

Index

A

- adjusted coefficient of determination, 166–167
- Agresti–Coull confidence interval, 321–322
- Akaike’s information criterion (AIC), 486–487, 520–521
- Akaike, Hirotugu, 486
- aligning, 262
- ANOVA table, 56–59, 92–93, 114–116, 166
- Anscombe’s quartet, 93–95, 118, 120, 121, 130, 135, 206
- Anscombe, Francis, 93
- ar (autoregression) function, 515–517, 523, 524, 549, 550, 553, 559, 576, 577, 590, 593
- AR(p) models, 457, 561–592
 - as MA(∞) models, 562–564
 - comparison with MA(q) models, 621
 - confidence intervals, 578–583
 - definition, 561
 - forecasting, 588–591
 - model assessment, 583–588
 - parameter estimation, 573–583
 - least squares estimators, 576–577
 - maximum likelihood estimators, 577–583
 - method of moments, 573–576
 - population autocorrelation function, 564–567
 - population partial autocorrelation function, 567–569
 - residuals, 583–588
 - shifted, 569–570
 - simulation, 570–573
 - stationarity, 562
- AR(1) models, 493–526
 - as MA(∞) models, 495
 - confidence intervals, 515–517
 - definition, 493
 - forecasting, 521–525
 - model assessment, 517–520
 - model selection, 520–521
 - parameter estimation, 507–516
 - least squares estimators, 508–511
 - maximum likelihood estimators, 511–515
 - method of moments, 507–508
 - population autocorrelation function, 497
 - population partial autocorrelation function, 497–499
 - residuals, 517–520
 - shifted, 499
 - simulation, 499–503
 - stationarity, 494–497
- AR(2) models, 526–561
 - as MA(∞) models, 535–536
 - confidence intervals, 550–552
 - definition, 526
 - forecasting, 557–560
 - geometry, 532, 534, 546
 - model assessment, 552–555
 - model selection, 555–557
 - parameter estimation, 544–552
 - least squares estimators, 546–548
 - maximum likelihood estimators, 548–552
 - method of moments, 544–546
 - population autocorrelation function, 529–533
 - population partial autocorrelation function, 533–535
 - residuals, 552–555
 - shifted, 536–537
 - simulation, 537–541
 - stationarity, 527–529
- arma function, 520, 551, 556, 582, 583, 585, 593, 617, 622–626, 631
- ARIMA(p, d, q) models, 631–635
 - definition, 632
- ARMA(p, q) models, 456–465, 621–627
 - forecasting, 626–627
 - model assessment, 623–626
 - shifted, 463–465, 622
- asymptotic properties, 256–258, 551–552
- autocorrelation function, *see* population autocor-

- relation function, sample autocorrelation function
- autocovariance function, *see* population autocovariance function, sample autocovariance function
- autoregressive models, 492–594
- B**
- backshift operator, 425, 448–451, 495–496
- baseline hazard function, 242, 290–306
- bathhtub-shaped hazard function, 217–218
- Bayesian information criterion (BIC), 487
- bivariate normal distribution, 537–538
- Box, George, 5, 142, 631
- Box–Cox transformation, 142
- Box–Pierce test, 482–483, 518–519, 553, 623–624
- Brown, Robert, 378
- Brown–Forsythe test, 205
- Brownian motion, 378
- C**
- categorical independent variables, 162–163
- Cauchy–Schwarz inequality, 12, 68
- causality, 451–456, 494–495
- censoring, 259–265
 - interval censoring, 260
 - left censoring, 260
 - right censoring, 259–265
 - likelihood function, 263
 - random censoring, 260
 - Type I censoring, 260
 - Type II censoring, 259
- characteristic polynomials, 457–460
- Clopper–Pearson confidence interval, 321–322
- Cochran’s theorem, 92
- Cochran, William, 92
- coefficient of correlation, 53–59, 116, 148
- coefficient of determination, 53–59, 116, 148, 166–167
- comparing two survivor functions, 329–332
- competing risks, 332–342
 - crude lifetimes, 335–337
 - general case, 338–342
 - net lifetimes, 333–334
- complete data sets, 266–273, 318–323
- conditional intensity function, 354
- conditional survivor function, 212–213
- confidence intervals
 - in simple linear regression, 69–90
 - in survival analysis, 269, 272, 275, 280–285
 - in time series analysis, 472–476, 515–517
- confidence regions
 - in simple linear regression, 90–91
 - in survival analysis, 288
- Cook’s distances, 134–139
- Cook, R. Dennis, 134
- corrected Akaike’s information criterion (AICC), 487
- counting function, 344
- counting process, 344
- covariates, *see* proportional hazards model
- Cox proportional hazards model, *see* proportional hazards model
- Cox, David, 142, 241, 329
- coxph (Cox proportional hazards) function, 302, 305
- crude lifetimes, 335–337
- cumulative hazard function, 219
- cumulative intensity function, 350
- D**
- decomposition, 434–440
- dependent variable, 2, 6–9
- design matrix, 146, 158
- deterioration, 343
- deterministic models, 2–4
- detrending filters, 422–426
- DFR class, 216, 343
- diagnostics, 128–139, 480–486
- Dickey–Fuller test, 633
- difference–sign test, 491
- differencing, 425–426, 631–640
- duality, 495, 562–564
- Durbin–Watson test, 490
- E**
- Einstein, Albert, 378
- empirical survivor function, 319–323
- exponential distribution, 220–227, 231
 - hypothesis testing, 278
 - lifetime distribution representations, 220
 - memoryless property, 221–222
 - moments, 223–224
 - parameter estimation, 266–285
 - complete data sets, 266–273

- randomly censored data sets, 281–285
 - Type I censored data sets, 279–281
 - Type II censored data sets, 274–279
 - self-reproducing property, 224–225
- exponential power distribution, 233
- exponentially-weighted moving average, 432–433
- F**
- filtering, 419–434
- Fisher information matrix, 197, 269, 274, 279, 286, 292
- Fisher, Ronald, 470
- fitted values, 32–38, 148
- Forbes, James, 44
- forecasting, 476–480
 - geometry, 477
 - prediction intervals, 478–480
- forward stepwise regression, 171–172
- G**
- Galton, Francis, 105
- gamma distribution, 232
- Gauss, Carl Friedrich, 9
- Gaussian white noise, 371
- general linear models, 446–456
- generalized Pareto distribution, 234
- glm (generalized linear model) function, 198
- Gompertz distribution, 234
- Greenwood's formula, 328–329
- H**
- Haenszel, William, 329
- hat matrix, 129, 150, 159
- hazard function, 214–219
 - bathtub-shaped, 217–218
- Hessian matrix, 11, 67–68
- hyperexponential distribution, 235
- hypergeometric distribution, 330
- hypoexponential distribution, 235
- I**
- IDB distribution, 234
- idempotent matrix, 159
- IFR class, 216, 343
- iid noise, 371
- improvement, 343
- independent increments, 345
- independent variables, 2, 6–9
- inference concerning β_0 , 76–80, 116–117
- inference concerning β_0 and β_1 , 90–91, 117–118, 150
- inference concerning β_1 , 72–76, 101–102, 116–117
- inference concerning σ^2 , 69–72, 116, 149
- inference concerning $E[Y_h]$, 80–84, 102–103, 149
- inference concerning Y_h^* , 85–90, 103–105, 149
- inference in simple linear regression, 64–118
- influential points, 134–139
- information matrix, *see* Fisher information matrix, observed information matrix
- intensity function, 343, 350–355
- interaction terms, 163–165
- interval censoring, 260, 312
- inverse Gaussian distribution, 233, 254–255, 257
- invertibility, 451–456, 461–463
- J**
- Jeffreys Bayesian credible interval, 321–322
- Jenkins, Gwilym, 631
- K**
- Kaplan, Edward, 324
- Kaplan–Meier estimator, 324–329
- Kepler, Johannes, 207
- L**
- least absolute deviation criterion, 61
- least squares estimators, 9–17, 469, 508–511, 546–548, 576–577
 - geometry, 12, 16–17, 157
 - in matrix form, 147, 158
 - properties, 18–32, 158–159
 - Gauss–Markov theorem, 29–32, 148, 158
 - linear combinations, 22–25, 147, 158
 - unbiasedness, 18–22, 147, 158
 - variance–covariance matrix, 25–29, 147, 158
- left censoring, 260
- Legendre, Adrien–Marie, 9
- leverage, 128–134, 159
 - definition, 129
- lifetime distribution representations, 210–219
 - cumulative hazard function, 219
 - hazard function, 214–219
 - probability density function, 213–214
 - survivor function, 212–213
- likelihood ratio statistic, *see* log likelihood function

- likelihood theory, 253–255
- linear filters, 427–433
- Ljung–Box test, 483, 518–519, 553, 623–624
- lm (linear model) function, 15, 20, 33, 35, 44, 46, 49, 57, 72, 75, 76, 79, 83, 84, 88, 94, 97, 107, 113, 126, 131, 141, 161, 169, 179, 180
- log likelihood function, 282–285, 287–288
- log logistic distribution, 233
- log normal distribution, 233
- log-log model, 191–193
- log-rank test, 329–332
- logistic regression, 189–203
 - interpreting coefficients, 194–196, 200–203
 - log-log model, 191–193
 - logit model, 191–193
 - odds, 200–203
 - parameter estimation, 196–200
 - probit model, 191–193
- logit model, 191–193
- M**
- MA(q) models, 457, 618–621
 - comparison with AR(p) models, 621
 - definition, 618
 - invertibility, 620
 - population autocorrelation function, 620
 - shifted, 620
 - simulation, 620
 - stationarity, 620
- MA(1) models, 595–614
 - as AR(∞) models, 600
 - confidence intervals, 612–614
 - definition, 595
 - invertibility, 599–600
 - parameter estimation, 607–614
 - least squares estimators, 610–612
 - maximum likelihood estimators, 612–614
 - method of moments, 607–610
 - population autocorrelation function, 596–599
 - population partial autocorrelation function, 601–602
 - shifted, 602
 - simulation, 602–607
 - stationarity, 596–599
- MA(2) models, 615–618
 - definition, 615
 - invertibility, 615
 - model selection, 616–618
 - population autocorrelation function, 616
 - shifted, 615
 - simulation, 616
 - stationarity, 615
- Makeham distribution, 234
- Mantel, Nathan, 329
- Mantel–Haenszel test, *see* log-rank test
- matrix approach
 - in survival analysis, 290, 296
 - to multiple linear regression, 157–159
 - to simple linear regression, 146–155
 - to weighted least squares, 174–175
- maximum likelihood estimators, 65–69, 149, 159, 196–200, 254–255, 267, 274, 280, 285, 291, 469–476, 511–515, 548–552, 577–583
- mean square error, 40–41
- Meier, Paul, 324
- memoryless property, 221–222
- method of moments, 468–469, 507–508, 544–546, 573–576
- Mill’s ratio, 214
- model selection
 - in multiple linear regression, 171–172
 - in time series analysis, 486–488
- moment ratio diagrams, 235–241
- Monte Carlo simulation, 19–22, 28–29, 48–50, 61, 118–120, 204, 206, 223, 247, 248, 308, 309, 360, 362, 363, 373, 443, 444, 475, 489, 490, 499–503, 537–541, 570–573, 616–618, 647
- moving average, 427–433
- moving average models, 594–621
- multicollinearity, 167–171
- multiple linear regression, 155–172
 - adjusted coefficient of determination, 166–167
 - ANOVA table, 166
 - categorical independent variables, 162–163
 - coefficient of determination, 166–167
 - examples, 155
 - fitted values, 158
 - geometry, 156
 - hat matrix, 159
 - interaction terms, 163–165
 - interpreting coefficients, 160
 - least squares estimators, 158

matrix approach, 157–159
 maximum likelihood estimators, 159
 model, 156, 158
 model selection, 171–172
 multicollinearity, 167–171
 nonlinear terms, 161
 normal equations, 158
 normal error terms, 157, 159
 residuals, 159
 variance inflation factors, 168–170
 multivariate normal distribution, 381, 570–573
 Muth distribution, 231

N

net lifetimes, 333–334
 nls (nonlinear least squares) function, 185
 noise terms in time series analysis
 Gaussian white noise, 371
 iid noise, 371
 white noise, 371
 nonhomogeneous Poisson processes, 350–355
 noninformative censoring, *see* randomly censored data sets
 nonlinear least squares, 184–185
 nonparametric methods, 318–332
 nonstationary time series models, 627–640
 ARIMA(p, d, q) models, 631–635
 detrending, 627–631
 SARIMA models, 635–640
 normal equations, 10, 147, 158
 normal error terms, 64–65, 149, 157
 normalized spectral density function, 644–645
 Nyquist frequency, 642

O

observed information matrix, 197, 269, 274, 279, 282, 286, 292
 odds, 200–203
 overdispersed renewal processes, 347

P

Pareto distribution, 233
 partial autocorrelation function, *see* population partial autocorrelation function, sample partial autocorrelation function
 partitioning the total sum of squares, 51–59, 148
 geometry, 152
 periodogram, 645–649
 Peto, Julian, 332

point processes, 342–355
 nonhomogeneous Poisson processes, 350–355
 Poisson processes, 345–346
 renewal processes, 346–350
 Poisson processes, 345–346
 population autocorrelation function, 380–388, 497, 529–533, 564–567
 population autocovariance function, 380–388
 population mean function, 382
 population partial autocorrelation function, 411–417, 497–499, 533–535, 567–569
 prediction intervals
 in simple linear regression, 87, 104
 in survival analysis, 308
 in time series analysis, 478–480, 522–525
 probability density function, 213–214
 probit model, 191–193
 product-limit estimator, 324–329
 proportional hazards model, 241–244, 290–306
 known baseline function, 291–297
 unknown baseline function, 297–306

Q

QQ plot, 100, 109–111, 114, 143
 quadratic regression, 180–182

R

random variate generation, *see* Monte Carlo simulation
 random walk, 372–376, 385–386, 388
 randomly censored data sets, 281–289
 rank vector, 299
 Rayleigh distribution, 263–265, 315
 redistribute-to-the-right algorithm, 326–327
 regression, *see* simple linear regression, multiple linear regression
 regression function, 6
 regression models with nonlinear terms, 180–188
 nonlinear least squares, 184–185
 quadratic regression, 180–182
 transformation technique, 182–184
 regression through the origin, 122–128
 sum of squares for error, 128
 regression to the mean, 105
 remedial procedures, 140–145
 renewal processes, 346–350
 overdispersed, 347

- underdispersed, 347
- residuals, 33–38, 47, 98–101, 108–111, 148, 480–486
 - standardized, 108–110, 113–114, 143
- ridge regression, 170–171
- right censoring, 259–265
 - estimating $S(t)$, 323–329
 - likelihood function, 263
 - random censoring, 260, 281–285
 - Type I censoring, 260, 279–281
 - Type II censoring, 259, 274–279
- S**
- sample autocorrelation function, 399–411, 482–483
- sample autocovariance function, 399–411
- sample partial autocorrelation function, 417–418
- SARIMA models, 635–640
- scatterplot, 13–14, 97, 107, 111–113
- seasonal moving average, 430–431
- Shapiro–Wilk test, 101, 110, 114, 143, 485
- shifted AR(p) models, 569–570
- shifted AR(1) models, 499
- shifted AR(2) models, 536–537
- shifted ARMA(p, q) models, 463–465, 622
- simple linear regression, 2–59
 - ANOVA table, 56–59, 92–93, 114–116
 - coefficient of correlation, 53–59, 116, 148
 - coefficient of determination, 53–59, 116, 148
 - diagnostics, 128–139
 - influential points, 134–139
 - leverage, 128–134
 - fitted values, 32–38, 148
 - geometry, 12, 16–17, 51, 65, 81–82, 152
 - hat matrix, 129
 - inference in, 64–118
 - concerning β_0 , 76–80, 116–117
 - concerning β_0 and β_1 , 90–91, 117–118, 150
 - concerning β_1 , 72–76, 101–102, 116–117
 - concerning σ^2 , 69–72, 116, 149
 - concerning $E[Y_h]$, 80–84, 102–103, 149
 - concerning Y_h^* , 85–90, 103–105, 149
 - least squares estimators, 9–17, 147
 - matrix approach, 146–155
 - maximum likelihood estimators, 65–69, 149
 - mean square error, 40–41, 148
 - model, 6–9, 147
 - normal equations, 10, 147
 - normal error terms, 64–65, 149
 - partitioning the total sum of squares, 51–59, 148, 152
 - procedure, 7–8
 - regression through the origin, 122–128
 - remedial procedures, 140–145
 - residuals, 33–38, 47, 98–101, 108–111, 113–114, 148
 - sum of squares for error, 40–41, 52–59
 - sum of squares for regression, 52–59
 - total sum of squares, 52–59
 - variance of error terms, 39–51
 - with nonlinear terms, 180–188
- spectral analysis, 641–649
 - periodogram, 645–649
 - spectral density function, 642–645
- spectral density function, 642–645
- stationarity, 388–399, 461–463
 - covariance, 391
 - second-order, 391
 - strict, 389
 - weak, 391
- statistical models, 5–6
- stepwise regression, 171–172
- sum of squares for error, 40–41, 52–59, 152
- sum of squares for regression, 52–59, 152
- superpositioning, 354–355
- survfit (fit survival curve) function, 326, 329
- survival analysis
 - probability models, 210–244
 - statistical methods, 253–306
 - topics in, 318–355
- survivor function, 212–213
- survivor function estimation
 - complete data sets, 318–323
 - right-censored data sets, 323–329
- T**
- time series analysis
 - basics, 366–442
 - classification, 377–378
 - goals, 376–377
 - computing, 378–380, 418, 440–442, 592–594
 - nonstationary models, 627–640
 - ARIMA(p, d, q) models, 631–635
 - detrending, 627–631

- SARIMA models, 635–640
- operations, 419–442
 - backshift operator, 425, 448–451
 - decomposition, 434–440
 - detrending filters, 422–426
 - differencing, 425–426
 - exponentially-weighted moving average, 432–433
 - filtering, 419–434
 - linear filters, 427–433
 - moving average, 427–433
 - seasonal moving average, 430–431
 - transformations, 420–422
- probability models, 446–465
 - AR(p) models, 457, 561–592
 - AR(1) models, 493–526
 - AR(2) models, 526–561
 - ARMA(p, q) models, 456–465, 621–627
 - general linear models, 446–456
 - MA(q) models, 457, 618–621
 - MA(1) models, 595–614
 - MA(2) models, 615–618
 - shifted ARMA(p, q) models, 463–465
- properties, 380–418
 - causality, 451–456
 - invertibility, 451–456, 461–463, 599–600, 620
 - population autocorrelation function, 380–388, 497, 529–533, 564–567, 596–599, 620
 - population autocovariance function, 380–388
 - population partial autocorrelation function, 411–417, 497–499, 533–535, 567–569, 601–602
 - sample autocorrelation function, 399–411
 - sample autocovariance function, 399–411
 - sample partial autocorrelation function, 417–418
 - stationarity, 388–399, 461–463, 494–497, 527–529, 562, 596–599, 620
- spectral analysis, 641–649
 - periodogram, 645–649
 - spectral density function, 642–645
- statistical methods, 466–488
 - forecasting, 476–480, 521–525, 557–560, 588–591, 626–627
 - model assessment, 480–486, 517–520, 552–555, 583–588, 623–626
 - model selection, 486–488, 520–521, 555–557
 - parameter estimation, 466–476, 507–516, 544–552, 573–583, 607–614
 - total sum of squares, 52–59, 152
 - transformations, 420–422
- Tucker, Justin, 189
- turning point test, 483–484, 519, 554–555, 624–625
- Type I censored data sets, 279–281
- Type II censored data sets, 274–279
- U**
 - underdispersed renewal processes, 347
 - uniform distribution, 233
 - unit roots analysis, 461–463, 496, 562
- V**
 - variance inflation factors, 168–170
 - variance of error terms, 39–51
- W**
 - Wald confidence interval, 321–322
 - Walker, Gilbert, 529
 - Weibull distribution, 215–216, 223, 227–231, 231
 - lifetime distribution representations, 227–228
 - moments, 229
 - parameter estimation, 285–289
 - self-reproducing property, 231
 - Weibull, Waloddi, 227
 - weighted least squares, 172–180, 185–188
 - estimators, 174
 - matrix approach, 174–175
 - normal equations, 173–174
 - white noise, 371
 - Wilson–score confidence interval, 321–322
 - Working–Hotelling confidence band, 121
- Y**
 - Yule, George, 529
 - Yule–Walker equations, 529–530, 567, 574
 - Yule–Walker estimators, 567, 574