

Personalized Top-N Sequential Recommendation via Convolutional Sequence Embedding

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Abstract

- We study *sequential recommendation* problem as the order of interaction implies that sequential patterns play an important role on user's next action.
- Under such setting, sequential patterns should be carefully modeled, in both point-level and union-level.
- We propose a *Convolutional Sequence Embedding Recommendation Model* (Caser) to model the above two types of sequential patterns.
- The experiments on public data sets demonstrated that Caser consistently outperforms state-of-the-art sequential recommendation methods

The network architecture of Caser

- *Convolutional Neural Network* (CNN) is used to capture both point-level and union-level sequential patterns.
- By incorporating *Latent Factor Model* (LFM), Caser is also able to capture user's general preferences.



Experimental Setup

• *Datasets*: 4 datasets with large *Sequential Intensity* is used MovieLens, Gowalla, Foursquare and Tmall.

Sequential Interactive (SI)	#rules
Sequential Intensity (SI) =	= #users

Datasets	Sequential Intensity	#users	#items	avg. actions per user
MovieLens	0.3265	6.0k	3.4k	165.50
Gowalla	0.0748	13.1k	14.0k	40.74
Foursquare	0.0378	10.1k	23.4k	30.16
Tmall	0.0104	23.8k	12.2k	13.93

Baselines (non-sequential): POP, BPR, \bullet

Baselines (sequential): FPMC, Fossil and GRU4Rec ullet

Sequential Recommendation

Given a user's sequences Su , recommend a list of items that maximize her/his future needs, by considering both general preferences and sequential patterns.

- General Preferences: represent user's long term and static behaviors and are unlikely to change in a short period of time.

- Sequential Patterns: represent user's short term and dynamic behaviors and come from a close proximity of time.

General Preferences Sequential Patterns

Capture Union-level Sequential Pattern with Horizontal Convolutional Filters

- Borrow the idea of using CNN in text classification, we use convolutional filters to search for sequential patterns.
- Sliding horizontally (from top to bottom), the horizontal convolutional filters are used with different height (multiple union sizes) but same width (same to the latent dimension).
- Max pooling operation on the result for extracting the most significant feature from a particular filter.

User Sequence Latent Space Horizontal Filters **Predictions**

- **Evaluation Metrics:** \bullet
- Precision@n $(n \in \{1, 5, 10\})$
- 2) Recall@n ($n \in \{1, 5, 10\}$)
- Mean Average Precision (MAP) 3)

Experimental Results

• Overall performance:

Dataset Metric POP BPR FMC FPMC Fossil GRU4Rec Caser Improvement MovieLens Prec@1 0.1280 0.1478 0.1748 0.2022 0.2306 0.2515 0.2502 -0.5% MovieLens Prec@10 0.1113 0.1288 0.1505 0.1669 0.2000 0.2146 0.2175 1.4% MovieLens Prec@10 0.0101 0.113 0.1317 0.1460 0.1806 0.01163 0.0148 -3.3% Recall@1 0.0050 0.0070 0.0144 0.0113 0.0144 0.0153 0.0143 0.0143 0.0143 0.0143 0.0143 0.0143 0.0144 0.0153 0.0143 0.0143 0.0143 0.0143 0.0143 0.0143 0.0143 0.0143 0.0143 0.0143 0.1440 0.1532 0.553 0.1376 0.1640 0.1532 0.1555 0.173 0.1129 8.0% 0.0241 0.1050 0.1233 0.054 0.0271 0.1233 0.52										
MovieLens Prec@1 0.1280 0.1478 0.1748 0.2022 0.2306 0.2515 0.2502 -0.5% MovieLens Prec@10 0.1113 0.1288 0.1505 0.1616 0.2000 0.2146 0.2175 1.4% Recall@1 0.0007 0.0104 0.01806 0.01916 0.1916 4.0% Recall@10 0.0375 0.0560 0.0722 0.0777 0.1061 0.1093 0.1121 2.6% MAP 0.0687 0.0913 0.0949 0.1533 0.145 0.1400 0.1507 4.7% Prec@1 0.0517 0.0647 0.0949 0.1533 0.145 0.0721 0.1129 8.0% Prec@10 0.0281 0.0726 0.657 0.0698 0.0782 0.0571 0.0833 6.5% Recall@10 0.0295 0.0234 0.0266 0.0277 0.0155 0.0310 11.9% Recall@10 0.0402 0.1077 0.059 0.1166 0.0826 0.1223 <td< td=""><td>Dataset</td><td>Metric</td><td>POP</td><td>BPR</td><td>FMC</td><td>FPMC</td><td>Fossil</td><td>GRU4Rec</td><td>Caser</td><td>Improv</td></td<>	Dataset	Metric	POP	BPR	FMC	FPMC	Fossil	GRU4Rec	Caser	Improv
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Foursquare Recall@1 0.0376 0.0445 0.0305 0.0440 0.0497 0.0369 0.0565 13.79 Recall@5 0.0800 0.0888 0.0689 0.0959 0.0948 0.0770 0.1035 7.9% Recall@10 0.0954 0.1061 0.0911 0.1200 0.1187 0.1011 0.1291 7.6% MAP 0.0636 0.0719 0.0571 0.0782 0.0823 0.0643 0.0909 10.4% Prec@1 0.0010 0.0111 0.0197 0.0210 0.0280 0.0139 0.0312 11.4% Prec@10 0.0007 0.0063 0.0084 0.0090 0.0149 0.0090 0.0179 20.1% Tmall Recall@1 0.0007 0.0063 0.0084 0.0090 0.0149 0.0070 0.0132 26.9% Tmall Recall@1 0.0004 0.0046 0.0079 0.0082 0.0117 0.0056 0.0130 11.1%	T	Prec@10	0.0304	0.0348	0.0309	0.0385	0.0399	0.0331	0.0425	6.5%
Recall@5 0.0800 0.0888 0.0689 0.0959 0.0948 0.0770 0.1035 7.9% Recall@10 0.0954 0.1061 0.0911 0.1200 0.1187 0.1011 0.1291 7.6% MAP 0.0636 0.0719 0.0571 0.0782 0.0823 0.0643 0.0909 10.4% Prec@1 0.0010 0.0111 0.0197 0.0210 0.0280 0.0139 0.0312 11.4% Prec@5 0.0009 0.0081 0.0114 0.0120 0.0149 0.0090 0.0132 26.9% Recall@1 0.0004 0.0046 0.0079 0.0822 0.0117 0.0056 0.0130 11.1%	Foursquare	Recall@1	0.0376	0.0445	0.0305	0.0440	0.0497	0.0369	0.0565	13.7%
Recall@10 0.0954 0.1061 0.0911 0.1200 0.1187 0.1011 0.1291 7.6% MAP 0.0636 0.0719 0.0571 0.0782 0.0823 0.0643 0.0909 10.4% Prec@1 0.0010 0.0111 0.0197 0.0210 0.0280 0.0139 0.0312 11.4% Prec@5 0.0009 0.0081 0.0114 0.0120 0.0149 0.0090 0.0179 20.1% Prec@10 0.0007 0.0063 0.0084 0.0090 0.0104 0.0070 0.0132 26.9% Recall@1 0.0004 0.0046 0.0079 0.0082 0.0117 0.0056 0.0130 11.1% Recall@5 0.0019 0.0169 0.0226 0.0245 0.0306 0.0180 0.0366 19.6%		Recall@5	0.0800	0.0888	0.0689	0.0959	0.0948	0.0770	0.1035	7.9%
MAP 0.0636 0.0719 0.0571 0.0782 0.0823 0.0643 0.0909 10.47 Prec@1 0.0010 0.0111 0.0197 0.0210 0.0280 0.0139 0.0312 11.47 Prec@5 0.0009 0.0081 0.0114 0.0120 0.0149 0.0090 0.0179 20.17 Prec@10 0.0007 0.0063 0.0084 0.0090 0.0104 0.0070 0.0132 26.97 Recall@1 0.0004 0.0046 0.0079 0.0082 0.0117 0.0056 0.0130 11.17 Recall@5 0.0019 0.0169 0.0226 0.0245 0.0306 0.0180 0.0366 19.67		Recall@10	0.0954	0.1061	0.0911	0.1200	0.1187	0.1011	0.1291	7.6%
Tmall Prec@1 0.0010 0.0111 0.0197 0.0210 0.0280 0.0139 0.0312 11.49 Prec@5 0.0009 0.0081 0.0114 0.0120 0.0149 0.0090 0.0179 20.19 Prec@10 0.0007 0.0063 0.0084 0.0090 0.0104 0.0070 0.0132 26.99 Recall@1 0.0004 0.0046 0.0079 0.0082 0.0117 0.0056 0.0130 11.19 Recall@5 0.0019 0.0169 0.0226 0.0245 0.0306 0.0180 0.0366 19.69		MAP	0.0636	0.0719	0.0571	0.0782	0.0823	0.0643	0.0909	10.4%
TmallPrec@50.00090.00810.01140.01200.01490.00900.017920.19Prec@100.00070.00630.00840.00900.01040.00700.013226.99Recall@10.00040.00460.00790.00820.01170.00560.013011.19Recall@50.00190.01690.02260.02450.03060.01800.036619.69	Tmall	Prec@1	0.0010	0.0111	0.0197	0.0210	0.0280	0.0139	0.0312	11.4%
Tmall Prec@10 0.0007 0.0063 0.0084 0.0090 0.0104 0.0070 0.0132 26.99 Recall@1 0.0004 0.0046 0.0079 0.0082 0.0117 0.0056 0.0130 11.19 Recall@5 0.0019 0.0169 0.0226 0.0245 0.0306 0.0180 0.0366 19.69		Prec@5	0.0009	0.0081	0.0114	0.0120	0.0149	0.0090	0.0179	20.1%
Imall Recall@1 0.0004 0.0046 0.0079 0.0082 0.0117 0.0056 0.0130 11.19 Recall@5 0.0019 0.0169 0.0226 0.0245 0.0306 0.0180 0.0366 19.69		Prec@10	0.0007	0.0063	0.0084	0.0090	0.0104	0.0070	0.0132	26.9%
Recall@5 0.0019 0.0169 0.0226 0.0245 0.0306 0.0180 0.0366 19.69		Recall@1	0.0004	0.0046	0.0079	0.0082	0.0117	0.0056	0.0130	11.19
		Recall@5	0.0019	0.0169	0.0226	0.0245	0.0306	0.0180	0.0366	19.6%
Recall@10 0.0026 0.0260 0.0333 0.0364 0.0425 0.0278 0.0534 25.6%		Recall@10	0.0026	0.0260	0.0333	0.0364	0.0425	0.0278	0.0534	25.6%

Related Works and Motivations

- Existing works model sequential pattern in point-level, fail to model sequential pattern in union-level.
- **point-level:** each of the previous actions influences the target action individually, instead of collectively – union-level: several previous actions jointly influence the

target action.



• Find the existence of union-level sequential pattern.

When we mine sequential association rules of the form

```
(\mathcal{S}_{t-L}^u, \cdots, \mathcal{S}_{t-2}^u, \mathcal{S}_{t-1}^u) \to \mathcal{S}_t^u.
```



The first horizontal filter picks up the union-level sequential pattern "(Airport, Hotel) \rightarrow Great Wall" by having larger values in the latent dimensions where Airport and Hotel have larger values.

Capture Point-level Sequential Pattern with Vertical Convolutional Filters

- Sliding vertically (from left to right), the vertical convolutional filters have same height (*i.e.*, *L*) and same width (*i.e.*, 1).
- Vertical convolutional filters are learned to *aggregate* the latent embeddings of previous items.





Case Studies

• Visualize the influences of Caser's prediction when masking out certain items within a sequence.

With confidence=50% and support=5, most of the resulting rules have the length larger than 1 (L > 1), indicating the existence of union-level influences.



In other words, they are performing *weighted sum* over previous items' latent representations, thus capture point-level sequential pattern.

Network Training

- Extract every *L* item as input, and the next *T* items as targets.
- Sigmoid Negative Log-Loss with random negative sampling is used as optimization criterion.

Codes and Data are available at: http://www.sfu.ca/~jiaxit/



increasing number of items in the sequence:



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