

Recommender Systems:

Interaction-Based

Mining Massive Datasets

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Sources

- Data Mining, The Textbook (2015) by Charu Aggarwal (Section 18.5) – slides by Lijun Zhang
- Mining of Massive Datasets 2nd edition (2014) by Leskovec et al. (Chapter 9) – slides A, B

Interaction-based recommendations

Missing-value estimation/completion

- The matrix is extremely **large** and **sparse**

$$M = \begin{bmatrix} \blacksquare & & \blacksquare & & \blacksquare & & \\ & \blacksquare & & \blacksquare & \blacksquare & & \blacksquare \\ \blacksquare & & & \blacksquare & & \blacksquare & \\ & & \blacksquare & & \blacksquare & & \\ & \blacksquare & & \blacksquare & & & \\ & & & \blacksquare & & & \blacksquare \end{bmatrix} \in \mathbb{R}^{n \times d}$$

Only black squares have non-zero values.

Types of algorithms

- Neighborhood-Based Methods
 - User-Based or Item-Based Similarity with Ratings
- Graph-Based Methods
- Clustering Methods
 - Adapting k-Means Clustering or Adapting Co-Clustering
- Latent Factor Models
 - Matrix Factorization, e.g., Singular Value Decomposition

User-based similarity with ratings

- Let $I_{u,v}$ be common ratings between two users
- Similarity: Pearson correlation coefficient

$$\text{sim}(u, v) = \frac{\sum_{i \in I_{u,v}} (u_i - \hat{u}) \cdot (v_i - \hat{v})}{\sqrt{\sum_{i \in I_{u,v}} (u_i - \hat{u})^2 \cdot \sum_{i \in I_{u,v}} (v_i - \hat{v})^2}}$$

$$\hat{u} = \frac{1}{|u|} \sum_{i=1}^{|u|} u_i \quad \hat{v} = \frac{1}{|v|} \sum_{i=1}^{|v|} v_i$$

Note: averages are taken over all elements, not only ones in common

User-based similarity with ratings (cont.)

$$\text{sim}(u, v) = \frac{\sum_{i \in I_{u,v}} (u_i - \hat{u}) \cdot (v_i - \hat{v})}{\sqrt{\sum_{i \in I_{u,v}} (u_i - \hat{u})^2 \cdot \sum_{i \in I_{u,v}} (v_i - \hat{v})^2}}$$







- Score of recommendation

$$\text{score}(u, i) = \hat{u} + \frac{\sum_{v: v_i \neq \text{NULL}} \text{sim}(v, u) \cdot (v_i - \hat{v})}{\sum_{v: I_{u,v} \neq \emptyset} |\text{sim}(v, u)|}$$

Note: for efficiency one can take only the most similar users

Exercise



	2			4	5	
	5		4			1
			5		2	
		1		5		4
			4			2
	4	5		1		



$$\text{sim}(u, v) = \frac{\sum_{i \in I_{u,v}} (u_i - \hat{u}) \cdot (v_i - \hat{v})}{\sqrt{\sum_{i \in I_{u,v}} (u_i - \hat{u})^2 \cdot \sum_{i \in I_{u,v}} (v_i - \hat{v})^2}}$$

$$\text{score}(u, i) = \hat{u} + \frac{\sum_{v: v_i \neq \text{NULL}} \text{sim}(v, u) \cdot (v_i - \hat{v})}{\sum_{v: I_{u,v} \neq \emptyset} |\text{sim}(v, u)|}$$

Complete yellow cells in spreadsheet:

1. Similarities $\text{sim}(u, v)$
2. Predicted rating of all movies that user u has not seen yet

Which movie is recommended?

Spreadsheet links: <https://upfbarcelona.padlet.org/chato/hogch321o6pws1fd>



You can do the same with items!

- Item-based similarities with ratings

$$\text{sim}(i, j) = \frac{\sum_{u \in I_{i,j}} (u_i - \hat{i}) \cdot (u_j - \hat{j})}{\sqrt{\sum_{u \in I_{i,j}} (u_i - \hat{i})^2 \cdot \sum_{u \in I_{i,j}} (u_j - \hat{j})^2}}$$

- Item-based recommendations

$$\text{score}(u, i) = \hat{i} + \frac{\sum_{j: u_j \neq \text{NULL}} \text{sim}(i, j) \cdot (u_j - \hat{j})}{\sum_{j: I_{i,j} \neq \emptyset} |\text{sim}(i, j)|}$$

(Do it at home)



						
	2			4	5	
	5		4			1
			5		2	
		1		5		4
			4			2
	4	5		1		

1. Compute $\text{avg}(j)$ for all items
2. Compute $\text{sim}(i, j)$ for all items for which there is some intersection with i
3. Compute $\text{score}(u, i)$ for all users who have not seen i yet

$$\text{sim}(i, j) = \frac{\sum_{u \in I_{i,j}} (u_i - \hat{i}) \cdot (u_j - \hat{j})}{\sqrt{\sum_{u \in I_{i,j}} (u_i - \hat{i})^2 \cdot \sum_{u \in I_{i,j}} (u_j - \hat{j})^2}}$$

$$\text{score}(u, i) = \hat{i} + \frac{\sum_{j: u_j \neq \text{NULL}} \text{sim}(i, j) \cdot (u_j - \hat{j})}{\sum_{j: I_{i,j} \neq \emptyset} |\text{sim}(i, j)|}$$

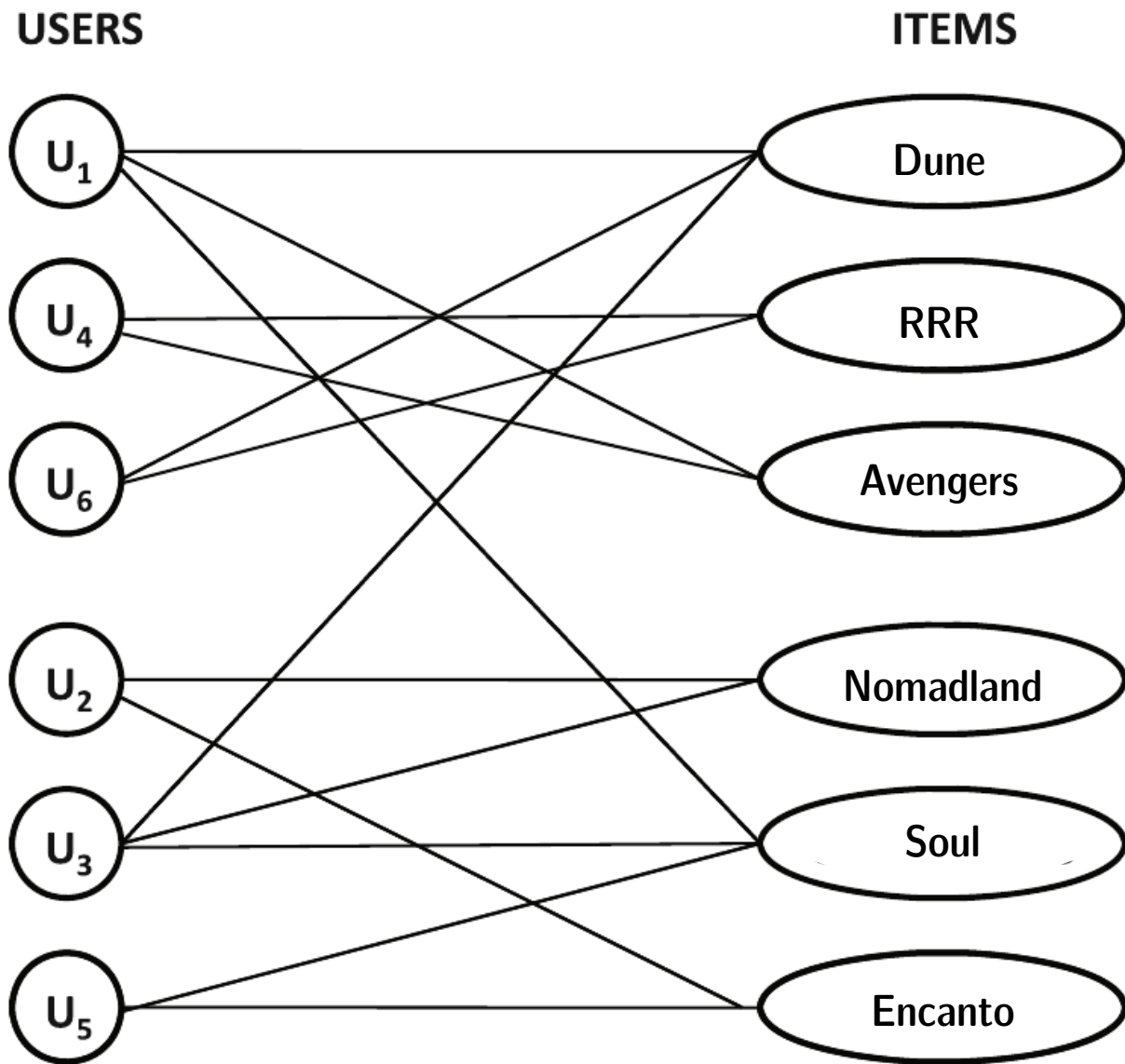
Note

- There are many ways of computing user-based similarity and item-based similarity
- There are many ways of using these to generate recommendations
- The method we have described is aware of the **bias of users**, in the sense of some users being more positive/negative than others in general

Graph- and clustering-based methods

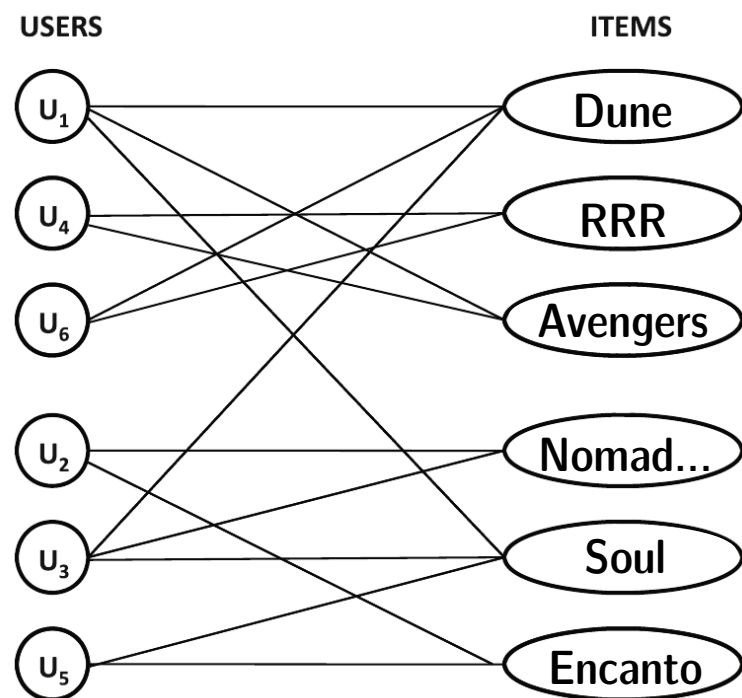
Graph-based methods

- Bipartite user-item graph with nodes $N_u \cup N_i$
- N_u users
- N_i items
- Non-zero utility \Rightarrow edge



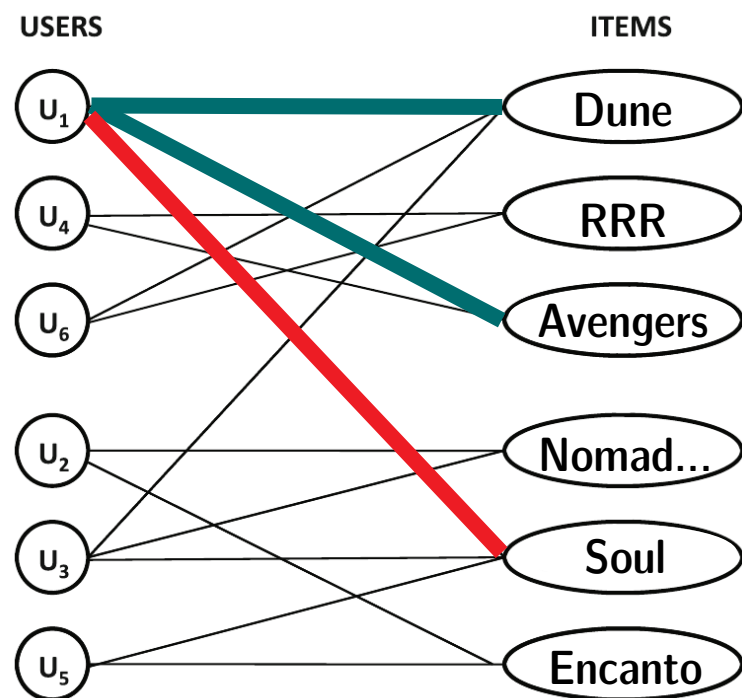
Graph-based methods (cont.)

- Use graph-based methods
 - **Random walk** with restart to a user or item
 - *SimRank* (not seen in class)
- Low “random jump” probability might favor popular items



Graph-based methods (cont.)

- Signed networks can be used
 - Remember to interpret ratings with respect to user and item averages
 - Below average rating $\Rightarrow -$
 - Above average rating $\Rightarrow +$
- Positive link prediction problem



Clustering methods

- Motivations
 - Reduce computational cost
 - To some extent address data sparsity
- Results of clustering
 - Clusters of users for user-user similarity recs.
 - Clusters of items for item-item similarity recs.

Clustering methods (cont.)

- User-user recommendation approach
 - Cluster users into groups
 - For any user u , compute average normalized rating for each item i the user has not seen
 - Report these ratings for (u,i)
- Same with item-item recommendations
- Neighborhoods will be smaller

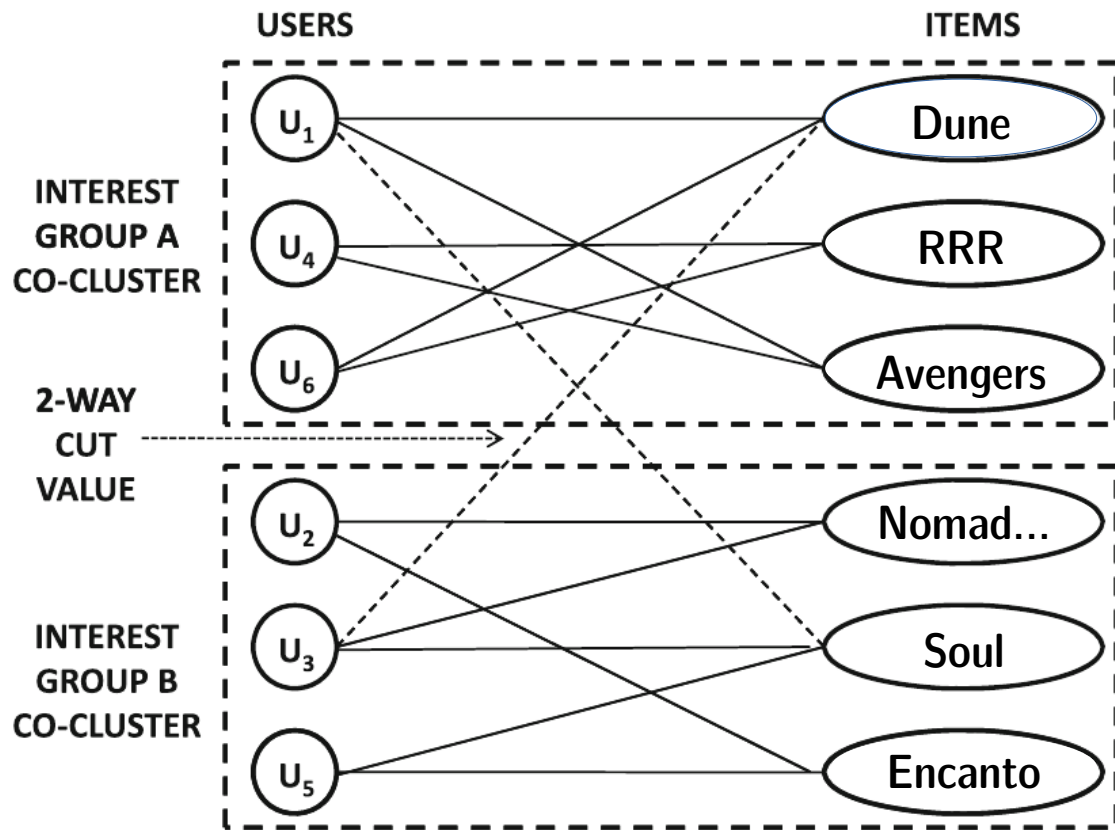
Co-Clustering Approach

INTEREST GROUP A CO-CLUSTER

	Dune	RRR	Avengers	Nomadland	Soul	Encanto
U_1	1		1		1	
U_2		1	1			
U_3	1	1				
U_4				1		1
U_5	1			1	1	
U_6					1	1

INTEREST GROUP B CO-CLUSTER

(a) Co-cluster



(b) User-item graph

Summary

Things to remember

- Interaction-based recommendations
 - User-based
 - Item-based
- Graph-based / clustering-based recommendations

Exercises for TT16-TT18

- Mining of Massive Datasets 2nd edition (2014) by Leskovec et al. Note that some exercises cover advanced concepts:
 - Exercises 9.2.8
 - Exercises 9.3.4
 - Exercises 9.4.6