Recommendation Systems

- Predict items a user may be interested in based on information about the user and the items
- An effective way to help people cope with information overload
- Examples: Amazon, Netflix, Tivo, ...

So How Can We Do It?

- The content based approach
  - E.g. full text search results
- The user feedback based approach
  - E.g. rating and modding

Which one is better?? Any room for improvement??

Collaborative Filtering

- Rate items based on the ratings of other users who have similar taste as you

Basic Assumptions

- Items are evaluated by users explicitly or implicitly
  - Ratings, reviews
  - Purchases, browsing behaviors
  - ...
- We may map explicit and implicit evaluations to a rating scale, e.g. 1-5.

Problem Definitions

- Prediction
  - Given: a user and k items
  - Return: predicted rating for each item
- Recommendation
  - Given: a user
  - Return: k items from the database with the highest predicted rating
Heuristic

People who agreed in the past are likely to agree in the future

Problem Formulation

User-Item Matrix

<table>
<thead>
<tr>
<th>Item</th>
<th>Ken</th>
<th>Lee</th>
<th>Meg</th>
<th>Nan</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5</td>
<td>2</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>5</td>
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<td>3</td>
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<td>4</td>
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<td>1</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>5</td>
<td>2</td>
<td>5</td>
<td>1</td>
<td>4</td>
</tr>
</tbody>
</table>

So what would be Ken’s rating for Item 6??

Pearson Correlation Coefficient

Let \( x \) and \( y \) be two users, and \( r_{x,i} \) be the rating of item \( i \) by user \( x \)

\[
W_{x,y} = \frac{\text{cov}(x, y)}{\sigma_x \sigma_y} = \frac{\sum_{i}(r_{x,i} - \bar{r}_x)(r_{y,i} - \bar{r}_y)}{\sqrt{\sum_{i}(r_{x,i} - \bar{r}_x)^2} \sqrt{\sum_{i}(r_{y,i} - \bar{r}_y)^2}}
\]

So what is \( W_{ken,lee} \)??

Predicted Rating

\( p_{x,i} \) is the predicted rating of item \( i \) by user \( x \)

\[
p_{x,i} = \bar{r}_i + \frac{\sum_{x} (r_{x,i} - \bar{r}_x) \times W_{x,i}}{\sum_{u} W_{x,u}}
\]

So what is \( p_{ken,6} \)??

Algorithm Quality Metrics

Coverage – percentage of items for which the system can produce a prediction

Accuracy
- Statistical metrics
- Mean Absolute Error (MAE)

Efficiency
- Throughput – number of recommendations per second

Variations and Optimizations

Similarity measure
Significance weighting
Item rating variance
Neighborhood selection
Combine neighborhood ratings
Similarity Measures
- Pearson Correlation
- Spearman Correlation
- Cosine similarity
- Entropy
- Mean-squared-difference
- ...

Significance Weighting
- Weight users in additional to the similarity measure
  \[ w = \begin{cases} 
  1 & n \geq 50 \\
  n/50 & n < 50 
\end{cases} \]
  where \( n \) is the number of items rated by both users.

Item Rating Variance
- Some items are more telling about tastes than others
  - E.g. “Sleepless in Seattle” is more telling about taste than “Titanic”
  - Give more weight to items with high variance in ratings

Neighborhood Selection
- Select a subset of users for better performance and accuracy
  - Correlation threshold
  - Best \( n \) neighbors

Combine Neighborhood Ratings
- Weighted average
- Deviation from mean
- Weighted average of z-scores

And The Winners Are ...
- Similarity measure
  - Pearson Correlation
  - Spearman Correlation*
- Significance weighting
- Neighborhood selection
  - Best \( n \) neighbors with \( n=20 \)
- Combine neighborhood ratings
  - Deviation from mean
Other Recommendation Algorithms

- Combine collaborative and content-based filtering
- Item-item collaborative filtering
- Bayesian networks

Some Libraries

- Taste – http://taste.sourceforge.net/
- COFE – http://eecs.oregonstate.edu/iis/CoFE/
- And more – http://en.wikipedia.org/wiki/Collaborative_filtering#Software_libraries

Non-personalized Recommendation

- What if the user is new to the site?
- What if the site itself is new, i.e. no previous user transactions?

Sales Transactions

| 11: Beef, Chicken, Milk |
| 12: Beef, Cheese |
| 13: Cheese, Boots |
| 14: Beef, Chicken, Cheese |
| 15: Beef, Chicken, Clothes, Cheese, Milk |
| 16: Chicken, Clothes, Milk |
| 17: Chicken, Milk, Clothes |

Amazon-like recommendation:
Users who purchased milk also purchased the following items:
- Clothes
- Chicken

Association Rule Mining

- \( \{i_1, i_2, ..., i_n\} \rightarrow j \)
- Confidence: the probability of finding item \( j \) in a transaction that has \( \{i_1, i_2, ..., i_n\} \)
- Support: the number of transactions that have \( \{i_1, i_2, ..., i_n\} \) and \( j \)

A-Priori Algorithm

- Observation: A set of items \( X \) has support \( s \), then each subset of \( X \) must have support at least \( s \).
- Example: find the association rules that have at least 20% support and 50% confidence
<table>
<thead>
<tr>
<th>Item Similarity under Vector-Space Model</th>
</tr>
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<tbody>
<tr>
<td>◆ Each unique term is a dimension</td>
</tr>
<tr>
<td>◆ Each document is a vector</td>
</tr>
<tr>
<td>◆ Similarity</td>
</tr>
<tr>
<td>◆ Euclidean distance</td>
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<tr>
<td>◆ Cosine similarity measure</td>
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<td>◆ GroupLens: An Open Architecture for</td>
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<td>Collaborative Filtering of Netnews by P.</td>
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<td>◆ An Algorithmic Framework for</td>
</tr>
<tr>
<td>Performing Collaborative Filtering by J.</td>
</tr>
<tr>
<td>Herlocker et. al, 1999.</td>
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<td>◆ E-Commerce Recommendation Applications</td>
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