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Network Embedding Learning in Knowledge Graph

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Abstract

Knowledge Graph stores a large number of human knowledge facts in form of multi-relational network structure, is widely used as a core technique in real-world applications including search engine, question answering system, and recommender system. Knowledge Graph is used to provide extra info box for user query in Google search engine, the WolframAlpha site provides question answering service relying on Knowledge Graph, and the eBay uses Knowledge Graph as semantic enhance for their recommendation service.

Motivated by several characteristics of Knowledge Graph including incompleteness, structural inferability, and semantical application enhancement, a few efforts have been put into the Knowledge Graph analysis area. Some works contribute to Knowledge Graph construction and maintenance through crowdsourcing. Some previous network embedding learning models show good performance on homogeneous network analysis, while the performance of directly using them on Knowledge Graph is limited because the multiple relationship information of the Knowledge Graph is ignored. Then, the concept of Knowledge Graph embedding learning is given, by learning representation for Knowledge Graph components including entities and relations, the latent semantic information is extracted into embedding representation. And the embedding techniques are also utilized in collaborative learning for Knowledge Graph and external application scenarios, the target is to use Knowledge Graph as a semantic enhancement to improve the performance of external applications.

However, some problems still remain in Knowledge Graph completion, reasoning, and external application. First, a proper model is required for Knowledge Graph self-completion, and a proper integration solution is also required to add extra conceptual taxonomy information into the process of Knowledge Graph completion. Then, a framework to use sub-structure information of Knowledge Graph network into knowledge reasoning is needed. After that, a collaborative learning framework for knowledge graph completion and downstream machine learning tasks is needed to be designed. In this thesis, we take recommender systems as an example of downstream machine learning tasks.

To address the aforementioned research problems, a few approaches are proposed in the works introduced in this thesis.

- A bipartite graph embedding based Knowledge Graph completion approach for Knowledge Graph self-completion, each knowledge fact is represented in the form of bipartite graph structure for more reasonable triple inference.

- An embedding based cross completion approach for completing the factual Knowledge Graph with additive conceptual taxonomy information, the components of factual Knowledge Graph and conceptual taxonomy, entities, relations, types, are jointly represented by embedding representation.
- Two sub-structure based Knowledge Graph transitive relation embedding approaches for knowledge reasoning analysis based on Knowledge Graph sub-structure, the transitive structural information contained in Knowledge Graph network sub-structure is learned into relation embedding.
- Two hierarchical collaborative embedding approaches for proper collaborative learning on Knowledge Graph and Recommender System through linking Knowledge Graph entities with Recommender items, then entities, relations, items, and users are represented by embedding in collaborative space.

The main contributions of this thesis are proposing a few approaches which can be used in multiple Knowledge Graph related domains, Knowledge Graph completion, reasoning and application. Two approaches achieve more accurate Knowledge Graph completion, other two approaches model knowledge reasoning based on network sub-structure analysis, and the other approaches apply Knowledge Graph into a recommender system application.

CERTIFICATE OF ORIGINAL AUTHORSHIP

I, Zili Zhou declare that this thesis, is submitted in fulfilment of the requirements for the award of Doctor of Philosophy, in the School of Computer Science at the University of Technology Sydney.

This thesis is wholly my own work unless otherwise reference or acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

This document has not been submitted for qualifications at any other academic institution. I certify that the work in this thesis has not previously been submitted for a degree nor has it been submitted as part of the requirements for a degree at any other academic institution except as fully acknowledged within the text. This thesis is the result of a Collaborative Doctoral Research Degree program with Shanghai University.

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Zili Zhou

DATE: 21st August, 2019

Dedication

To my beloved wife . . .

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Zili Zhou
Sydney, Australia
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List of Publications

Related to the Thesis :

1. Zhou, Z., Xu, G., Zhu, W., Li, J., & Zhang, W. (2017, May). Structure embedding for knowledge base completion and analytics. In 2017 International Joint Conference on Neural Networks (IJCNN) (pp. 737-743). IEEE.

2. Zhou, Z., Liu, S., Xu, G., Xie, X., Yin, J., Li, Y., & Zhang, W. (2018, June). Knowledge-Based Recommendation with Hierarchical Collaborative Embedding. In Pacific-Asia Conference on Knowledge Discovery and Data Mining (pp. 222-234). Springer, Cham.

3. Zhou, Z., Liu, S., Xu, G., & Zhang, W. (2019, July). On Completing Sparse Knowledge Base with Transitive Relation Embedding. In Proceedings of the AAAI Conference on Artificial Intelligence (Vol. 33, pp. 3125-3132).

4. Zhou, Z., Liu, S., Xu, G. & Zhang, W. Meta-structure Transitive Relation Embedding for Knowledge Graph Completion. Prepared to be submitted as a Conference Paper.

5. Zhou, Z., Liu, S., Xu, G. & Zhang, W. Cross Completion for Factual Knowledge Graph and Conceptual Taxonomy. Prepared to be submitted as a Journal Paper.

6. Zhou, Z., Liu, S., Xu, G. & Zhang, W. Knowledge Graph based Collaborative Network Embedding for Recommender System. Prepared to be submitted as a Journal Paper.

Others :

7. Zhou, Z., Xu, G., Zhu, X., & Liu, S. (2017, October). Latent factor analysis for low-dimensional implicit preference prediction. In 2017 International Conference on Behavioral, Economic, Socio-cultural Computing (BESC) (pp. 1-2). IEEE.

8. Liu, S., Xu, G., Zhu, X., & Zhou, Z. (2017, October). Towards simplified insurance application via sparse questionnaire optimization. In 2017 International Conference on Behavioral, Economic, Socio-Cultural Computing (BESC) (pp. 1-2). IEEE.

9. Yin, J., Zhou, Z., Liu, S., Wu, Z., & Xu, G. (2018, June). Social Spammer Detection: A Multi-Relational Embedding Approach. In Pacific-Asia Conference on Knowledge Discovery and Data Mining (pp. 615-627). Springer, Cham.

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