Network Embedding

Theories, Methods, and Applications

Synthesis Lectures on Artificial Intelligence and Machine Learning

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Cheng Yang, Zhiyuan Liu, Cunchao Tu, Chuan Shi, and Maosong Sun

ISBN: 978-3-031-00462-9 paperback
ISBN: 978-3-031-01590-8 ebook
ISBN: 978-3-031-00035-5 hardcover

DOI 10.1007/978-3-031-01590-8

A Publication in the Springer series
SYNTHESIS LECTURES ON ARTIFICIAL INTELLIGENCE AND MACHINE LEARNING

Lecture #48
Series Editors: Ronald Brachman, *Jacobs Technion-Cornell Institute at Cornell Tech*
Francesca Rossi, *IBM Research AI*
Peter Stone, *University of Texas at Austin*
Series ISSN
Print 1939-4608 Electronic 1939-4616

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Theories, Methods, and Applications

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SYNTHESIS LECTURES ON ARTIFICIAL INTELLIGENCE AND MACHINE LEARNING #48

ABSTRACT

Many machine learning algorithms require real-valued feature vectors of data instances as inputs. By projecting data into vector spaces, representation learning techniques have achieved promising performance in many areas such as computer vision and natural language processing. There is also a need to learn representations for discrete relational data, namely networks or graphs. Network Embedding (NE) aims at learning vector representations for each node or vertex in a network to encode the topologic structure. Due to its convincing performance and efficiency, NE has been widely applied in many network applications such as node classification and link prediction.

This book provides a comprehensive introduction to the basic concepts, models, and applications of network representation learning (NRL). The book starts with an introduction to the background and rising of network embeddings as a general overview for readers. Then it introduces the development of NE techniques by presenting several representative methods on general graphs, as well as a unified NE framework based on matrix factorization. Afterward, it presents the variants of NE with additional information: NE for graphs with node attributes/contents/labels; and the variants with different characteristics: NE for community-structured/large-scale/heterogeneous graphs. Further, the book introduces different applications of NE such as recommendation and information diffusion prediction. Finally, the book concludes the methods and applications and looks forward to the future directions.

KEYWORDS

network embedding, network representation learning, node embedding, graph neural network, graph convolutional network, social network, network analysis, deep learning

Contents

Preface xix

Acknowledgments xxi

PART I Introduction to Network Embedding 1

1 The Basics of Network Embedding 3

1.1 Background 3
1.2 The Rising of Network Embedding 5
1.3 The Evaluation of Network Embedding 5
1.3.1 Node Classification 6
1.3.2 Link Prediction 7
1.3.3 Node Clustering 7

2 Network Embedding for General Graphs 9

2.1 Representative Methods 9
2.1.1 Early Work (Early 2000s – Early 2010s) 9
2.1.2 Modern Work (After 2014) 10
2.2 Theory: A Unified Network Embedding Framework 13
2.2.1 K-Order Proximity 13
2.2.2 Network Embedding Framework 14
2.2.3 Observations 17
2.3 Method: Network Embedding Update (NEU) 18
2.3.1 Problem Formalization 18
2.3.2 Approximation Algorithm 19
2.4 Empirical Analysis 20
2.4.1 Datasets 20
2.4.2 Baselines and Experimental Settings 21
2.4.3 Multi-Label Classification 22
2.4.4 Link Prediction 22

2.4.5 Experimental Results Analysis 25
2.5 Further Reading 25

PART II Network Embedding with Additional Information 27

3 Network Embedding for Graphs with Node Attributes 29
3.1 Overview 29
3.2 Method: Text-Associated DeepWalk 31
3.2.1 Low-Rank Matrix Factorization 31
3.2.2 Text-Associated DeepWalk (TADW) 31
3.2.3 Complexity Analysis 32
3.3 Empirical Analysis 33
3.3.1 Datasets 33
3.3.2 TADW Settings 33
3.3.3 Baseline Methods 34
3.3.4 Classifiers and Experiment Setup 34
3.3.5 Experimental Results and Analysis 35
3.3.6 Case Study 36
3.4 Further Reading 37

4 Revisiting Attributed Network Embedding: A GCN-Based Perspective 39
4.1 GCN-Based Network Embedding 39
4.1.1 Graph Convolutional Network (GCN) 39
4.1.2 Attributed Network Embedding based on GCN 40
4.1.3 Discussions 41
4.2 Method: Adaptive Graph Encoder 42
4.2.1 Problem Formalization 43
4.2.2 Overall Framework 43
4.2.3 Laplacian Smoothing Filter 43
4.2.4 Adaptive Encoder 46
4.3 Empirical Analysis 49
4.3.1 Datasets 49
4.3.2 Baseline Methods 49
4.3.3 Evaluation Metrics and Parameter Settings 50

4.3.4 Node Clustering Results . . . 51
4.3.5 Link Prediction Results . . . 51
4.3.6 GAE vs. LS+RA . . . 53
4.3.7 Ablation Study . . . 53
4.3.8 Selection of k . . . 55
4.3.9 Visualization . . . 55
4.4 Further Reading . . . 56

5 Network Embedding for Graphs with Node Contents . . . 59
5.1 Overview . . . 59
5.2 Method: Context-Aware Network Embedding . . . 61
5.2.1 Problem Formalization . . . 61
5.2.2 Overall Framework . . . 61
5.2.3 Structure-Based Objective . . . 62
5.2.4 Text-Based Objective . . . 62
5.2.5 Context-Free Text Embedding . . . 63
5.2.6 Context-Aware Text Embedding . . . 63
5.2.7 Optimization of CANE . . . 65
5.3 Empirical Analysis . . . 66
5.3.1 Datasets . . . 66
5.3.2 Baselines . . . 66
5.3.3 Evaluation Metrics and Experimental Settings . . . 67
5.3.4 Link Prediction . . . 68
5.3.5 Node Classification . . . 69
5.3.6 Case Study . . . 72
5.4 Further Reading . . . 72

6 Network Embedding for Graphs with Node Labels . . . 75
6.1 Overview . . . 75
6.2 Method: Max-Margin DeepWalk . . . 76
6.2.1 Problem Formalization . . . 77
6.2.2 DeepWalk Based on Matrix Factorization . . . 77
6.2.3 Max-Margin DeepWalk . . . 77
6.2.4 Optimization of MMDW . . . 78
6.3 Empirical Analysis . . . 80
6.3.1 Datasets and Experiment Settings . . . 80
6.3.2 Baseline Methods . . . 80

6.3.3 Experimental Results and Analysis 81
6.3.4 Visualization 83
6.4 Further Reading 83

PART III Network Embedding with Different Characteristics 85

7 Network Embedding for Community-Structured Graphs 87
7.1 Overview 87
7.2 Method: Community-Enhanced NRL 88
7.2.1 Problem Formalization 88
7.2.2 DeepWalk 90
7.2.3 Community-Enhanced DeepWalk 90
7.3 Empirical Analysis 93
7.3.1 Datasets 93
7.3.2 Baseline Methods 93
7.3.3 Parameter Settings and Evaluation Metrics 94
7.3.4 Node Classification 95
7.3.5 Link Prediction 96
7.3.6 Community Detection 96
7.3.7 Visualizations of Detected Communities 97
7.4 Further Reading 97

8 Network Embedding for Large-Scale Graphs 99
8.1 Overview 99
8.2 Method: COmpresSIve Network Embedding (COSINE) 101
8.2.1 Problem Definition 101
8.2.2 Graph Partitioning 103
8.2.3 Group Mapping 103
8.2.4 Group Aggregation 104
8.2.5 Objective Function and Optimization 106
8.3 Empirical Analysis 107
8.3.1 Datasets 107
8.3.2 Baselines and Experimental Settings 107
8.3.3 Link Prediction 108

8.3.4 Multi-Label Classification 109
8.3.5 Scalability 111
8.3.6 Time Efficiency 113
8.3.7 Different Partitioning Algorithms 115
8.4 Further Reading 116

9 Network Embedding for Heterogeneous Graphs 119

9.1 Overview 119
9.2 Method: Relation Structure-Aware HIN Embedding 121
9.2.1 Problem Formalization 121
9.2.2 Data Observations 122
9.2.3 Basic Idea 124
9.2.4 Different Models for ARs and IRs 125
9.2.5 A Unified Model for HIN Embedding 126
9.3 Empirical Analysis 126
9.3.1 Datasets 126
9.3.2 Baseline Methods 126
9.3.3 Parameter Settings 127
9.3.4 Node Clustering 127
9.3.5 Link Prediction 128
9.3.6 Multi-Class Classification 129
9.3.7 Comparison of Variant Models 129
9.3.8 Visualization 131
9.4 Further Reading 131

PART IV Network Embedding Applications 133

10 Network Embedding for Social Relation Extraction 135

10.1 Overview 135
10.2 Method: TransNet 136
10.2.1 Problem Formalization 136
10.2.2 Translation Mechanism 137
10.2.3 Edge Representation Construction 138
10.2.4 Overall Architecture 139
10.2.5 Prediction 140

10.3 Empirical Analysis 140
10.3.1 Datasets 140
10.3.2 Baselines 141
10.3.3 Evaluation Metrics and Parameter Settings 142
10.3.4 Results and Analysis 142
10.3.5 Comparison on Labels 143
10.3.6 Case Study 144
10.4 Further Reading 144

11 Network Embedding for Recommendation Systems on LBSNs 147

11.1 Overview 147
11.2 Method: Joint Network and Trajectory Model (JNTM) 149
11.2.1 Problem Formalization 150
11.2.2 Modeling the Construction of the Social Network 150
11.2.3 Modeling the Generation of the Mobile Trajectories 152
11.2.4 The Joint Model 158
11.2.5 Parameter Learning 159
11.3 Empirical Analysis 160
11.3.1 Data Collection 160
11.3.2 Evaluation Tasks and Baselines 161
11.3.3 Experimental Results on Next-Location Recommendation 164
11.3.4 Experimental Results on Friend Recommendation 167
11.4 Further Reading 168

12 Network Embedding for Information Diffusion Prediction 171

12.1 Overview 171
12.2 Method: Neural Diffusion Model (NDM) 173
12.2.1 Problem Formalization 174
12.2.2 Model Assumptions 174
12.2.3 Extracting Active Users with Attention Mechanism 176
12.2.4 Unifying Active User Embeddings for Prediction with Convolutional Network 177
12.2.5 Overall Architecture, Model Details, and Learning Algorithms . . . 178
12.3 Empirical Analysis 178
12.3.1 Datasets 179
12.3.2 Baselines 180
12.3.3 Hyperparameter Settings 181

12.3.4 Microscopic Diffusion Prediction 181
12.3.5 Benefits from Network Embeddings 183
12.3.6 Interpretability 185
12.4 Further Reading 186

PART V Outlook for Network Embedding 189

13 Future Directions of Network Embedding 191
13.1 Network Embedding Based on Advanced Techniques 191
13.2 Network Embedding in More Fine-Grained Scenarios 191
13.3 Network Embedding with Better Interpretability 192
13.4 Network Embedding for Applications 192

Bibliography 193

Authors' Biographies 219

Preface

Representation learning techniques, which can extract useful information from data for learning classifiers and other predictors, have achieved promising performance in many areas such as computer vision and natural language processing. There is also a need to learn representations for discrete relational data, namely networks or graphs. By mapping similar nodes in a network to the neighboring regions in the vector space, Network Embedding (NE) is able to learn the latent features that encode the properties of a network. NE has shed a light on the analysis of graph-structured data, and became a hot topic across machine learning and data mining areas during the last five years.

This book provides a comprehensive introduction to the basic concepts, models, and applications of network representation learning (NRL).

We start the book from NE on general graphs where only the topology structure of a network is given for representation learning in Part I. By introducing the history and several representative methods of network embedding, we further propose a general framework for NRL from a theoretic perspective. The framework can cover a number of typical NE algorithms and motivates us to develop an efficient and effective algorithm that can be applied on any NE methods to enhance their performances.

Next, we will introduce NE on graphs with additional information in Part II. In the real world, a vertex in a network usually has rich information, such as text features and other meta data. A joint learning from network structure and these additional information will significantly benefit the quality of network embeddings. We will present NE algorithms with node attributes (Chapter 3), contents (Chapter 5), and labels (Chapter 6) as instances in this part, respectively. We also revisit attributed network embedding from a Graph Convolutional Network(GCN)-based perspective in Chapter 4.

Afterward, we will present network embedding on graphs with different characteristics in Part III, including community-structured graphs (Chapter 7), large-scale graphs (Chapter 8), and heterogeneous graphs (Chapter 9). Community structures widely exist in social networks, and can provide complementary global knowledge to network embeddings which focus on local neighborhoods. Real-world networks are also large-scale and heterogeneous, which motivates us to specialize network embedding algorithms for these kinds of graphs to achieve better efficiency and effectiveness.

We will then show the applications of NE technique on various scenarios in Part IV, namely social relation extraction (Chapter 10), recommendation system (Chapter 11), and information diffusion prediction (Chapter 12). NE respectively serves as the main body/a key part/auxiliary inputs of the algorithms in Chapters 10, 11, and 12.

Finally, we will outlook the future directions of NE and conclude the book in Part V.

The intended readers of this book are researchers and engineers in the fields of machine learning and data mining, especially network analysis. Though the contents in each chapter are mainly self-contained, it is necessary for the readers to have a basic background in machine learning, graph theory, and popular deep learning architectures (e.g., convolutional neural network, recurrent neural network, and attention mechanism). The readers are suggested to quickly understand the area of network embedding through Part I and deeply study the variants in different scenarios through Parts II–IV. We hope the outlook chapter in Part V inspires readers to develop their own NE methods.

Cheng Yang, Zhiyuan Liu, Cunchao Tu, Chuan Shi, and Maosong Sun
February 2021

Acknowledgments

We would like to express our sincere thanks to all those who worked with us on this book. Some parts of this book are based on our previous published or pre-printed papers [Cui et al., 2020, Lu et al., 2019, Tu et al., 2016a,b, 2017a,b, Yang et al., 2015, 2017a,b, 2018a, Zhang et al., 2018b], and we are grateful to our co-authors in the work of network embedding: Edward Chang, Ganqu Cui, Zhichong Fang, Shiyi Han, Linmei Hu, Leyu Lin, Han Liu, Haoran Liu, Yuanfu Lu, Huanbo Luan, Hao Wang, Xiangkai Zeng, Deli Zhao, Wayne Xin Zhao, Bo Zhang, Weicheng Zhang, Zhengyan Zhang, and Jie Zhou. In addition, this work is supported by the National Key Research and Development Program of China (No. 2018YFB1004503), the National Natural Science Foundation of China (No. 62002029, U20B2045, 61772082), and the Fundamental Research Funds for the Central Universities (No. 2020RC23). We would also thank all the editors, reviewers, and staff who helped with the publication of the book. Finally, we would like to thank our families for their wholehearted support.

Cheng Yang, Zhiyuan Liu, Cunchao Tu, Chuan Shi, and Maosong Sun
February 2021