

Index

P statistic, 903
 T -squared sampling tests, 902
 Γ statistic, 870, 876
 γ statistic, 874
 ν -SVM, 135
 k -medoids algorithms, 744–746
 l_p metric dissimilarity measures, 604–605
 t -distribution, 272, 925
 t -test, 273, 576
 k Nearest neighbor density estimation, 56–57

A

Absolute moments, 414
 Acceptance interval, 271
 Activation function, 101
 Active learning, 511
 AdaBoost, 231
 Adaline, 108
 Adaptive fuzzy C-shells (AFCS) algorithm, 724
 Adaptive momentum, 182
 Adaptive resonance theory (ART2), 635
 Agglomerative algorithms, 629
 definitions, 655–658
 generalized, 654–655
 graph theory and, 667–676
 implementation issues, 667
 matrix theory and, 658–664
 monotonicity and crossover, 664–667
 proximity matrix, 676–679
 Agglomerative hierarchical algorithms, 654
 Akaike Information Criterion, 306, 310, 887
 Algebraic distance, 719, *see also* distance
 between a point and a quadratic surface
 Alternating Cluster Estimation (ACE), 733
 Alternating Optimization (AO), 716
 Alternative hypothesis, 268
 Analysis filters, 377
 Ancillary unit, 161
 Angular second moment, 416
 Any path method, 536
 Approximation properties, 194–196
 Arithmetic average rule, 224
 Audio classification, 451–466
 Auto-associative networks, 298
 Autocorrelation matrix, 104, 430, 433
 Autoregressive-moving average (ARMA (p, m)), 429
 Autoregressive processes (AR), 428
 one-dimensional, 428–429
 two-dimensional, 431
 Average expected quantization error, 750
 Average partition density (PA), 891
 Average partition shell density, 892
 Average proximity function, 616, 621
 Average Risk, 16
 minimizing, 16–18

B

Backpropagation algorithm, 162, 167
 batch and pattern modes, 169
 momentum term, 170
 Bagging (bootstrap aggregating), 220, 226
 Barlow's hypothesis, 342
 Barycentric correction procedure, 101
 Basic sequential algorithmic scheme (BSAS), 633–634
 modified, 637–638
 Basis images, 325
 Basis images (matrices), 325
 Basis sequences, 365, 378
 Basis vectors, 324
 Batch mode, 168
 algorithms, 780
 Baum-Welch reestimation, 540
 Bayes classification rule, 14
 naive, 59–61
 normal distributions and, 20–33
 Bayes decision theory, 13
 Bayes rule, 13
 Bayesian Inference, 39
 Bayesian Information Criterion (BIC), 310, 887
 Bayesian learning, 175–176
 Bayesian networks, 66
 Bellman's optimality principle, 484
 Bending energy, 442
 Best path method, 539
 Beta distribution, 925
 Between-class scatter matrix, 281
 Bhattacharyya distance, 278
 Bias-Variance Dilemma, 114
 Binary morphology clustering algorithms (BMCAs), 789
 algorithmic scheme, 796–798
 cluster determination in a discretebinary set, 794–795
 discretization, 790–791

- Binary morphology clustering algorithms (BMCAs) (*continued*)
 - feature vector assignment, 795–796
 - morphological operations, 791–794
- Bioinformatics, 632
- Biorthogonal expansion, 378
- Biorthogonality condition, 381
- BIRCH algorithm, 690
- BLAST, 838
- Boosting, 230
- Bootstrap, 220, 572
- Bootstrap aggregating, 220, 226
- Bootstrap method, 572
- Bootstrapping techniques, 866
- Boundary detection algorithms (BDA), 630
- Branch and bound, 288
- Branch and bound clustering (BBC)
 - algorithms, 630, 805
- Branch and bound methods, 803
- Brownian motion, 446–447
- BUBBLE and BUBBLE-FM algorithms, 690

C

- c-means algorithm, *see* isodata algorithm
- Cascade correlation, 181
- Cauchy–Schwarz inequality, 499
- Cell-based clustering method (CBF), 832
- Center of mass, 442
- Central limit theorem, 20, 923
- Central moments, 413
- Centroid condition, 750
- Cepstrum, 456
- Cepral coefficients, 494
- Chain codes, 439
- Chaining effect, 660
- Chameleon algorithm, 686
- Channel equalization, 527
- Character recognition, 1–2
- Characteristic functions, 601
- Chernoff bound, 278
- Chi-square distribution, 274, 924–925
- Circular backpropagation model, 184
- CLARA algorithm, 748
- CLARANS, 748
- Class imbalance problem, 237
- Class separability measures, 276–283
- Classification error probability, 6, 15
 - minimizing, 15
- Classification task, 5
- Classification tree, 804
- Classifiers, 4
 - Bayes decision theory and, 13–71
 - design stage, 6
 - generalization performance of, 120
 - linear, 91–141, 185–187
 - nonlinear, 151–239
 - polynomial, 189–190
 - soft margin, 209
- CLIQUE algorithm, 825
- Closing, 793
- CLTree algorithm, 832
- Cluster, 595, 600
 - compact, 701
 - linear-shaped, 701
 - ring-shaped, 701, 708
 - shell-shaped, 701
 - spherical, 728
- Cluster-based graph formulation (CBGF), 841
- Cluster detection algorithm for
 - discrete-valued sets (CDADV), 794
- Cluster validity, 863
 - hypothesis testing and, 866–876
 - of individual clusters, 893–896
- Cluster variation, 889
- Clustering algorithms, *see also*
 - under name of*
 - categories of, 629–632
- Clustering algorithms, cost function
 - optimization, 629, 701, 930, *see also*
 - under name of*
 - branch and bound, 630, 803–807
 - deterministic annealing, 765, 808–810
 - fuzzy, 630, 712–733
 - genetic, 630, 810–811
 - hard, 630, 739–749
 - mixture decomposition schemes, 703–712
 - possibilistic, 630, 733–739
 - simulating annealing, 765, 807–808
 - vector quantization, 749–751
- Clustering algorithms, hierarchical, *see also*
 - under name of*
 - agglomerative, 629, 654–679
 - applications, 653
 - cophenetic matrix, 679–680
 - divisive, 629, 680–682
 - for large data sets, 682–690
 - selecting the best, 690–692
- Clustering algorithms, sequential, 629, 633–641, *see also* *under name of*
 - basic, 633–635
 - modified basic, 637–638
 - neural network implementation, 643–646
 - number of possible, 627–628, 635–636
 - refinement stages, 641–643
 - role of, 629
 - two-threshold scheme, 638–641
- Clustering/clusters, 7–8, 600–601, 627
 - applications, 598–599

- compact and hyperellipsoidal, 705–709
 - criterion, 595–597
 - definitions, 600–601
 - proximity measures, 602–622
 - Clustering criterion, 595–596, 597
 - Clustering hypothesis, 896
 - Clustering tendency, 597, 863, 896–905
 - applications, 896
 - tests for spatial randomness, 900–905
 - Co-association matrix, 841
 - Code vector, 749, *see also* reproduction vector
 - Combination of clusterings, 839
 - Combining classifiers, 10, 222–230
 - Compactness and separation validity function, 8, 890, *see also* Xie-Beni index
 - Competitive learning algorithms, 631, 780, 789
 - applications, 782
 - basic, 782–783
 - conscientious, 784–785
 - cost functions and, 785–786
 - generalized, 781
 - leaky, 783–784
 - self-organizing maps, 786–788
 - vector quantization, 788–789
 - Competitive learning associated with cost functions, 785
 - Complementary slackness, 122, 124, 939, 944
 - Complete link algorithm, 659, 671–672
 - Computer-aided diagnosis, 2
 - Computer storage utilization, 749
 - Concordant pair, 875
 - Confidence intervals, 271–272
 - Confusion matrix, 573, 707, 718
 - Conjugate gradient algorithm, 171, 934
 - Conscientious competitive learning algorithms, 784
 - Constant-Q filter banks, 382
 - Constrained problems, optimization for, 935–945
 - Constraint-based clustering algorithms, 839
 - Constraint clustering, 839
 - Constraints, 497
 - Constructive techniques, 160, 178, 181
 - Content-Based Image Retrieval (CBIR), 509
 - Content-based retrieval, 508
 - Context-dependent classification, 521
 - Bayes classifier, 521–522
 - channel equalization, 527–532
 - hidden Markov models, 532–551
 - Markov chain models, 522–523
 - Markov random fields, 554–556
 - neural networks and training, 552–553
 - Viterbi algorithm, 523–527
 - Contingency table, 608
 - Continuous observation HMM, 543
 - Continuous speech recognition (CSR), 491
 - Contrast, 416
 - Convex function, 809, 937
 - Convex hull, 898
 - Convex programming, 123, 126, 943–944
 - Convex set, 126, 138, 938
 - Co-occurrence matrices, 414–417
 - Cophenetic correlation coefficient (CPCC), 874
 - Cophenetic distance, 679
 - Cophenetic matrix, 680
 - “Corrected” statistic, 872
 - Correlation, 104
 - Correlation matrix, 108, 928–929
 - Correlations, template matching and measures based on, 498–504
 - Cosine similarity measure, 606
 - Cost function(s), 701, *see also* clustering algorithms, cost function optimization
 - backpropagation algorithm and, 162–165
 - competitive learning algorithms, 780–781
 - convex, 123
 - cross-entropy, 173–174
 - least square, 172
 - penalty terms, 180
 - quadratic error, 174
 - selecting, 172–176
 - Co-training, 589
 - Covariance matrix, 21
 - Cox-Lewis test, 902
 - Cramer-Rao lower bound, 36, 923
 - Crisp clustering algorithm, *see* hard/crisp algorithms
 - Critical bandwidth, 458
 - Critical interval, 269
 - Cross-correlation, 104
 - Cross-correlation coefficient, 499
 - Cross-entropy, 173, 545
 - Cross-entropy cost function, 173–174
 - Cross-validation with active pattern selection, 572
 - Crossover, 665
 - Cumulants, 344–345, 917–918
 - CURE algorithm, 683
 - Curse of dimensionality, 55
 - Curvature features, 440
- D**
- Data
 - missing, 263–265, 614–615
 - reduction, 598
 - Data compression, 598, 749

- Data normalization, 263
 - Daubechies' low-pass filters, 379
 - Davies-Bouldin (DB) index, 883–884
 - Davies-Bouldin like indices, 883–884
 - DBCLASD, 818
 - DBSCAN, 815
 - Decision surfaces, 19–20
 - hyperplanes, 26–30, 91–92
 - Decision trees, 215
 - Decomposition layers, 902
 - Decomposition technique, sparse, 902–905
 - Deformable template models, 504–508
 - Degrees of freedom, 273
 - Delta-bar-delta, 171
 - Delta-delta rule, 171
 - DENCLUE, 819
 - Dendrogram, 656, *see also* threshold dendrogram
 - Density-based algorithms, 631
 - for large data sets, 815–821
 - Density function, 819
 - Deterministic annealing, 808–810
 - Diagnostic methods, 583
 - Diameter of a cluster, 882
 - Dilation, 791
 - Dimensionality reduction, 331, 350
 - Directed acyclic graph (DAG), 66
 - Directed graphs, 667
 - Directed path, 770
 - Directed tree, 770
 - Direction length features, 440
 - Discordant pairs, 875
 - Discrete binary (DB) set, 790
 - Discrete cosine transform (DCT), 366
 - Discrete Fourier transform (DFT), 363
 - one-dimensional, 364–366
 - short time, 454
 - two-dimensional, 366
 - Discrete observation HMM models, 539
 - Discrete sine transform (DST), 367
 - Discrete time wavelet coefficients, 378
 - Discrete time wavelet transform (DTWT), 375
 - many bands case, 380–384
 - two-band case, 376–380
 - Discrete wavelet frame, 394
 - Discriminant functions, 19
 - Discriminative learning, 174
 - Dispersion of a cluster, 883–884
 - Dissimilarity matrix, 655
 - Dissimilarity measure (DM)
 - between discrete-valued vectors, 608–609
 - between points, 620, 622
 - between real-valued vectors, 604–607
 - between sets, 603, 620
 - defined, 602
 - Distance between a point and a quadratic surface, 719
 - Algebraic distance, 719
 - normalized radial, 721
 - perpendicular distance, 720
 - radial, 720
 - Distances
 - between two sequences, 483
 - Bhattacharyya, 278, 279
 - classifiers, 30–33
 - Euclidean, 30, 603
 - Mahalanobis, 30, 32
 - Minkowski, 716
 - Distortion function, 750
 - Distortion measure, 750
 - Distributed clustering, 846
 - Divergence, 276, 278, 283
 - Divisive hierarchical algorithm(s), 653, 680, 690
 - DNA microarray analysis, 632
 - DNA sequencing, 838
 - Downward closure property, 825, 827, 831
 - Dunn index, 882
 - Dunn-like indices, 882
 - Dynamic Bayesian networks, 545
 - Dynamic programming, 287, 484
 - Dynamic Similarity Measures, 610
 - Dynamic time warping in speech recognition, 491–498
- E**
- Eccentricity, 442
 - Edge connectivity, 670
 - Edge cut set, 687
 - Edgeworth expansion, 346, 918–919
 - Edit distance, 487
 - EM-algorithm, 703
 - Empirical classification error, 299
 - ENCLUS algorithm, 830
 - End point constraints, 494
 - Entropy, 43, 330, 414, 417
 - Entropy estimation, maximum, 43–44
 - Epochs, 169, 175, 182
 - Erosion, 791
 - Error counting approach, 568
 - Euclidean dimension, 445
 - Euclidean distance, 30, 603
 - Exclusive OR (XOR) problem, 151–153
 - Expectation maximization (EM) algorithm, 45
 - description of, 45–46, 703, 751–752
 - mixture modeling problem and, 46–47
 - Extended self similar (ESS) processes, 451
 - External criteria, 864, 867–873
 - External energy, 505–507

F

- FASTA, 838
- Feature generation, audio analysis and, 412
 - cepstrum, 455–457
 - example, 463–466
 - mel-cepstrum, 457–460
 - short time processing of signals, 452–455
 - spectral features, 460–462
 - time domain features, 462–463
- Feature generation, image analysis and
 - extraction, 421–423
 - fractals, 444–451
 - local linear transforms for texture, 421–423
 - moments, 423–427
 - parametric models, 427–435
 - shape and size characterization, 435–443
 - texture characterization, 412–421
- Feature generation, linear transforms and
 - applications, 390–396
 - basis vectors and images, 324–326
 - discrete cosine and sine transforms, 366–368
 - discrete Fourier transform, 363–366
 - discrete time wavelet transform, 375–384
 - Haar transform, 369–375, 382–384
 - Hadamard transform, 368–369
 - independent component analysis, 342–349
 - Karhunen-Loève transform, 326–334
 - multiresolution interpretation, 384–386
 - singular value decomposition, 335–341
 - two-dimensional generalizations, 388–390
 - wavelet packets, 387–388
- Feature generation methods, 822
- Feature selection, 6, 261, 596
 - Bayesian information criterion, 309–310
 - class separability measures, 276–282
 - neural networks and, 298–299
 - optimal generation, 288–297
 - preprocessing, 262–265
 - receiver operating characteristics curve, 275–276
 - scalar, 283–284
 - statistical hypothesis testing and, 268–275
 - subset, 283–288
 - Vapnik-Chervonenkis learning theory, 300–309
 - vectors, 284–288
- Feature selection methods, 822
- Features, 4
 - defined, 5
 - interval scaled, 599
 - maps, 184
 - nominal, 599
 - ordinal, 599
 - ratio-scaled, 599, 676
 - vectors, 6
 - types of, 599
- Filter approach, 285
- Filter model, 823
- Finite impulse response (FIR), 376, 947
- Finite state automaton, 535
- First-order statistics features, 412–414
- Fisher's discriminant ratio (FDR), 282, 289
- Fisher's linear discriminant, 204, 294
- Floating search methods, 286–287
- Fourier descriptors, 437–439
- Fourier features, 436–439
- Fourier transform, 455
- Fowlkes and Mallows index, 870
- Fractal dimension, 444–446
- Fractals, 444–451
- Fractional Brownian motion, 446–451
- Frequency ratio, 50
- Frobenius norm, 337, 350
- Fukuyama-Sugeno index, 890
- Fundamental frequency, 461–462
- Fuzzifier, 713
- Fuzzy approaches, 702, *see also* fuzzy
 - clustering algorithms
- Fuzzy C ellipsoidal shells (FCES) algorithm, 726
- Fuzzy C plano-quadric shells (FCPQS), 727
- Fuzzy C quadric shells (FCQS) algorithm, 727
- Fuzzy clustering algorithms, 630, 712–716
 - alternating cluster estimation, 733
 - convergence aspects, 732–733
 - generalized, 715
 - geometrical interpretation, 732
 - hyperplane representatives, 728–732
 - internal criteria, 894–896
 - point representatives, 617–619
 - quadric surface representatives, 718–724
 - relative criteria, 877–880
 - shell, 724–728
- Fuzzy c-Means (FCM) algorithm, 717
- Fuzzy decision trees, 221
- Fuzzy density, 891
- Fuzzy hypervolume, 891
- Fuzzy k-means algorithm, 717
- Fuzzy measures, 613
- Fuzzy proximity measures, 613–614
- Fuzzy shell clustering algorithms, 724–728
- Fuzzy shell density, 892

G

- Gabor filter, 394
- Gabriel graphs (GG), 770, 882, 884
- Gap statistic, 885
- Gauss-Newton method, 717
- Generalization error probability, 300

- Generalization performance of classifiers, 120
 - Generalized agglomerative scheme (GAS), 654
 - Generalized competitive learning scheme (GCLS), 781
 - Generalized divisive scheme (GDS), 681
 - Generalized fuzzy algorithmic scheme (GFAS), 715
 - Generalized hard algorithmic scheme (GHAS), 740
 - Generalized linear classifiers, 185
 - Generalized mixture decomposition algorithmic scheme (GMDAS), 704
 - Generalized possibilistic algorithmic scheme (GPAS), 735
 - Generalized XB index, 890
 - Generative models, 579
 - Genetic algorithms, 630, 765, 810, 811
 - crossover, 810
 - mutation, 810
 - reproduction, 810
 - Geometric average rule, 223–224
 - Geometric features, 442–443
 - Geometric moments, 423
 - Gibbs random fields, 554
 - Global constraints, 485, 495
 - Global convergence theorem, 732
 - Grade of membership, 601
 - Gradient descent algorithm, 95, 172, 930–933
 - Graph
 - complete, 766
 - edges, 667, 766
 - inconsistent edges, 766
 - vertices, 667
 - Graph embedding, 361
 - Graph theory, 765
 - agglomerative algorithms, and, 667–676
 - directed trees, 770–772
 - minimum spanning tree, 675–676, 766–770
 - regions of influence, 768–770
 - Graph theory-based algorithmic scheme (GTAS), 670
 - Gray level run lengths, 417
 - Grid-based subspace clustering algorithms (GBSCAs), 825
 - Gustafson-Kessel (G-K) algorithm, 728
- H**
- Haar transform, 369, 384
 - Hadamard transform, 368
 - Hammersley-Clifford theorem, 554
 - Hamming distance, 608–609
 - Hamming window, 454
 - Hard clustering, 702
 - Hard/crisp clustering algorithms, 630, 739
 - CLARA and CLARANS algorithms, 748–749
 - generalized, 740–741
 - internal criteria, 867, 873–876
 - isodata, k-means, and c-means algorithms, 741–745
 - k-medoids algorithms, 745–749
 - PAM algorithm, 746–748
 - relative criteria, 877–880
 - Hermitian operation, 324
 - Hessian matrix, 123, 171, 933–934
 - Hidden layer, 156
 - Hidden Markov models (HMMs), 532
 - coin tossing example, 532–533
 - continuous observation, 543–545
 - discrete observation, 539–543
 - recognition, 536–539
 - state duration modeling and, 545–551
 - training, 539
 - Hierarchical clustering algorithms, 629
 - agglomerative algorithms, 629
 - divisive algorithms, 629
 - Hierarchical search, 502
 - High-dimensional data sets, clustering algorithms for, 821–837
 - Higher order, 184
 - Hilbert space, 199
 - Histogram approximation, 50
 - Ho-Kashyap algorithm, 109
 - Holdout method, 570
 - Hopkins test, 901
 - Hu moments, 425–426
 - Hubert's Γ statistic, 870, *see also* Γ statistic
 - Hughes phenomenon, 303
 - Hurst parameter, 447
 - Hybrid bipartite graph formulation (HBGF), 842
 - Hyperbolic tangent, kernels, 200
 - Hypercube, 709, 732
 - Hyperellipses, 30, 719
 - Hyperparameters, 202
 - Hyperplanes, 26–30, 91–92
 - margin, 106, 182, 266
 - representatives, 619, 728–732
 - Hyperquadrics, 25
 - Hypersphere, 867
 - Hyperspherical representatives, 619–620
 - Hypothesis generation, 598
 - Hypothesis testing, 598, 864–876
 - basics, 268–269
 - cluster analysis and, 598
 - cluster validity and, 866–876
 - feature selection and, 268–275
 - known variance case, 269–271
 - null, 268
 - t-test, 273–275
 - unknown variance case, 272–273

I

Images, basis, 324–326
 Incomplete data set, 45
 Independent component analysis (ICA), 342–343
 based on mutual information, 345–348
 based on second- and fourth-order cumulants, 344–345, 917–918
 identifying condition for, 343–344
 simulation example, 348–349
 Inequality constraints, 937–945
 Influence function, 819
 Information theory based criteria, 886–887
 Inner product, 606
 Input layer, 156
 Instance-based graph formulation (IBGF), 841
 Internal criteria, 864, 867, 873–876
 Internal energy, 505–506
 Interpoint distances, 900
 Interpolation functions, 185–186
 polynomial classifiers, 189–190
 radial basis, 190–194
 Interpretation of clustering results, 597
 Intersymbol interference, 527
 Interval scaled, 599
 Intrinsic dimension, 331
 Invariance, transformation, 183
 Inverse difference moment, 417
 Isodata algorithm, 742
 Isolated word recognition (IWR), 491
 ISOMAP, 359
 Itakura constraints, 495, 496
 Itakura global constraints, 495
 Itakura–Saito distortion, 782
 Iterative function optimization schemes, 629

J

Jaccard coefficient, 869–870
 Jaccard measure, 842

K

k-means algorithm, *see* isodata algorithm
 Kalman filtering approach, 171
 Karhunen–Loève transform, 326, 822
 Karush–Kuhn–Tucker (KKT) conditions, 121, 126, 939–941
 Kernel clustering methods, 811
 Kernel Euclidean distance classifier, 203
 Kernel PCA, 351
 Kernel perceptron algorithm, 205
 Kernels, 51
 Kesler's construction, 101
 Koch curve, 445–446
 Kohonen self-organizing maps, 787

Kronecker's delta, 18
 Kruskal's algorithm, 676
 Kruskal–Wallis statistic, 274
 Kullback–Leibler (KL) probability distance measure, 223, 277, 350, 919–920
 Kurtosis, 413

L

Label propagation, 586
 Lagrange multipliers, 122, 124, 940–941
 Lagrangian duality, 123, 943–945
 Laplacian eigenmaps, 353
 Laplacian matrix, 355
 Laplacian regularized kernel least squares, 585
 Latent semantics indexing, 337
 LBG algorithm, 751
 Leaky learning algorithm, 783
 Learning machines, perceptrons, 101, 114
 Learning subspace methods, 333
 Learning theory, Vapnik–Chervonenkis, 231, 300–309
 Least squares methods (LSM), 103
 algorithm, 105–107
 cost function, 172
 mean square error estimation, 103–105, 110–117
 stochastic approximation, 105–108
 sum of error squares estimation, 108–110
 Leave-one-out method, 570
 Levenberg–Marquardt (L-M) method, 717
 Levenberg–Marquardt algorithm, 171, 717
 Levenstein distance, 490
 Levinson's algorithm, 430
 Lexicographic ordering, 324
 Lifetime of a cluster, 690
 Likelihood function, 24, 35
 Likelihood ratio, 18
 Likelihood ratio test, 57
 Linear classifiers, 91
 functions and decision hyperplanes, 91–92
 generalized, 185–187
 least squares methods, 103–110
 logistic discrimination, 117–119
 mean square estimation, 110–117
 perceptron algorithm, 93–103
 support vector machines, 119–133
 Linear dichotomies, 187
 Linear discriminant analysis (LDA), 33, 288
 Linear discrimination, 288, 294
 Linear time invariant (LTI) systems, 946–947
 Linear transforms, *see* feature generation, linear transforms and
 Link graph, 686
 Lloyd's algorithm, 751

- LMS algorithm, 105
- Local constraints, 484, 495
- Local feature extractor, 421
- Local linear embedding, 357
- Local linear transforms for texture extraction, 421–423
- Log-likelihood function, 36–37, 46, 118
- Logarithmic search, 501–502
- Logistic discrimination, 117
- Logistic function, 162
- Long run emphasis, 420
- Loss matrix, 17
- Loss minimization algorithm, 101
- M**
- Machine intelligence systems, 1
- Machine vision, 1
- MAFIA algorithm, 831
- Mahalanobis distance, 32
- Majority Voting Rule, 225
- Manhattan norm, 605
- Manhattan segmental distance, 833
- Many-to-one mapping, 45
- Marginalization, 916
- Markov chain models, 522–523, *see also*
 - hidden Markov models
- Markov chain Monte Carlo (MCMC)
 - techniques, 40
- Markov edit distance, 490
- Markov model, 522
- Markov random fields, 434, 554
- Masks, 422–423, 471–472
- Matching score generator, 643
- Matrix theory, 658–664
- Matrix updating algorithmic scheme (MUAS), 658, 659
- Max proximity function, 616, 620
- Maximally complete subgraph, 668
- Maximally connected subgraph, 668
- Maximum a *posteriori* probability
 - estimation, 38
- Maximum entropy estimation, 43
- Maximum likelihood, 34
- Maximum margin classifiers, 308
- Maximum variance unfolding, 361
- Maxmin algorithm, 638
- MaxNet, 643, 644
- McCulloch-Pitts neuron, 101, 162
- Mean center, 617
- Mean proximity function, 621
- Mean square error (MSE)
 - bias-variance dilemma, 114–117
 - estimation, 103–104
 - Karhunen-Loève transform, 326–329
 - multiclass generalization, 104–105
 - posterior class probabilities, 112–113
 - regression, 110–111
- Mean square error estimation, 103
- Mean square error regression, 110
- Mean value, 106, 182, 266
- Mean vector/point, 617
- Median center, 618
- Median clustering, 843
- Mel Cepstrum, 457
- Mellin transforms, 500
- Membership functions, 601
- Mercer's theorem, 199
- Merging procedure, 641
- Metric multidimensional scaling (MDS), 332
- Min proximity function, 616, 620
- Minimum cut bisector, 687
- Minimum cut set, 687
- Minimum Description Length (MDL), 887
- Minimum distance classifier, 30
- Minimum spanning tree (MST), 766, 882, 884, 900, 902
- Minimum variance algorithm, 662, *see also*
 - ward's algorithm
- Minkowski distance, 716
- Min-max duality, 942–943
- Mixture decomposition, 702
- Mixture decomposition schemes, 703–712
- Mixture models, 44–45
 - expectation maximization (EM) algorithm
 - and, 45–49
- Mixture of Experts, 230
- Mixture scatter matrix, 281
- Model sparsification, 205
- Mode-seeking algorithms, 737, 772
- Mode-seeking property, 737
- Modified BSAS, 637
- Modified fuzzy C quadric shells (MFCQS)
 - algorithm, 726, 727
- Modified Hubert Γ statistic, 880
- Moment-based features, 441–442
- Moment generating function, 917
- Moments, 423–427
 - absolute, 414
 - central, 413, 424
 - geometric, 423–425
 - of Hu, 424
 - Zernike, 425–427
- Momentum factor, 170
- Monothetic algorithms, 682
- Monotonicity, 496, 665
- Monte Carlo techniques, 865
- Moore machine model, 535
- Morphological operations, 791–794
 - closing, 793
 - dilation, 791

- erosion, 791
- opening, 793
- translation, 791
- Morphological transformation techniques,
 - algorithms based on, 631
- Motion compensation, 498
- Motion estimation, 498
- Mountain method, 837
- Multiclass generalization, 104–105
- Multi-class tasks, 127
- Multifractional Brownian motion, 451
- Multiple additive regression trees (MART), 236
- Multiresolution analysis, 386
- Multiresolution decomposition, 375
- Multiresolution interpretation, 384
- Multispectral remote sensing, 7
- Multivariate Gaussian, 920–921
- Mutation, 810, 811
- Mutual information, 545
 - ICA based on, 345–348

N

- Naive-Bayes classifier, 59–61
- Natural clusters, 600
- Natural gradient, 347
- Nearest Neighbor, 901–902
 - k Nearest Neighbor (k NN) density estimation, 56
- Nearest neighbor condition, 750
- Nearest neighbor distances tests, 901
- Nearest neighbor rule, 61–64, 161
- Nested clusterings, 653
- Nesting effect, 286
- Network size selection, 176–181
- Networks, 183
- Neural networks, 552
 - basic sequential algorithmic scheme and, 644–646
 - feature selection and, 298–299
 - training Markov models, 552–553
- Neurocomputers, 169
- Neurons, *see* perceptrons
- Newton's algorithm, 934
- Neyman-Pearson decision rule, 18
- Neyman-Scott procedure, 898
- Noble identity, 372, 380
- Node connectivity, 670
- Node degree, 670
- Node impurity, 218, 219, 220
- Nonlinear classifiers
 - algorithms based on classification of training set, 160–162
 - approximation properties, 194–196
 - backpropagation algorithm, 162–169
 - combining, 222–235

- cost function, selecting, 172–176
- decision trees, 215–222
 - linear dichotomies, 187–189
 - polynomial classifiers, 189–190
 - radial basis functions, 190–194
 - support vector machines, 198–203
 - three-layer perceptrons, 158–160
 - two-layer perceptrons, 153–158
 - XOR (exclusive OR) problem, 151–153
- Nonlinear optimization iterative techniques, 44
- Nonnegative matrix factorization (NMF), 349
- Nonparametric estimation, 49–59
- Normal distributions, Bayesian classification for, 20–33
- Normalization, 790
 - data, 263
- Normalized central moments, 424
- Normalized radial distance, 721–723, *see also* distance between a point and a quadratic surface
- Normalized Γ statistic, 870
- Null hypothesis, 268, 864, 866

O

- Octave-band filter banks, 382
- One-dimensional DFT, 364
- One-tailed statistical test, 865
 - left-tailed statistical test, 866
 - right-tailed statistical test, 866
- Online mode, 168
- Opening, 793
- Optical character recognition (OCR), 435, 789
- OPTICS, 818
- OptiGrid, 801
- Optimization, 935
- ORCLUS algorithm, 834
- Ordinal proximity matrices, 894
- Ordinary binary classification trees (OBCTs), 216
- Orientation, 442
- Orthogonal projection, 104
- Orthogonality condition, 104
- Outliers, 262, 710, 732, 734
- Output layer, 156
- Overtraining, 177

P

- PAC bounds, 301
- PAC learning theory, 301
- Packing density, 899
- PAM algorithm, 746
- Parallel connection, 948

- Parametric models, 427
 - one-dimensional, 428–431
 - two-dimensional, 431–433
 - Paraunitary, 379
 - Partial clusterings, 804
 - Partition algorithmic schemes, 737
 - Partition coefficient (PC), 888, 891
 - Partition density, 891–893
 - Partition density (PD) index, 891
 - Partition entropy (PE), 888, 891
 - Partition entropy coefficient, 888
 - Partition shell density, 892
 - Parzen windows, 51, 802
 - Pattern mode algorithms, 780
 - Pattern recognition
 - importance of, 1–4
 - supervised versus unsupervised, 7–9
 - syntactic, 12
 - Peaking phenomenon, 265
 - Pearson's correlation coefficient, 606
 - Penalty terms, 180
 - Perceptron(s), 100
 - description of, 100–101
 - three-layer, 158–160
 - two-layer, 153–158
 - Perceptron algorithm, 93
 - convergence proof, 95–97
 - pocket algorithm, 101
 - variants of, 98
 - Perceptron cost, 93
 - Perfect reconstruction, 378
 - Perpendicular Distance, 720, *see also* distance
 - between a point and a quadratic surface
 - pFCM, 717
 - Pitch, 461
 - signal, 461, 462
 - Pocket algorithm, 101
 - Point representatives, 617–619, 716–718, 888
 - Point spread function, 948
 - Point-based subspace clustering algorithms (PBSCA), 832
 - Poisson distribution, 899
 - Poisson process, 899
 - Polyhedra, 157–158
 - Polynomial classifiers, 189–190
 - kernels, 199
 - Polythetic algorithms, 682
 - Positive definite/symmetric matrices, 927–928
 - Possibilistic algorithms, 630, 738
 - Possibilistic clustering algorithms, 630, 733–739
 - Potential functions, 51
 - Power function, 864
 - Precision, 573
 - Prediction based on groups, 599
 - Prim's algorithm, 676
 - Principal Component Analysis (PCA), *see* Karhunen-Loève transform
 - Probabilistic clustering algorithms, 630
 - Probabilistic neural networks, 58, 196
 - Probability chain rule, 64
 - Probability density functions (pdf), 13
 - Edgeworth expansion, 346, 918
 - estimating unknown, 34–61
 - mixture models, 44–47
 - nonparametric estimation, 49–59
 - normal density function, 20–33, 920–921
 - PROCLUS algorithm, 832
 - Projection pursuit, 186
 - Proximity dendrogram, 656
 - Proximity function
 - between a point and a set
 - average proximity function, 616
 - maximum proximity function, 616
 - minimum proximity function, 616
 - between two sets
 - average proximity function, 621
 - maximum proximity function, 620
 - mean proximity function, 621
 - minimum proximity function, 620
 - Proximity graph, 669, 894
 - dissimilarity graph, 669
 - Proximity matrix, 655
 - Proximity measure, 597
 - between a point and a set, 616–620
 - between two points, 604–616
 - between two sets, 620–622
 - definitions, 602–604
 - Pruning techniques, 178
 - Pseudolikelihood function, 556
 - Psychoacoustics, 461
 - Pythagoras' theorem, 333
- Q**
- QROCK, 686
 - Quadrat analysis, 900
 - Quadratic classifier, 25
 - Quadratic discriminant analysis (QDA), 33
 - Quadratic surface, 719
 - hyperellipses, 719
 - hyperparabolas, 719
 - representatives, 718–728, 731–732
 - Quasistationary signals, 452
 - Quefrency, 456
 - Query point method (QPM), 513
 - Quickprop, 171

R

Radial basis functions (RBFs), 190–194
 kernels, 201
 Radial distance, 720, *see also* distance
 between a point and a quadratic
 surface
 Rand statistic, 869
 Random fields, 428
 Gibbs, 554
 Markov, 434, 554–556
 Random Forests, 221
 Random graph hypothesis, 867
 Random label hypothesis, 868
 Random position hypothesis, 867
 Random projections method, 823
 Random variables, 5
 Random walk, 446
 Randomness hypothesis, 866, 896
 Ratio-scaled proximity matrices, 895
 Reassignment procedure, 642
 Recall, 573
 Receiver operating characteristics (ROC)
 curve, 275
 Receptive field, 184
 Recognition, hidden Markov model,
 536–539
 Reduced Convex hull (RCH), 138
 Redundancy reduction, 342
 Regions of influence, 768
 algorithms based on, 768–770
 Regression, mean square error, 110–111
 Regularity assumption, 935
 Regularity hypothesis, 896
 Regularization parameter, 180
 Relative closeness, 688
 Relative criteria, 864, 877–893
 Relative edge consistency, 769
 Relative interconnectivity, 687–688
 Relative neighborhood graph (RNG), 770,
 882, 884
 Relevance Feedback (RF), 509
 Relevance vector machines, 208
 Representatives
 hyperplane, 728
 point, 716–717
 quadric surfaces, 718
 Reproducing kernel Hilbert space (RKHS),
 199
 Reproduction, 810
 Reproduction set, 750
 Reproduction vector, 749
 Resubstitution method, 570
 Reward and punishment schemes, 98
 Ridge regression, 214
 Right-tailed statistical test, 866

Risk or loss, 17
 Risk, minimizing average, 16–18
 Robbins–Monro iteration, 783
 Robust statistics, 211
 ROCK algorithm, 685
 Rotation forest, 230
 Roundness ratio, 442
 Run length nonuniformity, 420
 Run percentage, 421

S

Sakoe and Chiba, 497
 Saliency, 179
 Sample complexity, 302
 Sample correlation matrix, 108
 Sample mean, 270
 Sampling frame, 897
 Sampling window, 897
 Scalar feature selection, 283–284
 Scan test, 900
 Scatter matrices, 280
 Searching techniques
 optimal, 287–288
 suboptimal, 285–287
 Second characteristic function, 917
 Second moment structure, 900
 Second-order statistics features, 414–417
 Segment modeling, 551
 Segmental k-means training algorithm, 542
 Self-affine, 448
 Self-Organizing Maps (SOM), 786
 Self-similarity, 444
 Self-training, 588
 Semi-supervised learning, 577
 Sequential backward selection, 285
 Sequential clustering algorithms, *see*
 clustering algorithms, sequential
 Sequential decomposition, 902
 Sequential forward selection, 286
 Sequential Minimal Optimization (SMO), 129
 Sequential search, 503
 Serial connection, 948
 Shannon's information theory, 43, 218
 Shape and size characterization, 435
 chain codes, 439–441
 Fourier features, 436–439
 geometric features, 442–443
 moment-based features, 441–442
 Shell hypervolume, 892
 Shell partition density, 892
 Shell-shaped clusters, 892–893
 Short run emphasis, 420
 Short-time autocorrelation, 455
 Short-time DFT, 454
 Short-time Fourier transform, 386

- Short time processing of signals, 452–455
 - Sigmoid functions, 162
 - Significance level, 269
 - Silhouette index, 885
 - Similarity matrix, 655
 - Similarity measure (SM)
 - between discrete-valued vectors, 607–608
 - between real-valued vectors, 606
 - defined, 602
 - Simple sequential inhibition (SSI), 899
 - Simulated annealing, 807–808
 - Sine transforms, 366
 - Single link algorithm, 659, 670–671
 - Singular value decomposition, 335, 822
 - Skewness, 413
 - Slack variables, 125
 - Small sample size problem, 295
 - Soft margin classifiers, 133
 - Softmax activation, 241
 - Softmax activation function, 174
 - Spanning tree, 675
 - Sparse decomposition technique, 902–905
 - Sparsification, *see* model sparsification
 - Spatial dependence matrix, *see* co-occurrence matrices
 - Spatial randomness, tests for, 900–905
 - Speaker-dependent recognition, 491
 - Speaker-independent recognition, 491
 - Spectral clustering, 772
 - Spectral features, 460–462
 - Spectral representation, 335
 - Speech recognition, 2–3, 451, 789
 - dynamic time warping in, 491–498
 - Squashing functions, 162
 - Stacking, 226
 - State duration HMM, 545
 - Statistical hypothesis testing, 268–275
 - one-tailed, 865
 - two-tailed, 865
 - Statistical independence, 916
 - Statistically self-affine, 447
 - Step function, 154
 - Stirling numbers of the second kind, 628
 - Stochastic approximation, 105
 - Stochastic relaxation methods, 630–631
 - String patterns, 482
 - Structural graph tests, 900
 - Structural risk minimization, 303
 - Structuring element, 791–794
 - Subgraph, 668
 - complete, 668
 - connected, 668
 - Subsampling, 371
 - Subspace classification, 333
 - Subspace clustering algorithms (SCAs), 631, 824
 - grid-based, 825–832
 - point-based, 832–836
 - Sum of error squares estimation, 108
 - Support vector machines (SVMs)
 - geometric viewpoint, 136–138
 - nonlinear, 198–203
 - nonseparable classes, 124–127
 - reduced convex hulls, 138–142
 - separable classes, 119–124
 - Vapnik-Chervonenkis learning theory, 301–303
 - v-SVM, 133–136
 - Support vectors, 122
 - Surface density criterion, 895
 - SVMs, *see* support vector machines (SVMs)
 - Sweep, 807
 - Synapses, 101
 - Synthesis filters, 377
 - System evaluation, 6, 567
 - error counting, 568–569
 - finite size of data set, 569–573
 - medical imaging example, 573–577
- T**
- Tabu search method, 837
 - Tanimoto measure/distance, 606–607
 - Tanimoto measure for discrete valued, 609
 - Template matching, 481
 - Bellman's principle, 484–487
 - defined, 481
 - deformable models, 504–508
 - dynamic programming, 484–487
 - dynamic time warping in speech recognition, 491–498
 - edit distance, 487–491
 - measures based on correlations, 498–504
 - measures based on optimal path searching, 482–498
 - Templates, 481
 - Test statistic, 269
 - Texture, 393, 412
 - Texture characterization, 393, 412–421
 - Texture classification, 393–396
 - Thermal perceptron algorithm, 101
 - Three-layer perceptrons, 158–160
 - Threshold dendrogram, 674
 - Threshold graph, 668, 904
 - Tied-mixture densities, 544
 - Tiling algorithm, 160
 - Time domain features, 462–463
 - Toeplitz matrix, 430, 433
 - Topological sorting, 66
 - Total fuzzy average shell thickness, 892

Total probability, 915
 Total variation, 889
 Touching clusters, 767–768
 Training Markov models, 552–553
 Training patterns/feature vectors, 6
 Transductive inference, 577
 Transductive SVM, 586
 Transfer function, 947
 Transformation invariance, 183
 Transformed divergence, 278
 Tree-structured filter bank, 374
 Triangular inequality, 603
 Truth tables, 152, 154
 Two-dimensional AR models, 431
 Two-dimensional DFT, 366
 Two-dimensional parametric models, 431–433
 Two-tailed statistical test, 865
 Two-threshold sequential algorithmic scheme (TTSAS), 639–640

U

Uncertainty principle, 395
 Undirected graphs, 667
 Universal approximators, 194
 Universum, 590
 Unsupervised learning, 595
 Unsupervised pattern recognition, 7
 Unweighted graphs, 667
 Unweighted pair group method average (UPGMA), 661
 Unweighted pair group method centroid (UPGMC), 661
 Utility function, 843

V

Validation of clustering results, 597
 Valley-seeking algorithms, 631, 801–803
 Vapnik–Chervonenkis learning theory, 299
 Variables, slack, 125
 Variance, 916
 Variance dilemma, bias-, 114–117, 228
 Variational similarity, 487
 Vector quantization, 749
 Vector quantizer, 749
 decoder, 750
 encoder, 750
 Vectors, 4

 basis, 324–326
 discrete-valued, 607–610
 mixed-valued, 610–612
 noisy feature, 710
 quantization, 749–751, 788
 real-valued, 604–607
 selecting, 284–288
 support, 122
 Video coding, 481
 Viterbi algorithm, 523
 Viterbi reestimation, 542
 Voronoi tessellation, 64

W

Ward's/minimum variance algorithm, 662–663
 WaveCluster algorithm, 838
 Wavelet packets, 387
 Web content mining, 632
 Web data mining, 632, 838
 Web mining, 590
 Web usage mining, 632
 Weierstrass theorem, 195
 Weight elimination, 180
 Weight sharing, 183–184
 Weighted graphs, 667
 Weighted pair group method average (WPGMA), 661
 Weighted pair group method centroid (WPGMC), 661
 Well-formed functions, 172
 Widrow-Hoff algorithm, 107
 Within-class scatter matrix, 280
 Within scatter matrix, 741
 Wolfe dual representation form, 123, 200, 214, 812, 944–945
 Wrapper approach, 285
 Wrapper model, 823

X

Xie-Beni (XB) index, 890
 XOR problem, 151

Z

Zernike moments, 425
 Zero-crossing rate, 462