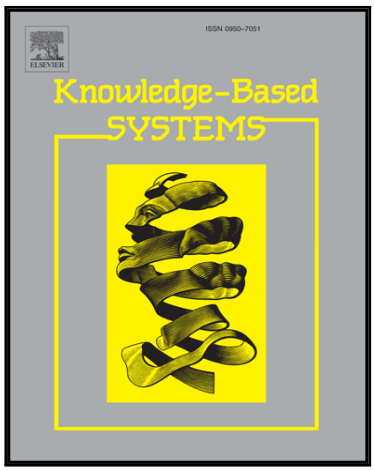

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Dual-Regularized Matrix Factorization with Deep Neural Networks for Recommender Systems ☆

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Abstract

In recommender systems, many efforts have been made on utilizing textual information in matrix factorization to alleviate the problem of data sparsity. Recently, some of the works have explored neural networks to do an in-depth understanding of textual item content and achieved impressive effectiveness by generating more accurate item latent models. Nevertheless, there remains an open issue as how to effectively exploit description documents of both users and items in matrix factorization. In this paper, we proposed dual-regularized matrix factorization with deep neural networks (DRMF) to deal with this issue. DRMF adopts a multilayered neural network model by stacking convolutional neural network and gated recurrent neural network, to generate independent distributed representations of contents of users and items. Then, representations serve to regularize the generation of latent models both for users and items in matrix factorization. We propose the corresponding algorithm for learning all parameters in DRMF. Experimental results proved that the dual-way regularization strategy significantly improves the matrix factorization methods on the accuracy of rating prediction and the recall of top-n recommendations. Also, as the components of DRMF, the new neural network model works better than the single convolutional neural network model.

Keywords: Recommender Systems, Matrix Factorization, Deep Neural Networks, Regularization

1. Introduction

Recommender systems aim to mitigate the negative impact of information overload by filtering and providing users the most attractive and relevant items (such as photos, video, musics, articles, etc.) and thus have achieved big success in the era of big data (Wu et al., 2015; Lu et al., 2015). Various techniques have been proposed to build recommendation systems in the past decade from different societies (Lü et al., 2012; Bobadilla et al., 2013; Lu et al., 2015), such as collaborative filtering (Bobadilla et al., 2013) and network-based methods (Zhou et al., 2010; Lü & Zhou, 2011; Lü et al., 2012; Chen et al., 2017; Wang et al., 2017a,b). Among them, matrix factorization based collaborative filtering (CF) is a dominant method owing to its successful application in recommendation systems (Koren et al., 2009). In traditional CF methods, only the feedback matrix which contains either explicit (e.g., ratings) or implicit feedback (e.g., tagging, clicks, purchases) is used for training and prediction. Typically, the feedback matrix is sparse, which means that most users come into contact with a few items. Resulting from this sparsity problem, traditional CF with only feedback information will suffer from unsatisfactory performance.

Many researchers have proposed utilizing content information to alleviate the data sparsity problem in CF (Lops et al., 2011; Chen et al., 2015; Cao et al., 2017a). In particular, recent representative works are to extract semantic information of textual contents by using the topic model and deep neural network model (Wang & Blei, 2011; Wang et al., 2015; Zhang et al., 2016; Kim et al., 2016), as synopsis and reviews are more prevalent online. Collaborative topic regression (CTR) (Wang & Blei, 2011) combines the merits of both probabilistic matrix factorization and topic modeling approaches. It represents users with topical interests and assumes that items (documents) are produced by LDA model (Blei et al., 2003). Following CTR, Collaborative deep learning (CDL) (Wang et al., 2015) aims at learning more powerful representations of items by exploiting a deep learning model-Stack Denoising AutoEncoder (SDAE). Both CTR and CDL make a success of using textual content of items for recommendations. However, LDA and SDAE analyze "*bag-of-words model*" of item descriptions to generate latent models, and ignore the usage of the contexts of words, such as surrounding words of word and word order, which has been proved as the important features to improve the understanding and representation in natural language processing (Johnson & Zhang, 2014). To overcome the defects of CTR and CDL, Convolutional Matrix Factorization (ConvMF) (Kim et al., 2016) exploits a convolutional neural network to make a deeper understanding of item descriptions considering surrounding words and word order as "*contexts*" and thus generate more accurate

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