

- acceptance–rejection, 280
- algorithm, 281
- beta density, 282
- comparison function, 280
- adaptive coefficients, 307
- aperiodic random processes, 563
 - discrete Karhunen–Loeve (K–L) expansion, 571
 - Karhunen–Loeve (K–L) expansion, 565
 - eigenfunctions, 565
 - eigenvalues, 565
 - nonstationary process, 566
- AR(1) process, 522
- arcsine law, 192, 194
- attenuation coefficient, 668
- autoregressive process, 439

- bandpass signals, 606
 - analytic signal representation, 607
 - natural envelope, 606
 - lower side band, 607
 - upper side band, 606
 - complex envelope, 610
 - quadrature representation, 607
- Bayesian estimation, 384
 - discrete probability, 398
 - MAP Criterion, 395
 - ML criterion, 396
- Bayes' theorem, 20, 669
- Bayes' theorem for densities, 132
- Bernoulli
 - distribution, 37
 - trials, 37
 - independent identically distributed, 37
- Bernoulli process, 505
 - modified, 510
- Bessel function of zero order
 - modified, 107, 217, 621
- bilinear form, 302
- binomial coefficient, 29
 - Pascal's identity, 29
 - triangle, 30
 - properties, 29
 - sum, 39
 - Vandermonde's identity, 30
- binomial process, 506, 509
- birthdays problem, 27, 53
- bivariate Gaussian distribution, 144, 154
- block matrices, 308
 - properties, 309
- Bose Einstein statistics, 32
- bound, 242
 - Chebyshev, 242
 - alternate forms, 244
 - geometric derivation, 243
 - Chernoff, 248
- Brownian motion (see Wiener process), 492, 523

- Catalan numbers, 31
- Cauchy
 - density, 232
 - distribution, 115, 221, 226
- Cauchy–Riemann conditions, 303
- Cayley Hamilton theorem, 294
- central limit theorem, 260
- characteristic functions, 155, 212, 213
 - examples, 157
 - continuous random variables, 159
 - discrete random variables, 157
 - existence, 155
 - joint characteristic functions, 157
 - moment generating properties, 156
- chi-squared test, 267
- combinations, 28
 - sampling with replacement, 32
 - sampling without replacement, 29
- comparison of Gaussian and Poisson approximations, 93
- conditional densities, 122

- conditional distributions, 122
 - properties, 122
- conditional distributions and densities, 122, 313
 - clarification, 315
 - $P(A) = 0$, 126
 - $P(A) \neq 0$, 122
- confidence coefficient, 351, 364
- confidence interval, 351, 364
 - coefficients of simple linear regression, 371
 - unknown mean of population, 364
 - known variance, 364
 - unknown variance, 366
 - unknown variance with unknown mean, 369
- confidence region
 - simple linear regression line, 372
- congruential generator, 264
 - linear, 264
 - mixed, 264
 - multiplicative, 264
- continuous distributions, 79, 95
 - beta distribution, 114
 - Cauchy distribution, 115
 - chi distribution, 104
 - Maxwell density, 106
 - Nakagami density, 108
 - Rayleigh density, 105
 - Rice's density, 107
 - chi-square, 102
 - double Laplace distribution, 118
 - Erlang distribution, 97
 - exponential distribution, 80
 - hazard rate, 82
 - instantaneous, 82
 - Poisson arrival process, 81
 - gamma, 99
 - reproductive property, 100
 - Gaussian distribution, 84
 - Gibbs distribution, 118, 674
 - potential function, 118
 - Laplace distribution, 96
 - double Laplace distribution, 118
 - lognormal distribution, 112
 - Pareto distribution, 117
 - Snedecor F -distribution, 111
 - Student- t density, 110
 - summary, 119
 - triangular, 95
 - uniform distribution, 79
 - Weibull, 101
- continuous Kalman filter, 660
 - assumptions, 660
 - matrix Riccati equation, 661
- continuous random variables, 151
 - means and variances, 150
 - exponential distribution, 151
 - Gaussian distribution, 152
- convergence, 256
 - almost sure, 257
 - Cauchy criterion, 257
 - in distribution, 258
 - in probability, 257
 - mean square, 258
 - pointwise, 256
 - properties, 258
 - quadratic mean, 258
- convolution techniques, 279
 - Erlang distribution, 279
 - triangular distribution, 279
- counting, 25
 - addition rule, 25
 - multiplication rule, 25
- convex function, 254
- covariance matrices, 320
 - diagonalization principles, 330
 - diagonalization to an identity matrix, 331
 - principles, 330
 - simultaneous diagonalization, 334
 - summary of procedures, 335
- covariance of ACF estimators, 452
- craps game, 16
- cumulants, 167
 - Gaussian distribution, 169
 - Poisson distribution, 169
- cumulant generating functions, 167
- cyclostationary process, 560
- density function, 65
- differentiation, 301
 - complex variable, 303
 - Cauchy–Riemann conditions, 303
 - partial derivative, 304
 - regular point, 304
 - singular point, 304
 - total derivative, 303
 - complex vectors, 305
 - partial differentiation, 305
 - real matrices, 308
 - real vectors, 301
- direct determination of density, 194
 - conditions, 196
 - steps, 196
- direct determination of joint density, 227
- discrete distributions
 - Bernoulli, 37
 - Benford, 55

- discrete distributions (*Continued*)
 - binomial, 38
 - approximation, 50
 - geometric, 42
 - hypergeometric, 46
 - logarithmic, 55
 - finite law, 55
 - first significant digit, 55
 - second significant digit, 58
 - infinite law, 60
 - multinomial, 41
 - negative binomial, 44
 - Pascal distribution, 44
 - Poisson, 48
 - approximation to binomial, 50
 - summary, 62
- discrete Kalman filter, 647
 - across observations, 649, 651
 - algorithm, 655
 - assumptions, 650
 - between observations, 649, 652
 - comments, 654
 - covariance propagation, 655
 - Kalman gain, 650
 - scalar case, 657
 - timing diagram, 649, 653
- discrete random variables, 150
 - means and variances, 150
 - binomial distribution, 150
 - Poisson distribution, 151
- discrete time processes, 458
 - Anderson's theorem, 470
 - estimation of autocorrelation
 - functions, 467
 - estimation of covariance of NACF, 469
 - estimation of NACF, 468
 - large-lag approximations, 469
 - variance of autocovariance estimators, 464
 - white noise, 470
- discrete time stationary processes, 437
 - moments, 437
- distribution and density functions, 66
 - properties, 73
 - cumulative distribution function
 - $F_X(x)$, 73
 - probability density function $f_X(x)$, 74
 - probability mass function, 74
- distribution function, 66
 - from density, 75
- distribution of $Y = g(X)$, 174
 - steps for determination, 175
- eigenvalues of matrices, 294
 - characteristic polynomial, 293
- eigenvectors of matrices, 296
 - normalization, 297
- emission tomography, 667
- ergodic processes, 439
 - correlation-ergodic, 441
 - mean-ergodic, 439
 - power ergodic, 442
 - time average, 439
- estimated regression coefficients, 358
 - covariance, 359
 - from data, 358
- estimated regression line, 360
 - variance, 360
- estimation
 - likelihood function, 389
 - likelihood ratio, 389
 - linear estimation of vector
 - variables, 337
 - overdetermined system, 338
 - underdetermined system, 338
 - maximum a posteriori probability (MAP), 388
 - minimization of average probability of error, 389
 - maximum likelihood, ML, 391
 - properties, 391
 - parameters, 350
 - Bayesian estimation, 384
 - covariance, 355
 - higher order moments, 358
 - interval estimation, 351
 - mean, 351
 - unbiased, 351
 - minimum mean square, 353
 - point estimation, 351
 - variance, 354
 - standard error, 355
 - statistic, 351
- estimation criteria, 340
 - consistent, 341
 - efficient, 341
 - Rao–Cramer bound, 341
 - log-likelihood, 341
 - maximum likelihood, 341
 - mean square error, 340
 - minimum variance, 340
 - unbiased, 340
- estimation of a random variable
 - by a constant, 342
 - by a function of another random variable, 342
- expectation maximization algorithm, 672
 - one step late, 672
 - RMS error, 680

- field, 8, 11
 - Boolean field, 9
 - Borel σ -field, 9
- functions of a single random variable, 173
 - higher order moments, 203
 - moments, 202
 - random variable $g(X)$, 173
 - conditions, 173
- function of two random variables, 206
 - image, 206
 - inverse image, 206
 - conditions, 206
 - steps for determining $F_Z(z)$, 207
- gambler's ruin, 518
- gamma function, 99
 - incomplete, 100
- Gaussian approximation to binomial distribution, 91
 - Demoivre–Laplace limit theorem, 91
- Gaussian distribution, 84
 - density function, 84
 - distribution function, 84
 - mean, 84
 - standard, 85
 - properties, 87
 - tails function $Q(x)$, 88
 - lower bound, 89
 - properties, 90
 - upper bound, 89
 - variance, 84
- Gaussian process, 521
 - properties, 521
- generating functions, 161
 - examples, 162
 - binomial distribution, 163
 - geometric distribution, 164
 - Poisson distribution, 163
 - moment generating properties, 162
- Gibbs' distribution, 118, 674
 - potential function, 674
 - Incosh, 674
 - sigmoid, 675
- Gibbs' prior, 667
- higher order moments, 153
 - cross moments, 154
- Hilbert transform, 607
 - table, 610
- histograms, 266
- hypothesis testing, 373
 - acceptance region, 374
 - alternate hypothesis, 373
 - binary, 375
 - composite hypothesis, 374
 - cost for errors, 401
 - mean μ —known variance σ^2 , 378
 - mean μ —unknown variance σ^2 , 379
 - ML rule, 394
 - number of samples n for given α and β , 382
 - null hypothesis, 373
 - operating characteristic, 376
 - power of the test, 376
 - procedure for testing, 378
 - rejection region, 374
 - significance testing, 373, 374
 - simple hypothesis, 374
 - statistic, 373
- image, 64
- independence, 4, 18
 - functional, 4, 18
 - statistical, 4, 18
- independent increment process, 507
 - stationary independent increment, 507
- indicator function, 205, 243
 - properties, 205
- inequalities, 242
 - Cauchy–Schwartz, 251
 - frequency domain, 253
 - Chebyshev, 242
 - geometric derivation, 243
 - generalized Chebyshev, 244
 - Jensen, 254
 - Markov, 246
- innovations process, 648
- interval estimation, 364
- inverse Hilbert transform, 607
- inverse image, 64
- inverse problem $g(x)$ from $f_X(x)$ and $f_Y(y)$, 200
- inverse transformation, 269
 - discrete distributions, 270
 - continuous distributions, 272
 - exponential distribution, 272
 - Rayleigh distribution, 274
 - Weibull distribution, 273
- tables, 278
- Jacobian determinant, 227, 230, 233
- Jacobian matrix, 227, 230, 233
- joint cumulants, 169
- joint distribution, 135
 - continuous distribution, 136
 - discrete distribution, 135

- joint distribution (*Continued*)
 - joint probability mass function, 135
 - marginal distribution, 135
 - properties, 137
 - region bounded by a function, 140
 - regions bounded by constants, 138
 - regions bounded by functions, 141
- joint distribution of two vectors, 312
- joint moments of two random vectors, 321
 - cross correlation matrix, 321
 - cross covariance matrix, 322
- joint Gaussian density, 213

- Karhunen–Loeve transform, 565
 - continuous, 565
 - discrete, 571
 - matrix formulation, 572
- Kolmogorov axioms, 11
 - Boolean additivity, 11
 - non negativity, 11
 - normalization, 11
 - sigma additivity, 11
- kurtosis, 168

- Lagrange multipliers, 351
- likelihood function, 341
- log likelihood function, 341
- limit theorems, 259
 - central limit theorem, 260
 - strong law of large numbers, 260
 - weak law of large numbers, 259
- linear filters, 592
 - carrier frequency, 592
 - cut-off frequency, 592
 - ideal band-pass, 592
 - ideal high-pass, 592
 - ideal low-pass, 592
 - matched filters, 596
- linear systems, 574
 - causal system, 574
 - convolution integral, 574
 - impulse response, 574
 - state transition matrix, 575
 - transfer function, 575
- linear regression, 343
 - evaluating coefficients, 343
 - multiple, 343
 - simple, 343, 360
 - estimated regression line, 361
 - variance of regression coefficients, 362
- linear transformations, 328

- marginal distributions, 142, 143
- Markov chains, 536
 - classification of states, 544
 - absorbing state, 544
 - aperiodic, 545
 - ergodic, 545
 - intercommunicating, 544
 - irreducible, 544
 - periodic, 545
 - recurrent, 545
 - reducible, 544
 - transient, 545
 - discrete, 536
 - first passage probability, 544
 - first return probability, 545
 - homogeneous, 536
 - mean first passage time, 545
 - mean recurrence time, 545
 - null recurrent, 545
 - positive recurrent, 545
 - m -step transition probability, 536
 - steady state, 539
 - properties, 550
 - state occupancy probabilities, 538
 - stochastic matrix, 537
- Markov process, 527
 - AR process, 534
 - Chapman–Kolmogorov equation, 528
 - homogeneous, 529
 - Markov property, 527
 - Poisson process, 532
 - properties, 530
 - transition probability density, 528
 - Wiener process, 533
- martingale process, 551
 - continuous martingale, 552
 - discrete martingale, 552
 - likelihood ratio martingale, 555
 - Poisson martingale, 554
 - random walk, 553
 - Wiener martingale, 554
- Mass megabucks, 46
- matched filters, 596
 - input signal to noise ratio, 597
 - non-white Gaussian noise, 604
 - output signal to noise ratio, 597
 - properties, 599
 - rectangular pulse, 600
 - sinusoidal pulse, 600
- matrices, 284
 - addition, 285
 - adjoint, 291
 - characteristic equation, 293
 - characteristic polynomial, 293
 - definiteness, 295
 - negative definite, 295

- positive definite, 295
 - definition, 284
 - determinant, 286
 - properties, 287
 - diagonalization, 298
 - inverse, 290
 - properties, 292
 - multiplication, 285
 - orthogonal, 293
 - principal minors, 295
 - rank, 288
 - similarity transformation, 300
 - singular, 287
 - square, 284
 - symmetric, 299
 - properties, 299
 - trace, 288
 - transpose, 286
- means and variances table, 170
- means of estimated autocovariances, 449
- minimum mean square estimator
 - mean, 353
- mixed distributions, 118
- modal matrix, 297
- modified Bessel function $I_0(z)$, 107, 217, 621
- modulation, 434
- moment generating functions, 164
 - gamma distribution, 167
 - Gaussian distribution, 166
 - negative binomial, 165
- Monty Hall problem, 22
- multiple functions of random variables, 238
- narrowband bandpass process, 612
 - analytic signal representation, 615
 - complex envelope, 615
 - natural envelope representation, 618
 - quadrature representation, 614
 - properties, 615
 - with additive sinusoid, 619
- normal equations, 344
- operating characteristic, 376
- orthogonal increment processes, 508
- orthogonality principle, 346
 - random processes, 626
 - random variables, 625
- Paley–Wiener criterion, 593, 631
- partial differentiation, 304
 - complex vectors, 305
 - real matrices, 308
 - real vectors, 301
- periodic random processes, 557
 - stationary, 558
- permutations, 26
 - sampling with replacement, 26
 - sampling without replacement, 26
- Poisson process, 491, 492, 508
 - formal derivative, 503
 - generalized, 501
 - autocorrelation, 502
 - autocovariance, 503
 - mean, 502
 - interarrival time, 496
 - distribution, 496
 - waiting time, 496
 - distribution, 497
- Poisson white noise, 504
- Polya urn model, 534
- power spectral density, 472
- predictable process, 557
- probability, 10
 - conditional, 14
 - reduced sample space, 14, 17
 - density, 13
 - distribution function, 13
 - measure, 11
 - space, 10
 - total, 20
- probability mass function, 38, 74
- pseudoinverse, 338
- quadrature components
 - properties, 615
- quadratic error surface, 307
- quadratic form, 302
- random binary wave, 429
- random number generator, 264
 - properties, 265
- random processes, 406
 - bandpass processes, 606
 - classification, 490
 - continuous state continuous time, 491
 - continuous state discrete time, 491
 - discrete state continuous time, 491
 - discrete state discrete-time process, 490
 - definition, 406
 - distribution and density, 408
 - estimation of parameters, 445
 - continuous time processes, 445
 - autocovariance, 447
 - covariance, 452
 - variance, 454

- random processes (*Continued*)
 - mean, 446
 - variance, 446
 - discrete time processes, 458
 - autocovariance, 459
 - estimation, 461
 - Lagrange multiplier, 459
 - mean, 458
 - higher order distributions, 414
 - independent, 416
 - means and variances, 408
 - normalized autocovariance, 416
 - normalized cross covariance, 416
 - orthogonal, 417
 - second order moments, 415
 - autocorrelation, 415
 - autocovariance, 415
 - cross correlation, 416, 435
 - cross covariance, 416
 - normalized autocovariance, 416
 - normalized cross-covariance, 416
 - second order process, 414
 - through linear systems, 578
 - cross spectral density, 580
 - output power spectral density, 580
 - threshold filter, 588
 - uncorrelated, 417
- random telegraph wave, 432
- random variable, 64
 - conditional moments, 146
 - conditional expectation, 148
 - conditional variance, 149
 - continuous, 79
 - correlation coefficient, 150
 - covariance, 150
 - definition, 64
 - degenerate, 241
 - discrete, 37
 - independent, 147
 - distribution and density, 66
 - properties, 73
 - moments, 146
 - expectation, 146
 - properties, 147
 - joint, 148
 - variance, 149
 - properties, 149
 - orthogonal, 147
 - uncorrelated, 147
- random vectors, 311
 - Bayes theorem, 316
 - conditional density, 328
 - inner product, 320
 - independent, 323
 - joint density, 313, 326
 - moments, 319
 - correlation matrix, 319
 - properties, 324
 - covariance matrix, 320
 - properties, 324
 - expectation vector, 319
 - orthogonal, 323
 - outer product, 320
 - uncorrelated, 323
- random walk process, 490, 512
 - elementary, 509
 - symmetric, 510
 - two absorbing barriers, 514
 - unrestricted, 512
- Rayleigh density, 215, 621
- Rayleigh distribution, 215, 232, 619
- recursive estimation, 648
- regression coefficients, 343
- Rice's density, 217, 621
- Rice's distribution, 217, 621
- sample space, 10
 - continuous, 10
 - discrete, 10
- sample variance, 354
- set, 1
 - cardinality, 2
 - unions and intersections, 5
 - Cartesian product, 7
 - complement, 6
 - De Morgan's laws, 6
 - difference, 6
 - element, 1
 - empty set, 2
 - equal, 3
 - event, 9
 - finite, 1
 - inclusion–exclusion principle, 5
 - intersection, 4
 - mutually exclusive, 4
 - null, 11
 - partition, 7
 - power set, 3
 - relative complement, 6
 - subset, 2
 - symmetric difference, 7
 - table of set properties, 8
 - union, 3
 - universal, 2
 - Venn diagram, 2
- shaping filter, 580
- signal to noise ratio, 253, 597
- significance level, 351, 364, 374
- similarity transformations, 300
- skewness, 168

- solution of linear equations, 291
- special methods, 274
 - Box–Mueller transformation, 275
 - Gaussian distribution, 275
 - Rayleigh distribution with phase, 277
- spectral density–continuous time, 472
 - bandlimited process, 475, 476
 - bandpass process, 477
 - cross spectral density, 473
 - power spectral density, 473
 - alternate form, 480
 - estimation, 482
 - periodogram, 480
 - properties, 479
 - white noise, 478
 - Wiener–Khinchine theorem, 472
- spectral density–discrete time, 484
 - power spectral density, 484
 - alternate form, 486
 - discrete white noise, 488
- spectral factorization, 633
 - additive factoring, 634
 - multiplicative factoring, 633
- standard error, 355
- stationary random processes, 420
 - autocorrelation, 421
 - autocovariance, 421
 - cross correlation, 422
 - cross covariance, 422
 - first order, 420
 - independent, 421
 - mean, 421
 - normalized autocovariance, 421
 - normalized cross covariance, 422
 - n th order stationary, 420
 - orthogonal, 421
 - periodic, 423
 - properties of correlation
 - functions, 422
 - second order, 420
 - strict sense, 420
 - uncorrelated, 421
 - variance, 421
 - wide sense, 420
- stochastic estimation algorithm, 671
 - expectation step, 671
 - maximization step, 672
- strong law of large numbers, 260
- submartingale, 552
 - decomposition, 557
- supermartingale, 552
- tables
 - cumulative binomial, 708
 - cumulative Gaussian, 687
 - cumulative Poisson, 704
 - Fourier transform, 683
 - inverse chi-square, 694
 - inverse Gaussian, 692
 - inverse Student- t , 701
- tails probability, 242
- total probability for densities, 131
- transmission tomography
 - computer simulation, 676
 - pathlength matrix, 676
 - backward, 677
 - forward, 677
 - phantom description, 676
 - probability model, 668
 - reconstructed images, 679
 - cross sectional histograms, 680
 - RMS error, 680
- two functions of two random variables, 222
 - conditions, 223
 - auxiliary random variable, 233
 - derivation of Student- t , 237
- type I error, 374
 - false alarm, 374
 - producer's risk, 374
- type II error, 374
 - consumer's risk, 374
 - missed alarm, 374
- uncorrelated increment process, 508
- uniform distribution, 264
- variance of the estimated regression line, 360
- vector Gaussian random variables, 323
- weak law of large numbers, 259
- weighted Poisson process, 501
- white Gaussian noise, 521
- whitening filter, 632
- white noise process, 422
- Wiener filtering, 627
 - causal, 631
 - filtering, 627, 638
 - noncausal, 627
 - prediction, 627, 641
 - smoothing, 627, 642
- Wiener–Hopf integral equation, 632
 - filtering solution, 634
 - prediction-smoothing solution, 637
- Wiener process, 523
 - conditions, 523
 - derivation, 524
 - formal derivative, 526
 - properties, 526