

Contents

Preface	ix
1 Introduction	1
1.1 Data and Knowledge	2
1.2 Knowledge Discovery and Data Mining	5
1.2.1 The KDD Process	6
1.2.2 Data Mining Tasks	7
1.2.3 Data Mining Methods	8
1.3 Graphical Models	10
1.4 Outline of this Book	12
2 Imprecision and Uncertainty	15
2.1 Modeling Inferences	15
2.2 Imprecision and Relational Algebra	17
2.3 Uncertainty and Probability Theory	19
2.4 Possibility Theory and the Context Model	21
2.4.1 Experiments with Dice	22
2.4.2 The Context Model	27
2.4.3 The Insufficient Reason Principle	30
2.4.4 Overlapping Contexts	31
2.4.5 Mathematical Formalization	35
2.4.6 Normalization and Consistency	37
2.4.7 Possibility Measures	39
2.4.8 Mass Assignment Theory	43
2.4.9 Degrees of Possibility for Decision Making	45
2.4.10 Conditional Degrees of Possibility	47
2.4.11 Imprecision and Uncertainty	48
2.4.12 Open Problems	48
3 Decomposition	53
3.1 Decomposition and Reasoning	54
3.2 Relational Decomposition	55

3.2.1	A Simple Example	55
3.2.2	Reasoning in the Simple Example	57
3.2.3	Decomposability of Relations	61
3.2.4	Tuple-Based Formalization	63
3.2.5	Possibility-Based Formalization	66
3.2.6	Conditional Possibility and Independence	70
3.3	Probabilistic Decomposition	74
3.3.1	A Simple Example	74
3.3.2	Reasoning in the Simple Example	76
3.3.3	Factorization of Probability Distributions	77
3.3.4	Conditional Probability and Independence	78
3.4	Possibilistic Decomposition	82
3.4.1	Transfer from Relational Decomposition	83
3.4.2	A Simple Example	83
3.4.3	Reasoning in the Simple Example	84
3.4.4	Conditional Degrees of Possibility and Independence	85
3.5	Possibility versus Probability	87
4	Graphical Representation	93
4.1	Conditional Independence Graphs	94
4.1.1	Axioms of Conditional Independence	94
4.1.2	Graph Terminology	97
4.1.3	Separation in Graphs	100
4.1.4	Dependence and Independence Maps	102
4.1.5	Markov Properties of Graphs	106
4.1.6	Markov Equivalence of Graphs	111
4.1.7	Graphs and Decompositions	114
4.1.8	Markov Networks and Bayesian Networks	120
4.2	Evidence Propagation in Graphs	121
4.2.1	Propagation in Undirected Trees	122
4.2.2	Join Tree Propagation	128
4.2.3	Other Evidence Propagation Methods	136
5	Computing Projections	139
5.1	Databases of Sample Cases	140
5.2	Relational and Sum Projections	141
5.3	Expectation Maximization	143
5.4	Maximum Projections	148
5.4.1	A Simple Example	149
5.4.2	Computation via the Support	151
5.4.3	Computation via the Closure	152
5.4.4	Experimental Evaluation	155
5.4.5	Limitations	156

6	Naive Classifiers	157
6.1	Naive Bayes Classifiers	157
6.1.1	The Basic Formula	157
6.1.2	Relation to Bayesian Networks	160
6.1.3	A Simple Example	161
6.2	A Naive Possibilistic Classifier	162
6.3	Classifier Simplification	164
6.4	Experimental Evaluation	164
7	Learning Global Structure	167
7.1	Principles of Learning Global Structure	168
7.1.1	Learning Relational Networks	168
7.1.2	Learning Probabilistic Networks	177
7.1.3	Learning Possibilistic Networks	183
7.1.4	Components of a Learning Algorithm	192
7.2	Evaluation Measures	193
7.2.1	General Considerations	193
7.2.2	Notation and Presuppositions	197
7.2.3	Relational Evaluation Measures	199
7.2.4	Probabilistic Evaluation Measures	201
7.2.5	Possibilistic Evaluation Measures	228
7.3	Search Methods	230
7.3.1	Exhaustive Graph Search	230
7.3.2	Greedy Search	232
7.3.3	Guided Random Graph Search	239
7.3.4	Conditional Independence Search	247
7.4	Experimental Evaluation	259
7.4.1	Learning Probabilistic Networks	259
7.4.2	Learning Possibilistic Networks	261
8	Learning Local Structure	265
8.1	Local Network Structure	265
8.2	Learning Local Structure	267
8.3	Experimental Evaluation	271
9	Inductive Causation	273
9.1	Correlation and Causation	273
9.2	Causal and Probabilistic Structure	274
9.3	Faithfulness and Latent Variables	276
9.4	The Inductive Causation Algorithm	278
9.5	Critique of the Underlying Assumptions	279
9.6	Evaluation	284

10 Visualization	287
10.1 Potentials	288
10.2 Association Rules	289
11 Applications	295
11.1 Diagnosis of Electrical Circuits	295
11.1.1 Iterative Proportional Fitting	296
11.1.2 Modeling Electrical Circuits	297
11.1.3 Constructing a Graphical Model	299
11.1.4 A Simple Diagnosis Example	301
11.2 Application in Telecommunications	304
11.3 Application at Volkswagen	307
11.4 Application at DaimlerChrysler	310
A Proofs of Theorems	317
A.1 Proof of Theorem 4.1.2	317
A.2 Proof of Theorem 4.1.18	321
A.3 Proof of Theorem 4.1.20	322
A.4 Proof of Theorem 4.1.26	327
A.5 Proof of Theorem 4.1.28	332
A.6 Proof of Theorem 4.1.30	335
A.7 Proof of Theorem 4.1.31	337
A.8 Proof of Theorem 5.4.8	338
A.9 Proof of Lemma 7.2.2	340
A.10 Proof of Lemma 7.2.4	342
A.11 Proof of Lemma 7.2.6	344
A.12 Proof of Theorem 7.3.1	345
A.13 Proof of Theorem 7.3.2	346
A.14 Proof of Theorem 7.3.3	347
A.15 Proof of Theorem 7.3.5	350
A.16 Proof of Theorem 7.3.7	351
B Software Tools	353
Bibliography	359
Index	383