Recommendation System using Graph Neural Networks (GNNs)

Mughees Asif

MSc. Artificial Intelligence

m.asif@se18.qmul.ac.uk

Queen Mary, University of London (QMUL)

August 15, 2022

Overview

Introduction

- Recommendation systems are a vital tool to:
  - Streamline the UX.
  - Mitigate information overload by pinpointing areas of interest.
  - Enhance customer satisfaction.
  - Increase business profitability.
- Graph Neural Networks (GNNs) leverage deep learning methodologies on non-Euclidean data structures:
  - Preserve structural information.
  - Node classification.
  - Link estimation.
- Aim of the project was the development, exploration, and testing of a GNN framework for recommendation tasks.

Graph Neural Networks (GNNs)

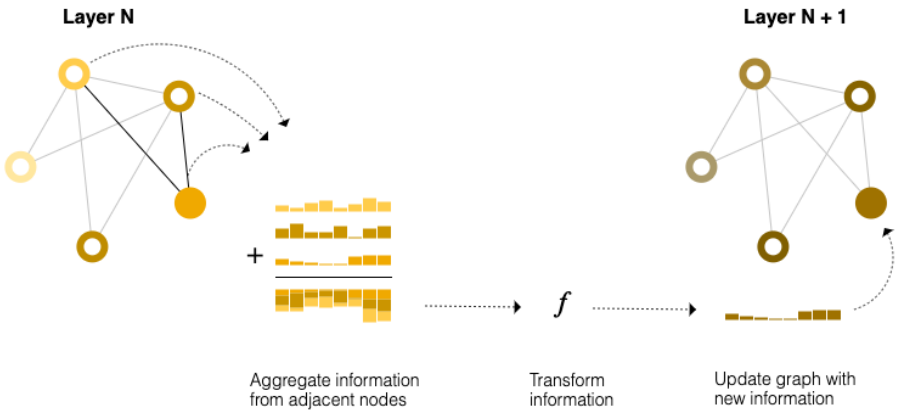

Figure 1: GNN operations

- Graphs are all around us; real world objects are often defined in terms of their connections to other things.
- Two main operations within a GNN[1]:
  - **Aggregation**: Enables the equal treatment of each neighbouring node with a mean-pooling operation or via an attention mechanism.
  - **Update**: The aggregated neighbourhood is integrated into an updated representation of the current node.

[1] Zhou, J., Cui, G., Hu, S., Zhang, Z., Yang, C., Liu, Z., Wang, L., Li, C. and Sun, M., 2020. Graph Neural Networks: A review of methods and applications. *AI Open*, 1, pp.57-81.

Recommendation System

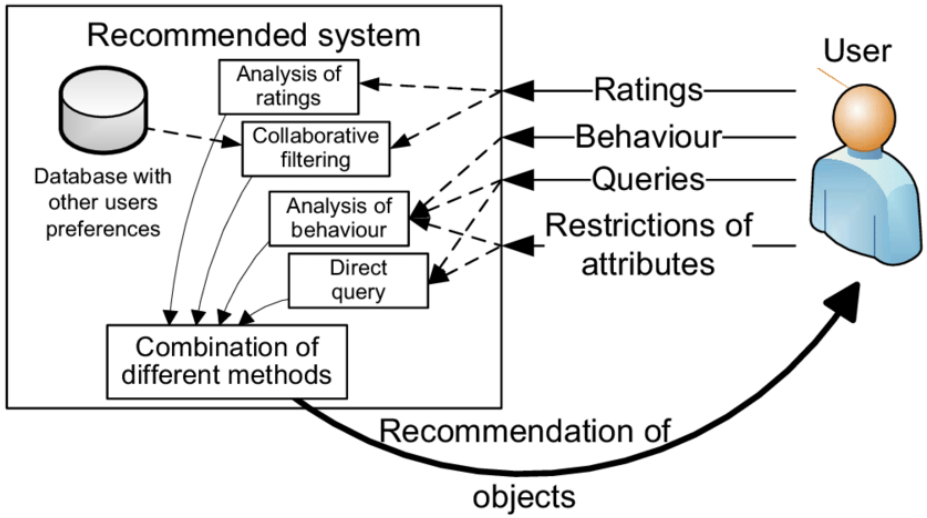

Figure 2: Overview of a recommendation system

- A subclass of information filtering systems that provide suggestions for items that are most pertinent to a particular user.
- Capable of integrating multiple sources of attributes to increase precision of the recommendation such as user-to-user social network information and user-to-item interactions.

Overview

Problem definition

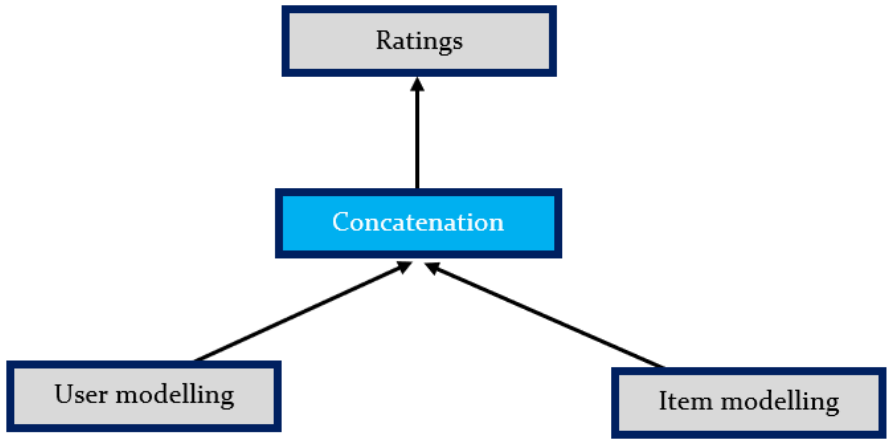

Figure 3: Goal of the GNN system is to find the rating

Consider a system comprised of sets of users and items, both of which are mapped onto separate graphs. If an item is rated by a certain user and another rating is passed by another user, the underlying social connection influence can be used to develop a prediction rating. The aim of the project is to predict the rating likely to be given by a user[2].

[2] Marsden, P.V. and Friedkin, N.E., 1993. Network studies of social influence. *Sociological Methods & Research*, 22(1), pp.127-151.

User modelling

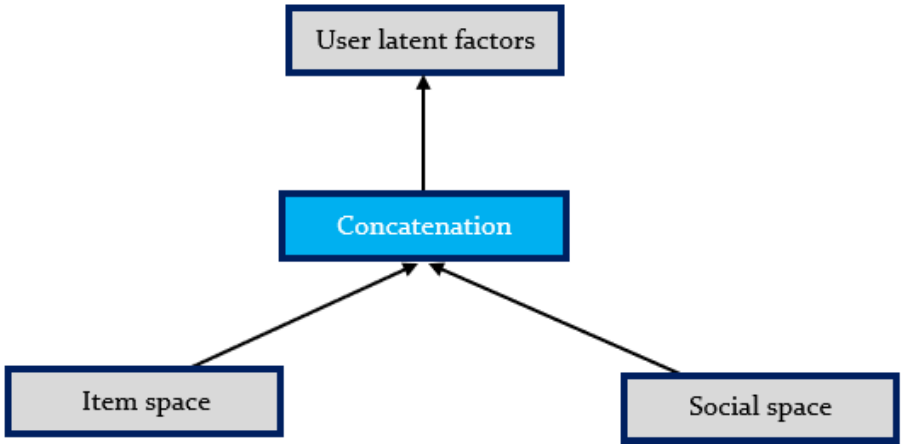

Figure 4: User modelling operations

- **Item space operation** h_i^I: Utilises the interactions between the users and items $C(i)$, and also the users preferences $\mathbf{x}_{ia}$ regarding an item:

$$\mathbf{h}_i^I = \sigma\left(\mathbf{W} \cdot A_{\text{item}}\left(\mathbf{x}_{ia}, \forall a \in C(i)\right) + \boldsymbol{b}\right) \tag{1}$$

- **Social space operation** h_i^S: To encode heterogeneous strengths of social relations $N(i)$, an attention mechanism is introduced:

$$\mathbf{h}_i^S = \sigma\left(\mathbf{W} \cdot A_{\text{neighbours}}\left(\mathbf{h}_o^I, \forall o \in N(i)\right) + \boldsymbol{b}\right) \tag{2}$$

Item modellling

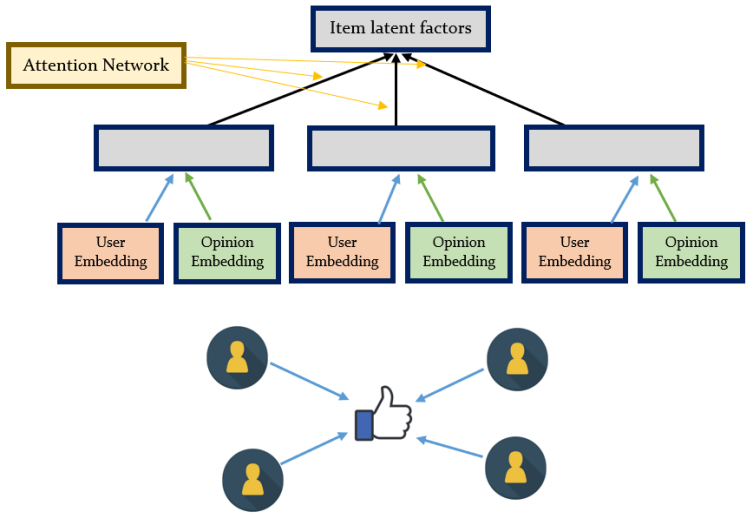

Figure 5: Item modelling operation

- For each item, the user's preferences are aggregated i.e., the mean of the ratings for all items ($R = r \in 1, 2, 3, 4, 5$), and using a Multi-Layer Perceptron (MLP), the two vectors holding information regarding plain user embedding and opinion embedding are concatenated:

$$\mathbf{z}_j = \sigma\left(\mathbf{W} \cdot A_{\text{users}}\left(\mathbf{f}_{jt}, \forall t \in B(j)\right) + \boldsymbol{b}\right) \tag{3}$$

$$\tag{4}$$

Datasets

- Two datasets from prominent product review websites were used: **Epinions** and **Caio**.
- The contents of the datasets contained several data points including *user* and *item ID* and the *rating* given to a specific item by a user.
- Multiple users had given ratings for a specific item, thereby establishing the social relationship aspect that could be modelled.

Training and testing

- **Training**:
  - The model was built using the `PyTorch` library in the Python programming language ecosystem, as per the industry standard.
  - Dropout was added.
  - The system contained multiple decoupled modules.
- **Testing**:
  - The original framework was split into three variants:
    - **Model** X_a: Original
    - **Model** X_b: Item space operation disabled
    - **Model** X_c: Social space operation disabled
  - The variants were also benchmarked against published recommendation systems from academic literature.
  - Evaluation metrics:
    - Mean Squared Error (MAE)
    - Root Mean Squared Error (RMSE)

Results

TABLE V
WEIGHTED AVERAGE OF MAE AND RMSE

Algorithm	Dataset	
	Ciao	Epinions
SoRec	0.925	1.115
SoReg	0.950	1.120
DeepSoR	0.940	0.990
GC-MC	0.945	1.040
$\boldsymbol{X_a}$	0.985	1.000
$\boldsymbol{X_b}$	0.885	1.000
$\boldsymbol{X_c}$	0.945	0.945

Figure 6: Final averaged results

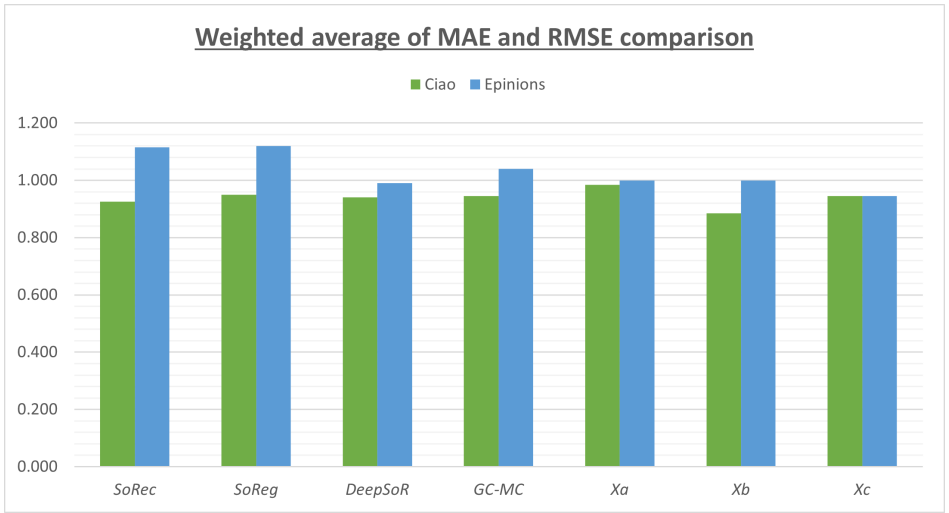

Figure 7: Weighted averages of MAE and RMSE

Future work

- Ensure all the frameworks are implemented from the first principles to establish constancy with regard to architectural designs and operating system idiosyncrasies.
- Unit and integration testing.
- Use different types of datasets that contain more than social network information.
- Use multiple architectures together i.e., GNNs with recurrent neural networks.

Overview

Conclusion

- Evaluation metrics shows a favourable framework with fluid mapping abilities.
- Incorporation of more features leading to increased accuracy.
- The architectural choice of GNNs in recommendation systems depends on several parameters.
- Results have been analysed and further suggested work has been highlighed.

Overview

Acknowledgements

- I would like to thank my supervisor, **Dr Angadh Nanjangud**, for the amazing support, and mentorship, and for the facilitation of my request to research this domain.
- I would also like to extend a big thank you to the **School of Electronic Engineering and Computer Science** for delivering a brilliant Artificial Intelligence postgraduate programme.
- Lastly, I would like to thank **QuantumBlack/Office of AI** for enabling my research interests by providing me with the financial resources needed to complete the degree programme.

Thank You!

– End –