

DEEP LEARNING BASED RECOMMENDER SYSTEMS

Tselepidis Nikolaos

ntselepidis@student.ethz.ch

Goetschmann Philippe

pgoetsch@student.ethz.ch

Maksimov Anton

antonma@student.ethz.ch

Pollak Georg Richard

pollakg@student.ethz.ch

ABSTRACT

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem. Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor. Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris. Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit amet ipsum. Nunc quis urna dictum turpis accumsan semper.

Introduction

Recommender systems are information filtering techniques that aim to predict the level of preference of a user over a specific item. In the era of big data, such techniques have attracted the interest of the scientific community, as they provide a natural approach to improving the user experience on various services, through personalization. Classical recommender systems usually make use of either content-based or collaborative filtering approaches. Content-based filtering techniques utilize specific characteristics of an item in order to recommend additional items with similar properties, while collaborative filtering approaches utilize users' past behaviour i.e. preferences and interactions with items, as well as decisions of other users with similar interests. In most cases, collaborative filtering (CF) techniques yield improved predictions compared to the content-based approaches. There are two main categories of methods when it comes to CF; (i) the Nearest-Neighbor techniques, and (ii) the Matrix Factorization (aka Latent Factor) methods. As the Netflix Prize competition has demonstrated, Matrix Factorization methods are superior to classic Nearest-Neighbor techniques, as they allow the incorporation of additional information to the models, and can thus achieve improved model capacity [8].

Recently, both academia and industry have been in a race to design deep learning based recommender systems in an attempt to overcome the obstacles of conventional models and to achieve higher recommendation quality. In fact, deep learning can effectively capture non-linear and non-trivial user-item relationships, and also enable codification of more

complex abstractions as data representations in the higher levels [13]. Various deep neural network architectures have been proposed and shown to be effective for predicting user preferences. Neural Collaborative Filtering (NCF) generalizes the Matrix Factorization (MF) approach by replacing the inner product utilized in MF models by a multi-layer perceptron that can learn non-linear user-item interaction functions, and thus increases the expressiveness of the MF model [6]. Collaborative Memory Networks (CMN) unify the two classes of collaborative filtering models into a hybrid approach, combining the strengths of the global structure of the latent factor model, and the local neighborhood-based structure in a nonlinear fashion, by fusing a memory component and a neural attention mechanism as the neighborhood component [4]. Neural Graph Collaborative Filtering (NGCF) injects the collaborative signal into the embedding process by exploiting the user-item graph structure, so that it can effectively model high-order connectivity in the user-item interaction graph, and thus achieves improved recommendation quality [12]. Other deep learning based recommendation methods include Autoencoders, [11], Variational Autoencoders (VAE), [9], and Restricted Boltzmann Machines (RBMs) [10]. However, as authors have stated in [3] there has been a reproducibility issue with regards to neural recommendation approaches.

In this work, we conduct an objective study of four recently proposed state-of-the-art neural network approaches, namely NCF [6], CMN [4], NGCF [12], and VAE [9], that can be used in the context of collaborative filtering, on the basis of implicit feedback. Implicit feedback reflects users'

preference through behaviours like watching videos, purchasing products, and clicking items [7]. As opposed to explicit feedback (i.e. ratings and reviews), implicit feedback can be tracked automatically, but is more challenging to utilize, since only user-item interactions are collected instead of user preferences.

In Section 2, we briefly present the aforementioned approaches along with the main underlying concepts. In Section 3, we give extensive comparative results of the selected approaches on three datasets from different application domains, i.e MovieLens (movie recommendations), cf. [5], Epinions (product recommendations), cf. [2], and Jester (joke recommendations), cf. [1]. In Section 4, we discuss the strengths and weaknesses of the selected methods based on the results, and finally in Section 5 we summarize our work.

Models and Methods

1. Neural Collaborative Filtering

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem. Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor. Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris. Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit amet ipsum. Nunc quis urna dictum turpis accumsan semper.

2. Collaborative Memory Network

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem. Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor. Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris. Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit amet ipsum. Nunc quis urna dictum turpis accumsan semper.

3. Neural Graph Collaborative Filtering

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem. Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor. Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris. Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit amet ipsum. Nunc quis urna dictum turpis accumsan semper.

4. Variational Autoencoder

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem. Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor.

Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris. Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit amet ipsum. Nunc quis urna dictum turpis accumsan semper.

Results

Discussion

Summary

References

- [1] Anonymous Ratings Data from the Jester Online Joke Recommender System. <https://goldberg.berkeley.edu/jester-data/>. Accessed: 2019-12-12.
- [2] Recommender Systems Datasets. http://cseweb.ucsd.edu/~jmcauley/datasets.html#social_data. Accessed: 2020-01-12.
- [3] Maurizio Ferrari Dacrema, Paolo Cremonesi, and Dietmar Jannach. Are we really making much progress? A worrying analysis of recent neural recommendation approaches. In *Proceedings of the 13th ACM Conference on Recommender Systems*, pages 101–109. ACM, 2019.
- [4] Travis Ebesu, Bin Shen, and Yi Fang. Collaborative Memory Network for Recommendation Systems. In *The 41st International ACM SIGIR Conference on Research & Development in Information Retrieval*, pages 515–524. ACM, 2018.
- [5] F Maxwell Harper and Joseph A Konstan. The Movielens Datasets: History and Context. *ACM Transactions on Interactive Intelligent Systems (TIIS)*, 5(4):19, 2016.
- [6] Xiangnan He, Lizi Liao, Hanwang Zhang, Liqiang Nie, Xia Hu, and Tat-Seng Chua. Neural Collaborative Filtering. In *Proceedings of the 26th international conference on world wide web*, pages 173–182. International World Wide Web Conferences Steering Committee, 2017.
- [7] Yifan Hu, Yehuda Koren, and Chris Volinsky. Collaborative filtering for implicit feedback datasets. In *2008 Eighth IEEE International Conference on Data Mining*, pages 263–272. IEEE, 2008.
- [8] Yehuda Koren, Robert Bell, and Chris Volinsky. Matrix Factorization Techniques for Recommender Systems. *Computer*, (8):30–37, 2009.
- [9] Dawen Liang, Rahul G Krishnan, Matthew D Hoffman, and Tony Jebara. Variational Autoencoders for Collaborative Filtering. In *Proceedings of the 2018 World Wide Web Conference*, pages 689–698. International World Wide Web Conferences Steering Committee, 2018.
- [10] Ruslan Salakhutdinov, Andriy Mnih, and Geoffrey Hinton. Restricted Boltzmann Machines for Collaborative Filtering. In *Proceedings of the 24th international conference on Machine learning*, pages 791–798. ACM, 2007.
- [11] Suvash Sedhain, Aditya Krishna Menon, Scott Sanner, and Lexing Xie. AutoRec: Autoencoders Meet Collaborative Filtering. In *Proceedings of the 24th International Conference on World Wide Web*, pages 111–112. ACM, 2015.
- [12] Xiang Wang, Xiangnan He, Meng Wang, Fuli Feng, and Tat-Seng Chua. Neural Graph Collaborative Filtering. *arXiv preprint arXiv:1905.08108*, 2019.
- [13] Shuai Zhang, Lina Yao, Aixin Sun, and Yi Tay. Deep Learning based Recommender System: A Survey and New Perspectives. *ACM Computing Surveys (CSUR)*, 52(1):5, 2019.