

Recommender system

Wang Jianfang

王建芳(in Chinese)

September 1, 2020

Plan

- 24(Lesson)+24(Lab.)

Time/Day	Monday	Tuesday	Wednesday	Thursday
8.00-9.50				Recommender system (Chen Feng, Wang <u>Jianfang</u>) (1-6,202)
10.10-12.00		Recommender system (Chen Feng, Wang <u>Jianfang</u>) (1-6,110)		

Agenda

- Concepts
 - Collaborative Filtering
 - Algorithms (user-based)
 - Evaluation Metrics
 - Practise
-

Entertainment

The image shows a screenshot of the YouTube homepage interface. On the left is a dark sidebar with navigation options: Home, Trending, Subscriptions, Library, History, Watch later, Liked videos, and Math. Below these are 'SUBSCRIPTIONS' with channels like The Office, Antastesia, and Supreme Bana... The main area has a search bar at the top and a 'Recommended' section below. A tooltip 'Image for post' points to the first video thumbnail. The recommended videos are arranged in two rows of four. Each video card includes a thumbnail, title, channel name, and view/age information.

Thumbnail	Title	Channel	Views	Age
	How craving attention makes you less creative Joseph...	TED	661K views	6 days ago
	Pride and Prejudice: Marriage Proposal	BBC Studios	2.3M views	11 years ago
	I Ate Like BILLIE EILISH For 24 Hours..	Supreme Banana	97K views	1 week ago
	D'Arcy Carden Talks About Impersonating Her...	Late Night with Seth Meye...	797K views	8 months ago
	TECHNIQUE CRITIQUE S1 - E12 Accent Expert Breaks Down 17 Actors Playing Real...	WIRED		
	La littérature est-elle morte?	Antastesia	6.2K views	20 hours ago
	Kardashians at Area 51	SimgmProductions	235K views	5 days ago
	73 Questions With Olivia Colman Vogue	Vogue	587K views	1 week ago

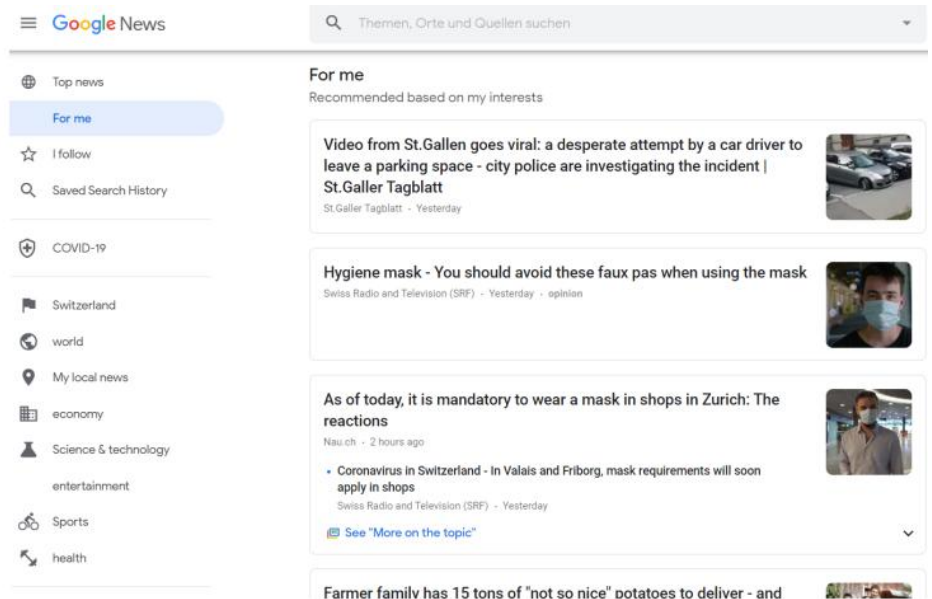
Entertainment



News Recommendation



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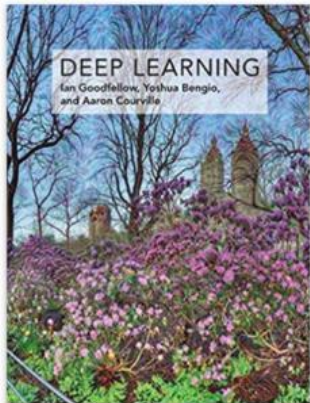


Online Shopping

Deep Learning (Adaptive Computation and Machine Learning)

by Ian Goodfellow (Author), Yoshua Bengio (Author), Aaron Courville (Author)

★★★★☆ 819 ratings



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ISBN-10: 0262035618

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- 腕表 / 眼镜 / 珠宝饰品
- 手机 / 数码 / 电脑办公
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Online Shopping

The image shows the JD.com (京东) homepage. A red rectangle highlights the search bar area, which includes the JD logo, a search input field containing the text "除螨皂" (Deodorant Soap), a camera icon, and a search button. Below the search bar, a horizontal navigation bar lists various categories: "爱家省心装" (Love Home Mindful Design), "图书钜惠" (Book Big Sale), "品质居家" (Quality Home), "5折家电" (50% Off Appliances), "家装建材" (Home Renovation Materials), "抢优惠券" (Grab Coupons), "割草机" (Lawn Mower), "茅台" (Moutai), and "鳗鱼" (Eel). Below this, a row of links includes "秒杀" (Flash Sale), "优惠券" (Coupons), "PLUS会员" (PLUS Member), "品牌闪购" (Brand Flash Sale), "拍卖" (Auction), "京东家电" (JD Appliances), "京东超市" (JD Supermarket), "京东生鲜" (JD Fresh), "京东国际" (JD International), and "京东金融" (JD Finance). The main content area features a large promotional banner for "低至5折再叠券" (Low to 50% Off, Plus More Coupons) for "阿玛尼季末清仓" (Armani End of Season Clearance), with a "立即购买" (Buy Now) button. To the right of the banner is a large image of an Armani watch. On the far right, there are three vertical promotional boxes: "家具家装节 每满300减60" (Furniture Home Decor Festival, Every 300 Yuan off 60 Yuan), "农资畜牧 全场直降" (Agriculture Livestock, Full Site Direct Drop), and "物美价更优 发现品质好物" (Good Quality and Better Price, Discover Quality Goods).

京东

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发现品质好物

Why are
recommender
systems so
pervasive?

Benefits for customers

- Ease information overload
- Sales assistance (guidance, advisory, persuasion,...)
- ...

Benefits for industry

- Improve user experience
- Increase sales
- ...

History

Toward the next generation of recommender systems: a survey of the state-of-the-art and possible extensions

Adomavicius, Gediminas, and Alexander Tuzhilin. 2005

Recommendation Approach	Recommendation Technique	
	Heuristic-based	Model-based
Content-based	<p>Commonly used techniques:</p> <ul style="list-style-type: none"> • TF-IDF (information retrieval) • Clustering <p>Representative research examples:</p> <ul style="list-style-type: none"> • Lang 1995 • Balabanovic & Shoham 1997 • Pazzani & Billsus 1997 	<p>Commonly used techniques:</p> <ul style="list-style-type: none"> • Bayesian classifiers • Clustering • Decision trees • Artificial neural networks <p>Representative research examples:</p> <ul style="list-style-type: none"> • Pazzani & Billsus 1997 • Mooney et al. 1998 • Mooney & Roy 1999 • Billsus & Pazzani 1999, 2000 • Zhang et al. 2002
Collaborative	<p>Commonly used techniques:</p> <ul style="list-style-type: none"> • Nearest neighbor (cosine, correlation) • Clustering • Graph theory <p>Representative research examples:</p> <ul style="list-style-type: none"> • Resnick et al. 1994 • Hill et al. 1995 • Shardanand & Maes 1995 • Breese et al. 1998 • Nakamura & Abe 1998 • Aggarwal et al. 1999 • Delgado & Ishii 1999 • Pennock & Horwitz 1999 • Sarwar et al. 2001 	<p>Commonly used techniques:</p> <ul style="list-style-type: none"> • Bayesian networks • Clustering • Artificial neural networks • Linear regression • Probabilistic models <p>Representative research examples:</p> <ul style="list-style-type: none"> • Billsus & Pazzani 1998 • Breese et al. 1998 • Ungar & Foster 1998 • Chien & George 1999 • Getoor & Sahami 1999 • Pennock & Horwitz 1999 • Goldberg et al. 2001 • Kumar et al. 2001 • Pavlov & Pennock 2002 • Shani et al. 2002 • Yu et al. 2002, 2004 • Hofmann 2003, 2004 • Marlin 2003 • Si & Jin 2003
Hybrid	<p>Combining content-based and collaborative components using:</p> <ul style="list-style-type: none"> • Linear combination of predicted ratings • Various voting schemes • Incorporating one component as a part of the heuristic for the other 	<p>Combining content-based and collaborative components by:</p> <ul style="list-style-type: none"> • Incorporating one component as a part of the model for the other • Building one unifying model <p>Representative research examples:</p>

History

TABLE 2: Overview of collaborative filtering techniques.

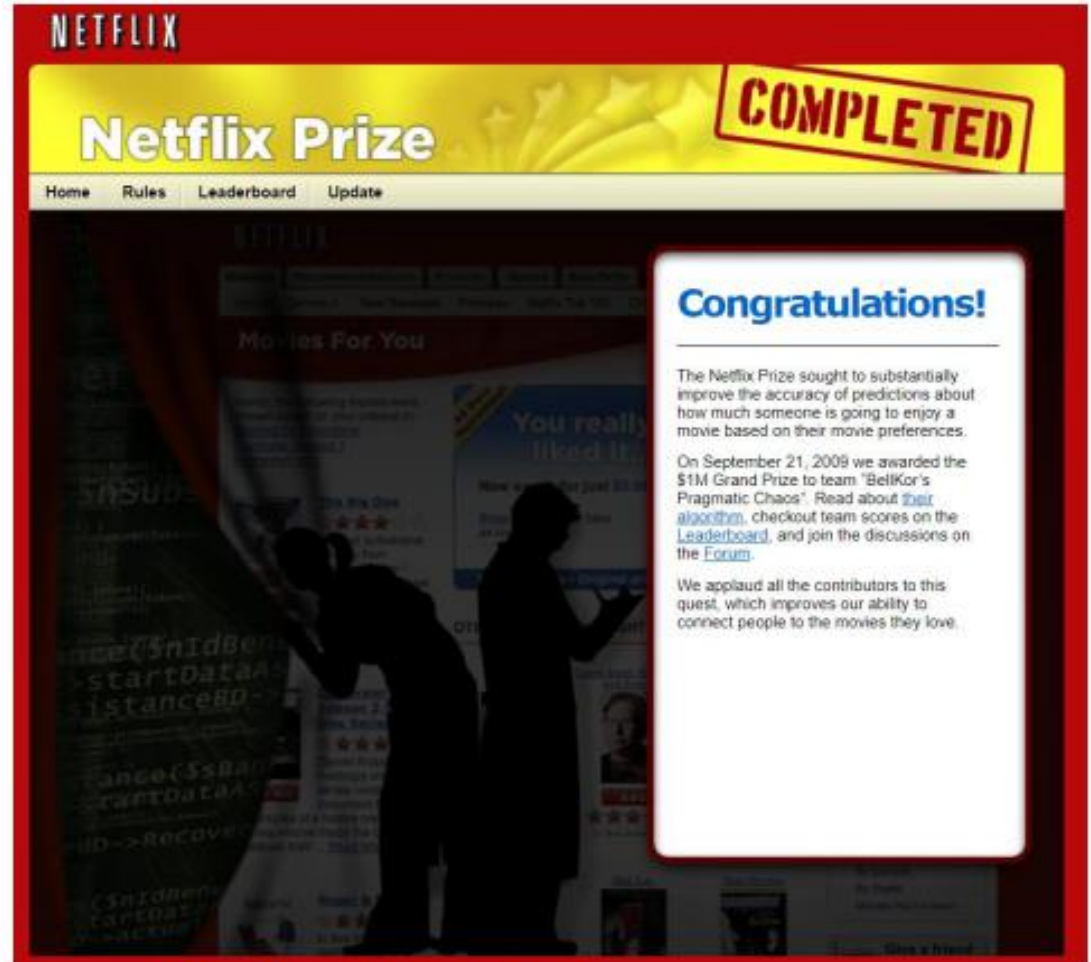
CF categories	Representative techniques	Main advantages	Main shortcomings
Memory-based CF	<ul style="list-style-type: none"> * Neighbor-based CF (item-based/user-based CF algorithms with Pearson/vector cosine correlation) * Item-based/user-based top-N recommendations 	<ul style="list-style-type: none"> * easy implementation * new data can be added easily and incrementally * need not consider the content of the items being recommended * scale well with co-rated items 	<ul style="list-style-type: none"> * are dependent on human ratings * performance decrease when data are sparse * cannot recommend for new users and items * have limited scalability for large datasets
Model-based CF	<ul style="list-style-type: none"> * Bayesian belief nets CF * clustering CF * MDP-based CF * latent semantic CF * sparse factor analysis * CF using dimensionality reduction techniques, for example, SVD, PCA 	<ul style="list-style-type: none"> * better address the sparsity, scalability and other problems * improve prediction performance * give an intuitive rationale for recommendations 	<ul style="list-style-type: none"> * expensive model-building * have trade-off between prediction performance and scalability * lose useful information for dimensionality reduction techniques
Hybrid recommenders	<ul style="list-style-type: none"> * content-based CF recommender, for example, <i>Fab</i> * content-boosted CF * hybrid CF combining memory-based and model-based CF algorithms, for example, Personality Diagnosis 	<ul style="list-style-type: none"> * overcome limitations of CF and content-based or other recommenders * improve prediction performance * overcome CF problems such as sparsity and gray sheep 	<ul style="list-style-type: none"> * have increased complexity and expense for implementation * need external information that usually not available

A Survey of Collaborative Filtering Techniques
 Xiaoyuan Su and Taghi M. Khoshgoftaar
 2009

Netflix Prize

The **Netflix Prize** was an open competition for the best [collaborative filtering algorithm](#) to predict user ratings for [films](#), based on previous ratings without any other information about the users or films.

On September 21, 2009 we awarded the \$1M Grand Prize to team “BellKor’s Pragmatic Chaos”.



<https://www.netflixprize.com/>

Collaborative Filtering (CF)

- The most prominent approach to generate recommendations
 - used by large, commercial e-commerce sites
 - well-understood, various algorithms and variations exist
 - applicable in many domains (book, movies, DVDs, ..)
- Approach
 - use the "wisdom of the crowd" to recommend items
- Basic assumption and idea
 - Users give ratings to catalog items (implicitly or explicitly)
 - Customers who had similar tastes in the past, will have similar tastes in the future



Pure CF Approaches

- Input
 - Only a matrix of given user–item ratings
- Output types
 - A (numerical) prediction indicating to what degree the current user will like or dislike a certain item
 - A top-N list of recommended items

Concepts

■ Collaborative Filtering

- The process of information filtering by collecting human judgments (ratings)
- “word of mouth”

■ User

- Any individual who provides ratings to a system

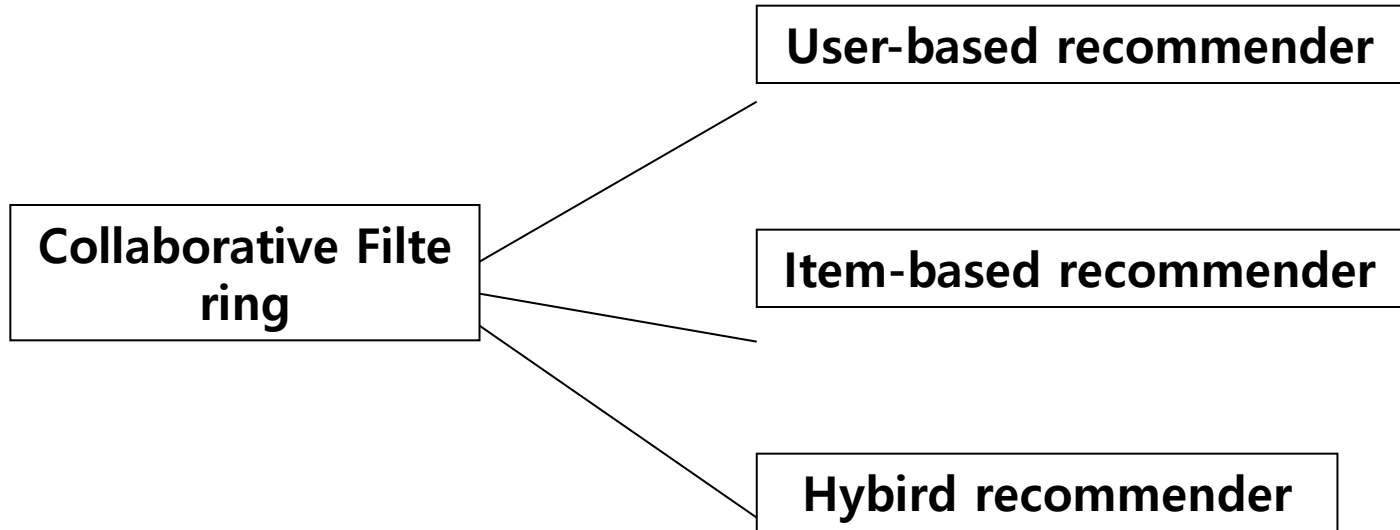
■ Items

- Anything for which a human can provide a rating
-

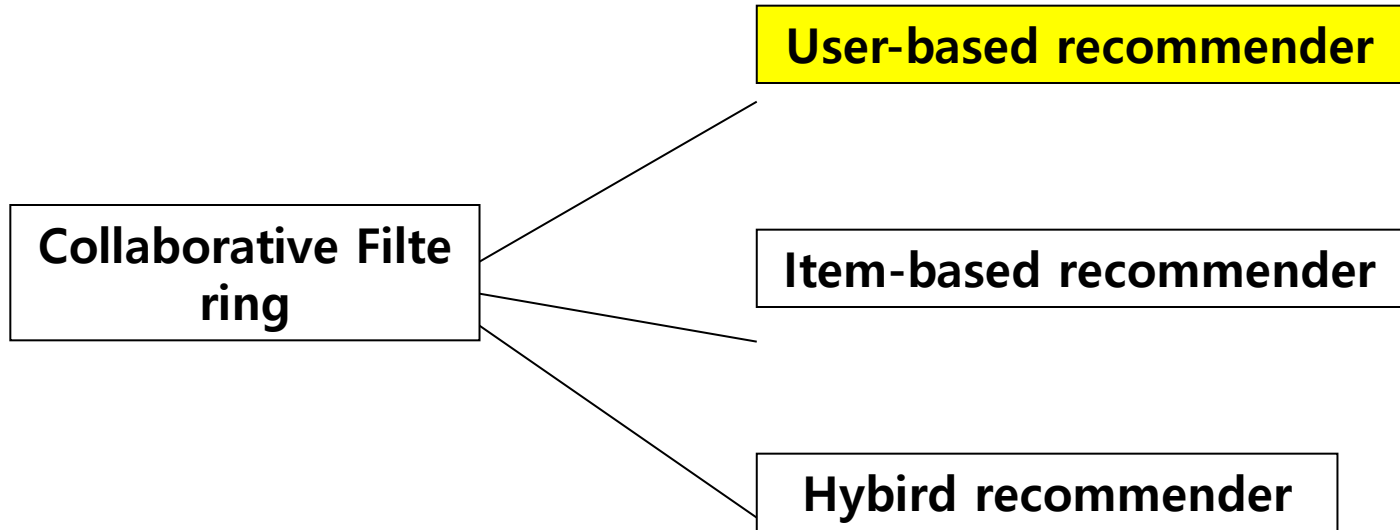
Uses for CF : Domains

- Many items
 - Many ratings
 - Many more users than items recommended
 - Users rate multiple items
 - For each user of the community, there are other users with common needs or tastes
 - Item evaluation requires personal taste
 - Items persists
 - Taste persists
 - Items are homogenous
-

Algorithms



Algorithms



Algorithms : User-Based

■ User-Based Nearest Neighbor

- Neighbor = similar users
- Generate a prediction for an item i by analyzing ratings for i from users in u 's neighborhood

$$pred(u, i) = \bar{r}_u + \frac{\sum_{n \in neighbors(u)} sim(u, n) \cdot (r_{ni} - \bar{r}_n)}{\sum_{n \in neighbors(u)} sim(u, n)}$$

Algorithms : Item-Based

■ Item-Based Nearest Neighbor

- Generate predictions based on similarities between items.
- Prediction for a user u and item i is composed of a weighted sum of the user u 's ratings for items most similar to i .

$$pred(u, i) = \frac{\sum_{j \in ratedItems(u)} sim(i, j) \cdot r_{uj}}{\sum_{j \in ratedItems(u)} sim(i, j)}$$

Practical Issues : Ratings

- Explicit vs. Implicit ratings
 - Explicit ratings
 - Users rate themselves for an item
 - Most accurate descriptions of a user's preference
 - Challenging in collecting data
 - Implicit ratings
 - Observations of user behavior
 - Can be collected with little or no cost to user
 - Ratings inference may be imprecise.

Amazon.com: Books: A Little Book on Perl - Microsoft Internet Explorer

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Customer Reviews

Average Customer Review: ★★★★★
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1 of 1 people found the following review helpful:

★★★★★ **Great for people who already know how to program**, December 5, 2001
Reviewer: **A reader**
This book is great for those who already know how to program in C or C++. I am a C++ programmer and I needed to quickly learn the basics of Perl and this book was great. It's short, concise, and to the point - it got me up and running really fast. Within a few days, I was writing useful small scripts and ready to move on to some more advanced materials, including the O'Reilly books on Perl.

I think only one addition would make this book even better: have a list of resources (other books, web sites) at the end of each chapter to find more information about certain topics. For instance, the chapter on CGI programming can point readers to Lincoln Stein's book on CGI.pm for more detailed information.

Was this review helpful to you? [\(Report this\)](#)

2 of 2 people found the following review helpful:

★★★★★ **Mediocre at Best**, April 11, 2001
Reviewer: **A reader**
We are using this book in my Perl class, and the general consensus is that this book is mediocre at best. Much of this comes from the fact that we are required to do the exercises at the back of the book, which, among other things, sometimes require you know information that has not yet been covered. Also some of the chapters do a poor job at explaining things, especially the functions chapter, in which even the examples in the chapter did not work when compiled. To be fair, the book is not perfect, but the fact that it is short

Amazon.com: Books: A Little Book on Perl - Microsoft Internet Explorer

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- ☐ Perl (Computer program language)
- ☐ Programming Languages - CGI, Javascript, Perl, VBScript
- ☐ Computers / Programming Languages / CGI, JavaScript, Perl, VBScript


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Practical Issues : Ratings

■ Rating Scales

□ Scalar ratings

- Numerical scales
- 1-5, 1-7, etc.

□ Binary ratings

- Agree/Disagree, Good/Bad, etc.

□ Unary ratings

- Good, Purchase, etc.
- Absence of rating indicates no information

User-based nearest-neighbor collaborative filtering (1)

■ The basic technique

- Given an "active user" (Alice) and an item i not yet seen by Alice
 - find a set of users (peers/nearest neighbors) who liked the same items as Alice in the past **and** who have rated item i
 - use, e.g. the average of their ratings to predict, if Alice will like item i
 - do this for all items Alice has not seen and recommend the best-rated

■ Basic assumption and idea

- If users had similar tastes in the past they will have similar tastes in the future
- User preferences remain stable and consistent over time

User-based nearest-neighbor collaborative filtering (2)

■ Example

- A database of ratings of the current user, Alice, and some other users is given:

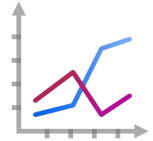
	Item1	Item2	Item3	Item4	Item5
Alice	5	3	4	4	?
User1	3	1	2	3	3
User2	4	3	4	3	5
User3	3	3	1	5	4
User4	1	5	5	2	1

- Determine whether Alice will like or dislike *Item5*, which Alice has not yet rated or seen

User-based nearest-neighbor collaborative filtering (3)

■ Some first questions

- How do we measure similarity?
- How many neighbors should we consider?
- How do we generate a prediction from the neighbors' ratings?



	Item1	Item2	Item3	Item4	Item5
Alice	5	3	4	4	?
User1	3	1	2	3	3
User2	4	3	4	3	5
User3	3	3	1	5	4
User4	1	5	5	2	1

Measuring user similarity (1)

■ A popular similarity measure in user-based CF: Pearson correlation

a, b : users

$r_{a,p}$: rating of user a for item p

P : set of items, rated both by a and b

- Possible similarity values between -1 and 1

$$\text{sim}(a, b) = \frac{\sum_{p \in P} (r_{a,p} - \bar{r}_a)(r_{b,p} - \bar{r}_b)}{\sqrt{\sum_{p \in P} (r_{a,p} - \bar{r}_a)^2} \sqrt{\sum_{p \in P} (r_{b,p} - \bar{r}_b)^2}}$$

Measuring user similarity (2)

■ A popular similarity measure in user-based CF: Pearson correlation

a, b : users

$r_{a,p}$: rating of user a for item p

P : set of items, rated both by a and b

- Possible similarity values between -1 and 1

	Item1	Item2	Item3	Item4	Item5
Alice	5	3	4	4	?
User1	3	1	2	3	3
User2	4	3	4	3	5
User3	3	3	1	5	4
User4	1	5	5	2	1



sim = 0,85

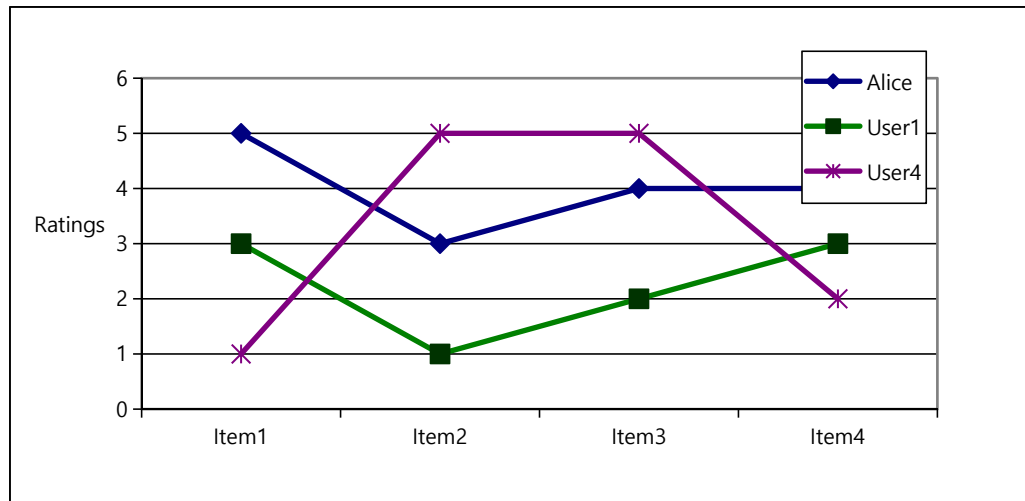
sim = 0,00

sim = 0,70

sim = -0,79

Pearson correlation

- Takes differences in rating behavior into account



- Works well in usual domains, compared with alternative measures
 - such as cosine similarity

Making predictions

- A common prediction function:

$$pred(a, p) = \bar{r}_a + \frac{\sum_{b \in N} sim(a, b) * (r_{b,p} - \bar{r}_b)}{\sum_{b \in N} sim(a, b)}$$



- Calculate, whether the neighbors' ratings for the unseen item i are higher or lower than their average
- Combine the rating differences – use the similarity with a as a weight
- Add/subtract the neighbors' bias from the active user's average and use this as a prediction

similarity function

- Pearson

$$\text{sim}(a, b) = \frac{\sum_{p \in P} (r_{a,p} - \bar{r}_a)(r_{b,p} - \bar{r}_b)}{\sqrt{\sum_{p \in P} (r_{a,p} - \bar{r}_a)^2} \sqrt{\sum_{p \in P} (r_{b,p} - \bar{r}_b)^2}}$$

- Cosine Similarity

$$w_{uv} = \frac{|N(u) \cap N(v)|}{|N(u) \cup N(v)|}$$

- Jaccard

$$w_{uv} = \frac{|N(u) \cap N(v)|}{\sqrt{|N(u)| |N(v)|}}$$

similarity function

■ Pearson

$$\text{sim}(a, b) = \frac{\sum_{p \in P} (r_{a,p} - \bar{r}_a)(r_{b,p} - \bar{r}_b)}{\sqrt{\sum_{p \in P} (r_{a,p} - \bar{r}_a)^2} \sqrt{\sum_{p \in P} (r_{b,p} - \bar{r}_b)^2}}$$

■ Pearson(simpler)

$$r = \frac{\sum_{XY} - \frac{\sum X \sum Y}{N}}{\sqrt{(\sum X^2 - \frac{(\sum X)^2}{N})(\sum Y^2 - \frac{(\sum Y)^2}{N})}}$$

- Pearson(simpler)

$$r = \frac{\sum XY - \frac{\sum X \sum Y}{N}}{\sqrt{(\sum X^2 - \frac{(\sum X)^2}{N})(\sum Y^2 - \frac{(\sum Y)^2}{N})}}$$

- X rating is [1, 2, 3] , Y rating is [2, 5, 6]. what is the person similarity.

Pratise

- How to get the similarity?

$$sim(a,b) = \frac{\sum_{p \in P} (r_{a,p} - \bar{r}_a)(r_{b,p} - \bar{r}_b)}{\sqrt{\sum_{p \in P} (r_{a,p} - \bar{r}_a)^2} \sqrt{\sum_{p \in P} (r_{b,p} - \bar{r}_b)^2}}$$

	Item1	Item2	Item3	Item4	Item5
Alice	5	3	4	4	?
User1	3	1	2	3	3
User2	4	3	4	3	5
User3	3	3	1	5	4
User4	1	5	5	2	1



sim = 0,85

sim = 0,00

sim = 0,70

sim = -0,79

similarity function

- Pearson

$$\text{sim}(a, b) = \frac{\sum_{p \in P} (r_{a,p} - \bar{r}_a)(r_{b,p} - \bar{r}_b)}{\sqrt{\sum_{p \in P} (r_{a,p} - \bar{r}_a)^2} \sqrt{\sum_{p \in P} (r_{b,p} - \bar{r}_b)^2}}$$


- Pearson correlation coefficient formula is used to calculate the correlation coefficient of XY to verify the correctness of the code

$$\rho_{X,Y} = \frac{\text{COV}(X, Y)}{\sigma_X \sigma_Y} = \frac{E[(X - \mu_X)(Y - \mu_Y)]}{\sigma_X \sigma_Y} = \frac{E(XY) - E(X)E(Y)}{\sqrt{E[X^2] - E[X]^2} \sqrt{E[Y^2] - E[Y]^2}}$$

Homework

- ex1. gaining the Pearson similarity by the detail process .
(Alice with user1, user2,user3,user4) .

	Item1	Item2	Item3	Item4	Item5
Alice	5	3	4	4	?
User1	3	1	2	3	3
User2	4	3	4	3	5
User3	3	3	1	5	4
User4	1	5	5	2	1



sim = 0,85
sim = 0,00
sim = 0,70
sim = -0,79

ex2. reading the file(1.1-collaborative filtering.pdf) , and memeory th
e user-based collaborative filtering algorithm mainly consists of two
steps, and understand the Cosine Similarity.

ex3. setup Anaconda3 software.

Questions and Comments?

Thank you!!
