Contents

Updated and revised content xxvii Acknowledgments Part I Machine learning tools and techniques What's it all about? 1.1 Data mining and machine learning Describing structural patterns Machine learning Data mining Simple examples: The weather problem and others 1.2 9 The weather problem 10 Contact lenses: An idealized problem 13 Irises: A classic numeric dataset CPU performance: Introducing numeric prediction Labor negotiations: A more realistic example Soybean classification: A classic machine learning success 18 Fielded applications Decisions involving judgment 22 Screening images 23 Load forecasting 24 Diagnosis Marketing and sales 26 Other applications

Foreword

Preface

xxiii

1.4	Machine learning and statistics 29
1.5	Generalization as search 30 Enumerating the concept space 31 Bias 32
1.6	Data mining and ethics 35
1.7	Further reading 37
2	Input: Concepts, instances, and attributes 41
2.1	What's a concept? 42
2.2	What's in an example? 45
2.3	What's in an attribute? 49
2.4	Preparing the input 52 Gathering the data together 52 ARFF format 53 Sparse data 55 Attribute types 56 Missing values 58 Inaccurate values 59 Getting to know your data 60
2.5	Further reading 60
3	Output: Knowledge representation 61
3.1	Decision tables 62
3.2	Decision trees 62
3.3	Classification rules 65
3.4	Association rules 69
3.5	Rules with exceptions 70
3.6	Rules involving relations 73
3.7	Trees for numeric prediction 76
3.8	Instance-based representation 76
3.9	Clusters 81
3.10	Further reading 82

4	Algorithms: The basic methods 83
4.1	Inferring rudimentary rules 84 Missing values and numeric attributes 86 Discussion 88
4.2	Statistical modeling 88 Missing values and numeric attributes 92 Bayesian models for document classification 94 Discussion 96
4.3	Divide-and-conquer: Constructing decision trees 97 Calculating information 100 Highly branching attributes 102 Discussion 105
4.4	Covering algorithms: Constructing rules 105 Rules versus trees 107 A simple covering algorithm 107 Rules versus decision lists 111
4.5	Mining association rules 112 Item sets 113 Association rules 113 Generating rules efficiently 117 Discussion 118
4.6	Linear models 119 Numeric prediction: Linear regression 119 Linear classification: Logistic regression 121 Linear classification using the perceptron 124 Linear classification using Winnow 126
4.7	Instance-based learning 128 The distance function 128 Finding nearest neighbors efficiently 129 Discussion 135
4.8	Clustering 136 Iterative distance-based clustering 137 Faster distance calculations 138 Discussion 139
10	Further reading 130

5	Credibility: Evaluating what's been learned 143
5.1	Training and testing 144
5.2	Predicting performance 146
5.3	Cross-validation 149
5.4	Other estimates 151 Leave-one-out 151 The bootstrap 152
5.5	Comparing data mining methods 153
5.6	Predicting probabilities 157 Quadratic loss function 158 Informational loss function 159 Discussion 160
5.7	Counting the cost 161 Cost-sensitive classification 164 Cost-sensitive learning 165 Lift charts 166 ROC curves 168 Recall-precision curves 171 Discussion 172 Cost curves 173
5.8	Evaluating numeric prediction 176
5.9	The minimum description length principle 179
5.10	Applying the MDL principle to clustering 183
5.11	Further reading 184
6	Implementations: Real machine learning schemes 187
6.1	Decision trees 189 Numeric attributes 189 Missing values 191 Pruning 192 Estimating error rates 193 Complexity of decision tree induction 196 From trees to rules 198 C4.5: Choices and options 198 Discussion 199
6.2	Classification rules 200

200

201

Criteria for choosing tests

Missing values, numeric attributes

	Generating good rules 202 Using global optimization 205 Obtaining rules from partial decision trees 2 Rules with exceptions 210 Discussion 213	07
6.3	The maximum margin hyperplane 215 Nonlinear class boundaries 217 Support vector regression 219 The kernel perceptron 222 Multilayer perceptrons 223 Discussion 235	
6.4	Instance-based learning 235 Reducing the number of exemplars 236 Pruning noisy exemplars 236 Weighting attributes 237 Generalizing exemplars 238 Distance functions for generalized exemplars Generalized distance functions 241 Discussion 242	239
6.5	Numeric prediction 243 Model trees 244 Building the tree 245 Pruning the tree 245 Nominal attributes 246 Missing values 246 Pseudocode for model tree induction 247 Rules from model trees 250 Locally weighted linear regression 251 Discussion 253	
6.6	Clustering 254 Choosing the number of clusters 254 Incremental clustering 255 Category utility 260 Probability-based clustering 262 The EM algorithm 265 Extending the mixture model 266 Bayesian clustering 268 Discussion 270	
6.7	Bayesian networks 271 Making predictions 272 Learning Bayesian networks 276	

7.1

7.2

7.3

7.4

CONTENTS
Specific algorithms 278 Data structures for fast learning 280 Discussion 283
Transformations: Engineering the input and output
Attribute selection 288 Scheme-independent selection 290 Searching the attribute space 292 Scheme-specific selection 294 Discretizing numeric attributes 296 Unsupervised discretization 297 Entropy-based discretization 298 Other discretization methods 302 Entropy-based versus error-based discretization 302 Converting discrete to numeric attributes 304
Some useful transformations 305 Principal components analysis 306 Random projections 309 Text to attribute vectors 309 Time series 311 Automatic data cleansing 312 Improving decision trees 312 Robust regression 313 Detecting anomalies 314 Combining multiple models 315
Combining multiple models 315

285

7.5

Bagging Bagging with costs 319 Randomization 320 Boosting 321 Additive regression 325 Additive logistic regression 327 Option trees 328 Logistic model trees 331 Stacking 332 Error-correcting output codes 334

7.6 Using unlabeled data Clustering for classification 337 Co-training 339 EM and co-training 340

7.7 Further reading 341

8	Moving on: Extensions and applications 345
8.1	Learning from massive datasets 346
8.2	Incorporating domain knowledge 349
8.3	Text and Web mining 351
8.4	Adversarial situations 356
8.5	Ubiquitous data mining 358
8.6	Further reading 361
Part II	The Weka machine learning workbench 363
9	Introduction to Weka 365
9.1	What's in Weka? 366
9.2	How do you use it? 367
9.3	What else can you do? 368
9.4	How do you get it? 368
10	The Explorer 369
10.1	Getting started 369 Preparing the data 370 Loading the data into the Explorer 370 Building a decision tree 373 Examining the output 373 Doing it again 377 Working with models 377 When things go wrong 378
10.2	Exploring the Explorer 380 Loading and filtering files 380 Training and testing learning schemes 384 Do it yourself: The User Classifier 388 Using a metalearner 389 Clustering and association rules 391 Attribute selection 392 Visualization 393
10.3	Filtering algorithms 393 Unsupervised attribute filters 395 Unsupervised instance filters 400 Supervised filters 401

10.4	Learning algorithms 403 Bayesian classifiers 403 Trees 406 Rules 408 Functions 409 Lazy classifiers 413 Miscellaneous classifiers 414	
10.5	•	
10.6	Clustering algorithms 418	
10.7	Association-rule learners 419	
10.8	Attribute selection 420 Attribute subset evaluators 422 Single-attribute evaluators 422 Search methods 423	
11	The Knowledge Flow interface 427	
11.1	Getting started 427	
11.2	The Knowledge Flow components 430	
11.3	Configuring and connecting the components	431
11.4	Incremental learning 433	
12	The Experimenter 437	
12.1	Getting started 438 Running an experiment 439 Analyzing the results 440	
12.2	Simple setup 441	
12.3	Advanced setup 442	
12.4	The Analyze panel 443	
12.5	Distributing processing over several machines	445

13	The command-line interface 449
13.1	Getting started 449
13.2	The structure of Weka 450 Classes, instances, and packages 450 The weka.core package 451 The weka.classifiers package 453 Other packages 455 Javadoc indices 456
13.3	Command-line options 456 Generic options 456 Scheme-specific options 458
14	Embedded machine learning 461
14.1	A simple data mining application 461
14.2	Going through the code 462 main() 462 MessageClassifier() 462 updateData() 468 classifyMessage() 468
15	Writing new learning schemes 471
15.1	An example classifier 471 buildClassifier() 472 makeTree() 472 computeInfoGain() 480 classifyInstance() 480 main() 481
15.2	Conventions for implementing classifiers 483
	References 485
	Index 505

About the authors 525