Cross-Domain Collaborative Filtering

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Motivation

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	3	4		3	
	3			4	
4					4
			2	5	

Sparsity in Recommender Systems ➔

Matrix Factorization Overfitting

Transfer Learning

Q: Can we transfer rating knowledge from one recommendation domain to another to improve its rating prediction performance?

A: Yes, as long as two domains are "related"

- Users are related in interest
- Items are related in attributes

MOVIES (e.g. IMDB)

	A		B	
I	3	3	1	1
	3	3	1	1
II	2	2	3	3
	2	2	3	3

BOOKS (e.g. Amazon)

	A		B	
I	3	3	2	2
	3	3	2	2
II	1	1	3	3
	1	1	3	3

User/Item Group-Matching

A ⇔ B Romance Movies/Books
B ⇔ A Sci-Fi Movies/Books

I ⇔ II Girls on IMDB/Amazon
II ⇔ I Boys on IMDB/Amazon

Asymmetric Setting

Codebook Transfer[1] (CBT)

- Auxiliary domain: A dense rating matrix $\mathbf{X}aux$ (e.g., movie)
- Target domain: A sparse rating matrix $\mathbf{X}tgt$ (e.g., book)

	a	b	c	d	e	f
1	2	3	3	3	2	?
2	3	1	2	2	?	1
3	3	1	?	2	3	1
4	?	2	1	1	3	2
5	2	3	3	3	2	3
6	3	2	1	?	3	2

Auxiliary Matrix

	a	e	b	f	c	d
2	3	?	1	1	2	2
3	3	3	1	1	?	2
1	2	2	3	?	3	3
5	2	2	3	3	3	3
4	?	3	2	2	1	1
6	3	3	2	2	1	?

	A	B	C
I	3	1	2
II	2	3	3
III	3	2	1

Codebook

$$\min_{\mathbf{U}\in\{0,1\}^{I\times K},\mathbf{V}\in\{0,1\}^{J\times L}} \left\|\left(\mathbf{X}_{tgt}-\mathbf{U}\mathbf{B}\mathbf{V}^{\mathrm{T}}\right)\circ\mathbf{W}\right\|_F^2$$

$$\text{s.t. } \mathbf{U}\mathbf{1}=\mathbf{1},\mathbf{V}\mathbf{1}=\mathbf{1}$$

	a	b	c	d	e
1	1	1	3	3	1
2	3	3	2	2	3
3	2	2	3	3	2
4	1	1	3	3	1
5	1	1	3	3	1
6	3	3	2	2	3
7	2	2	3	3	2

Reconstructed

1	1	0	0
2	0	1	0
3	0	0	1
4	1	0	0
5	1	0	0
6	0	1	0
7	0	0	1

User-cluster Indicators

	A	B	C
I	3	1	2
II	2	3	3
III	3	2	1

Codebook

	a	b	c	d	e
	0	0	1	1	0
	1	1	0	0	1
	0	0	0	0	0

Item-cluster Indicators

Symmetric Setting

Rating-Matrix Generative Model[2] (RMGM)

- All the domains share the same group-level rating matrix **B**
- Each domain has specific membership matrices $\mathbf{P}^{(z)}$ and $\mathbf{Q}^{(z)}$

$$\hat{\mathbf{X}}^{(z)}=\mathbf{P}^{(z)}\mathbf{B}[\mathbf{Q}^{(z)}]^{\mathrm{T}} \text{ where } \mathbf{B}_{k,l}=\sum_r rp(r\mid k,l)$$

User $u^{(z)}$'s membership in user group k: $\mathbf{P}^{(z)}_{u,k}=p(k\mid u^{(z)})$

$$p(k\mid u^{(z)})\propto p(u^{(z)}\mid k)p(k)$$

Item $m^{(z)}$'s membership in item group l: $\mathbf{Q}^{(z)}_{m,l}=p(l\mid m^{(z)})$

$$p(l\mid m^{(z)})\propto p(m^{(z)}\mid l)p(l)$$

E – Step :

$$p(k,l\mid x^{(z)}_{u,m})=\frac{p(x^{(z)}_{u,m}\mid k,l)p(u^{(z)}\mid k)p(k)p(m^{(z)}\mid l)p(l)}{\sum_{k,l}p(x^{(z)}_{u,m}\mid k,l)p(u^{(z)}\mid k)p(k)p(m^{(z)}\mid l)p(l)}$$

M – Step :

$$p(k)=\frac{\sum_z\sum_l\sum_{w^{(z)}_{u,m}=1}p(k,l\mid x^{(z)}_{u,m})}{\sum_z\sum_{(u,m)}w^{(z)}_{u,m}},\quad p(l)=\frac{\sum_z\sum_k\sum_{w^{(z)}_{u,m}=1}p(k,l\mid x^{(z)}_{u,m})}{\sum_z\sum_{(u,m)}w^{(z)}_{u,m}}$$

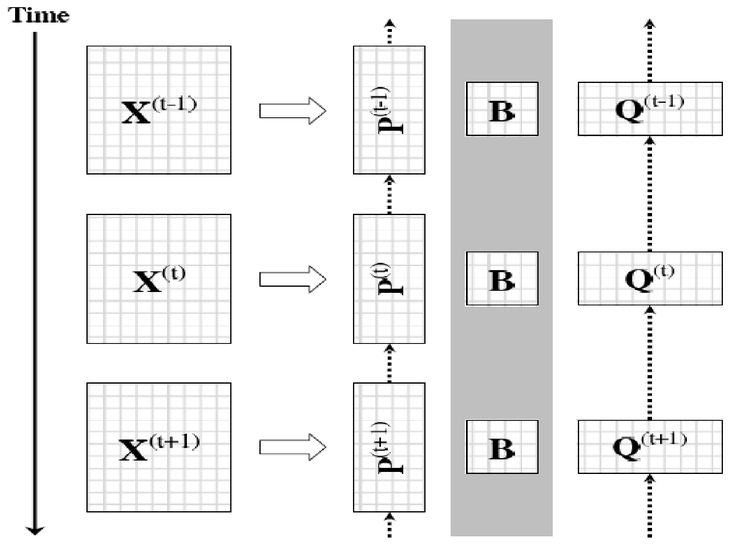
$$p(u^{(z)}\mid k)=\frac{\sum_l\sum_{w^{(z)}_{u,m}=1\cap v=u}p(k,l\mid x^{(z)}_{v,m})}{p(k)\sum_z\sum_{(u,m)}w^{(z)}_{u,m}},\quad p(m^{(z)}\mid l)=\frac{\sum_k\sum_{w^{(z)}_{u,m'}=1\cap m'=m}p(k,l\mid x^{(k)}_{u,m'})}{p(l)\sum_z\sum_{(u,m)}w^{(z)}_{u,m}}$$

$$p(r\mid k,l)=\frac{\sum_{w^{(z)}_{u,m}=1\cap x^{(k)}_{u,m}=r}p(k,l\mid x^{(k)}_{u,m})}{\sum_{w^{(z)}_{u,m}=1}p(k,l\mid x^{(k)}_{u,m})}$$

Temporal Setting

Rating-Matrix Generative Model[3] (RMGM-OT)

- Group-level rating matrix **B** *unchanged* over time
- $\mathbf{P}^{(t)}$ and $\mathbf{Q}^{(t)}$ vary over time but *dependent* on their predecessors



1. For joint group (k,l), draw $\mathbf{T}_{k,l}\sim Dirichlet(\beta)$
2. For user u, draw $\mathbf{p}^{(t)}_u\sim Dirichlet(\lambda\mathbf{p}^{(t-1)}_u)$
3. For item m, draw $\mathbf{q}^{(t)}_m\sim Dirichlet(\lambda\mathbf{q}^{(t-1)}_m)$
4. For rating $x_{u,m,t}$
   a) Draw a user group $z^U_{u,m,t}\sim Multinomial(\mathbf{p}^{(t)}_u)$
   b) Draw an item group $z^I_{u,m,t}\sim Multinomial(\mathbf{q}^{(t)}_m)$
   c) Draw the rating $x_{u,m,t}\sim Multinomial(\mathbf{T}_{z^U_{u,m,t},z^I_{u,m,t}})$

References

[1] Li *et al.*: Can Movies and Books Collaborate? Cross-Domain Collaborative Filtering for Sparsity Reduction, *IJCAI* 2009
[2] Li *et al.*: Transfer Learning for Collaborative Filtering via a Rating-Matrix Generative Model, *ICML* 2009
[3] Li *et al.*: Cross-Domain Collaborative Filtering over Time, *IJCAI* 2011
[4] Li: Cross-Domain Collaborative Filtering: A Brief Survey, *ICTAI* 2011