
Introduction to Statistical Relational Learning

edited by
Lise Getoor
Ben Taskar

The MIT Press
Cambridge, Massachusetts
London, England

Contents

Series Foreword	xi
Preface	xlii
1 Introduction	1
<i>Lise Getoor, Ben Taskar</i>	
1.1 Overview	1
1.2 Brief History of Relational Learning	2
1.3 Emerging Trends	3
1.4 Statistical Relational Learning	3
1.5 Chapter Map	5
1.6 Outlook	8
2 Graphical Models in a Nutshell	13
<i>Daphne Koller, Nir Friedman, Lise Getoor, Ben Taskar</i>	
2.1 Introduction	13
2.2 Representation	14
2.3 Inference	22
2.4 Learning	42
2.5 Conclusion	54
3 Inductive Logic Programming in a Nutshell	57
<i>Sašo Džeroski</i>	
3.1 Introduction	57
3.2 Logic Programming	58
3.3 Inductive Logic Programming: Settings and Approaches	64
3.4 Relational Classification Rules	71
3.5 Relational Decision Trees	75
3.6 Relational Association Rules	80
3.7 Relational Distance-Based Methods	84
3.8 Recent Trends in ILP and RDM	89
4 An Introduction to Conditional Random Fields for Relational Learning	93
<i>Charles Sutton, Andrew McCallum</i>	
4.1 Introduction	93
4.2 Graphical Models	94
4.3 Linear-Chain Conditional Random Fields	100
4.4 CRFs in General	108
4.5 Skip-Chain CRFs	116
4.6 Conclusion	122

5 Probabilistic Relational Models	129
<i>Lise Getoor, Nir Friedman, Daphne Koller, Avi Pfeffer, Ben Taskar</i>	
5.1 Introduction	129
5.2 PRM Representation	130
5.3 The Difference between PRMs and Bayesian Networks	140
5.4 PRMs with Structural Uncertainty	141
5.5 Probabilistic Model of Link Structure	141
5.6 PRMs with Class Hierarchies	151
5.7 Inference in PRMs	159
5.8 Learning	161
5.9 Conclusion	173
6 Relational Markov Networks	175
<i>Ben Taskar, Pieter Abbeel, Ming-Fai Wong, Daphne Koller</i>	
6.1 Introduction	175
6.2 Relational Classification and Link Prediction	177
6.3 Graph Structure and Subgraph Templates	178
6.4 Undirected Models for Classification	180
6.5 Learning the Models	184
6.6 Experimental Results	187
6.7 Discussion and Conclusions	197
7 Probabilistic Entity-Relationship Models, PRMs, and Plate Models	201
<i>David Heckerman, Chris Meek, Daphne Koller</i>	
7.1 Introduction	201
7.2 Background: Graphical Models	202
7.3 The Basic Ideas	204
7.4 Probabilistic Entity-Relationship Models	210
7.5 Plate Models	226
7.6 Probabilistic Relational Models	228
7.7 Technical Details	229
7.8 Extensions and Future Work	233
8 Relational Dependency Networks	239
<i>Jennifer Neville, David Jensen</i>	
8.1 Introduction	239
8.2 Dependency Networks	242
8.3 Relational Dependency Networks	243
8.4 Experiments	252
8.5 Related Work	262
8.6 Discussion and Future Work	264
9 Logic-based Formalisms for Statistical Relational Learning	269
<i>James Cussens</i>	
9.1 Introduction	269
9.2 Representation	271
9.3 Inference	278
9.4 Learning	281
9.5 Conclusion	287
10 Bayesian Logic Programming: Theory and Tool	291
<i>Kristian Kersting, Luc De Raedt</i>	

10.1 Introduction	291
10.2 On Bayesian Networks and Logic Programs	293
10.3 Bayesian Logic Programs	296
10.4 Extensions of the Basic Framework	304
10.5 Learning Bayesian Logic Programs	311
10.6 BALIOS – The Engine for Basic Logic Programs	315
10.7 Related Work	315
10.8 Conclusions	318
11 Stochastic Logic Programs: A Tutorial	323
<i>Stephen Muggleton, Niels Pahlavi</i>	
11.1 Introduction	323
11.2 Mixing Deterministic and Probabilistic Choice	324
11.3 Stochastic Grammars	330
11.4 Stochastic Logic Programs	333
11.5 Learning Techniques	335
11.6 Conclusion	337
12 Markov Logic: A Unifying Framework for Statistical Relational Learning	339
<i>Pedro Domingos, Matthew Richardson</i>	
12.1 The Need for a Unifying Framework	339
12.2 Markov Networks	341
12.3 First-Order Logic	342
12.4 Markov Logic	344
12.5 SRL Approaches	350
12.6 SRL Tasks	354
12.7 Inference	356
12.8 Learning	358
12.9 Experiments	360
12.10 Conclusion	367
13 BLOG: Probabilistic Models with Unknown Objects	373
<i>Brian Milch, Bhaskara Marthi, Stuart Russell, David Sontag, Daniel L. Ong, Andrey Kolobov</i>	
13.1 Introduction	373
13.2 Examples	375
13.3 Syntax and Semantics: Possible Worlds	378
13.4 Syntax and Semantics: Probabilities	383
13.5 Evidence and Queries	388
13.6 Inference	388
13.7 Related Work	393
13.8 Conclusions and Future Work	394
14 The Design and Implementation of IBAL: A General-Purpose Probabilistic Language	399
<i>Avi Pfeffer</i>	
14.1 Introduction	399
14.2 The IBAL Language	401
14.3 Examples	407
14.4 Semantics	411
14.5 Desiderata for Inference	415
14.6 Related Approaches	416
14.7 Inference	419

14.8 Lessons Learned and Conclusion	429
15 Lifted First-Order Probabilistic Inference	433
<i>Rodrigo de Salvo Braz, Eyal Amir, Dan Roth</i>	
15.1 Introduction	433
15.2 Language, Semantics and Inference problem	435
15.3 The First-Order Variable Elimination (FOVE) algorithm	437
15.4 An experiment	444
15.5 Auxiliary operations	446
15.6 Applicability of lifted inference	448
15.7 Future Directions	449
15.8 Conclusion	449
16 Feature Generation and Selection in Multi-Relational Statistical Learning	453
<i>Alexandrin Popescul, Lyle H. Ungar</i>	
16.1 Introduction	453
16.2 Detailed Methodology	458
16.3 Experimental Evaluation	463
16.4 Related Work and Discussion	471
16.5 Conclusion	472
17 Learning a New View of a Database: With an Application in Mammography	477
<i>Jesse Davis, Elizabeth Burnside, Inês Dutra, David Page, Raghu Ramakrishnan, Jude Shavlik, Vitor Santos Costa</i>	
17.1 Introduction	477
17.2 View Learning for Mammography	478
17.3 Naive View Learning Framework	482
17.4 Initial Experiments	483
17.5 Integrated View Learning Framework	490
17.6 Further Experiments and Results	491
17.7 Related Work	493
17.8 Conclusions and Future Work	494
18 Reinforcement Learning in Relational Domains: A Policy-Language Approach	499
<i>Alan Fern, SungWook Yoon, Robert Givan</i>	
18.1 Introduction	499
18.2 Problem Setup	502
18.3 Approximate Policy Iteration with a Policy Language Bias	503
18.4 API for Relational Planning	507
18.5 Bootstrapping	516
18.6 Relational Planning Experiments	520
18.7 Related Work	527
18.8 Summary and Future Work	530
19 Statistical Relational Learning for Natural Language Information Extraction	535
<i>Razvan C. Bunescu, Raymond J. Mooney</i>	
19.1 Introduction	535
19.2 Background on Natural Language Processing	536
19.3 Information Extraction	537
19.4 Collective Information Extraction with RMNs	538
19.5 Future Research on SRL for NLP	549
19.6 Conclusions	550

20 Global Inference for Entity and Relation Identification via a Linear Programming Formulation	553
<i>Dan Roth, Wen-tau Yih</i>	
20.1 Introduction	553
20.2 The Relational Inference Problem	556
20.3 Integer Linear Programming Inference	560
20.4 Solving Integer Linear Programming	562
20.5 Experiments	563
20.6 Comparison with Other Inference Methods	570
20.7 Conclusion	576
Contributors	581
Index	587