Matrix Factorization with Domain Knowledge and Behavioral Patterns for Intent Modeling

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The Task

- **Motivations**
  - An typical SDS has two main challenges:
    1) **Predefined ontology**: the domain ontology is required to support the corresponding functions.
    2) **Language ambiguity**: same utterance may infer different intents during different situations.
- **Approaches**: Feature-Enriched MF-SLU
  - Enrich semantics with the structured knowledge or behavioral patterns for improving intent prediction.
  - Unify the human written knowledge and automatically inferred information in a matrix and predict user intents in the mean time.

- **Results**
  - Feature-enriched MF-SLU benefits from hidden information and rich features, and then outperforms the baselines for both single-turn requests and multi-turn interactions.

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Feature-Enriched MF-SLU: Spoken Language Understanding by Matrix Factorization

**Experiment 1: Single-Turn Request**

- **Enriched Semantics Matrix**
  - Main idea: slot types and word embeddings help imply semantics for expanding domain knowledge.
  - Entity Type from Structured Knowledge (e.g., Wikipedia/Freebase).
  - Example: "play lady gaga's bad romance".

- **Intent Matrix**
  - Main idea: retrieve the apps that are more likely to support users' requests for self-training.

**Experiment 2: Multi-Turn Interaction**

- **Challenge: language ambiguity**
  1) User preference
  2) App-level contexts
- **User Utterance**
  - Example: "take this photo, tell vivian this is me in the lab, check my grades on website, send an email to professor, take a photo of this send it to alice.

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Matrix Factorization

- **Objective**
  \[
  \arg \max P(\theta^+) - \arg \min P(\theta^-) \]
- **MF learns a set of well-ranked intents per utterance.**

**Experiments**

<table>
<thead>
<tr>
<th>Feature Matrix</th>
<th>ASR Transcripts</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Single-Turn</strong></td>
<td><strong>Transcripts</strong></td>
</tr>
<tr>
<td>Word Observation</td>
<td>25.1</td>
</tr>
<tr>
<td>+ Type-Enriched Semantics</td>
<td>31.5</td>
</tr>
<tr>
<td>Multi-Turn</td>
<td></td>
</tr>
<tr>
<td>Word Observation</td>
<td>52.1</td>
</tr>
<tr>
<td>+ Behavioral Patterns</td>
<td>53.9</td>
</tr>
</tbody>
</table>

**The feature-enriched MF-SLU can benefit from both hidden information modeled by MF and enriched semantics including structured knowledge and behavioral patterns to improve Intent prediction.**

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Chen et al., "Leveraging Behavioral Patterns of Mobile Applications for Personalized Spoken Language Understanding," in Proc. of ICMI, 2015.

Data Available at http://AppDialogue.com/

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Conclusions

- In a smart-phone intelligent assistant setting (e.g., requesting an app), the feature-enriched MF-SLU can handle users' open domain intents by returning relevant apps that provide desired functionality either locally available or by suggesting installation of suitable apps and doing so in an unsupervised way.
- The framework can extend to incorporate personal behavior history for improving a system's ability to assist users pursuing personalized multi-app activities.
- The effectiveness of the feature-enriched MF-SLU model can be shown in different domains, indicating good generality and providing a reasonable direction for the future work.