

Recommendation Systems

Data Science Dojo

Overview

- Introduction
 - Collaborative vs Content-based
- How do they work?
 - Data structure
 - Ranking by similarity
 - Predicting
 - Evaluation
- Advantages/Disadvantages
- Example using Azure ML

Overview

- **Introduction**

- Collaborative vs Content-based

- How do they work?

- Data structure
 - Ranking by similarity
 - Predicting
 - Evaluation

- Advantages/Disadvantages

- Example using Azure ML

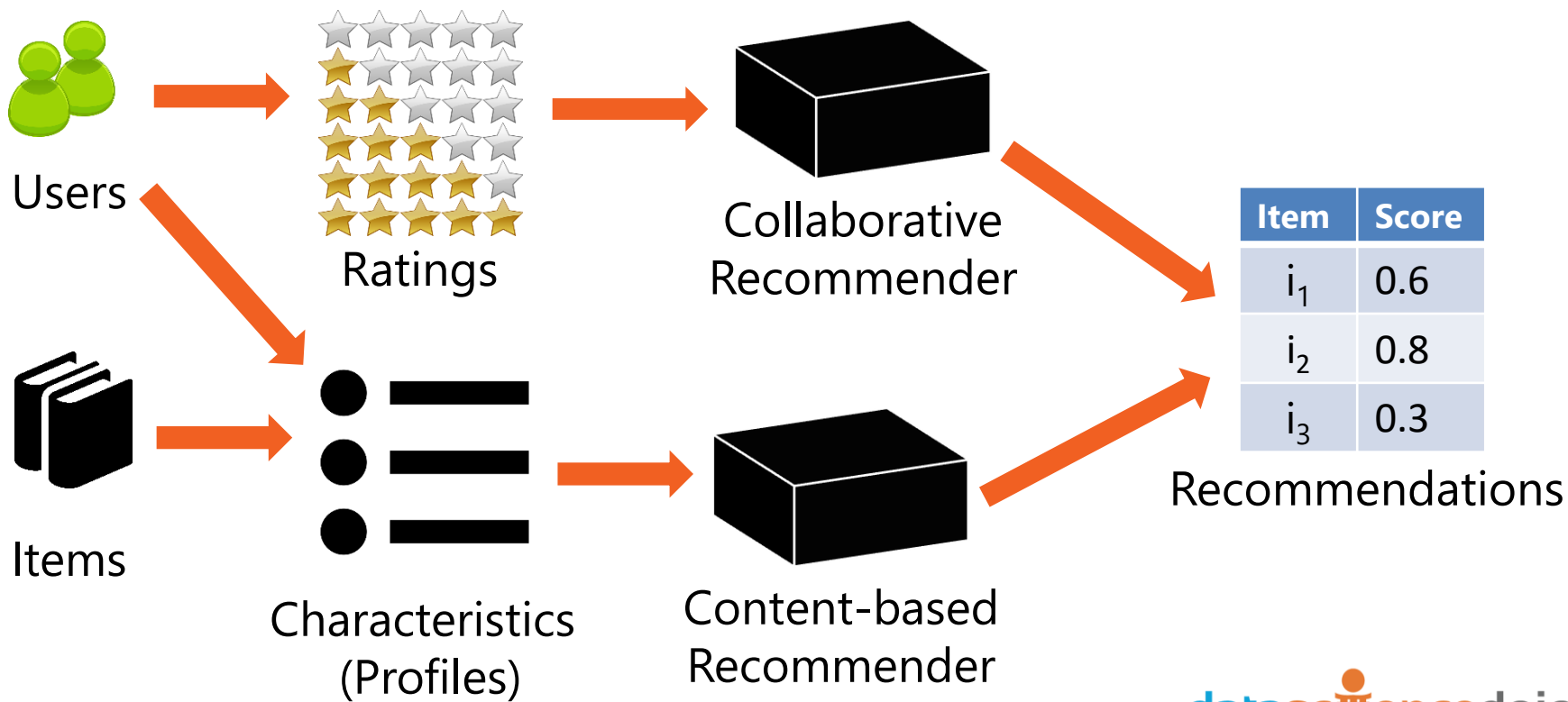
Recommendation Systems

- What are Recommendation Systems?
 - Automated systems to filter and recommend products based on users' interest and taste.
 - Designed to solve the information overload problem

Why recommendation systems?

- For Customers
 - Narrow down the set of choices
 - Discover new, interesting things
 - Save time
- For Business
 - Increase the number of items sold
 - Sell more diverse items
 - Better understand what the user wants

Two Types of Recommenders



Two Types of Recommenders

Collaborative

- 'Give me items that **people like me** enjoy'
- Wisdom of the crowds
- Widely applicable

Content-Based

- 'Give me items similar to **items I like**'
- Content analysis based
- Related to Information Retrieval

Two Types of Recommenders

Collaborative

- Users, Items, & Ratings
- Use Ratings of similar Users to recommend unseen Items

Content-Based

- User & Item profiles
- Use overlap of User and Item characteristics to recommend unseen items

Example: Netflix

Top Picks for Cassandra



Frasier

★★★★★ 200 TV-PG 11 Seasons

Frasier Crane is a snooty but lovable Seattle psychiatrist who dispenses advice on his call-in radio show while ignoring it in his own relationships.

Starring: Kelsey Grammer, Jane Leeves, David Hyde Pierce

Genres: TV Shows, TV Comedies, Sitcoms

This show is: Witty

Winner of more than 37 Emmys, including three for Best Comedy and four Best Actor awards for Kelsey Grammer.

NETFLIX

Browse

KIDS

Taste Preferences

How often do you watch

Never

Sometimes

Often

Moods

Absurd



Adrenaline Rush



Bawdy



Campy



Cerebral



Chilling



Mind-bending Movies



Quirky Comedies



Cerebral TV Shows



Example: Social Media & Search

People You May Know



[Redacted Name]
The Old School Of Hard Knocks
[Redacted Name] and 2 other mutual friends



[Redacted Name]
The new guy at DePaul LED
[Redacted Name] and 23 other mutual friends



[Redacted Name]
Works at The Home Depot

Ads You May Be Interested In



Big Data in 2015
Learn about 5 emerging trends in 2015 that have high ROI.



Attn: Successful Women
You're Invited to Join National Association of Professional Women



Invitation for Editorial
Clinical & Translational Research

Data Science

[Web](#) [News](#) [Images](#) [Books](#) [Videos](#) [More ▾](#) [Search tools](#)

Data science - Wikipedia, the free encyclopedia

https://en.wikipedia.org/wiki/Data_science ▾ [Wikipedia ▾](#)

Data Science is an interdisciplinary field about processes and systems to extract knowledge or insights from large volumes of data in various forms, either ...

[Overview](#) - [History](#) - [Domain specific interests](#) - [Criticism](#)

Data Science | Coursera

<https://www.coursera.org/specializations/jhudatascience> ▾ [Coursera ▾](#)

Become an expert with Data Science Specialization offered by Johns Hopkins University. Take free online classes from 120+ top universities and educational ...

Certificate in Data Science - UW Professional & Continuing ...

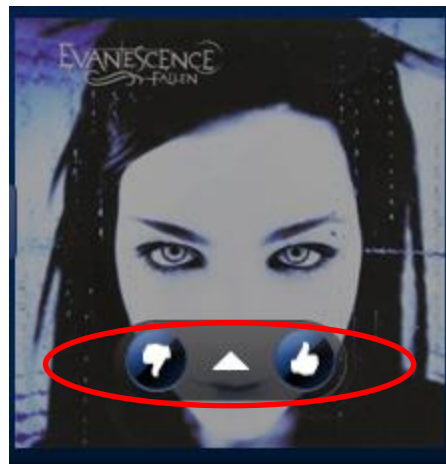
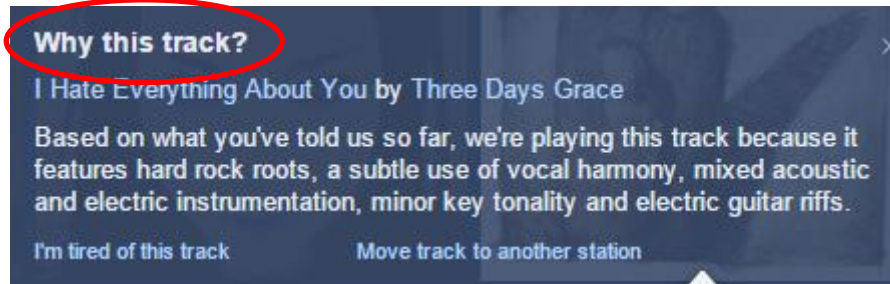
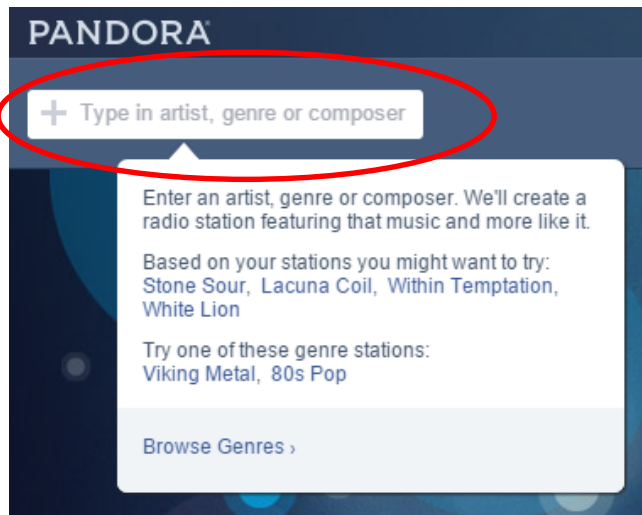
www.pce.uw.edu/certificates/data-science.html ▾

University of Washington offers a certificate program in data science, with flexible evening and online classes to fit your schedule.

Jan 14, 2016 [Online](#)

Mar 28, 2016 [Bellevue](#)

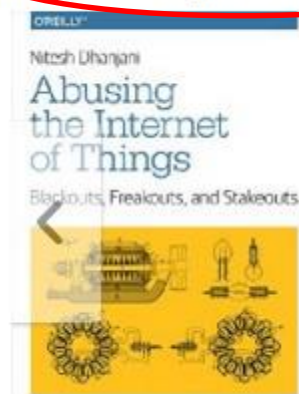
Example: Pandora



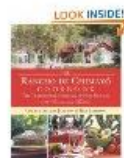
Example: Amazon

Inspired by Your Wishlist [See more](#)

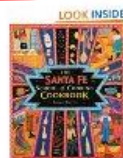
Related to Items You've Viewed [See more](#)



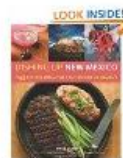
Customers Who Bought This Item Also Bought



Rancho de Chimayo
Cookbook: The...
Cheryl Jamison
★★★★☆ 10
Paperback
\$19.05 [Prime](#)



The Santa Fe School of
Cooking Cookbook
Susan D. Curtis
★★★★☆ 16
Paperback
\$21.14 [Prime](#)



Dishing Up® New Mexico:
145 Recipes from the...
Dave DeWitt
★★★★☆ 7
Paperback
\$15.45 [Prime](#)

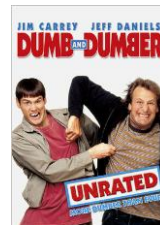
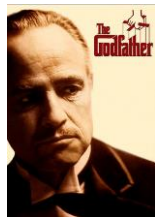
Overview

- Introduction
 - Collaborative vs Content-based
- **How do they work?**
 - **Data structure**
 - Ranking by similarity
 - Predicting
 - Evaluation
- Advantages/Disadvantages
- Example using Azure ML

Data Structure

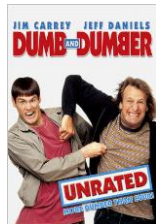
- What kind of data?
 - Collaborative
 - Ratings of Items by Users
 - Content-based
 - Characteristic profiles of Users and Items

Data Structure - Collaborative



Alice	5	3	4	4	?
Bob	3	1	2	3	3
Chris	4	3	4	3	5
Donna	3	3	1	5	4
Evi	1	5	5	2	1

Data Structure – Content-based



Item/User	Drama?	Comedy?	Adventure?	Romance?
<i>The Godfather</i>	5	1	2	1
<i>Titanic</i>	4	3	2	5
<i>Lord of the Rings</i>	4	2	5	1
<i>Dumb & Dumber</i>	1	5	2	2
<i>Spirited Away</i>	5	3	5	2
Alice	5	4	1	4
Bob	3	1	1	1
Chris	4	2	5	2

Content-based: User Profiles

- **User Provided**

- Ask for preferences
- Needs accounts
- Often low completion rates

- **Automated Generation**

- Cookies follow behavior
- No user persistence (often)
- Loss in translation

Content-based: Item Profiles

- **Expert Labeling**

- Assign keywords based on content
- May be provided by creators/distributors
- Crowd sourcing?

- **Automated Indexing**

- Used for text documents
- Based on word content of document set
- No expert knowledge involved

Overview

- Introduction
 - Collaborative vs Content-based
- **How do they work?**
 - Data structure
 - **Similarity**
 - Predicting
 - Evaluation
- Advantages/Disadvantages
- Example using Azure ML

Similarity Measurements

- Given two vectors \vec{x} and \vec{y} with n components each
 - Ratings of User x and User y
 - Ratings for Item x and Item y
 - Profiles of User x and Item y
- How similar are the Users/Items?

Similarity Measurements

- Pearson's Correlation

$$\text{sim}(\vec{x}, \vec{y}) = \frac{\sum_{i=1}^n (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^n (x_i - \bar{x})^2} \sqrt{\sum_{i=1}^n (y_i - \bar{y})^2}}$$

- Cosine Similarity

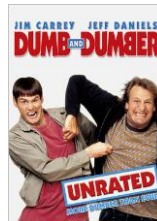
$$\text{sim}(\vec{x}, \vec{y}) = \frac{\vec{x} \cdot \vec{y}}{|\vec{x}| * |\vec{y}|} = \frac{\sum_{i=1}^n x_i y_i}{\sqrt{\sum_{i=1}^n x_i^2} \sqrt{\sum_{i=1}^n y_i^2}}$$

Collaborative: User-Based

- Goal: Predict User u 's rating on a movie m they haven't seen
 - Find the N most similar Users to u who have seen m
 - Use their ratings to predict u 's rating

Collaborative: User-based

Which metric should we use?



Alice	5	3	4	4	?
Bob	3	1	2	3	3
Chris	4	3	4	3	5
Donna	3	3	1	5	4
Evi	1	5	5	2	1



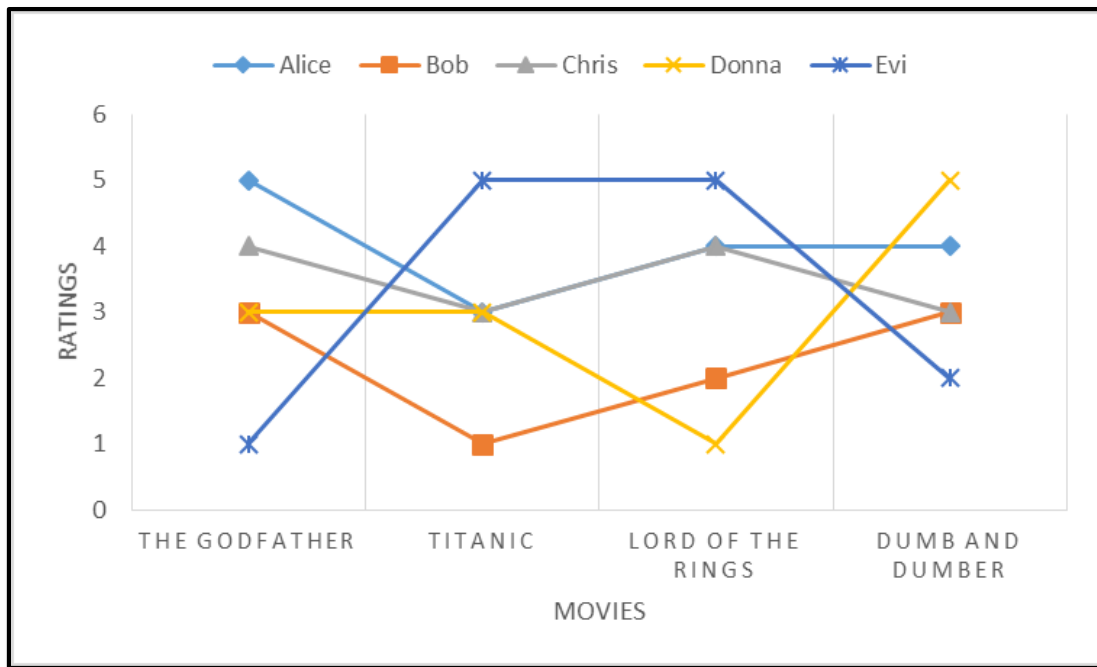
sim = ?

sim = ?

sim = ?

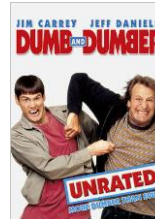
sim = ?

Collaborative: User-based



Collaborative: User-based

Pearson's correlation corrects for varied baselines



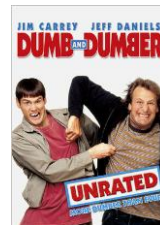
Alice	5	3	4	4	?	 sim=0.85 sim=0.90 sim=0.70 sim=0.79
Bob	3	1	2	3	3	
Chris	4	3	4	3	5	
Donna	3	3	1	5	4	
Evi	1	5	5	2	1	

Collaborative: Item-based

- Alternate approach:
 - Use the similarity between items (and not users) to make predictions
 - Look for movies that are similar to movie m
 - Take **Alice**'s ratings for these items to predict the rating for movie m

Collaborative: Item-based

Which metric should we use?



Alice	5	3	4	4	?
Bob	3	1	2	3	3
Chris	4	3	4	3	5
Donna	3	3	1	5	4
Evi	1	5	5	2	1

sim = ?

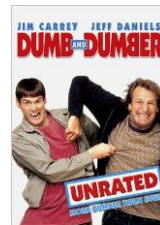
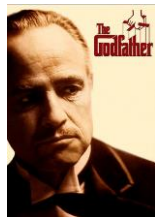
sim = ?

sim = ?

sim = ?

Collaborative: Item-based

Cosine
similarity allows
for objective
good/bad



Alice	5	3	4	4	?
Bob	3	1	2	3	3
Chris	4	3	4	3	5
Donna	3	3	1	5	4
Evi	1	5	5	2	1

sim=0.99

sim=0.74

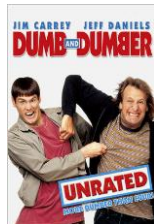
sim=0.72

sim=0.93

Content-based: Similarity

- Goal: Return a recommendation list of items for each user
 - Find similarity of each User to each Item
 - Order Items by similarity

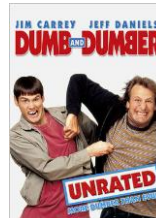
Content-based: Similarity



Item/User	Drama?	Comedy?	Adventure?	Romance?
<i>The Godfather</i>	5	1	2	1
<i>Titanic</i>	4	3	2	5
<i>Lord of the Rings</i>	4	2	5	1
<i>Dumb & Dumber</i>	1	5	2	2
<i>Spirited Away</i>	5	3	5	2
Alice	5	4	1	4
Bob	3	1	1	1
Chris	4	2	5	2



Content-based: Similarity



Alice	0.83	0.96	0.72	0.79	0.83
Bob	0.99	0.86	0.85	0.59	0.91
Chris	0.87	0.82	0.99	0.69	0.99

- Cosine similarity doesn't erase baselines
- Predict order, not exact rating

Overview

- Introduction
 - Collaborative vs Content-based
- **How do they work?**
 - Data structure
 - Similarity
 - **Predicting**
 - Evaluation
- Advantages/Disadvantages
- Example using Azure ML

Collaborative: Predictions

- Use "Aggregation Function"
- Choose N nearest neighbors to User u
- Combine each neighbor j 's rating on Item i ($r_{j,i}$)
- Simple
 - $r_{u,i} = \frac{1}{N} \sum_{j=1}^N r_{j,i}$
- Weighted & Centered
 - $r_{u,i} = \bar{r}_u + \alpha \sum_{j=1}^N sim(j, u)(r_{j,i} - \bar{r}_j)$

Content-based: Predictions

- Simple
 - Rank in order of similarity
- Information retrieval techniques
 - Well studied, wide diversity of models
 - Classification algorithms

Overview

- Introduction
 - Collaborative vs Content-based
- **How do they work?**
 - Data structure
 - Similarity
 - Predicting
 - **Evaluation**
- Advantages/Disadvantages
- Example using Azure ML

Evaluating Recommendation

- **Mean Absolute Error (*MAE*)**
computes the deviation between predicted ratings and actual ratings
- **Root Mean Square Error (*RMSE*)** is similar to *MAE*, but places more emphasis on larger deviation

$$MAE = \frac{1}{n} \sum_{i=1}^n |p_i - r_i|$$

$$RMSE = \sqrt{\frac{1}{n} \sum_{i=1}^n (p_i - r_i)^2}$$

Metrics

- Order matters, not exact ranking value
- Graded Relevance
 - Have humans assign scores to possible results
 - Ideal results will be ordered by relevance, high to low
- Discounted cumulative gain (DCG)
 - Logarithmic reduction factor

$$DCG_N = rel_1 + \sum_{i=2}^N \frac{rel_i}{\log_2 i}$$

Where:

- N is the length of the recommendation list
- rel_i returns the relevance of recommendation at position i

Metrics

- **Ideal discounted cumulative gain (IDCG)**

- DCG value when items are ordered perfectly

$$IDCG_N = rel_1 + \sum_{i=2}^N \frac{rel_i}{\log_2 i}$$

- **Normalized discounted cumulative gain (nDCG)**

$$nDCG_{pos} = \frac{DCG_{pos}}{IDCG_{pos}}$$

- Normalized to the interval [0..1]

Overview

- Introduction
 - Collaborative vs Content-based
- How do they work?
 - Data structure
 - Similarity
 - Predicting
 - Evaluation
- **Advantages/Disadvantages**
- Example using Azure ML

Advantages

Collaborative

- Wide applicability
- Serendipity
- Simple

Content-based

- No community needed
- Transparency
- Good cold start

Disadvantages

Collaborative

- Poor cold start
- Grey Sheep
 - Shared accounts
- Shilling
- Poor scaling

Content-based

- Limited profiles
 - New users
 - Cost of expert labeling
- Over-specialization
 - Lack of diversity

Back to Netflix

Top Picks for Cassandra



Frasier

★★★★★ 2003 TV-PG 11 Seasons

Frasier Crane is a snooty but lovable Seattle psychiatrist who dispenses advice on his call-in radio show while ignoring it in his own relationships.

Starring: Kelsey Grammer, Jane Leeves, David Hyde Pierce

Genres: TV Shows, TV Comedies, Sitcoms

This show is: Witty



Winner of more than 37 Emmys, including three for Best Comedy and four Best Actor awards for Kelsey Grammer.

Mind-bending Movies



Quirky Comedies



Cerebral TV Shows



QUESTIONS

Overview

- Introduction
 - Collaborative vs Content-based
- How do they work?
 - Data structure
 - Similarity
 - Predicting
 - Evaluation
- Advantages/Disadvantages
- **Example using Azure ML**