Knowledge-enhanced Session-based Recommendation

Yu Wang

Amin Javari

Mentor

Janani Balaji

Manager

Vanderbilt University
Computer Science
Network and Data Science Lab
https://yuwvandy.github.io/

Knowledge graph provides a better way to learn item information for Subsequent Purchase Prediction (SPP)

What

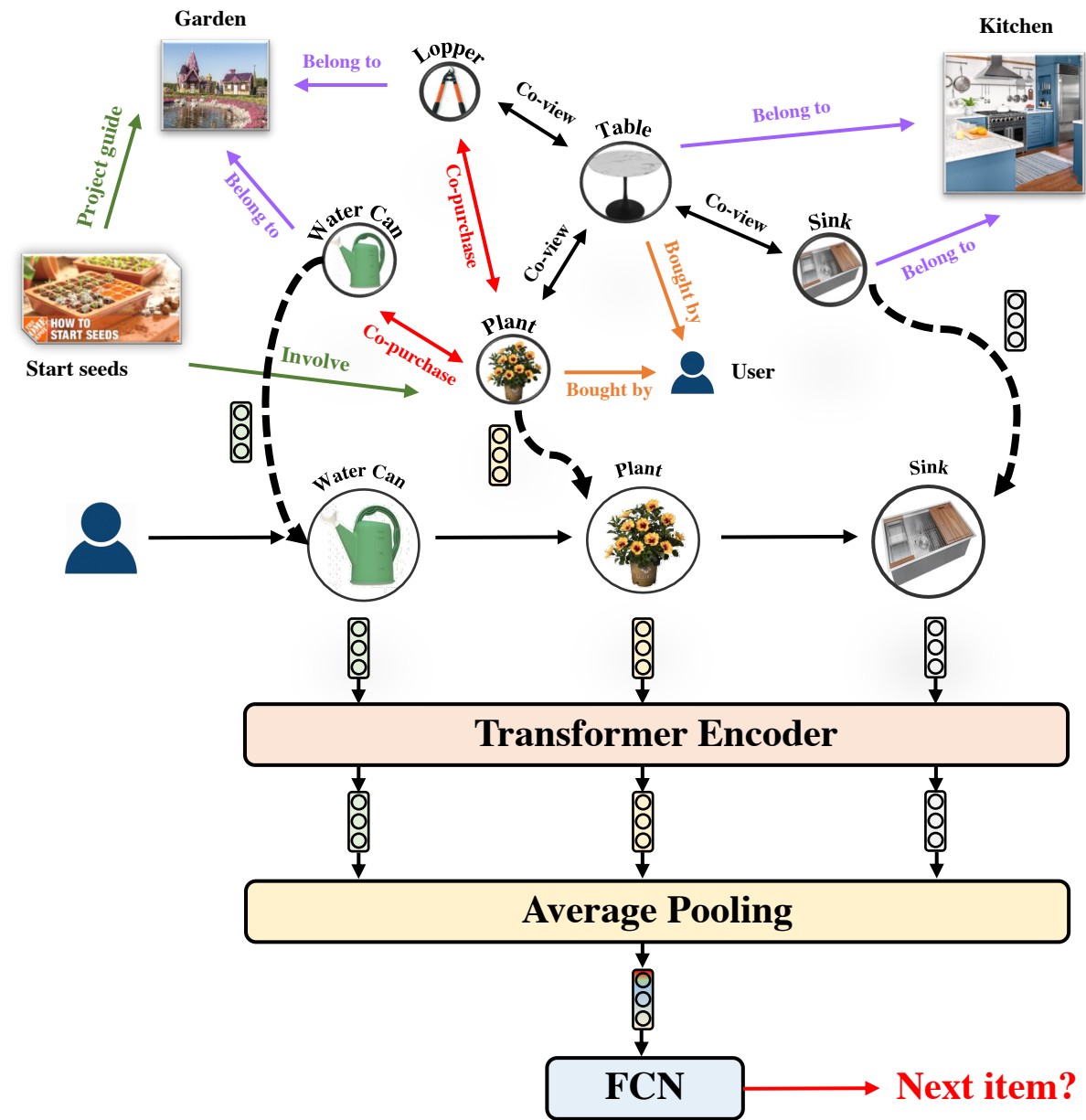- Use **Knowledge Graph** to learn item information for **Subsequent Purchase Prediction**

Why

- **Knowledge graph** can incorporate **every information**
- The learned item embedding is useful for **SPP**

Results

- Consistently Improve **Hit-Ratio** and **Recall by ~1%-2%.**

| Hit-ratio	@5	@10	@20
SPP at THD	0.2703	0.3370	0.4014
KGS (Ours)	0.2755	0.3427	0.4058
Gain (%)	**1.9%**	**1.7%**	**1.1%**

The current SPP model can be improved by incorporating complex item information from knowledge graph

Subsequent Purchase Prediction aims at predicting the next item that the user wants to atc given a sequence of attributed items that have been previously add-to-the-cart by this user in the sequence.
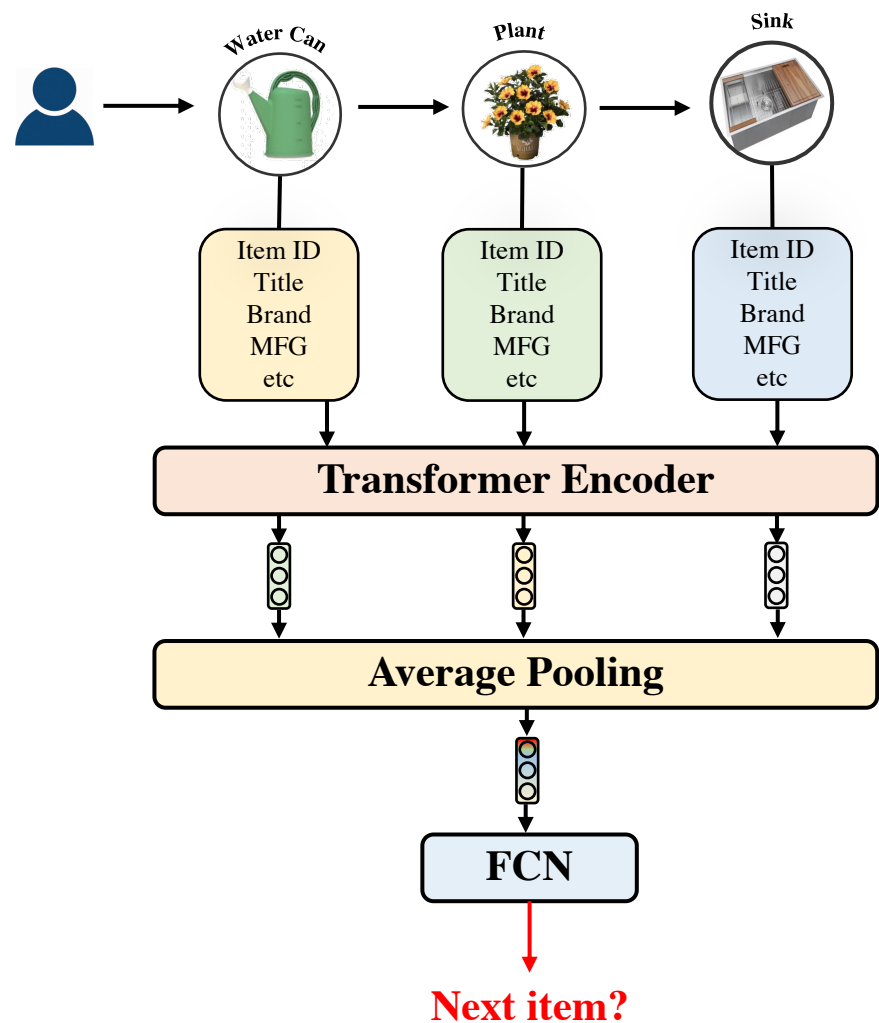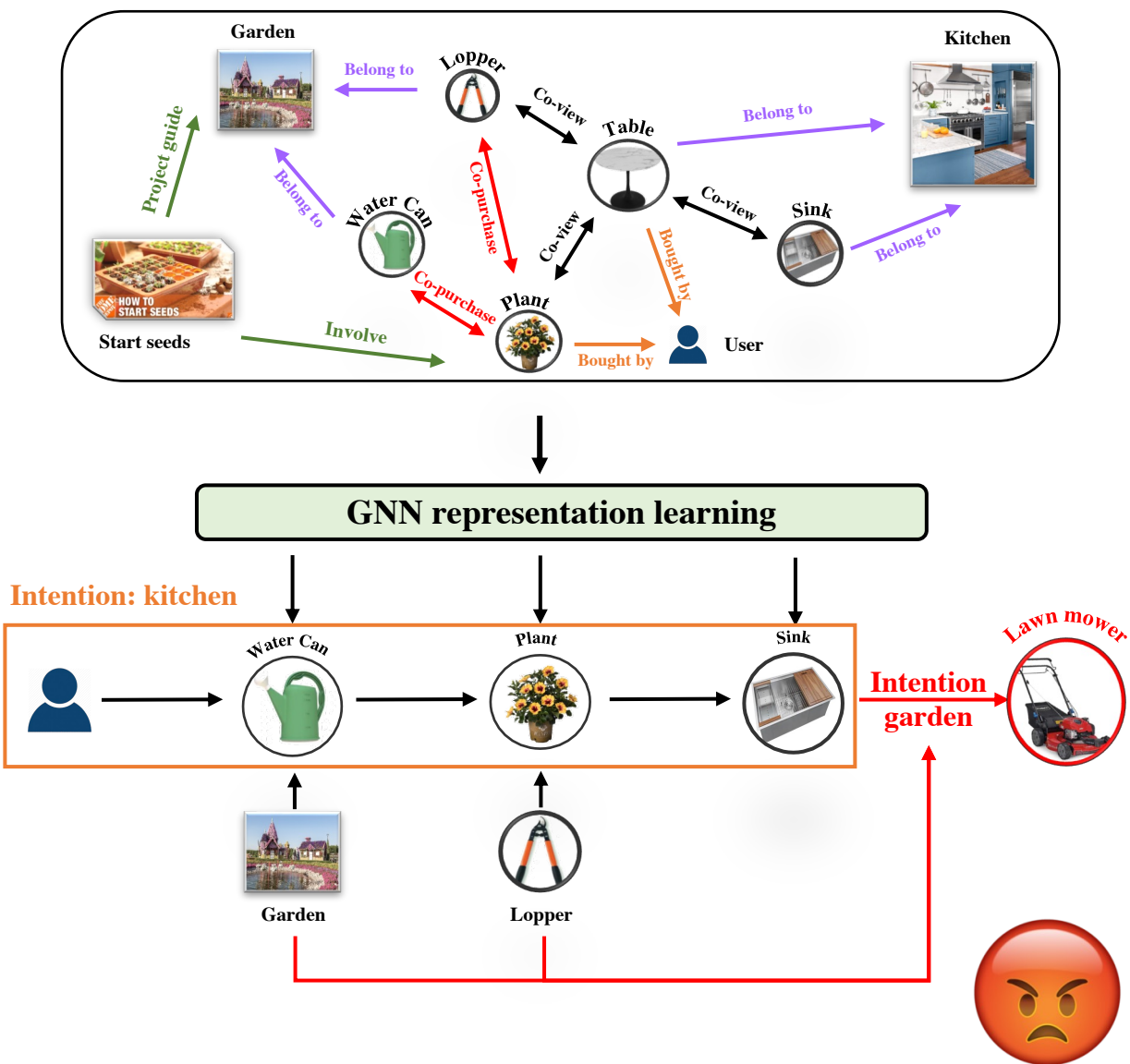

However, this model can be further improved by using complex item information such as:
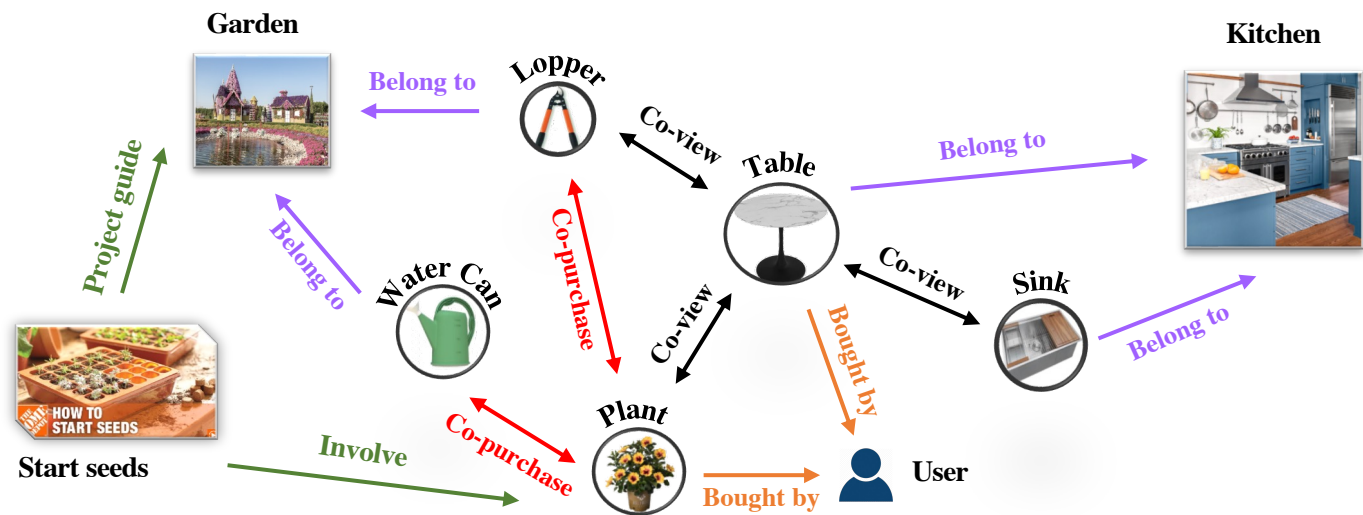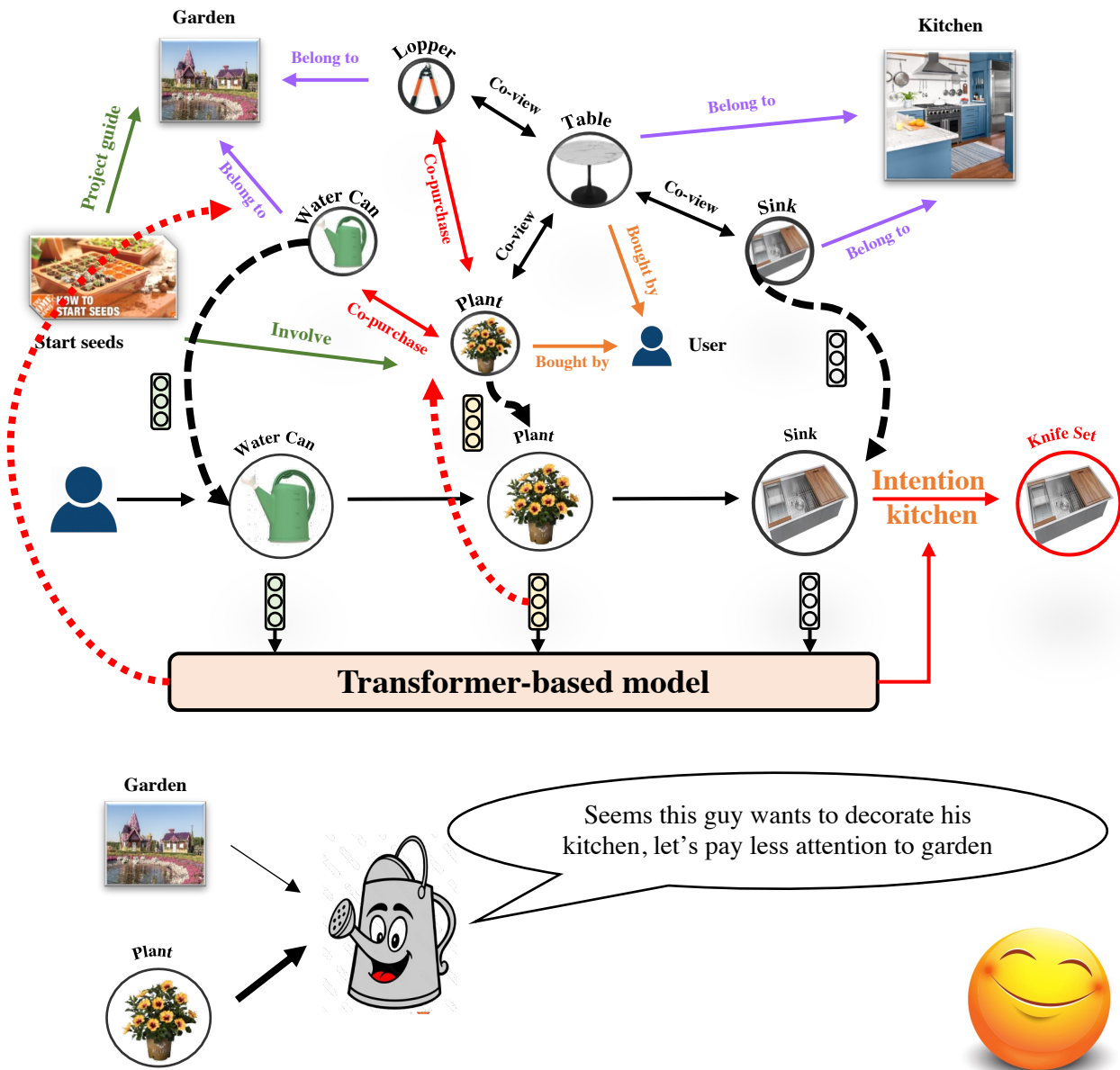
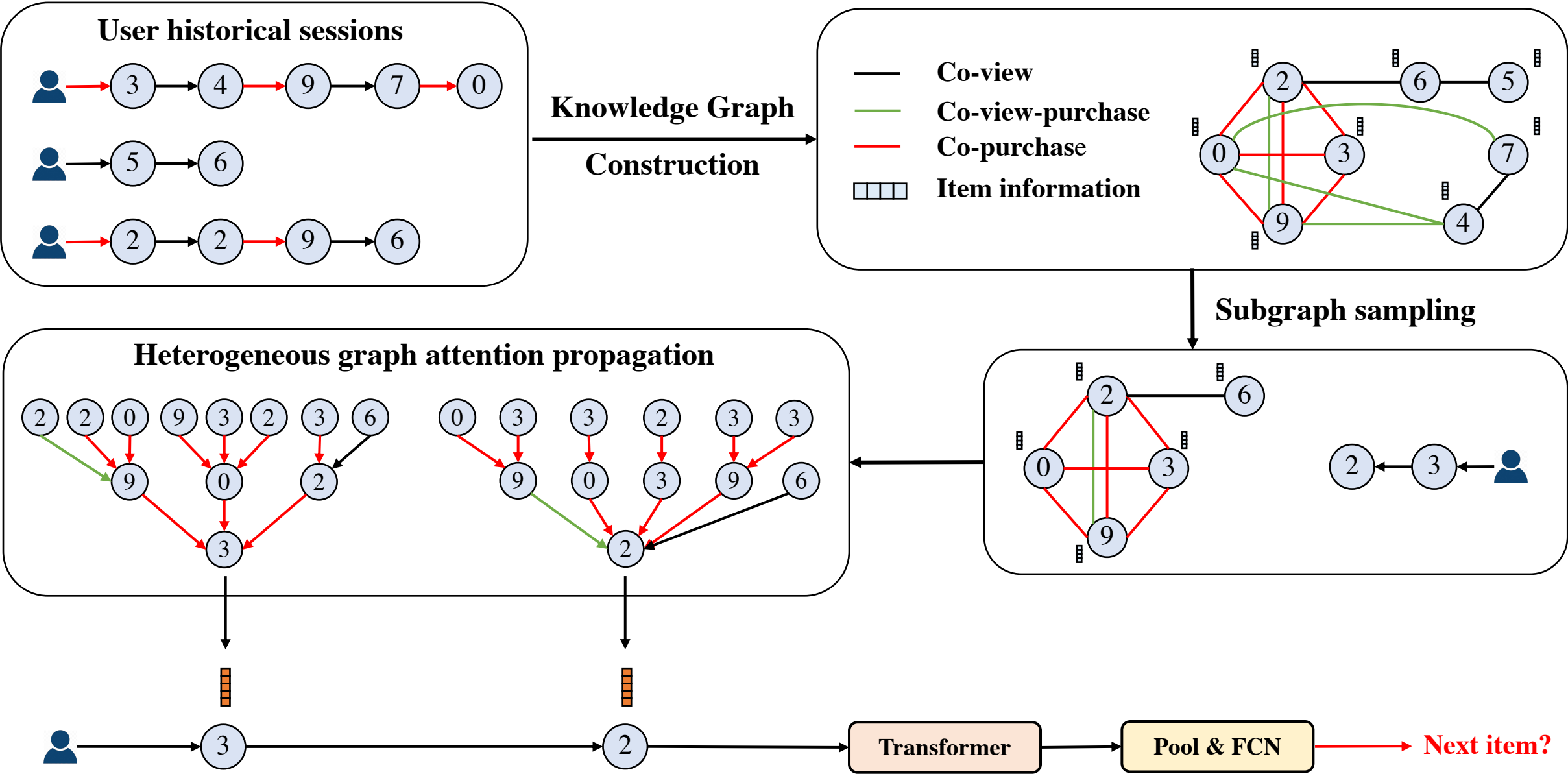# Let the purchase sequence to tell GNN which item information should we learn from Knowledge Graph

Knowledge graph construction and heterogeneous graph attention propagation

Recall and Hit-ratio at all top-k recommendation are consistently improved

Hit-ratio	@5	@10	@20
SPP at THD	0.2703	0.3370	0.4014
Transformer	0.2709	0.3369	0.4000
KGS (Ours)	0.2755	0.3427	0.4058
Gain (%)	**1.9%**	**1.7%**	**1.1%**

Recall	@5	@10	@20
SPP at THD	\	\	\
Transformer	0.3272	0.4003	0.4695
KGS (Ours)	0.3324	0.4065	0.4756
Gain (%)	**1.6%**	**1.5%**	**1.3%**

- KGS consistently improves **Hit-Ratio** and **Recall by ~1-2%** over existing transformer model.

- We are still improving model and further tuning the parameters.

Future work

Further Extend the current model

- Extend the current knowledge graph by adding item category information and user information.

Category l_2

Category l_1

Item l_1

User layer
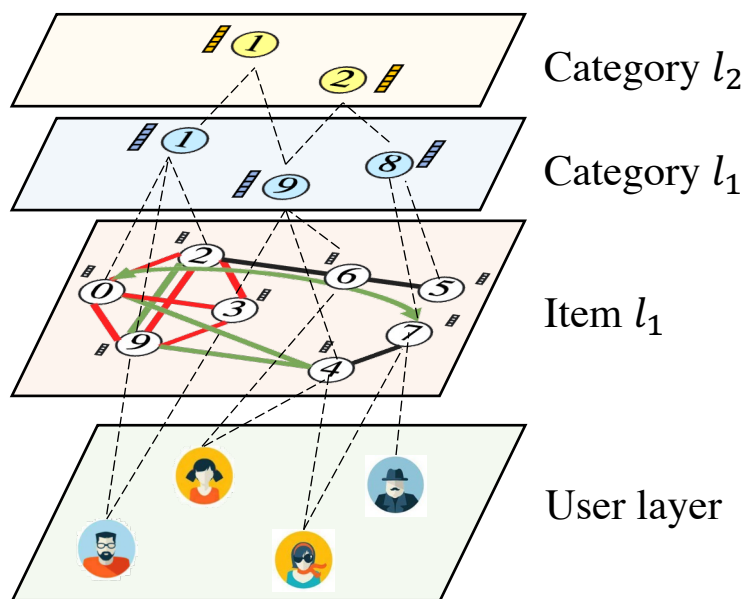
- Personalized recommendation

Further Generalize the current model

- The transformer model that we use for this session-based recommendation can be viewed as **a prediction head**. This prediction head can be replaced with any model at THD that uses representation learning.
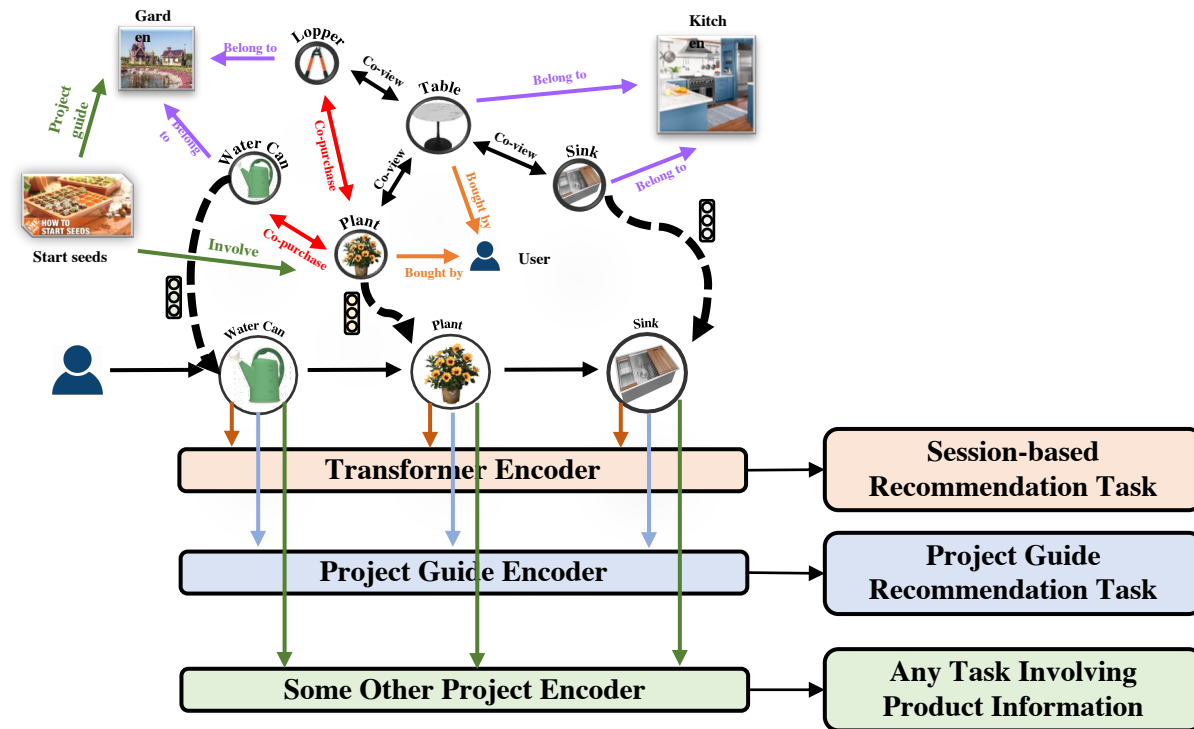
Summary

My first internship!

Great teamwork and collaborations towards the common goal of a successful project!

Everyone is very supportive, hard-working and could help me solve the issue in no time!

Appendix

Appendix – Building the Knowledge Graphs

User historical sessions

2020-06-09 - 2022-06-07

Knowledge Graph Construction

- Co-view
- Co-view-purchase
- Co-purchase
- Item embedding

Top-k edge thresholding

# of co-purchase/ co-view/ co-purchase-view to threshold edges
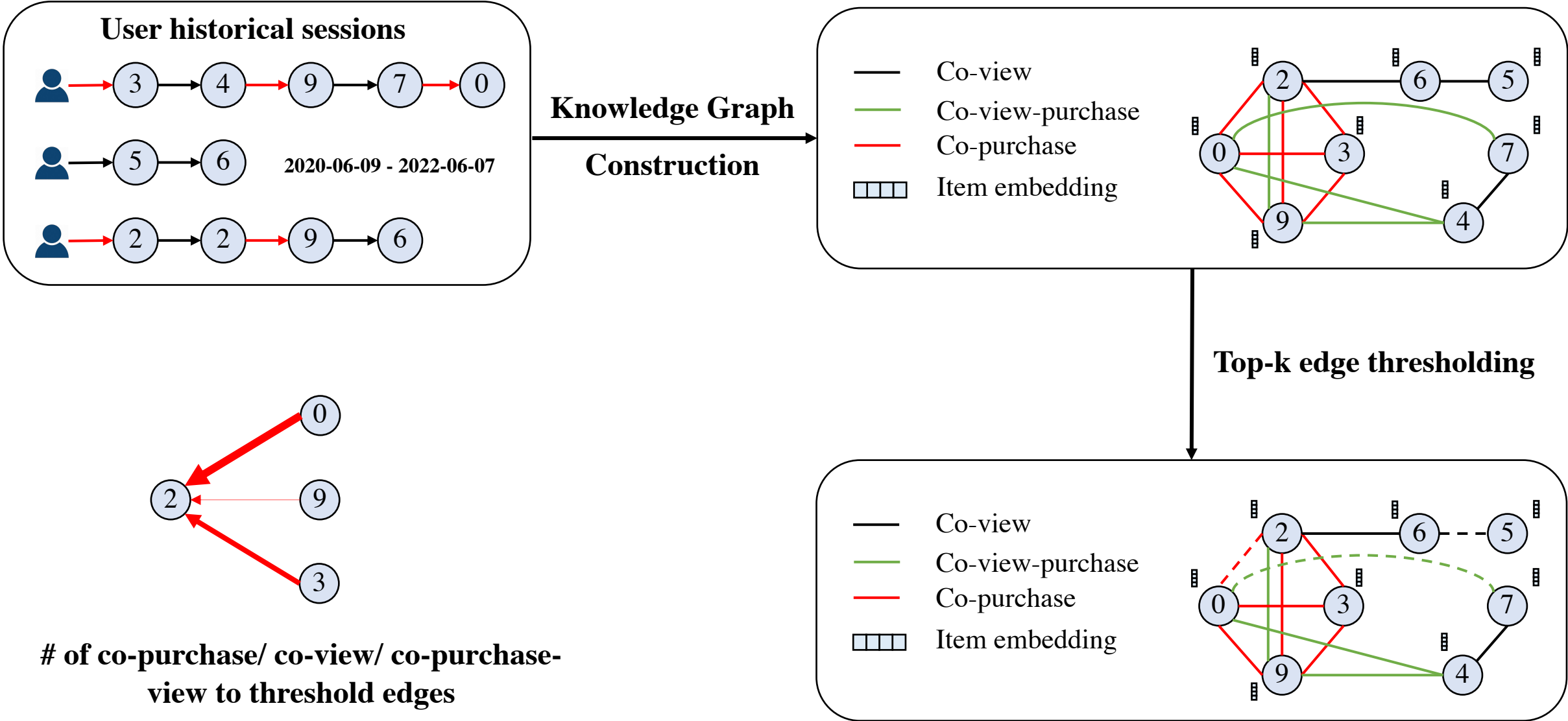
Appendix – Heterogeneous graph attention

$$H^l[t] \leftarrow \underset{\forall s \in N(t), \forall e \in E(s,t)}{\textbf{Aggregate}} \left(\textbf{Attention}(s,t) \cdot \textbf{Message}(s) \right)$$

$$\textbf{Attention}_{HGT}(s,e,t) = \underset{\forall s \in N(t)}{\text{Softmax}} \left(\underset{i \in [1,h]}{\parallel} \textit{ATT-head}^i(s,e,t) \right) \qquad \textbf{Message}_{HGT}(s,e,t) = \underset{i \in [1,h]}{\parallel} \textit{MSG-head}^i(s,e,t)$$

$$\textit{ATT-head}^i(s,e,t) = \left(K^i(s)\, W^{ATT}_{\phi(e)}\, Q^i(t)^T \right) \cdot \frac{\mu_{\langle \tau(s), \phi(e), \tau(t) \rangle}}{\sqrt{d}} \qquad \textit{MSG-head}^i(s,e,t) = \text{M-Linear}^i_{\tau(s)} \left(H^{(l-1)}[s] \right) W^{MSG}_{\phi(e)}$$

$$K^i(s) = \text{K-Linear}^i_{\tau(s)} \left(H^{(l-1)}[s] \right)$$

$$Q^i(t) = \text{Q-Linear}^i_{\tau(t)} \left(H^{(l-1)}[t] \right)$$

Appendix - Data

The # of sessions/items/interactions	Number
All items	1677456
Unique items in session	1209852
Unique items in co-purchase graph	1022815
Unique items in co-view graph	1348919
Unique items in co-view-purchase graph	721947
Joint items between session and co-purchase graph	913788
Joint items between session and co-view graph	930062
Joint items between session and co-view-purchase graph	649345
Joint items between co-view and co-purchase graph	857381
Joint items between co-view and co-view-purchase graph	708976
Joint items between co-purchase and co-view-purchase graph	657102
Copurchase interactions (2020-06-09 - 2022-06-07)	5836093
Coview interactions (2020-06-09 - 2022-06-07)	7779503
Coview-purchase interactions (2020-06-09 - 2022-06-07)	2370450
Train_seqs (2020-06-09 -- 2022-06-07)	63382809
Valid_seqs (2022-06-08 -- 2022-06-14)	672873

Appendix - Result

Hit-ratio	@1	@3	@5	@10	@20
SPP at THD	0.1270	\	0.2703	0.3370	0.4014
Transformer	0.1239	0.2217	0.2709	0.3369	0.4000
KGS	0.1254	**0.2253**	**0.2746**	**0.3419**	**0.4054**

Recall	@1	@3	@5	@10	@20
SPP at THD	\	\	\	\	\
Transformer	0.1566	0.2711	0.3272	0.4003	0.4695
KGS	**0.1587**	**0.2758**	**0.3318**	**0.4062**	**0.4755**