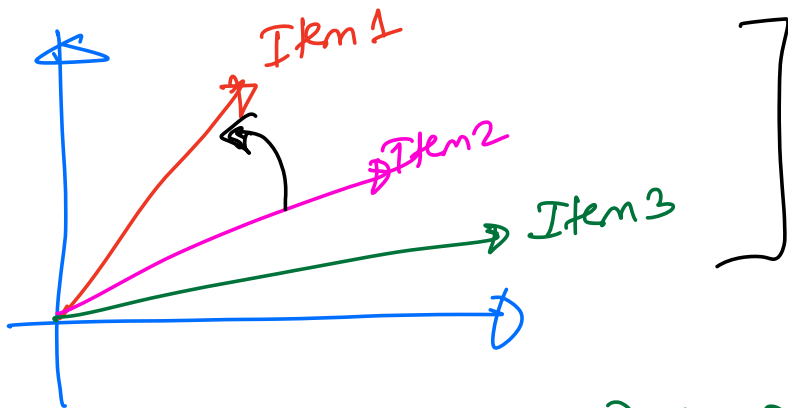
$$\in \mathbb{R}^N$$

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

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

## 7. Dot products

↳ Item-Item Similarity  
(Frequently Bought Together)



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

↓  
I purchased this

$$I_1 \in \mathbb{R}^d$$

$$I_2 \in \mathbb{R}^d$$

$$I_1 \cdot I_2 = I_1^T I_2$$

$$\begin{bmatrix} \ ] \end{bmatrix}$$

$$I_1 \cdot I_2 = I_{11}I_{21} + I_{12}I_{22} + \dots + I_{1d}I_{2d}$$

$$I_1 = \begin{bmatrix} I_{11} \\ I_{12} \\ \vdots \\ I_{1d} \end{bmatrix} \quad I_2 = \begin{bmatrix} I_{21} \\ I_{22} \\ \vdots \\ I_{2d} \end{bmatrix}$$

normalize dot product  $\Rightarrow$  Cosine Similarity!!

$$-1 \leq \frac{I_1 \cdot I_2}{\|I_1\| \|I_2\|} \leq 1$$

## 8. Norms

vector norm Magnitude of a vector or a matrix!

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

Matrix Norm

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

Appln: -

1) Cosine Similarity

2) Convergence of a ML Algorithm

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

$$\frac{\|\theta^{t+1} - \theta^t\|_2}{\|\theta^t\|_2} \leq \frac{1}{10^{-2}}$$

3) Distance between cluster centers

Similarity  $\rightarrow$  Dot products

Distance  $\rightarrow$  Norms of difference of vectors

9. Nent Lecture

→ SVD?

→ Eigen Decomp.

} Adv. Matrix  
Operations

10. Gradient Arithmetic

→ Back propagation

→ Gradient composition.

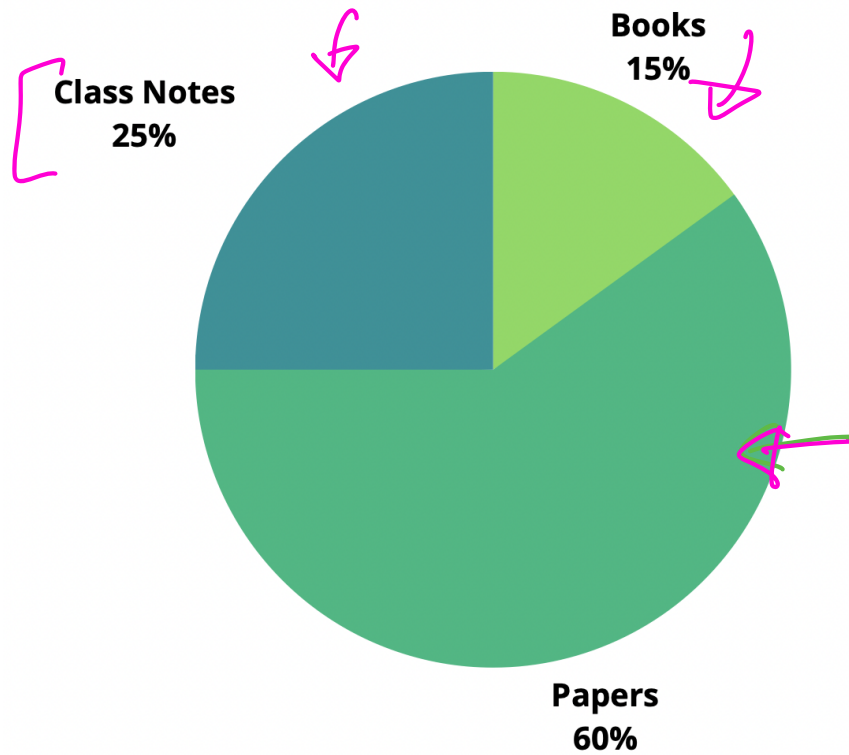
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# Assignment 1

- 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, GPM in person!

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

Join Discord!! (check Email)