One for All, All for One: Learning and Transferring User Embeddings for Cross-Domain Recommendation

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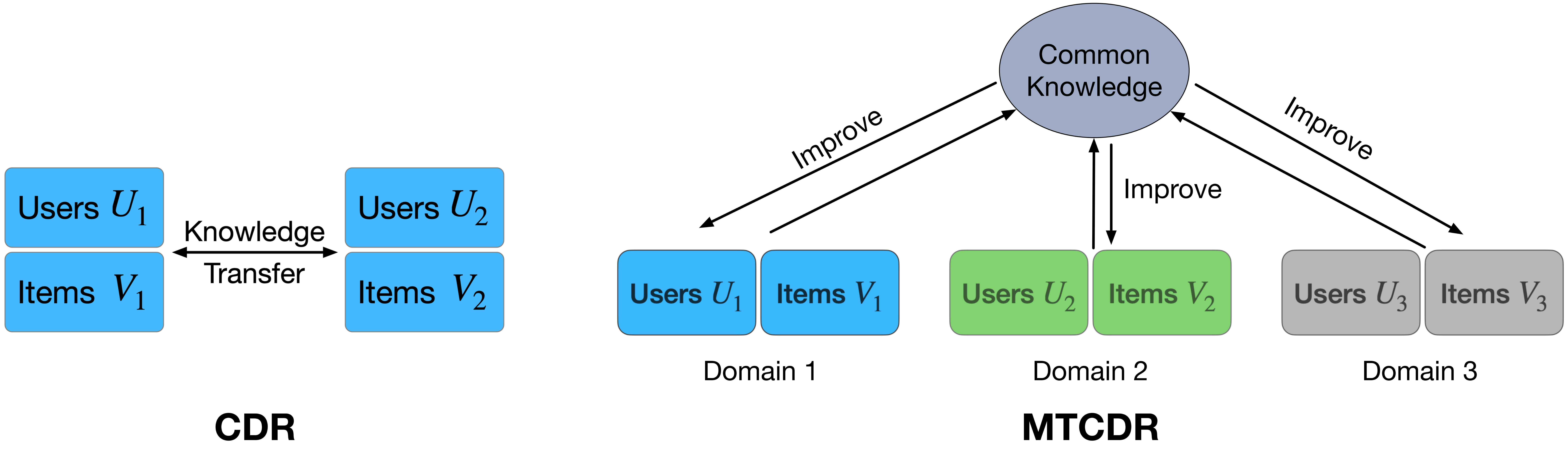
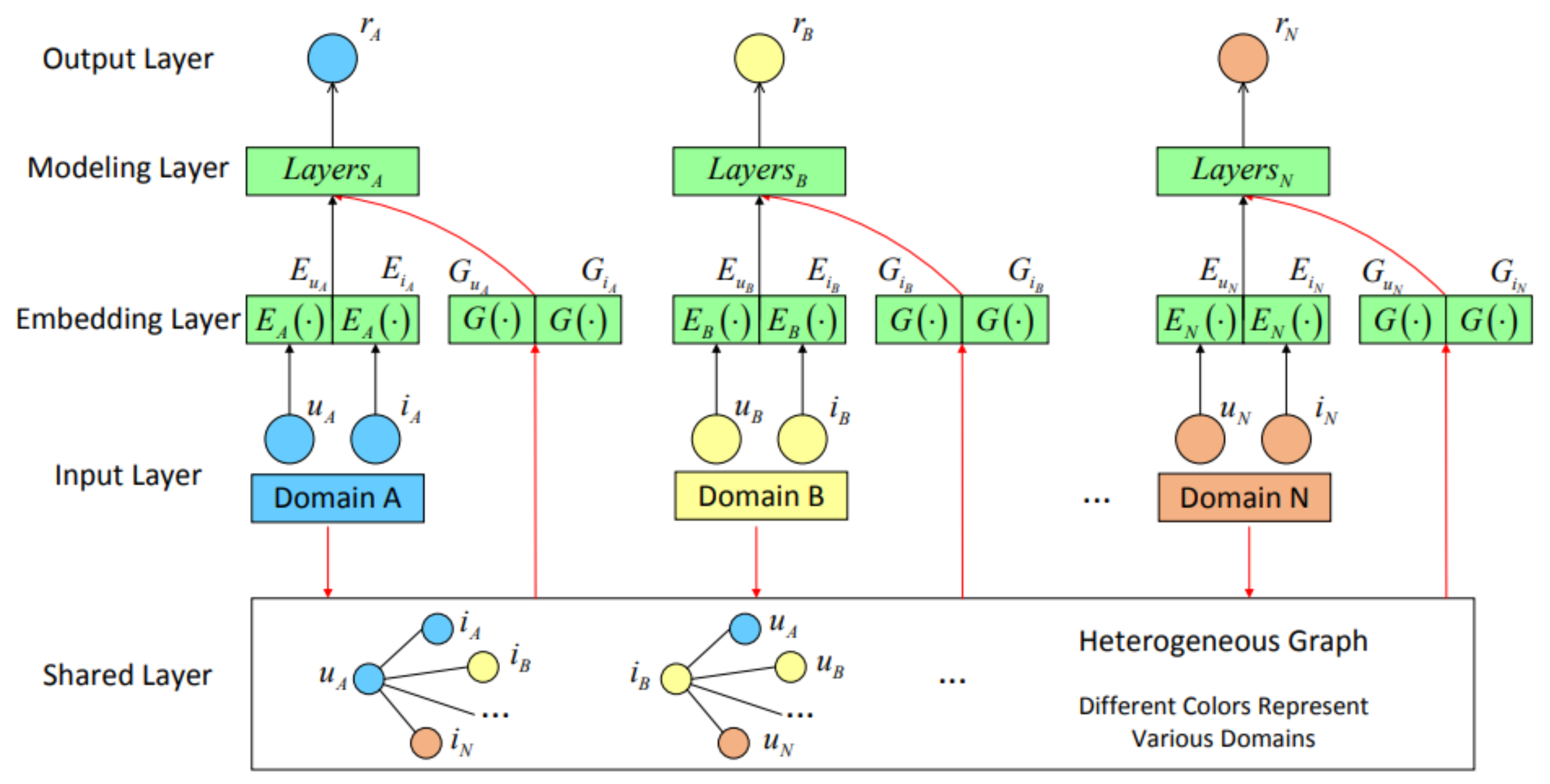
Multi-target CDR

- Multiple domains (≥ 3)
- Boost recommendations in all domains simultaneously

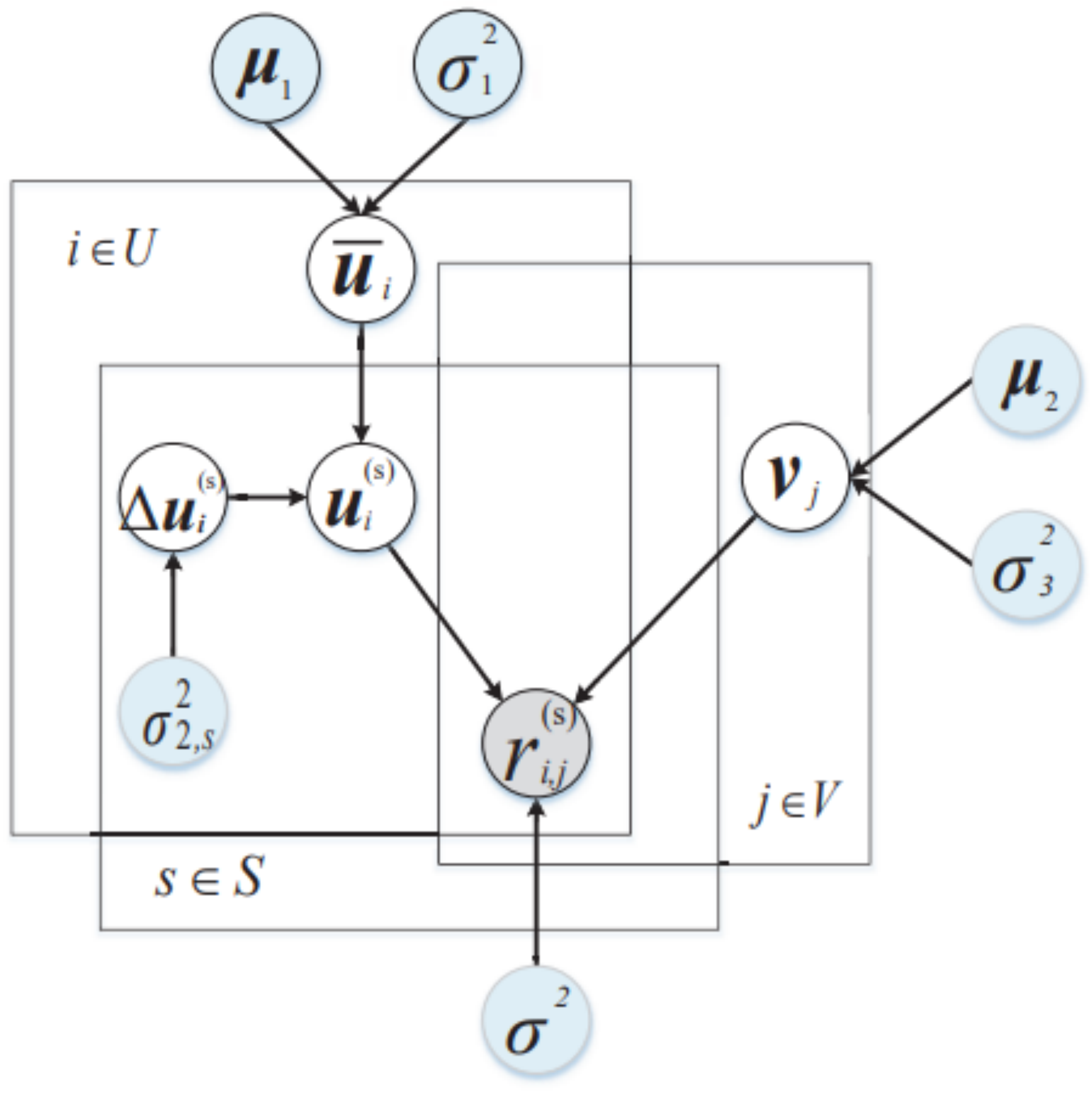


Previous Methods

- Global representation
- Joint training
- Sharing of raw data



HeroGraph[1]

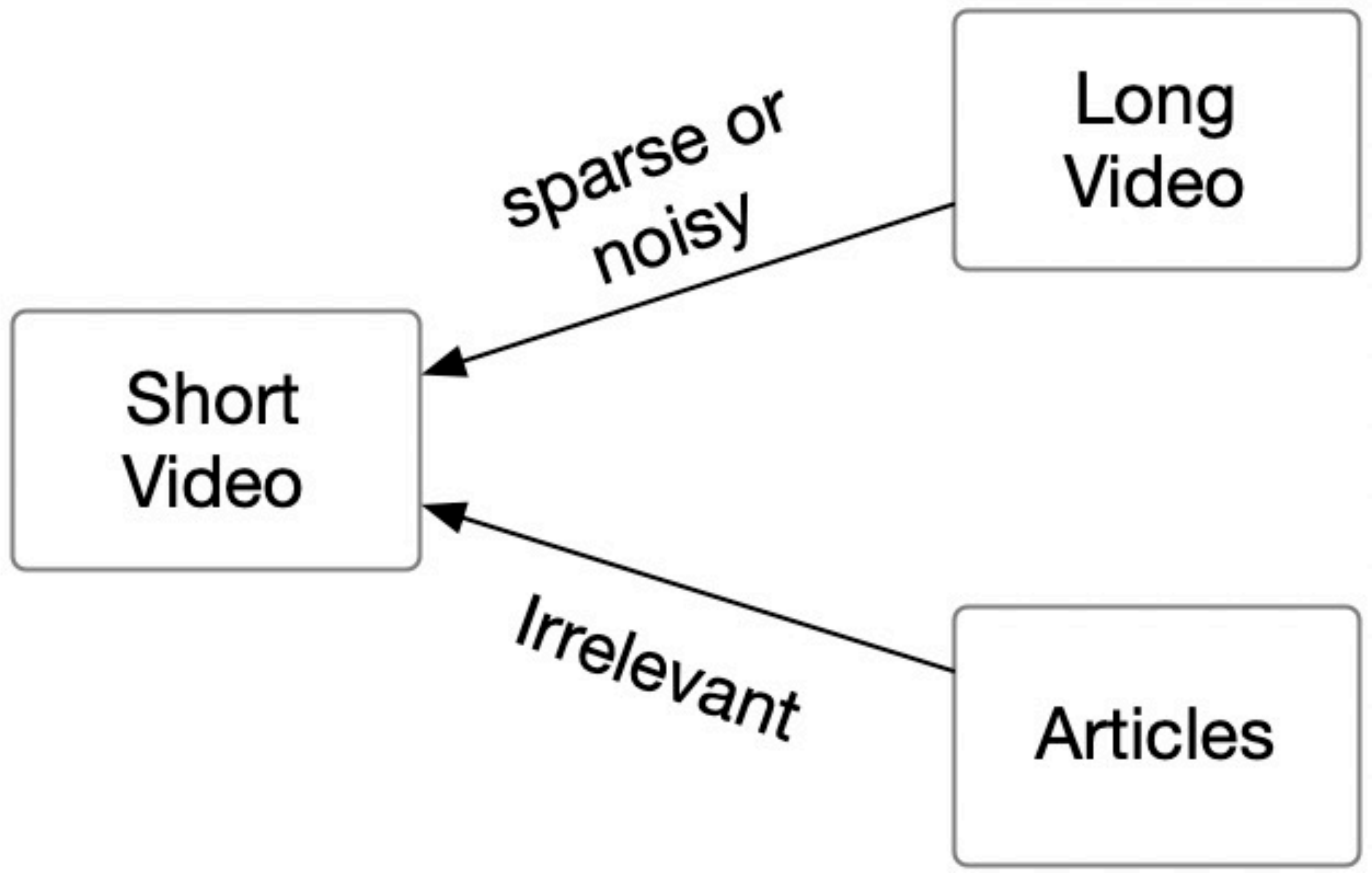


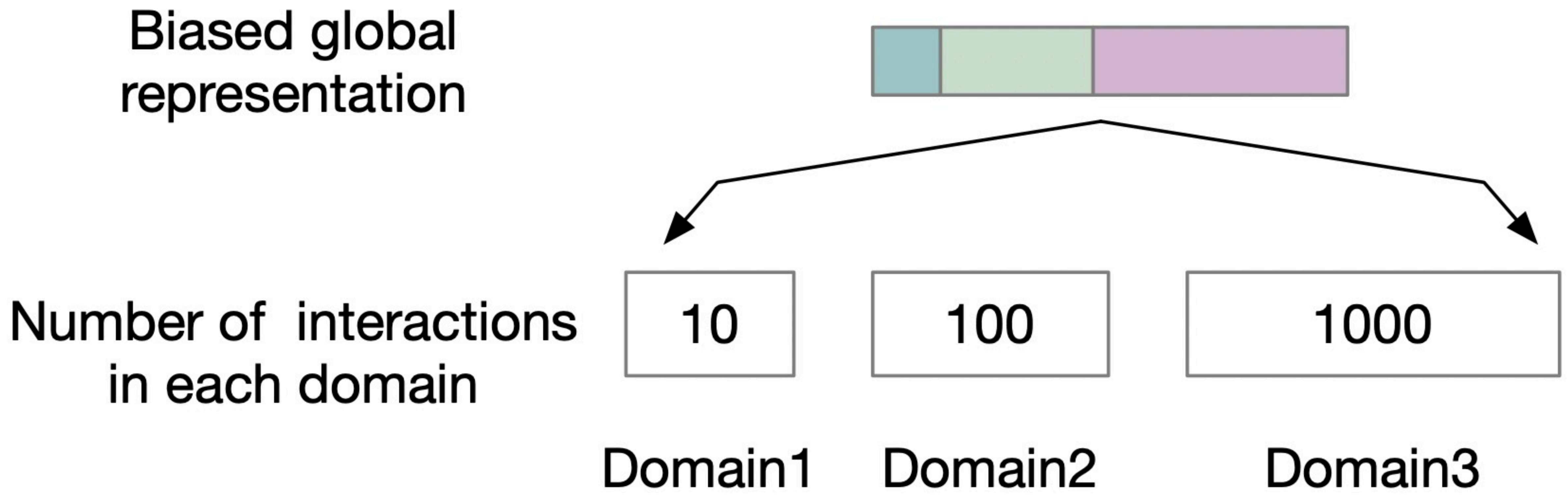
MPF[2]

[1]HeroGRAPH: A Heterogeneous Graph Framework for Multi-Target Cross-Domain Recommendation
[2]Multi-site User Behavior Modeling and Its Application in Video Recommendation

MTCDR: Challenges

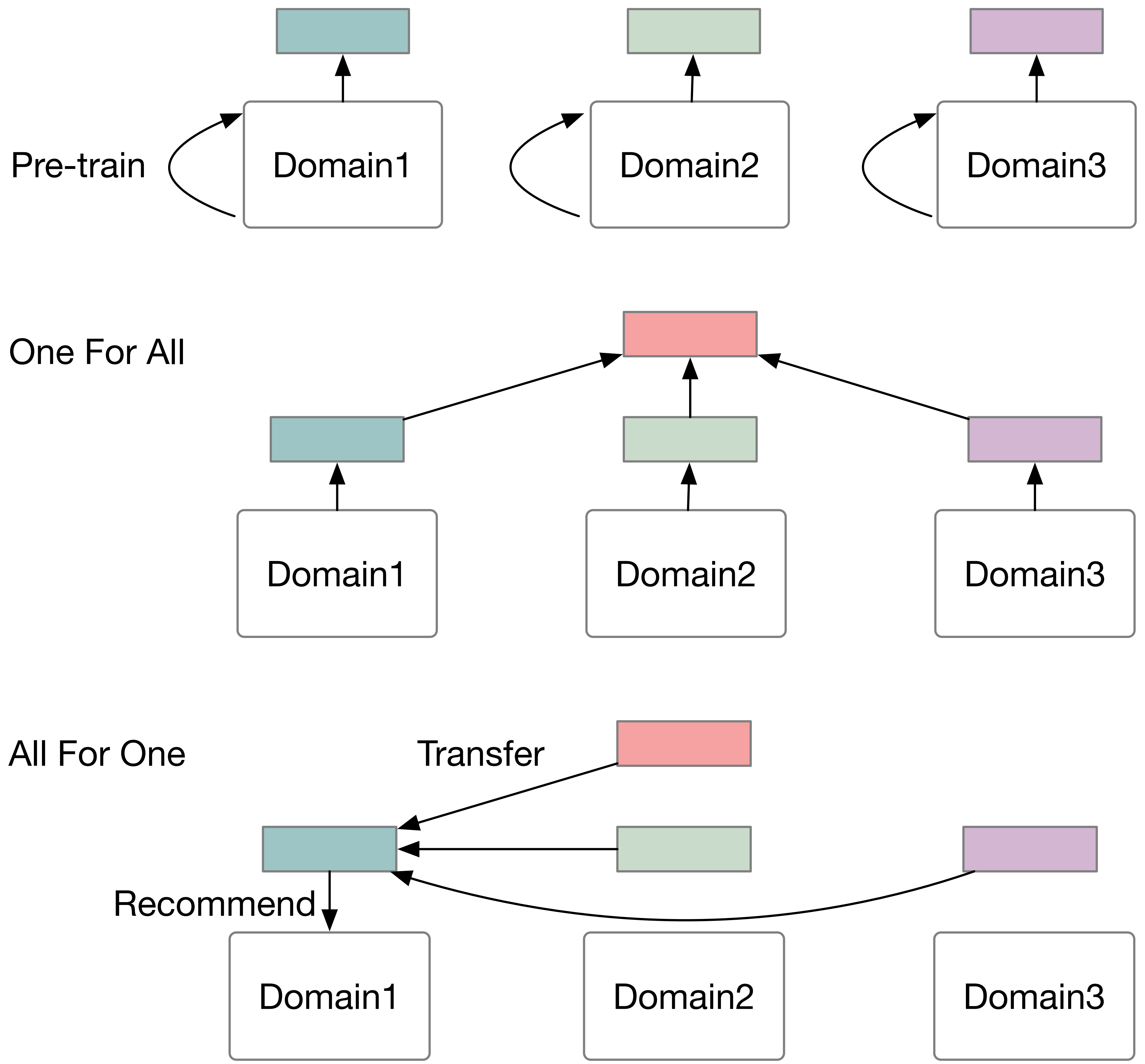
- Negative transfer
  - Irrelevant or noisy information
- Biased global representation
  - Data unbalance between domains
  - Biased towards dense domain
- Data privacy





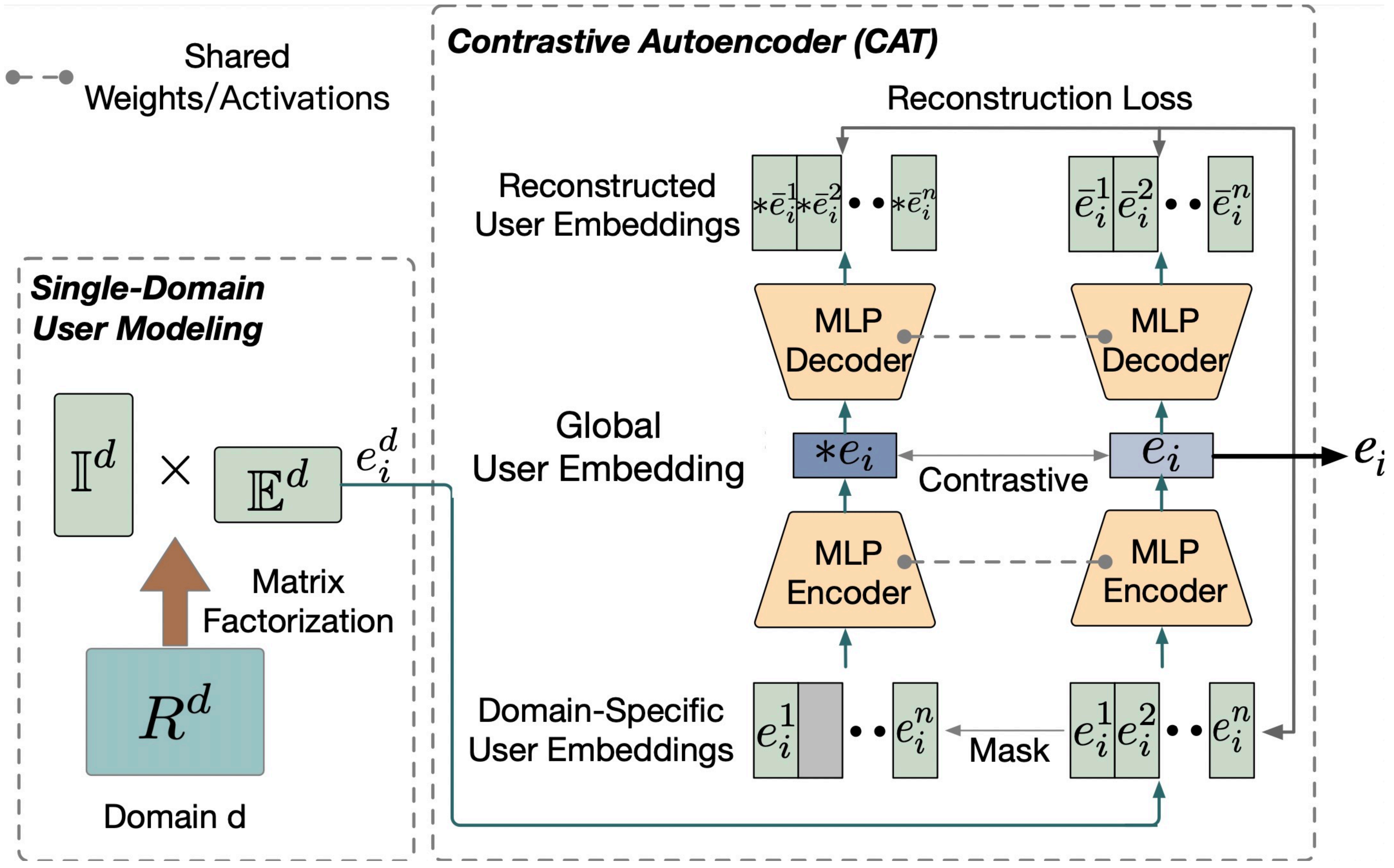
Proposed Method

- Overview
  - Pre-train in a single domain
    - Share latent user embedding
  - One For All
    - Extract unbiased global representation
  - All For One
    - Transfer all useful features to help recommend in the target domain



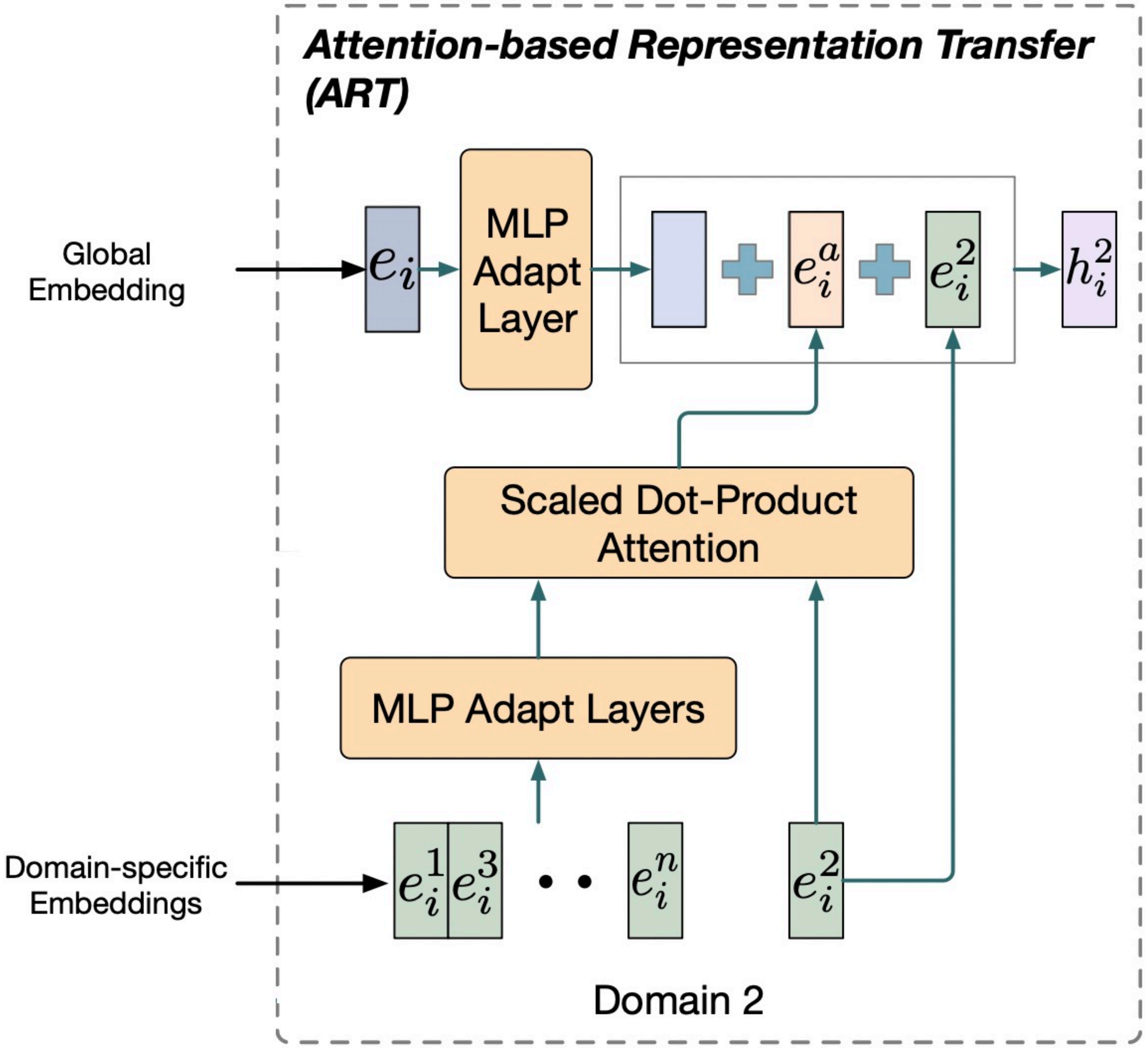
One For All

- Global user representation
  - AutoEncoder
- Unbiased global representation
  - Contrastive AutoEncoder (CAT)
    - Randomly mask out one domain



All For One

- All available features are transferred
- Final user embedding
  - Target domain-specific features
  - Unbiased global embedding
  - Source domain-specific features
    - Attention-based representation transfer (ART)



Model Training

- Loss
  - BPR loss
  - Reconstruction (MSE)
  - Contrastive (Cross-entropy)
- Training scheme

Algorithm 1: CAT-ART Algorithm

Input: User set U, and item sets: $\{V_1, \cdots V_n\}$, $n \geq 3$;
User-Item interaction matrices: $\{R^1, \cdots, R^n\}$;
Stage 1 (parallel):
for $\forall d \in [1, n]$ **do**
  Train domain-specific user and item embeddings: $\mathbb{E}^d$ and $\mathbb{I}^d$ according to BPR loss.
Stage 2:
Train the CAT module according to reconstruction and contrastive loss.
Stage 3 (parallel):
Fix the CAT module and domain-specific user embeddings in all domains.
for $\forall d \in [1, n]$ **do**
  Train the ART unit according to the BPR loss and the enhanced user embedding.

Evaluation: Experiment Settings

- Datasets
    - 5 domains: App install, App usage, Articles, Long video, Short video
- Baselines
    - Single-domain MF
    - CMF, MPF, GA-MTCDR, HeroGraph
- Metrics
    - Precision, Recall, NDCG

Table 1: Statistics of the Collected Dataset with 5 Domains.

Domain	#Users	#Items	#Interactions	Density(‰)
App-Ins		100,000	101,981,793	0.874
APP-Use		100,000	18,156,535	0.155
Articles	1,166,552	50,000	102,832,656	1.763
Video-S		50,000	74,911,020	1.284
Video-L		50,000	11,412,988	0.196

Evaluation: Main Results

- Negative transfer
  - Avoiding NT in all domains
- Boosted performance in all domains

Model	Domain	Precision		Recall		NDCG	
		@10	@20	@10	@20	@10	@20
SMF	APP-Ins	33.82±0.70	25.46±0.88	21.51±0.39	31.91±1.22	32.56±0.43	32.53±0.89
	APP-Use	20.91±0.23	12.21±0.26	65.5±0.89	75±1.50	57.39±1.46	60.81±1.72
	Article	16.02±0.73	12.05±0.58	16.64±0.43	23.25±0.40	21.59±1.30	21.93±1.06
	Video-S	3.9±0.03	3.86±0.02	3.59±0.44	6.9±0.77	3.83±0.13	4.84±0.25
	Video-L	5.98±0.20	3.91±0.10	26.73±0.87	34.6±0.88	20.37±1.19	22.91±1.2
CMF	APP-Ins	33.57±0.37↓	25.19±0.37↓	21.8±0.19	32.05±0.43	32.39±0.29↓	32.45±0.27↓
	APP-Use	20.41±0.11↓	12.17±0.05↓	64.91±0.27↓	75.54±0.16	43.99±0.78↓	47.89±0.74↓
	Article	10.29±0.27↓	8.37±0.19↓	8.83±0.23↓	13.79±0.28↓	11.24±0.34↓	12.07±0.31↓
	Video-S	3.87±0.12	3.81±0.12↓	4.08±0.17	7.6±0.29	4.00±0.14	5.04±0.18
	Video-L	4.74±0.03↓	3.26±0.01↓	21.44±0.12↓	29.14±0.06↓	12.67±0.07↓	15.14±0.05↓
MPF	APP-Ins	36.08±1.53	27.11±0.41	23.28±0.99	34.29±0.44	36.95±5.56	36.53±4.02
	APP-Use	20.95±0.12	12.26±0.16	65.55±0.44	75.18±0.84	55.67±2.71↓	59.14±2.52↓
	Article	14.55±0.16↓	11.14±0.11↓	15.35±0.07↓	21.72±0.12↓	20.96±0.63↓	21.29±0.52↓
	Video-S	3.63±0.29↓	3.67±0.13↓	3.71±0.30	7.16±0.68	3.85±0.40	4.91±0.11
	Video-L	2.74±0.95↓	2.09±0.52↓	11.96±4.31↓	18.2±4.66↓	8.03±3.65↓	10.01±3.79↓
GA-MTCDR	APP-Ins	16.77±0.05↓	10.35±0.02↓	11.7±0.01↓	14.37±0.03↓	17.81±0.08↓	16.01±0.03↓
	APP-Use	13.88±0.05↓	10.46±0.01↓	45.44±0.13↓	67.2±0.16↓	32.35±0.13↓	40.16±0.1↓
	Article	4.62±0.13↓	3.73±0.03↓	4.12±0.14↓	6.37±0.11↓	6.22±0.18↓	6.36±0.13↓
	Video-S	3.44±0.03↓	3.1±0.02↓	3.48±0.08↓	6.03±0.06↓	4.22±0.05	4.69±0.04
	Video-L	3.18±0.15↓	2.22±0.07↓	14.21±0.74↓	19.76±0.54↓	10.46±0.63↓	12.23±0.49↓
HeroGRAPH-L	APP-Ins	34.05±2.01	24.47±1.16↓	22.34±1.14	31.61±1.35↓	40.5±1.91	38.12±1.51
	APP-Use	20.68±0.36↓	11.98±0.15↓	66.11±0.83	74.96±0.61↓	59.51±1.08	62.74±0.98
	Article	11.27±0.12↓	8.61±0.12↓	15.01±0.2↓	20.68±0.33↓	18.19±0.16↓	18.86±0.23↓
	Video-S	**3.99**±0.14	3.7±0.15	**5.29**±0.21	**8.97**±0.34	**5.31**±0.18	**6.2**±0.23
	Video-L	5.42±0.29↓	3.65±0.15↓	24.62±1.22↓	32.84±1.29↓	18.71±1.21↓	21.35±1.24↓
CAT-ART	APP-Ins	**38.36**±0.58	**27.96**±0.31	**24.86**±0.34	**35.46**±0.39	**43.47**±1.23	**41.55**±0.94
	APP-Use	**21.23**±0.18	**12.33**±0.18	**66.53**±0.65	**75.66**±1.02	**59.98**±0.86	**63.27**±1.02
	Article	**16.82**±0.21	**12.4**±0.13	**18.76**±0.56	**25.47**±0.6	**25.97**±0.61	**25.79**±0.58
	Video-S	3.93±0.08	**3.93**±0.06	3.83±0.50	7.35±0.82	3.93±0.14	5.05±0.24
	Video-L	**6.08**±0.09	**3.96**±0.08	**27.18**±0.39	**35.01**±0.67	**21.03**±0.38	**23.54**±0.86

Evaluation: Ablation Study

- Base model (SMF)
- +Autoencoder
- +Contrastive
  - The full CAT module
- +ART
  - Features from all domains
- -Attention

Domain	Metric	SMF	+Autoencoder	+Contrastive	+ART	-Attention
App-Ins	Precision@10	33.82±0.70	37.64±1.17	37.95±0.45	**38.36**±0.58	36.24±0.26
	Recall@10	21.51±0.39	24.35±0.76	24.58±0.35	**24.86**±0.34	23.35±0.23
	NDCG@10	32.56±0.43	41.34±3.75	42.56±2.02	**43.47**±1.23	36.08±1.54
APP-Use	Precision@10	20.91±0.23	21.00±0.11	21.08±0.23	**21.23**±0.18	21.01±0.07
	Recall@10	65.50±0.89	65.77±0.33	66.01±0.88	**66.53**±0.65	65.92±0.41
	NDCG@10	57.39±1.46	59.09±0.37	58.61±0.40	**59.98**±0.86	59.28±0.24
Article	Precision@10	16.02±0.73	16.54±0.46	16.46±0.34	**16.82**±0.21	15.88 ± 0.15↓
	Recall@10	16.64±0.43	17.48±1.21	17.19±1.13	**18.76**±0.56	15.89±0.38↓
	NDCG@10	21.59±1.30	23.98±2.28	23.54±2.75	**25.97**±0.61	22.25±1.71
Video-S	Precision@10	3.89±0.025	3.91±0.08	**3.97**±0.13	3.93±0.08	3.82±0.28↓
	Recall@10	3.59±0.44	3.71±0.40	3.72±0.37	**3.83**±0.50	3.46±0.25↓
	NDCG@10	3.83±0.13	3.87±0.08	3.91±0.05	**3.93**±0.14	3.73±0.18↓
Video-L	Precision@10	5.98±0.20	6.04±0.01	6.07±0.04	**6.08**±0.09	5.86±0.03↓
	Recall@10	26.73±0.87	27.00±0.08	27.17±0.20	**27.18**±0.39	26.27±0.09↓
	NDCG@10	20.37±1.19	21.00±0.14	21.12±0.21	**21.03**±0.38	20.26±0.15↓

Thank you!
Q & A