

# Search and Recommendation

Hao Sheng  
August 9th, 2023



# hello!

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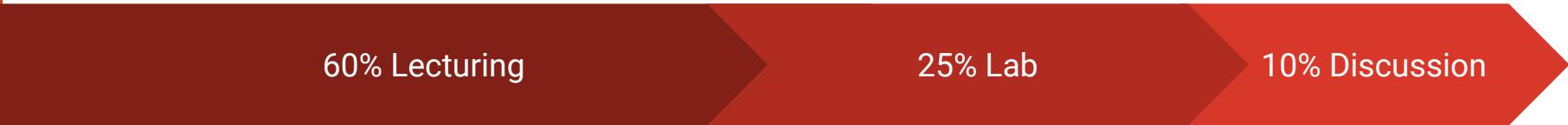


# Requirements

- **Laptop with networks**
- **Attention is all you need**

# Agenda

- **Introduction**
- **Lecturing:** The history of recommendation system
- **Break-out:** Recommendation system in daily life
- **Lecturing:** Recommendation as an ML problem
- **Lecturing:** Evaluate recommendation systems
- **Lab:** Recommendation system notebook I



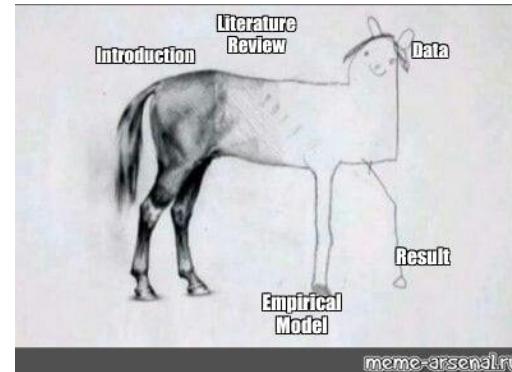
60% Lecturing

25% Lab

10% Discussion



# Introduction



# Introduction - Netflix @ 2025

**NETFLIX.**

[Home](#) | [Members Sign In](#)

**Rent as many DVDs as you want  
for \$20 a month**

[!\[\]\(47d1411aadf4583e0f0c35490d7d8747\_img.jpg\) Sign Up Now](#) [!\[\]\(f8e7be3c2bd30232a05cdc54a8b2d22a\_img.jpg\) Learn More](#) [Preview Our Selection](#)

Have a special offer or gift subscription?  [Redeem](#)

Find movies, actors & genres:  [SEARCH](#)

[Recommendations](#)  
[New Releases](#)  
[Critics' Picks](#)  
[Netflix Top 100](#)  
[Academy Awards®](#)

**GENRES**

- [See All Genres](#)
- [Action & Adventure](#)
- [Anime](#)
- [Children & Family](#)
- [Classics](#)
- [Comedy](#)
- [Documentary](#)
- [Drama](#)
- [Foreign](#)
- [Gay & Lesbian](#)
- [Horror](#)
- [Independent](#)
- [Music & Concert](#)
- [Romance](#)
- [Sci-Fi & Fantasy](#)
- [Special Interest](#)

**Recommendations**

Recommendations are one of the best ways to find movies at Netflix. Rate movies you've seen and we'll generate personalized recommendations just for you.

**1**   
 Not Interested

**Rate Movies You've Seen or Rented!**

**2** 

**Get Recommendations!**

[Start Rating Movies](#)

# Introduction - Airbnb @ 2008

AirBed & Breakfast®

Events Tour About Help Join Log In + Provide Feedback

Share housing. Save money. Meet cool people.

The fun, affordable alternative to hotels for an upcoming event.

Host

Going to an event in your city? Make money by turning your place into a DIY bed & breakfast. » See how

Attend

Traveling to another city for an event? Save money by staying at another attendee's AirBed & Breakfast. » See how

Join!

Tour!

Airbeds!

Start by finding your event!

Event:   
City:   
When:    
Search →

Featured Event:

Spread the Word:

Meet awesome people like you while making extra bucks! Share this site now.

New Users:

Dsc05459 Photo\_58 Andrew3 Jules\_tap\_144\_Richard1 Deborah\_chesky\_web Elevator-icon BiopC2 Face Portrait2 Moi Bws

New Beds:

Rausch\_004 Desk Ausapt4 Ausapt3 Ausapt2 Ausapt1 Ausapt4 Ausapt3 Ausapt2 Ausapt1 Ausapt4 Ausapt3

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Excellent idea!"

Swissmiss.com

JoshSpear.com

» Read all testimonials

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# Introduction - Airbnb @ 2023

airbnb

Anywhere | Any week | Add guests

Airbnb your home

Beachfront Amazing views Amazing pools Play Off-the-grid Mansions Lakefront Cabins OMG! Luxe Treehouses Trending Camping Design Castles Farms Tiny homes National parks Domes Countryside Boats Vineyards

Display total price | includes all fees, before taxes

Manchester, California ★ 4.96  
Manchester State Park  
7 nights · Jul 7 – 14  
\$3,404 total before taxes

Moss Beach, California ★ 4.94  
Moss Beach  
5 nights · Aug 27 – Sep 1  
\$7,286 total before taxes

Half Moon Bay, California ★ 4.89  
Mavericks Beach  
5 nights · Sep 4 – 9  
\$4,855 total before taxes

Moss Beach, California ★ 4.85  
Moss Beach  
5 nights · Aug 1 – 6  
\$23,965 total before taxes

Bodega Bay, California ★ 4.87  
Scotty  
5 nights · Oct 20 – 25  
\$4,285 total before taxes

Santa Cruz, California ★ 4.89  
Pleasure Point  
5 nights · Aug 24 – 29  
\$5,609 total before taxes

Muir Beach, California ★ 4.91

Watsonville, California ★ 4.84

Aptos, California ★ 4.91

Moss Landing, California ★ 4.96

Stinson Beach, California ★ 4.98

Dillon Beach, California ★ 5.0

# Introduction - PizzaHut @ 2002

[pizzahut.com](http://pizzahut.com)

**Pizza Hut**

ORDER ONLINE	STORE FINDER	GET COUPONS	MORE PIZZA HUT®
<p>Online ordering is coming to you soon!</p> <ul style="list-style-type: none"><li>Check to see if it's in your city...</li></ul> <p><b>ORDER ONLINE</b> </p> <p><small>click to register or login</small></p>	<p>Find your nearest Pizza Hut® store instantly by entering your zipcode below</p> <p></p> <p><small>enter zip and go</small></p>	<p>Enter your zip code below and receive the best deals from your neighborhood Pizza Hut®</p> <p></p> <p><small>enter zip and go</small></p>	<p><b>NEW!</b></p> <p><b>CHICAGO DISH</b></p> <p><b>click here for more on Pizza Hut®</b></p> <p><b>click and go</b></p>

# Introduction - PizzaHut @ 2023

Pizza Hut Deals Menu ▾ HUT REWARDS Sign In 0 \$0.00

NY-INSPIRED. TURTLE APPROVED.  
**The Big New Yorker**  
6 XL Slices \$13.99  
ORDER NOW

Limited time only. Prices higher in some locations.  
©2023 FPC, Inc.

Pizza Hut X TEENAGE MUTANT NINJA TURTLES MUTANT MAYHEM ONLY IN THEATERS AUGUST 2

**Start here** Find your store to see local deals FIND DEALS

## Featured SEE MORE >

**75¢ Boneless Wings**  
Limited time in participating locations. Boneless only. 75¢/wing, must buy 8. Excl. tax, delivery fee & driver tip. Adult exclusions apply.

75¢ Boneless Wings  
Tossed in one of our nine signature sauces >

**NEW Melts \$6.99**

Price varies

\$6.99 NEW Pizza Hut Melts  
Crispy. Dippable. Loaded with toppings & cheese. >

**ONLY \$9.99 Large 1-Topping**

Limited Time. Hand Tossed Only.

\$9.99 Large 1-Topping Pizza  
Our best delivery deal >

# Introduction - YouTube @ 2005

[Home](#) | [My Videos](#) | [My Favorites](#) | [My Messages](#) | [My Profile](#)

[Sign Up](#) | [Log In](#) | [Help](#)



Your Digital Video Repository

[Search Videos](#)

[Upload Your Videos](#)

[nansheng](#) : [azlan](#) : [wereldband](#) : [ny](#) : [superbike](#) : [japan](#) : [sinceretheory](#) : [jozef](#) : [party](#) : [amazon](#) : [board](#) : [skate](#) : [buckley](#) : [shubs](#) : [falls](#) : [de](#) : [stockshot](#) : [cubbyhole](#) : [burnout](#) : [satellite](#) : [poughkeepsie](#) : [cruise](#) : [heritage](#) : [orgel](#) : [chin](#) : [themed](#) : [mill](#) : [music](#) : [new](#) : [live](#) : [to](#) : [farmer](#) : [mtv](#) : [puenbrouck](#) : [sicily](#) : [fairfield](#) : [musical](#) : [coffeehouse](#) : [bud](#) : [2005](#) : [trip](#) : [jfk](#) : [woordjes](#) : [death](#) : [xianz](#) : [skill](#) : [olie](#) : [nature](#) : [ads](#) : [dance](#) :

[See More Tags](#)

# Introduction - YouTube @ 2020

ICME

YouTube

Search

SIGN IN

Home

Trending

Subscriptions

Library

History

Sign in to like videos, comment, and subscribe.

LET'S GO

YouTube Music

Get family plan. YouTube Music ad-free and background play for up to 6 household members.

X

Recommended

SQUIRREL NINJA OBSTACLE COURSE

21:40

Building the Perfect Squirrel Proof Bird Feeder

Mark Rober 21M views • 1 week ago

Free Fight: Khabib Nurmagomedov vs Conor McGregor

UFC - Ultimate Fighting Championship 4.3M views • 4 days ago

POLICE GOT MAD

12:24

I Built A Working Car Using Only LEGOS

MrBeast 31M views • 1 year ago

4K UHD GIANT ANTONOV AN-225 "Mriya" - Amazing...

KNIGHT FLIGHT VIDEO 5.8M views • 3 months ago

STREET MAGICIAN Does

5:26

35 SIMPLE PAINTING

15:09

GQ

SAVING PRIVATE RYAN

17:34

Navy SEAL Jocko Willink

vevo

Camilo - Favorito (Official)

3:31

BEST OF YOUTUBE

Music

Sports

Gaming

News

Live

Fashion

Learning

360° Video

+ Browse channels

# Introduction - Steam @ 2004

VALVE

The image shows the official Steam website homepage from 2004. At the top, the Valve logo is visible. Below it is the Steam logo with a stylized gear icon. A banner on the right side reads "Steam delivers Valve's games to your desktop and connects you to a massive gaming community. Check out the full [feature list](#) now." A "GET STEAM NOW!" button is also present. The main navigation bar includes links for NEWS, GET STEAM NOW, CYBER CAFÉS, SUPPORT, FORUMS, and STATUS. On the left, there's a large image of Gabe Newell holding a copy of Half-Life 2, with the text "GET THE GAMES" above it. To the right, four purchase options for Half-Life 2 are listed in boxes:

- HALF-LIFE 2 BRONZE** \$49.95  
INCLUDES:
  - Half-Life® 2\*
  - Counter-Strike™: Source™With Steam installed, [CLICK HERE to PURCHASE](#)  
Without Steam, [CLICK HERE to sign up](#)
- HALF-LIFE 2 SILVER** \$59.95  
INCLUDES:
  - Half-Life 2\*
  - Counter-Strike: Source
  - Half-Life 1: Source\*
  - Day of Defeat™: Source\*
  - PLUS: Valve's back catalog available on Steam.With Steam installed, [CLICK HERE to PURCHASE](#)  
Without Steam, [CLICK HERE to sign up](#)
- HALF-LIFE 2 GOLD** \$89.95  
INCLUDES:
  - Half-Life 2\*
  - Counter-Strike: Source
  - Half-Life 1: Source\*
  - Day of Defeat: Source\*
  - Valve's back catalog available on Steam.
  - PLUS: HL2 posters, full strat guide, soundtrack, hat, collector's box, postcard & moreWith Steam installed, [CLICK HERE to PURCHASE](#)  
Without Steam, [CLICK HERE to sign up](#)

**ORDER NOW >**  
Click [here](#) for more details.

**Latest News**

**Half-Life 2 Pre-Loading Phase 6**  
The sixth phase of the Half-Life 2 preload has begun for Steam account holders. This will allow users to download the Half-Life 2 maps in encrypted form.

**Half-Life 2 Steam Offers Ready**  
The Half-Life 2 Steam offers are now ready for purchase. Those who purchase via Steam, will receive the final version of Counter-Strike: Source immediately.

**Technical Support**

**Questions, Answers, Etc...**

Steam's support pages offer message boards, a list of frequently asked questions, and the Steam Troubleshooter to help identify and resolve any technical support issues.

**Cyber Café Licensing**

**Games Your Customers Want...**

If you run a cyber café or gaming venue, Steam makes it easy for you to bring Valve's games to your customers. Over 1000 gaming venues have signed up for Valve's Cyber Café Program.

**Get Steam Now**

**Sign Up and Play Games Today!**

Start playing Valve's award-winning games within minutes. With Steam, you'll also get access to an instant messenger, automatic updates, and more. If you don't already have Steam,

# Introduction - Steam @ 2023

The screenshot shows the Steam homepage with a dark blue header. The header includes the Steam logo, navigation links for STORE, COMMUNITY, ABOUT, and SUPPORT, and a green button for "Install Steam". On the right side of the header is a user icon, "Install Steam", "login", and a "language" dropdown.

The main content area has a dark blue background. On the left, there's a sidebar with sections for GIFT CARDS, RECOMMENDED (By Friends, By Curators, Tags), DISCOVERY QUEUES (Recommendations, New Releases), BROWSE CATEGORIES (Top Sellers, Recently Updated, New Releases, Upcoming, Specials, Virtual Reality, Steam Controller Friendly), and BROWSE BY GENRE (Free to Play, Early Access, Action, Adventure, Casual, Indie, Massively Multiplayer, Racing, RPG, Simulation, Sports).

The central part of the page features a "FEATURED & RECOMMENDED" section with a grid of game thumbnails. One prominent thumbnail is for "Grand Theft Auto V", showing the main title and several character and vehicle screenshots. Below this, there's a "Now Available" section for "Grand Theft Auto V" with a "Top Seller" badge and a price of 29,99€.

At the bottom, there's a "SPECIAL OFFERS" section with three highlighted deals: "WEEKLONG DEALS", "GOLDEN WEEK SALE" (April 30 - May 6, 10 AM Pacific), and "METaverse KEEPER" (Today's deal: 56.52-35, -37% off, 7.86€). A "BROWSE MORE" button is located in the top right corner of the offers section.

# Homepages @ 2023

The Steam homepage features a dark header with links for STORE, COMMUNITY, ABOUT, and SUPPORT. Below the header is a search bar and a "Grand Theft Auto V" promotional banner. The main content area is titled "FEATURED & RECOMMENDED" and shows a grid of game thumbnails. A sidebar on the left lists various categories like GAMES, COMMENDED, BY FRIENDS, BY CREATORS, and more.

The YouTube homepage has a light blue header with links for Home, Trending, Subscriptions, and Library. A "YouTube Music" promotional banner for a family plan is displayed. The main content area shows a grid of video thumbnails from various locations, each with a rating and price. The sidebar includes links for Amazing views, Amazing places, Map, Off-the-grid, Mansions, Lofted, Cabins, DMOs, Love, Treehouses, Trending, Camping, Design, Castles, Tiny homes, National parks, Domes, Countryside, Boats, Vineyards, and Filters.

The Pizza Hut homepage features a large banner for "The Big New Yorker" pizza. It includes a "ORDER NOW" button and a "NY-INSPIRED TURTLE APPROVED" badge. Below the banner is a "Start here" section with a "Find your store to see local deals" button and a "FIND DEALS" button. The main content area is titled "Featured" and shows three promotional sections: "5¢ Boneless Wings", "NEW Melts \$6.99", and "ONLY \$9.99 Large 1-Topping Pizza". Each section includes a thumbnail image and a brief description.

Everyone gives user recommendations on the first impression!

# Introduction

- Every website gives user recommendations right on visiting.
- The recommendation is getting very “aggressive”?
  - 8 videos from 800 millions videos on YouTube (used to recommend categories only)
  - 8-10 cities (and all in CA) from 100,000 cities on AirBnb
  - GTA V from more than 50k games
  - The Big New Yorker Pizza from 10 crusts x 21 toppings x 6 sources

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  -
- What makes them so confident that this is a good move?

# The History of Recommendation System



“I know of no people ... that does not consider that future things are indicated by signs and that it is possible ... to recognize those signs and predict what will happen.”

--- Marcus Tullius Cicero (44 BC)





**Oracle bones** (Chinese: 甲骨; pinyin: jiǎgǔ) are pieces of ox scapula and turtle plastron, which were used for pyromancy – a form of divination – in ancient China, mainly during the late Shang dynasty. Scapulimancy is the specific term if ox scapulae were used for the divination, plastromancy if turtle plastrons were used.



- Step 1: Journey to Delphi
- Step 2: Preparation of the supplicant
- Step 3: Visit to the Oracle
- Step 4: Return home





**Aquarius**  
January 20 - February 18



**Aries**  
March 21 - April 19



**Cancer**  
June 22 - July 22



**Capricorn**  
December 22 - January 19



**Gemini**  
May 21 - June 21



**Leo**  
July 23 - August 22



**Libra**  
September 23 - October 22



**Pisces**  
February 19 - March 20



**Sagittarius**  
November 22 - December 21



**Scorpio**  
October 23 - November 21



**Taurus**  
April 20 - May 20

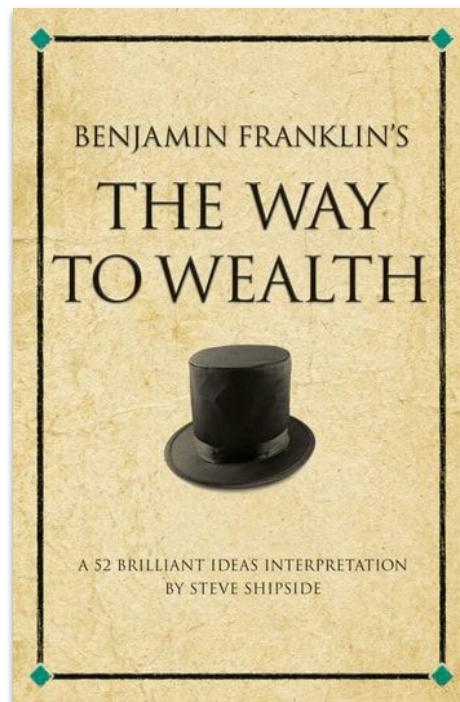
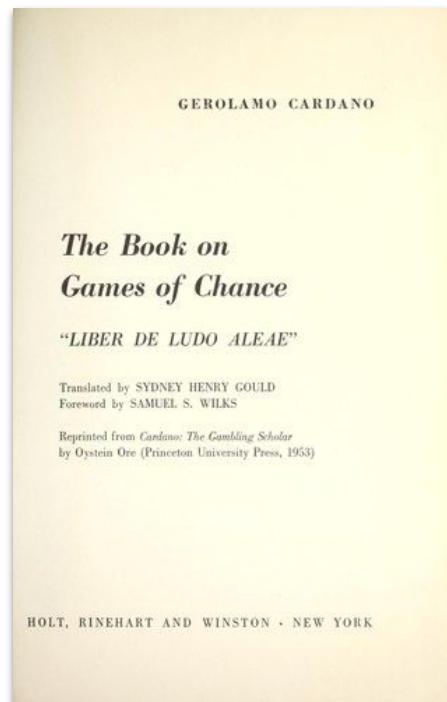


**Virgo**  
August 23 - September 22

## Aries March 21 - April 19

Today you should put good conversation at the top of your priority list! But in order to make it happen, you have to be ready to take things to a deeper level than you usually do with people you don't usually talk to. Small talk is for small minds right now, and since you certainly don't have one of those, why not prove it? Instead of asking about someone's weekend, ask them how they feel about international politics. You might get an odd look, but you'll also get great insight into another person.





Cardano, 1663



Samuel Smiles, 1859

## Recommendation Literature: 1859 AD - Today

- How to Win Friends and Influence People (1936)
- Think and Grow Rich (1937)
- ...
- Oracle of the Coffee House (1972)
- The 7 Habits of Highly Effective People (1989)
- Awaken the Giant (1992)
- Chicken Soup of the Soul (1993)
- ...
- The One Minute Manager (2001)
- A Guide to the Good Life (2009)
- Personal Development for Smart People (2009)

## Recommendation (System): 1500 BC - Today

- People all over the world seek tools/techniques in their personal quest for actionable advice.
- Personalization and quantitative models are introduced.
- Self-help literature reflect the historical strand of recommendation: Curation.

## Recommendation System: Definition?

“.. is a subclass of information filtering system that provide suggestions for items that are most pertinent to a particular user.” --- *Wikipedia*

“Recommender systems (RSs) are software tools and techniques that provide suggestions for items that are most likely of interest to a particular user.” --- *Introduction to Recommender Systems Handbook*

“A recommender system can be described as a system which automatically selects personally relevant information for users based on their preferences.” --- *Intelligent and Relevant*

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# First Recommendation System -- Grundy: 1979

COGNITIVE SCIENCE 3, 329-354 (1979)

## User Modeling via Stereotypes \*

ELAINE RICH

*The University of Texas at Austin*

This paper addresses the problems that must be considered if computers are going to treat their users as individuals with distinct personalities, goals, and so forth. It first outlines the issues, and then proposes stereotypes as a useful mechanism for characterizing individual users on the basis of a minimum of information about them. In order to build user models quickly, a formalism of user knowledge must be incorporated into the models. The issue of how to resolve the conflicts that will arise among such inferences is discussed. A system, Grundy, is described that builds models of its users, with the aid of stereotypes, and then explores the usefulness of stereotypes for guiding its performance. The kinds of stereotypes that appear to be useful to Grundy, they must accurately characterize the users of the system. Some techniques to modify stereotypes on the basis of experience are discussed. An analysis of Grundy's performance shows that its user models are effective in guiding its performance.

### 1. INTRODUCTION

#### Scene I

Some man walks into a large library, tells the librarian that he is interested in China, and asks for some books. What sort of books does the librarian recommend? That depends. Is the person a small child who just saw a TV show about China and wants to see more? Or is the person interested in Chinese history? Or is the person interested in Chinese culture? Or is the person interested in Chinese thought? Can the person read Chinese? The librarian needs to know these things before he can point the reader to the right books. Some of what he needs to know he'll know before he even thinks about it, such as the approximate age of the person. Some things he'll assume until he has evidence to the contrary, such as that the person does not read Chinese. To find out other things, he'll ask a few specific questions. Only after he has a rough model of the person he's talking to can he answer the question.

#### Scene II

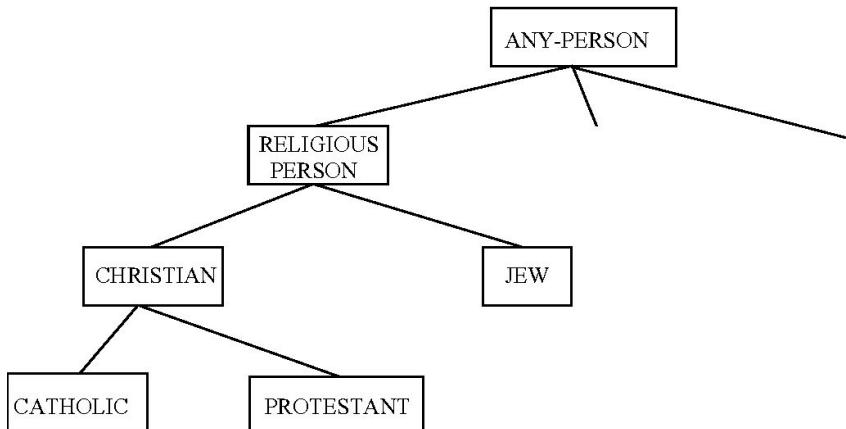
The phone rings in the information division of a large pharmaceutical firm. The caller wants information about a drug the company makes. What sort of information should be provided? That depends. Is the caller a doctor, a patient, or an FDA representative? To provide the right information, the person answering the phone needs to know some facts about the caller.

The scenes above illustrate some kinds of situations in which people need to form a *model* of the person with whom they are dealing before they can behave appropriately. They form their model by collecting a few specific pieces of information and then invoking the knowledge they have about the groups to which the current person belongs, such as scholar or medical patient.

As computers come to be used by a larger number of people to help perform a great variety of tasks, it is becoming more and more important for them to be easy for people to use. There are many factors that can contribute to the ease of use of a computer system, ranging from the good design of input devices such as terminals to the speed of the system's response, the appropriateness of its response, and the naturalness of its input and output languages. Appropriate models of the users of a system can be an important contribution because they can simultaneously affect several of these factors, such as speed and quality of response and habitability of the language interface.

Most systems that interact with human users contain, even if only implicitly, some sort of model of the creatures they will be dealing with. For example, the central assumption behind the mini-max strategy used by game playing programs is that the opponent is trying to win and will therefore make his best possible move. Although it is almost always true to say that the opponent wants to win, it is much less often true that he will therefore make the best move. He may and probably does have idiosyncrasies of style or strategy that preclude that. Of course, human players know that and watch for evidence of such quirks in their opponents.

The term "user model" can be used to mean several different things. The three major dimensions along which user models can be classified are:



# First Recommendation System Used: 1992, Palo Alto

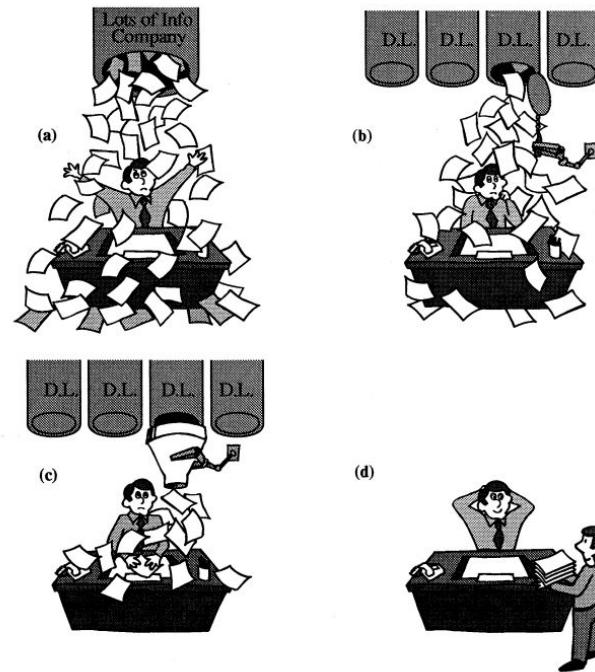
Palo Alto Research Center

## Using Collaborative Filtering to Weave an Information Tapestry

David Goldberg, David Nichols, Brian Oki, and Douglas Terry

XEROX

Figure 1.  
(a) electronic mail overload  
(b) using distribution lists  
(c) conventional filtering  
(d) collaborative filtering



# First-generation “Real” Recommendation System: 1992, Palo Alto

Active Messages									
MoveTo	Display	Delete	AddTo	NewMail	Places	Levels	MsgOps	SortBy	
99>	18 Mar 93	Maria<Eblin...			Re: marked-up thesis proposal				
99>	18 Mar 93	elib@eclipse...			Elib Response				
99>	19 Mar 93	Dan Swineh...			Here's a topic for a future meeting				
94>	18 Mar 93	To: elib%cs....			Test of Stanford SDI Service				
85>	13 Mar 93	tapestry@pa...			ICDCS'13 program				
70>	12 Mar 93	weiser:PAR...			here is a new service being offered by the stanford CS library				
?	99> 22 Mar 93	weiser:PAR...			hiring meeting after dealer				
?	99> 22 Mar 93	Bellotti@eur...			Re: UbiCore meeting on Security				
?	99> 22 Mar 93	chauser:PA...			Request for more help in tapbrowser				
?	90> 22 Mar 93	Nancy Frei...			HIRING MTG. SCHEDULED...				
?	90> 22 Mar 93	weiser:PAR...			Re: IMPORTANT AGAIN: YES hiring meeting after Dealer...				
?	85> 22 Mar 93	saraswat@pa...			[erjun@cs.stanford.edu: Two talks in Concurrency Theory]				
?	85> 21 Mar 93	tapestry@pa...			Briefs California (Mar 17 11 am PST)				
?	80> 22 Mar 93	Gary Eman...			Equipment Shipping crates and boxes in warehouse				
?	80> 22 Mar 93	Andrea Spi...			Fry's Electronics Blanket Order (PARC Only)				
?	75> 21 Mar 93	tapestry@pa...			****OnLine Bookstore Offers "Electronic Lit" over Internet 03/19/93				

Figure 1. My Active folder showing old messages followed by prioritized new mail.

# First-generation “Real” Recommendation System: 1992, Palo Alto

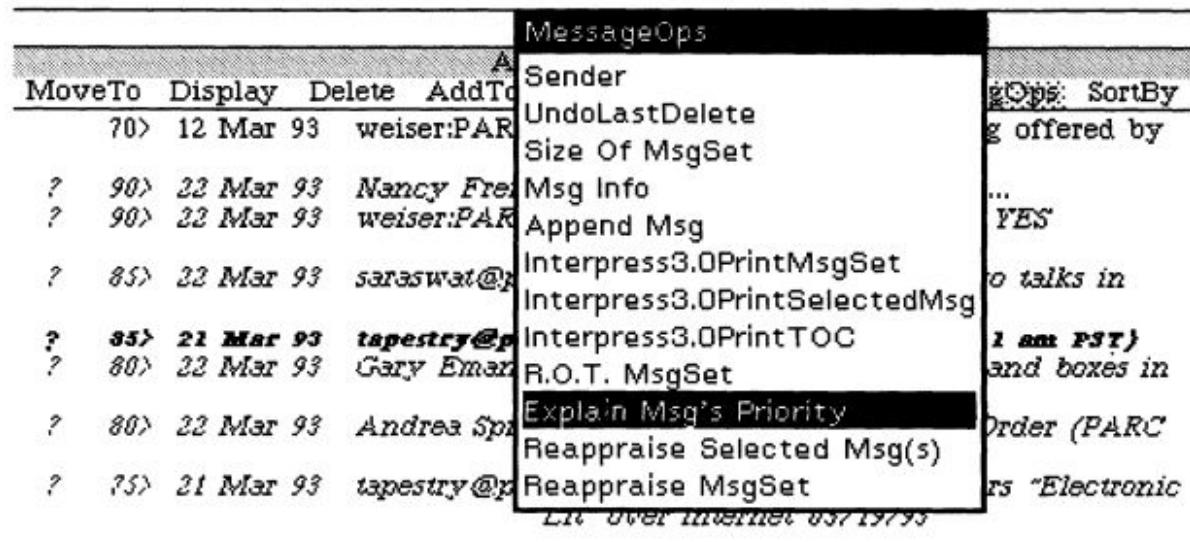
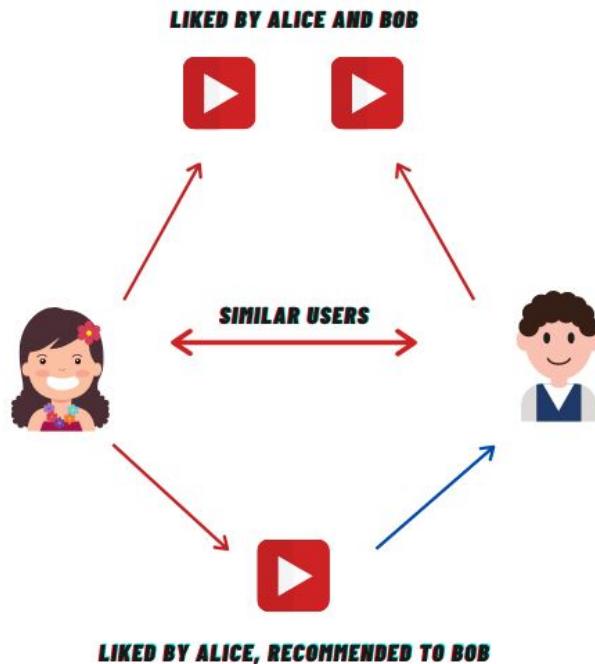


Figure 2. Requesting an explanation for a message's priority.

Annotations for message \$ XNS-SMTP-Gateway:Parc:Xerox  
appraiser terry\$text:Bakersfield => priority 85  
appraiser terry\$Subject:Briefs<California => priority 55  
appraiser terry\$sender:tapestry => priority 10

Figure 3. An explanation of priorities assigned to a message by various appraisers.

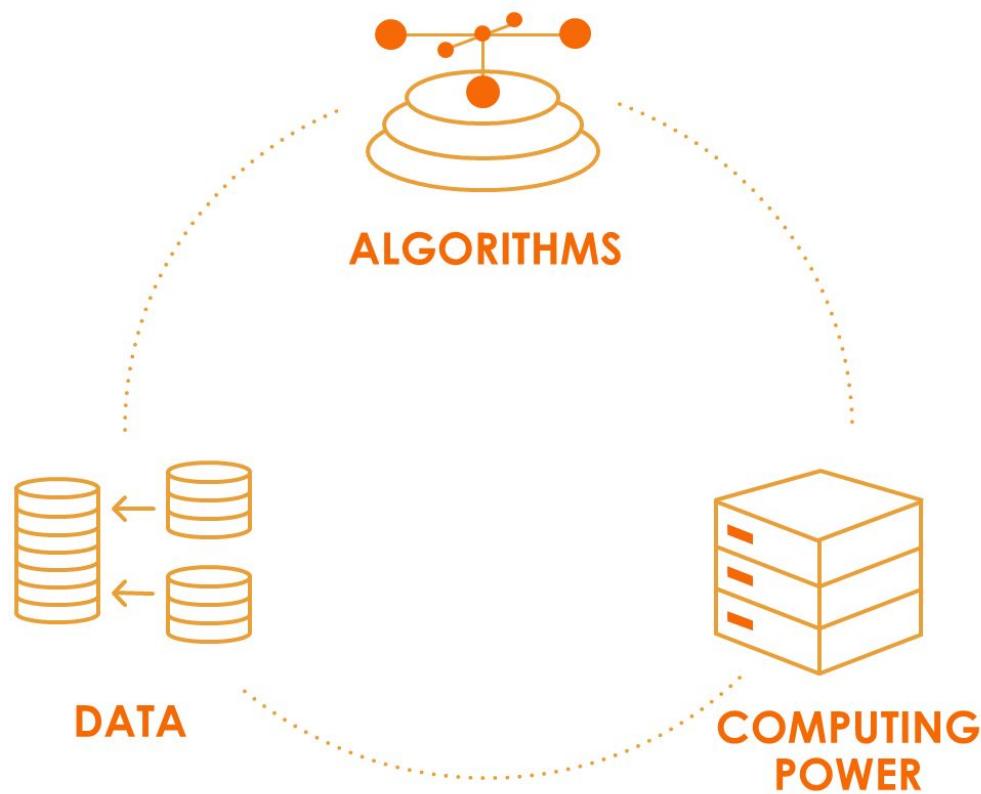
## COLLABORATIVE FILTERING



# Earlier Recommendation Systems

- Recommendation system: RS automatically selects personalized information based on users' preferences.
- **Grundy:**
  - Ask user questions and assign stereotype.
  - **Content-based filtering.**
- **Tapestry:**
  - Find similar users and recommend their choices.
  - **Collaborative filtering.**

# Backbone of Recommendation System: Not Only the Algorithm



# Recommendation System in Daily Life



Our next recommendation  
is a 25 minute video on the  
history of Parmesan  
cheese.

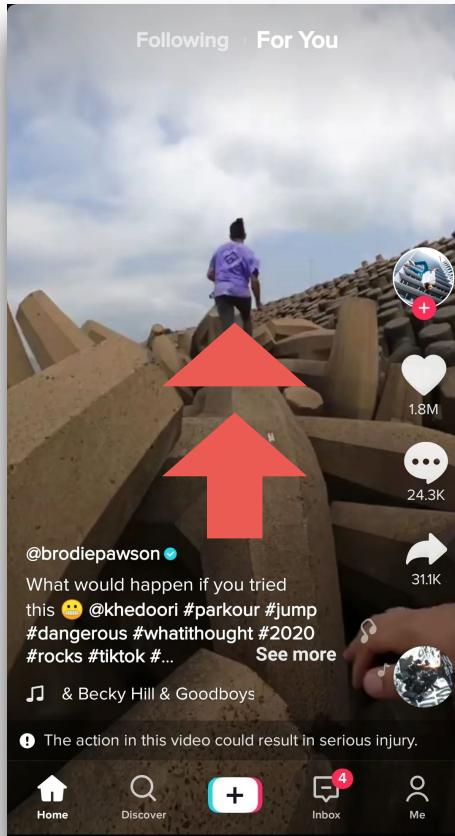
Yes.

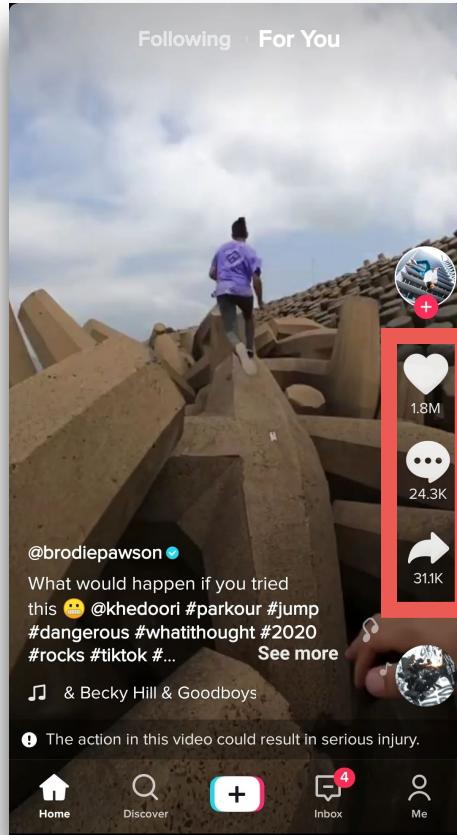
# Recommendation System in Daily Life

- Q: What is the input/outputs of the system?
- Q: Why is this useful?
- Q: Can you guess what's behind the system?









- **Q:** What is the input/outputs of the system?
  - Input: Historical user behavior (e.g. like/comment/share or not; How long did I stay; Did I finish the video)
  - Outputs: Next short video I would like to watch. Or some Ads that I have high chance to spend my money on.
- **Q:** Why is this useful?
  - Well, it helps to.. kill my time more effectively(?). I don't need to search for videos I am interested in. Moreover, I explored my interests in a way I could never think about.
- **Q:** Can you guess what's behind the system?
  - Hmm. Maybe just like the Grundy example? They assigned me a “stereotype”?

Take a 10 minute break



## At Your Service: Coffee Beans Recommendation From a Robot Assistant

Jacopo de Berardinis\*, Gabriella Pizzuto<sup>†</sup>, Francesco Lanza<sup>‡</sup>, Antonio Chella<sup>‡</sup>, Jorge Meira<sup>§</sup>, Angelo Cangelosi\*

\*School of Engineering, The University of Manchester

<sup>†</sup>School of Informatics, The University of Edinburgh

<sup>‡</sup>Department of Engineering, University of Palermo

<sup>§</sup>Department of Computer Science and Information Technologies, University of A Coruña

# Recommendation as an ML Problem

# Recommendation System an ML Problem

- How to model recommendation problem mathematically.
- Classic recommendation algorithms
  - Collaborative filtering
    - Memory-based filtering
    - Model-based filtering
  - \*Content-based filtering
- How to evaluate recommendation modeling.

# Recommendation System an ML Problem

	1	2	3	4	5	6
a	5		1	1		2
b		2		4		4
c	4	5		1	1	2
d			3	5	2	
e	2		1		4	4



prediction:  $r_{u,i}$



recommend top-N items

# Recommendation System an ML Problem

	1	2	3	4	5	6
a	+	?	-	-	?	-
b		-		+		+
c	+	+	-	-	-	-
d			+	+	-	
e	-		-		+	+



prediction:  $r_{u,i}$

recommend top-N items

# Recommendation System an ML Problem

	1	2	3	4	5	6
a	+	?	-	-	?	-
b		-		+		+
c	+	+	-	-	-	-
d			+	+	-	
e	-		-		+	+



prediction:  $r_{u,i}$

recommend top-N items

# Recommendation System an ML Problem



Sara	5	3		2	2	2
Jesper	4	3	4		3	3
Therese	5	2	5	2	1	1
Helle	3	5	3		1	1
Pietro	3	3	3	2	4	5
Ekaterina	2	3	2	3	5	5

# Recommendation System an ML Problem



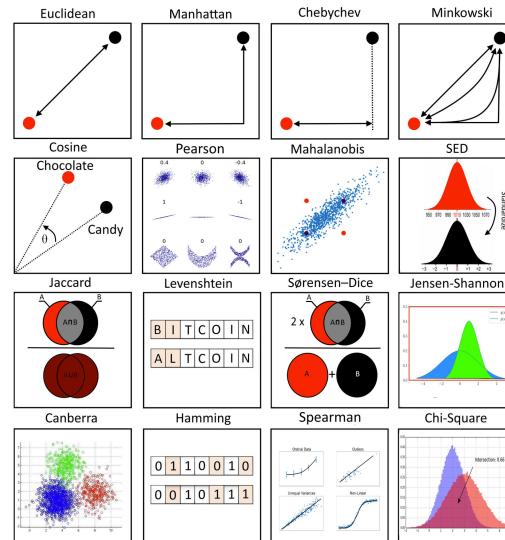
# Recommendation System an ML Problem

- How to model recommendation problem mathematically.
- Classic recommendation algorithms
  - Collaborative filtering
    - Memory-based filtering
    - Model-based filtering
  - \*Content-based filtering
-



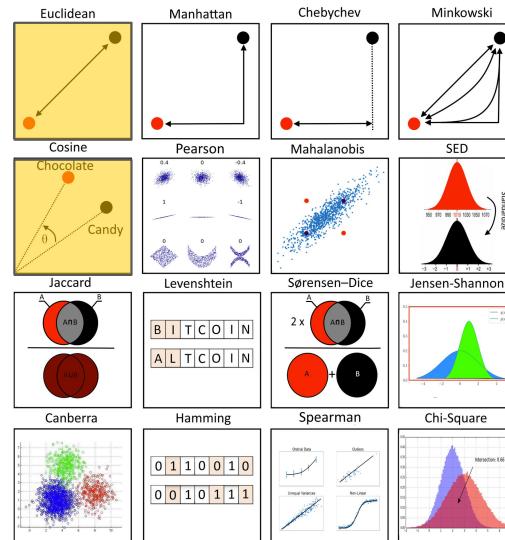
# Collaborative Filtering: Similarity Function

You can calculate similarity in many ways, but the overall problem can be defined as follows: Given two items,  $i_1$  and  $i_2$ , the similarity between them is given by the function  $\text{sim}(i_1, i_2)$ .



# Collaborative Filtering: Similarity Function

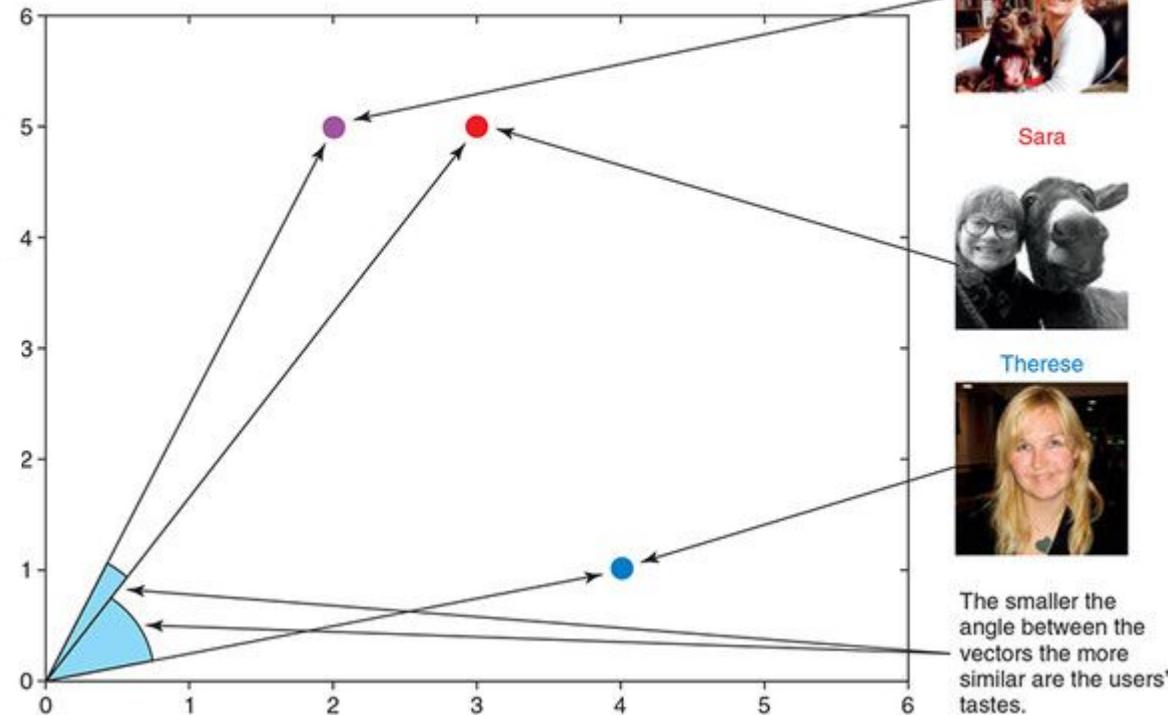
You can calculate similarity in many ways, but the overall problem can be defined as follows: Given two items,  $i_1$  and  $i_2$ , the similarity between them is given by the function  $\text{sim}(i_1, i_2)$ .



# Collaborative Filtering: Cosine Similarity



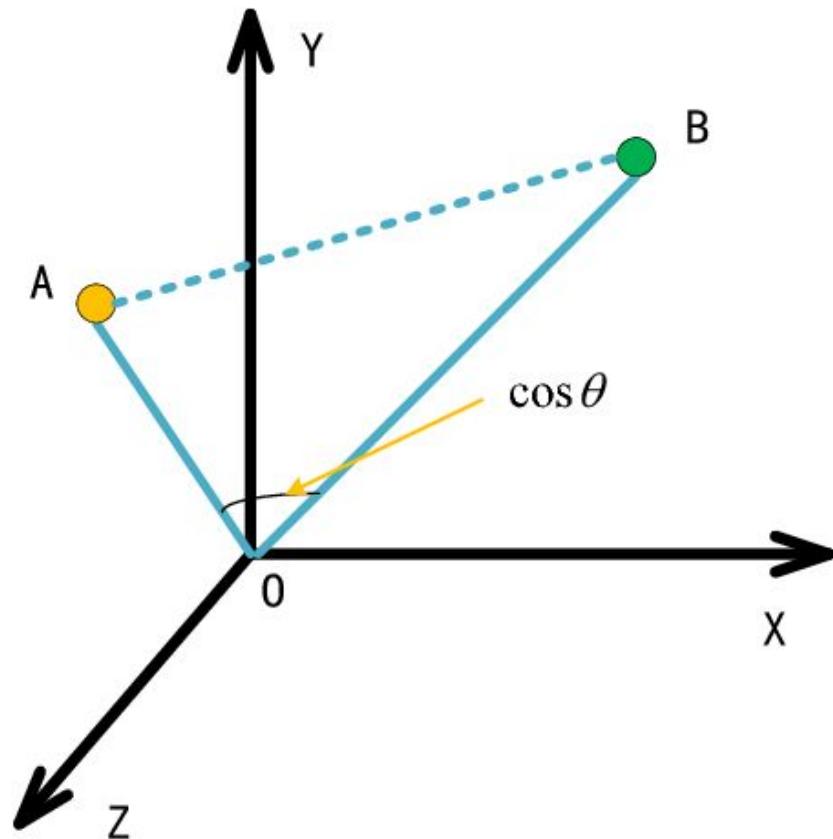
	Barbie	Oppenheimer
Helle	5	2
Sara	5	3
Therese	1	4



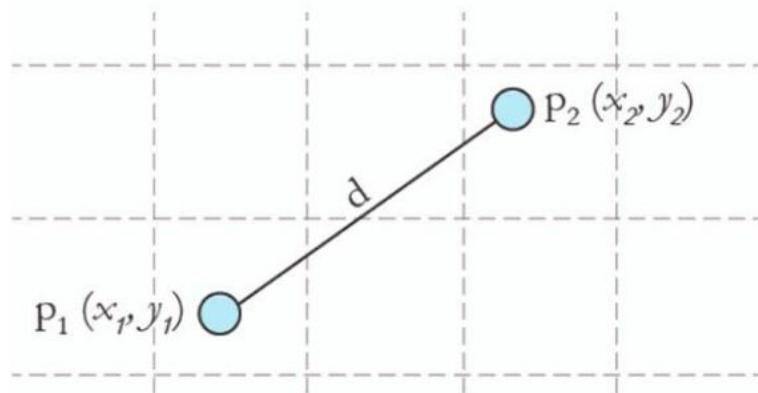
# Collaborative Filtering: Cosine Similarity



	Barbie	Oppenheimer	Spider-Man: Across the Spider-Verse
Helle	5	2	3
Sara	5	3	4
Therese	1	4	3



# Collaborative Filtering: Euclidean Similarity



$$\text{Euclidean distance } (\delta) = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}$$

What if we have 20 million active users?

Calculate similarities of current user <-> 20 million users?

What if we have 20 million active users?

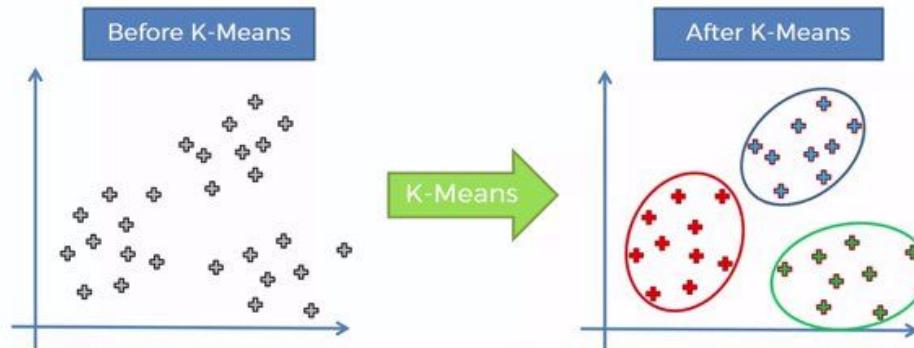
Calculate similarities of current user <-> 20 million users?



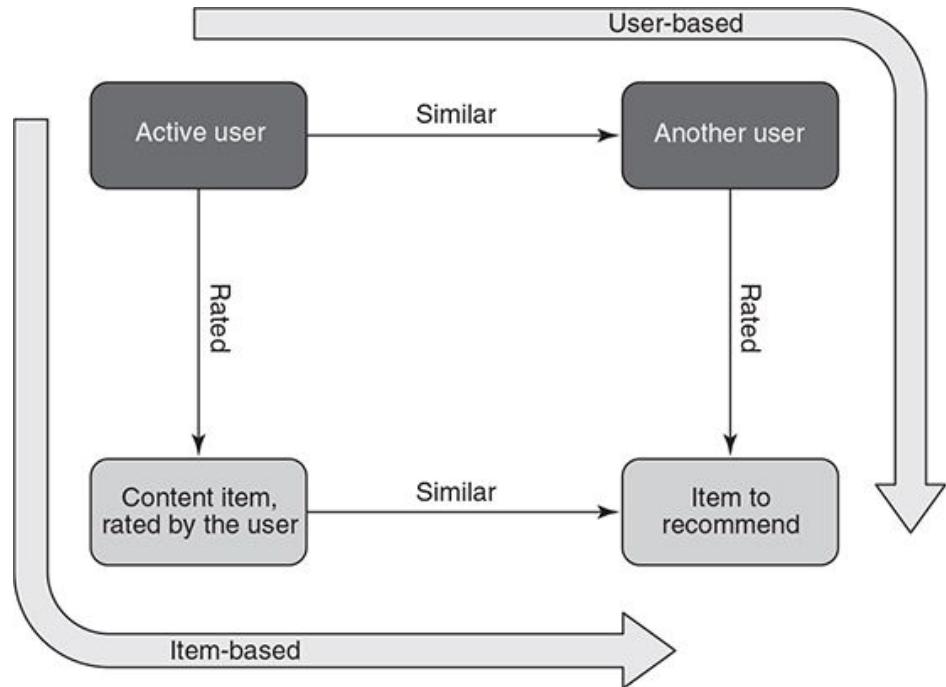
# Collaborative Filtering: Scale-up Similarity Calculation

What if we have 20 million active users?

Calculate similarities of current user <-> 20 million users?



# Collaborative Filtering: Memory-based



# Collaborative Filtering: Model-based Filtering

- How to model recommendation problem mathematically.
- Classic recommendation algorithms
  - Collaborative filtering
    - Memory-based filtering
    - Model-based filtering
  - \*Content-based filtering
-

# Collaborative Filtering: Motivation of Model-based Filtering

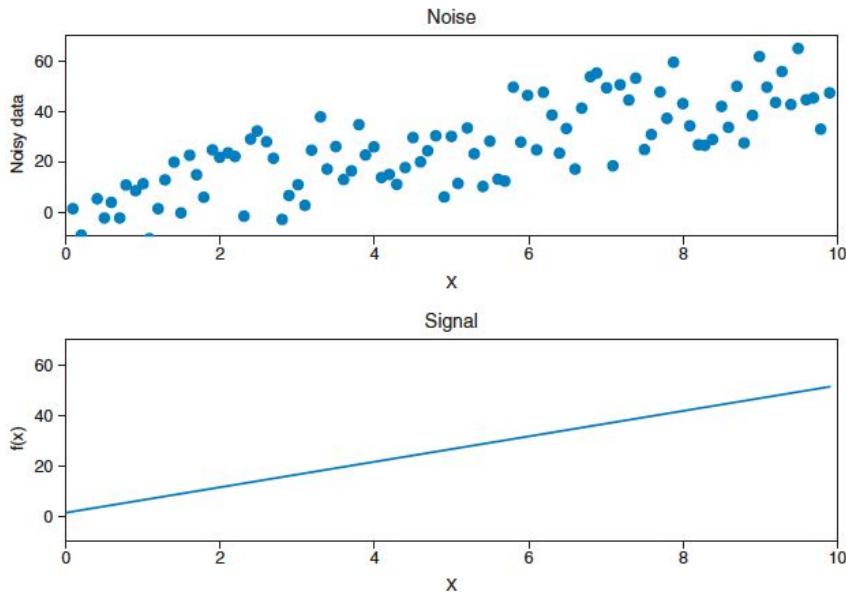


Figure 11.1 A scatter plot of noisy data (top) and the signals that uncover the information in the data (bottom)

# Collaborative Filtering: Factorization



Sara	5	3		2	2	2
Jesper	4	3	4		3	3
Therese	5	2	5	2	1	1
Helle	3	5	3		1	1
Pietro	3	3	3	2	4	5
Ekaterina	2	3	2	3	5	5

$$R = \begin{bmatrix} 5 & 3 & 0 & 2 & 2 & 2 \\ 4 & 3 & 4 & 0 & 3 & 3 \\ 5 & 2 & 5 & 2 & 1 & 1 \\ 3 & 5 & 3 & 0 & 1 & 1 \\ 3 & 3 & 3 & 2 & 4 & 5 \\ 2 & 3 & 2 & 3 & 5 & 5 \end{bmatrix}$$

# Collaborative Filtering: SVD Factorization

$$\mathbf{M} = \mathbf{U} \Sigma \mathbf{V}^T$$

$$\begin{bmatrix} 5 & 3 & 0 & 2 & 2 & 2 \\ 4 & 3 & 4 & 0 & 3 & 3 \\ 5 & 2 & 5 & 2 & 1 & 1 \\ 3 & 5 & 3 & 0 & 1 & 1 \\ 3 & 3 & 3 & 2 & 4 & 5 \\ 2 & 3 & 2 & 3 & 5 & 5 \end{bmatrix} = \begin{bmatrix} -0.34 & 0.05 & 0.91 & 0.11 & 0.19 & -0.00 \\ -0.43 & 0.16 & -0.31 & -0.12 & 0.74 & 0.35 \\ -0.39 & 0.56 & -0.19 & 0.63 & -0.32 & 0.02 \\ -0.33 & 0.42 & 0.02 & -0.76 & -0.37 & -0.05 \\ -0.48 & -0.34 & -0.18 & 0.03 & 0.10 & -0.78 \\ -0.46 & -0.61 & -0.06 & 0.02 & -0.40 & 0.51 \end{bmatrix} \begin{bmatrix} 17.27 & 0 & 0 & 0 & 0 & 0 \\ 0 & 5.84 & 0 & 0 & 0 & 0 \\ 0 & 0 & 3.56 & 0 & 0 & 0 \\ 0 & 0 & 0 & 3.13 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1.67 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0.56 \end{bmatrix} \begin{bmatrix} -0.50 & -0.44 & -0.41 & -0.22 & -0.40 & -0.43 \\ 0.46 & 0.17 & 0.42 & -0.22 & -0.49 & -0.55 \\ 0.50 & 0.22 & -0.78 & 0.26 & -0.08 & -0.13 \\ 0.34 & -0.77 & 0.17 & 0.51 & -0.02 & -0.01 \\ 0.41 & -0.36 & -0.16 & -0.76 & 0.19 & 0.25 \\ -0.01 & -0.03 & 0.01 & -0.02 & 0.75 & -0.66 \end{bmatrix} \mathbf{V}^T$$

# Collaborative Filtering: SVD Factorization

```
def rank_k(k):           ←  
    U_reduced= np.mat(U[:, :k])  
    Vt_reduced = np.mat(Vt[:, :, :])  
    Sigma_reduced = Sigma_reduced = np.eye(k)*Sigma[:, :k]  
    Returns the reduced  
    matrices
```

```
        return U_reduced, Sigma_reduced, Vt_reduced,  
U_reduced, Sigma_reduced, Vt_reduced = rank_k(4)    ←  
M_hat = U_reduced * Sigma_reduced * Vt_reduced      ←
```

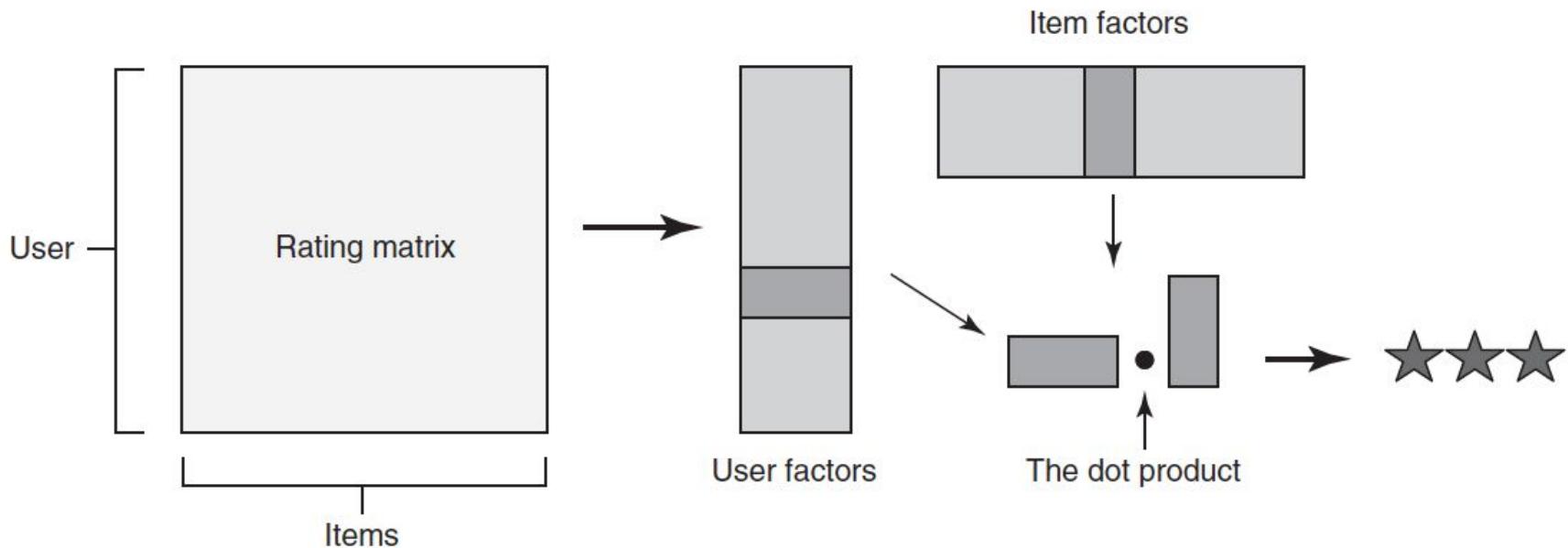
Uses rank\_k to  
return the reduced  
matrices

Calculates the  
deduced matrix M\_hat

$$R = \begin{bmatrix} 5 & 3 & 0 & 2 & 2 & 2 \\ 4 & 3 & 4 & 0 & 3 & 3 \\ 5 & 2 & 5 & 2 & 1 & 1 \\ 3 & 5 & 3 & 0 & 1 & 1 \\ 3 & 3 & 3 & 2 & 4 & 5 \\ 2 & 3 & 2 & 3 & 5 & 5 \end{bmatrix}$$

Sara	4.87	3.11	0.05	2.24	1.94	1.92
Jesper	3.49	3.46	4.19	0.95	2.62	2.82
Therese	5.22	1.80	4.92	1.59	1.10	1.14
Helle	3.25	4.77	2.90	-0.47	1.14	1.13
Pietro	2.93	3.05	3.03	2.11	4.30	4.67
Ekaterina	2.27	2.77	1.89	2.50	4.92	5.35

# Collaborative Filtering: Model-based



# Collaborative Filtering: Funk Factorization

$$\begin{bmatrix} 5 & 3 & 0 & 2 & 2 & 2 \\ 4 & 3 & 4 & 0 & 3 & 3 \\ 5 & 2 & 5 & 2 & 1 & 1 \\ 3 & 5 & 3 & 0 & 1 & 1 \\ 3 & 3 & 3 & 2 & 4 & 5 \\ 2 & 3 & 2 & 3 & 5 & 5 \end{bmatrix} = \begin{bmatrix} u_{1,1} & u_{1,2} \\ u_{2,1} & u_{2,2} \\ u_{3,1} & u_{3,2} \\ u_{4,1} & u_{4,2} \\ u_{5,1} & u_{5,2} \\ u_{6,1} & u_{6,2} \end{bmatrix} \begin{bmatrix} v_{1,1} & v_{1,2} & v_{1,3} & v_{1,4} & v_{1,5} & v_{1,6} \\ v_{2,1} & v_{2,2} & v_{2,3} & v_{2,4} & v_{2,5} & v_{2,6} \end{bmatrix}$$

$$RMSE = \sqrt{\frac{1}{|known|} \sum_{(u,i) \in known} (r_{ui} - u_u v_i)^2}$$

# Collaborative Filtering: More about Funk



Netflix provided a *training* data set of 100,480,507 ratings that 480,189 users gave to 17,770 movies



[<< | Prev | Index | Next | >>]

Monday, December 11, 2006

*Netflix Update: Try This at Home*



At one point Simon Funk was #3 on the list. However, Simon is an independent software developer who works on Netflix prize in his spare time between his trips around New Zealand! He freely published his code and ideas – the first top leader to do so!

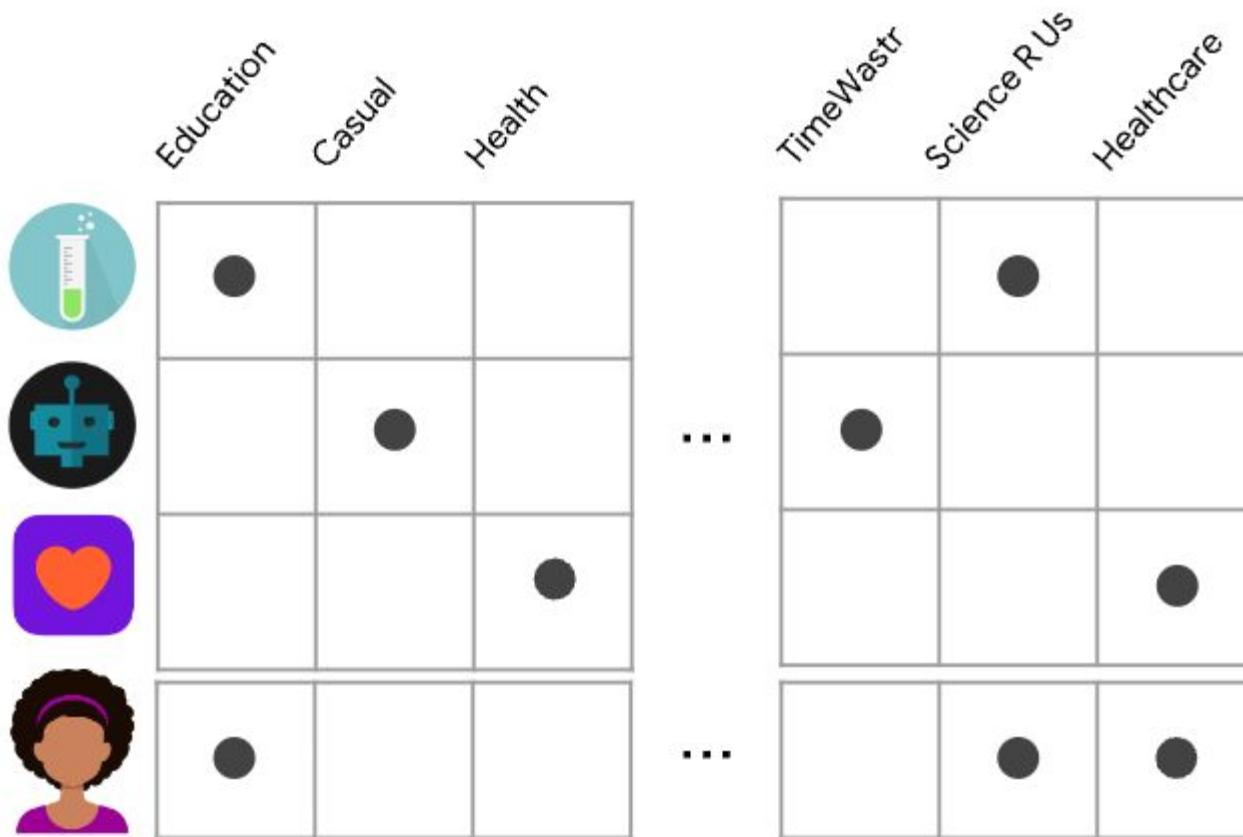
# Collaborative Filtering: Pros & Cons

- No domain knowledge necessary
  - Exploratory
- 
- Sparsity
  - Side features
  - Cold start
  - Gray sheep
  - Not using popularity

# Content-based Filtering

- How to model recommendation problem mathematically.
- Classic recommendation algorithms
  - Collaborative filtering
    - Memory-based filtering
    - Model-based filtering
  - \*Content-based filtering

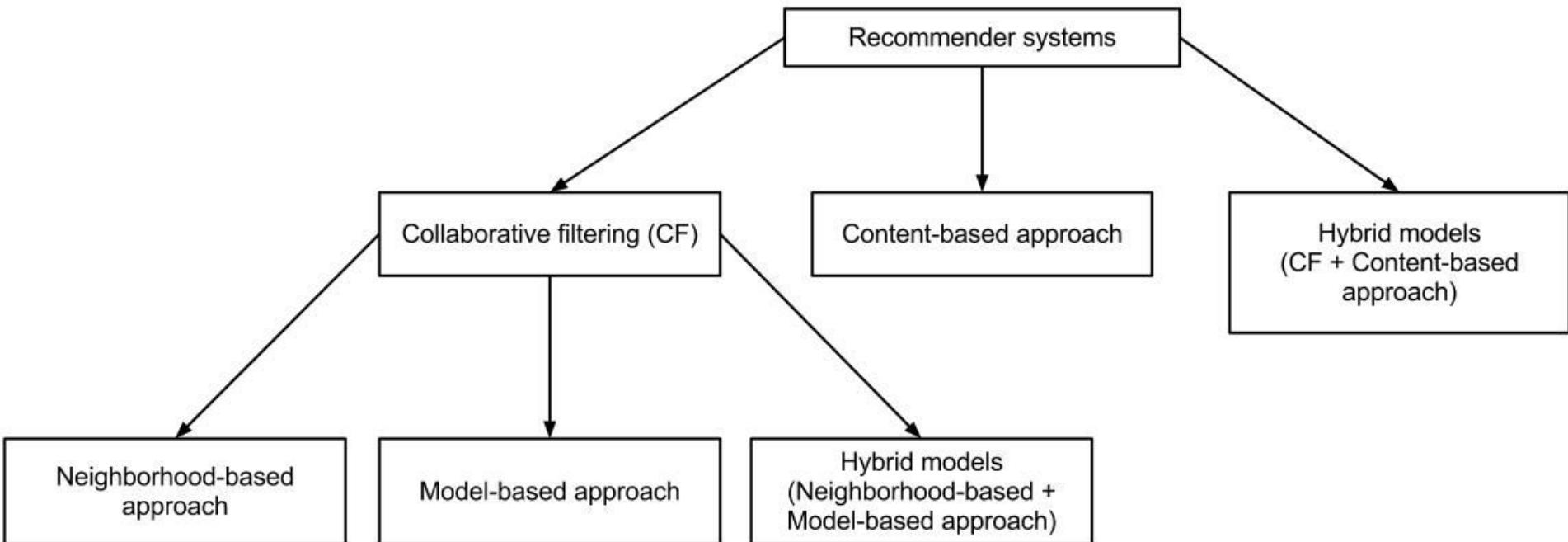
# Content-based Filtering



# Content-based Filtering: Pros & Cons

- Easy to scale
  - Explainable
- 
- Hand-engineered features
  - Not exploratory

# Recommendation System an ML Problem



# Evaluate Recommendation Systems

How likely are you to recommend Windows 10 to a friend or colleague?

1

2

3

4

5

Not at all likely

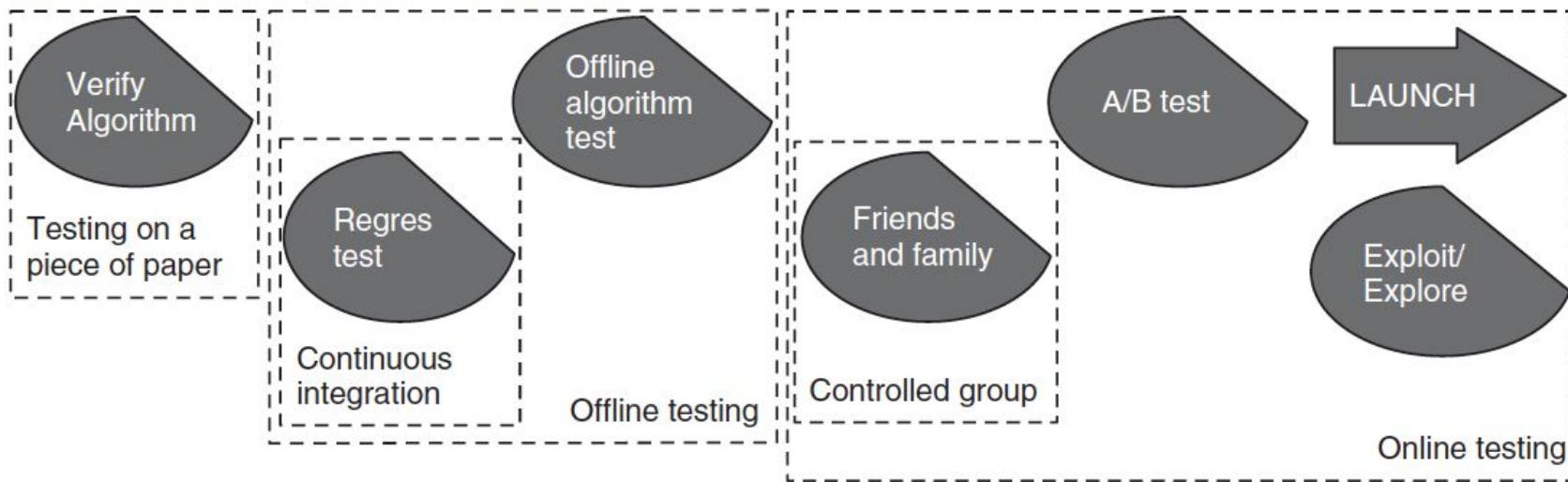
Extremely likely

Please explain why you gave this score.

I need you to understand that people don't have conversations where they randomly recommend operating systems to one another

# Evaluate Recommendation Systems

## Recommender algorithm evaluation:



## Involved:

Engineers

Users

# Evaluate Recommendation Systems

- Goals and Metrics
- Offline Evaluation
- Online Evaluation

# Evaluate Recommendation Systems: Goals

- Accuracy
- Diversity and coverage
- Serendipity
- Scalability

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

MSE = mean squared error

$n$  = number of data points

$Y_i$  = observed values

$\hat{Y}_i$  = predicted values

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

MAE = mean absolute error

$y_i$  = prediction

$x_i$  = true value

$n$  = total number of data points

# Evaluate Recommendation Systems: Goals

- Accuracy
- Diversity and coverage
- Serendipity
- Scalability

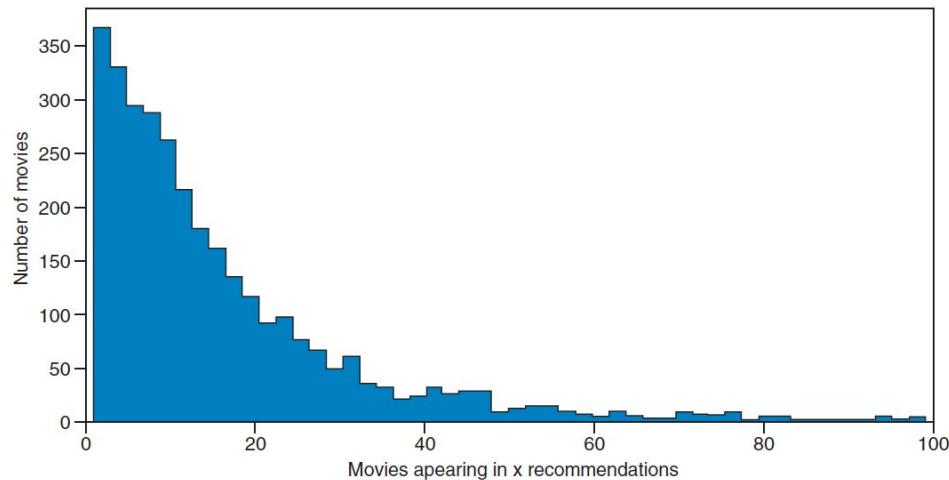
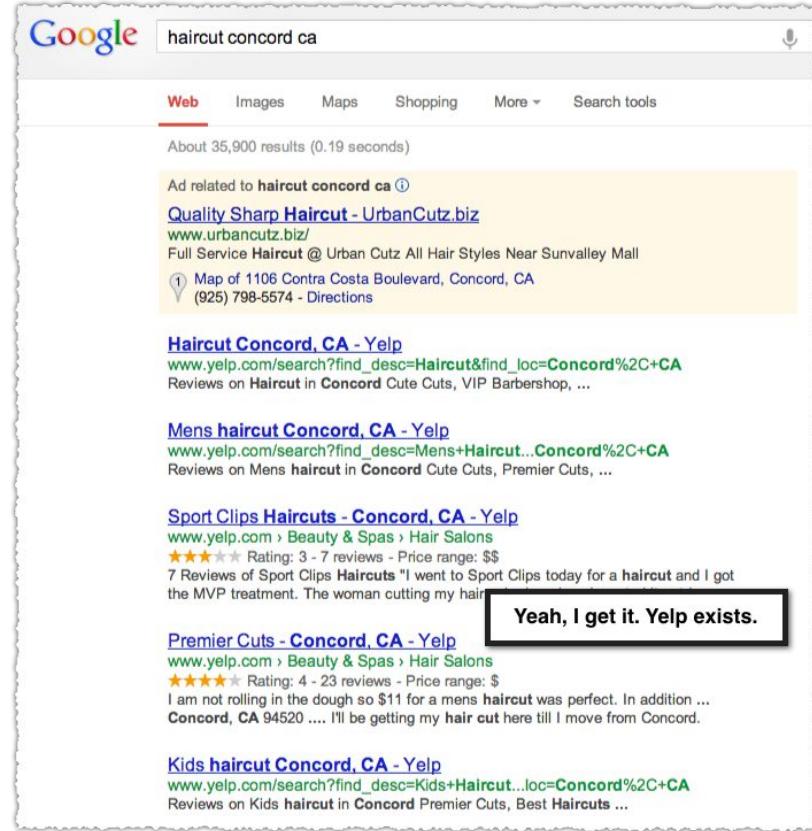


Figure 9.3 How many movies are shown X number of times. More than 350 movies are shown in only one recommendation. Counterintuitively, the movies that are most popular are the ones that are in the long tail.

# Evaluate Recommendation Systems: Goals

- Accuracy
- Diversity and coverage
- Serendipity
- Scalability



Google haircut concord ca

Web Images Maps Shopping More Search tools

About 35,900 results (0.19 seconds)

Ad related to haircut concord ca ⓘ  
[Quality Sharp Haircut - UrbanCutz.biz](#)  
www.urbancutz.biz/  
Full Service Haircut @ Urban Cutz All Hair Styles Near Sunvalley Mall  
Map of 1106 Contra Costa Boulevard, Concord, CA  
(925) 798-5574 - Directions

[Haircut Concord, CA - Yelp](#)  
www.yelp.com/search?find\_desc=Haircut&find\_loc=Concord%2C+CA  
Reviews on Haircut in Concord Cute Cuts, VIP Barbershop, ...

[Mens haircut Concord, CA - Yelp](#)  
www.yelp.com/search?find\_desc=Mens+Haircut...Concord%2C+CA  
Reviews on Mens haircut in Concord Cute Cuts, Premier Cuts, ...

[Sport Clips Haircuts - Concord, CA - Yelp](#)  
www.yelp.com › Beauty & Spas › Hair Salons  
★★★★★ Rating: 3 - 7 reviews - Price range: \$\$  
7 Reviews of Sport Clips Haircuts "I went to Sport Clips today for a haircut and I got the MVP treatment. The woman cutting my hair

Yeah, I get it. Yelp exists.

[Premier Cuts - Concord, CA - Yelp](#)  
www.yelp.com › Beauty & Spas › Hair Salons  
★★★★★ Rating: 4 - 23 reviews - Price range: \$  
I am not rolling in the dough so \$11 for a mens haircut was perfect. In addition ...  
Concord, CA 94520 .... I'll be getting my hair cut here till I move from Concord.

[Kids haircut Concord, CA - Yelp](#)  
www.yelp.com/search?find\_desc=Kids+Haircut...loc=Concord%2C+CA  
Reviews on Kids haircut in Concord Premier Cuts, Best Haircuts ...

# Evaluate Recommendation Systems: Goals

- Accuracy
- Diversity and coverage
- Serendipity
- Scalability

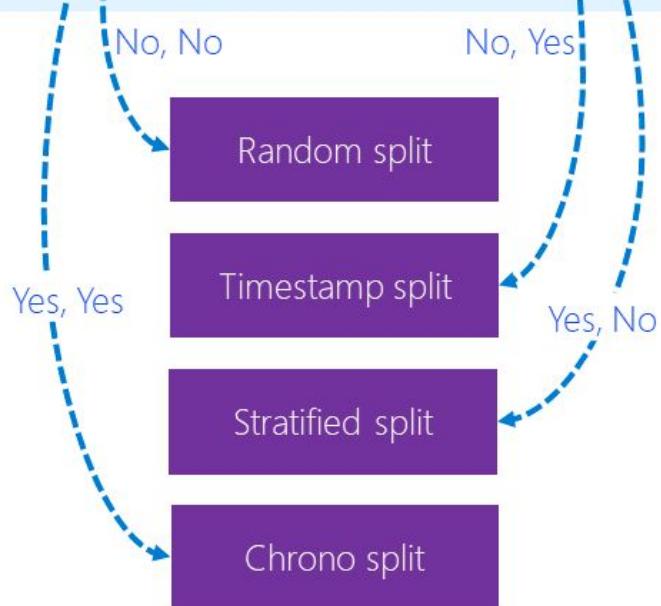


## Evaluate Recommendation Systems: Goals

- Accuracy
- Diversity and coverage
- Serendipity
- Scalability -> More to come tomorrow!

# Evaluate Recommendation Systems: Offline Evaluation - Split

How do you want to split:  
- Stratified?  
- Time dependent?



	Barbie	Openheimer	Spider-Man: Across the Spider-Verse	The Avengers: Endgame	Big Hero 6	Incredibles 2
Sara	5	3		2	2	2
Jesper	4	3	4		3	3
Therese	5	2	5	2	1	1
Helle	3	5	3		1	1
Pietro	3	3	3	2	4	5
Ekaterina	2	3	2	3	5	5

# Evaluate Recommendation Systems: Offline Evaluation - Split

ICME

How do you want to split:  
- Stratified?  
- Time dependent?

No, No

No, Yes

Random split

Timestamp split

Stratified split

Chrono split

Yes, Yes

Yes, No



Sara	5	3		2	2	2
Jesper	4	3	4		3	3
Therese	5	2	5	2	1	1
Helle	3	5	3		1	1
Pietro	3	3	3	2	4	5
Ekaterina	2	3	2	3	5	5

# Evaluate Recommendation Systems: Online Evaluation

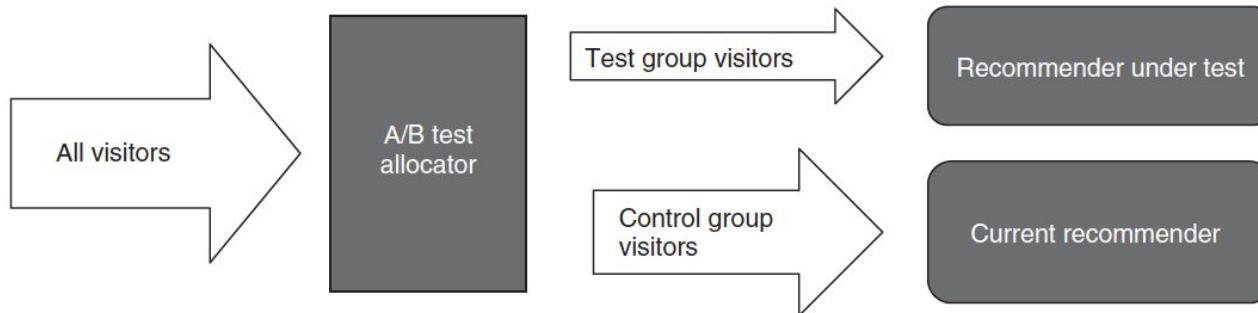


Figure 9.16 In an A/B test, visitors are split into two groups: the test group that sees the new feature and a control group that continues as usual.

# Evaluate Recommendation Systems: Online Evaluation

Success! Results are ready, but the test is still running  
This experiment has been running for 18 days and collected data for 1200 users. Remote config parameters specified for each variant are still being sent to players. Please stop the test to remove players from the experiment.

**COPY** **STOP TEST**

Experiment details

GA Test Game	Config key	Target users	Build(s)	Filter(s)
1 variation(s) of led_place	button_color	100% of new users	0.9	- No filters -

Detailed test results for Retention (Day 1)

	Users exposed	Retention (Day 1) ⓘ	Probability to be the best ⓘ	Improvement over Control ⓘ	Distribution ⓘ
Control group Default value	571	33.84%	2.22%	0% ~ 0%	--
Stop - Winner button_color = red	614	39.42%	97.78%	-7.5% - 40.8%	--

Retention (Day 1)

All variants selected

The chart displays retention rates over a two-week period. The Control group starts at 0%, peaks at 38.0% on Sat 27, and then declines to 0% by Sat 4. The Stop variant starts at 0%, peaks at 50.6% on Sat 27, and remains at 0% thereafter. A legend at the bottom indicates the blue line with circles represents the Control group and the orange line with diamonds represents the Stop variant.

Date	Control group (%)	Stop (%)
Thu 25 Jun 2020	0%	0%
Fri 26	~28%	0%
Sat 27	38.0%	50.6%
Sun 28	~28%	~28%
Mon 29	~30%	~32%
Tue 30	~28%	~32%
Wed 1 Jul 2020	~22%	~32%
Thu 2	~25%	~25%
Fri 3	0%	~22%
Sat 4	0%	0%
Sun 5	0%	0%
Mon 6	0%	0%
Tue 7	0%	0%
Wed 8	0%	0%
Thu 9	0%	0%
Fri 10	0%	0%
Sat 11	0%	0%
Sun 12	0%	0%
Mon 13	0%	0%

# Evaluate Recommendation Systems: Online Evaluation

RETENTION REPORT

Report Settings

Media Source: All Geo: All Date Range: All

Group By: Media Source, Campaign, Adset, Ad

Min Cohort Size: 10 ✓

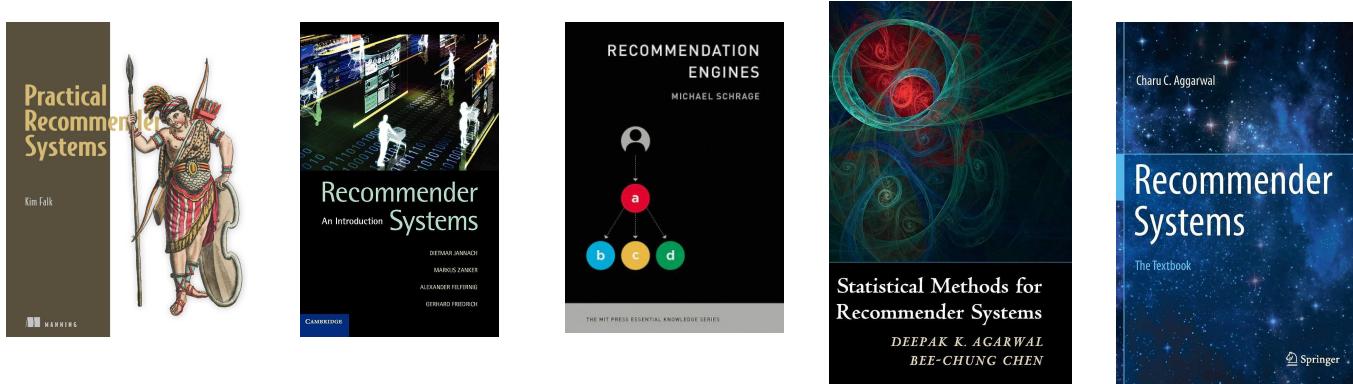
Add More Filters

Media Source	Campaign	Adset	Ad	Install Day	Day 1	Day 2	Day 3	Day 4
organic	N/A	N/A	N/A	100% 5,212	17.19% 896	10.57% 551	8.65% 451	7.77% 405
liftoff_int	iphone	N/A	320x480_C... 	100% 651	15.36% 100	8.45% 55	7.22% 47	6.3% 41
liftoff_int	iphone	N/A	320x480_C... 	100% 649	15.41% 100	9.24% 60	6.78% 44	4.31% 28
Facebook Ads	iOS	iOS Interest AEP	20190404_MWC_2k1...	100% 544	12.68% 69	6.99% 38	4.78% 26	3.86% 21

# Evaluate Recommendation Systems: Online Evaluation



# Reference



	PRS	IRS	RE	SERS	RST
Related Chap.	Chap. 7-11.	Chap. 2, 7	Chap. 1-5.	Chap. 1, 2, 4.	Chap 1-4.
Hao's Rating	5	3	4	2	4

## Coffee Break

Take a 5 minute break



Local Coffee  
Outlet  
Recommender

Based on Yelp data

A white rectangular box containing text and icons related to a local coffee outlet recommender based on Yelp data. It features a blue triangle icon, the text "Local Coffee Outlet Recommender", "Based on Yelp data", and three small icons representing coffee, people, and data analysis.

# Lab Time!

