Data Mining

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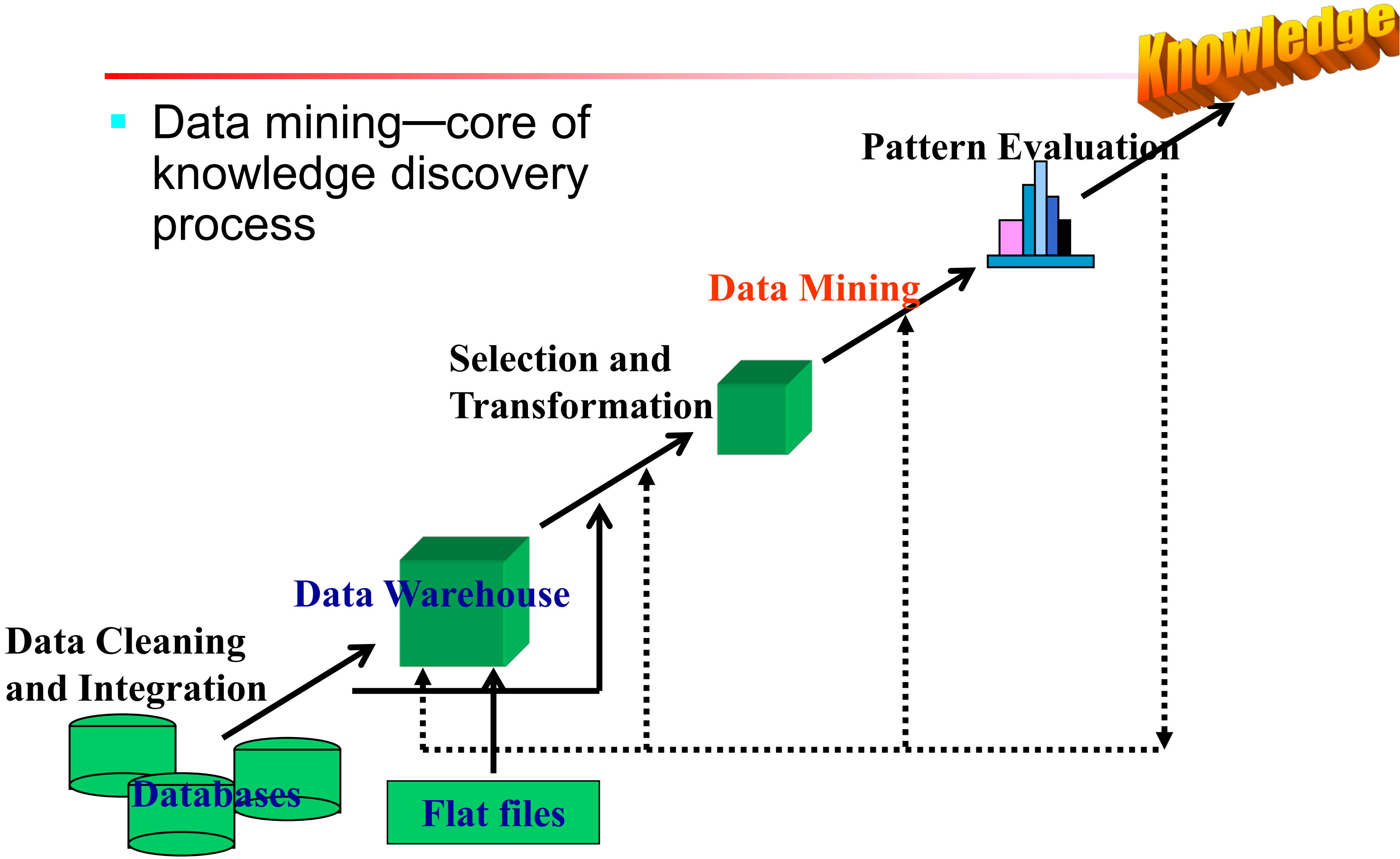
Review

- Data mining—core of knowledge discovery process



Outline

- What is Recommender System?
- Recommendation Algorithms
- Evaluation of Recommender Systems

Motivation

- Which digital camera should I buy?
- Where should I spend my holiday?
- Which movie should I see?
- Whom should I follow?
- Where should I find interesting news article?

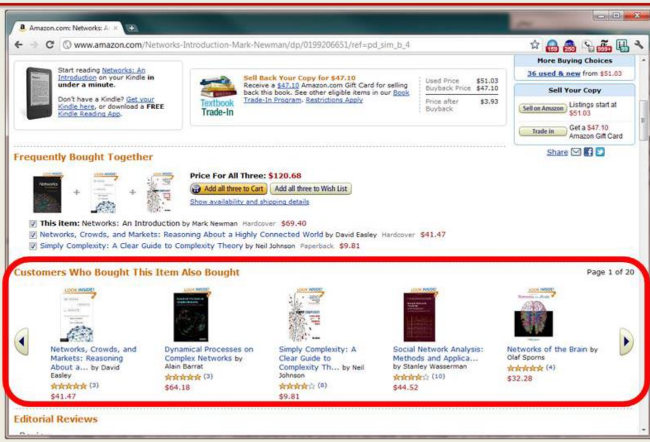
Motivation

- There are many choices
- There are no obvious advantages among them
- We do not have enough resources to check all options (*information overload*)
- We do not have enough knowledge and experience to choose

- Solution
  - ***Recommendation: automatically come up with a short list of items that fits user's interests!***

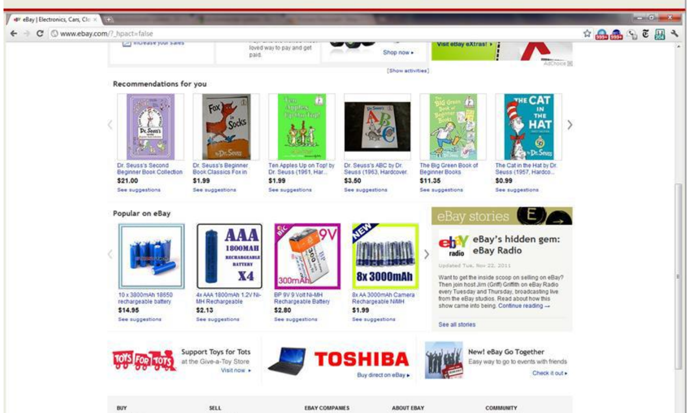
Examples

Book recommendation in Amazon

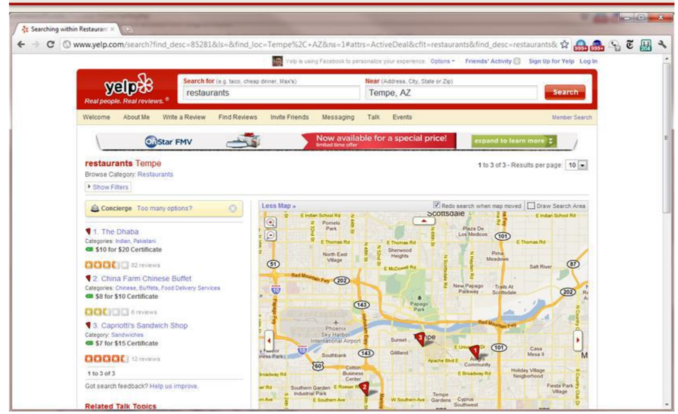


Video clip recommendation in YouTube

Product Recommendation in ebay



Restaurant Recommendation in Yelp



Recommender Systems

- Idea: Use historical data such as the user's past preferences or similar users' past preferences to predict future likes
- Basic assumption
  - Users' preferences are likely to remain stable, and change smoothly over time
  - Users with similar tastes have similar ratings for an item
- By watching the past users' or groups' preferences, try to predict their future likes
  - Then we can recommend items of interest to them

Recommender Systems

- Formally, a recommender system takes a set of users U and a set of items I and *learns a function f* such that:

$$f : U \times I \to \mathbb{R}$$

Recommendation vs. Search

- One way to get answers is using search engines
- Search engines find results that match the query provided by the user
- The results are generally provided as a list ordered with respect to the relevance of the item to the given query
- Consider the query “best 2014 movie to watch”
  - The same results for an 8 year old and an adult

Search engines’ results are not customized!

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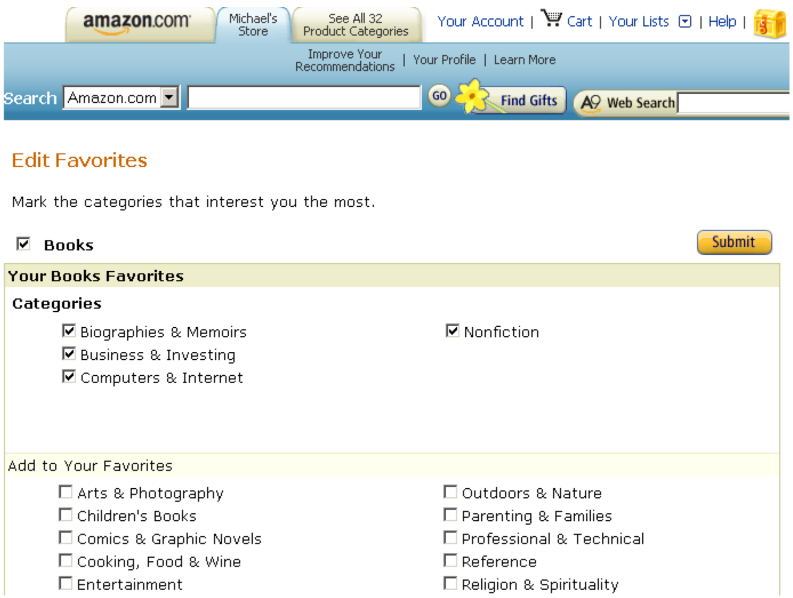
Content-based Methods

- Content-based methods are based on the fact that a user's interest should match the description of the items that she should be recommended
- The more similar the item's description to that of the user's interest, the more likely the user finds the item's recommendation interesting
- Core idea: Find the similarity between the user and all of the existing items

Example


amazon.com
Michael's Store
See All 32 Product Categories
Your Account | Cart | Your Lists | Help |
Improve Your Recommendations | Your Profile | Learn More
Search Amazon.com
GO
Find Gifts
Web Search
Edit Favorites
Mark the categories that interest you the most.
Books
Submit
Your Books Favorites
Categories
Biographies & Memoirs
Business & Investing
Computers & Internet
Nonfiction
Add to Your Favorites
Arts & Photography
Children's Books
Comics & Graphic Novels
Cooking, Food & Wine
Entertainment
Outdoors & Nature
Parenting & Families
Professional & Technical
Reference
Religion & Spirituality


amazon.com
Michael's Store
See All 32 Product Categories
Your Account | Cart | Your Lists | Help |
Improve Your Recommendations | Your Profile | Learn More
Search Amazon.com
GO
Find Gifts
Web Search
Recommended For You > Books
Recommendations by Category in Books
Your Favorites Edit
Business & Investing
Computers & Internet
Biographies & Memoirs
Nonfiction
More Categories
Arts & Photography
Children's Books
Comics & Graphic Novels
Cooking, Food & Wine
Entertainment
Gay & Lesbian
Health, Mind & Body
History
Home & Garden
These recommendations are based on items you own and more.
view: All | New Releases | Coming Soon
More results
1.
The Search: How Google and Its Rivals Rewrote the Rules of Business and Transformed Our Culture
by John Battelle
Average Customer Review:
Publication Date: September 8, 2005
Our Price: $16.35
Used & new from $10.95
Add to cart
Add to Wish List
I Own It
Not interested
Rate it
Recommended because you purchased Amazonia and more (edit)
2.
Writing Successful Science Proposals
by Andrew J. Friedland, Carol L Folt
Average Customer Review:
Publication Date: June 10, 2000

Content-based Methods

- Steps

1. Describe the items to be recommended
2. Create a profile of the user that describes the types of items the user likes
3. Compare items with the user profile to determine what to recommend

Content-based Algorithm

- 1. Represent both user profiles and item descriptions by vectorizing them using a set of *k* keywords
- 2. Vectorize (e.g., using TF-IDF) both users and items and compute their similarity

$$I_j = (i_{j,1}, i_{j,2}, \ldots, i_{j,k}) \qquad U_i = (u_{i,1}, u_{i,2}, \ldots, u_{i,k}).$$

余弦相似度

$$sim(U_i, I_j) = cos(U_i, I_j) = \frac{\sum_{l=1}^{k} u_{i,l} i_{j,l}}{\sqrt{\sum_{l=1}^{k} {u_{i,l}}^2} \sqrt{\sum_{l=1}^{k} {i_{j,l}}^2}}$$

- 3. Recommend the top most similar items to the user

如果没有内容

⇓ 协同过滤

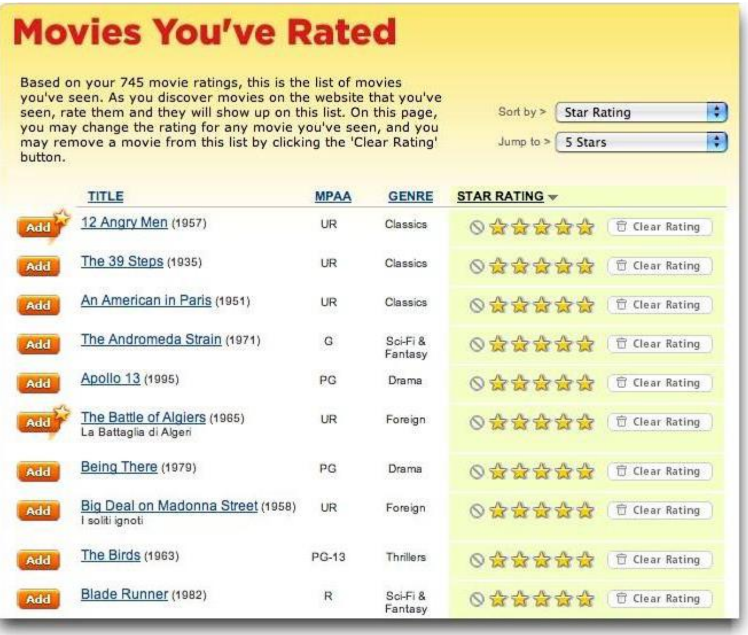
Collaborative Filtering

- Assumption
  - User-based CF
    - Users with similar previous ratings for items are likely to rate future items similarly
  - Item-based CF
    - Items that have received similar ratings previously from users are likely to receive similar ratings from future users (item-based CF)

	I1	I2	I3	I4
U1	1	2	4	4
U2	1	2	4	?
U3	2	5	2	2
U4	5	2	3	3

	I1	I2	I3	I4
U1	1	2	4	4
U2	1	2	4	?
U3	2	5	2	2
U4	5	2	3	3

Example



Movies You've Rated

Based on your 745 movie ratings, this is the list of movies you've seen. As you discover movies on the website that you've seen, rate them and they will show up on this list. On this page, you may change the rating for any movie you've seen, and you may remove a movie from this list by clicking the 'Clear Rating' button.

Sort by > Star Rating

Jump to > 5 Stars

	TITLE	MPAA	GENRE	STAR RATING	
Add	12 Angry Men (1957)	UR	Classics	★★★★★	Clear Rating
Add	The 39 Steps (1935)	UR	Classics	★★★★★	Clear Rating
Add	An American in Paris (1951)	UR	Classics	★★★★★	Clear Rating
Add	The Andromeda Strain (1971)	G	Sci-Fi & Fantasy	★★★★★	Clear Rating
Add	Apollo 13 (1995)	PG	Drama	★★★★★	Clear Rating
Add	The Battle of Algiers (1965) La Battaglia di Algeri	UR	Foreign	★★★★★	Clear Rating
Add	Being There (1979)	PG	Drama	★★★★★	Clear Rating
Add	Big Deal on Madonna Street (1958) I soliti ignoti	UR	Foreign	★★★★★	Clear Rating
Add	The Birds (1963)	PG-13	Thrillers	★★★★★	Clear Rating
Add	Blade Runner (1982)	R	Sci-Fi & Fantasy	★★★★★	Clear Rating

Value	Graphic representation	Textual representation
5	☆ ☆ ☆ ☆ ☆	Excellent
4	☆ ☆ ☆ ☆	Very good
3	☆ ☆ ☆	Good
2	☆ ☆	Fair
1	☆	Poor

Table 9.1: User-Item Matrix

	Lion King	Aladdin	Mulan	Anastasia
John	3	0	3	3
Joe	5	4	0	2
Jill	1	2	4	2
Jane	3	?	1	0
Jorge	2	2	0	1

Collaborative Filtering

- Rating matrix
  - **Explicit ratings:** entered by a user directly
    - i.e., “Please rate this on a scale of 1-5”

  - **Implicit ratings:** inferred from other user behavior
    - Play lists or music listened to, for a music Rec system
    - The amount of time users spent on a webpage

Collaborative Filtering Algorithm

- Steps

  1. Weigh all users/items with respect to their similarity with the current user/item
  2. Select a subset of the users/items (neighbors) as recommenders
  3. Predict the rating of the user for specific items using neighbors’ ratings for the same (or similar) items
  4. Recommend items with the highest predicted rank

Collaborative Filtering Algorithm

- Measure Similarity between Users (or Items)

$$sim(U_i, U_j) = cos(U_i, U_j) = \frac{U_i \cdot U_j}{||U_i|| \, ||U_j||} = \frac{\sum_k r_{i,k} r_{j,k}}{\sqrt{\sum_k {r_{i,k}}^2} \sqrt{\sum_k {r_{j,k}}^2}}$$

- Pearson Correlation Coefficient

$$sim(U_i, U_j) = \frac{\sum_k (r_{i,k} - \bar{r}_i)(r_{j,k} - \bar{r}_j)}{\sqrt{\sum_k (r_{i,k} - \bar{r}_i)^2} \sqrt{\sum (r_{j,k} - \bar{r}_j)^2}}$$

Collaborative Filtering Algorithm

Updating the ratings:

User v's mean rating

User u's mean rating

$$r_{u,i} = \bar{r}_u + \frac{\sum_{v \in N(u)} sim(u,v)(r_{v,i} - \bar{r}_v)}{\sum_{v \in N(u)} sim(u,v)},$$

Predicted rating of user u for item i

Observed rating of user v for item i

$\bar{r}_{user1} = \frac{10}{4} = 2.5$

$\bar{r}_2 = \frac{12}{\ } = 4$

$9+25+16$

Example

$\bar{r}_3 = \frac{6}{4} = 1.5$

$\bar{r}_4 = \frac{10}{4} = 2.5$

$\bar{r}_5 = \frac{10}{4} = 2.5$

	Lion King	Aladdin	Mulan	Anastasia
John	3	0	3	3
Joe	5	4	0	2
Jill	1	2	4	2
Jane	3	?	1	0
Jorge	2	2	0	1

Predict Jane's rating for Aladdin

1- Calculate average ratings

$$\bar{r}_{John} = \frac{3+3+0+3}{4} = 2.25$$

$$\bar{r}_{Joe} = \frac{5+4+0+2}{4} = 2.75$$

$$\bar{r}_{Jill} = \frac{1+2+4+2}{4} = 2.25$$

$$\bar{r}_{Jane} = \frac{3+1+0}{3} = 1.33$$

$$\bar{r}_{Jorge} = \frac{2+2+0+1}{4} = 1.25$$

2- Calculate user-user similarity

$$sim(Jane, John) = \frac{3\times3+1\times3+0\times3}{\sqrt{10}\sqrt{27}} = 0.73$$

$$sim(Jane, Joe) = \frac{3\times5+1\times0+0\times2}{\sqrt{10}\sqrt{29}} = 0.88$$

$$sim(Jane, Jill) = \frac{3\times1+1\times4+0\times2}{\sqrt{10}\sqrt{21}} = 0.48$$

$$sim(Jane, Jorge) = \frac{3\times2+1\times0+0\times1}{\sqrt{10}\sqrt{5}} = 0.84$$

$sim(u_2, u_1) = \frac{3+25+12}{\ldots} = 0.96$

$\text{sim}(u_2, u_3) = \frac{3+5+4}{\sqrt{50}\cdot\sqrt{13}} = 0.98$

$\text{sim}(u_2, u_4) = \frac{12+10+4}{\sqrt{50}\cdot\sqrt{21}} = 0.80$

$\text{sim}(u_2, u_5) = \frac{6+10+16}{\sqrt{50}\cdot\sqrt{24}} = 0.92$

Example

3- Calculate Jane's rating for Aladdin,
Assume that neighborhood size = 2

$$
\begin{aligned}
r_{Jane,Aladdin} &= \bar{r}_{Jane} + \frac{sim(Jane, Joe)(r_{Joe,Aladdin} - \bar{r}_{Joe})}{sim(Jane, Joe) + sim(Jane, Jorge)} \\
&+ \frac{sim(Jane, Jorge)(r_{Jorge,Aladdin} - \bar{r}_{Jorge})}{sim(Jane, Joe) + sim(Jane, Jorge)} \\
&= 1.33 + \frac{0.88(4 - 2.75) + 0.84(2 - 1.25)}{0.88 + 0.84} = 2.33
\end{aligned}
$$

$\cancel{0.96(1-2.5)} + 0.98(3-1.5)$

0.96 × 0.98

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Outline

- What is Recommender System?
- Recommendation Algorithms
- Evaluation of Recommender Systems

Evaluation is Challenging

- Different algorithms may be better or worse on different datasets (applications)
  - Many algorithms are designed specifically for datasets
  - Differences exist for rating density, rating scale, and other properties of datasets
- The goals to perform evaluation may differ
  - Early evaluation work focused specifically on the "accuracy" in "predicting"
  - Other properties also have important effect on user satisfaction and performance

Evaluation is Challenging

- It is challenge in deciding what combination of measures should be used in comparative evaluation

Predictive Accuracy Metrics

- Mean Absolute Error (*MAE*) measures the average absolute deviation between a predicted rating (p) and the user's true rating (r)
  - NMAE = MAE/(r_{max}–r_{min})

$$MAE = \frac{\sum_{ij} |\hat{r}_{ij} - r_{ij}|}{n}$$

- Root Mean Square Error (*RMSE*) is similar to *MAE*, but places more emphasis on larger deviation

$$RMSE = \sqrt{\frac{1}{n}\sum_{i,j}(\hat{r}_{ij} - r_{ij})^2}$$

Example

Consider the following table with both the predicted ratings and true ratings of five items

Item	*Predicted Rating*	*True Rating*
1	1	3
2	2	5
3	3	3
4	4	2
5	4	1

$$
\begin{aligned}
MAE &= \frac{|1-3|+|2-5|+|3-3|+|4-2|+|4-1|}{5} = 2 \\
NMAE &= \frac{MAE}{5-1} = 0.5 \\
RMSE &= \sqrt{\frac{(1-3)^2+(2-5)^2+(3-3)^2+(4-2)^2+(4-1)^2}{5}} \\
&= 2.28
\end{aligned}
$$

Relevance: Precision and Recall

- **Precision:** a measure of exactness, determines the fraction of relevant items retrieved out of all items retrieved

$$P = \frac{N_{rs}}{N_s}$$

- **Recall:** a measure of completeness, determines the fraction of relevant items retrieved out of all relevant items

$$R = \frac{N_{rs}}{N_r}$$

	Selected	Not Selected	Total
Relevant	N_{rs}	N_{rn} 推荐但没选	N_r
Irrelevant	N_{is}	N_{in}	N_i
Total	N_s	N_n	N

Example

	Selected	*Not Selected*	*Total*
Relevant	*9*	*15*	*24*
Irrelevant	*3*	*13*	*16*
Total	*12*	*28*	*40*

$$P = \frac{9}{12} = 0.75$$

$$R = \frac{9}{24} = 0.375$$

$$F = \frac{2 \times 0.75 \times 0.375}{0.75 + 0.375} = 0.5$$

Evaluating Ranking

推荐的先后顺序

- Spearman's Rank Correlation

$$\rho = 1 - \frac{6\sum_{i=1}^{n}(x_i - yi)^2}{n^3 - n}$$

- Kendall's τ
  - It checks the concordant the items of the recommended ranking list against the ground truth ranking list
  - If the two orders are consistent, it is concordant
  - For top 4 items in ranking list, there are 4*3/2=6 pairs

$$\tau = \frac{c-d}{\binom{n}{2}} \quad C_n^2$$

where c is the number of concordants and d of disconcordants

Example

Consider a set of four items I = {i_1 , i_2 , i_3 , i_4} for which the predicted and true rankings are as follows

	Predicted Rank	*True Rank*
i_1	1	1
i_2	2	4
i_3	3	2
i_4	4	3

→ discordant

Pair of items and their status {concordant/discordant} are

(i_1, i_2) : *concordant*

(i_1, i_3) : *concordant*

(i_1, i_4) : *concordant*

(i_2, i_3) : *discordant*

(i_2, i_4) : *discordant*

(i_3, i_4) : *concordant*

顺序对

$$\tau = \frac{4-2}{6} = 0.33$$