Neural-Symbolic Reasoning over Knowledge Graph for Multi-stage Explainable Recommendation

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Task: KG-based Explainable Recommendation

- **Challenge:**
  - Unknown target: items (target node) are NOT known before path finding.
  - Large node degree: this leads to large search space.

Method: A Neural-Symbolic Reasoning Approach

1. Neural-Symbolic Representation Learning
   - $$\ell_{path}(\Theta; \{L_u\}) = \sum_{L_u} \log P(L_u|u; \Theta)$$
   - $$\ell_{rank}(\Theta; \{L_u\}) = \sum_{L_u} \sum_{i^-} \sigma \left( s(i^-, r|L_u|, u, h|L_u|) - s(i^+, r|L_u|, u, h|L_u|) \right)$$
   - $$\ell_{all}(\Theta) = \sum_{u} \ell_{path}(\Theta; \{L_u\}) + \lambda \ell_{rank}(\Theta; \{L_u\})$$

2. Neural-Symbolic Explainable Recommendation
   (Generate explanations in two stages)

Output: Coarse-grained Explanation

- **Abstract meta-layout**

Output: Fine-grained explanation

- **Concrete paths**

- **Recommendations**

Diagram:

- Nodes: user A, item A, item B, user B, item D, feature A, feature B, item C, brand A, category A, item E, item F
- Relations: purchase, mention, described, produced, belong to, also buy, also view, buy together
- **Relations R**
  - purchase
  - mention
  - described
  - produced
  - belong to
  - also buy
  - also view
  - buy together

Diagram:

- Nodes: ROOT, $$\phi_{r_1}$$, $$\phi_{r_2}$$, $$\phi_{r_3}$$, $$\phi_{r_4}$$, $$\phi_{r_5}$$
- Edges: $$r_1$$, $$r_2$$, $$r_3$$, $$r_4$$, $$r_5$$, $$r_6$$
- Connections: $$f_1$$, $$f_2$$, $$f_3$$, $$f_4$$

Concrete paths:

- $$r_1$$ from $$l_1$$ to $$l_2$$
- $$r_2$$ from $$l_2$$ to $$l_3$$
- $$r_3$$ from $$l_3$$ to $$l_4$$
- $$r_4$$ from $$l_4$$ to $$l_5$$
- $$r_5$$ from $$l_5$$ to $$l_6$$
Main Results

### Influence of Ranking Loss

<table>
<thead>
<tr>
<th>Measures (%)</th>
<th>CDs &amp; Vinyl</th>
<th>Clothing</th>
<th>Cell Phones</th>
<th>Beauty</th>
</tr>
</thead>
<tbody>
<tr>
<td>NDCG</td>
<td>Recall</td>
<td>HR</td>
<td>Prec.</td>
<td>NDCG</td>
</tr>
</tbody>
</table>

### Effectiveness of Layout

<table>
<thead>
<tr>
<th>Dataset</th>
<th>NDCG</th>
<th>Recall</th>
<th>HR</th>
<th>Prec.</th>
<th>NDCG</th>
<th>Recall</th>
<th>HR</th>
<th>Prec.</th>
</tr>
</thead>
<tbody>
<tr>
<td>uniform</td>
<td>4.545</td>
<td>7.229</td>
<td>10.192</td>
<td>1.087</td>
<td>6.293</td>
<td>9.256</td>
<td>15.564</td>
<td>1.918</td>
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<tr>
<td>prior</td>
<td>6.255</td>
<td>10.842</td>
<td>15.097</td>
<td>1.659</td>
<td>6.880</td>
<td>10.393</td>
<td>17.258</td>
<td>2.224</td>
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<tr>
<td>heuristic</td>
<td>6.313</td>
<td>11.086</td>
<td>15.531</td>
<td>1.692</td>
<td>7.061</td>
<td>10.948</td>
<td>18.099</td>
<td>2.270</td>
</tr>
</tbody>
</table>

**Case Study:**

**Case (1)**

- **ROOT**
  - **purchase**
    - **belong_to**
      - **rev_belong_to**
    - **bought_together**
      - **rev_bought_together**
  - **mention**
    - **rev_described_by**
  - **Skin Care**
    - **Category**
  - **Rev_Bought_Together**
    - **Soap**
  - **Rev_Belong_To**
    - **Shampoo**
  - **Rev_Described_By**
    - **Facial Cream**
  - **user**
    - **mention**
      - **absorb**
        - **rev_described_by**
          - **vitamin**
  - **conditioner**
  - **lotion**
  - **facial cleanser**
  - **vitamin serum**