

LITTLE IS MUCH: BRIDGING CROSS-PLATFORM BEHAVIORS THROUGH OVERLAPPED CROWDS

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cross-platform behavior prediction

AAAI-16 THIRTIETH AAAI CONFERENCE ON
ARTIFICIAL INTELLIGENCE

We Need Multiple Platforms



Cross-Platform: e.g., Facebook+App

Add Facebook Login to Your App or Website

Facebook Login for Apps is a secure, fast and convenient way for people to log into your app or website.



iOS



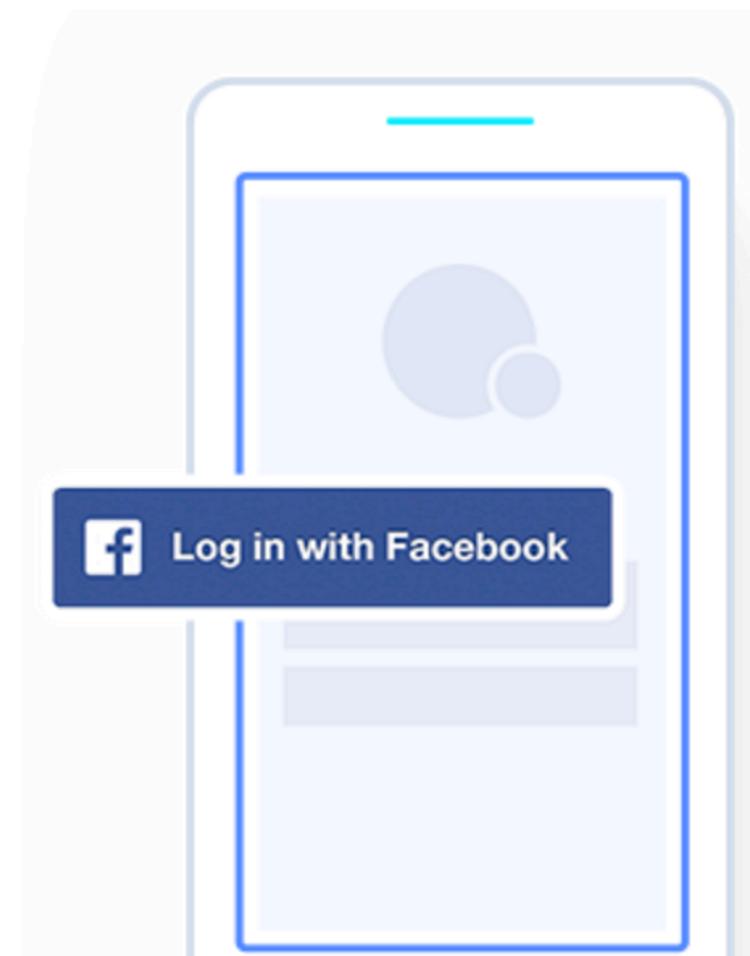
Android



Websites or mobile websites



More platforms



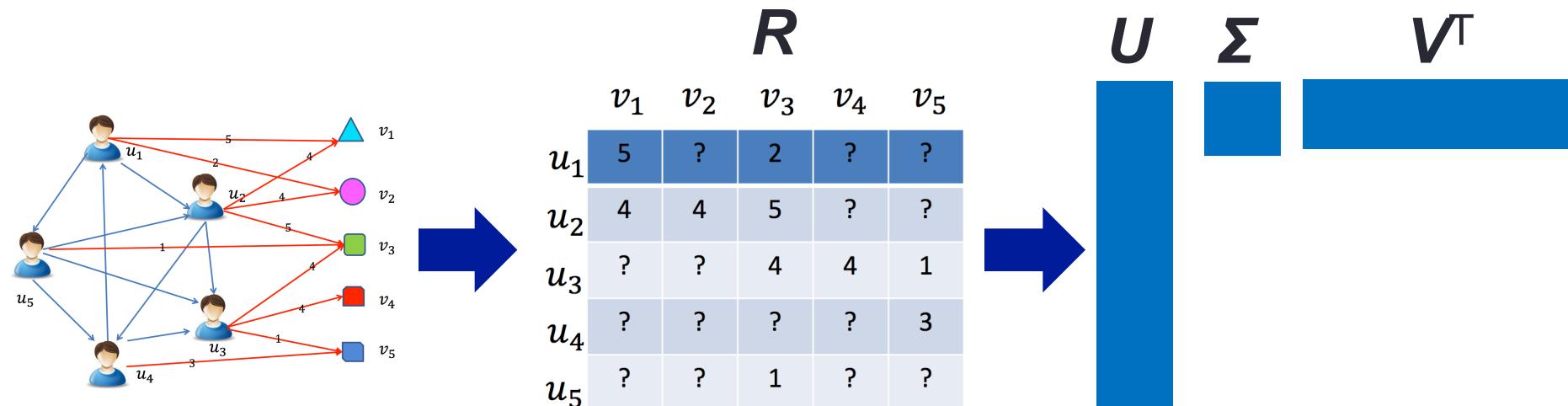
Behavior Prediction

- ❖ Predict missing entries in behavioral data
- ❖ Applications
 - ❖ Uber, Netflix, Amazon...
 - ❖ Recommender systems
 - ❖ Target advertising



Matrix Factorization

- ❖ Low-rank MF on the user-item rating matrix R
- ❖ User preference vector U and Item vector V
- ❖ High sparsity is the key challenge
- ❖ If we have auxiliary data...



Koren. Factorizatoin Meets the Neighborhood: A Multifaceted Collaborative Filtering Model. KDD, 2008.

Knowledge Transfer: Alleviate the Sparsity

Problem	Bridge	Method
Cross- Source		
Cross- Domain		
Cross- Platform		

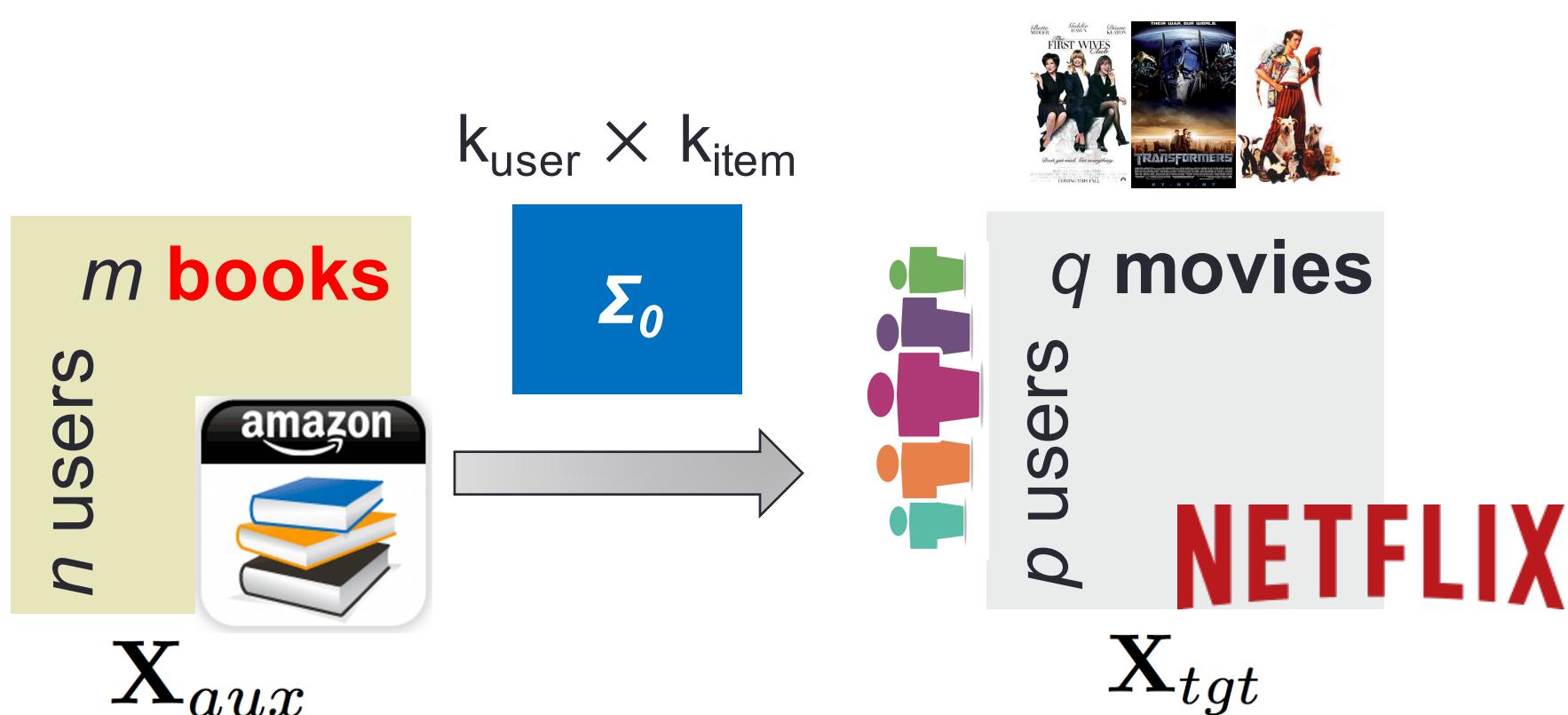
Cross Data Sources

- ❖ Non-overlapped: Codebook Transfer (CBT)



Cross Data Sources

- ❖ Non-overlapped: Codebook Transfer (CBT)



Cross Data Sources

- ❖ Codebook Transfer (CBT)

$$\mathbf{X}_{aux} \stackrel{m \times l}{\sim}$$

$$\min_{\mathbf{U} \geq 0, \mathbf{V} \geq 0, \mathbf{S} \geq 0} \|\mathbf{X}_{aux} - \mathbf{USV}^\top\|_F^2$$

$$\text{s.t. } \mathbf{U}^\top \mathbf{U} = \mathbf{I}, \mathbf{V}^\top \mathbf{V} = \mathbf{I},$$

Codebook = User Group \times Item Group

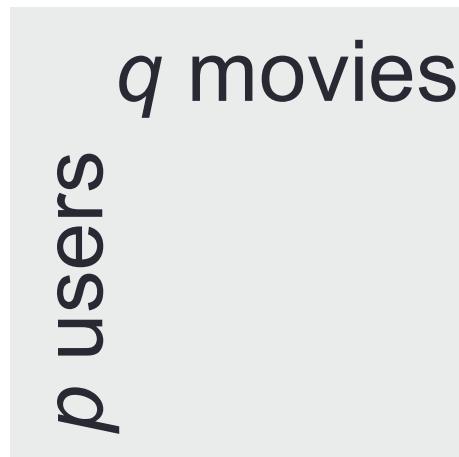
$$\mathbf{X}_{aux} \stackrel{k \times l}{\sim}$$

$$\mathbf{B} = [\mathbf{U}_{aux}^\top \mathbf{X}_{aux} \mathbf{V}_{aux}] \oslash [\mathbf{U}_{aux}^\top \mathbf{1}\mathbf{1}^\top \mathbf{V}_{aux}]$$

Cross Data Sources

- ❖ Codebook Transfer (CBT)

Codebook: $k \times l$



\mathbf{X}_{tgt}

$$\begin{aligned}
 & \min_{\substack{\mathbf{U}_{tgt} \in \{0,1\}^{p \times k} \\ \mathbf{V}_{tgt} \in \{0,1\}^{q \times l}}} \left\| [\mathbf{X}_{tgt} - \mathbf{U}_{tgt} \mathbf{B} \mathbf{V}_{tgt}^\top] \circ \mathbf{W} \right\|_F^2 \\
 & \text{s.t. } \mathbf{U}_{tgt} \mathbf{1} = \mathbf{1}, \mathbf{V}_{tgt} \mathbf{1} = \mathbf{1},
 \end{aligned}$$

$p \times k$ $q \times l$

$\mathbf{U}_{tgt} \mathbf{B} \mathbf{V}_{tgt}^\top$

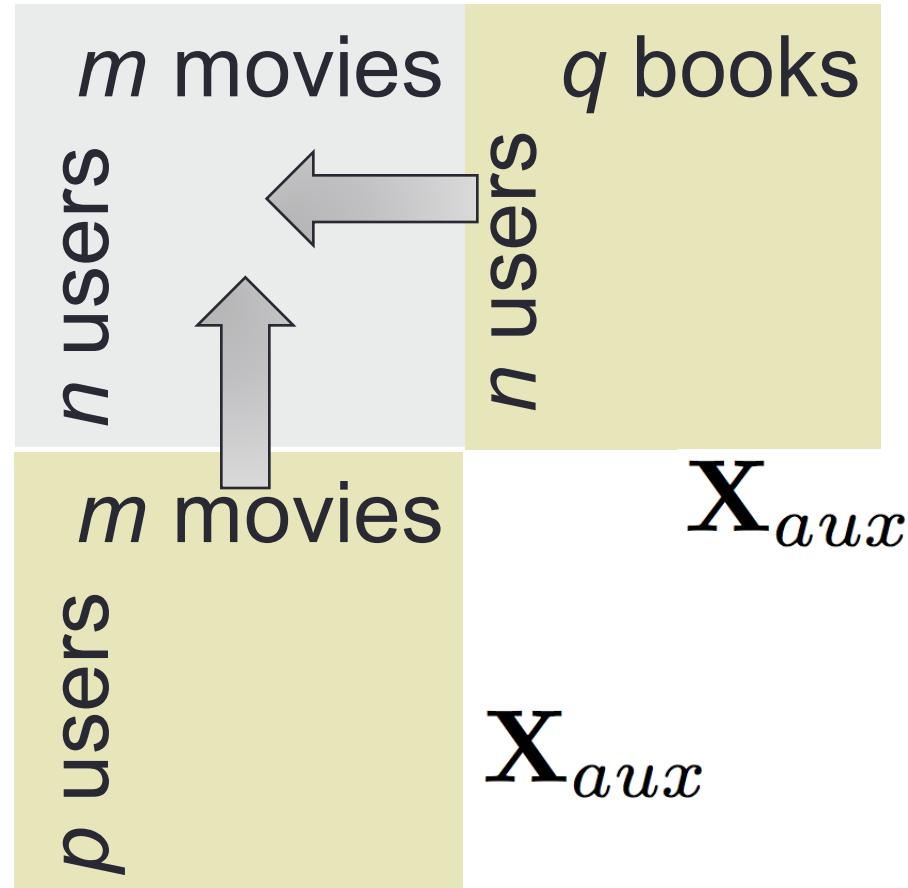
Knowledge Transfer: Alleviate the Sparsity

Problem	Bridge	Method
Cross- Source	Non-overlapped → User cluster \times Item cluster → The same latent representation	CBT
Cross- Domain		
Cross- Platform		

Cross Domains

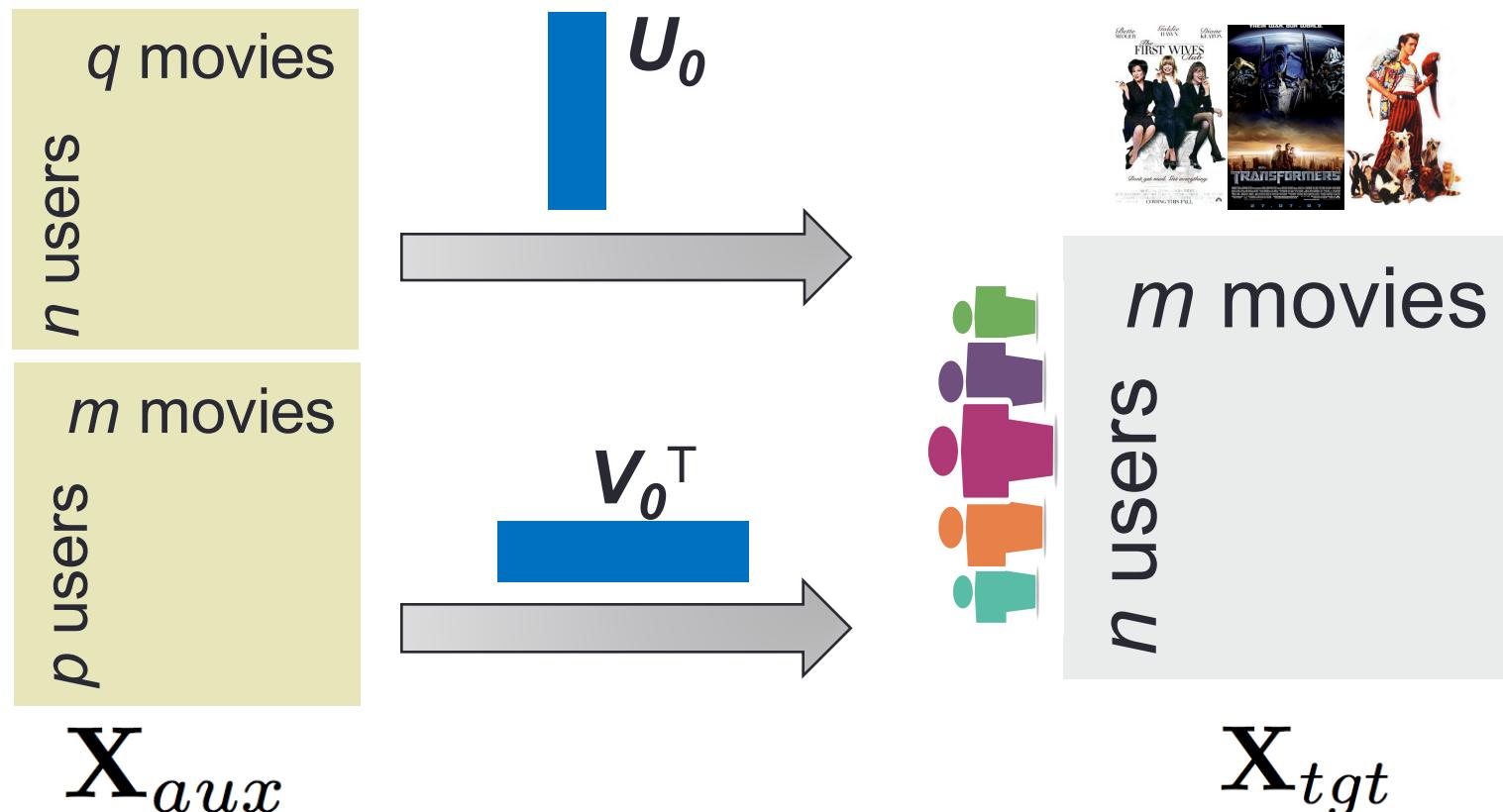
- ❖ Fully overlapped

\mathbf{X}_{tgt}



Cross Domains

❖ Coordinate System Transfer (CST)



Cross Domains

- ❖ Coordinate System Transfer (CST)

Auxiliary data:

$$\min_{\mathbf{U}^{(i)}, \mathbf{V}^{(i)}, \mathbf{B}^{(i)}} \|\mathbf{Y}^{(i)} \odot (\mathbf{R}^{(i)} - \boxed{\mathbf{U}^{(i)} \mathbf{B}^{(i)} \boxed{\mathbf{V}^{(i)T}}})\|_F^2$$

Target data:

$$\min_{\mathbf{U}, \mathbf{V}, \mathbf{B}} \|\mathbf{Y} \odot (\mathbf{R} - \mathbf{U} \mathbf{B} \mathbf{V}^T)\|$$

$$+ \boxed{\frac{\rho_u}{2} \|\mathbf{U} - \mathbf{U}_0\|_F^2} + \boxed{\frac{\rho_v}{2} \|\mathbf{V} - \mathbf{V}_0\|_F^2}$$

$$\text{s.t. } \mathbf{U}^T \mathbf{U} = \mathbf{I}, \mathbf{V}^T \mathbf{V} = \mathbf{I}$$

Knowledge Transfer: Alleviate the Sparsity

Problem	Bridge	Method
Cross-Source	Non-overlapped → User cluster × Item cluster → The same latent representation	CBT
Cross-Domain	Fully overlapped users OR Fully overlapped items → User vector OR Item vector → The same latent representation	CST
Cross-Platform		

Cross-Platform: e.g., Facebook+App

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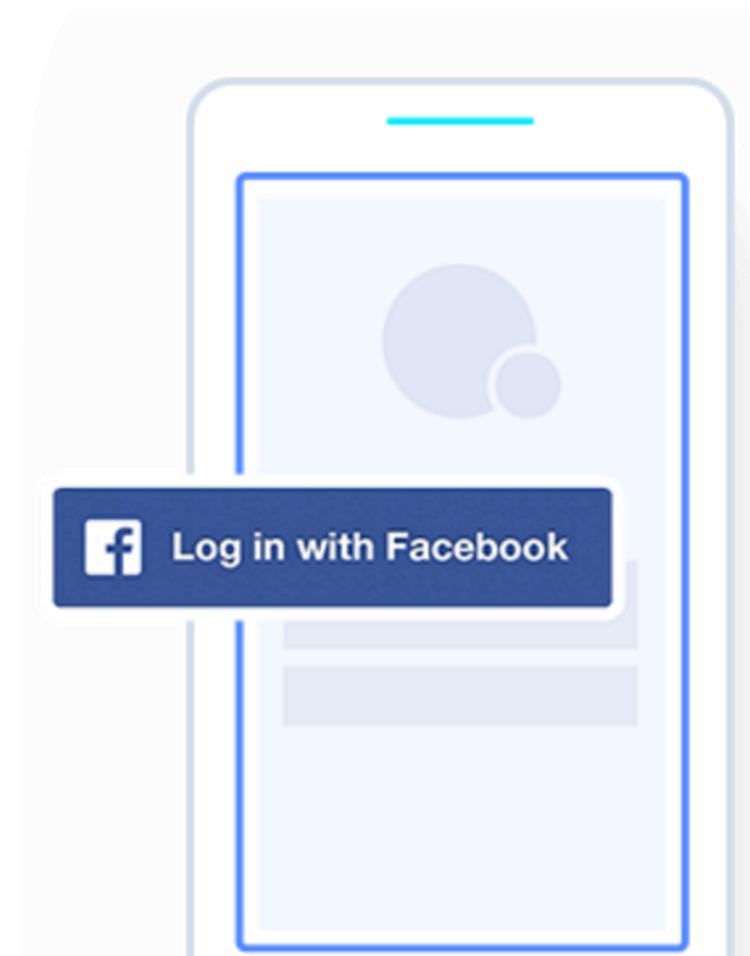
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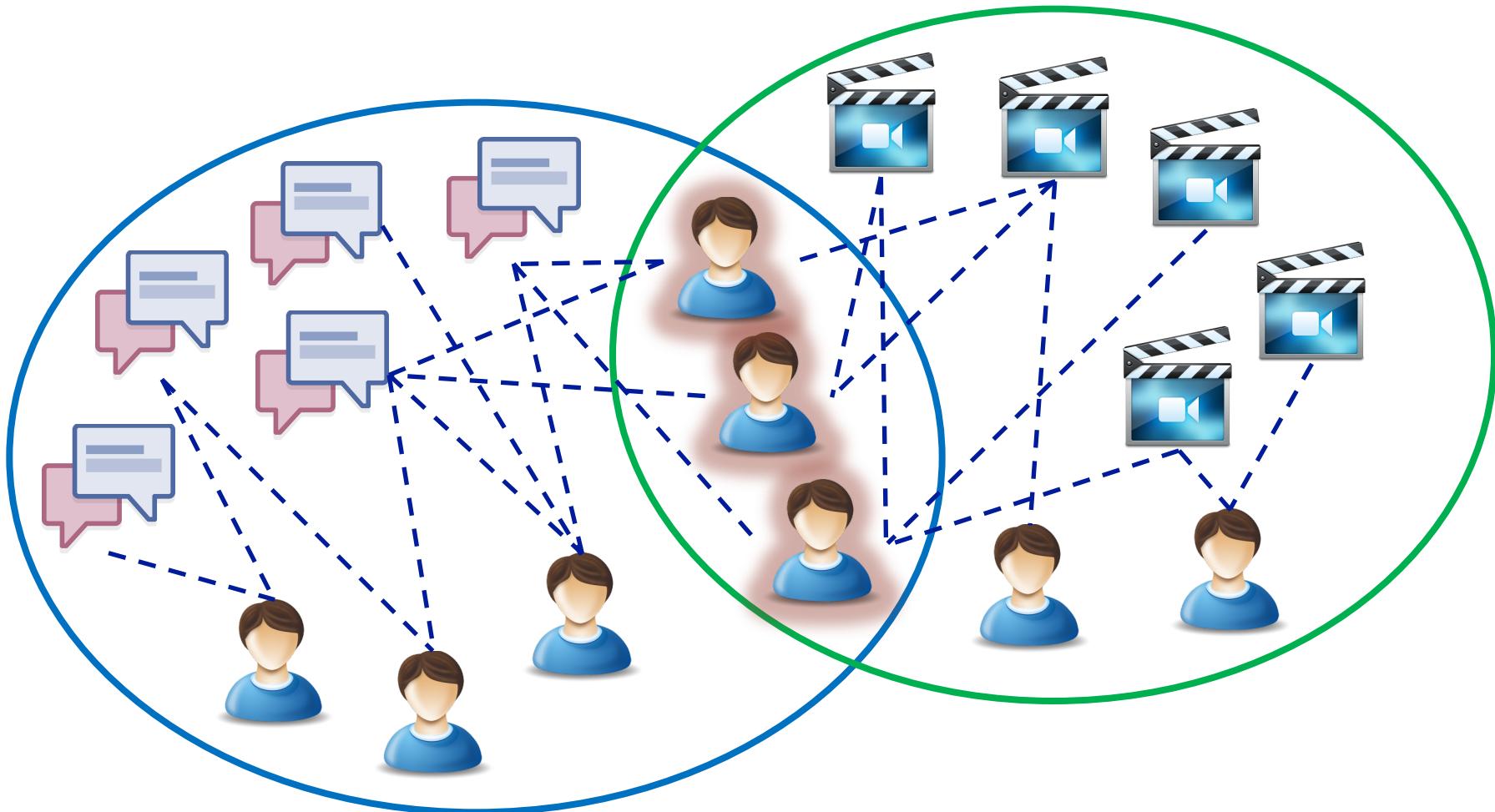
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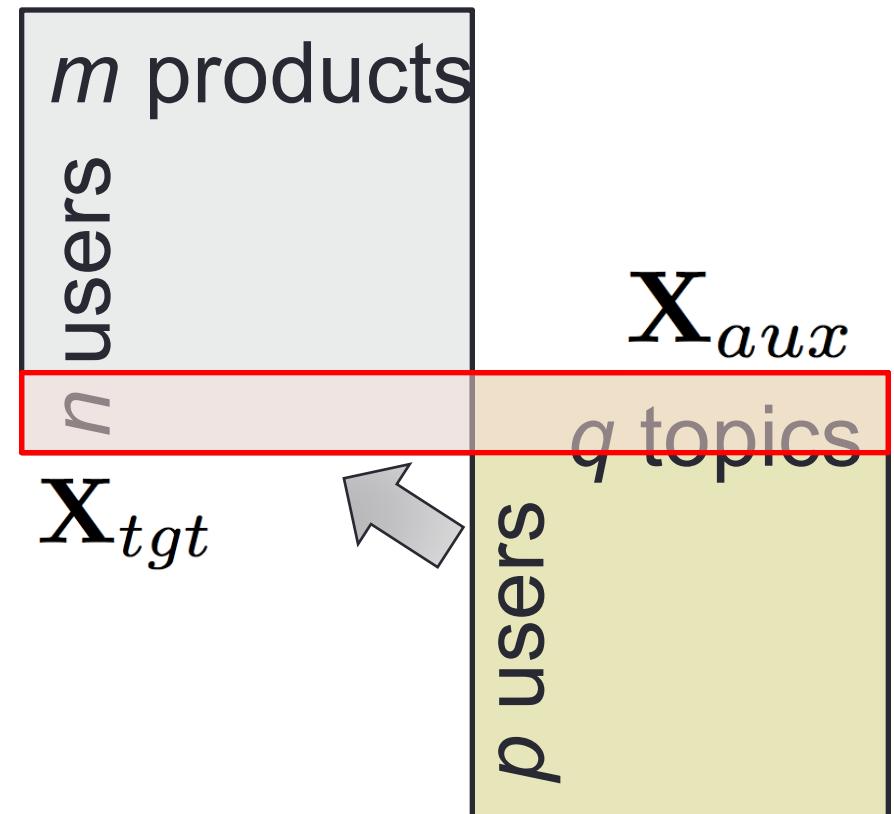
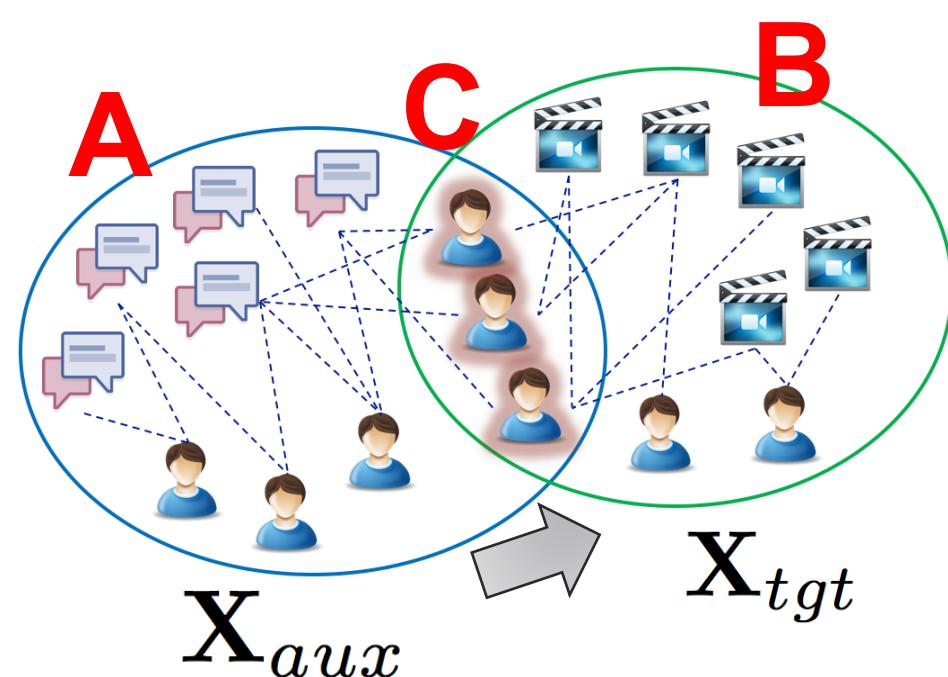
More platforms



Facebook/Twitter/Google Chrome (Auxiliary) Uber/Amazon/Netflix (Target)



Partially Overlapped Users



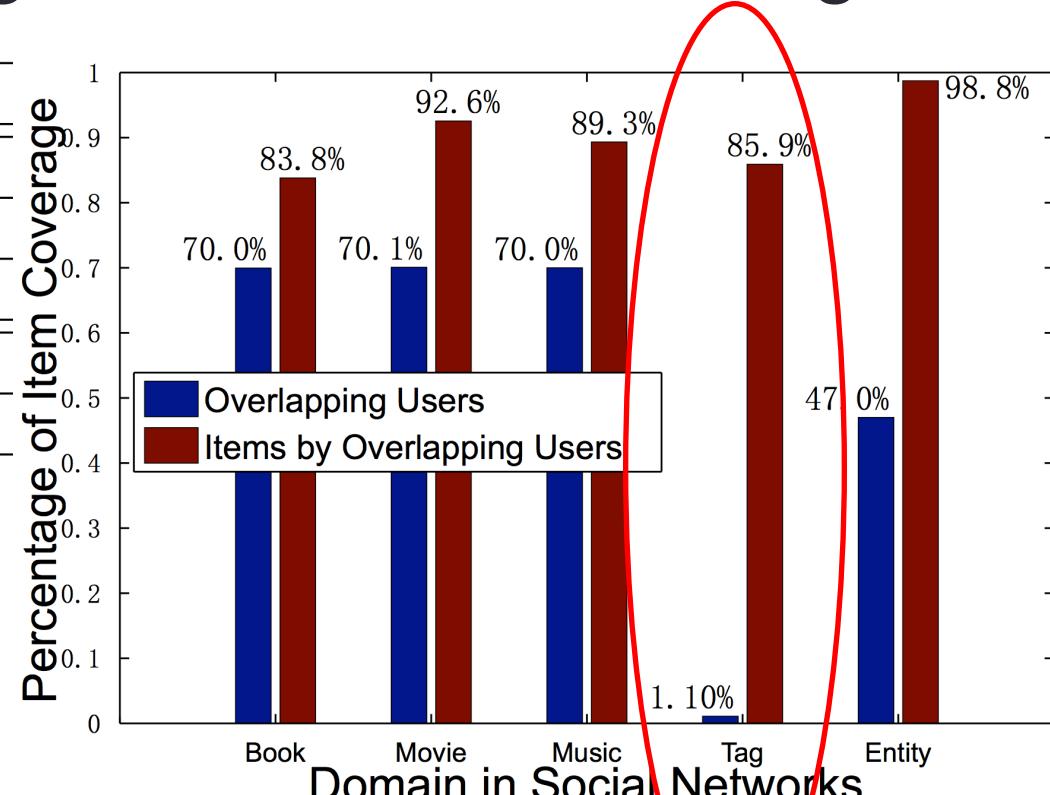
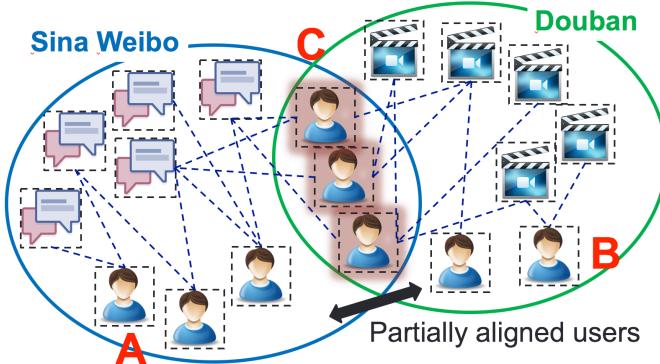
Knowledge Transfer: Alleviate the Sparsity

Problem	Bridge	Method
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Cross- Domain	Fully overlapped users OR Fully overlapped items → User vector OR Item vector → The same latent representation	CST
Cross- Platform	Partially overlapped users → ?	?

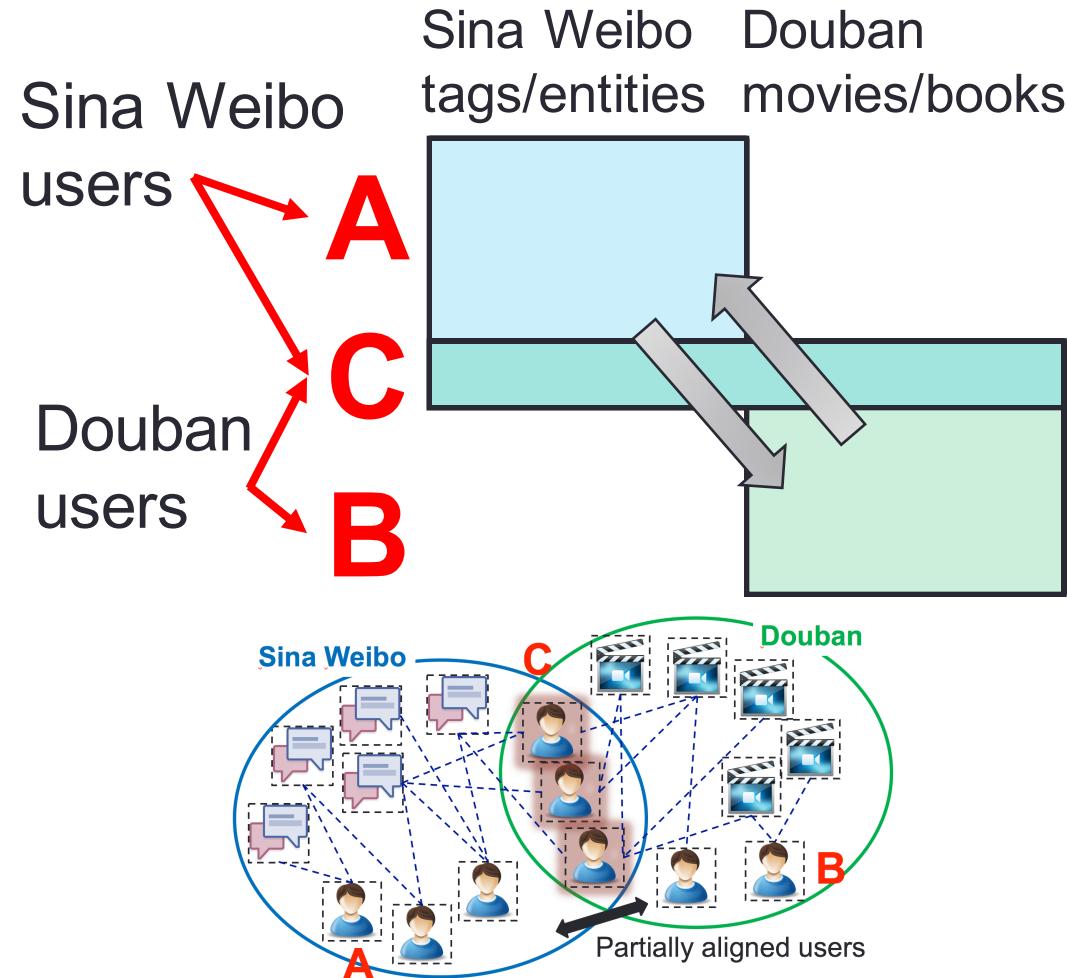
If Overlapped Users Adopted Many Items

- ❖ 1.1% Overlapping Crowd: 85% Coverage

	#User	#Item
Book	30,536	212,835
Movie	40,246	64,090
Music	33,938	286,464
Social tag	2,721,365	10,176
Tweet entity	25,586	113,591



When NO Transfer



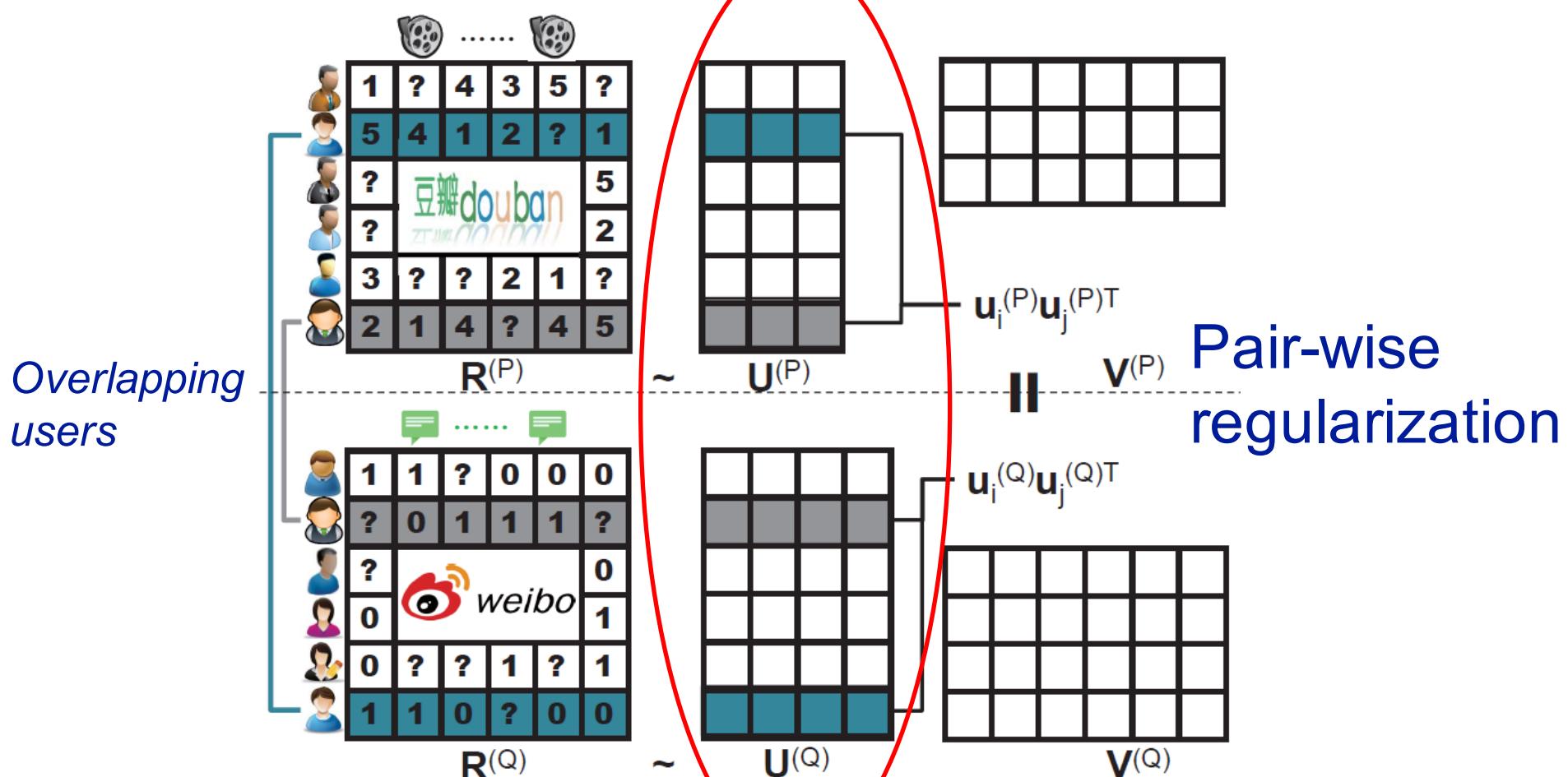
User set	Weibo tweet entity to Douban movie	
	RMSE	MAP
A	Auxiliary platform data!	
C	0.779	0.805
B	1.439	0.640

User set	Douban book to Weibo social tag	
	RMSE	MAP
A	0.429	0.464
C	0.267	0.666
B	Auxiliary platform data!	

Knowledge Transfer: Alleviate the Sparsity

Problem	Bridge	Method
Cross-Source	Non-overlapped → User cluster × Item cluster → The same latent representation	Codebook
Cross-Domain	Fully overlapped users OR Fully overlapped items → User vector OR Item vector → The same latent representation	CST
Cross-Platform	Partially overlapped users → User vector → Different latent representations	XPTTrans

XPTTrans: User Representations



XPTrans: Semi-Supervised Transfer

■ Input

- Tgt./Aux. platform P/Q ;
- Behavior data $R^{(P)}/R^{(Q)}$;
- Observation $W^{(P)}/W^{(Q)}$;
- Overlapping indicator $W^{(P,Q)}$,

■ Output

- User latent representation $U^{(P)}/U^{(Q)}$;
- Item latent representation $V^{(P)}/V^{(Q)}$;
- Missing values in $R^{(P)}$

■ Objective function

Target platform Auxiliary platform

$$\begin{aligned} \mathcal{J} = & \sum_{i,j} W_{i,j}^{(P)} \left(R_{i,j}^{(P)} - \sum_r U_{i,r}^{(P)} V_{r,j}^{(P)} \right)^2 \\ & + \lambda \sum_{i,j} W_{i,j}^{(Q)} \left(R_{i,j}^{(Q)} - \sum_r U_{i,r}^{(Q)} V_{r,j}^{(Q)} \right)^2 \\ & + \mu \sum_{i_1,j_1,i_2,j_2} W_{i_1,j_1}^{(P,Q)} W_{i_2,j_2}^{(P,Q)} \left(A_{i_1,i_2}^{(P)} - A_{j_1,j_2}^{(Q)} \right)^2 \end{aligned}$$

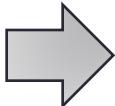
Overlapping user similarity
(Pair-wise regularization)

Leveraging Auxiliary Platform Data

NO Transfer

User set	Weibo tweet entity to Douban movie	
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B	Auxiliary platform data!	



Transfer via the Same Latent Space

User set	Weibo tweet entity to Douban movie	
	RMSE	MAP
A		
C	0.757	0.811
B	1.164 (-19%)	0.702 (+9.7%)

User set	Douban book to Weibo social tag	
	RMSE	MAP
A	0.411 (-4.2%)	0.487 (+5.0%)
C	0.256	0.681
B		

Leveraging Flexible Representation

Transfer via **the Same Latent Space**

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	RMSE	MAP
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C	0.757	0.811
B	1.164	0.702

User set	Douban book to Weibo social tag	
	RMSE	MAP
A	0.411	0.487
C	0.256	0.681
B		



Transfer via **Different Latent Spaces**

User set	Weibo tweet entity to Douban movie	
	RMSE	MAP
A		
C	0.715	0.821
B	0.722 (-38%)	0.820 (+17%)

User set	Douban book to Weibo social tag	
	RMSE	MAP
A	0.374 (-11%)	0.533 (+12%)
C	0.236	0.705
B		

Cross-Platform: Where Amazing Happens

NO Transfer

User set	Weibo tweet entity to Douban movie	
	RMSE	MAP
A	Auxiliary platform data!	
C	0.779	0.805
B	1.439	0.640

User set	Douban book to Weibo social tag	
	RMSE	MAP
A	0.429	0.464
C	0.267	0.666
B	Auxiliary platform data!	

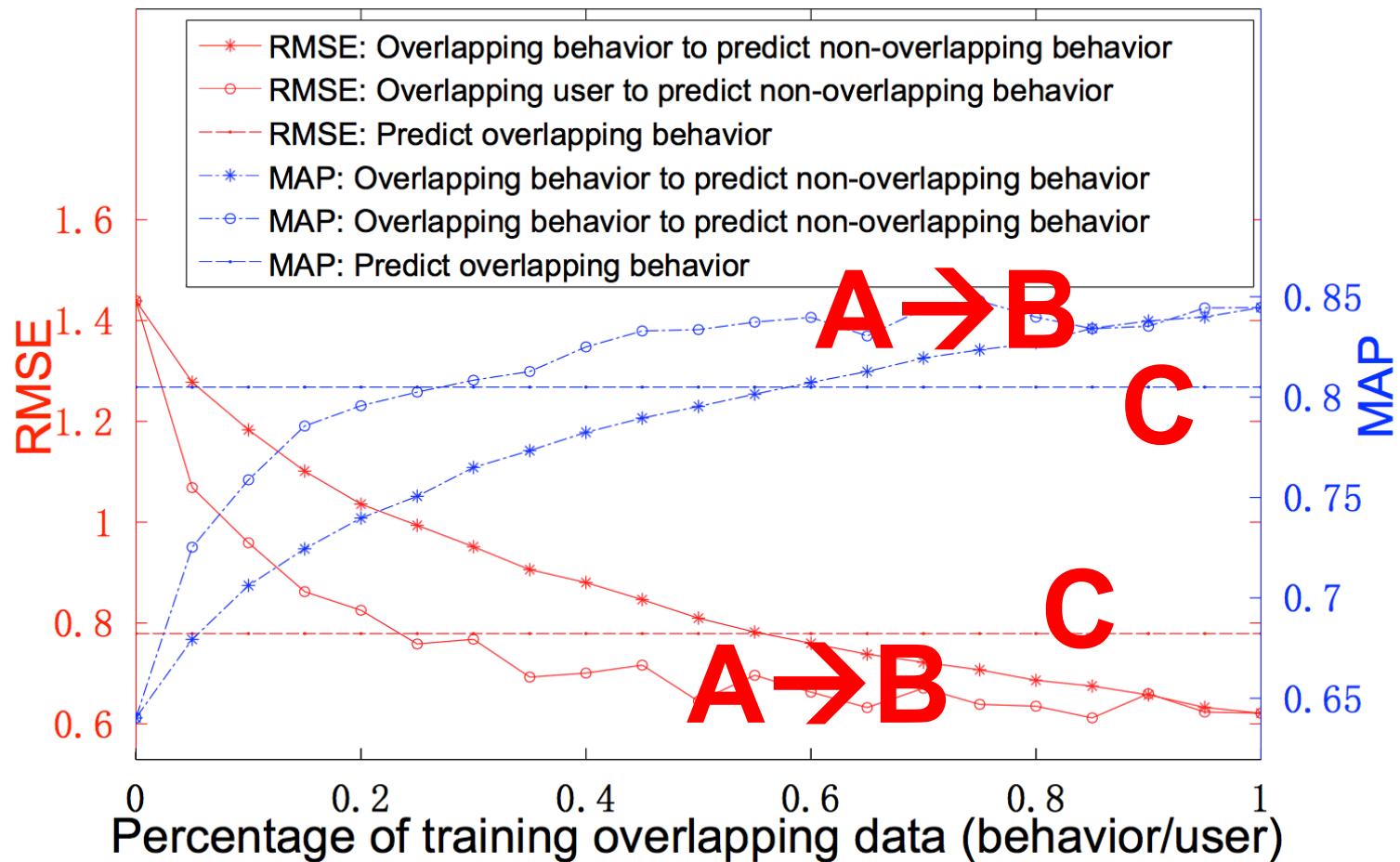


Transfer via Different Latent Spaces

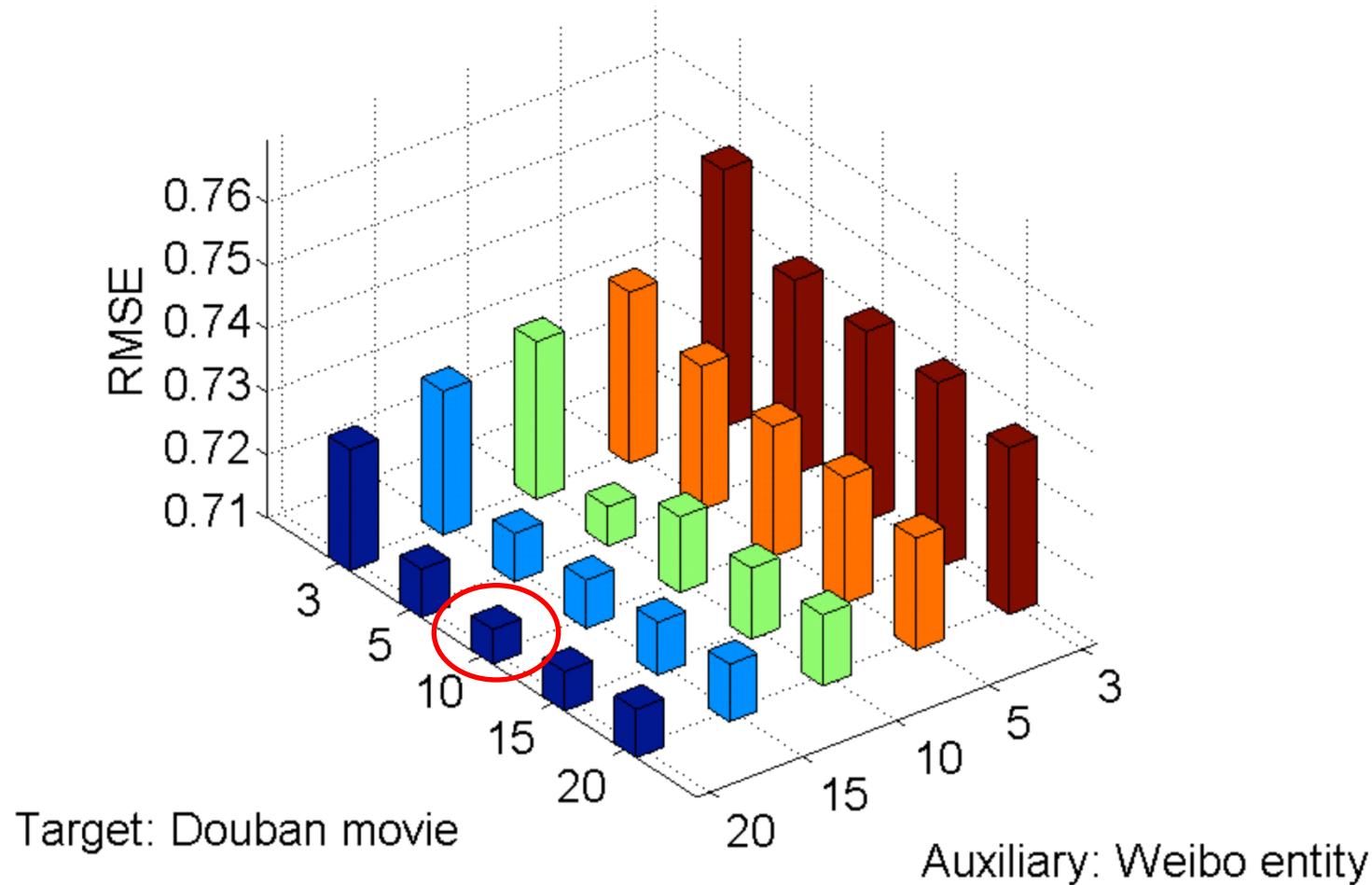
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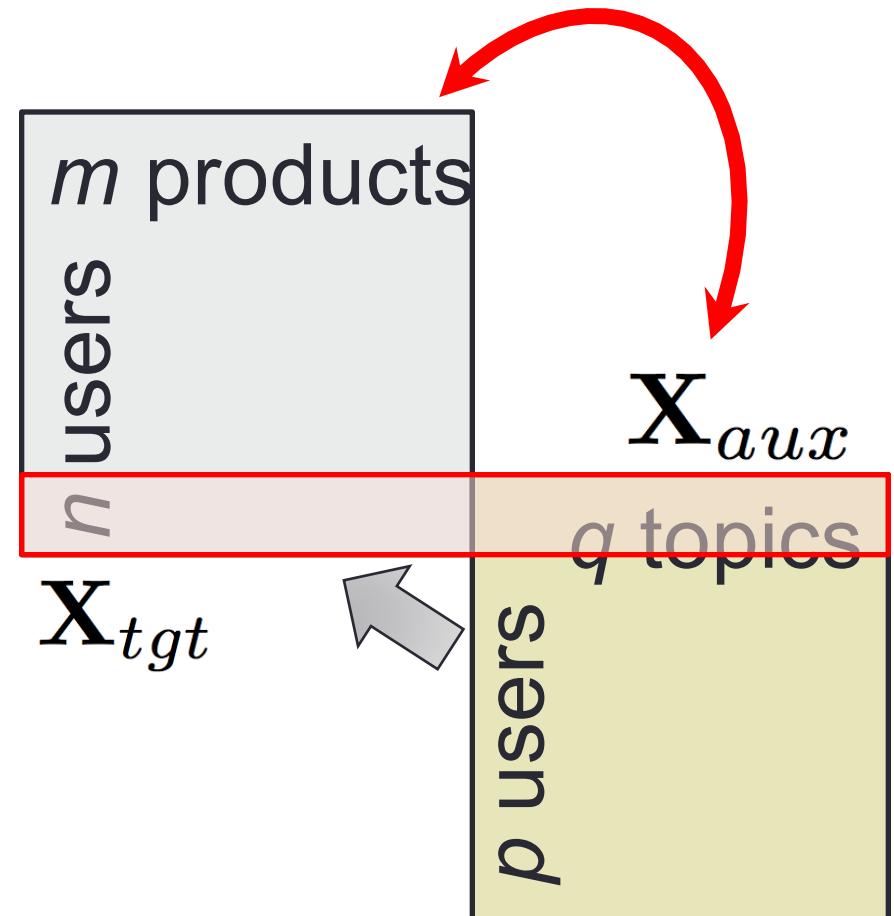
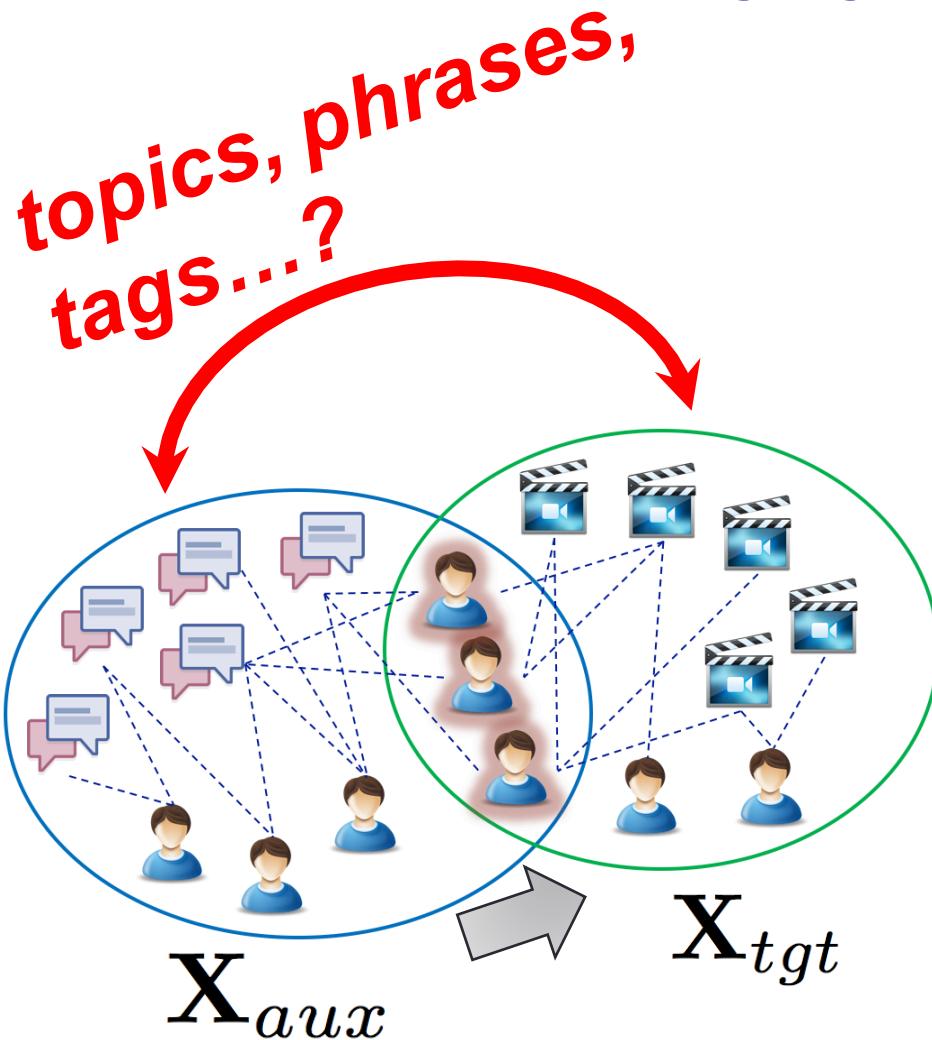
Performance



Different Sizes of Latent Space

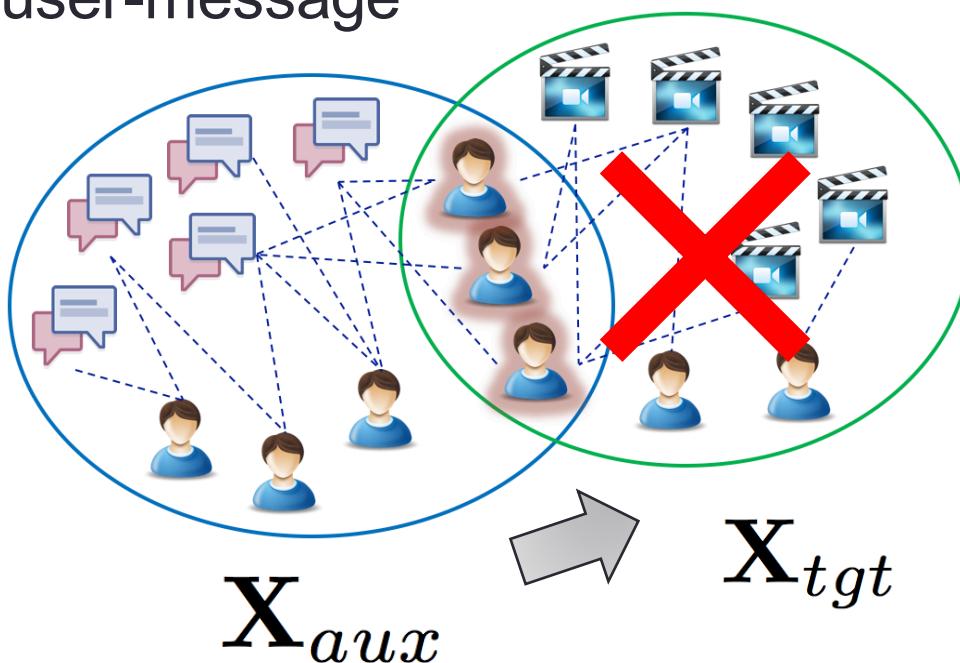


Discussion 1: Bridging Items with Semantics?



Discussion 2: Bridging Different Behavioral Data Structures?

Facebook
user-message



- Uber:**
spatio-temporal data
- Pinterest:**
multimedia data
- Amazon:**
user-product purchasing
- Netflix:**
user-movie rating
-

THANK YOU

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