# TPR: Text-aware Preference Ranking for Recommender Systems

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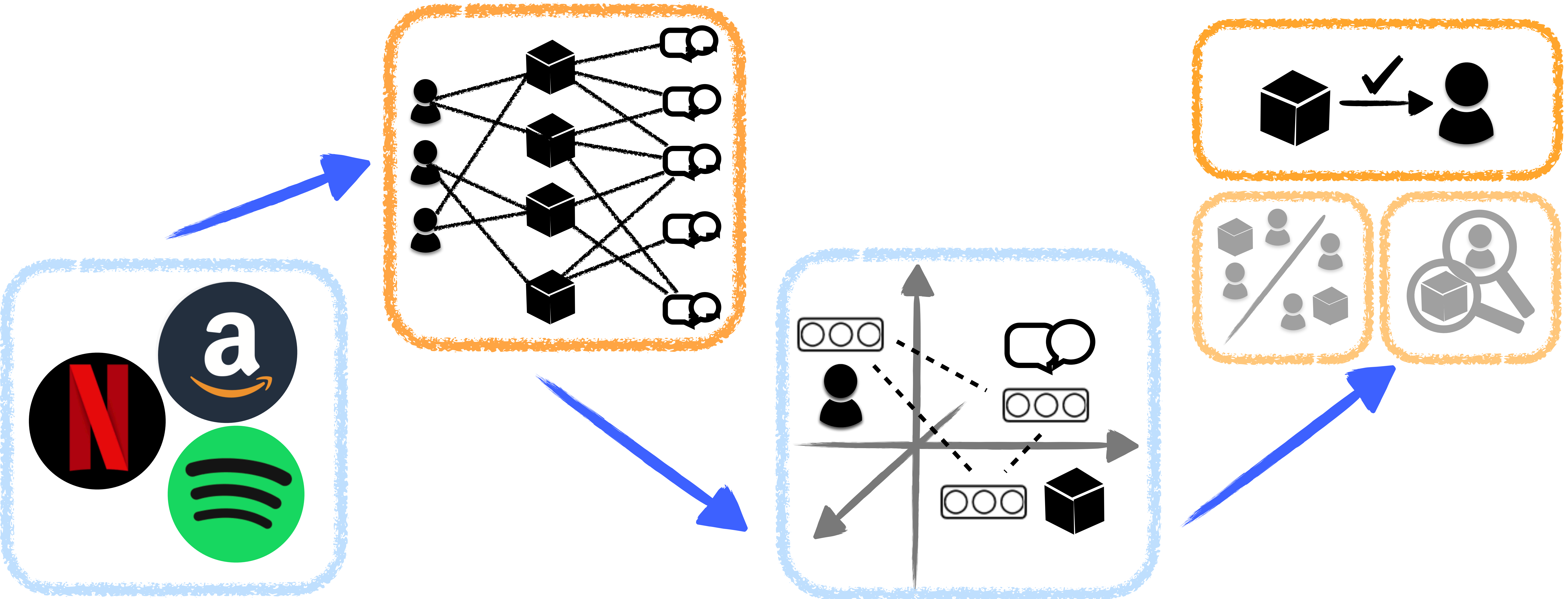
Prof. Yuan Fang, and Prof. Ee-Peng Lim

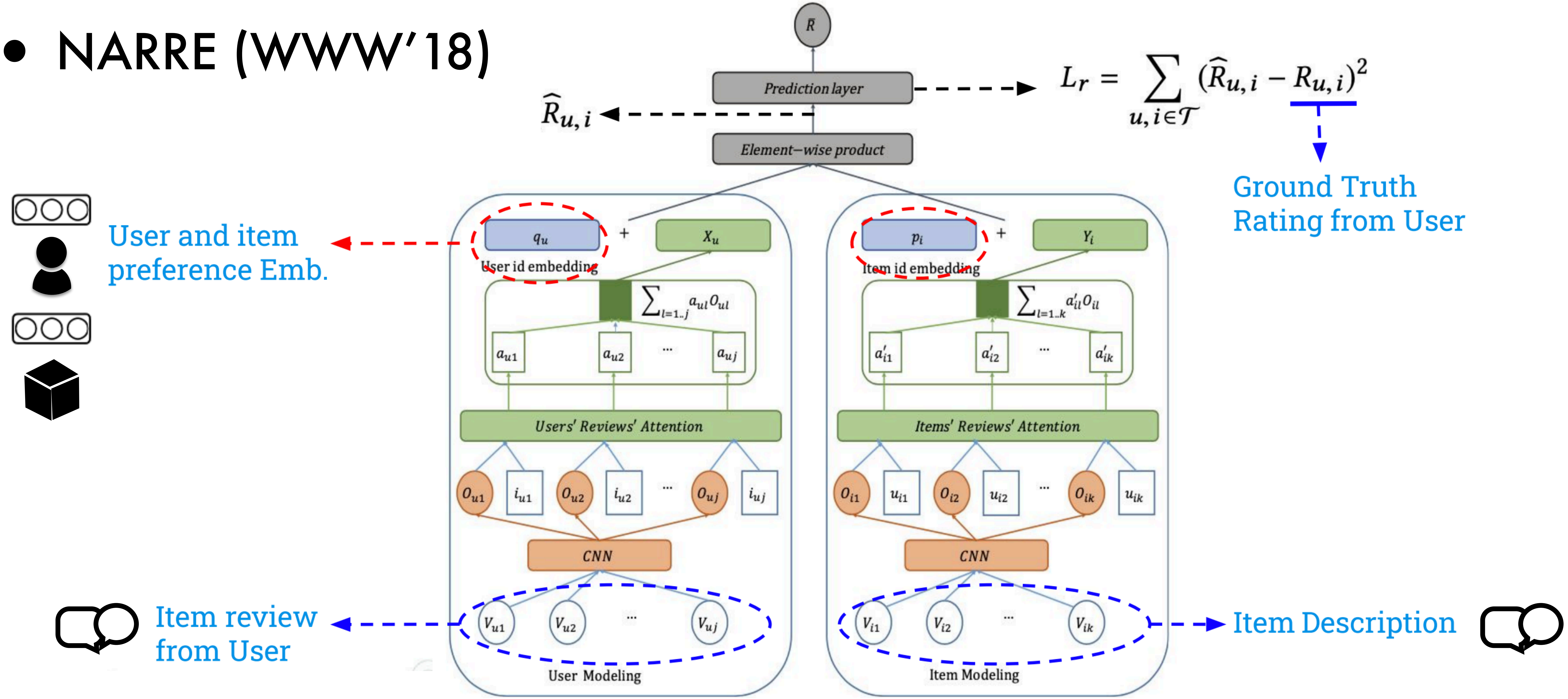
# Introduction

- What is graph embedding?



# Related work - Textual-based Recommendation

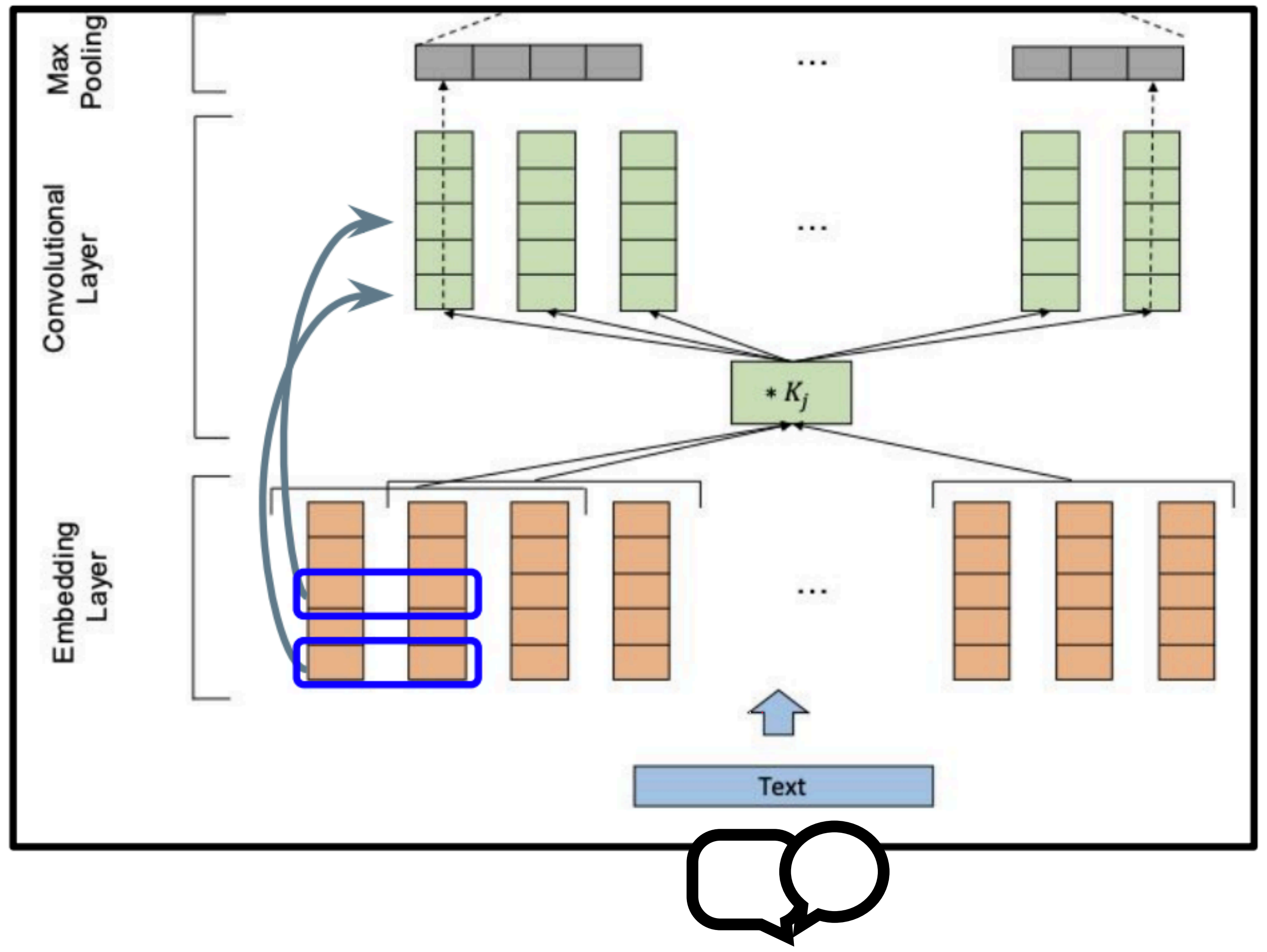
- NARRE (WWW'18)

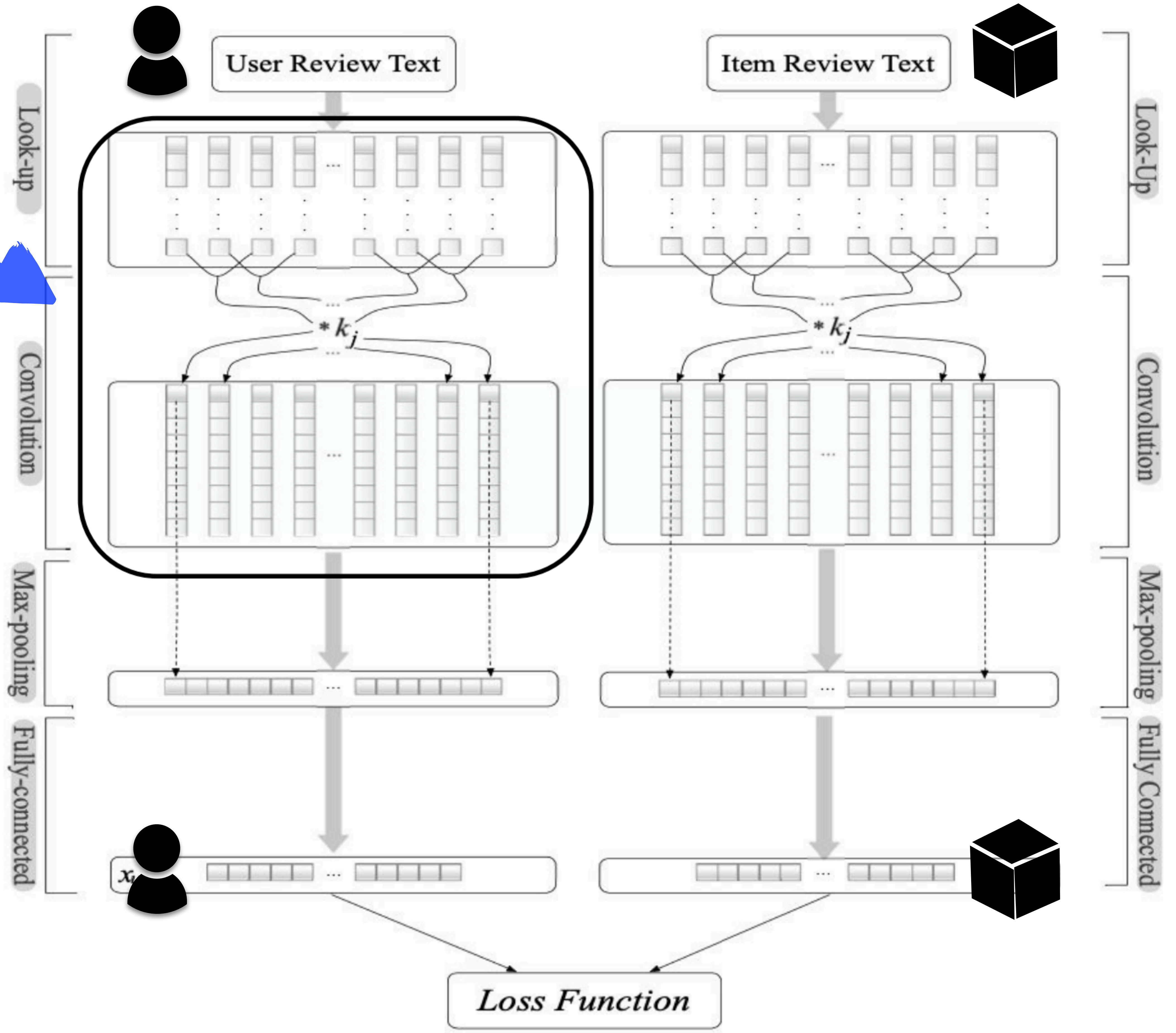


# Related work - Textual-based Recommendation

- DeepCoNN (WSDM'17)

Text-CNN

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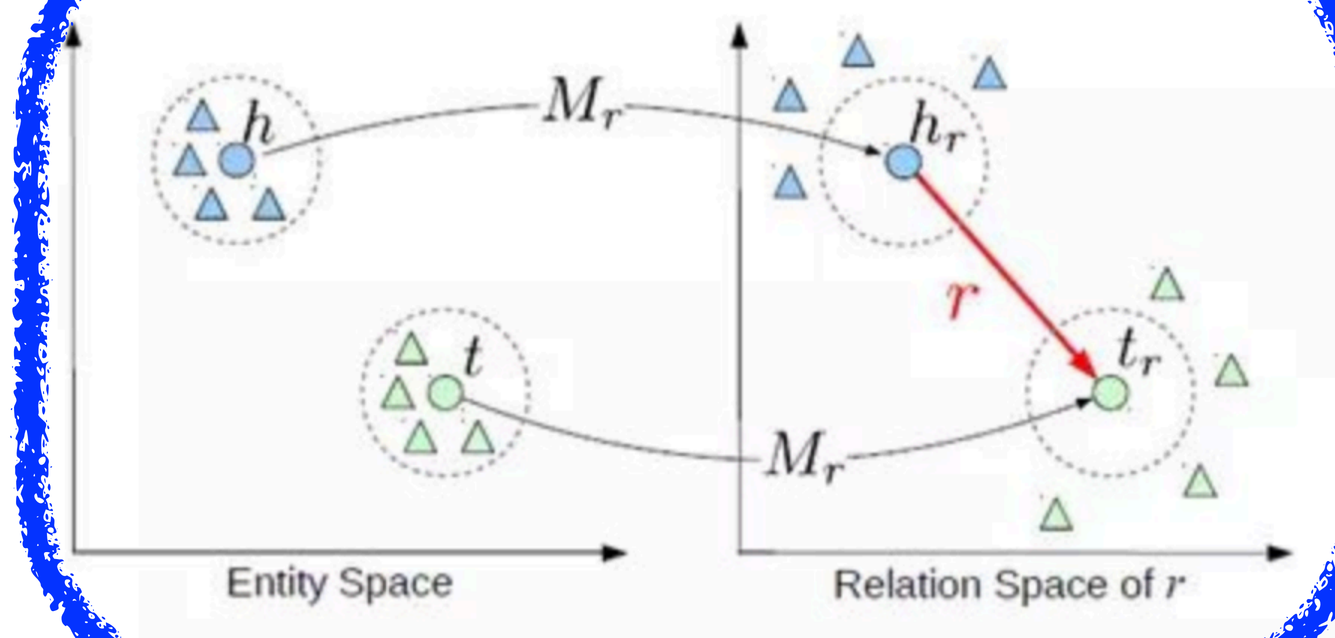
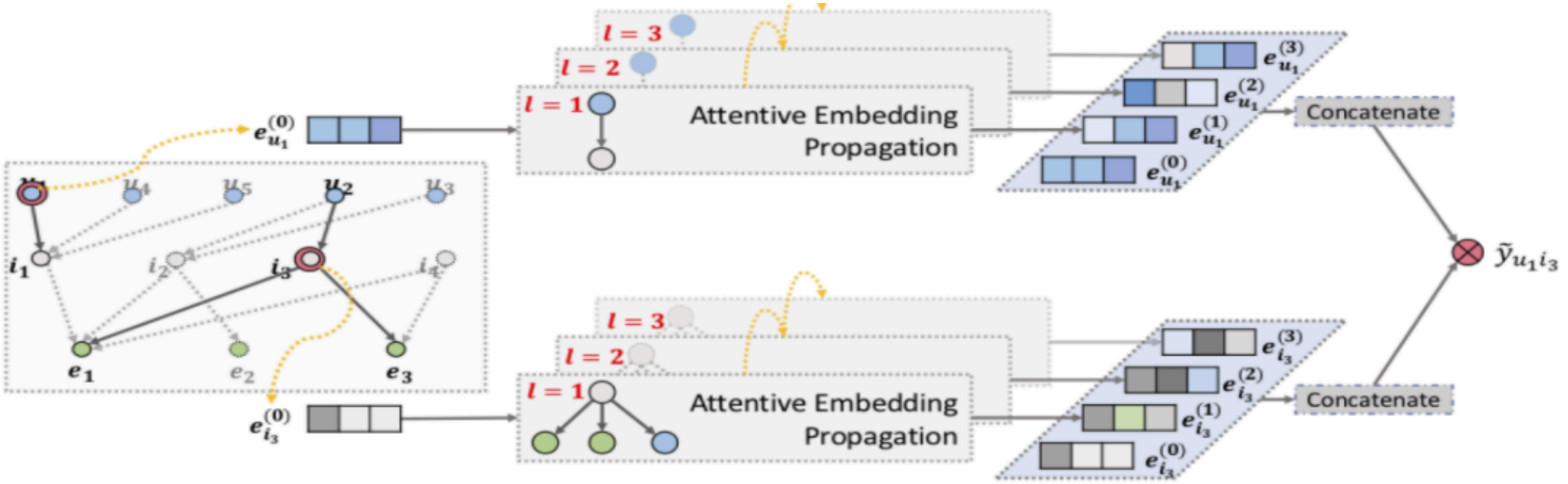
# Related work - Textual-based Recommendation

- KGAT: Knowledge Graph Attention Network for REC. (KDD’19)




**Learning TranR**

$$g(h,r,t) = \|\mathbf{W}_r\mathbf{e}_h + \mathbf{e}_r - \mathbf{W}_r\mathbf{e}_t\|_2^2$$

$$\mathcal{L}_{\mathrm{KG}} = \sum_{(h,r,t,t')\in\mathcal{T}} -\ln\sigma\left(g(h,r,t') - g(h,r,t)\right)$$

**GCN aggregation**

$$\mathbf{e}_h^{(1)} = f(\mathbf{e}_h, \mathbf{e}_{\mathcal{N}_h})$$

$$\mathbf{e}_{\mathcal{N}_h}^{(l-1)} = \sum_{(h,r,t)\in\mathcal{N}_h} \pi(h,r,t)\mathbf{e}_t^{(l-1)},$$

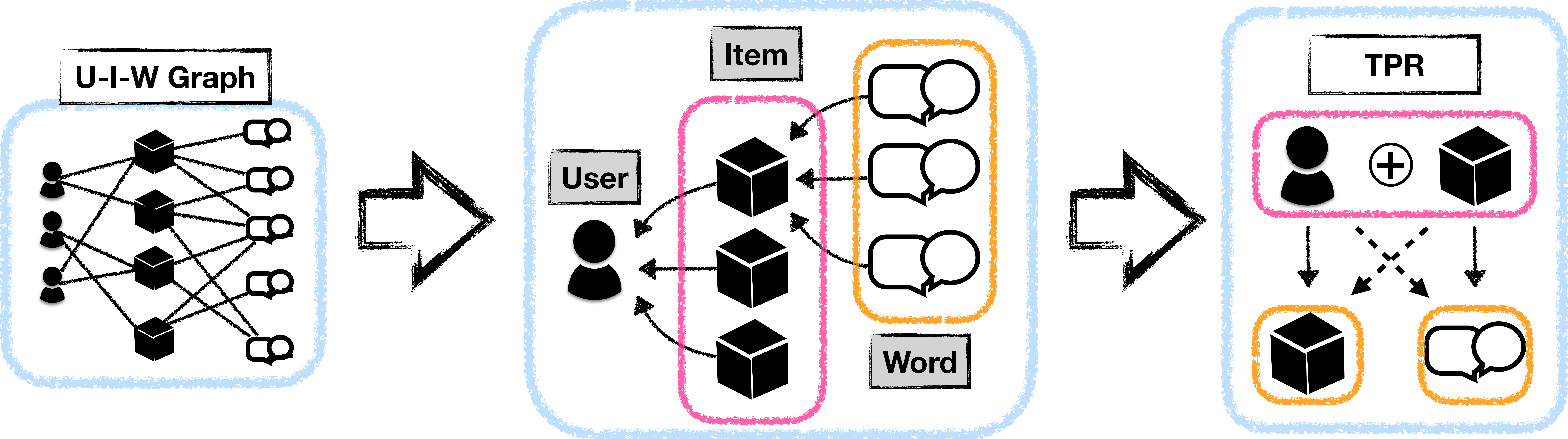
**Concat all layers**

$$\mathbf{e}_u^* = \mathbf{e}_u^{(0)}\|\cdots\|\mathbf{e}_u^{(L)}, \quad \mathbf{e}_i^* = \mathbf{e}_i^{(0)}\|\cdots\|\mathbf{e}_i^{(L)}$$

$$\mathcal{L}_{\mathrm{CF}} = \sum_{(u,i,j)\in O} -\ln\sigma\left(\hat{y}(u,i) - \hat{y}(u,j)\right)$$

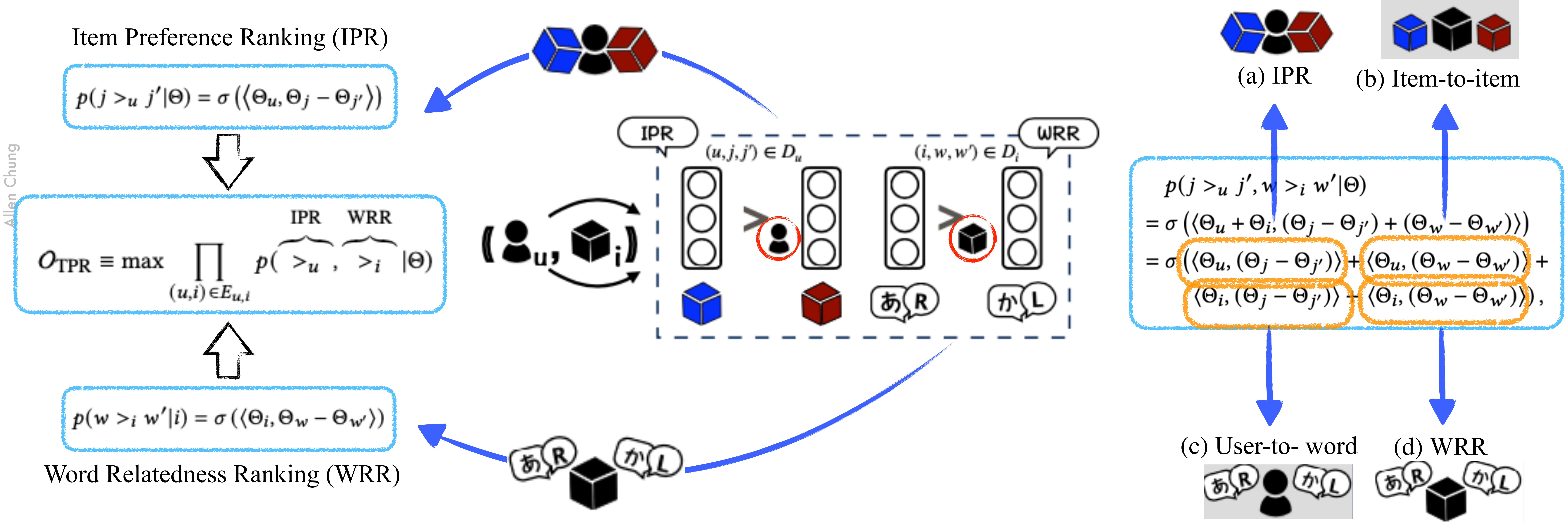
# Text-aware Preference Ranking

- Motivation: Seeking a method to jointly learn the feature from user log and text



# Text-aware Preference Ranking

- Two ranking structures, IPR and WRR, model the relation of U-I and I-W pairs



# Text-aware Preference Ranking

- Seeking a method to jointly learn two ranking structures : IPR and WRR

Item Preference Ranking (IPR) 

$$p(j >_u j' | \Theta) = \sigma\left(\langle \Theta_u, \Theta_j - \Theta_{j'} \rangle\right)$$

$$O_{\mathrm{TPR}} \equiv \max \prod_{(u,i) \in E_{u,i}} p(\overbrace{>_u}^{\mathrm{IPR}}, \overbrace{>_i}^{\mathrm{WRR}} | \Theta)$$

$$p(w >_i w' | i) = \sigma\left(\langle \Theta_i, \Theta_w - \Theta_{w'} \rangle\right)$$

Word Relatedness Ranking (WRR) 

TPR-OPT

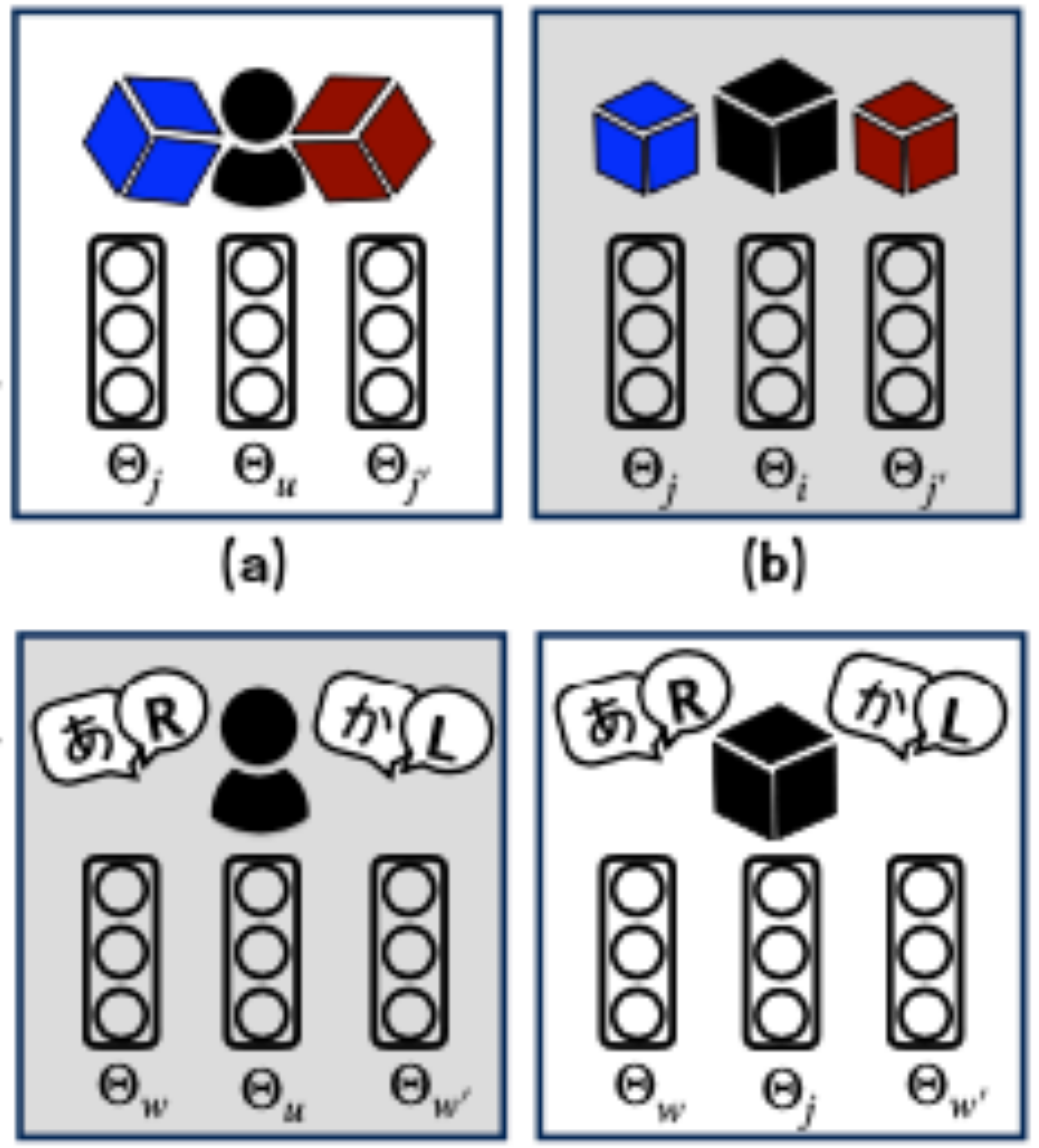
$$:= \ln p(\Theta | >_u, >_i) \propto \ln p(>_u, >_i | \Theta) p(\Theta)$$

$$= \ln \prod_{\substack{(u,j,j') \in D_u, \\ (i,w,w') \in D_i}} p(j >_u j', w >_i w' | \Theta) p(\Theta)$$

$$= \sum_{\substack{(u,j,j') \in D_u, \\ (i,w,w') \in D_i}} \ln \sigma\left(\langle \Theta_u + \Theta_i, (\Theta_j - \Theta_{j'}) + (\Theta_w - \Theta_{w'}) \rangle\right) - \lambda_\Theta \|\Theta\|^2$$

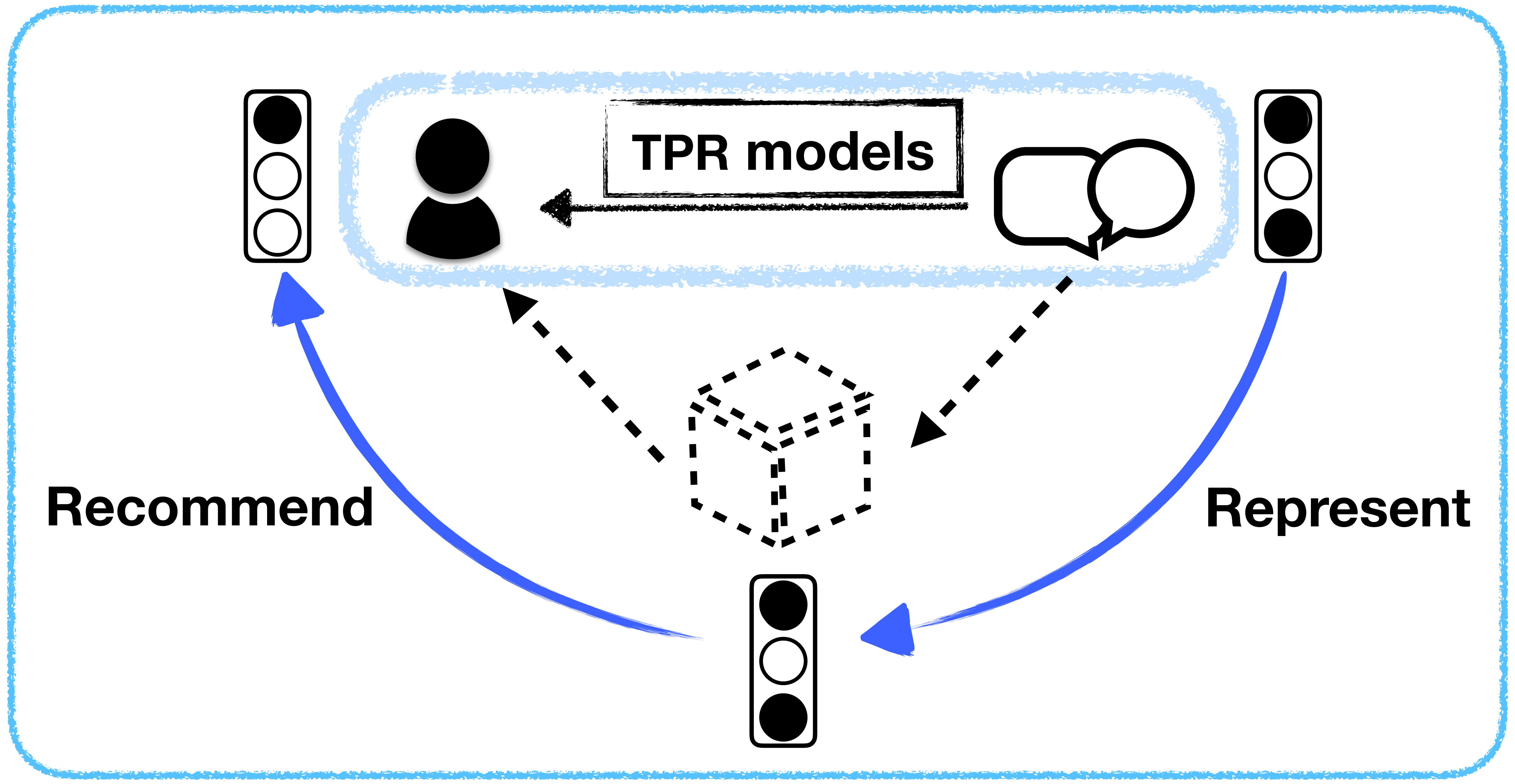
$\lambda_{IPR}$

$\lambda_{WRR}$

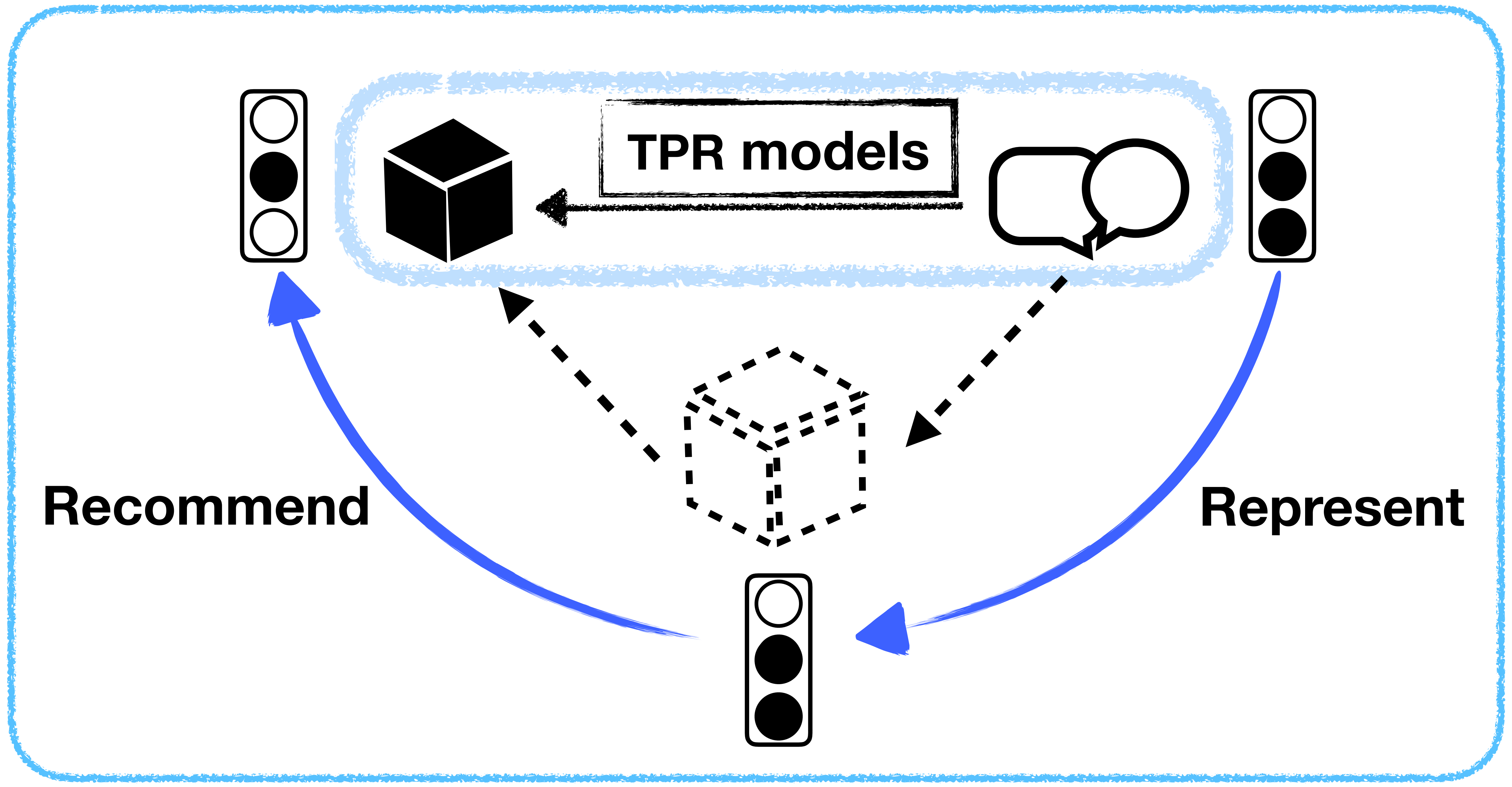


# Text-aware Preference Ranking

- Solutions of TPR to solve cold-start problem




(a) User-Item




(b) Item-Item

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# Experiment Results

- Datasets : Six different public real-world datasets.
  - Each of the dataset contains
    A. User-item interaction log (U-I)
    B. Item with its textual description (I-W)

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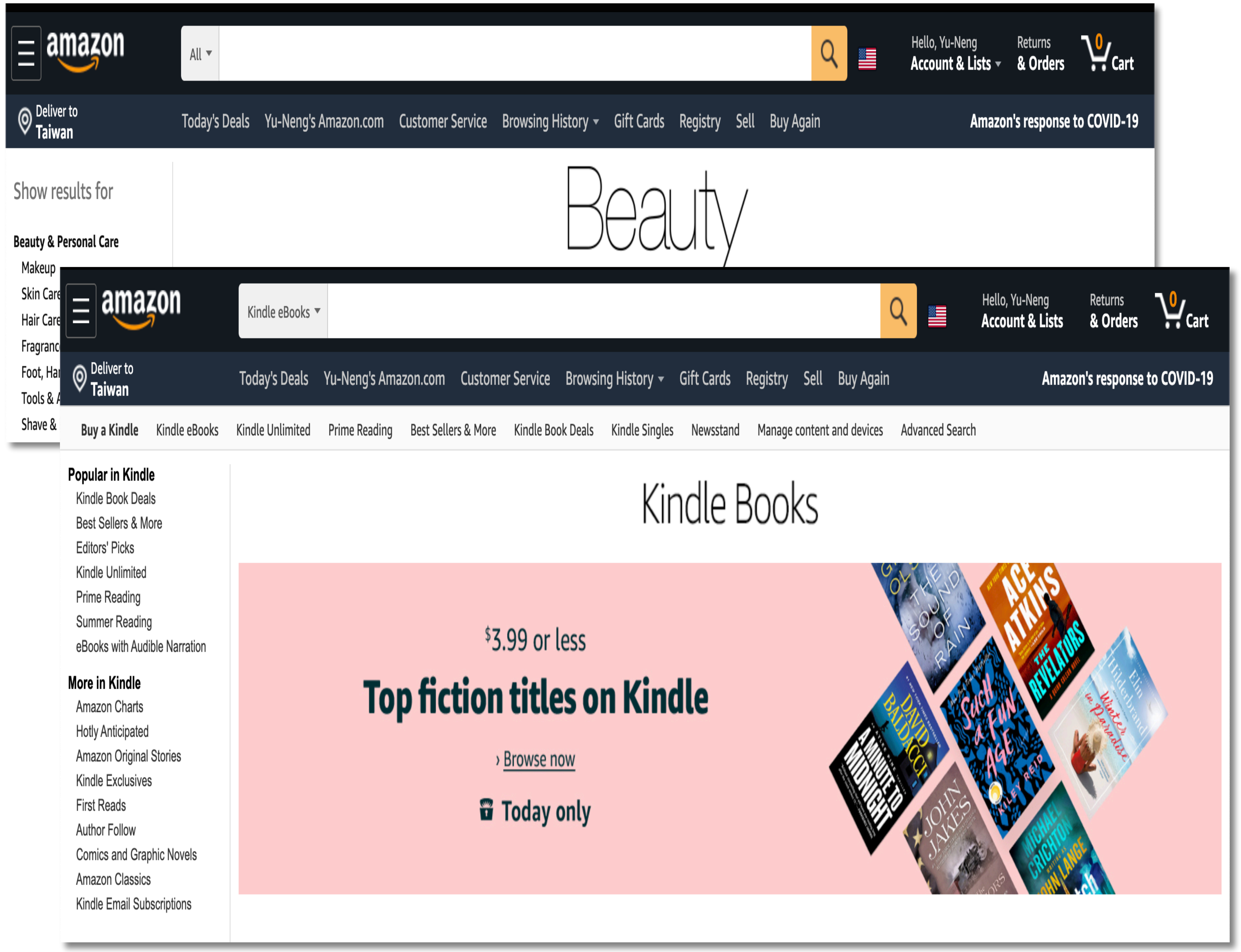
| | Users | Items | Words | U-I edges | I-W edges |
|---|---|---|---|---|---|
| Amazon-Magazine | 2,825 | 1,299 | 6,740 | 11,685 | 9,4381 |
| Amazon-Beauty | 4,801 | 4,865 | 4,115 | 11,685 | 159,475 |
| Amazon-Application | 11,823 | 5,554 | 9,712 | 42,675 | 410,079 |
| Amazon-Software | 13,634 | 9,325 | 11,111 | 57,793 | 766,112 |
| Amazon-Fashion | 19,875 | 36,080 | 5,076 | 75,596 | 442,136 |
| Amazon-Kindle | 363,303 | 356,634 | 36,445 | 3,334,521 | 6,794,209 |



# Experiment Results

- Top-K recommendation performance (IPR )

| | Amazon-Magazine | | Amazon-Beauty | | Amazon-Applications | | Amazon-Fashion | |
|---|---|---|---|---|---|---|---|---|
| | Recall@10 | NDCG@10 | Recall@10 | NDCG@10 | Recall@10 | NDCG@10 | Recall@10 | NDCG@10 |
| BPR [20] | 0.3306 | 0.1734 | 0.4278 | 0.3468 | 0.3035 | 0.1590 | 0.1563 | 0.1223 |
| WARP [23] | 0.3435 | 0.1892 | 0.3468 | 0.3437 | 0.3016 | 0.1655 | 0.1815 | 0.1298 |
| SINE [25] | 0.0360 | 0.0083 | 0.0549 | 0.0157 | 0.1283 | 0.0280 | 0.0865 | 0.0181 |
| HPE [3] | 0.3419 | 0.1377 | † 0.4773 | † 0.3652 | † 0.3552 | 0.1736 | † 0.2126 | † 0.1393 |
| GATE [13] | 0.2720 | 0.0489 | 0.3940 | 0.0812 | 0.1336 | 0.0225 | 0.0819 | 0.0186 |
| CKE [26] | 0.3838 | 0.2061 | 0.4208 | 0.3450 | 0.2933 | 0.1562 | 0.1581 | 0.1230 |
| KGAT [22] | † **0.4156** | † **0.2156** | 0.4321 | 0.3558 | 0.3213 | † 0.1862 | 0.1862 | 0.1268 |
| TPR ($\lambda_{\text{WRR}} = 0.001$) | 0.3681 | 0.1599 | ***0.4950** | *0.3735 | *0.3937 | *0.1779 | *0.2394 | *0.1525 |
| TPR ($\lambda_{\text{WRR}} = 0.005$) | 0.4101 | 0.1880 | *0.4925 | *0.3783 | ***0.4097** | *0.1951 | ***0.2270** | *0.1462 |
| TPR ($\lambda_{\text{WRR}} = 0.01$) | 0.4182 | 0.1840 | *0.4840 | ***0.3793** | *0.3997 | ***0.1971** | *0.2258 | ***0.1482** |
| Improv. (%) | −0.62% | −12.80% | +3.70% | +3.86% | +15.34% | +5.85% | +6.77% | +6.38% |

| | Amazon-Software | | Amazon-Kindle | | Course | | SG-OPN | |
|---|---|---|---|---|---|---|---|---|
| | Recall@10 | NDCG@10 | Recall@10 | NDCG@10 | Recall@10 | NDCG@10 | Recall@10 | NDCG@10 |
| BPR [20] | † 0.3669 | 0.1779 | 0.4414 | 0.2097 | 0.5731 | 0.4129 | 0.1008 | 0.0339 |
| WARP [23] | 0.3423 | 0.1556 | † 0.5461 | † 0.3392 | 0.5340 | 0.3639 | † 0.2623 | † 0.1131 |
| SINE [25] | 0.0976 | 0.0257 | 0.2812 | 0.1394 | 0.0357 | 0.0168 | 0.0412 | 0.0150 |
| HPE [3] | 0.3658 | 0.1405 | 0.5228 | 0.2803 | 0.3391 | 0.2294 | 0.0047 | 0.0040 |
| GATE [13] | 0.1326 | 0.0202 | - | - | 0.4477 | 0.3170 | 0.0010 | 0.0035 |
| CKE [26] | 0.3448 | 0.1497 | - | - | † 0.6094 | † **0.4583** | 0.1050 | 0.0837 |
| KGAT [22] | 0.3907 | † 0.1847 | - | - | 0.5902 | 0.4294 | 0.1473 | 0.0512 |
| TPR ($\lambda_{\text{WRR}} = 0.001$) | *0.3898 | 0.1615 | *0.5682 | *0.3448 | 0.5735 | 0.4177 | ***0.3110** | ***0.1411** |
| TPR ($\lambda_{\text{WRR}} = 0.005$) | *0.4252 | 0.1844 | *0.6065 | *0.3722 | 0.6014 | 0.4422 | *0.3094 | *0.1392 |
| TPR ($\lambda_{\text{WRR}} = 0.01$) | ***0.4319** | ***0.1956** | ***0.6164** | ***0.3804** | ***0.6155** | 0.4468 | *0.3086 | *0.1434 |
| Improv. (%) | +17.71% | +5.90% | +12.87% | +12.14% | +1.00% | −2.50% | +18.56% | +24.75% |

# Experiment Results

- Item-to-word reconstruction (WRR )

| | Amazon-Magazine | | Amazon-Beauty | | Amazon-Applications | | Amazon-Fashion | | Amazon-Software | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Recall@10 | NDCG@10 | Recall@10 | NDCG@10 | Recall@10 | NDCG@10 | Recall@10 | NDCG@10 | Recall@10 | NDCG@10 |
| HPE [3] | † 0.7378 | † 0.5910 | † 0.7423 | † 0.5651 | † 0.7015 | † 0.5383 | † 0.5680 | † 0.4927 | † 0.5788 | † 0.3682 |
| CKE [26] | 0.0441 | 0.0502 | 0.0222 | 0.0296 | 0.0435 | 0.0398 | 0.0124 | 0.0134 | 0.0635 | 0.0670 |
| KGAT [22] | 0.5273 | 0.4414 | 0.2884 | 0.2386 | 0.4109 | 0.2758 | 0.1869 | 0.1609 | 0.5138 | 0.3206 |
| TPR ($\lambda_{\text{WRR}} = 0.001$) | ***0.8371** | ***0.7653** | ***0.8244** | ***0.7343** | ***0.8530** | ***0.7595** | ***0.8645** | ***0.8037** | ***0.7159** | ***0.4703** |
| TPR ($\lambda_{\text{WRR}} = 0.005$) | 0.6294 | 0.5448 | 0.4738 | 0.3849 | 0.6109 | 0.5025 | 0.4930 | 0.4348 | 0.5476 | 0.3552 |
| TPR ($\lambda_{\text{WRR}} = 0.01$) | 0.5279 | 0.4411 | 0.4270 | 0.3580 | 0.4743 | 0.3722 | 0.3284 | 0.2825 | 0.4632 | 0.2949 |

**Table 6: Performance on item-to-word reconstruction**

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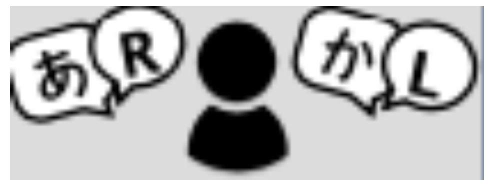
# Experiment Results

- User-to-word recommendation(  )





| | Amazon-Magazine | | Amazon-Beauty | | Amazon-Applications | | Amazon-Fashion | | Amazon-Software | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Recall@10 | NDCG@10 | Recall@10 | NDCG@10 | Recall@10 | NDCG@10 | Recall@10 | NDCG@10 | Recall@10 | NDCG@10 |
| HPE [3] | † 0.2002 | † 0.1938 | † 0.2206 | † 0.1684 | † **0.1955** | † 0.1543 | † 0.0829 | † 0.0725 | † 0.2414 | † 0.1971 |
| CKE [26] | 0.0374 | 0.0576 | 0.0173 | 0.0263 | 0.0435 | 0.0398 | 0.0189 | 0.0213 | 0.0691 | 0.0723 |
| KGAT [22] | 0.0248 | 0.0375 | 0.0117 | 0.0161 | 0.0123 | 0.0201 | 0.0463 | 0.0644 | 0.0073 | 0.0153 |
| TPR ($\lambda_{WRR} = 0.001$) | 0.1996 | 0.1941 | 0.3411 | *0.2943 | 0.1891 | **0.1556** | *0.1053 | *0.0833 | ***0.3018** | 0.2332 |
| TPR ($\lambda_{WRR} = 0.005$) | *0.2249 | *0.2190 | ***0.3728** | ***0.3147** | 0.1818 | 0.1537 | ***0.1134** | ***0.0865** | *0.2872 | ***0.2482** |
| TPR ($\lambda_{WRR} = 0.01$) | ***0.2274** | ***0.2198** | *0.3589 | *0.2948 | 0.1690 | 0.1447 | *0.1050 | *0.0767 | *0.2625 | *0.2455 |

**Table 7: Performance on user-to-word recommendation**

# Experiment Results

- Item-to-Item recommendation (  )

| | Amazon-Magazine | | Amazon-Beauty | | Amazon-Applications | | Amazon-Fashion | | Amazon-Software | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Recall@10 | NDCG@10 | Recall@10 | NDCG@10 | Recall@10 | NDCG@10 | Recall@10 | NDCG@10 | Recall@10 | NDCG@10 |
| BPR [20] | 0.3637 | 0.1964 | 0.4433 | 0.3689 | 0.3472 | † 0.1871 | 0.1655 | 0.1244 | 0.3993 | † 0.1933 |
| WARP [23] | 0.2769 | 0.1615 | 0.4248 | 0.3577 | 0.2686 | 0.1438 | 0.1435 | 0.1130 | 0.2989 | 0.1444 |
| SINE [25] | 0.1365 | 0.0877 | 0.2813 | 0.1041 | 0.1873 | 0.0857 | 0.1663 | 0.1160 | 0.2636 | 0.1065 |
| HPE [3] | 0.3584 | 0.1376 | 0.4575 | 0.3584 | 0.3380 | 0.1600 | † 0.2091 | † 0.1326 | 0.3552 | 0.1501 |
| CKE [26] | 0.3903 | 0.1986 | 0.4469 | 0.3570 | 0.3353 | 0.1838 | 0.1585 | 0.1245 | 0.3766 | 0.1887 |
| KGAT [22] | † 0.3972 | † 0.2049 | † 0.4587 | † 0.3710 | † 0.3645 | 0.1864 | 0.1530 | 0.1155 | † 0.4066 | 0.1699 |
| TPR ($\lambda_{\mathrm{WRR}} = 0.001$) | 0.3911 | 0.1781 | ***0.4855** | *0.3803 | *0.3786 | 0.1890 | ***0.2330** | ***0.1541** | 0.3992 | 0.1736 |
| TPR ($\lambda_{\mathrm{WRR}} = 0.005$) | *0.4155 | 0.2038 | *0.4822 | *0.3797 | ***0.3990** | *0.1960 | *0.2195 | *0.1487 | *0.4233 | 0.1946 |
| TPR ($\lambda_{\mathrm{WRR}} = 0.01$) | ***0.4201** | **0.2057** | *0.4755 | ***0.3819** | *0.3859 | ***0.2036** | *0.2133 | *0.1477 | ***0.4245** | ***0.1993** |
| Improv. (%) | +5.76% | +0.39% | +5.84% | +2.93% | +9.46% | +8.81% | +11.42% | +16.21% | +4.40% | +3.10% |

**Table 3: Performance on item-to-item recommendation**





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# Experiment Results

- Cold-start user-to-item recommendation

| | Amazon-Magazine | | Amazon-Beauty | | Amazon-Applications | | Amazon-Fashion | | Amazon-Software | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Recall@10 | NDCG@10 | Recall@10 | NDCG@10 | Recall@10 | NDCG@10 | Recall@10 | NDCG@10 | Recall@10 | NDCG@10 |
| HPE [3] | † 0.2454 | † 0.0609 | † 0.1203 | † 0.0419 | † 0.0794 | † 0.0101 | † 0.1326 | † 0.0344 | † 0.1149 | † 0.0114 |
| CKE [26] | 0.0636 | 0.0343 | 0.0093 | 0.0058 | 0.0072 | 0.0035 | 0.0090 | 0.0046 | 0.0104 | 0.0056 |
| KGAT [22] | 0.0363 | 0.0254 | 0.0152 | 0.0035 | 0.0033 | 0.0035 | 0.0152 | 0.0035 | 0.0083 | 0.0035 |
| TPR ($\lambda_{\text{WRR}} = 0.001$) | *0.2636 | *0.0875 | ***0.1654** | ***0.0640** | ***0.1569** | ***0.0340** | ***0.1698** | ***0.0700** | ***0.1511** | ***0.0337** |
| TPR ($\lambda_{\text{WRR}} = 0.005$) | *0.2590 | ***0.0919** | *0.1483 | *0.0570 | *0.1175 | *0.0200 | 0.1354 | *0.0527 | 0.1176 | 0.0168 |
| TPR ($\lambda_{\text{WRR}} = 0.01$) | ***0.2863** | 0.0609 | *0.1320 | *0.0501 | *0.1026 | *0.0167 | 0.1055 | 0.0374 | 0.0887 | 0.0106 |

**Table 4: Performance on cold-start user-to-item recommendation**

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# Experiment Results

- Cold-start item-to-item recommendation

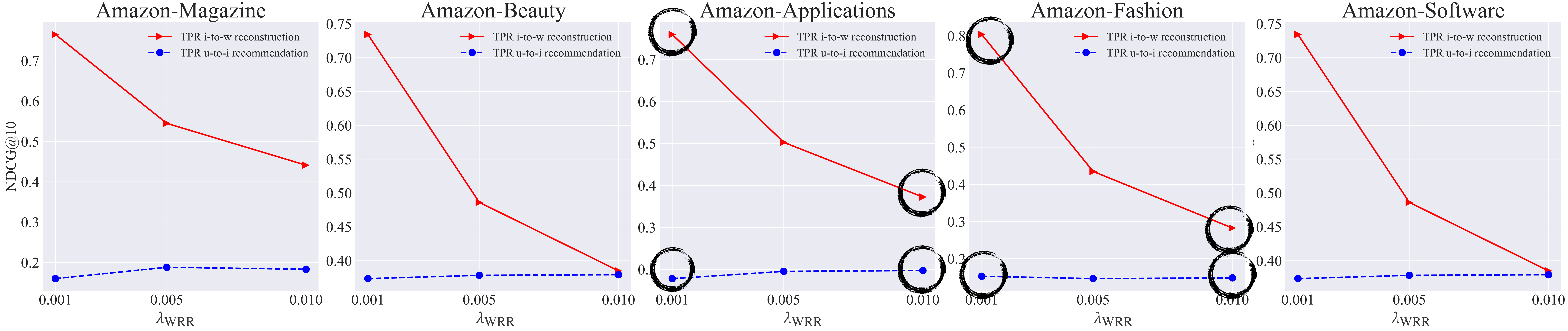
| | Amazon-Magazine | | Amazon-Beauty | | Amazon-Applications | | Amazon-Fashion | | Amazon-Software | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Recall@10 | NDCG@10 | Recall@10 | NDCG@10 | Recall@10 | NDCG@10 | Recall@10 | NDCG@10 | Recall@10 | NDCG@10 |
| HPE [3] | † 0.2454 | † 0.0609 | † 0.1203 | † 0.0419 | † 0.0794 | † 0.0101 | † 0.1326 | † 0.0344 | † 0.1149 | † 0.0114 |
| CKE [26] | 0.0636 | 0.0343 | 0.0093 | 0.0058 | 0.0072 | 0.0035 | 0.0090 | 0.0046 | 0.0104 | 0.0056 |
| KGAT [22] | 0.0363 | 0.0254 | 0.0152 | 0.0035 | 0.0033 | 0.0035 | 0.0152 | 0.0035 | 0.0083 | 0.0035 |
| TPR ($\lambda_{\mathrm{WRR}} = 0.001$) | *0.2636 | *0.0875 | ***0.1654** | ***0.0640** | ***0.1569** | ***0.0340** | ***0.1698** | ***0.0700** | ***0.1511** | ***0.0337** |
| TPR ($\lambda_{\mathrm{WRR}} = 0.005$) | *0.2590 | ***0.0919** | *0.1483 | *0.0570 | *0.1175 | *0.0200 | 0.1354 | *0.0527 | 0.1176 | 0.0168 |
| TPR ($\lambda_{\mathrm{WRR}} = 0.01$) | ***0.2863** | 0.0609 | *0.1320 | *0.0501 | *0.1026 | *0.0167 | 0.1055 | 0.0374 | 0.0887 | 0.0106 |

**Table 4: Performance on cold-start user-to-item recommendation**

# Experiment Results

- Item-to-word reconstruction
- User-to-item recommendation

- **Sensitivity check on regularization term ( $\lambda_{WRR}$ & $\lambda_{IPR}$ )**




- A smaller $\lambda_{WRR}$ can benefit modeling the relation between item and text
- A larger $\lambda_{IPR}$ can prevent overfitting problems on modeling User-Item relation
- A trade-off parameter provides the flexibility on modeling different tasks.

# Experiment Results

- Memory and Time Usage in Top-K recommendation

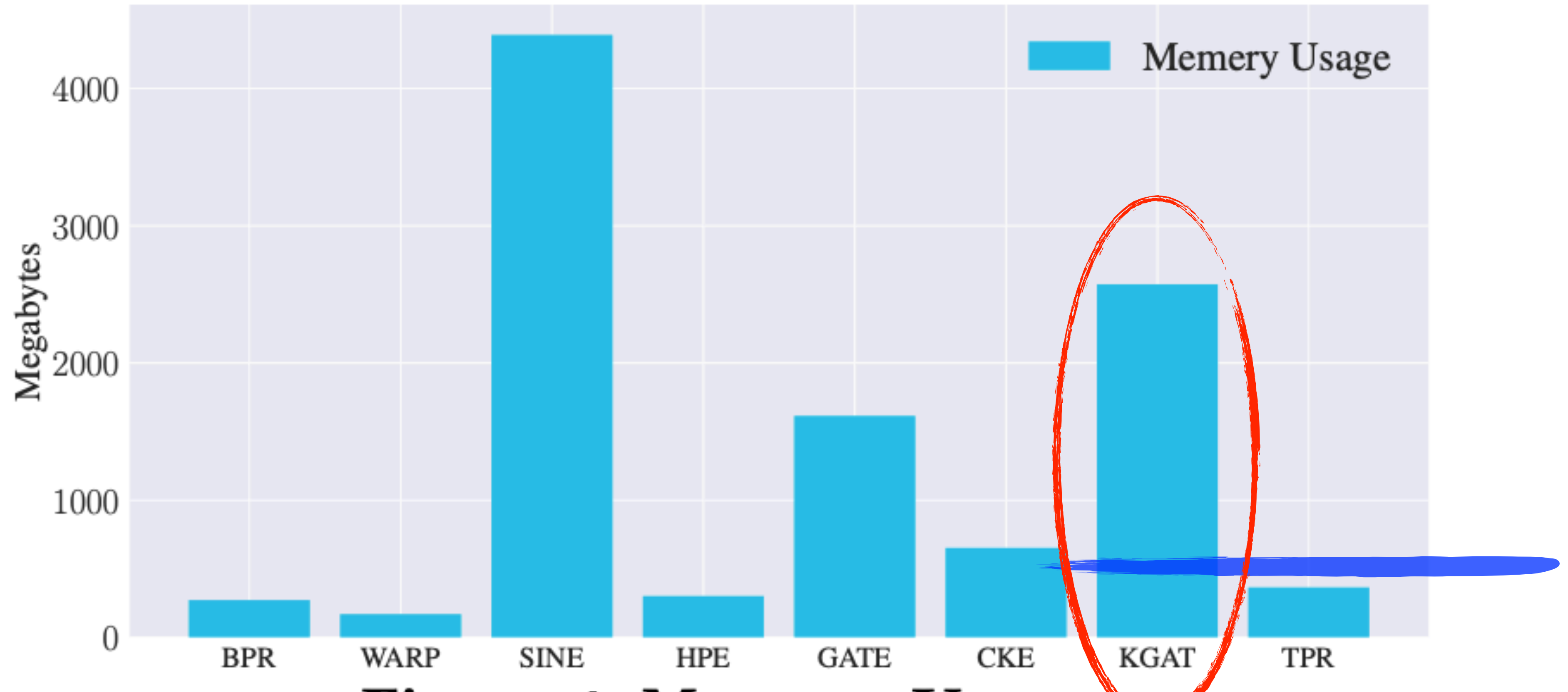



**Figure 4: Memory Usage**

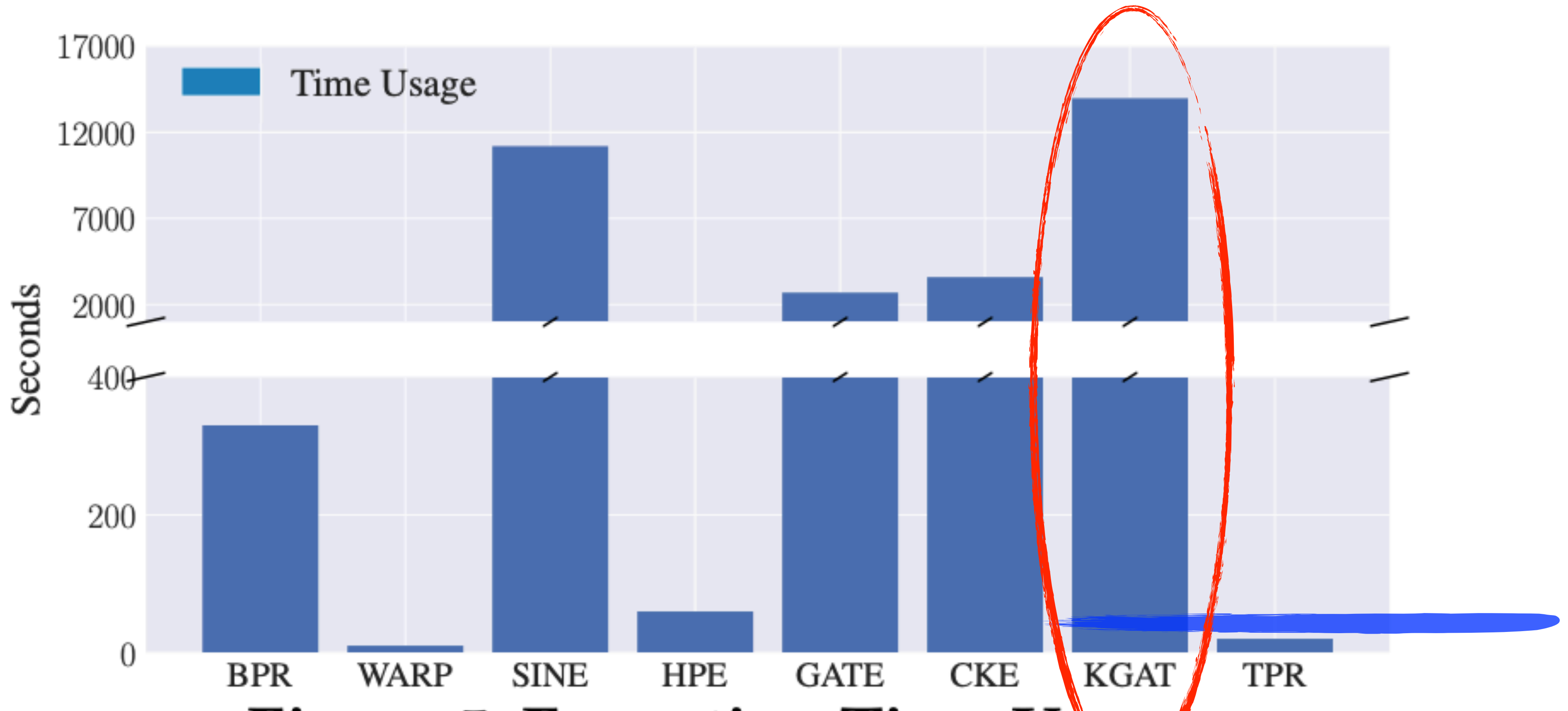



**Figure 5: Execution Time Usage**

SOTA among all baselines

# Conclusion

- Design a framework on joint association of user-item interaction and relations between items and associated text
- TPR comprehensively modeling four types of ranking relations on the six different tasks to attest the effectiveness of the learned embeddings
- TPR achieves high modeling efficiency in terms of execution time and memory usage.

# TPR Implementation

- TPR is now publicly available on GitHub:
  - Repo: https://github.com/cnclabs/codes.tpr.rec
- TPR is implemented on the framework of SMORe:
  - Repo: https://github.com/cnclabs/smore

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Thanks For Your Listening!

Any Question?