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
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 hosted on Kaggle.

Week by Week Break Down (Tentative)

Week	Lecture Material	Assignment
1	Intro to Recommender Systems	Sambazon case study
2	Recommender System Baselines	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	ML Pipeline for Recommender systems	Amazon case study
7	Real-time Recommendations	Amazon Fresh case study
8	Diversity and Relevance	Final Project
9	Scaling Recommender systems	Final Project
~~10~~	Special Topics	Final Project

Summer

Final Presentations

Logistics

- Lectures on Monday and Wednesday 4 pm pst

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- **TA Quiz Section:** Saturday/~~Sunday~~

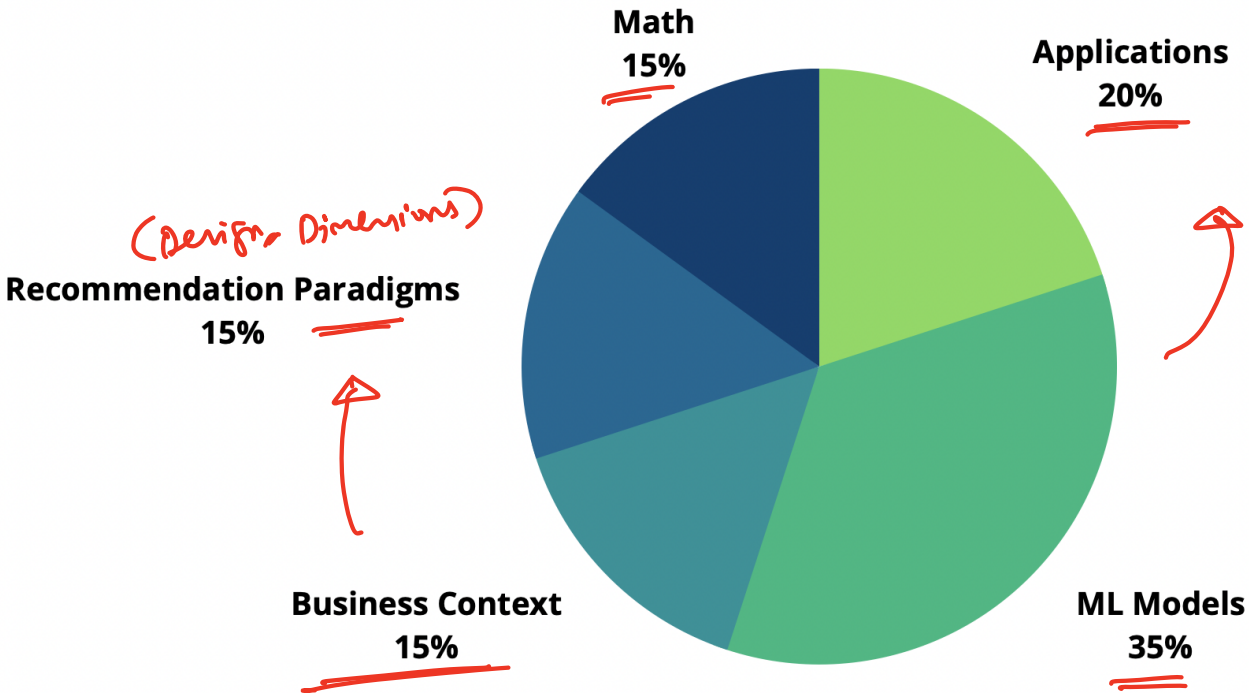
1-2PM

Recap material / For assignment

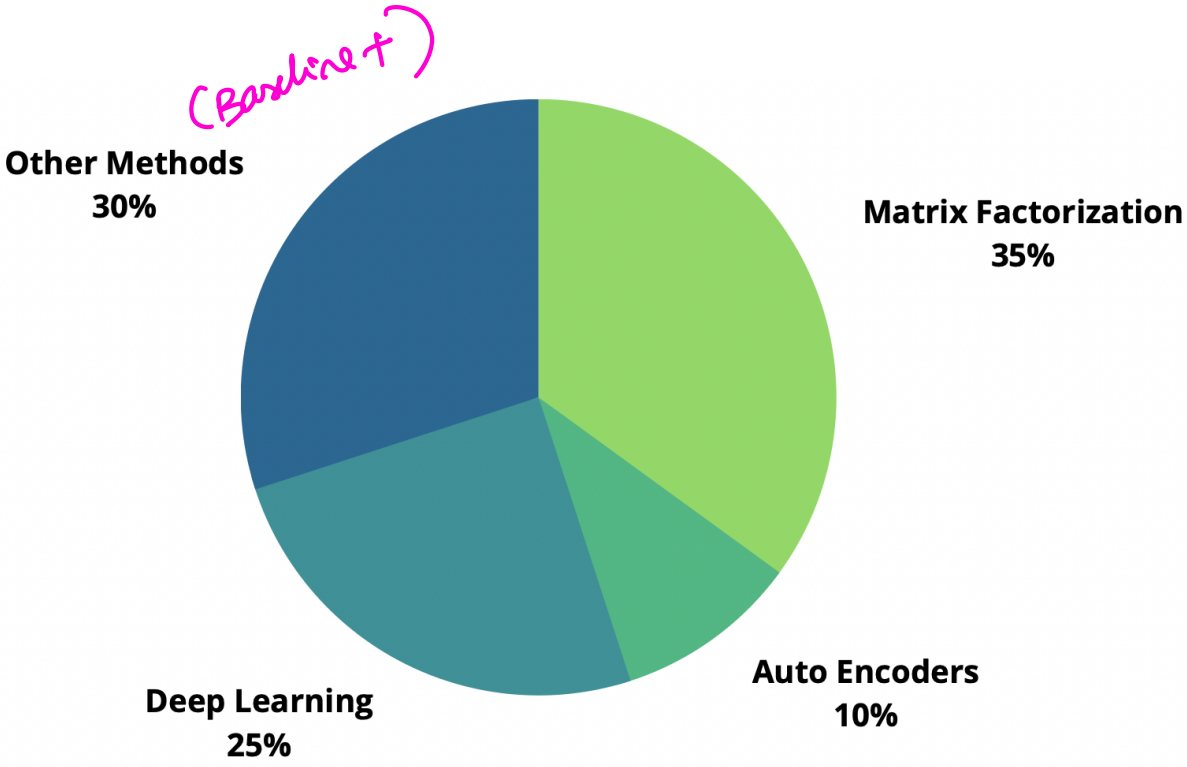
Logistics

- 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 4-5PM PST | Zoom
- **Karthik Office Hours:** Monday ~~6~~ 5-6 pm, EEB M258

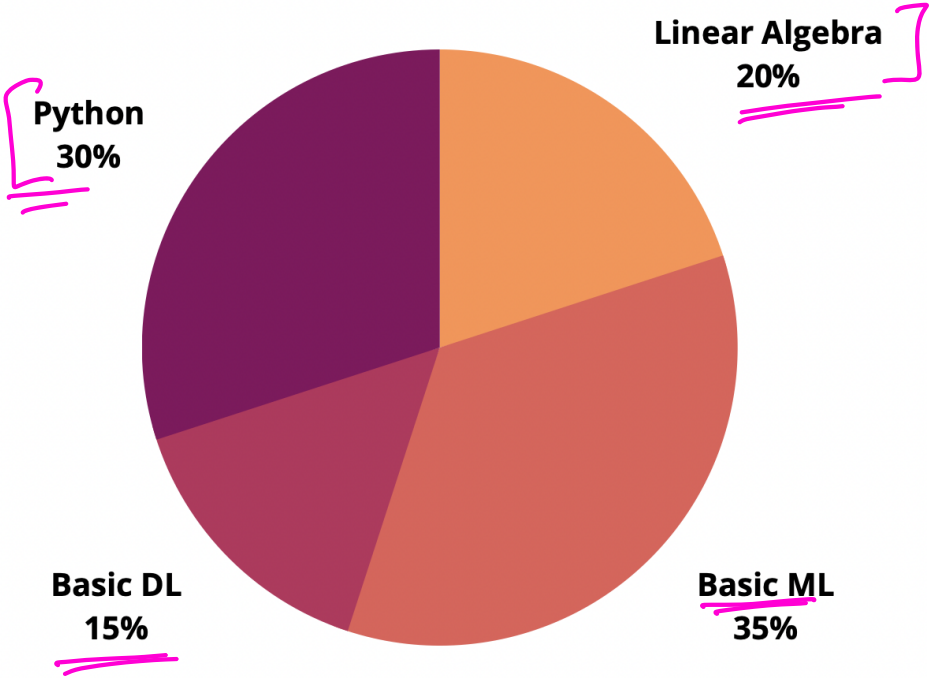
Content


Math
15%
Applications
20%
(Design Dimensions)
Recommendation Paradigms
15%
Business Context
15%
ML Models
35%

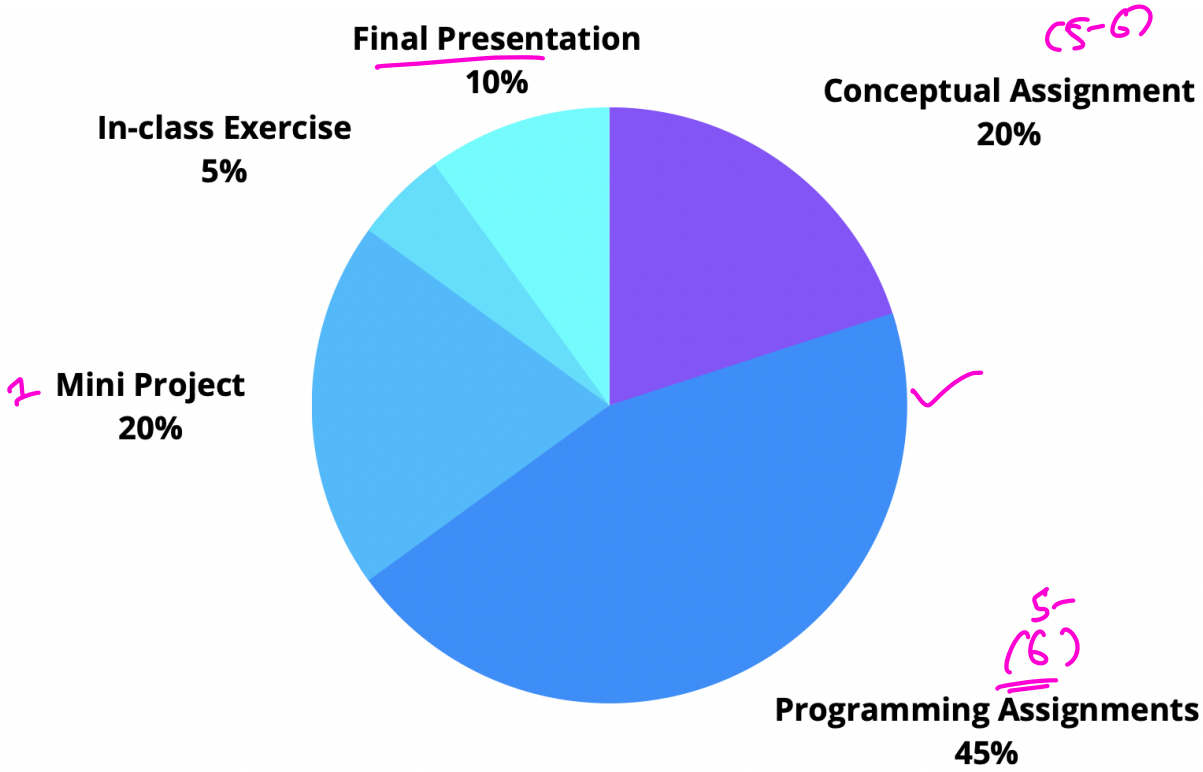
ML Methods


(Baseline+)
Other Methods
30%
Matrix Factorization
35%
Auto Encoders
10%
Deep Learning
25%

Pre-requisites

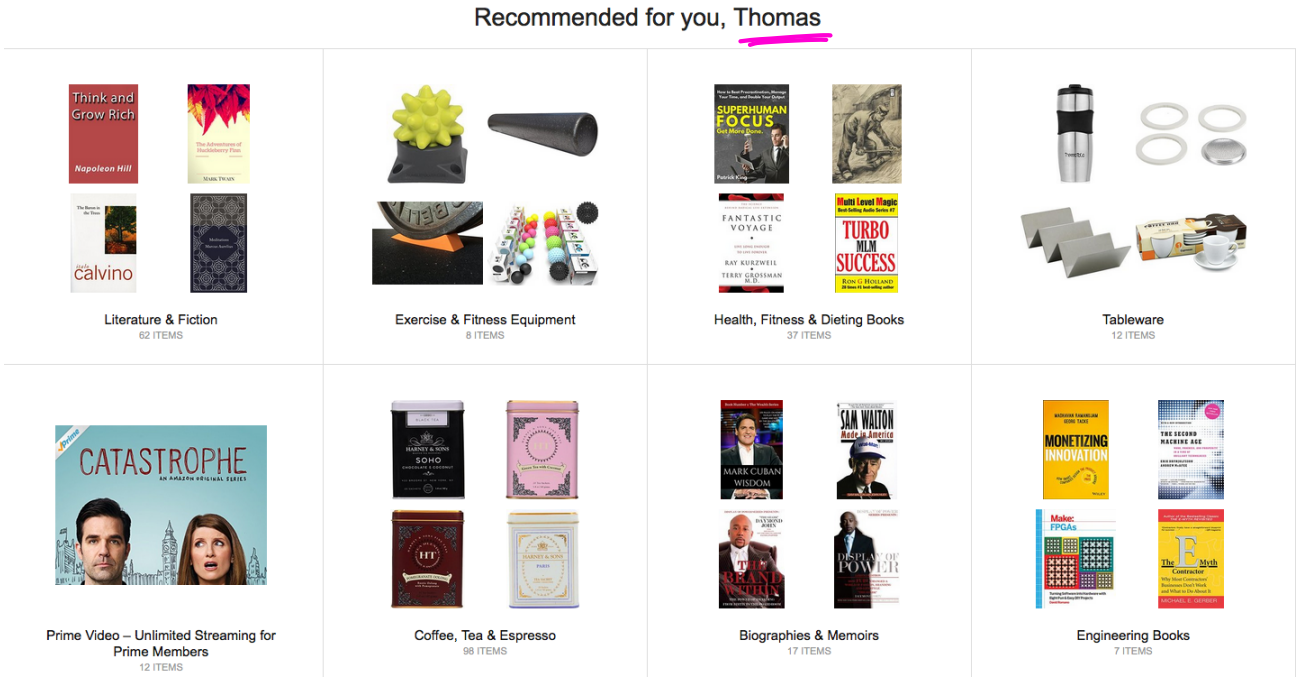


Assessments

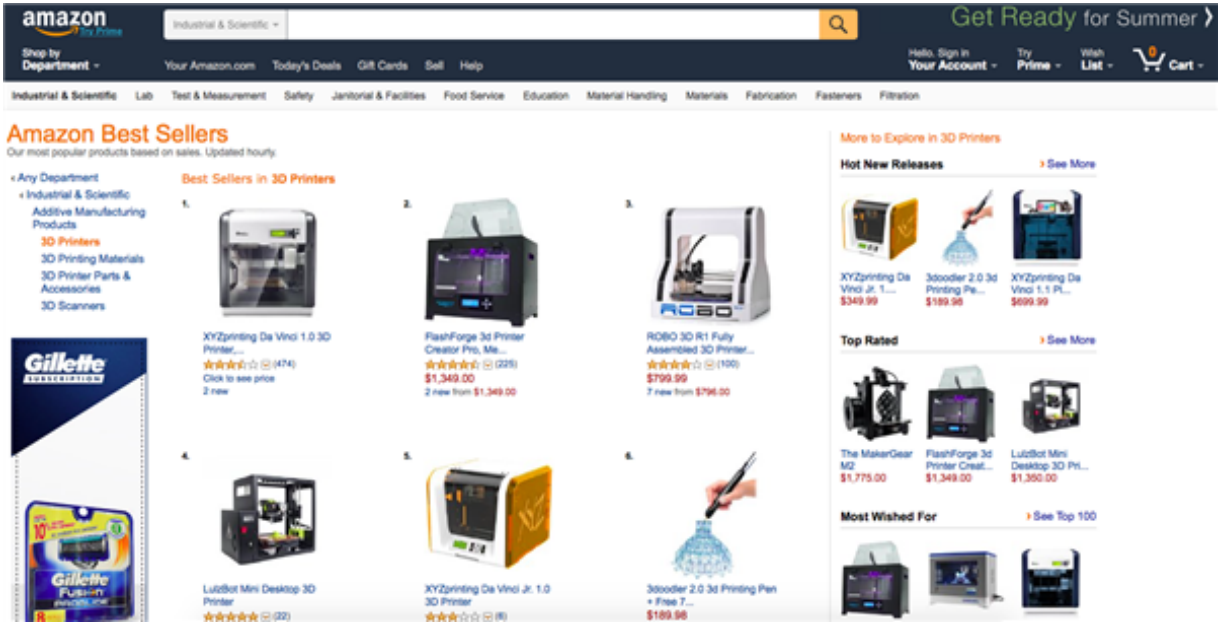


Real World Recommender System Examples

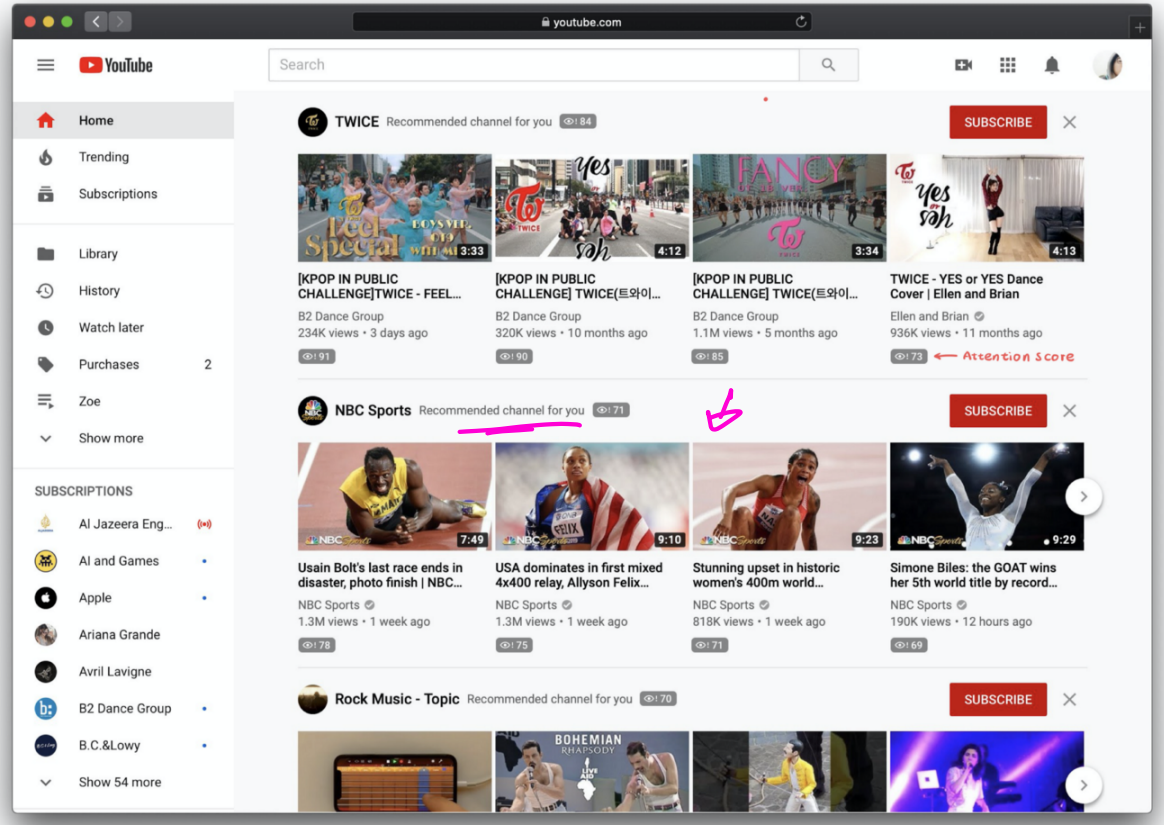
Amazon Recommendations



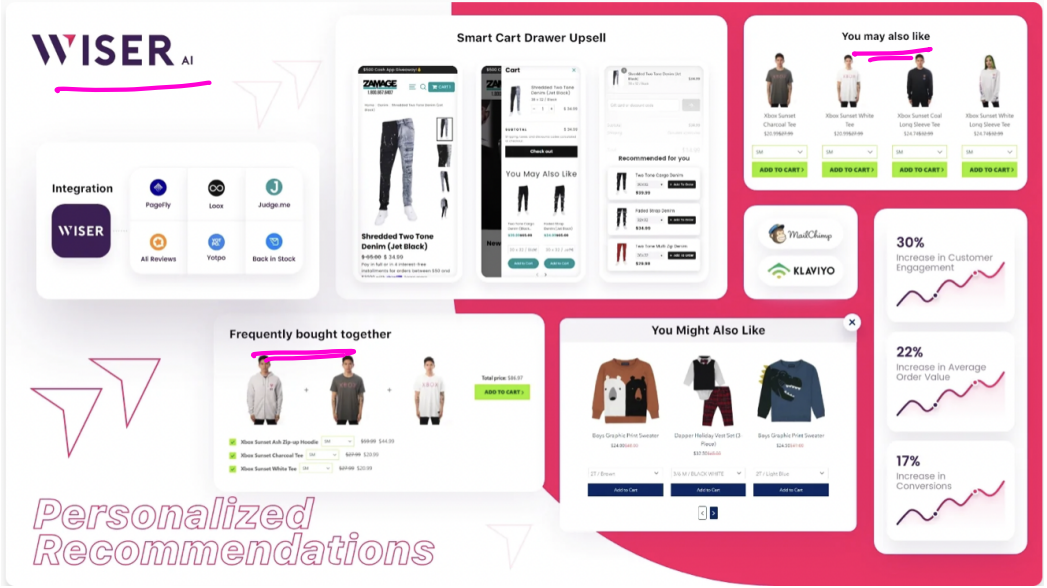
Amazon Recommendations



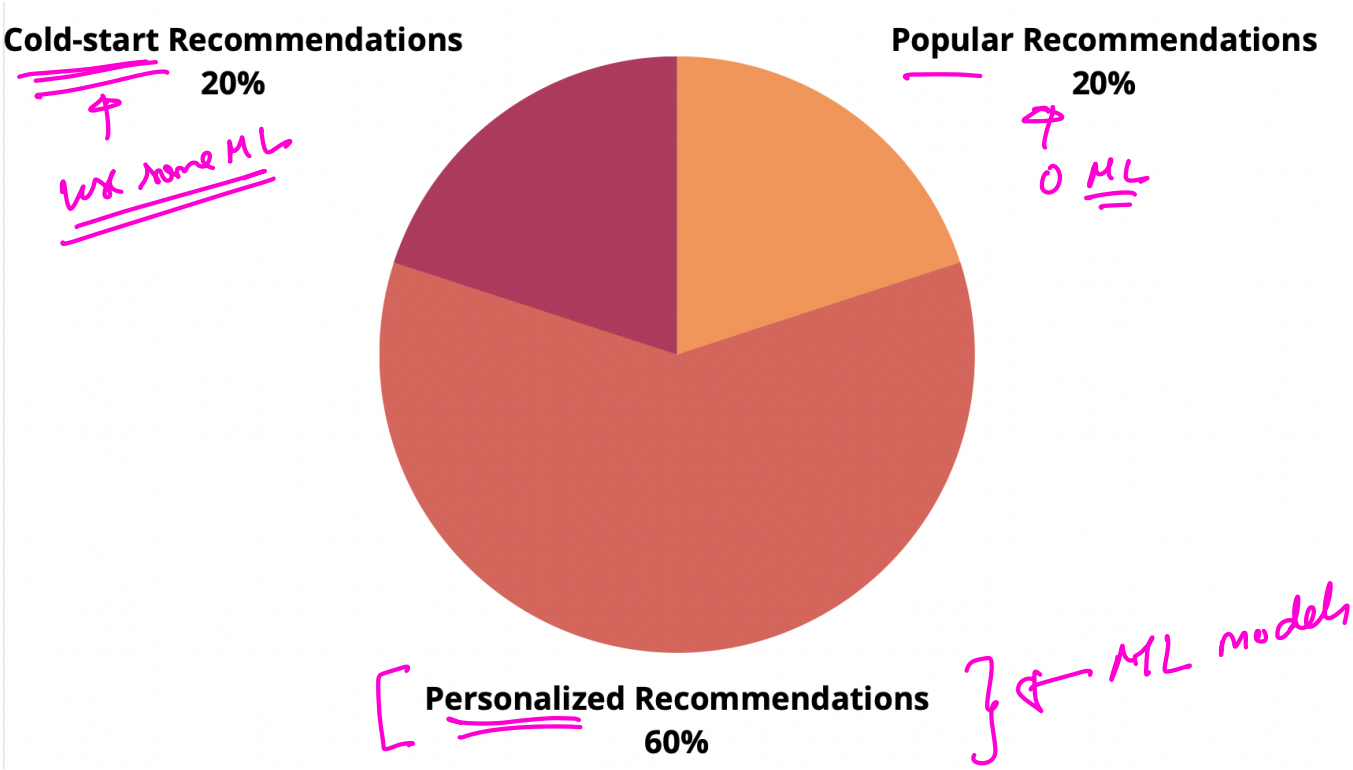
YouTube Recommendations



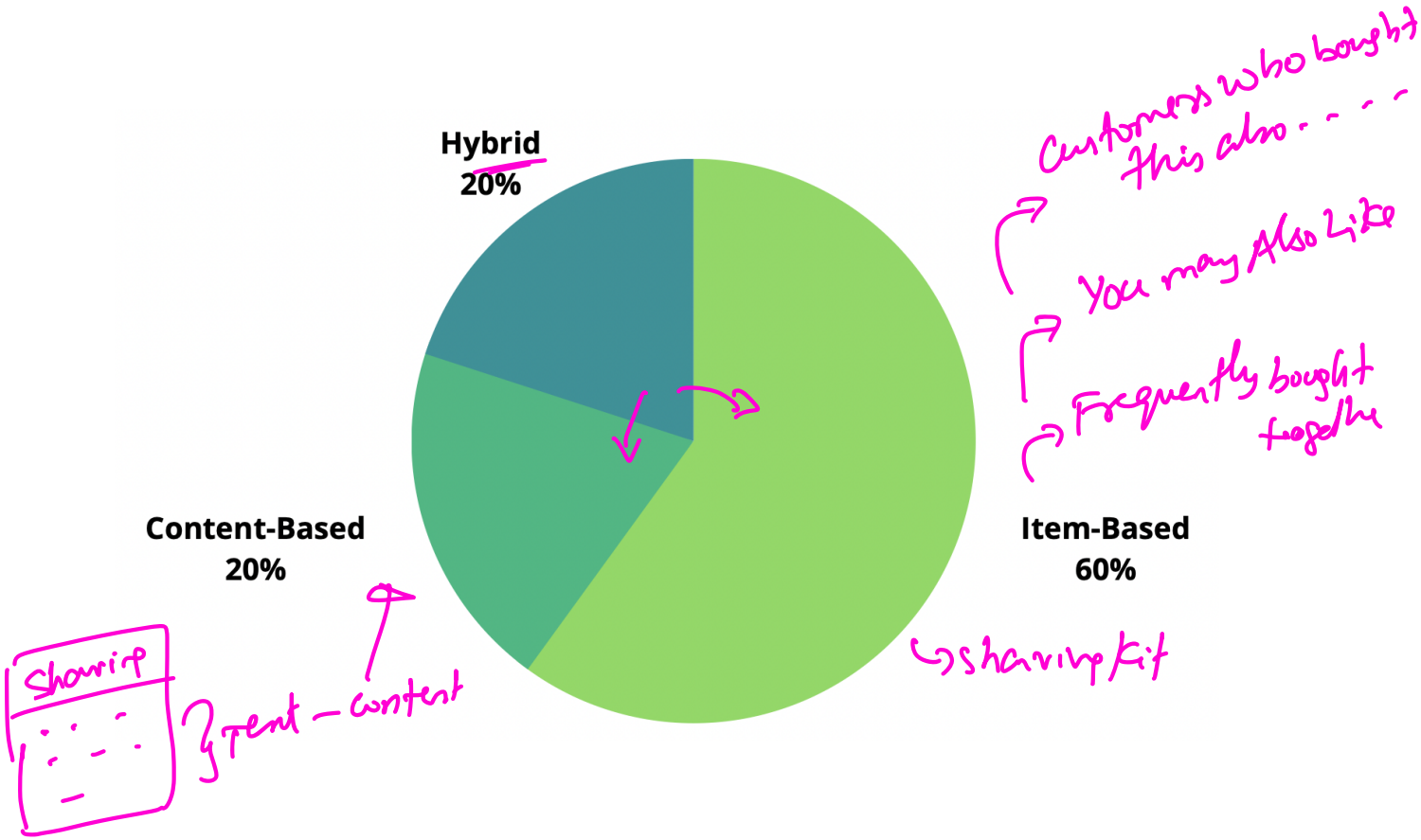
Shopify Recommendations



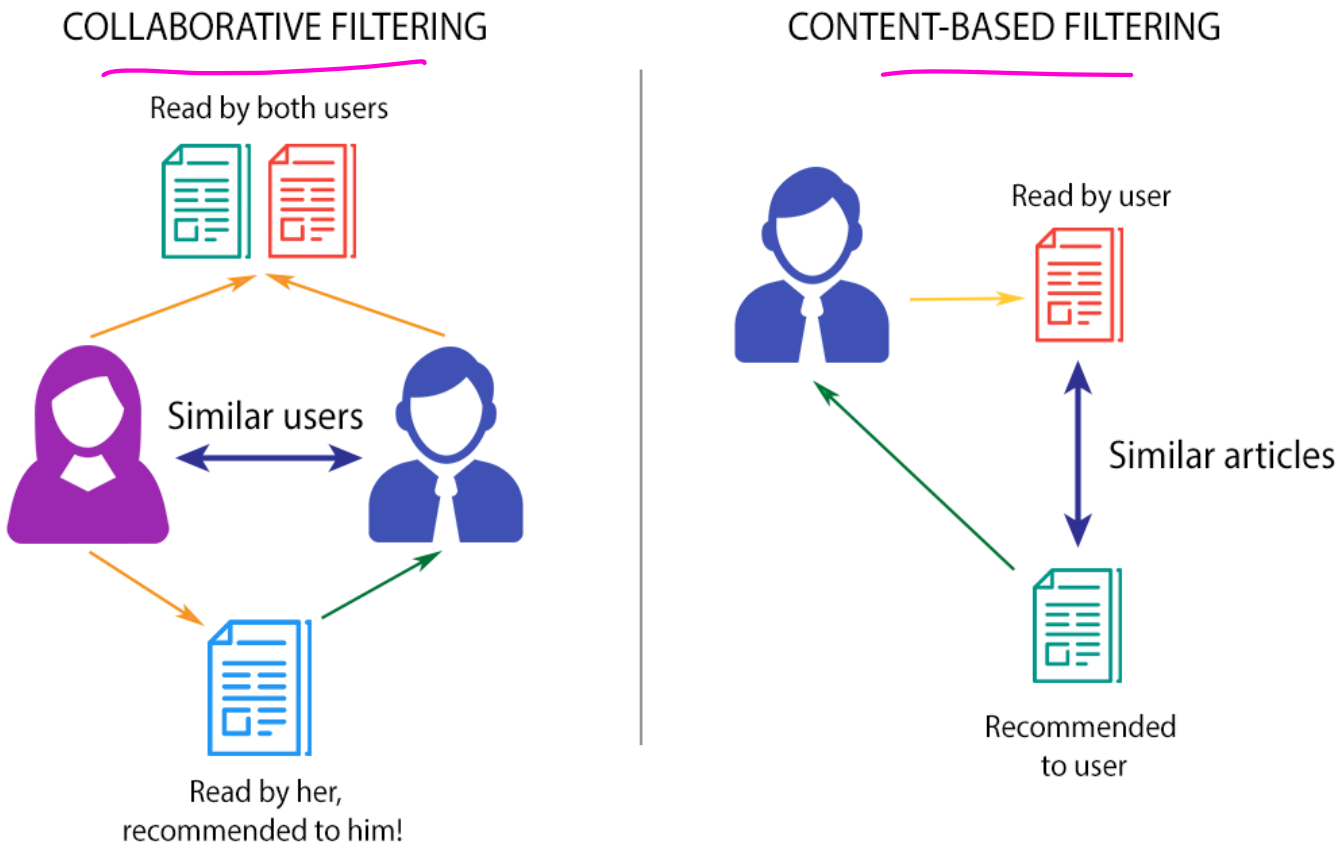
Recommender Types



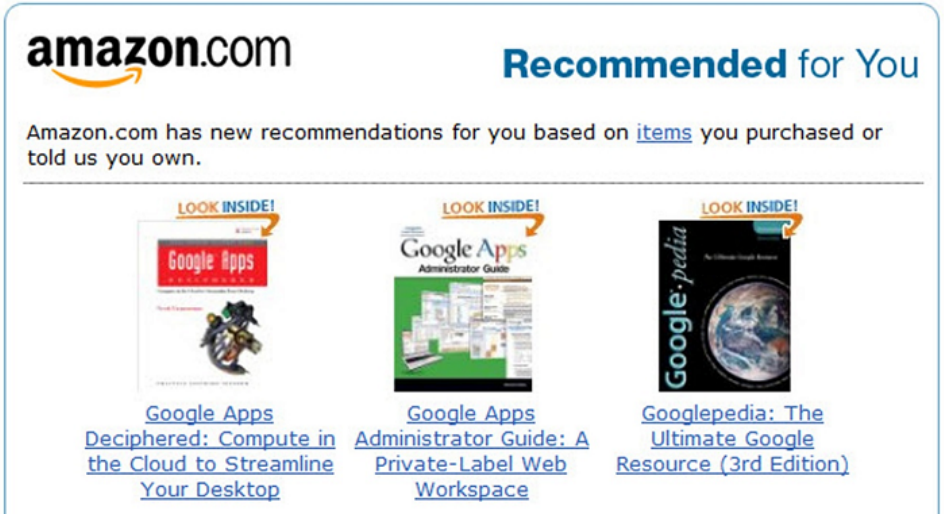
Recommenders (ML Models)



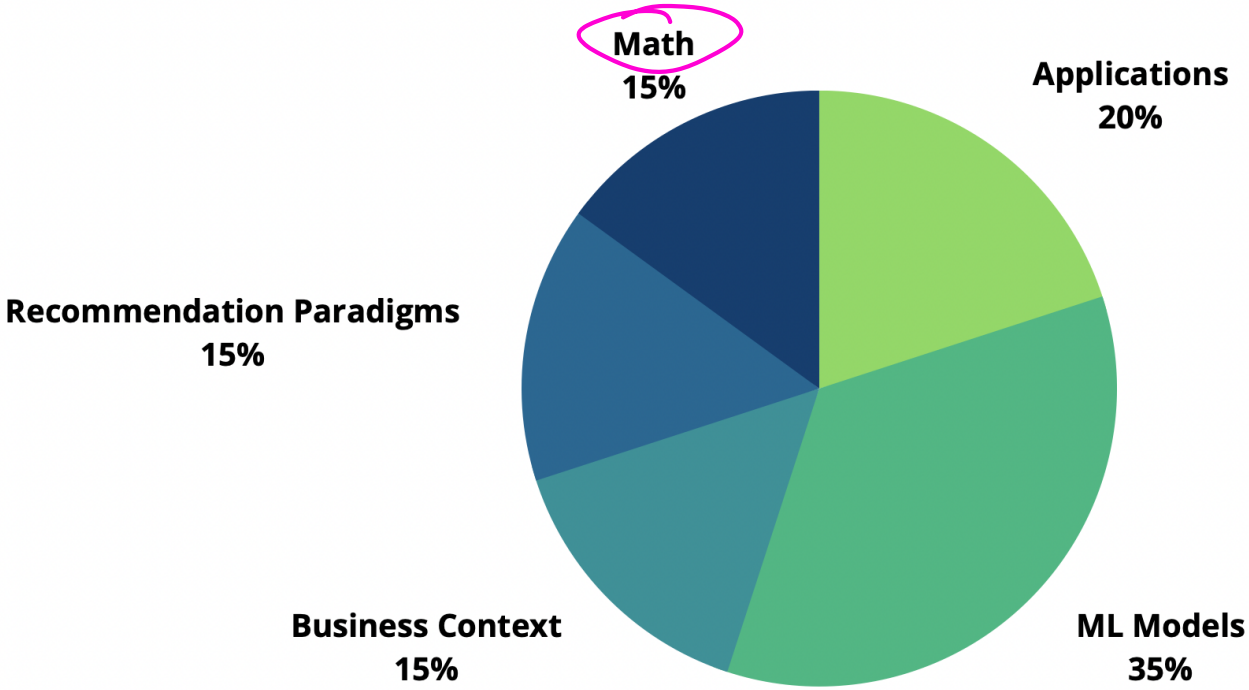
Collaborative filtering



Item based recommendations



Content


Math
15%
Applications
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ML Models
35%

Linear Algebra Background

Linear Algebra & Matrix

1. **Scalar**

$\alpha \in \mathbb{R}$ → scalar

$\alpha = 5$ → Integer

$\alpha = 0.3$ → Float

$\alpha = -0.2$

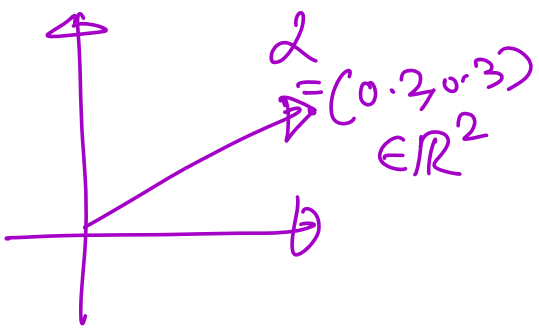
$p = 0.7$ → prob = 0.7 → scalar

2. **Vector**

$$\vec{\alpha} = \begin{bmatrix} \alpha_1 \\ \alpha_2 \\ \alpha_3 \\ \vdots \\ \alpha_d \end{bmatrix} \in \mathbb{R}^d$$

→ Array

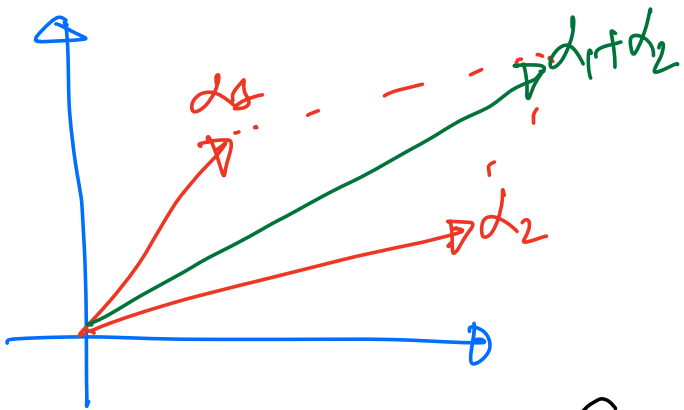
→ dimension of vector



2. vector Arithmetic

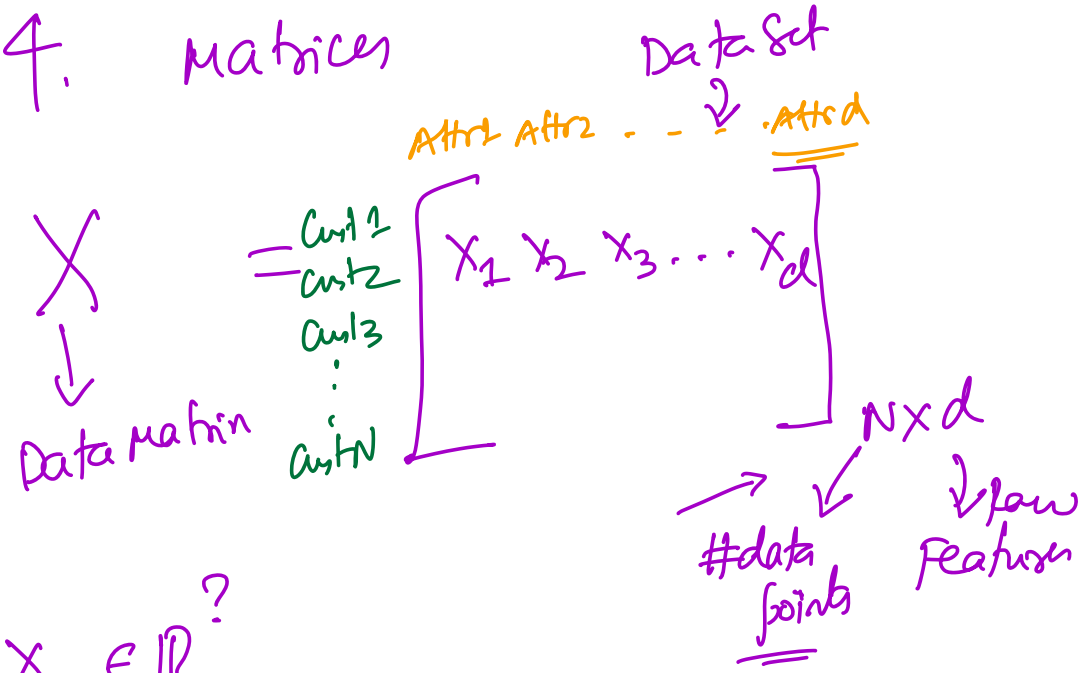
$$\alpha_1, \alpha_2 \in \mathbb{R}^d$$

$$\alpha_1 + \alpha_2 = \begin{bmatrix} \alpha_{11} + \alpha_{21} \\ \alpha_{12} + \alpha_{22} \\ \vdots \\ \alpha_{1d} + \alpha_{2d} \end{bmatrix} \in \mathbb{R}^d$$



$\beta \alpha$ ($\beta \in \mathbb{R}$, $\alpha \in \mathbb{R}^d$) $= \begin{bmatrix} \beta\alpha_1 \\ \beta\alpha_2 \\ \vdots \\ \beta\alpha_d \end{bmatrix} \in \mathbb{R}^d$

4. Matrices



$x_1 \in \mathbb{R}^?$

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

$X = [x_1 \; x_2 \; x_3 \; \cdots \; x_d]$

$Y = [y_1 \; y_2 \; y_3 \; \cdots \; y_d]$

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

Adding by columns

5. Matrix multiplication

X $\quad$ Y

$XY = ?$

$$\begin{bmatrix} — x_1^T — \\ — x_2^T — \\ \vdots \\ — x_n^T — \end{bmatrix} \begin{bmatrix} | & | & & | \\ y_1 & y_2 & \cdots & y_d \\ | & | & & | \end{bmatrix} = \begin{bmatrix} x_1^T y_1 & x_1^T y_2 & \cdots & x_1^T y_d \\ \vdots & \vdots & & \vdots \\ x_n^T y_1 & x_n^T y_2 & \cdots & x_n^T y_d \end{bmatrix}$$

$$\begin{bmatrix} \cdots & x_1^T & \cdots \end{bmatrix} \begin{bmatrix} | \\ y_2 \\ | \end{bmatrix} = x_1^T y_2 \in \mathbb{R}$$

↳ scalar

6. Matrix-vector multiplication

X y $\longrightarrow$ $\in \mathbb{R}^d$

$\hookrightarrow \in \mathbb{R}^{N \times d}$

$\hookrightarrow$ Data matrix

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

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

2. $\begin{bmatrix} x_1 & x_2 & \cdots & x_d \end{bmatrix} y$

$= x_1 y_1 + x_2 y_2 + \cdots + x_d y_d$

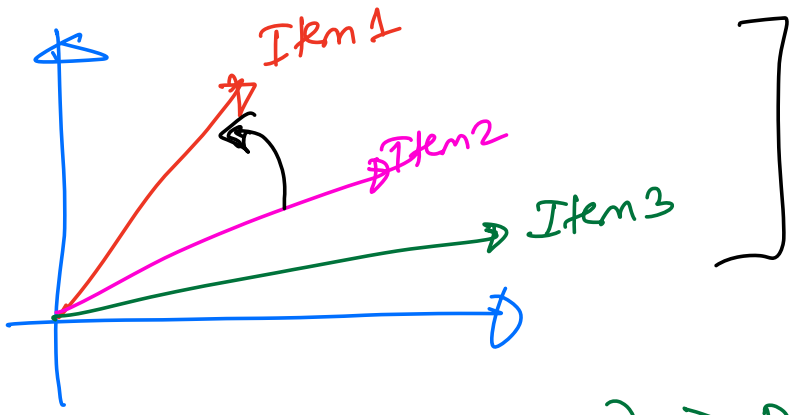
$\in \mathbb{R}^N$

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

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

7. Dot products

↳ Item-Item Similarity
(Frequently Bought Together)



Dot (Item 1, Item 2) > Dot (Item 1, Item 3)

↓

I purchased this

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

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

$I_1 \cdot I_2 = I_1^T I_2$

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

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

[ ] [ ]

Normalize dot product ⇒ Cosine Similarity!!

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

8. Norms

Magnitude of a vector or a matrix!

vector norm

$$\|I_1\|_2 = \sqrt{(I_{11})^2 + (I_{12})^2 + \cdots + (I_{1d})^2}$$

matrix norm

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

Appln:- 1) Cosine similarity

2) Convergence of an ML algorithm

θ^t θ^{t+1}

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

$t \downarrow 10^{-2}$

3) Distance between cluster centers

Similarity → Dot products

Distances → Norms of difference of vectors

9. Next Lecture

- SVD?
- Eigen Decomp.

} Adv. matrix operation

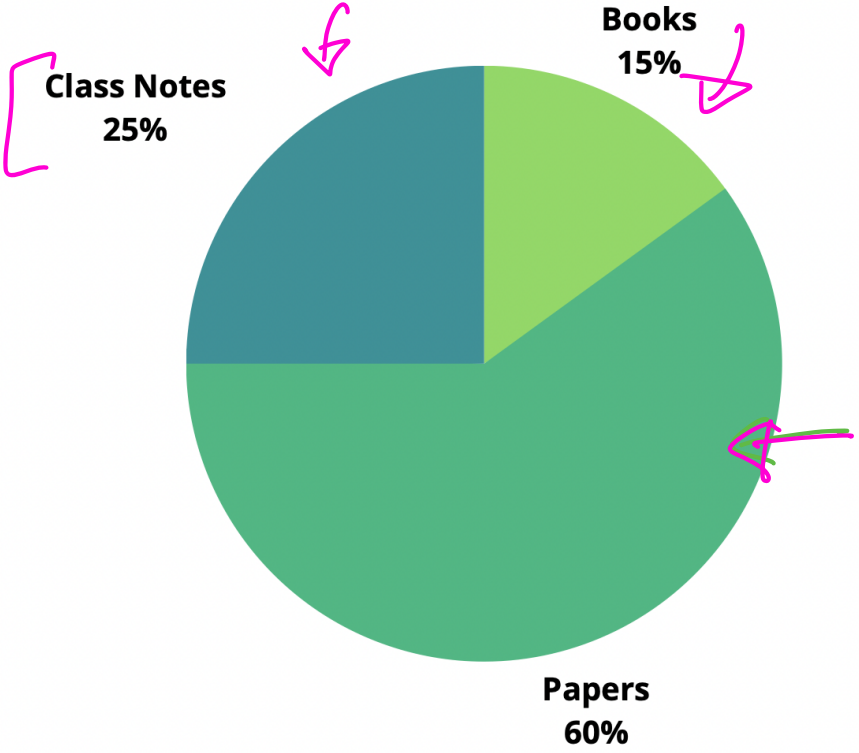
10. Gradient Arithmetic

- 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)