On the Effectiveness of Self-supervised Pre-training for Modeling User Behavior Sequences

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Agenda

Mobile Game Advertising
Sequential Representation Learning
Self-supervised Pre-training
Knowledge Transfer to Downstream Task
Experiments
Conclusion
Mobile Game Advertising

- Unity Ad
  - Game Monetization Solution
  - Optimize the conversion prediction accuracy
  - Show the most valuable ads to wide variety of users
User Behavior Sequence

User historical behavior is crucial to improve conversion prediction
Encode user behavior sequence into meaningful representation
Sequential Representation Learning

Challenges

○ Learn on outcomes (installs)
  ■ Installs are sparse
  ■ Ignore other signals about user's journey to conversion

○ Predict next items
  ■ Items are many
  ■ User historical sequence could be noisy
Self-supervised Pre-training

Self-supervised learning

- Extract useful information from the data itself without any labels

Motivations

- Pre-train the representation with the most updated history without waiting for conversion windows
- The downstream task - conversion prediction does not train from scratch
Pre-text Task

Predicting the relative probability of the correct next item instead of reconstructing the exact next item
Knowledge Transfer to Downstream Task

$$\mathcal{L}_b = -y_i \log \sigma(g_i) - (1 - y_i) \log (1 - \sigma(g_i))$$

$$\mathcal{L}_c = -\log \frac{\exp(\hat{h}_{t,m-1} \cdot \hat{e}_{t,m})}{\exp(\hat{h}_{t,m-1} \cdot \hat{e}_{t,m}) + \sum_{k=1}^{P} \exp(\hat{h}_{t,m-1} \cdot \hat{e}'_{k})}$$
Experiment Settings

Data
- One month of user behavior history
- Most updated 30 events

Network
- Dense + RNN with GRU
- Optimizer: Adam (learning rate: 0.001)
- Batch size: 5,000

Evaluation Metrics
- Log-loss
- AUC

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<table>
<thead>
<tr>
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<tbody>
<tr>
<td>training data size</td>
<td>20,000,000</td>
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<tr>
<td>validation data size</td>
<td>4,000,000</td>
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<tr>
<td>test data size</td>
<td>4,000,000</td>
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<tr>
<td>average sequence length</td>
<td>23.3</td>
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<tr>
<td>number of unique target items</td>
<td>2974</td>
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Visualization and Linear evaluation

Visualize pre-trained sequence representations for four target items (2,000 samples are selected)

Compare log-loss and AUC for models with and w/o pre-training

<table>
<thead>
<tr>
<th>Test case</th>
<th>Pre-trained</th>
<th>Log loss</th>
<th>Impr</th>
<th>AUC</th>
<th>RelaImpr</th>
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<tbody>
<tr>
<td>Linear evaluation</td>
<td>✔</td>
<td>0.07105</td>
<td>1.15%</td>
<td>0.7831</td>
<td>4.81%</td>
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<td>Full labeled data</td>
<td>✔</td>
<td>0.06924</td>
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Training with Different Proportions of labeled samples

- Information gain from pre-training is large when labeled data is sparse
- Achieve comparable log-loss and AUC with pre-training with less labeled data
Conclusion

Introduce a self-supervised pre-training scheme for modeling user behavior sequence in conversion prediction task

Models with the proposed self-supervised pre-training scheme converge quicker, achieve better log-loss and AUC score, and are label efficient

Other more efficient pre-text tasks of self-supervised learning can be further researched in the future
Thank You!