## Index

A Priori algorithm, 143, 147, 157-160
A priori relationships, 197
Absolute error, 216
Accurate measurements, 45
Actual error rate, 359
Acyclic directed graphical models, 290
AD-Tree data structure, 425
Additive form, 189
Additive predictor, 393-394
Advanced Scout system, 14
Agglomerative methods, 308, 311-314
Aggregate, 414
Aggregation, 414
Akaike information criterion (AIC), 225
Algebra, relational, 409
Algorithm parameters, 267
Algorithms. See Data mining algorithms; specific types
Alternative hypothesis, 124
ANNs, 391-393
Apparent error rate, 359
Approximation, 169, 265, 322-323
Artificial neural networks (ANNs), 391-393
ASCII characters and codes, 206-207
Association analysis, 315
Association rules, 14, 158-160, 433435
Assumption, 289

AT\&T, 13, 19
Attributes, 4, 405
Automated recommender systems, 471-472
Autoregressive models, 199-200, 202, 478
Average of points, 297
B-trees, 402-403
Backfitting algorithms, 394
Backpropagation method, 256
Backward elimination, 380
Backward selection algorithms, 243
Bandwidth, 176, 285, 350
Basic algorithms for partition-based clustering, 302-308
Basis functions, 195
Basket data, 405-406
Bayes assumption, first-order, 354
Bayes error rate, 334
Bayes factor, 130
Bayes rule, 337-338
Bayes theorem, 353
Bayesian approximations, 322-323
Bayesian estimation, 93, 96, 106, 116124, 220, 283
Bayesian Information Criterion (BIC), 225-227, 235, 292, 380
Bayesian model, 120, 359, 361-362
Beam search strategy, 246, 440
Beam width search strategy, 246

Belief networks, 290
Bernoulli distributions, 487
Best classification tree problem, 241
Best unbiased estimators, 107
Beta distributions, 119
Beta posterior, 122-123
Beta prior, 122-123
Between-cluster variation, 297-298
Bias of measurements, 45
Bias-variance, 221-224
trade-off, 223
Biased estimation, 106
Biasing, 283-284
BIC, 225-227, 235, 292, 380
Binary data, 36-37
Binomial distributions, 487
Blind search, 245-246
Bonferroni inequality, 131
Boolean conditions and propositions, 213, 411, 429, 458, 461, 475
Boosting methods, 358
Bootstrap methods, 116, 360-361
Box, George, 168
Boxplots, 61-63
Bracketing methods, 254-255
Branch-and-bound concept, 246-247
Breadth-first search, 245
Brent's method, 254
Brushing, 71
Building models, 378-381
Canonical discriminant function, 343
Canonical parameter, 388
CART algorithms, 145-151, 157, 228, 335,345
Cartesian product operations, 409, 412
Cases, 4
Categorical data, 187, 287-292
Categorical variables, 6
Causation, 101-102
Central limit theorem, 115-116
Centroid of points, 297

Chaining, 312-313
Chance, 93-97. See also Uncertainty
Chernoff faces, 74
Chi-squared distributions, 489-490
Chomsky hierarchy of grammars, 202
City-block metric, 36
Class identifiers, 367
Class of patterns, 204
Class variables, 329
Class-conditional approach, 335-339
Classical hypothesis testing, 124-130
Classical multidimensional scaling, 86
Classification
document, 469-470
in high dimensions, feature selection for, 362-363
maximal predictive, 301
multilayer perceptrons for, 153-157
predictive models for, 327-366
classification models and, 329339
evaluating and comparing, 359362
feature selection for highdimension, 362-363
linear discriminants and, 341-343
logistic discriminant analysis, 352-353
naive Bayes model, 353-356
nearest neighbor methods, 347352
other methods, 356-359
overview, 180-182,327-329
perceptrons and, 339-341
tree models, 343-347
text, 469-470
Classification And Regression Trees (CART), 145-151, 153, 228, 335, 345
Classification learning, 169, 328-329
Classification models
background information, 329-330
building real classifiers and, 335339
decision boundaries, 330-331
discriminative, 330-331
probabilistic models and, 331-334
Classifiers
building real, 335-339
evaluating and comparing, 359-362
Closed form methods, 249-250
Cluster analysis, 12, 293-296, 323
Cluster centers, 297
Clustering techniques, 12-13, 279. See also Hierarchical clustering; Partition-based clustering algorithms; Probabilistic modelbased clustering using mixture models
Clusters, 137
Co-occurrence patterns, 158
Coding, image, 166-167
Coefficients, 35, 37, 361
Collaborative filtering, 471-472
Collision, 404
Column vectors, 36
Combinatorial optimization, 236, 239
Commensurability, 32
Complete link method, 313
Complexity of models
nesting and, 172
scoring and, 220-228
bias-variance, 221-224
concepts in comparing, general, 220-221
penalizing, 224-227
validation and, external, 227-228
in selecting predictive models, 183
Compression, data, 166
Computational methods, 141, 235, 291
Computational resources, 268
Concatenation property, 27
Condensed nearest neighbor methods, 352

Conditional density, 98
Conditional error rate, 359
Conditional independence ("naive") Bayes model, 191, 353-356
Conditionally independent variables, 99-100, 289, 354
Confidence
interval, 115
itemsets and, frequent, 430-431
limits, 115
Confusion matrix, 361
Conjugate directions, 258
Conjugate families of distributions, 122-123
Constrained optimization, 259-260
Constraints, 10
Content retrieval. See Retrieval by content
Context-free grammar, 202
Contigency table, 188
Contour plots, 65-67
Convenience samples, 21, 48
"Cookbook" approach, 152-153
Cosine distance, 459
Counts, 31
Covariance matrix, 78, 299
Covariances, 33-35
Coverage of a pattern, 214
Coxcomb plot, 11
Credibility interval, 123
Critical region, 125
Cross-validation, 148-149, 227-228, 322,360
Cumulative distribution function, 485
Curse of dimensionality, 19, 193-196
Customer transactions, 405-406

Data. See also Databases; Graphical data exploration methods; Measurement and data
analysis, 166-167
background information, 25-26
basket, 405-406
binary, 36-37
categorical, 187, 287-292
compression, 166
cube, 419-420
defined, 25
experimental, 1
flattened, 7, 20, 43, 358
form of, 41-44
geographic, 44
high-dimensional, 194-196, 362363
image, 44
market-basket, 158, 429-430
maximum variability in, 77
mode and, 56
model, 405
multirelational, 42-43
observational, 1
orthogonality of, 240
"out-of-sample," 227,328, 372
quality, 44-51
for collection of data, 47-51
for individual measurements, 4447
poor, 51
repeated measures, 349-350
sequential, 477
spatial, 44
standard, 41
structured, models for, 197-203
summarizing, 54-57
summary information, 52
suspect, 50-51
in table, 41
time series, 476-481
transforming, 38-41, 194-196,363
unordered categorical, joint distri-
butions for, 187
warehousing, 417-419
Data management techniques, 17-

18, 143, 296, 421-426. See also Databases
Data matrix, 41, 203-206. See also Data sets
Data mining. See also Data mining algorithms
analysis of, 144
background information, 1-4
data sets and, 4-9
databases and, 421-426
defined, 1
dredging and, 22-23
fishing and, 22-23
interactive, 11, 450
keyword spotting and, 479
knowledge discovery in databases and, 3
models and, 1-2, 10-11, 175, 271
patterns and, 1-2, 10-11, 271
samples and, 93
snooping and, 22-23
statistics and, 18-21
structures, 9-11,142
summary information, 23-24
synthesis of, 144
tasks, 11-15, 142
visual techniques and, 11
Data mining algorithms. See also Score functions for data mining algorithms
background information, 141-145
Classification And Regression
Trees, 145-151, 153, 228, 335, 345
components of, 15-18, 142-145
defined, 141
nonscalable versions of, 424
reductionist viewpoint, 151-162
A Priori algorithm, 157-160
background information, 151153
multilayer perceptrons for regres-
sion and classification and, 153157
vector-space for text retrieval and, 160-162
scalable versions of, 423-424
summary information, 162-164
tuple, 146, 151, 154-155
Data sets. See also Databases
data mining and, 4-9
defined, 4,7
heterogeneous, 279
likelihood of, 108-109
massive, 421-426
nature of, 4-9
pseudo, 425-426
Data-driven hypothesis generation, 53
Data-squashing, 425
Databases. See also Data set
aggregation in, 414
background information, 399-400
data mining and, 421-426
data model in, 405
data warehousing, 417-419
index structures, 402-404
knowledge discovery in, 3
management of data and, 421-426
manipulating tables and, 409-412
massive data sets and, 421-426
memory hierarchy, 400-401
multidimensional indexing, 404405
online analytical processing, 417419
operational, 417
purpose of, 400
query execution and optimization, 415-417
relational, 405-409
strategic, 417
string, 420-421

Structured Query Language, 409, 413-415
Deciles, 56
Decision boundaries, 330-331
Decision region, 330
Decision surfaces, 330-331
Decision trees, 422
Degrees of freedom, 376-377, 489-490
Dendrograms, 313
Density estimation, 12, 184
Density function, 97-98, 355, 485. See also Probability distribution and density function models
Density mixtures, 279-281
Density models, parametric, 275-279. See also Probability distribution and density function models
Denumerable domain, 485
Dependency modeling, 12
Dependent variables, 35
Depth-first search, 245
Derived variables, 198
Descriptive models
background information, 271-272
cluster analysis, 293-296
functions of, 12-13
goal of, 12
hierarchical clustering, 308-315
agglomerative methods, 308, 311-314
background information, 308-311
divisive methods, 308, 314-315
nonprobabilistic, 219
partition-based clustering algorithms, 296-308
background information, 296297
basic algorithms for, 302-308
for nonprobabilistic predictive models, 219
score functions for, 296-302
probabilistic model-based clustering, 315-323
advantages, 319
background information, 315316
disadvantages, 319-321
examples, 316-319
techniques, 321-323
probability distribution and density function models and, 272-292
background information, 272274
Expectation Maximization algorithm for, 281-284
joint distributions for categorical data, 287-292
mixture distributions and densities, 279-281
nonparametric density estima-
tion, 284-287
parametric density models, 275279
score functions for, 274-275
score functions for, 212, 217-219
Deviance of model, 389-390
Diagnostic methods, 10, 338, 381-384
Dice coefficient, 37
Difference operation, 410
Discovery task, pattern, 205
Discriminant functions, 331
Discriminative approach, 335-339
Discriminative classification, 330-331
Disk access, special-purpose algorithms for, 424
Dispersion measurement, 56
Dispersion parameter, 388
Dissection, 293
Distance
cosine, 459
distance, 32-33, 85
edit-distance, 312
Euclidean, 32-33, 85, 459, 480

Mahalanobis, 276-277
measurements, 31-38
minimum, 298
pairwise, 312
between queries and documents, 462
similarity and, 15,451
weighted Euclidean, 33
Distortion of samples, 49-50
Distribution-free tests, 129
Distributions. See also Probability distribution and density function models
Bernoulli, 487
Beta, 119
binomial, 487
chi-squared distribution, 489-490
conjugate families of, 122-123
exponential family of, 388
F, 490
finite mixture, 280
independently and identically distributed, 108
joint
for categorical data, 287-292
for unordered categorical data, 187
left-skewed, 57
mixture, 279-281
multimodal, 56, 60
multinominal, 487-488
multivariate normal, 490
Normal, 60, 113, 115-116, 118, 121-
122, 127, 171, 276, 350, 488
Poisson, 280-281, 388, 488
posterior, 117,122-123
predictive, 120-121
prior, 117, 122-123
probability, 485, 487-490
relative, 459
right-skewed, 57
skewness of, 56-57
student's $t$-, 489
Divisive methods, 308, 314-315
Document, 456, 461-465, 469-470
Dredging, 22-23
Duplicates, 411
EDA, 11-12
Edit-distance, 312
Edited nearest neighbor methods, 352
EFFORT (software program), 29-30
EM algorithms. See Expectation Maximization algorithms
Entities, 4
Episodes, 207-208,436-438
Epsem sample, 134
Errors
absolute, 216
actual error rate, 359
apparent error rate, 359
Bayes error rate, 334
conditional error rate, 359
defined, 373
estimation, 216
family error rate, 131
mean squared, 107, 223-224
misclassification of objects and, 359-361
quadratic error function, 340
resubstitution error rate, 359
risk of, 45
squared, 216
true error rate, 359
Estimation
Bayesian, 93, 96, 106, 116-124, 220, 283
biased, 106
cross-validation, 148-149
defined, 93
density, 12, 184
errors, 216
maximum likelihood, $96,106,108-$ 116
nonparametric density, 284-287
over, 216
parameter, 240
probability distribution and density, 274-275
quasilikelihood, 390
query selectivity, 273
regression and, 13
stochastic, 123, 265
unbiased, 106, 227
uncertainty and, 105-124
background information, 105106
Bayesian, 93, 116-124
maximum likelihood and, 93, 108-116
properties of estimators and, desirable, 106-108
stochastic, 123, 265
under, 216
Estimators, 106-109
Euclidean distance, 32-33, 85, 459, 480
Euclidean metric, 36
Euclidean space, 298
Evaluation
of classifiers, 359-362
of models and patterns, 229-231
of retrieval systems, 452-456
Event-sequence, 43
"Exclusive-or" structure, 71
Expectation Maximization (EM) algorithms
function of, 21
for mixture models, 187, 281-284
optimization and, 260-265
red blood cell example, 317-318
Expected value, 486
Experimental data, 1
Experimental design, 132
Explainable variation, 179
Explanatory variable, 168

Exploratory data analysis (EDA), 1112
Exploring data. See Graphical data exploration methods
Exponential family of distributions, 388
Expressive power of model structure, 183

F distributions, 490
Factor analysis, 83
Factor loadings, 83
Factored form, 292
Factorization, 187-193, 290
Factors, 195
Family error rate, 131
Family of model structures, 238
Fate, 93-97. See also Uncertainty
Feasible region, 259
Feature extraction approach, 197-198
Feature selection for classification in high dimensions, 362-363
Features, 4
Feed-forward neural networks, 357, 391
Fields, 4, 202
File, inverted, 461
Filtering, collaborative, 471-472
Finite mixture distributions, 280
Finite state machine (FSM), 202
First normal form, 408
First-order autoregressive model, 199-201
First-order Bayes assumption, 354
First-order Markov property, 101
Fisher information, 122
Fisher, R.A., 341
Fisher's linear discriminant analysis method, 331, 353, 356, 362
Fishing, 22-23
Fitted model, 10-11
Flattened data, 7, 20, 43, 358

Forecasting, 133
Form of data, 41-44
Forward selection algorithms, 243, 379
Freedom, degrees of, 376-377, 489490
Frequency of episode, 436-437
Frequent itemsets, 429-433
Frequent sets, 204, 431, 433-435
Frequentist view of probability, 95
From clause, 413
FSM, 202
Function approximation problems, 169
Functional dependency, 206
Furthest neighbor methods, 313

Gaussian noise, 199
Generalizations, 295, 377-378, 435436, 476
Generalized additive models, 393-395
Generalized linear models, 173, 353, 384-390
Generative models, 272
Generic score functions, 16, 219
Genetic search, 266-267
Geographic data, 44
GIGO, 44-45
Gini coefficient of performance, 361
Global models, 442-443, 478-480
Global pattern, 9
Goodness-of-fit tests, 126, 142, 372, 377
Google system, 15
Grades, 31
Gradient descent method, 253
Gradient-based methods, 250-251
Grammars, 202
Graphical data exploration methods
background information, 53-55
hypothesis testing and, 53
multidimensional scaling, 84-90
principal components analysis, 7484
summarizing data, 54-57
visual techniques
for more than two variables, 7074
for relationships between two variables, 62-70
for single variables, 57-62
Graphical models, 189-190
Greedy heuristic search methods, 241
Hash indices, 403-404
Hazard, 93-97. See also Uncertainty
Heterogeneous data set, 279
Heteroscedasticity, 381
Heuristic search methods, 241, 244246, 439-440
Hidden Markov models (HMMs), 201-202, 291
Hidden variables, 187, 190-191,195
Hierarchical clustering
agglomerative methods, 308, 311314
background information, 308-311
divisive methods, 308, 314-315
Hierarchical structure, 44
High-dimensional data, 194-196,362363
"Hill-climbing" algorithm, 244
Histograms, 57-59, 61, 284
HMMs, 201-202, 291
Homoscedasticity, 381
Horseshoe effect, 88
Hypertetrahedron, 258
Hypothesis testing
graphical data exploration methods and, 53
random variables and, 99
uncertainty and, 124-132
background information, 124
classical, 124-130
in context, 130-132

IBM, 474
Icon plot, 74
Icons, 74
Idealization, 95
IDF, 463
iid, 108
Image
coding, 166-167
form of data and, 44
invariants, 475-476
local part of, 166
queries, 473-474
representation, 473
retrieval, 472-476
understanding, 473
whole, 166
Improper priors, 122
Independence in high dimensions, 187-193
Independent variables, 99, 188-189
Independently and identically distribution (iid), 108
Indicator matrix, 429-430
Individual contribution, 170
Individual preferences, modeling, 470-472
Individual X variables, 194-195
Individuals, 4
Inference, 377-378
Information retrieval (IR). See Text retrieval
Input variable, 329
Inspection, model, 381-384
Interactive techniques, 11, 456
Interestingness, criteria for, 440-441
Interquartile range, 56
Intersection operation, 410
Interval scale, 28-29
Inverse-document-frequency (IDF), 463

Inverted file, 461
IR. See Text retrieval
ISODATA algorithm, 307
Itemsets, frequent, 429-433
Iteratively weighted least square method, 258, 389

Jaccard coefficient, 37
Jackknife methods, 360-361
Jeffrey's prior, 122
Join operations, 412
Joint density function, 97-98
Joint distributions
for categorical data, 287-292
for unordered categorical data, 187
$K$-means algorithms, 298, 305
$k$-nearest neighbor method, 348-349
Kalman filters, 201-202
KDD, 3
Kernel density method, 284
Kernel estimates, 59-62, 176
Kernel function, 285
Kernel methods, 176-178
Kernel models, 287
Kernel plots, 61
Keyword spotting, 479
Knowledge discovery in databases (KDD), 3
Kolmogorov-Smirnov test statistic, 129-130
$k$ th mixing proportion, 281
$k$ th-order Markov model, 200
Kuhn-Tucker conditions, 260
Lagrange multipliers, 259-260
Laplace approximation, 323
Latent semantic indexing (LSI), 465469
Latent variables, 187,190-191,195
Least squares fitting computational issues in, 370-372
defined, 370
diagnostic methods and, 381-384
generalization and, 377-378
inference and, 377-378
interpreting, 375-377
model building and, 378-381
model inspection and, 381-384
Least squares method, $114,211,370$
Leaving-one-out method, 360
Lee, M., 425
Left-skewed distributions, 57
Length variables, 32
Letters, 206. See also Strings
Likelihood function, 105, 108-109, 274-275
Likelihood ratio, 125-126
Linear algebra methods, 249-250
Linear correlation, 35
Linear covariance, 35
Linear dependencies, 35
Linear discriminants, 341-343
Linear function, 9
Linear models
background information, 368-370
diagnostic methods and, 381-384
generalization and, 377-378
generalized, 384-390
global, 478
inference and, 377-378
inspection, 381-384
model building and, 378-381
probabilistic interpretation of, 372375
Linear predictor, 388
Linear programming, 259
Linear regression models. See Linear models
Linear structure, regression models with, 169-173
Local exploration, 243
Local extremum, finding, 251
Local improvement, 241
Local part of image, 166

Local piecewise model structures for regression, 174-175
Locally linear, 174
Locally weighted regression model, 175-176
Location measurements, 55
Location parameters, 184
Loess regression model, 175-176
Log-likelihood, 122, 274-275
Log-linear models, 292
Logistic discriminant analysis, 352353
Logistic link function, 385
Logistic regression, 384-385
Logit link function, 385
Logit transformation, 40
"Lower resolution" data samples, 11
LSI, 465-469
Luck, 93-97. See also Uncertainty

Mahalanobis distance, 276-277
Manhattan metric, 36
Manipulation of variables, 168
MAP method, 117, 226, 283, 291
Marginal density, 98
Marginal likelihoods, 130, 226
Market-basket data, 158, 429-430
Markov chain model, 189-190, 202, 290
Markov Chain Monte Carlo (MCMC) methods, 123, 268
Markov linear-switching model, 479480
Markov random fields, 202
Massive data sets, 421-426
Mathematical programming, 259
Maximal predictive classification, 301
Maximum likelihood estimation, 93, 106, 108-116
Maximum likelihood estimator (MLE), 109, 113

Maximum a posteriori (MAP) method, 117, 226, 283, 291
Maximum variability in data, 77
MCMC methods, 123, 268
MDL method, 226
Mean squared error (MSE), 107, 223224
Measurements. See also Data
accurate, 45-46
amounts and, 31
background information, 25-26
balances and, 31
bias of, 45
counted fractions and, 31
counts versus, 31
dispersion, 56
distance, 31-38
grades and, 31
individual data quality for, 44-47
location, 55
metrical versus categorical, 31
pairs of, 327
precise, 45
qualitative versus quantitative, 31
ranks and, 31
reliability of, 46
representational, 29-31
summary information, 52
types of, 26-31
validity of, 46-47
variability, 56
Median, 55
Memory hierarchy, 400-401
Minimum description length (MDL) method, 226
Minimum distance, 298
Minkowski metric, 36
Missing data, optimization with, 260265
Mixture distributions and densities, 279-281
Mixture models
autoregressive models, 202
parametric, 185-187
probabilistic model-based clustering using, 315-323
advantages, 319
background information, 315316
disadvantages, 319-321
examples, 316-319
techniques, 321-323
and radial basis function approaches, 357
MLE, 109, 113
MLPs, 153-157,357, 391
Mode, 56
Model averaging methods, 346
Models. See also Complexity of mod-
els; Patterns; specific types
background information, 165-167
building, 378-381
classes of structure, 235, 238
curse of dimensionality and, 193196
data, 405
data mining and, 1-2, 10-11, 175, 271
defined, 165
deviance of, 389-390
evaluation of, 229-231
expressive power of, 183
fundamentals, 167-168
generalized linear, 173, 353, 384-390
generative, 272
global, 442-443, 478-480
goal of, 102
for individual preferences, 470-472
inspection of, 381-384
$k$ th order Markov, 200
Markov chain, 189-190, 202, 290
parameters of, 167, 276
for prediction, 168-183
background information, 168169
local piecewise model structures for regression, 174-175
nonparametric "memory-based" local models, 175-178
regression models with linear structure, 169-173
selecting, of appropriate complexity, 183
stochastic components of, 178180
for probability distributions and density, 184-193
background information, 184
concepts, general, 184-185
factorization and independence in high dimensions, 187-193
joint distributions for unordered categorical data, 187
mixtures of, 185-187
search methods for, 238-241, 378381
background information, 238241
branch-and-bound, 246-247
heuristic search, 244-246
simple greedy search algorithm, 243-244
state-space formulation, 241-243
systematic search, 244-246
for structured data, 197-203
Momentum-based methods, 254
Monothetic divisive methods, 315
Monotonic regression, 87
Monte Carlo Markov Chain (MCMC) methods, 123, 268
Monte Carlo sampling techniques, 123, 226
Morse codes, 85
MSE, 107, 223-224
Multicollinearity, 371

Multidimensional indexing, 404-405
Multidimensional scaling, 84-90
Multidimensional scaling plot, 88
Multilayer perceptrons (MLPs), 153157, 357, 391
Multimodal distributions, 56, 60
Multinomial distributions, 487-488
Multiple regression, 368-369
Multirelational data, 42-43
Multivariate function, 113-114
Multivariate gradient descent method, 256
Multivariate normal distributions, 490
Multivariate parameter optimization, 255-259
Multivariate random variables, 97102

Naive Bayes model, 191, 353-356
NASA Earth Observing System, 19
Natural language processing (NLP), 457
Natural parameter, 388
Nearest neighbor methods
agglomerative methods and, 312313
condensed, 352
edited, 352
nonparametric "memory-based" local models and, 176, 178
pairwise distances of the members of each cluster and, 312-313
parametric models and, 351
predictive models for classification and, 347-352
reduced, 352
Nelder and Mead variant, 259
Nesting, 172
Neural networks, 173
Newton-Raphson (NR) method, 252253, 255, 389
Newton's method, 256-257

NIST, 456
NLP, 457
Nominal scales, 28, 31
Non-metric multidimensional scaling, 87
Nonlinear function, 10, 154
Nonlinear global models, 478-479
Nonparametric density estimation, 284-287
Nonparametric "memory-based" local models, 175-178
Nonparametric models, 185
Nonparametric test, 130
Nonprobabilistic descriptive models, 219
Nonrepresentational procedures, 30
Nonscalable versions of data mining algorithms, 424
Nonsystematic variation, 179-180
Normal density, 197, 355
Normal distribution, 60, 113, 115-116, 118, 121-122, 127, 171, 276, 350, 488
Normal posterior, 122-123
Normal prior, 122-123
NR method, 252-253, 255, 389
Null hypothesis, 124-126
Numerical scales, 31

Objects, 4
Observational data, 1
Odds ratio, 352-353
OLAP, 417-419
OLTP, 417-419
One-tailed test, 125
Online algorithms, 265-266
Online analytical processing (OLAP), 417-419
Online approximation, 265
Online transaction processing (OLTP), 417-419
Operational databases, 417

Operational procedures, 30
Opportunity samples, 21,48
Optimization
background information, 235-238
combinatorial, 236, 239
as component of data mining algorithms, 16-17, 142-143
constrained, 259-260
Expectation Maximization algorithm and, 260-265
maximum likelihood estimation and, 114
with missing data, 260-265
online algorithm and, 265-266
parameter optimization methods, 247-260
background information, 247249
closed form, 249-250
constrained, 259-260
gradient-based, 250-251
linear algebra, 249-250
multivariate, 255-259
univariate, 251-255
query, 415-417
single-scan algorithms and, 265266
stochastic, 266-268
Ordinal scales, 28, 31
Organization of data. See Databases
Orthogonality of data, 240
"Out-of-sample" data, 227, 328, 372
Overestimation, 216
Overfitting, 19, 183, 223
$p$-dimensional space, $10,12,165,180$, 277, 479
$p$-dimensional vector, $9,36,174,329-$ 330, 399
PageRank, 15
Pairs of measurements, 327
Pairwise distance, 312

Parallel coordinates plots, 74, 76
Parameter optimization methods background information, 247-249
closed form, 249-250
constrained, 259-260
gradient-based, 250-251
linear algebra, 249-250
multivariate, 255-259
univariate, 251-255
Parameters
algorithm, 267
canonical, 388
defined, 47
dispersion, 388
estimation, 240
linear function of, 9
location, 184
of models, 167, 276
natural, 388
regression model, 173
scale, 184, 388
Parametric models
density, 275-279
mixtures of, 185-187
nearest neighbor methods and, 351
overview, 184
Parents of variables, 189
Partition-based clustering algorithms
background information, 296-297
basic algorithms for, 302-308
for nonprobabilistic descriptive models, 219
score functions for, 296-302
Pattern search, 259
Patterns. See also Models
background information, 165-167
class of, 204
co-occurrence, 158
coverage of, 214
in data matrices, 203-206
data mining and, 1-2, 10-11, 271
defined, 165
detection of, 102
discovering, 13-14, 438-441
discovery task, 205
evaluation of, 229-231
finding, 427-448
association rules, 433-435
background information, 427428
episodes from sequences, 436438
from local patterns to global models, 442-443
generalizations, 435-436
itemsets, frequent, 429-433
predictive rule induction and,
443-447
rule representations, 428-429
selective discovery, 438-441
global, 9
local, to global models, 442-443
primitive, 204
Q, 450, 454
scoring, 212-215
search methods for, 238-241, 378381
background information, 238241
branch-and-bound, 246-247
heuristic search, 241, 244-246
simple greedy search algorithm, 243-244
state-space formulation, 241-243
systematic search, 244-246
for strings, 206-208
structure of, 158
structures, 203-208
in data matrices, 203-206
for strings, 206-208
text retrieval, 14
PCA. See Principal components analysis
Penalized likelihood, 321-322

Percentiles, 56
Perceptrons, 153-157, 339-341, 357, 391
Permutation tests, 129
Piecewise model structures for regression, 174-175, 182
Point estimates, 115,119
Poisson distributions, 280-281, 388, 488
Poisson regression, 388
Polysemy, 457
Polythetic divisive methods, 315
Population drift, 49
Position, sequential, 477
Posterior distributions, 117
Precise functional form, 176
Precise measurement, 45
Precision, 121, 453-456
Predicted intervals, 374-375
Predictive distributions, 120-121
Predictive models
background information, 168-169
for classification, 327-366
classification models and, 329339
evaluating and comparing, 359362
feature selection for highdimension, 362-363
linear discriminants and, 341-343
logistic discriminant analysis, 352-353
naive Bayes model, 353-356
nearest neighbor methods, 347352
other methods, 356-359
overview, 180-182,327-329
perceptrons and, 339-341
tree models, 343-347
examples of, 14
goal of, 13
local piecewise model structures for regression, 174-175
nonparametric "memory-based" local models, 175-178
for regression, 367-398
artificial neural networks, 391393
background information, 367368
generalized linear models, 384390
least squares fitting, 368-384
linear models, 368-384
other highly parameterized models, 393-397
regression models with linear structure, 169-173
score functions for, 212, 215-217
selecting, of appropriate complexity, 183
stochastic components of, 178-180
Predictive performance, 196
Predictive rule induction, 443-447
Predictor variables, 168,367
PREFERENCE property, 27
Preferences, modeling individual, 470-472
PRIM algorithms, 445-446
Primitive patterns, 204
Principal components, 195
Principal components analysis (PCA)
graphical data exploration methods and, 74-84
high-dimensional data and, 196
Principal coordinates method, 86
Prior distributions, 117
Priors, 122-123
Probabilistic model-based clustering using mixture models
advantages, 319
background information, 315-316
disadvantages, 319-321
examples, 316-319
techniques, 321-323
Probabilistic models for classification, 331-334
Probabilistic rule, 213-214,428
Probability, 93-97
Probability calculus,94-96
Probability distribution and density function models
background information, 184
concepts, general, 184-185
descriptive models and background information, 272274
Expectation Maximization algorithm for, 281-284
joint distributions for categorical data, 287-292
mixture distributions and densities, 279-281
nonparametric density estimation, 284-287
parametric density models, 275279
score functions for, 274-275
estimation, 274-275
factorization and independence in high dimensions, 187-193
joint distributions for unordered categorical data, 187
mixtures of, 185-187
Probability distributions, 485, 487-490
Probability mass function, 485
Probability theory, 94-95
Projection operation, 411
Projection pursuit methods, 77, 195196, 357, 395-397
Proximity, 32
Pruning, 153, 159
Pseudo data sets, 425-426
QBIC, 15, 474

Quadratic discriminant function, 343
Quadratic error function, 340
Quadratic function, 249
Quadratic programming, 259
Quality of data
for collection of data, 47-51
for individual measurements, 44-47
poor, 51
QUALITY OF LIFE property, 29
Quantitative variables, 6
Quartiles, 56
Quasi-likelihood methods, 180
Quasi-Newton methods, 257-258
Quasilikelihood estimation, 390
Query
aggregation in, 414
execution, 415-417
image, 473-474
matching, 461-465
optimization, 415-417
pattern Q, 450, 454
rectangular range, 404
selectivity estimation, 273
Structured Query Language, 409, 413-415
text, 456-457
Query by Image Content (QBIC), 15, 474

Radial basis function networks, 393
RAM, 17
Random samples, 20, 54, 123
Random variables, 97-102, 485-490
Random variation, 179-180
Random-access memory (RAM), 17
Randomization tests, 129
Randomness, 93-97. See also Uncertainty
Range, 56, 404
Ranks, 31
Ratio scales, 28
Recall, 453-456

Receiver Operating Characteristic (ROC) curve, 361, 454
Reciprocals of variances, 121
Records, 4
Rectangular range query, 404
Reduced nearest neighbor methods, 352
Reductionist viewpoint on data mining algorithms
A Priori algorithm, 157-160
background information, 151-153
multilayer perceptrons for regression and classification and, 153157
vector-space for text retrieval and, 160-162
Redundant variables, 194
Reference prior, 122
Regression
approach, 335-339
defined, 169, 328-329
estimation and, 13
line, 368
linear, probabilistic interpretation of, 372-375
local piecewise model structures for, 174-175
locally weighted model, 175-176
loess model, 175-176
logistic, 384-385
methods, 348
models with linear structure, 169173
monotonic, 87
multilayer perceptrons for, 153-157
multiple, 368-369
plane, 368-369
Poisson, 388
predictive models for, 367-398
artificial neural networks, 391393
background information, 367368
generalized linear models, 384390
least squares fitting, 368-384
linear models, 368-384
other highly parameterized models, 393-397
projection pursuit, 195-197, 395397
rule-based, 446
simple, 368
sum of squares, 376
Regular expression E, 207
Regular grammars, 202
Regularities, 134
Regularized discriminant analysis, 343
Reject option, 350
Rejection region, 125
Relation schema, 405
Relational algebra, 409
Relational data model, 405
Relational databases, 405-409
Relations, 405
Relative distributions, 459
Relevance feedback, 462, 470-471
Reliability of measurements, 46
Repeated measures data, 349-350
Representational measurements, 2931
Resampling techniques, 322
Residual sum of squares, 376
Residuals, 369
Response variable, 168, 367
Resubstitution error rate, 359
Retesting, effective, 46
Retrieval by content
applications of, 15
background information, 449-452
evaluation of systems, 452-456
goal of, 14
image retrieval, 472-476
sequence retrieval, 476-481
summary information, 481-482
for text, 456-470
background information, 456457
classification of document and text, 469-470
latent semantic indexing, 465-469
matching queries and docu-
ments, 461-465
patterns, 14
representation of text, 457-461
time series, 476-481
Right-skewed distributions, 57
Risk of error, 45
Robust methods, 231-232
ROC curve, 361, 454
Rocchio's algorithm, 470
Root node, 244-245
Rotations, random, 71
Rothamsted Experimental Station, 1112
Rows, 36
Rules
discovering, 13-14, 438-441
finding
association rules, 433-435
background information, 427428
episodes from sequences and, 436-438
from local patterns to global models, 442-443
generalizations, 435-436
itemsets, frequent, 429-433
predictive rule induction and, 443-447
rule representations, 428-429
selective discovery of, 438-441
probabilistic, 213-214,428
regression based on, 446
representations of, 428-429
set of, 443
structure of, 158

Sample correlation coefficient, 35
Sample covariance, 35
Sample mean, 33, 55
Sample-based estimate of sample mean, 55
Samples, 7. See also Data set
convenience, 21,48
data mining and, 93
distortion of, 49-50
epsem, 134
"lower resolution" data, 11
opportunity, 21, 48
random, 20, 54, 123
systematic, 133-134
uncertainty and, 102-105
Sampling fraction, 133
Sampling methods, 132-138, 338
Sampling paradigm, 128
Scalable versions of data mining algorithms, 423-424
Scale parameter, 184, 388
Scales, 28-29, 31
Scatterplot matrix, 71-72
Scatterplots, 64-65
Schemas, 41-44, 405, 410
Score functions for data mining algorithms
background information, 211-212
decomposable, 240
defined, 211, 235
descriptive, 212, 217-219
with different complexities, 220228
bias-variance, 221-224
concept in comparing, general, 220-221
penalizing, 224-227
validation and, external, 227-228
evaluating, 229-231
function of, 142
generic, 16, 219
for partition-based clustering algorithms, 296-302
patterns, scoring, 212-215
predictive, 212, 215-217
for probability distribution and density function models, estimating, 274-275
robust methods, 231-232
scoring method versus, 389
Scoring method
complexity of a model and, 220-228 bias-variance, 221-224
concepts in comparing, general, 220-221
penalizing, 224-227
validation and, external, 227-228
score functions versus, 389
Scree plots, 79-80
Search methods
background information, 235-238
blind, 245-246
branch-and-bound, 246-247
breadth-first, 245
as component of data mining algorithms, 16-17, 142-143
depth-first, 245
genetic, 266-267
greedy heuristic, 241
heuristic, 241, 244-246, 439-440
for models and patterns, 238-241, 378-381
simple greedy search algorithm, 243-244
state-space formulation, 241-243
stochastic, 266-268
systematic, 244-246
Search operators, 241-242
Search tree, 244-245, 402
Segmentation, 12, 293

Select clause, 413
Selection operation, 411
Selectivity, 273
Sequence retrieval, 476-481
Sequences, episodes from, 436-438
Sequential data, 477
Sequential position, 477
Set operations, 410
Set of rules, 443
SEVERITY property, 27
Severity scale, 28
Significance level, 105, 125
Similarity, 15, 449, 451, 480
Simple greedy search algorithm, 243244
Simple regression models, 368
Simplex algorithm, 258
Simplex search method, 258
Simpson's paradox, 100-101
Simulated annealing, 267-268
Simultaneous test procedures, 131
Single link method, 312-313
Single-link criterion, 298
Single-scan algorithm, 265
Singular-value decomposition (SVD), 415, 466
Skewness, 56-57
SKICAT system, 13
Sloan Digital Sky Survey, 19
Snooping, 22-23
Spatial data, 44
Special-purpose algorithms for disk access, 424
Spline function, 174
Splines, 174-175
Splitting a node, 344-345
SQL, 409, 413-415
Squared error, 216
SRM approach, 226
SSE, 155-156, 235
Standard data, 41
Standard deviation, 56, 60

Standardization, 38
Star icons, 74
Star plot, 75
State space representation, 241
State variables, 200-201
State-space formulation for search methods, 241-243
Stationarity, 198-199
Statistical inference, 102-105
Statistics, 18-21, 47, 425-426
Stepwise model, 130
Stochastic approximation, 265
Stochastic components of model structures, 178-180
Stochastic estimation, 123, 265
Stochastic search methods, 266-268
Strategic databases, 417
Stratified random sampling, 135
Strings, 43, 206-208, 420-421
Structural risk minimization (SRM) approach, 226
Structured data models, 197-203
Structured Query Language (SQL), 409, 413-415
Structures, data mining, 9-11, 142
Student' st-distributions, 489
Subsamples, 360
Subsets problem, 241
"Sufficient statistic" concept, 112-113
Sufficient statistics, 19-20, 425-426
Suffix tree data structure, 421
Sum of squared errors (SSE), 155-156, 235
Sum of squared residuals, 376
Summarizing data, 54-57
Supervised classification, 169, 328329
Support, 430
Support vector machines, 357
Surrogate document, 461
Suspect data, 50-51
SVD, 415, 466

## Synonmy, 457

Systematic sampling, 133-134
Systematic search methods, 244-246
Systematic variation, 179
T-dimensional "term space," 461
Tables, 41, 188, 408-412
Tasks, data mining, 11-15, 142
Taylor series, 227, 257, 369
Temperature schedule, 267
Ten-fold cross-validation, 322
Term, 456
Term frequency (TF), 463
Test set, 360
Text retrieval
background information, 456-457
classification of document and text, 469-470
latent semantic indexing, 465-469
matching queries and documents, 461-465
patterns, 14
representation of text, 457-461
Text retrieval Conferences (TREC), 456
TF, 463
Time series data, 476-481
Total sum of squares, 376
Training data, 7. See also Data set
Training data points, 346
Transactions, 405-406
Transforming data, 38-41, 195-196, 363
TREC, 456
Tree models, 174, 343-347
Tree-structured rule sets, 443
Trellis plotting, 71, 73-74
Trimmed mean, 231-232
True error rate, 359
True value concept, 45
Tuple, algorithm, 146, 151, 154-155
Unbiased estimation, 106, 227

Uncertainty
background information, 93
dealing with, 94-97
estimation and, 105-124
background information, 105106
Bayesian, 93, 116-124
maximum likelihood and, 93, 108-116
properties of estimators and, desirable, 106-108
stochastic, 123, 265
hypothesis testing and, 124-132
background information, 124
classical, 124-130
in context, 130-132
multivariate random variables and, 97-102
probability and, 93-97
random variables and, 97-102
samples and, 102-105
sampling method and, 132-138
statistical inference and, 102-105
summary information, 138
Underestimation, 216
Unexplainable variation, 179-180
Union operation, 410
Univariate parameter optimization, 251-255
Univariate random variables, 485-487
Universal table, 408
Unordered categorical data, joint distributions for, 187
U.S. National Institute of Standards and Technology (NIST), 456

Validation, 227-228
Validation log-likelihood, 275
Validation subset, 148-149
Validity of measurements, 46-47
Variability measurements, 56
Variables
categorical, 6
class, 329
conditionally independent, 99-100, 289, 354
defined, 4
dependent, 35
derived, 198
explanatory, 168
frequent sets of, 204
hidden, 187, 190-191, 195
independent, 99, 188-189
individual X, 194-195
input, 329
latent, 187, 190-191, 195
length, 32
linear dependencies between, 35
manipulating, 168
multivariate, 97-102
parents of, 189
predictor, 168,367
quantitative, 6
random, 97-102, 485-490
redundant, 194
response, 168, 367
selecting, 362-363
selection for high-dimensional data, 194-195
state, 200-201
transforming, 363
univariate random, 485-487
visual techniques for displaying more than two, 70-74
relationships between two, 62-70
single, 57-62
weight, 32
Variance function, 388
Variances, 56, 78, 121, 221-224
Variations, 297-298
Vector space representation, 458
Vector-space algorithms, 160-162
Visual techniques
data mining and, 11
for more than two variables, 70-74
for relationships between two variables, 62-70
for single variables, 57-62
Warehousing, data, 417-419
WEIGHT property, 26-28
Weight variables, 32
Weighted Euclidean distance, 33
Weighted least squares solution, 382
Where clause, 413
Whole image, 166
Wilcoxon test statistic, 129-130
Within-cluster sum-of-squares, 298
Within-cluster variation, 297-298
Zero skewness, 57

