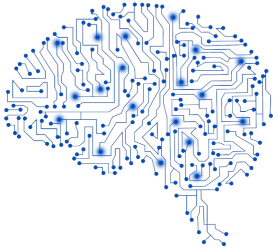
Recommendation System

Part I: Basic Concepts

Duc-Trong Le (PhD), VNU-UET

November 2022



Outline

- Real-life Examples
- Introduction to Recommendation Systems (RSs)
  - Item, User, Behavior
  - Role of RSs ? How do RSs work?
- Types of Recommendation Systems
- Learning Principles
  - Learning User-Item Associations
  - Learning Item-Item Associations
- Evaluation & Metrics
- Introduction to Cornac, a Recommendation Framework

1.

Real-life Examples

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3 Sick Bodybuilding Tips
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by malikje1
45,661
FEATURED
4:00
Pink Interview on her husband and daughter
by MsSupergalaxy
Recommended for you
12:44
Abhimaan (1973): Loote Koi Man Ka Nagar
by tonguesonfire
5:56 / 9:55
Song: Tere Mere Milan Ki Yeh Raina Film: Abhimaan (1973) With Sinhala S...
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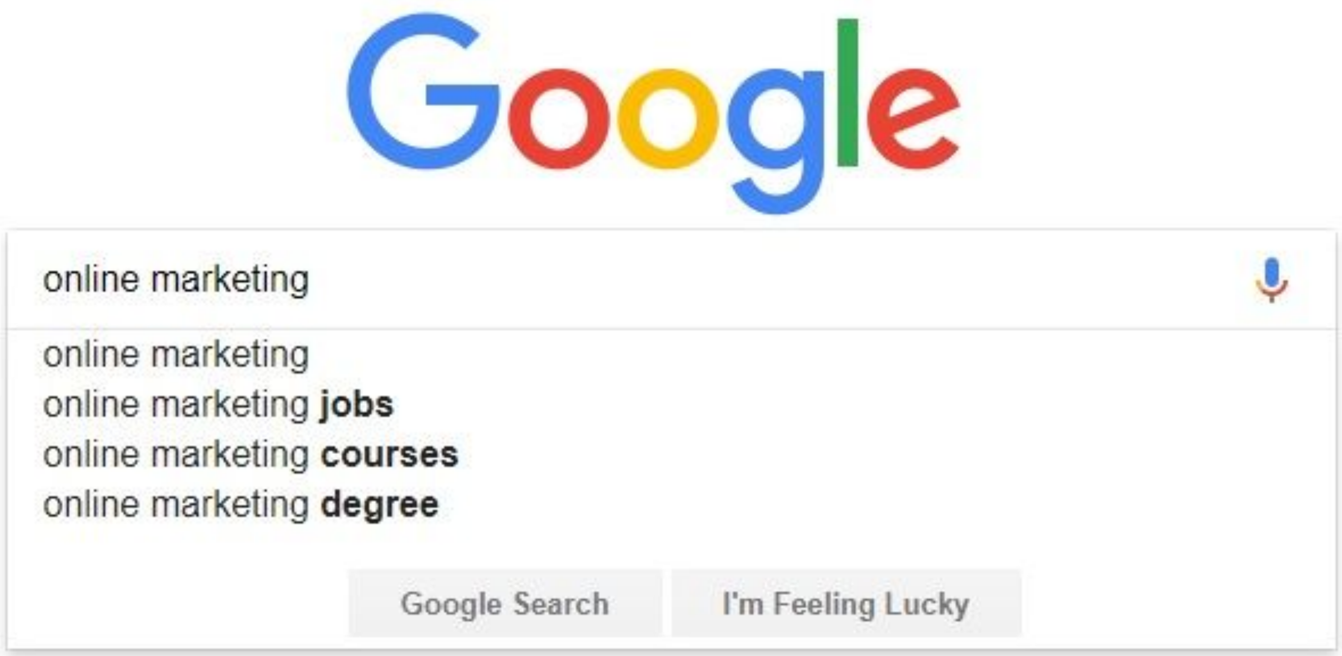

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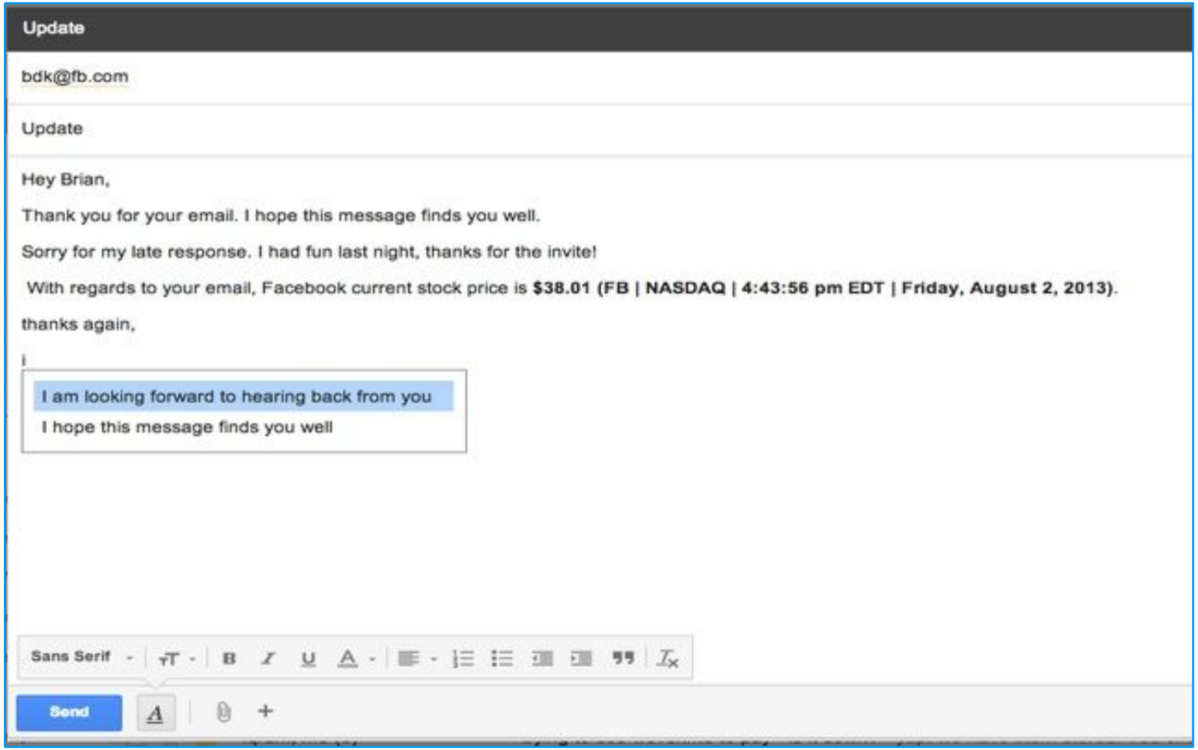

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bdk@fb.com
Update
Hey Brian,
Thank you for your email. I hope this message finds you well.
Sorry for my late response. I had fun last night, thanks for the invite!
With regards to your email, Facebook current stock price is $38.01 (FB | NASDAQ | 4:43:56 pm EDT | Friday, August 2, 2013).
thanks again,
I am looking forward to hearing back from you
I hope this message finds you well
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Send

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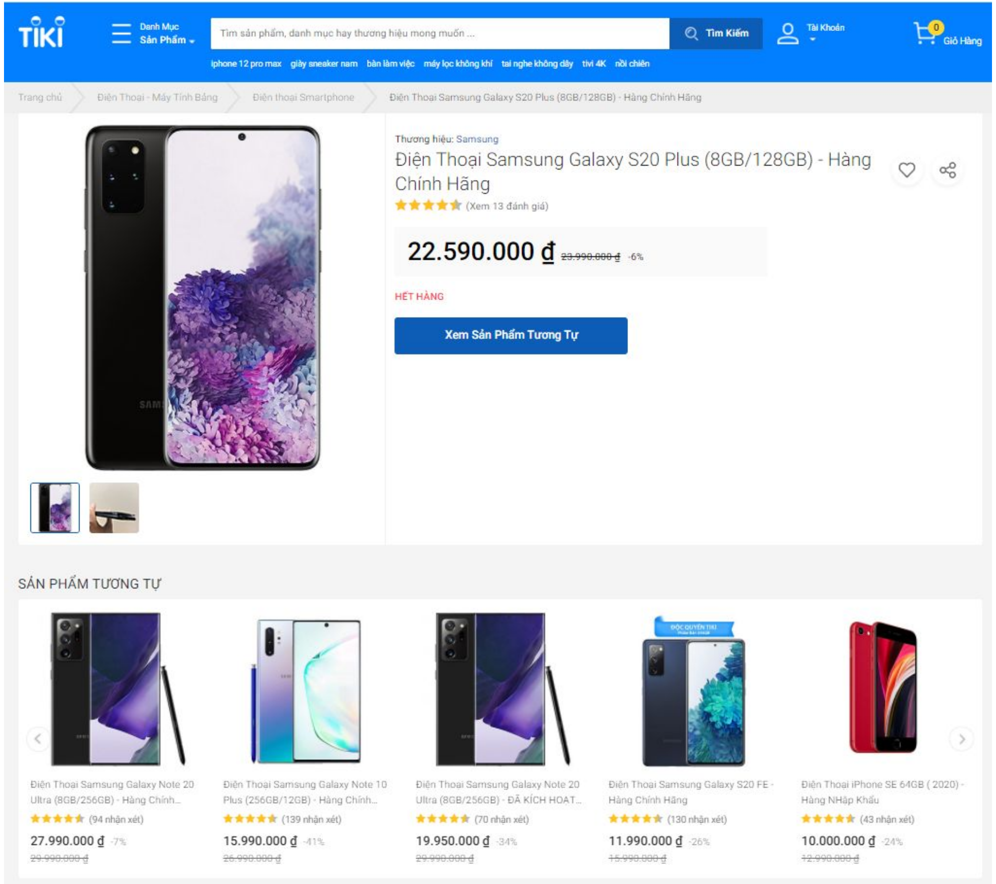
Tiki


TIKI
Danh Mục
Sản Phẩm
Tìm sản phẩm, danh mục hay thương hiệu mong muốn ...
Tìm Kiếm
Tài Khoản
Giỏ Hàng
iphone 12 pro max giày sneaker nam bàn làm việc máy lọc không khí tai nghe không dây tivi 4K nồi chiên
Trang chủ Điện Thoại - Máy Tính Bảng Điện thoại Smartphone Điện Thoại Samsung Galaxy S20 Plus (8GB/128GB) - Hàng Chính Hãng
Thương hiệu: Samsung
Điện Thoại Samsung Galaxy S20 Plus (8GB/128GB) - Hàng Chính Hãng
(Xem 13 đánh giá)
22.590.000 ₫ 23.990.000 ₫ -6%
HẾT HÀNG
Xem Sản Phẩm Tương Tự
SẢN PHẨM TƯƠNG TỰ
Điện Thoại Samsung Galaxy Note 20 Ultra (8GB/256GB) - Hàng Chính...
(94 nhận xét)
27.990.000 ₫ -7%
29.990.000 ₫
Điện Thoại Samsung Galaxy Note 10 Plus (256GB/12GB) - Hàng Chính...
(139 nhận xét)
15.990.000 ₫ -41%
26.990.000 ₫
Điện Thoại Samsung Galaxy Note 20 Ultra (8GB/256GB) - ĐÃ KÍCH HOẠT...
(70 nhận xét)
19.950.000 ₫ -34%
29.990.000 ₫
Điện Thoại Samsung Galaxy S20 FE - Hàng Chính Hãng
(130 nhận xét)
11.990.000 ₫ -26%
15.990.000 ₫
Điện Thoại iPhone SE 64GB (2020) - Hàng NHập Khẩu
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10.000.000 ₫ -24%
12.990.000 ₫

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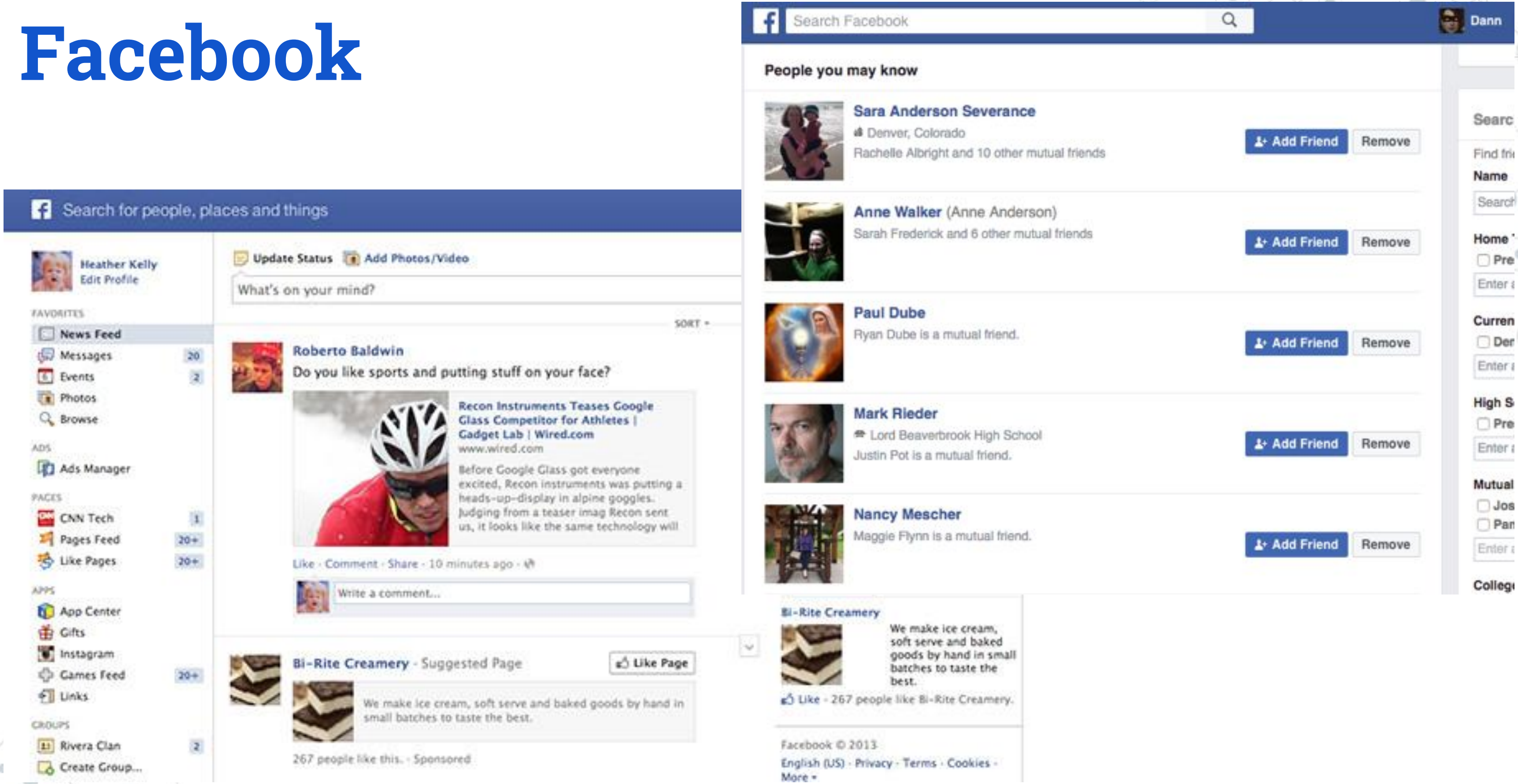

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Edit Profile
FAVORITES
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App Center
Gifts
Instagram
Games Feed 20+
Links
GROUPS
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What's on your mind?
SORT
Roberto Baldwin
Do you like sports and putting stuff on your face?
Recon Instruments Teases Google Glass Competitor for Athletes | Gadget Lab | Wired.com
www.wired.com
Before Google Glass got everyone excited, Recon Instruments was putting a heads-up-display in alpine goggles. Judging from a teaser imag Recon sent us, it looks like the same technology will
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Denver, Colorado
Rachelle Albright and 10 other mutual friends
Add Friend
Remove
Anne Walker (Anne Anderson)
Sarah Frederick and 6 other mutual friends
Add Friend
Remove
Paul Dube
Ryan Dube is a mutual friend.
Add Friend
Remove
Mark Rieder
Lord Beaverbrook High School
Justin Pot is a mutual friend.
Add Friend
Remove
Nancy Mescher
Maggie Flynn is a mutual friend.
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Remove
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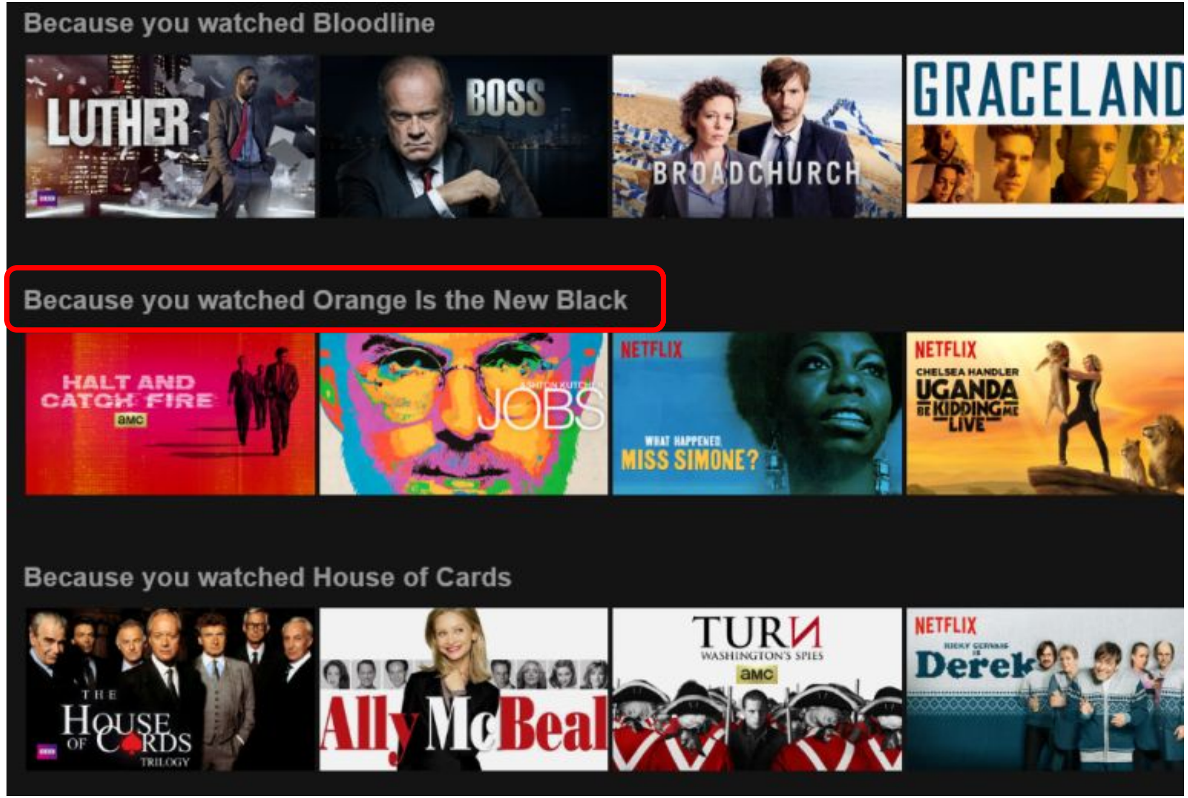
Netflix



Because you watched Bloodline
LUTHER
BOSS
BROADCHURCH
GRACELAND
Because you watched Orange Is the New Black
HALT AND CATCH FIRE
amc
JOBS
NETFLIX
WHAT HAPPENED, MISS SIMONE?
NETFLIX
CHELSEA HANDLER
UGANDA BE KIDDING ME LIVE
Because you watched House of Cards
THE HOUSE OF CARDS TRILOGY
Ally McBeal
TURN
WASHINGTON'S SPIES
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NETFLIX
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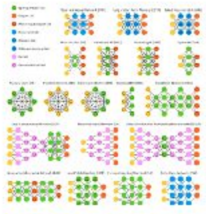

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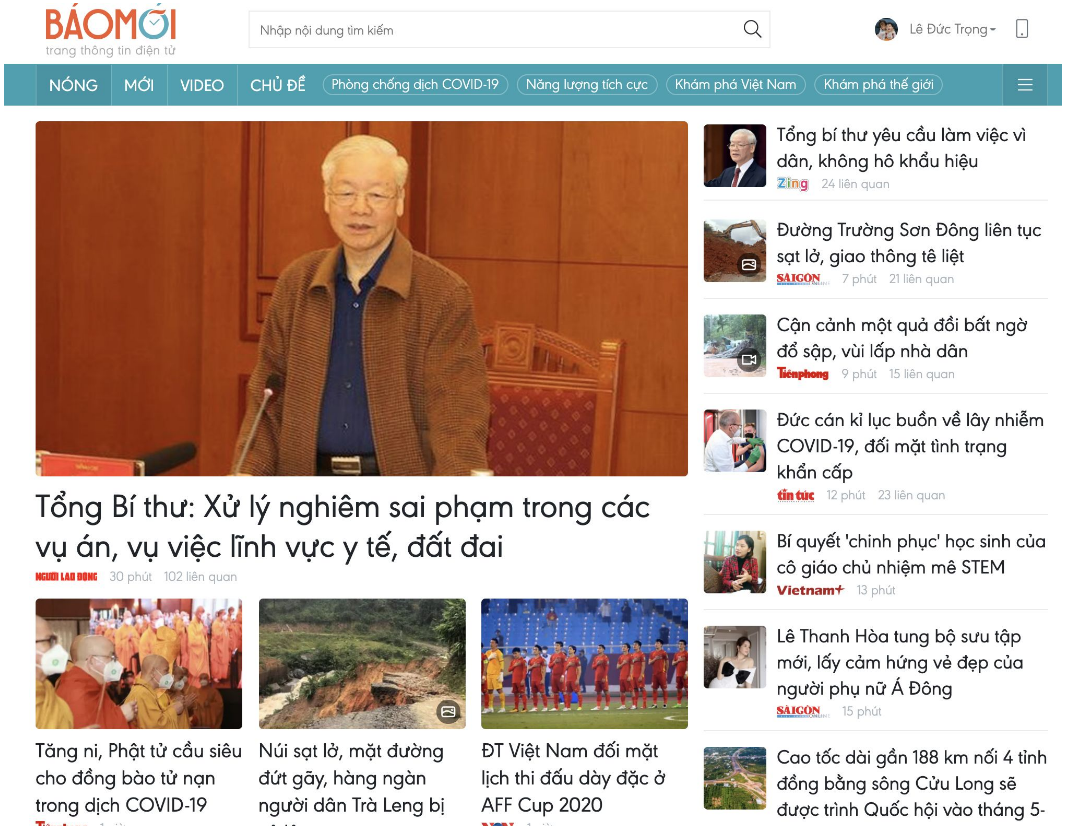
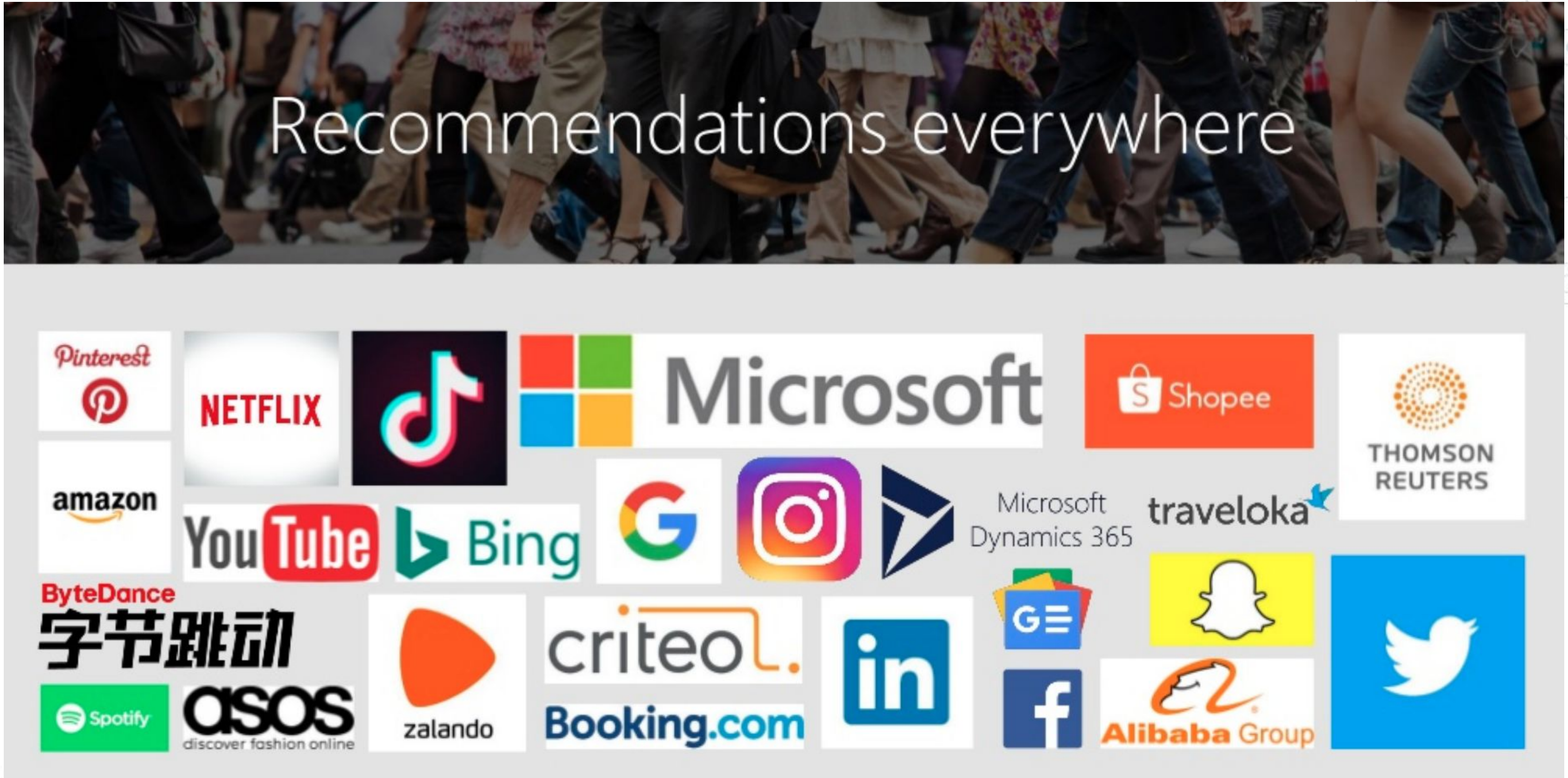

BÁOMỚI
trang thông tin điện tử
Nhập nội dung tìm kiếm
Lê Đức Trọng
NÓNG
MỚI
VIDEO
CHỦ ĐỀ
Phòng chống dịch COVID-19
Năng lượng tích cực
Khám phá Việt Nam
Khám phá thế giới
Tổng Bí thư: Xử lý nghiêm sai phạm trong các vụ án, vụ việc lĩnh vực y tế, đất đai
NGƯỜI LAO ĐỘNG 30 phút 102 liên quan
Tăng ni, Phật tử cầu siêu cho đồng bào tử nạn trong dịch COVID-19
Núi sạt lở, mặt đường đứt gãy, hàng ngàn người dân Trà Leng bị
ĐT Việt Nam đối mặt lịch thi đấu dày đặc ở AFF Cup 2020
Tổng bí thư yêu cầu làm việc vì dân, không hô khẩu hiệu
Zing 24 liên quan
Đường Trường Sơn Đông liên tục sạt lở, giao thông tê liệt
SÀIGÒN 7 phút 21 liên quan
Cận cảnh một quả đồi bất ngờ đổ sập, vùi lấp nhà dân
Tiền phong 9 phút 15 liên quan
Đức cán kỉ lục buồn về lây nhiễm COVID-19, đối mặt tình trạng khẩn cấp
tin tức 12 phút 23 liên quan
Bí quyết 'chinh phục' học sinh của cô giáo chủ nhiệm mê STEM
Vietnam+ 13 phút
Lê Thanh Hòa tung bộ sưu tập mới, lấy cảm hứng vẻ đẹp của người phụ nữ Á Đông
SÀIGÒN 15 phút
Cao tốc dài gần 188 km nối 4 tỉnh đồng bằng sông Cửu Long sẽ được trình Quốc hội vào tháng 5-


Recommendations everywhere
Pinterest
NETFLIX
Microsoft
Shopee
THOMSON REUTERS
amazon
YouTube
Bing
Microsoft Dynamics 365
traveloka
ByteDance
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criteo
zalando
Spotify
asos
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Booking.com
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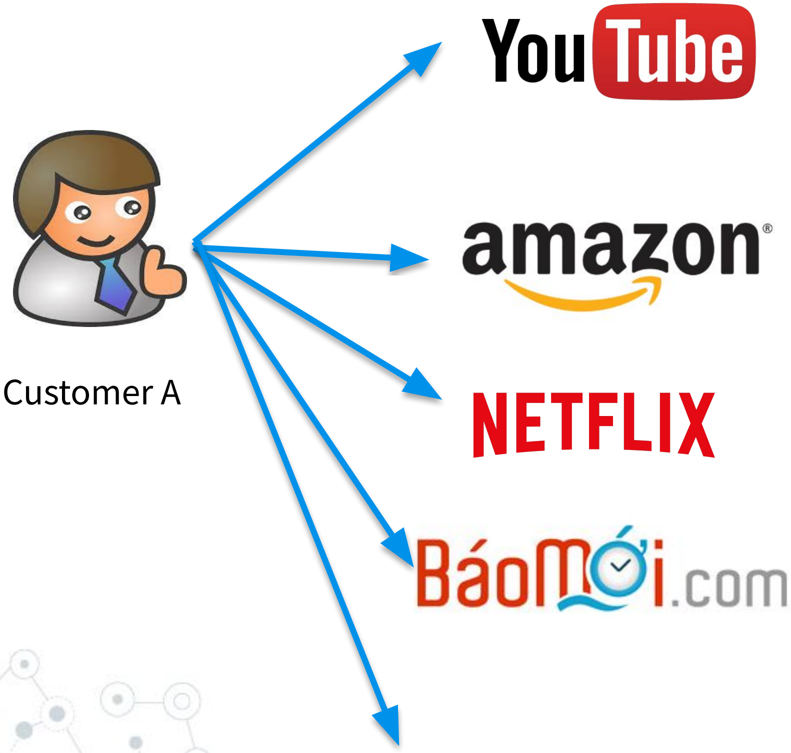
2.

Introduction to Recommendation Systems

Item, User & Behavior

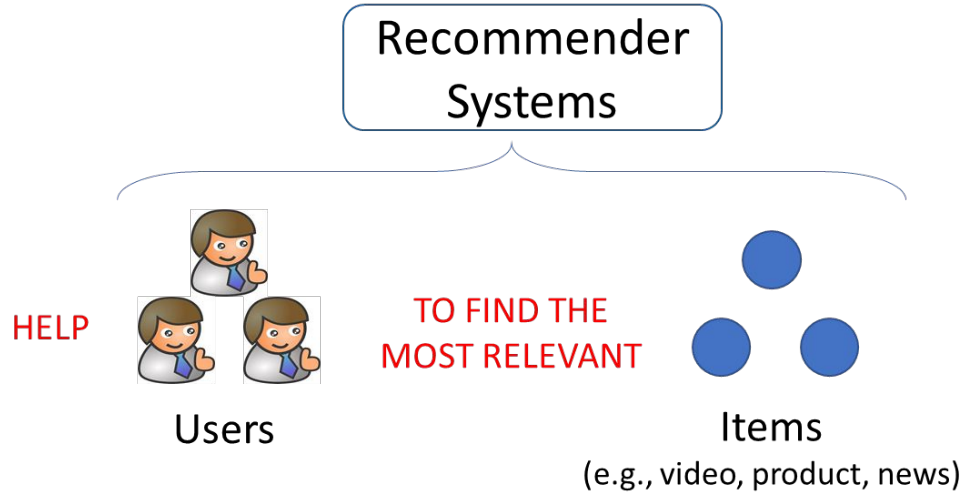


	Behavior	Item
YouTube	Click, Like/Dislike, Comment, Search	**Video**
amazon	Search, Click, Add-to-cart, Purchase, Review, Rate	**Product**
NETFLIX	Search, Click, Rate, Like	**Movie**
BáoMới.com	Search, Read, Duration, Comment	**News**
...	...	...

Why do we need Recommendation?

Millions of Items ...

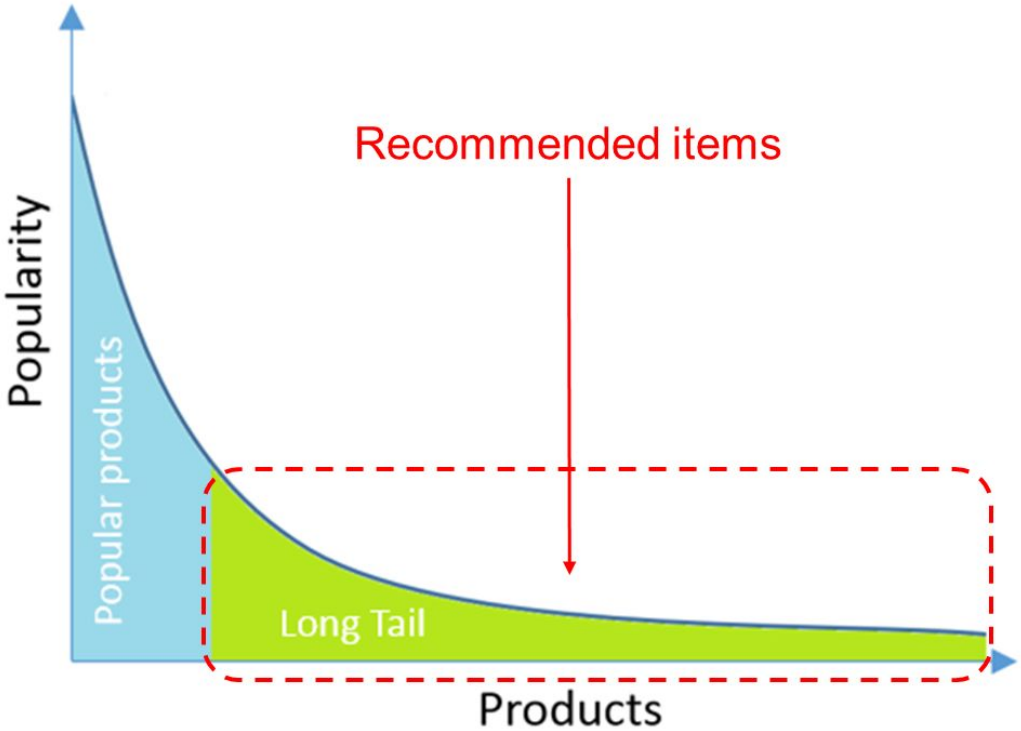
Roles of Recommendation Systems



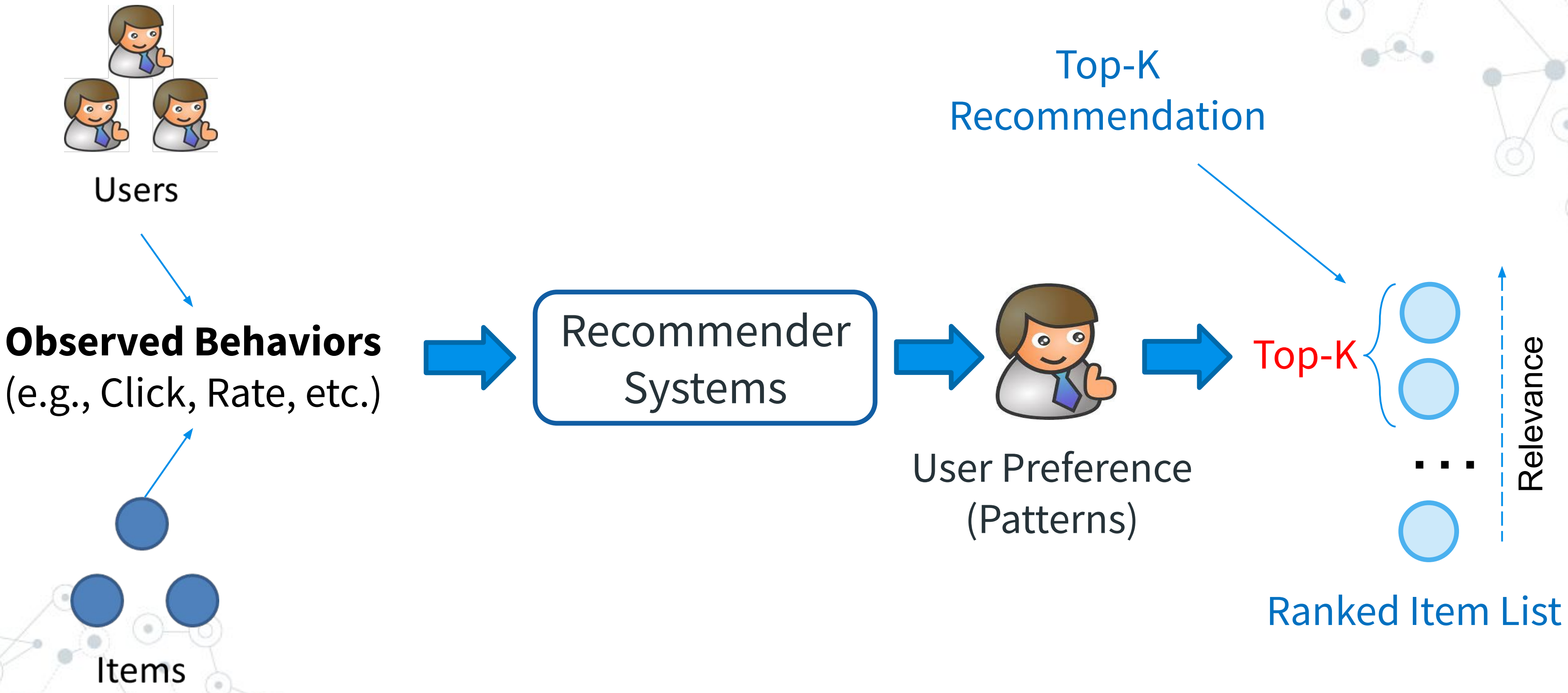
Advantages of RS:

Enterprise Perspective	Customer Perspective
• Reduce search costs • Increase customer satisfaction • Educate customers about product domains. • Optimize sales and profit	• Easy to find what he/she might want • Having an assistant in websites/systems

Long-tail Recommendation



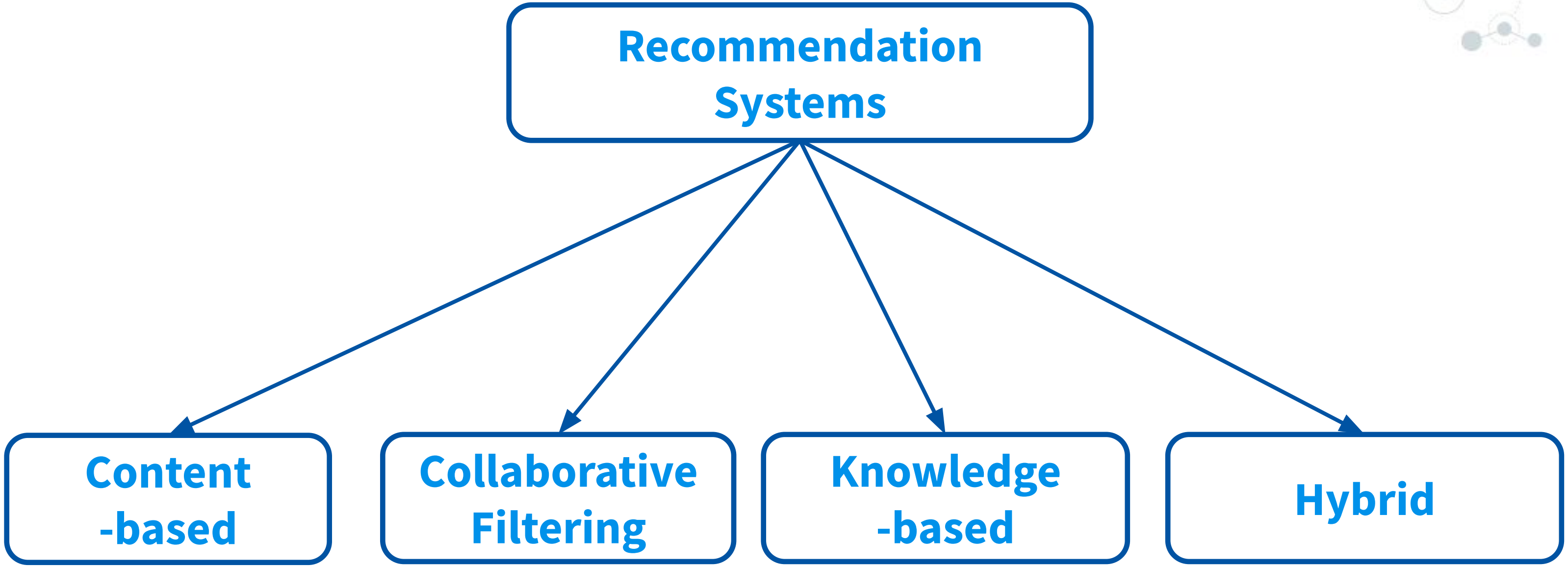
How does RS work?



3.

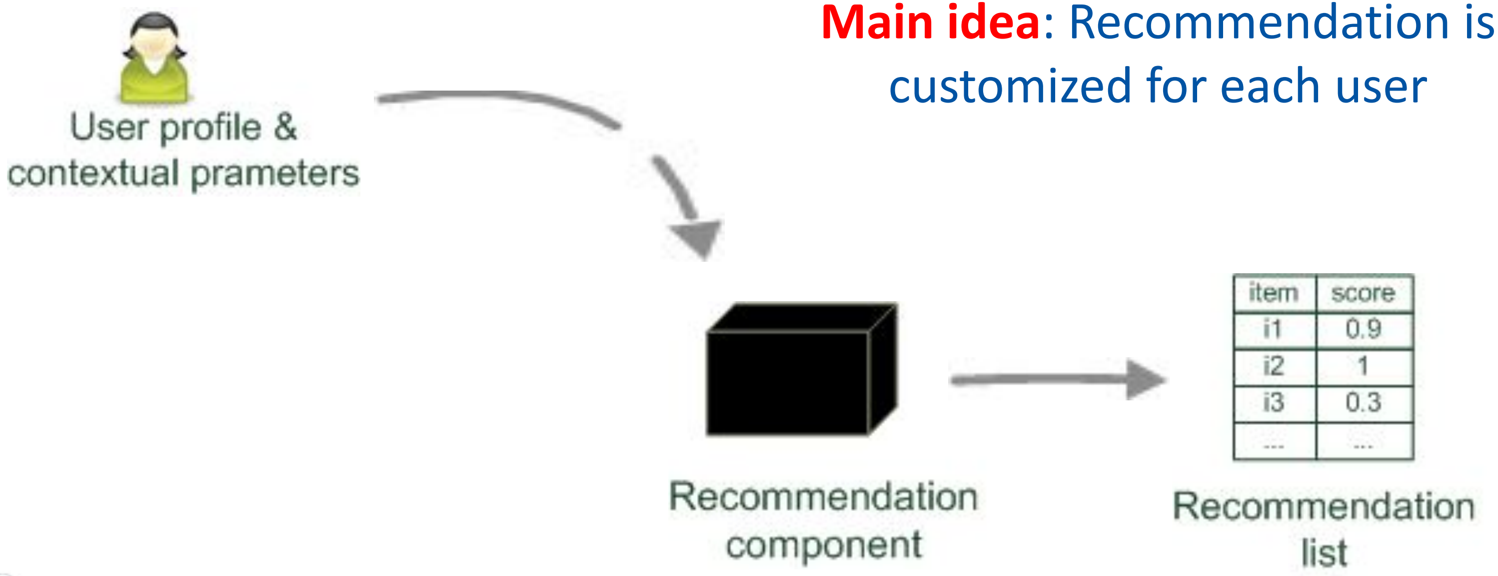
Types of Recommendation Systems

Types of Recommendation Systems



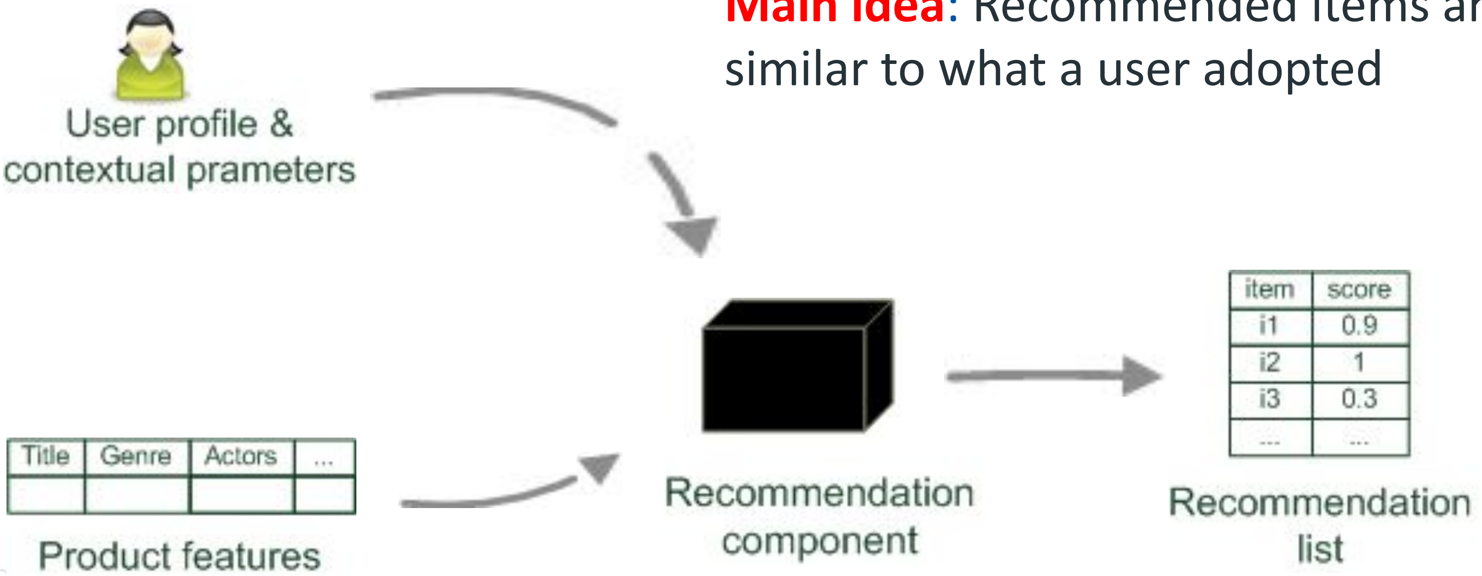
Personalized Recommendation

Main idea: Recommendation is customized for each user

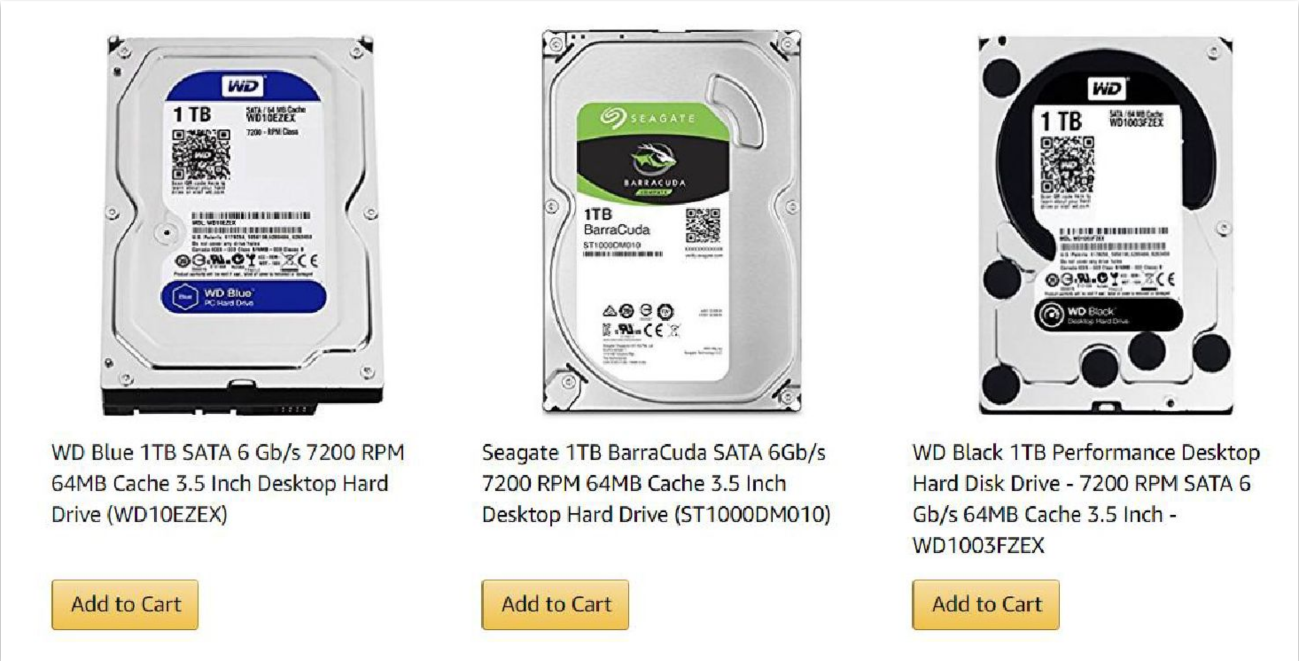


Content-based Recommendation (1)

Main idea: Recommended items are similar to what a user adopted

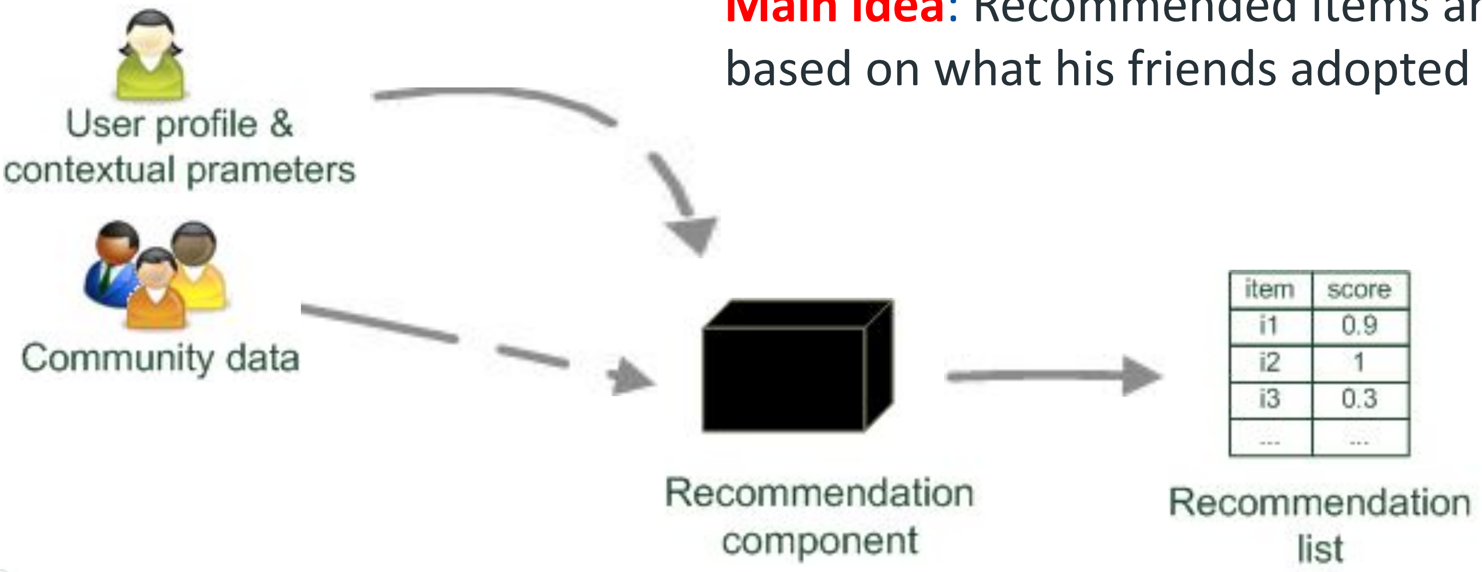


Content-based Recommendation (2)



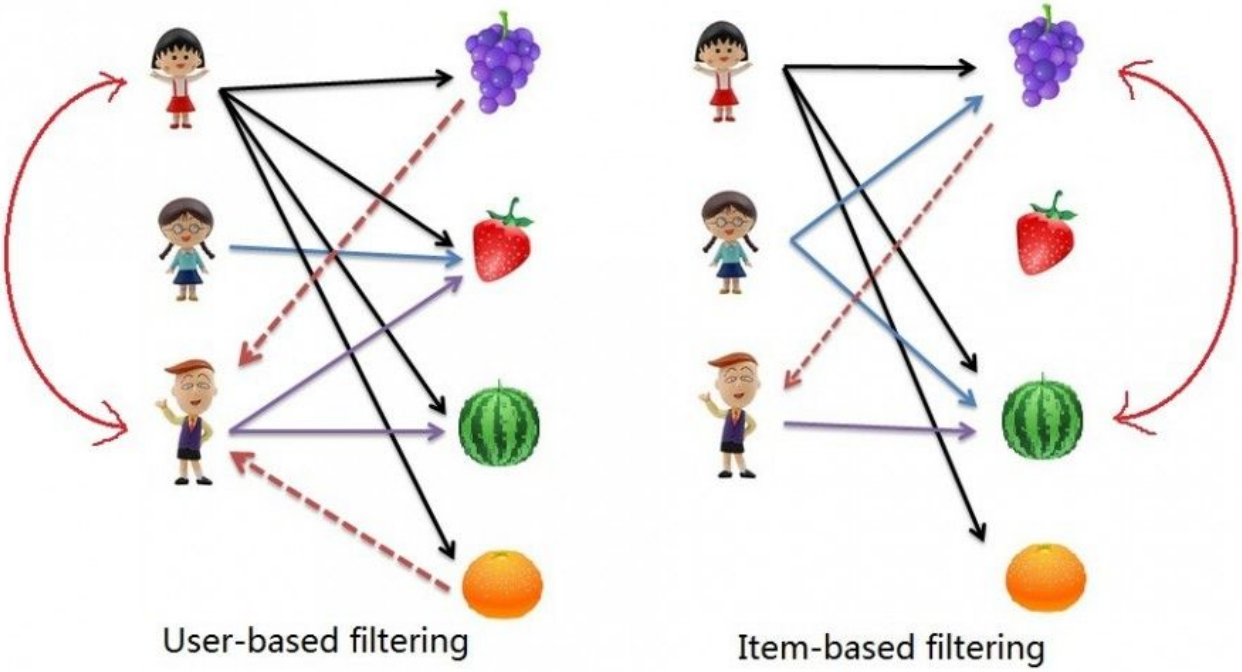
Recommendations for 1TB HDD on Amazon

Collaborative Filtering (1)



Main idea: Recommended items are based on what his friends adopted

Collaborative Filtering (2)



Netflix Prize

Netflix Prize

COMPLETED

Home | Rules | Leaderboard | Update | Download

Leaderboard

Showing Test Score. Click here to show quiz score

Display top 20 leaders.

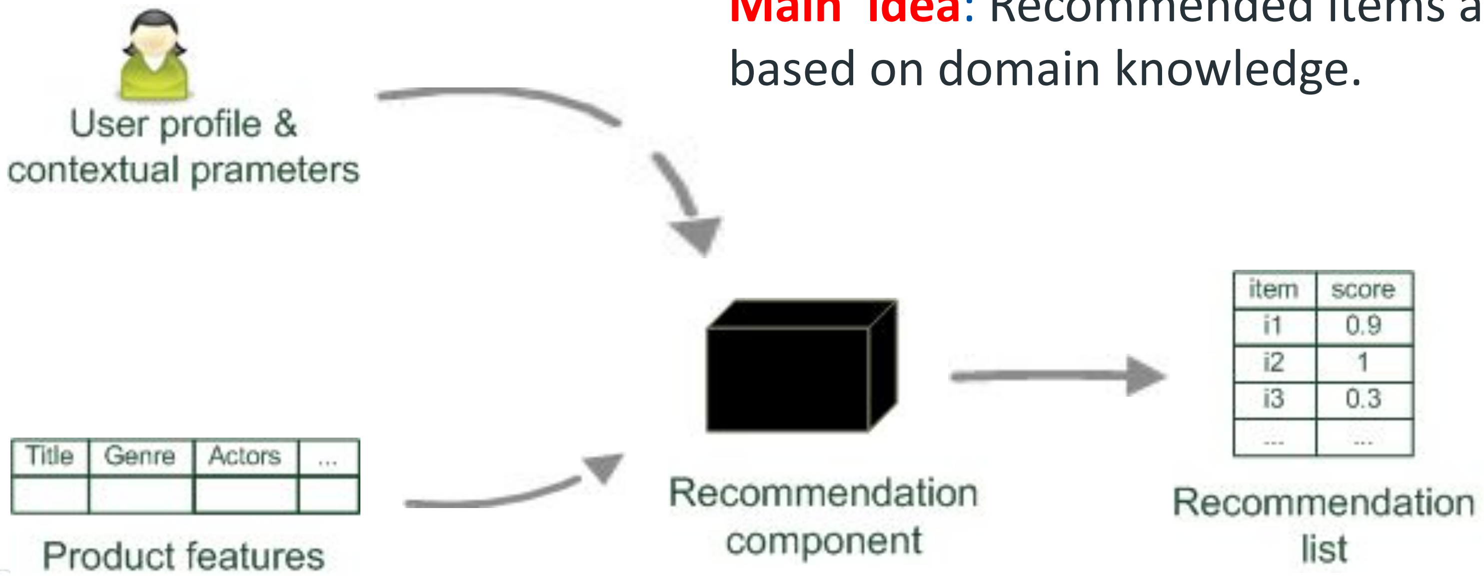
Rank	Team Name	Best Test Score	% Improvement	Best Submit Time
Grand Prize - RMSE = 0.8567 - Winning Team: BellKor's Pragmatic Chaos				
1	BellKor's Pragmatic Chaos	0.8567	10.06	
2	The Ensemble	0.8567	10.06	
3	Grand Prize Team	0.8582	9.90	
4	Opera Solutions and Vandelay United	0.8588	9.84	
5	Vandelay Industries !	0.8591	9.81	
6	PragmaticTheory	0.8594	9.77	
7	BellKor in BigChaos	0.8601	9.70	
8	Dace	0.8612	9.59	

	Movie 1	Movie 2	Movie 3
Ted	4	5	5
Carol		5	5
Bob		5	?

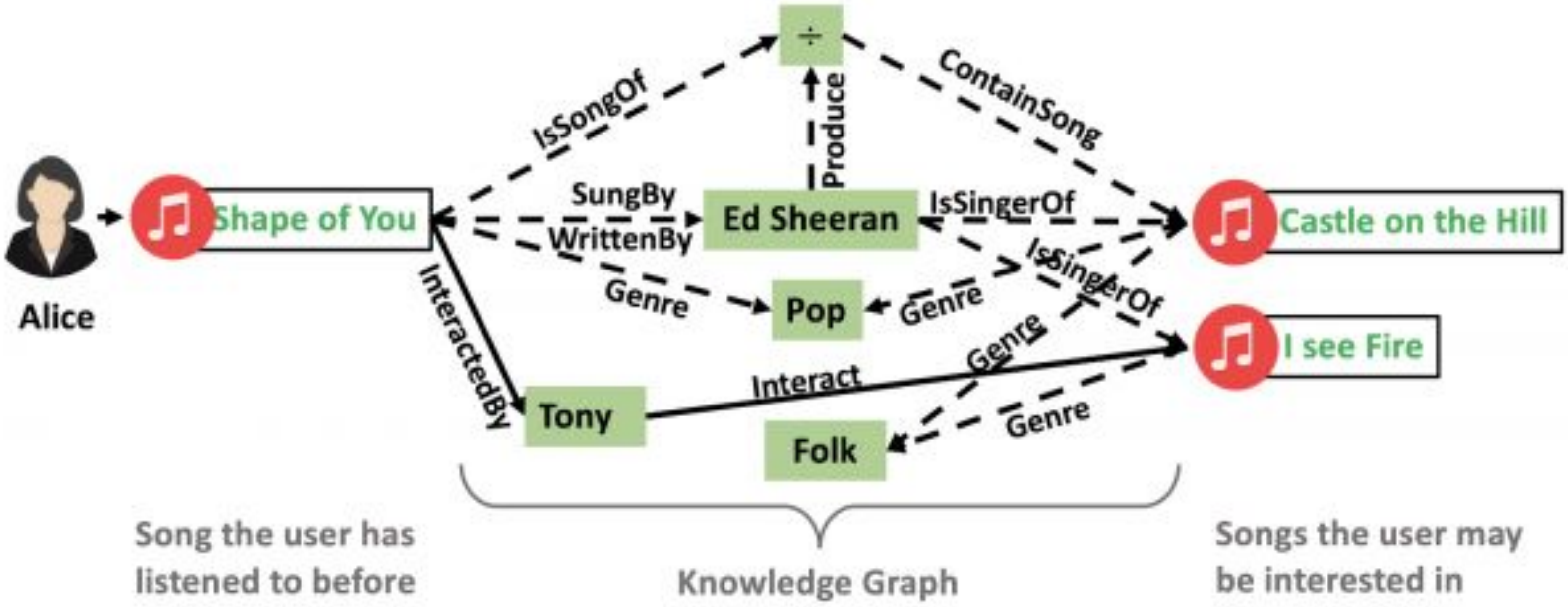
Netflix 1M $ challenge

Knowledge-based Recommendation (1)

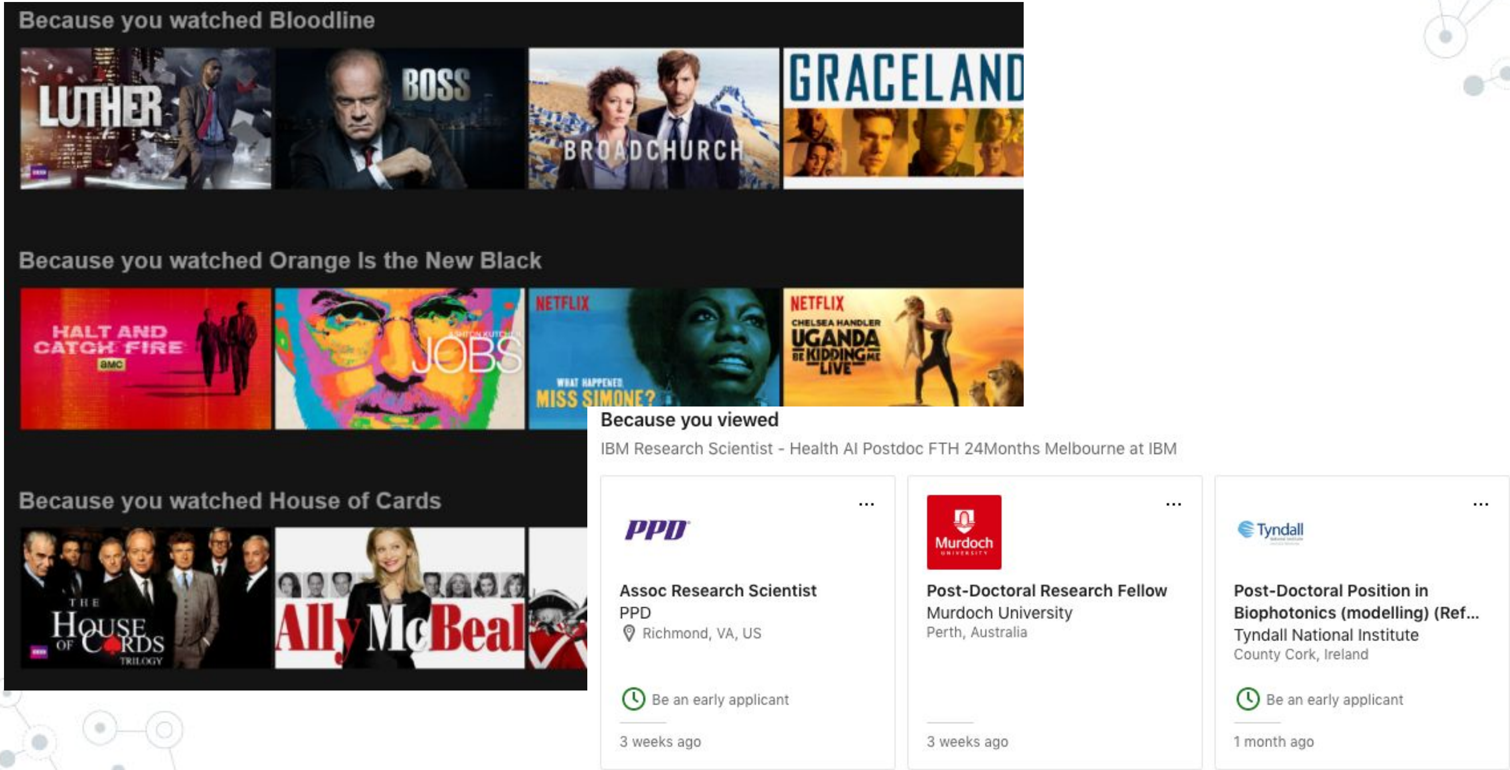
Main idea: Recommended items are based on domain knowledge.



Knowledge-based Recommendation (2)

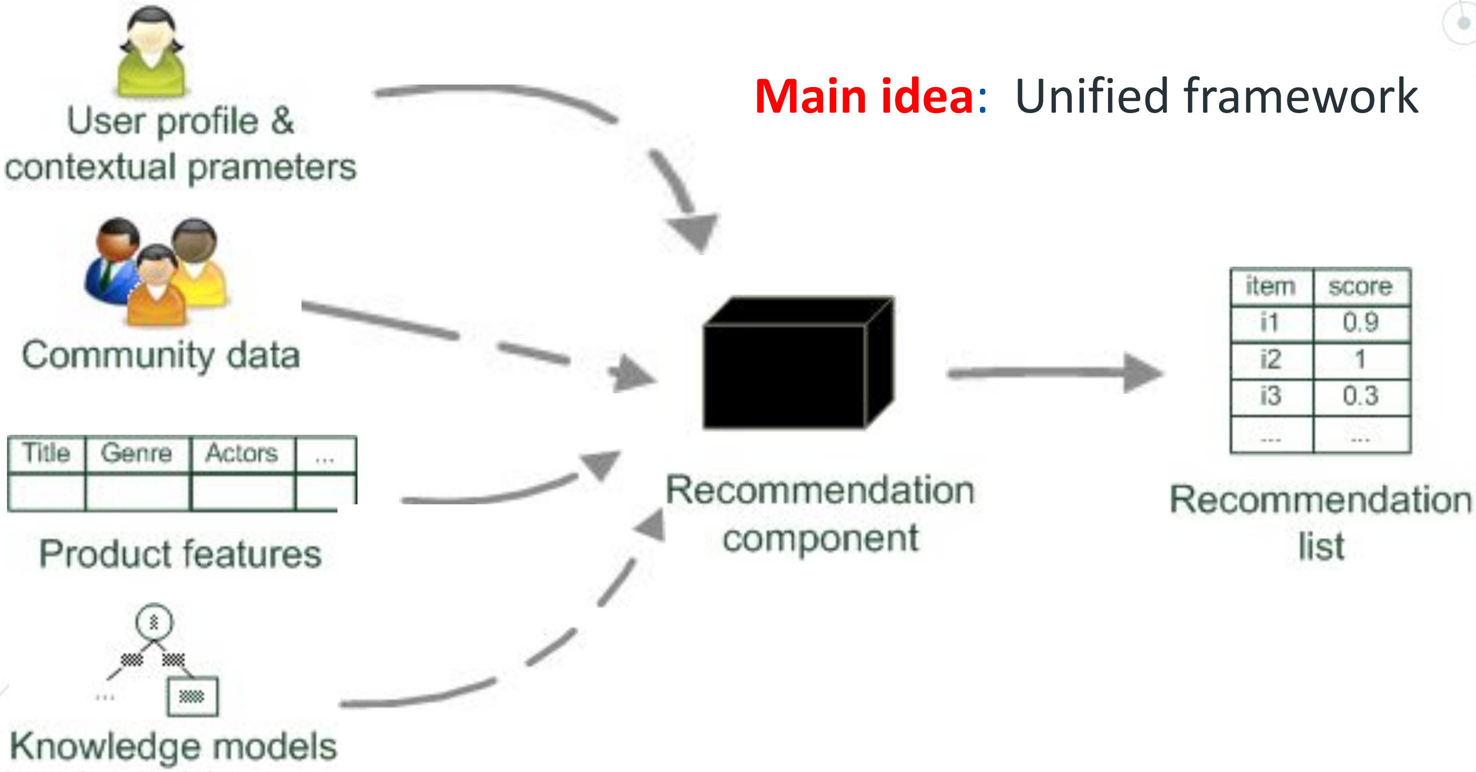


Knowledge-based Recommendation (3)

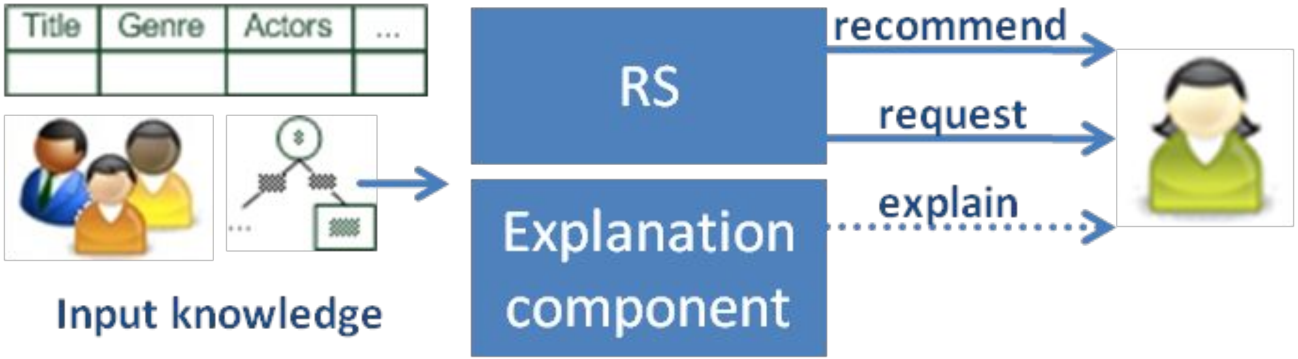


Hybrid Recommendation

Main idea: Unified framework



Explainable Recommendation

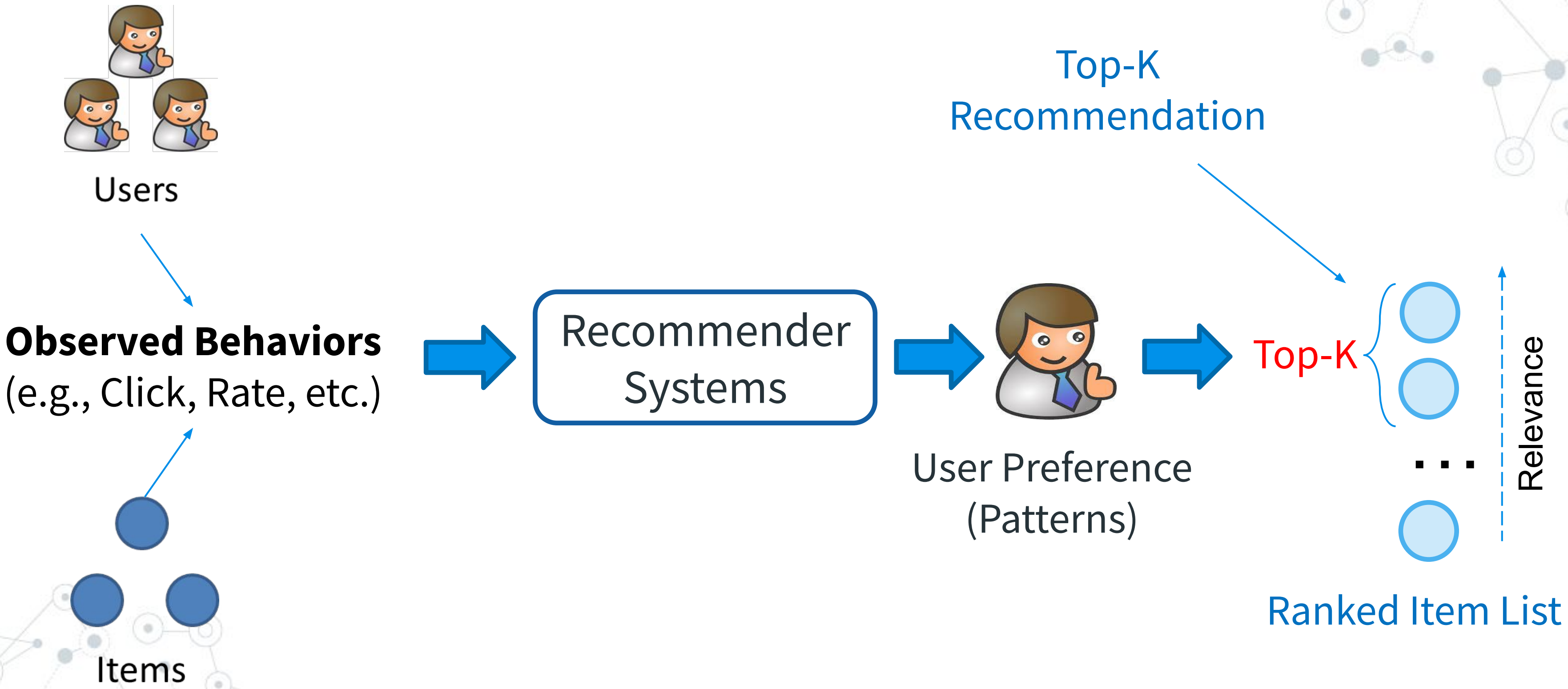


Main idea: Recommendation with explanation

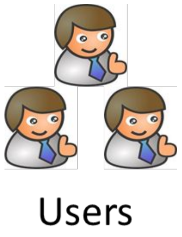
4.

Learning Principles

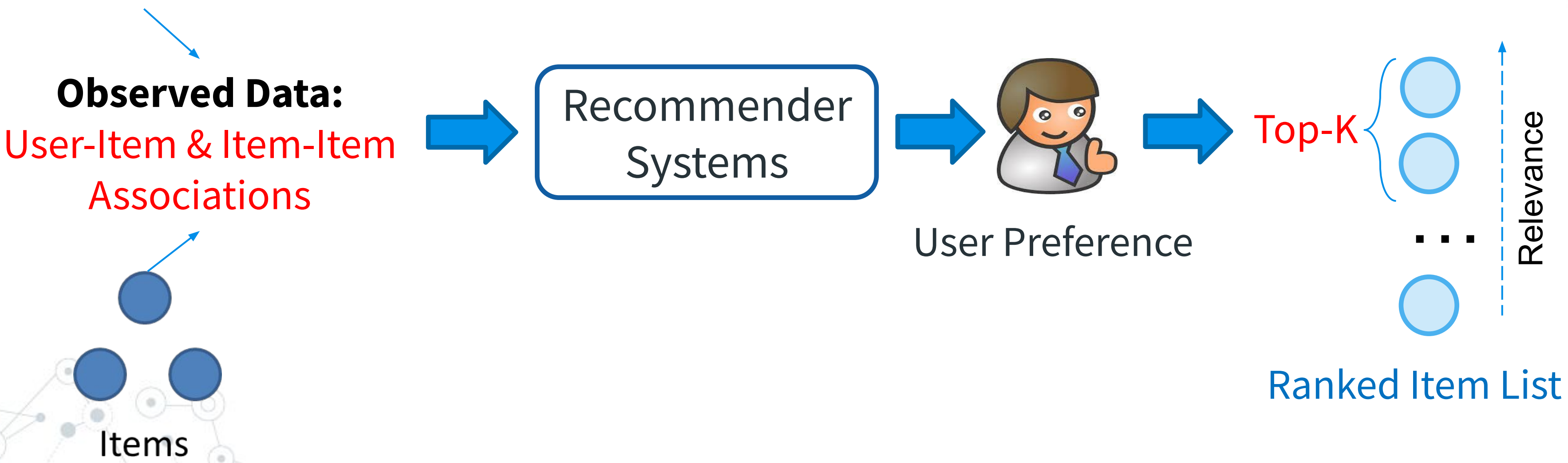
How does RS work?



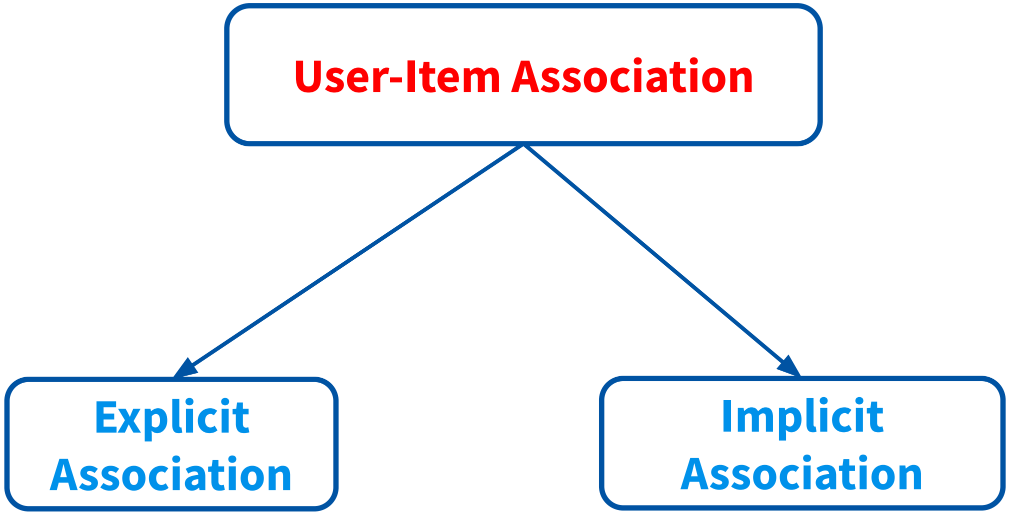
Top-K Recommendation



<u>Main idea</u>: Learning **user preferences** via modeling **associations** to generate **top-K recommendations**.



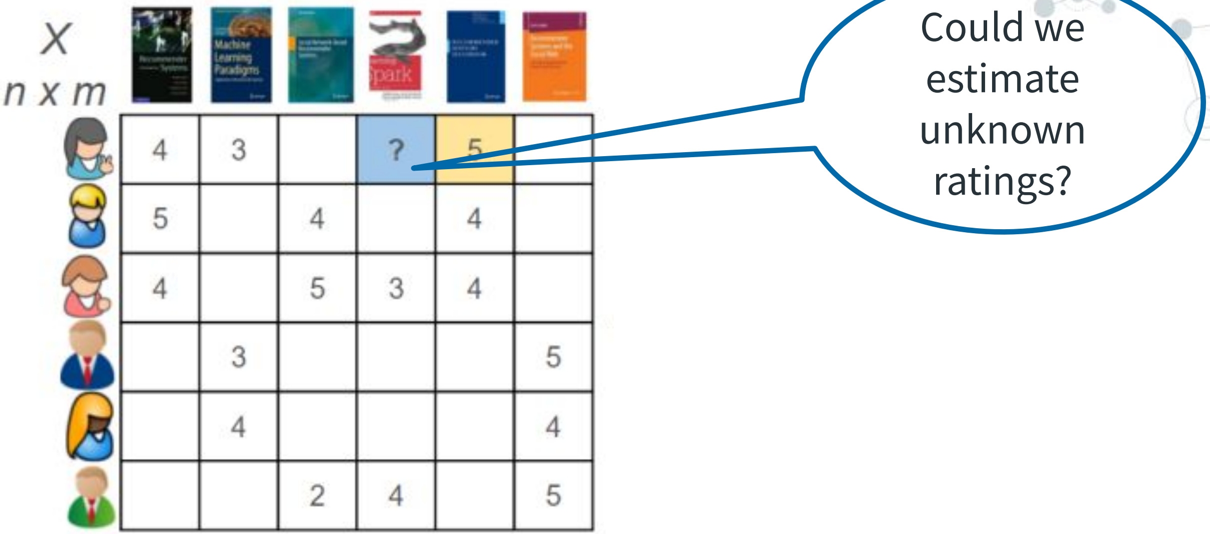
User-Item Association



e.g., rating, score, stars

e.g., click, view, purchase

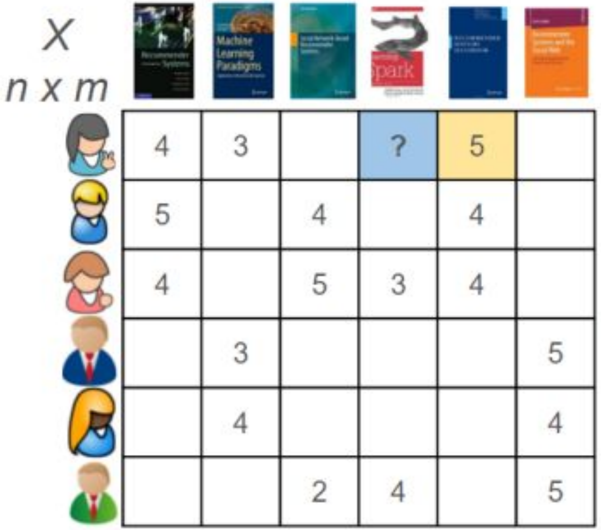
Explicit Association-based Recommendation



4	3		?	5	
5		4		4	
4		5	3	4	
	3				5
	4				4
		2	4		5

Main idea: Recommended items are high rating ones.

Rating Prediction

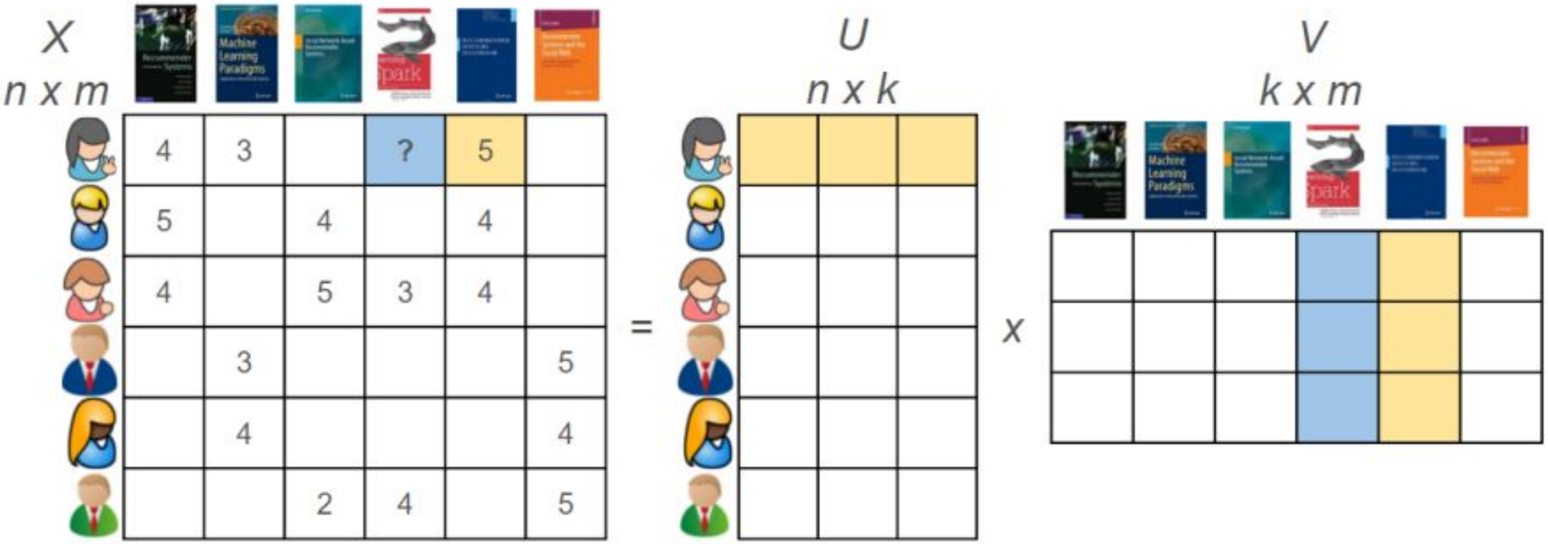


4	3		?	5	
5		4		4	
4		5	3	4	
	3				5
	4				4
		2	4		5

$$\hat{y}_{i,u} = \frac{\sum_{u_j \in \mathcal{N}(u,i)} \bar{y}_{i,u_j} \mathrm{sim}(u, u_j)}{\sum_{u_j \in \mathcal{N}(u,i)} |\mathrm{sim}(u, u_j)|}$$

Main idea: Rating is computed via similar users.

Rating Prediction with Matrix Factorization

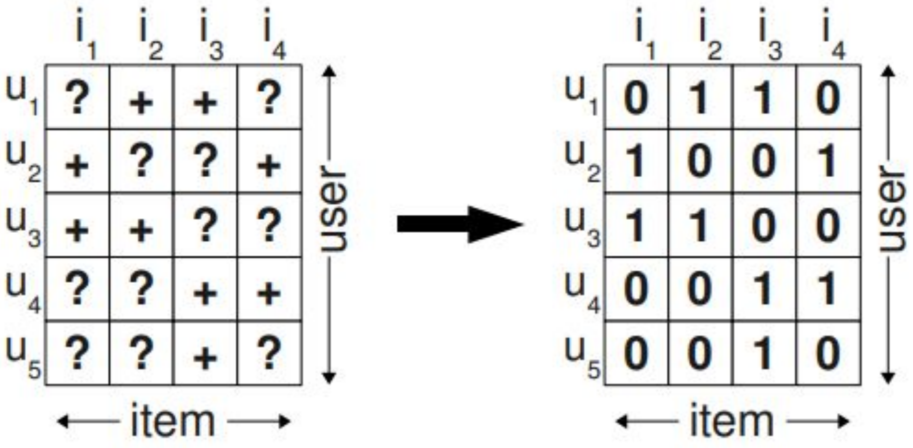


User
latent representation

Item
latent representation

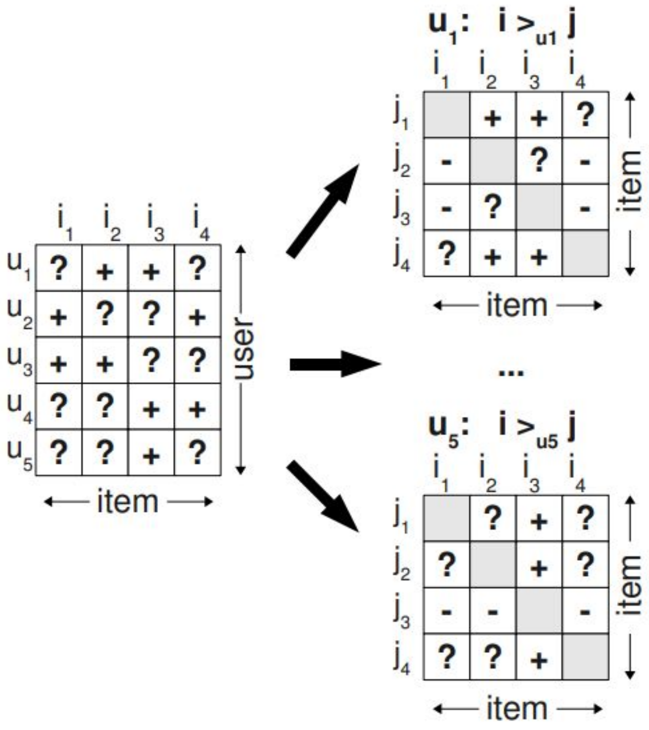
Learning Objective: Minimize $\left(X_{ij} - U_i \times V_j^T\right)^2 + \lambda(||U||_2 + ||V||_2)$

Implicit Association-based Recommendation



Main idea: Recommended items are popular (Counting)

Bayesian Personalized Ranking (BPR)



$$\prod_{u \in U} p(>_u | \Theta) = \prod_{(u,i,j) \in D_S} p(i >_u j | \Theta)$$

$$p(i >_u j | \Theta) := \sigma(\hat{x}_{uij}(\Theta))$$

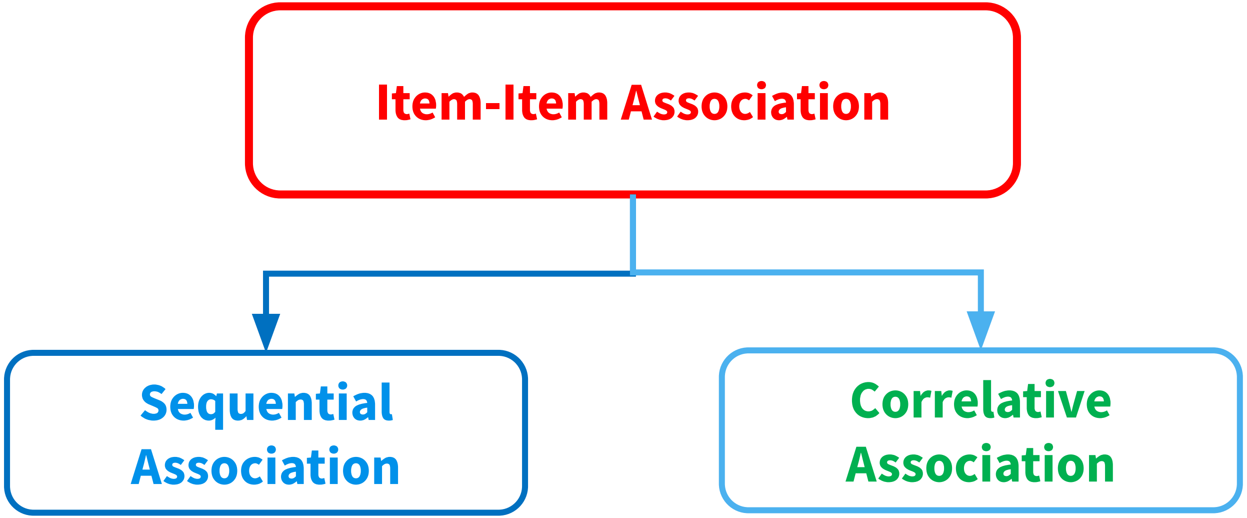
$$\hat{x}_{uij} := \hat{x}_{ui} - \hat{x}_{uj}$$

Main idea: Learn the relative ranking for each user

Ref: Rendle, S., Freudenthaler, C., Gantner, Z., & Schmidt-Thieme, L. BPR: Bayesian Personalized Ranking from Implicit Feedback.

Item-Item Association

Hypothesis: The adoption of a user on an item might be influenced by his past adoptions on other items.



Correlative Association

Data: Basket – Items are adopted at the same time.

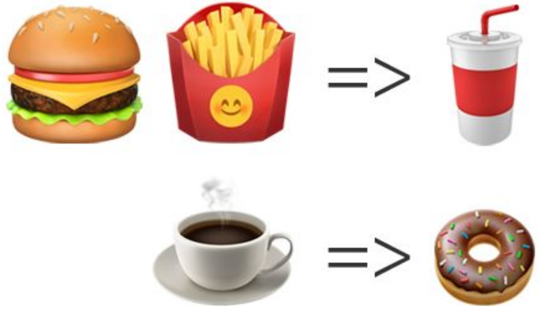
Hypothesis: Items within the same basket are correlated, refers to as *correlative dependencies*.

Association Rule-based Recommendation

instacart

Orders	Products	Users	Timeframe
+3M	+50K	+200K	1 Year

https://www.instacart.com/



Source:
https://www.quora.com/How-is-association-rule-compared-with-collaborative-filtering-in-recommender-systems

An Example of Amazon RS

Frequently Bought Together

Price for all three: $74.20

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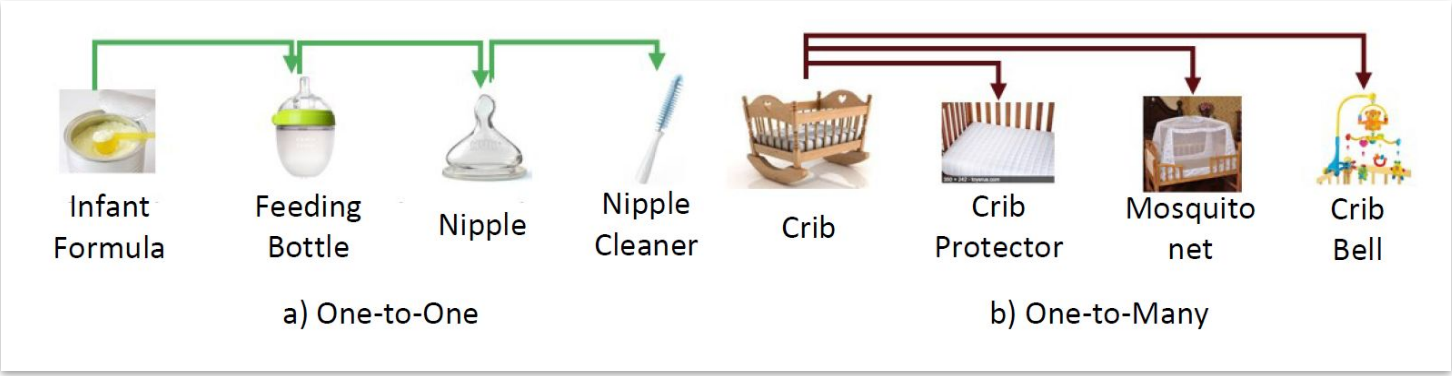
42	39	70	74	19
				#1 Best Seller in Ruby Programming Computer
Paperback	Paperback	Paperback	Paperback	Paperback
$16.94 Prime	$32.49 Prime	$29.48 Prime	$26.35 Prime	$29.67 Prime

Sequential Association

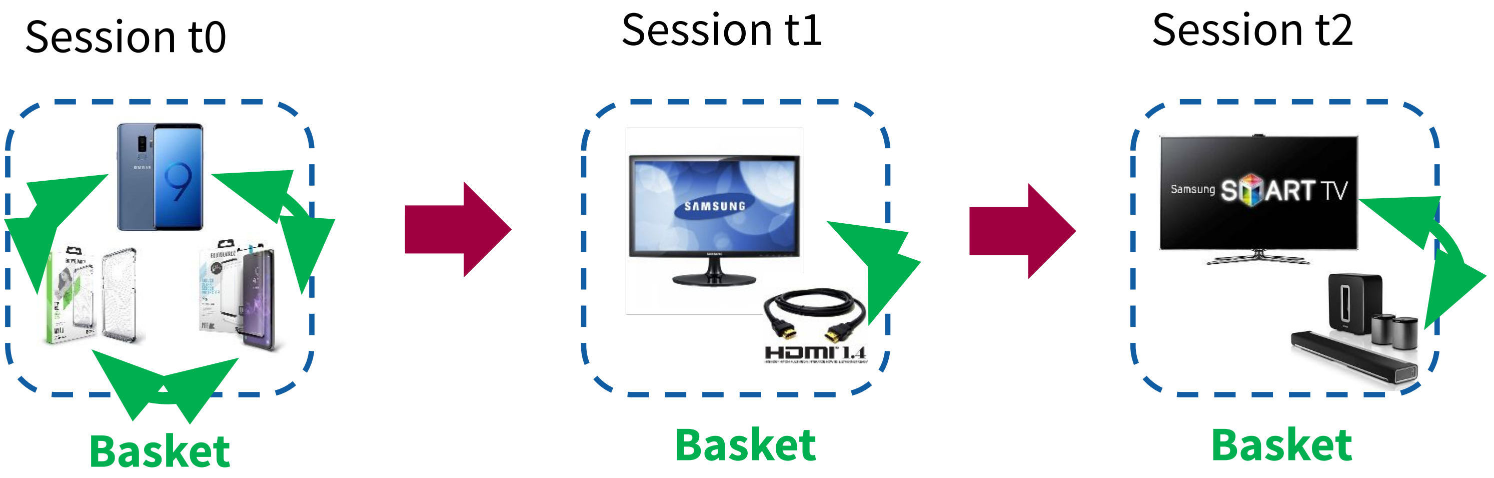
Data: Sequence – Items are adopted sequentially by time.



Hypothesis: The next selection (item) of a user is affected by his preceding adoptions

One more thing …

The notion of Basket Sequence



Correlative associations among items in a basket

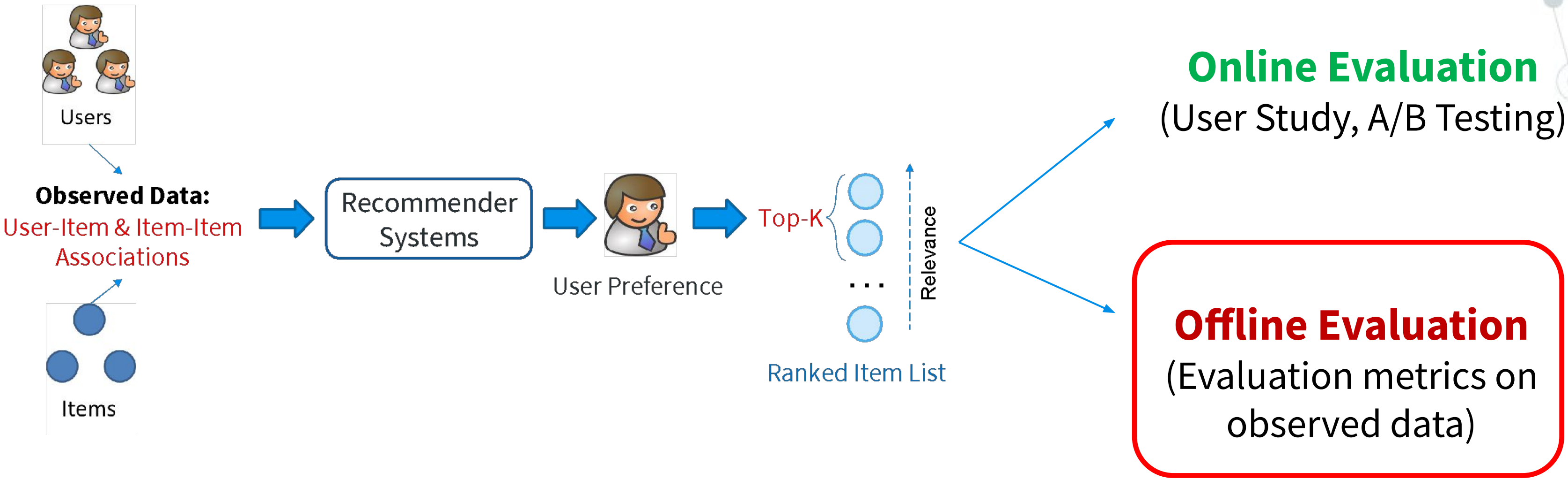
Sequential associations across baskets in a sequence

5.

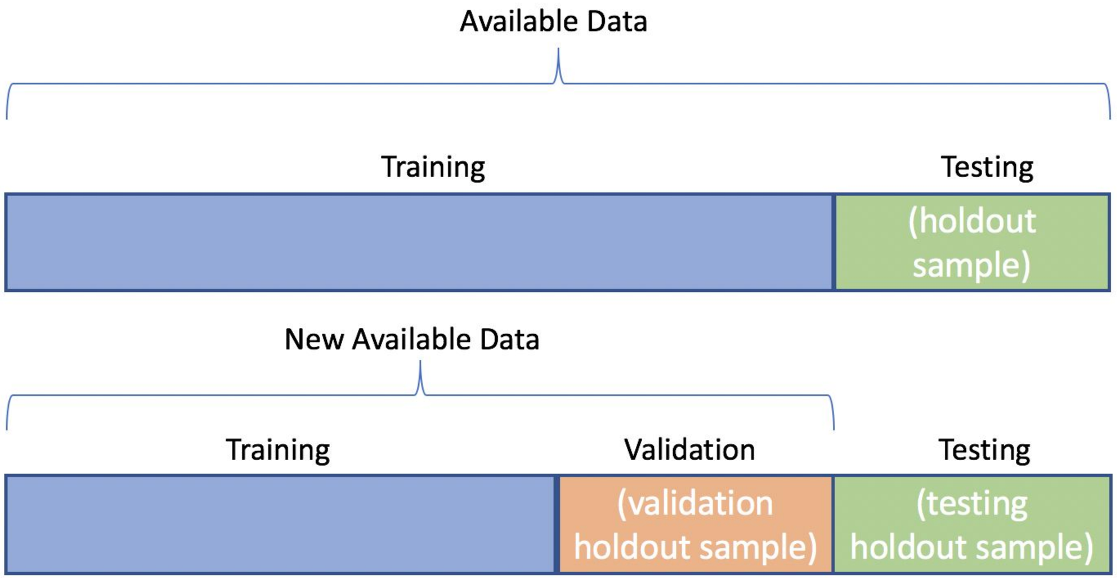
Evaluation and Metrics

“***Recommender systems** are systems that **help users discover items they may like**.*”

Evaluation Strategy



Offline Evaluation



Note: If the available data consists of item/basket sequence, the train/val/test should be split from non-overlapping consecutive periods

Error-based Metrics

$$\mathrm{MAE} = \frac{\sum_{i=1}^{n} |y_i - x_i|}{n}$$

$$\mathrm{MSE} = \frac{1}{n}\sum_{i=1}^{n}(Y_i - \hat{Y}_i)^2.$$

$$\mathrm{RMSD} = \sqrt{\frac{\sum_{t=1}^{T}(\hat{y}_t - y_t)^2}{T}}.$$

Recommendation via Rating Prediction

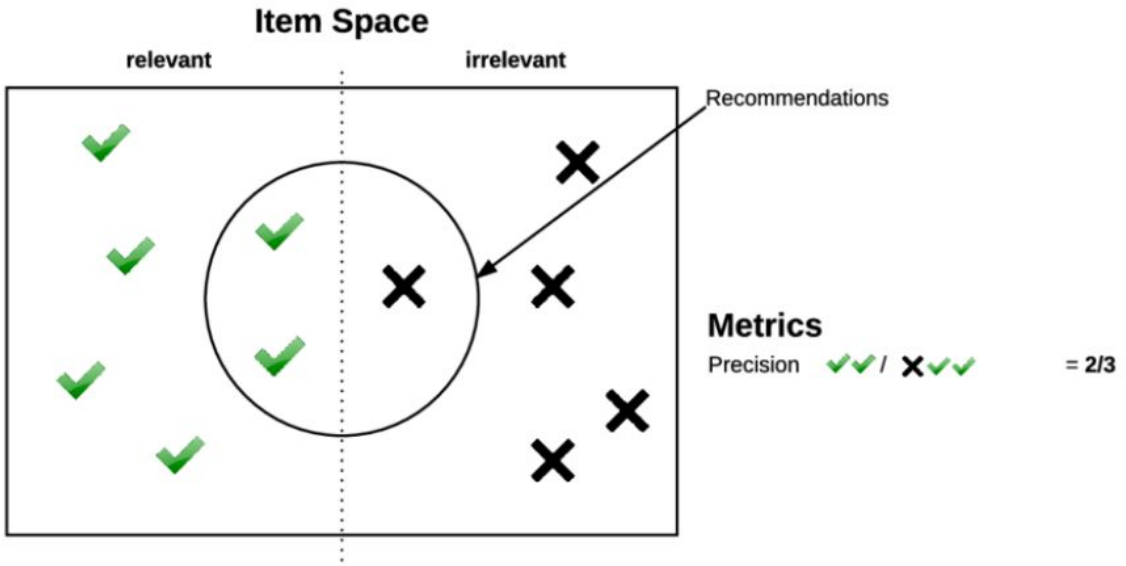
User	Actual	Pedicted	Absolute Error	Squared Error
	1: Toy Story (1995)	1: Toy Story (1995)	1: Toy Story (1995)	1: Toy Story (1995)
755	2	4	2	4
5277	1	2	1	1
1577		3	3	9
4388	2	2	0	0
1202		2	2	4
3823	3	5	2	4
5448		4	4	16
5347	2	3	1	1
4117	4	5	1	1
2765	4	4	0	0

MAE	MSE	RMSE
1.6	4	2.0

Source: https://towardsdatascience.com/an-exhaustive-list-of-methods-to-evaluate-recommender-systems-a70c05e121de

Classification-based Metrics (1)

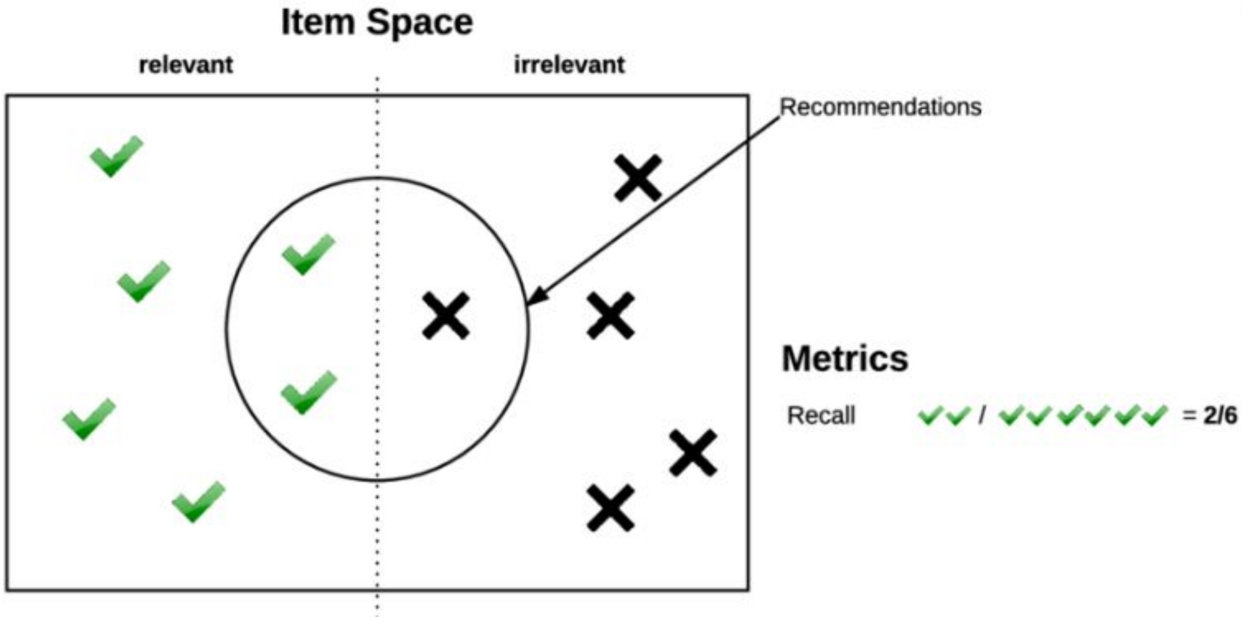
Precision@K for Top-K Recommendation



Source: https://towardsdatascience.com/an-exhaustive-list-of-methods-to-evaluate-recommender-systems-a70c05e121de

Classification-based Metrics (2)

Recall@K for Top-K Recommendation



Source: https://towardsdatascience.com/an-exhaustive-list-of-methods-to-evaluate-recommender-systems-a70c05e121de

Ranking-based Metrics (1)

Normalized Discounted Cummulative Gain (nDCG@K) for Top-K Recommendation

$$\mathrm{nDCG_p} = \frac{DCG_p}{IDCG_p}, \qquad \mathrm{DCG_p} = \sum_{i=1}^{p} \frac{rel_i}{\log_2(i+1)} \qquad \mathrm{CG_p} = \sum_{i=1}^{p} rel_i$$

Items Ranking	Relevancy Score
Movie 1	1
Movie 3	2
Movie 2	2
Movie 5	0
Movie 4	1

Perfect Ranking	Relevancy Score
Movie 3	2
Movie 2	2
Movie 1	1
Movie 4	1
Movie 5	0

CG =	6
DCG =	12.1

CG (p) =	6
DCG (p) =	13.9

nDCG = DCG/DCG (P) =	0.87

Source: https://towardsdatascience.com/an-exhaustive-list-of-methods-to-evaluate-recommender-systems-a70c05e121de

Ranking-based Metrics (2)

Mean Reciprocal Rank (MRR) for Top-K Recommendation

$$MRR = \frac{1}{N} \sum_{i=1}^{N} \frac{1}{rank_i}$$

Items Ranking	Relavent Items	Reciprocol Ranking
Movie 1	No	0
Movie 3	Yes	1/2
Movie 2	Yes	1/3
Movie 5	No	0
Movie 4	Yes	1/5

MRR =	1/2+1/3+1/5 =	1.03

Source: https://towardsdatascience.com/an-exhaustive-list-of-methods-to-evaluate-recommender-systems-a70c05e121de

6.

Introduction to Cornac
A Recommendation Framework

Cornac

Cornac is a comparative framework for multimodal recommender systems, which focuses on making it **convenient** to work with models leveraging **auxiliary data** (e.g., item descriptive text and image, social network, etc.)

Flow of an Experiment in Cornac

Website: https://cornac.preferred.ai/
Tutorials: Github Repo

Summary

- Real-life Examples
- Introduction to Recommendation Systems (RSs)
  - Item, User, Behavior
  - Role of RSs? How do RSs work?
- Types of Recommendation Systems
- Learning Principles
  - Learning User-Item Associations
  - Learning Item-Item Associations
- Evaluation & Metrics
- Introduction to Cornac, a Recommendation Framework

Thanks!

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