



Universiteit
Leiden
The Netherlands

Information diffusion analysis in online social networks based on deep representation learning

Chen, X.

Citation

Chen, X. (2022, October 25). *Information diffusion analysis in online social networks based on deep representation learning*. Retrieved from <https://hdl.handle.net/1887/3484562>

Version: Publisher's Version

License: [Licence agreement concerning inclusion of doctoral thesis in the Institutional Repository of the University of Leiden](#)

Downloaded from: <https://hdl.handle.net/1887/3484562>

Note: To cite this publication please use the final published version (if applicable).

Information Diffusion Analysis in Online Social Networks based on Deep Representation Learning

Xueqin Chen

Information Diffusion Analysis in Online Social Networks based on Deep Representation Learning

Proefschrift

ter verkrijging van
de graad van doctor aan de Universiteit Leiden,
op gezag van rector magnificus prof.dr.ir. H. Bijl,
volgens besluit van het college voor promoties
te verdedigen op dinsdag 25 oktober 2022
klokke 15.00 uur

door

Xueqin Chen

geboren te Sichuan, China
in 1993

Promotores:

Prof. dr. M.M. Bonsangue

Prof. dr. F. Zhang (Univ. of Electronic Science and Technology of China)

Co-promotor:

Dr. F. Zhou (Univ. of Electronic Science and Technology of China)

Promotiecommissie:

Dr. E. Isufi (Delft University of Technology)

Prof. dr. A.A. Khokhar (Iowa State University)

Prof. dr. A. Plaat

Prof. dr. F. Verbeek

Dr. S. Verberne

Copyright © 2022 Xueqin Chen

ISBN 978-94-6469-057-6

The research in this thesis was performed at the Leiden Institute of Advanced Computer Science (LIACS, Leiden University) and the University of Electronic Science and Technology of China.

This work is financially supported by the Chinese Scholarship Council (CSC No. 201906070093)

Contents

1	Introduction	1
1.1	Background	1
1.2	Research Questions and Contributions	3
1.3	Thesis Outline	6
2	Literature Review	9
2.1	Information Cascades Modeling	9
2.1.1	Conventional methods	9
2.1.2	Deep learning-based methods	11
2.2	Rumor Detection	12
2.2.1	Conventional methods	12
2.2.2	Deep learning-based methods	14
3	Preliminaries	17
3.1	General Definitions	17
3.2	Problem Definition	20
3.2.1	Information Cascades Modeling	20
3.2.2	Rumor Detection	20
3.3	A Brief Recall of Neural Networks	21
3.3.1	Recurrent Neural Networks	21
3.3.2	Graph Neural Networks	22
3.3.2.1	Graph Convolutional Networks	24
I	Information Cascades Modeling	27
4	Learning Structural-temporal Features for Cascades Modeling	29
4.1	Chapter Overview	29
4.2	Problem Statement	30
4.3	CasCN: Information diffusion prediction via recurrent cascades convolution	32
4.3.1	Cascade Graph as Sub-cascade Graph Sequences	32
4.3.2	Laplacian Transformation of Cascades	33
4.3.3	Structural and Temporal Modeling	35

4.3.4	Cascades Size Prediction	36
4.4	Evaluation	38
4.4.1	Datasets	38
4.4.2	Baselines	39
4.4.3	Variants of CasCN	42
4.4.4	Evaluation Metric	43
4.4.5	Hyper-parameters	43
4.4.6	Overall performance	43
4.4.7	Ablation study	45
4.4.8	Parameter analysis in CasCN	45
4.4.9	Discussions on feature learning	47
4.5	Summary	49
5	Extracting Multi-scale Information for Cascades Modeling	51
5.1	Chapter Overview	51
5.2	Preliminaries	53
5.3	MUCas: Multi-Scale Graph Capsule with Influence Attention for In-formation Cascades Prediction	53
5.3.1	Time interval-aware Sub-cascade Sampling	54
5.3.2	Multi-scale Cascade Representation Learning	55
5.3.3	Sub-graph Level Influence Attention	60
5.3.4	Information Cascade Prediction	61
5.3.5	Complexity Analysis	62
5.4	Evaluation	63
5.4.1	Datasets	64
5.4.2	Baselines	65
5.4.3	Evaluation Metric	66
5.4.4	Experimental Settings and Parameter Tuning	67
5.4.5	Performance Comparison (Q1)	67
5.4.6	Ablation Study (Q2)	70
5.4.7	Hyper-parameter Sensitivity (Q3)	72
5.4.8	Model Parameters and Computation Cost	75
5.5	Summary	76
II	Rumor Detection	77
6	Modeling Hierarchical Diffusion for Rumor Detection	79
6.1	Chapter Overview	79
6.2	Problem statement	80
6.3	MMRD: Modeling Microscopic and Macroscopic Information Diffu- sion for Rumor Detection	81
6.3.1	Macroscopic Diffusion Encoding Component	82

6.3.2	Microscopic Diffusion Encoding Component	85
6.3.3	Macroscopic and Microscopic Cross-learning	85
6.3.4	Feature fusion via hybrid aggregation layer	86
6.3.5	Rumor detection and optimization	87
6.3.6	Rumor detection with knowledge distilling	88
6.4	Evaluating MMRD	89
6.4.1	Datasets	91
6.4.2	Baselines	91
6.4.3	Parameter Settings and Evaluation Metrics	92
6.4.4	Overall performance (Q1)	94
6.4.5	Ablation study (Q2)	95
6.4.5.1	Variants comparison	95
6.4.5.2	Performance on knowledge distillation	96
6.4.5.3	Parameter analysis	98
6.4.6	Early detection (Q3)	98
6.5	Summary	99
7	Participant-level Rumor detection based on Information Diffusion Analysis	101
7.1	PLRD: A Participant-Level Rumor Detection Framework via Fine-grained User Representation Learning	102
7.1.1	Section Overview	102
7.1.2	Birds of a feather flock together: the perspective of all participants	103
7.1.2.1	Theory	103
7.1.2.2	Data	104
7.1.2.3	Model-free evidence	105
7.1.3	Methodology	107
7.1.3.1	Preliminaries and Problem Statement	108
7.1.3.2	Overall framework of PLRD	109
7.1.3.3	Social homophily learning from global graph	110
7.1.3.4	Users' influence and susceptibility learning	111
7.1.3.5	Users' temporal learning	112
7.1.3.6	Feature-level aggregation attention	112
7.1.3.7	VAE-based uncertainty learning	113
7.1.3.8	User-level aggregation attention	114
7.1.3.9	Rumor detection	114
7.1.3.10	Computational complexity analysis	115
7.1.4	Evaluation	115
7.1.4.1	Evaluation metrics and baselines	115
7.1.4.2	Experimental setup	116
7.1.4.3	Study on Twitter15/16	116
7.1.4.4	Study on Science	118

7.1.4.5	Study on RumourEval19	119
7.1.4.6	Ablation study	119
7.1.4.7	Privacy-preserving study	121
7.1.4.8	Early detection	122
7.1.4.9	Interpretability analysis	124
7.1.5	Summary	125
7.2	UMLARD: Multi-view Learning with Distinguishable Feature Fusion for Rumor Detection	128
7.2.1	Section Overview	128
7.2.2	Problem Statement	130
7.2.3	Methodology	131
7.2.3.1	Learning the User Profile-View	132
7.2.3.2	Learning the User Structural-View	133
7.2.3.3	Learning the User Temporal-View	134
7.2.3.4	View-Wise Attention for View-Level Feature Fusion	136
7.2.3.5	Capsule Attention for User-level Feature Fusion	137
7.2.3.6	Tweet Content Representation	138
7.2.3.7	Training Objective	139
7.2.3.8	Computational Complexity	139
7.2.4	Evaluation	140
7.2.4.1	Experimental Settings	141
7.2.4.2	Overall Performance (Q1)	143
7.2.4.3	Ablation Experiments (Q2)	146
7.2.4.4	Performance on Early Detection (Q3)	151
7.2.4.5	Interpretability Analysis (Q4)	152
7.2.5	Summary	154
8	Conclusions and Future work	155
8.1	Summary of Contributions	155
8.2	Future Work	157
	Bibliography	159
	English Summary	169
	Nederlandse Samenvatting	171
	Acknowledgements	173
	Curriculum Vitae	175