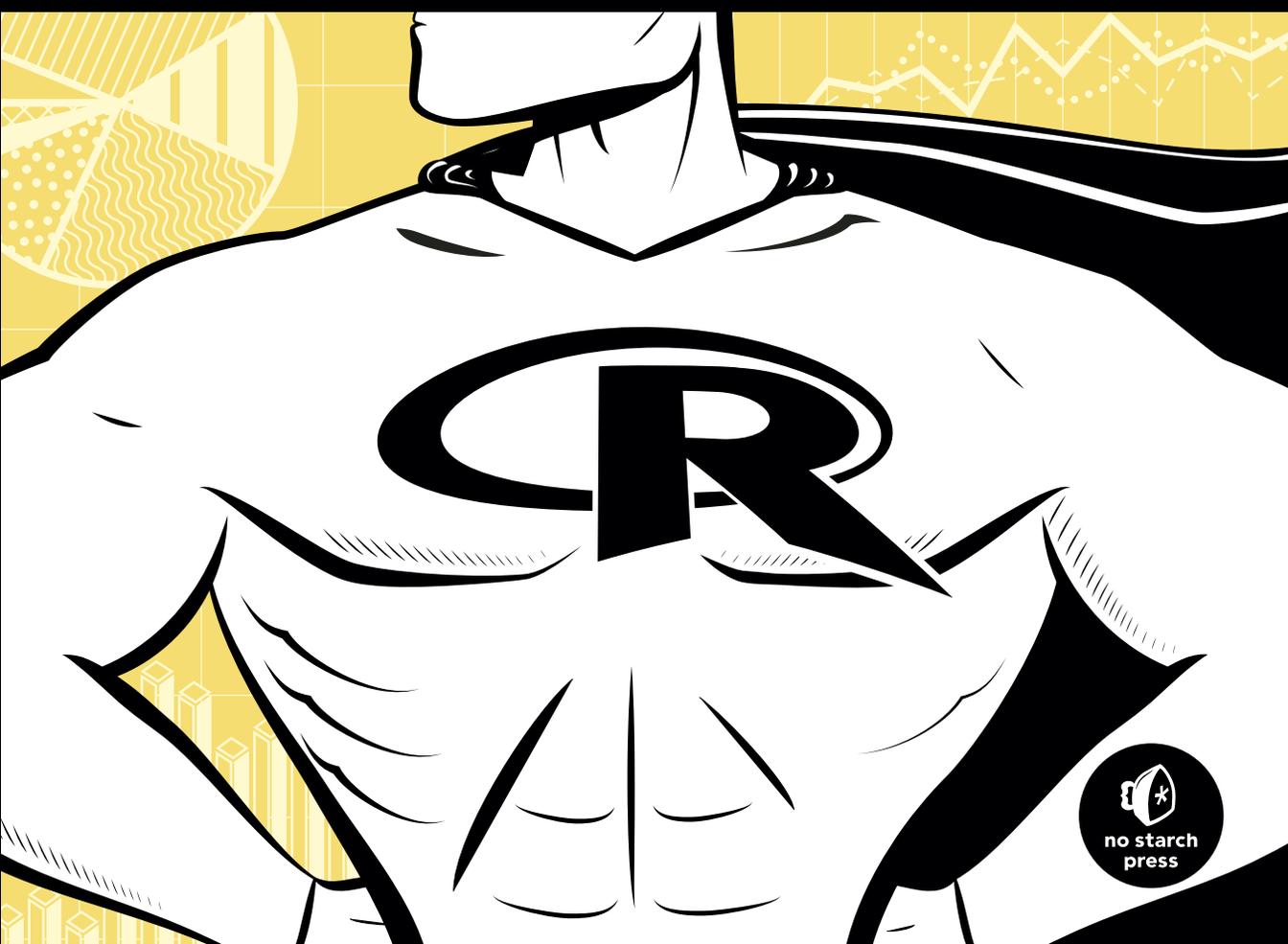


THE ART OF R PROGRAMMING

A TOUR OF STATISTICAL SOFTWARE DESIGN

NORMAN MATLOFF



INDEX

Special Characters

- : (colon operator), 32–33
- == operator, 54–55
- > operator, 40
- .libpaths() function, 356–357
- .Rdata file, 20
- .Rhistory file, 20
- .Rprofile file, 19
- <<- (superassignment operator), 9
 - simplifying code, 174
 - writing to nonlocals with, 161–162
- + operator, 31
- "%mut%"() function, 218

A

- abalone data set
 - recoding, 51–54
 - using lapply() function, 99
- abline() graphics function, 150
- abs() math function, 189
- accessing
 - data frames, 102–104
 - files on remote machines via
 - URLs, 243
 - Internet, 246–250
 - implementing parallel R example, 248–250
 - sockets, 247–248
 - TCP/IP, 247
 - keyboard and monitor, 232–235
 - using print() function, 234–235
 - using readline() function, 234
 - using scan() function, 232–234
 - list components and values, 93–95
- actual argument, 9
- adding
 - legends to graphs with legend() function, 270
 - lines with abline() function, 263–264
 - list elements, 88–90
 - matrix rows and columns, 73–78
 - points to graphs with points() function, 269–270
 - text to graphs with text() function, 270–271
- addmargins() function, 131
- adjacency matrix, 333
- aggregate() function, 136
- all() function, 35–39
- analogous operations, resizing
 - matrices, 74
- anonymous functions, 99, 187–188
- antibugging, 287
- any() function, 35–39
- application-specific functions, 165
- apply() function
 - applying functions to matrix rows and columns, 70–72
 - matrix-like operations, 107
 - obtaining variable marginal values, 131
- arguments. *See also specific argument by name*
 - actual, 9
 - default, 9–10
 - default values for, 146–147
 - formal, 9
- arithmetic operations, 30–31, 145–146
- array() function, 134
- arrays
 - higher-dimensional arrays, 82–83
 - as vectors, 28
- as.matrix() function, 81
- aspell() function, 211
- assign() function
 - variables, 109
 - writing nonlocals with, 163

atomic pragma, 343
atomic vectors, 85–86
attr() function, 212

B

batch mode, 1
 help feature, 24
 running R in, 3
Bernoulli sequence, 204
biglm package, 321
bigmemory package, 321
binary files, 237
binary search tree, 177–182
body() function, 149, 151
Boolean operators, 145–146
braces, 144
brackets, 87–88
Bravington, Mark, 300
breakpoints, setting, 289–290
 calling browser() function directly,
 289–290
 using setbreakpoint() function, 290
breaks component, hist() function, 14
break statement, 141
browser commands, 289
browser() function
 setting breakpoints, 289–290
 single-stepping through code, 288
by() function, 126–127
byrow argument, matrix() function,
 61, 236
byte code compilation, 320

C

c %in% y set operation, 202
cache, 346
calculus, 192–193
categorical variables, 121
cbind() function, 12, 74–75, 106–107
c browser command, 289
cdf (cumulative distribution
 function), 193
ceiling() math function, 190
cell counts, changing to
 proportions, 130
cex option, changing graph character
 sizes with, 272–273
c() function, 56–57
Chambers, John, 226

character strings, 251–259
 defined, 11
 regular expressions, 254–257
 forming filenames example,
 256–257
 testing filename for given suffix
 example, 255–256
 string-manipulation functions,
 251–254
 gregexpr(), 254
 grep(), 252
 nchar(), 252
 paste(), 252–253
 regexpr(), 253–254
 sprintf(), 253
 strsplit(), 253
 substr(), 253
 use of string utilities in edtdbg debug-
 ging tool, 257–259
child nodes, binary search tree, 177
Chinese dialects, aids for learning,
 115–120
chi-square distribution, 193–194
chol() linear algebra function, 197
choose() set operation, 202
chunking memory, 320–321
class() function, 212
cleaner code, 172
client/server model, 247
closures, 151, 174–175
cloud() function, 282–283
cluster, snow package, 335
clusterApply() function, snow package,
 72, 337, 339–340
code files, 3
code safety, 41
col() function, 69–70
colon operator (:), 32–33
color images, 63
column-major order, matrix storage,
 59, 61
combinatorial simulation, 205–206
combn() function, 203
comdat\$countabsamecomm component, 206
comdat\$numabchosen component, 206
comdat\$whosleft component, 206
comma-separated value (CSV) files, 103
comments, 3
complete.cases() function, 105–106
Comprehensive R Archive Network
 (CRAN), 24, 193, 353

- computed mean, saving in variable, 5
- concatenating, vectors, 4
- connections, 237–238
- constructors, 217
- contingency tables, 128, 229
- control statements, 139–144
 - if-else function, 143–144
 - looping over nonvector sets, 143
 - loops, 140–142
- copy-on-change policy, 314–315
- cos() math function, 190
- counter() function, 175
- counts component
 - hist() function, 14
 - mapsound() function, 116
- covariance matrix, generating, 69–70
- CRAN (Comprehensive R Archive Network), 24, 193, 353
- critical section, OpenMP, 344
- crossprod() function, 196
- cross-validation, 219, 222
- C-style looping, 140
- CSV (comma-separated value) files, 103
- ct.dat file, 128
- cumprod() math function, 190, 191
- cumsum() math function, 39, 190–191
- cumulative distribution function (cdf), 193
- cumulative sums and products, 191
- curve() function, 277–278
- customizing graphs, 272–280
 - adding polygons with polygon() function, 275–276
 - changing character sizes with cex option, 272–273
 - changing ranges of axes with xlim and ylim options, 273–275
 - graphing explicit functions, 276–277
 - magnifying portions of curve example, 277–280
 - smoothing points with lowess() and loess() functions, 276
- cut() function, 136–137

D

- data argument, array() function, 134
- data frames, 14–15, 101–102
 - accessing, 102–104
 - applying functions to, 112–120
 - aids for learning Chinese dialects example, 115–120
 - applying logistic regression models example, 113–115
 - using lapply() and sapply() on data frames, 112–113
- matrix-like operations, 104–109
 - apply() function, 107
 - extracting subdata frames, 104–105
 - NA values, 105–106
 - rbind() and cbind() functions, 106–107
 - salary study example, 108–109
- merging, 109–112
 - employee database example, 111–112
- reading from files, 236
- regression analysis of exam grades example, 103–104
- data structures, 10–16
 - character strings, 11
 - classes, 15–16
 - data frames, 14–15
 - lists, 12–14
 - matrices, 11–12
 - vectors, 10
- debug() function, 288
- debugger() function, performing checks after crash with, 291–292
- debugging, 285–304
 - ensuring consistency in debugging simulation code, 302
- facilities, 288–300
 - browser commands, 289
 - debug() and browser() functions, 288
 - debugging sessions, 292–300
 - setting breakpoints, 289–290
 - traceback() and debugger() functions, 291–292
 - trace() function, 291
- global variables and, 173
- parallel R, 351
- principles of, 285–287
 - antibugging, 287
 - confirmation, 285–286
 - modular, top-down manner, 286
 - starting small, 286
- running GDB on R, 303–304
- syntax and runtime errors, 303
- tools, 287–288, 300–302
- debug package, 300–301
- declarations, 28–29

- default arguments, 9–10
- deleting
 - list elements, 88–90
 - matrix rows and columns, 73–78
 - a node from binary search tree, 181
- density estimates, same graph, 264–266
- DES (discrete-event simulation),
 - writing, 164–171
- det() linear algebra function, 197
- dev.off() function, 3
- df parameter, mapsound() function, 116
- dgbsendeditcmd() function, 257–258
- diag() linear algebra function, 197–198
- diff() function, 50–51
- dim argument, array() function, 134
- dim attribute, matrix class, 79
- dimcode argument, apply() function, 70
- dimension reduction, avoiding, 80–81
- dim() function, 79
- dimnames argument, array() function, 134
- dimnames() function, 131
- dir() function, 245
- discrete-event simulation (DES),
 - writing, 164–171
- discrete-valued time series, predicting,
 - 37–39
- do.call() function, 133
- dosim() function, 165
- double brackets, 87–88
- drop argument, 68, 81
- dtldb debugging tool, use of string utilities in, 257–259
- dual-core machines, 341
- duplicate() function, 315
- dynamic task assignment, 348–350

E

- each argument, rep() function, 34
- edit() function, 150, 186–187
- edtdbg package, 300–302
- eigen() function, 197, 201
- eigenvalues, 201
- eigenvectors, 201
- elements
 - list, adding and deleting, 88–90
 - vectors
 - adding and deleting, 26
 - naming, 56
- embarrassingly parallel applications
 - defined, 347–348
 - turning general problems into, 350

- employee database example, 111–112
- encapsulation, 207
- end of file (EOF), 238
- envir argument
 - get() function, 159
 - ls() function, 155
- environment and scope, 151–159
 - functions have (almost) no side effects, 156–157
 - function to display contents of call frame example, 157–159
 - ls() function, 155–156
 - scope hierarchy, 152–155
 - top-level environment, 152
- EOF (end of file), 238
- ess-tracebug package, 300
- event list, DES, 164
- event-oriented paradigm, 164
- example() function, 21–22
- exists() function, 230
- expandut() function, 218
- explicit functions, graphing, 276–277
- exp() math function, 189
- extracting
 - subdata frames, 104–105
 - subtables, 131–134

F

- factorial() math function, 190
- factors, 121
 - functions, 123, 136
 - aggregate(), 136
 - by(), 126–127
 - cut(), 136–137
 - split(), 124–126
 - tapply(), 123–124
 - levels and, 121–122
- fangyan, 115
- fargs argument, apply() function, 70
- f argument, apply() function, 70
- Fedora, installing R on, 353–354
- file.exists() function, 245
- file.info() function, 245, 246
- filetype criterion, Google, 24
- filter() function, 328
- filtering, 45–48
 - defined, 25
 - generating filtering indices, 45–47
 - matrices, 66–69
 - with subset() function, 47
 - with which() selection function, 47–48

- findud() function, 50
- findwords() function, 90–91
- first-class objects, 149
- floor() math function, 190
- for loop, 306–313
 - achieving better speed in Monte Carlo simulation example, 308–311
 - generating powers matrix example, 312–313
 - vectorization for speedup, 306–308
- formal parameters
 - mapsound() function, 116
 - oddcoun() function, 9
- formals() function, 149, 151
- forming filenames, 256–257
- four-element vector, adding
 - element to, 26
- fromcol parameter, mapsound() function, 116
- functional programming, xxi–xxii, 314–316
 - avoiding memory copy example, 315–316
 - copy-on-change issues, 314–315
 - vector assignment issues, 314
- functions, 7–10. *See also* math functions; string-manipulation functions
 - anonymous, 187–188
 - applying to data frames, 112–120
 - aids for learning Chinese dialects example, 115–120
 - applying logistic regression models example, 113–115
 - using lapply() and sapply() functions, 112–113
 - applying to lists, 95–99
 - abalone data example, 99
 - lapply() and sapply() functions, 95
 - text concordance example, 95–98
 - applying to matrix rows and columns, 70–73
 - apply() function, 70–72
 - finding outliers example, 72–73
 - default arguments, 9–10
 - listing in packages, 358
 - as objects, 149–151
 - replacement, 182–186
 - for statistical distributions, 193–194
 - transcendental, 40
 - variable scope, 9
 - vector, 35–39, 311

G

- GCC, 325
- GDB (GNU debugger), 288, 327
- general-purpose editors, 186
- generating
 - covariance matrices, 69–70
 - filtering indices, 45–47
 - powers matrices, 312–313
- generic functions, xxi
 - classes, 15
 - implementing on S4 classes, 225–226
- getAnywhere() function, 211
- get() function, 159
 - looping over nonvector sets, 142
- getnextevt() function, 165
- getwd() function, 245
- global variables, 9, 171–174
- GNU debugger (GDB), 288, 327
- GNU S language, xix
- GPU programming, 171, 345
- GPUs (graphics processing units), 345
- gputools package, 345–346
- granularity, 348
- graphical user interfaces (GUIs), xx
- graphics processing units (GPUs), 345
- graphs, 261–283
 - customizing, 272–280
 - adding legends with legend() function, 270
 - adding lines with abline() function, 263–264
 - adding points with points() function, 269–270
 - adding polygons with polygon() function, 275–276
 - adding text with text() function, 270–271
 - changing character sizes with cex option, 272–273
 - changing ranges of axes with xlim and ylim options, 273–275
 - graphing explicit functions, 276–277
 - magnifying portions of curve example, 277–280
 - smoothing points with lowess() and loess() functions, 276
 - pinpointing locations with locator() function, 271–272
- plot() function, 262

- graphs (*continued*)
 - plots
 - restoring, 272
 - three-dimensional, 282–283
 - polynomial regression example, 266–269
 - saving to files, 280–281
 - starting new graph while keeping old, 264
 - two density estimates on same graph example, 264–266
- grayscale images, 63
- gregexpr() function, 254
- grep() function, 109, 252
- GUIs (graphical user interfaces), xx

H

- hard drive, loading packages from, 356
- help feature, 20–24
 - additional topics, 23–24
 - batch mode, 24
 - example() function, 21–22
 - help() function, 20–21
 - help.search() function, 22–23
 - online, 24
- help() function, 20–21
- help.search() function, 22–23
- higher-dimensional arrays, 82–83
- hist() function, 3, 13–14
- hosts, 345
- Huang, Min-Yu, 324

I

- identical() function, 55
- IDEs (integrated development environments), xx, 186
- ifelse() function, 48–49
 - assessing statistical relation of two variables example, 49–51
 - control statements, 143–144
 - recoding abalone data set example, 51–54
- if statements, nested, 141–142
- image manipulation, 63–66
- images component, mapsound() function, 116
- immutable objects, 314
- indexing
 - list, 87–88

- matrices, 62–63
- vector, 31–32
- indices, filtering, 45–47
- inheritance
 - defined, 207
 - S3 classes, 214
- initglbls() function, 165
- input/output (I/O). *See* I/O
- installing packages. *See* packages
- installing R, 353–354
 - downloading base package from CRAN, 353
 - from Linux package manager, 353–354
 - from source, 354
- install_packages() function, 356
- integrated development environments (IDEs), xx, 186
- intensity, pixel, 63–64
- interactive mode, 2–3
- interfacing R to other languages, 323–332
 - using R from Python, 330–332
 - writing C/C++ functions to be called from R, 323–330
 - compiling and running code, 325
 - debugging R/C code, 326–327
 - extracting subdiagonals from square matrix example, 324–325
 - prediction of discrete-valued time series example, 327–330
- internal data sets, 5
- internal storage, matrix, 59, 61
- Internet, accessing, 246–250
 - implementing parallel R example, 248–250
 - sockets, 247–248
 - TCP/IP, 247
- Internet Protocol (IP) address, 247
- intersect() set operation, 202
- intextract() function, 243
- I/O (input/output), 231–250
 - accessing Internet, 246–250
 - implementing parallel R example, 248–250
 - sockets in R, 247–248
 - TCP/IP, 247
 - accessing keyboard and monitor, 232–235
 - using print() function, 234–235
 - using readline() function, 234
 - using scan() function, 232–234

- reading files, 235
 - accessing files on remote machines via URLs, 243
 - connections, 237–238
 - reading data frame or matrix from files, 236
 - reading PUMS census files
 - example, 239–243
 - reading text files, 237
- writing files
 - getting files and directory information, 245
 - sum contents of many files
 - example, 245–246
 - writing to files, 243–245
- IP (Internet Protocol) address, 247

J

- join operation, 109

K

- keyboard, accessing, 232–235
 - printing to screen, 234–235
 - using `readline()` function, 234
 - using `scan()` function, 232–234
- KMC (k-means clustering), 338–340

L

- lag operations, vector, 50–51
- `lapply()` function
 - applying functions to lists, 95
 - lists, 50
 - looping over nonvector sets, 142
 - using on data frames, 112–113
- latency, 346
- lazy evaluation principle, 52, 147
- leaving-one-out method, 219, 222
- `legend()` function, 270
- `length()` function
 - obtaining length of vector, 27
 - vector indexing, 32
- levels, factors and, 121–122
- `.libPaths()` function, 356–357
- library functions, 165
- linear algebra operations, on vectors and matrices, 61, 196–201
 - finding stationary distributions of Markov chains example, 199–201
 - vector cross product example, 198–199

- `lines()` function, 264
- Linux package manager, installing R from, 353–354
- lists, 12–14, 85–100
 - accessing components and values, 93–95
 - applying functions to, 95–99
 - abalone data example, 99
 - `lapply()` and `sapply()` functions, 95
 - text concordance example, 95–98
 - general operations, 87–93
 - adding and deleting list elements, 88–90
 - getting size of list, 90
 - list indexing, 87–88
 - text concordance example, 90–93
 - recursive lists, 99–100
- `lm()` function, 15, 208–210
- load balance, 349–350
- `locator()` function
 - determining relevant rows and columns, 64–65
 - pinpointing locations with, 271–272
- `loess()` function, 276
- `log10()` math function, 189
- logical operations, 30–31
- logistic regression models, applying, 113–115
- `log()` math function, 189
- long-run state distribution, Markov modeling, 200
- loops, control statements, 140–142
- `lowess()` function, 276
- `ls()` function
 - environment and scope, 155–156
 - listing objects with, 226–227

M

- magnifying portions of curve, 277–280
- `makerow()` function, 241–242
- managers, snow package, 335
- managing objects, 226–230
 - determining object structure, 228–230
- `exists()` function, 230
- listing objects with `ls()` function, 226–227
- removing specific objects with `rm()` function, 227–228
- saving collection of objects with `save()` function, 228

- mapsound() function, 115–116
- marginal values, variable, 131
- m argument, apply() function, 70
- Markov chains, 199–201
- MASS package, 23, 356
- math functions, 189–193
 - calculating probability example, 190–191
 - calculus, 192–193
 - cumulative sums and products, 191
 - minima and maxima, 191–192
- matrices, 11–12, 59–83
 - adding and deleting rows and columns, 73–78
 - finding closest pair of vertices in graph example, 75–78
 - resizing matrix, 73–75
 - applying functions to rows and columns, 70–73
 - apply() function, 70–72
 - finding outliers example, 72–73
 - avoiding unintended dimension reduction, 80–81
 - linear algebra operations on, 196–201
 - naming rows and columns, 81–82
 - operations, 61–70
 - filtering, 66–69
 - generating covariance matrix example, 69–70
 - image manipulation example, 63–66
 - linear algebra operations, 61
 - matrix indexing, 62–63
 - reading from files, 236
 - vector/matrix distinction, 78–79
 - as vectors, 28
- matrix/array-like operations, 130–131
- matrix class, 79
- matrix() function, 60
- matrix-inverse update method, 222
- matrix-like operations, 104–109
 - apply() function, 107
 - extracting subdata frames, 104–105
 - NA values, 105–106
 - rbind() and cbind() functions, 106–107
 - salary study example, 108–109
- matrix-multiplication operator, 12
- maxima function, 191–192
- max() math function, 190, 192
- mean() function, 38
- memory
 - chunking, 320–321
 - functional programming, 314–316
 - avoiding memory copy example, 315–316
 - copy-on-change issues, 314–315
 - vector assignment issues, 314
 - using R packages for memory management, 321
- merge() function, 109–110
- merge sort method, numerical sorting, 347
- merging data frames, 109–112
 - employee database example, 111–112
- metacharacters, 254
- methods() function, 210
- microdata, 239
- minima function, 191–192
- min() math function, 190, 191
- M/M/1 queue, 165, 168
- modes
 - batch, 1, 3, 24
 - defined, 26
 - interactive, 2–3
- modulo operator, 44
- monitor, accessing, 232–235
 - using print() function, 234–235
 - using readline() function, 234
 - using scan() function, 232–234
- Monte Carlo simulation, achieving better speed in, 308–311
- multicore machines, 340–341
- mutlinks() function, 336
- mutual outlinks, 333–334, 341–342
- mvnrm() function, MASS package, 23, 356

N

- named arguments, 146–147
- names() function, 56
- naming
 - matrix rows and columns, 81–82
 - vector elements, 56
- NA values
 - matrix-like operations, 105–106
 - vectors, 43
- n browser command, 289
- nchar() function, 252
- ncol() function, 79

- negative subscripts, 32, 63
- network, defined, 247
- Newton-Raphson method, 192
- next statement, 141
- Nile data set, 5
- noise, adding to image, 65–66
- nominal variables, 121
- nonlocals
 - writing to with superassignment operator, 161–162
 - writing with `assign()` function, 163
- nonvector sets, looping control statements over, 143
- nonvisible functions, 211
- nreps values, 205
- nrow() function, 79
- NULL values, 44

O

- object-oriented programming. *See* OOP
- objects. *See also* managing objects
 - first-class, 149
 - immutable, 314
- oddcount() function, 7, 140
- omp barrier pragma, OpenMP, 344
- omp critical pragma, OpenMP, 344
- omp single pragma, OpenMP, 344–345
- OOP (object-oriented programming), xxi, 207–230
 - managing objects. *See* managing objects
 - S3 classes. *See* S3 classes
 - S4 classes, 222–226
 - implementing generic function on, 225–226
 - vs. S3 classes, 226
 - writing, 223–225
- OpenMP, 344–345
 - code analysis, 343
 - omp barrier pragma, 344
 - omp critical pragma, 344
 - omp single pragma, 344–345
- operations
 - list, 87–93
 - adding and deleting list elements, 88–90
 - getting size of list, 90
 - list indexing, 87–88
 - text concordance example, 90–93

- matrix, 61–70
 - filtering, 66–69
 - generating covariance matrix example, 69–70
 - image manipulation example, 63–66
 - indexing, 62–63
 - linear algebra operations, 61
- matrix/array-like, 130–131
- vector, 30–34
 - arithmetic and logical operations, 30–31
 - colon operator (`:`), 32–33
 - generating vector sequences with `seq()` function, 33–34
 - repeating vector constants with `rep()` function, 34
 - vector in, matrix out, 42–43
 - vector in, vector out, 40–42
 - vector indexing, 31–32
- operator precedence, 33
- order() function, 97, 194–195
- outliers, 49

P

- packages, 355–358
 - installing
 - automatically, 356–357
 - manually, 357–358
 - listing functions in, 358
 - loading from hard drive, 356
- parallel R, 333–351
 - debugging, 351
 - embarrassingly parallel applications, 347–348
 - turning general problems into, 350
 - implementing, 248–250
 - mutual outlinks, 333–334
 - resorting to C, 340–345
 - GPU programming, 345
 - multicore machines, 340–341
 - mutual outlinks, 341–342
 - OpenMP code analysis, 343
 - OpenMP pragmas, 344–345
 - running OpenMP code, 342
- snow package, 334–340
 - analyzing snow code, 336–337
 - k-means clustering (KMC), 338–340
 - running snow code, 335–336
 - speedup, 337–338

- snow package (*continued*)
 - sources of overhead, 346–347
 - networked systems of computers, 346–347
 - shared-memory machines, 346
 - static vs. dynamic task assignment, 348–350
 - parent.frame() function, 156
 - paste() function, 252–253, 257, 269
 - PDF devices, saving displayed
 - graphs, 281
 - pdf() function, 3
 - Pearson product-moment
 - correlation, 49
 - performance enhancement, 305–321
 - byte code compilation, 320
 - chunking, 320–321
 - functional programming, 314–316
 - avoiding memory copy example, 315–316
 - copy-on-change issues, 314–315
 - vector assignment issues, 314
 - for loop, 306–313
 - achieving better speed in a Monte Carlo simulation example, 308–311
 - generating powers matrix example, 312–313
 - vectorization for speedup, 306–308
 - using R packages for memory management, 321
 - using Rprof() function to find slow spots in code, 316–319
 - writing fast R code, 306
 - Perron-Frobenius theorem, 201
 - persp() function, 22, 282
 - pixel intensity, 63–64
 - plot() function, xxi, 16, 262
 - plots
 - restoring, 272
 - three-dimensional, 282–283
 - plyr package, 136
 - pmax() math function, 190, 192
 - pmf (probability mass function), 193
 - pmin() math function, 190, 191
 - pointers, 159–161
 - points() function, 269–270
 - polygon() function, 275–276
 - polymorphism
 - defined, xxi, 207
 - generic functions, 208
 - polynomial regression, 219–222, 266–269
 - port number, 247
 - powers matrix, generating, 312–313
 - pragmas, OpenMP, 343–345
 - preda() function, 38
 - principle of confirmation, debugging, 285–286
 - print() function, 18, 234–235
 - print.ut() function, 218
 - prntrslts() function, 165
 - probability, calculating, 190–191
 - probability mass function (pmf), 193
 - procpairs() function, 343
 - prod() math function, 190
 - programming structures. *See* R programming structures
 - Public Use Microdata Samples (PUMS)
 - census files, reading, 239
 - Python, using R from, 330–332
- Q**
- Q browser command, 289
 - qr() linear algebra function, 197
 - Quicksort implementation, 176–177
- R**
- race condition, 343
 - random variate generators, 204–205
 - rank() function, 195–196
 - rbind() function, 12, 106–107
 - ordering events, 171
 - resizing matrices, 74–75
 - rbinom() function, 204
 - R console, 2
 - .Rdata file, 20
 - Rdsm package, implementing
 - parallel R, 249
 - reactevnt() function, 165
 - readBin() function, 248
 - read.csv() function, 108
 - reading files, 235
 - accessing files on remote machines via URLs, 243
 - connections, 237–238
 - reading data frames or matrices from files, 236
 - reading PUMS census files example, 239–243
 - reading text files, 237

- readline() function, 234
- readLines() function, 248
- reassigning matrices, 73–74
- recursion, 176–182
 - binary search tree example, 177–182
 - Quicksort implementation, 176–177
- recursive argument, concatenate function, 100
- recursive vectors, 86
- recycling
 - defined, 25
 - vectors, 29–30
- reference classes, 160
- regexpr() function, 253–254
- regression analysis of exam grades, 16–19, 103–104
- regular expressions, character string manipulation, 254–257
- remote machines, accessing files on, 243
- repeat loop, 241–242
- repeat statement, 141
- rep() function, repeating vector constants with, 34
- replacement functions, 182–186
 - defined, 183–184
 - self-bookkeeping vector class example, 184–186
- reshape package, 136
- resizing matrices, 73–75
- return statement, 8
- return values, 147–149
 - deciding whether to explicitly call return() function, 148
 - returning complex objects, 148–149
- REvolution Analytics, 300
- rexp() function, 204
- Rf_PrintValue(s) function, 304
- rgamma() function, 204
- .Rhistory file, 20
- rm() function, 227–228
- rnorm() function, 3, 204
- round() function, 40–41, 190
- routers, 247
- row() function, 69–70
- rownames() function, 82
- R packages, for memory management, 321
- rpois() function, 204
- Rprof() function, 316–319
- .Rprofile file, 19
- R programming structures, 139
 - anonymous functions, 187–188
 - arithmetic and Boolean operators and values, 145–146
 - control statements, 139–144
 - if-else function, 143–144
 - looping over nonvector sets, 143
 - loops, 140–142
 - default values for arguments, 146–147
 - environment and scope issues, 151–159
 - function to display contents of call frame example, 157–159
 - ls() function, 155–156
 - scope hierarchy, 152–155
 - side effects, 156–157
 - top-level environment, 152
 - functions as objects, 149–151
 - pointers, lack of, 159–161
 - recursion, 176–182
 - binary search tree example, 177–182
 - Quicksort implementation, 176–177
 - replacement functions, 182–186
 - return values, 147–149
 - deciding whether to explicitly call return() function, 148
 - returning complex objects, 148–149
 - tools for composing function code, 186–187
 - edit() function, 186–187
 - text editors and IDEs, 186
 - writing, 161–175
 - binary operations, 187
 - closures, 174–175
 - discrete-event simulation (DES) in R example, 164–171
 - when to use global variables, 171–174
 - writing to nonlocals with assign() function, 163
 - writing to nonlocals with the super-assignment operator, 161–162
- RPy module
 - installing, 330
 - syntax, 330–332
- runif() function, 204
- running
 - GDB on R, 303–304
 - OpenMP code, 342

- running (*continued*)
 - R, 1–2
 - batch mode, 3
 - first session, 4–7
 - interactive mode, 2–3
 - snow code, 335–336
- runs of consecutive ones, finding, 35–37
- runtime errors, 303

S

- S (programming language), xix
- S3 classes, 208–222
 - class for storing upper-triangular matrices example, 214–219
 - finding implementations of generic methods, 210–212
 - generic functions, 208
 - OOP in `lm()` function example, 208–210
 - procedure for polynomial regression example, 219–222
 - vs. S4 classes, 226
 - using inheritance, 214
 - writing, 212–213
- S4 classes, 222–226
 - implementing generic function on, 225–226
 - vs. S3 classes, 226
 - writing, 223–225
- salary study, 108–109
- Salzman, Pete, 285
- `sapply()` function, 42
 - applying functions to lists, 95
 - using on data frames, 112–113
- `save()` function, saving collection of objects with, 228
- saving graphs to files, 280–281
- scalars, 10
 - Boolean operators, 145
 - vectors, 26
- `scan()` function, 142, 232–234
- scatter/gather paradigm, 335–336
- `schedevnt()` function, 165, 171
- scope hierarchy, 152–155. *See also* environment and scope
- `sepsoundtone()` function, 119
- `seq()` function, 21, 33–34
- `serialize()` function, 248
- `setbreakpoint()` function, 290
- `setClass()` function, 223
- `setdiff()` set operation, 202
- `setequal()` set operation, 202
- `setMethod()` function, 225
- set operations, 202–203
- `set.seed()` function, 302
- setting breakpoints, 289–290
 - calling `browser()` function directly, 289–290
 - using `setbreakpoint()` function, 290
- `setwd()` function, 245
- S expression pointers (SEXP), 304
- shared-memory systems, 341, 346–347
- shared-memory/threads model, GPUs, 345
- Sherman-Morrison-Woodbury formula, 222
- shortcuts
 - `help()` function, 20
 - `help.search()` function, 23
- `showframe()` function, 158
- `sim` global variable, 172–173
- simplifying code, 172
- simulation programming in R, 204–206
 - built-in random variate generators, 204–205
 - combinatorial simulation, 205–206
 - obtaining same random stream in repeated runs, 205
- single brackets, 87–88
- single-server queuing system, 168
- `sink()` function, 258
- `sin()` math function, 190
- slots, S4 class, 224
- snow package, 334–335
 - implementing parallel R, 248–249
 - k-means clustering (KMC), 338–340
 - snow code
 - analyzing, 336–337
 - running, 335–336
 - speedup, 337–338
- `socketConnection()` function, 248
- sockets, 247–248
- `socketSelect()` function, 248
- `solve()` function, 197
- sorting, numerical, 194–196
- sos package, 24
- source, installing R from, 354
- sourceval parameter, `mapsound()` function, 116
- Spearman rank correlation, 49

- speed
 - byte code compilation, 320
 - finding slow spots in code, 316–319
 - for loop, 306–313
 - achieving better speed in Monte Carlo simulation example, 308–311
 - generating powers matrix example, 312–313
 - vectorization for speedup, 306–308
 - writing fast R code, 306
- Spinu, Vitalie, 300
- split() function, 124–126, 336
- S-Plus (programming language), xix
- sprintf() function, 253
- sqrt() function, 42, 189
- stack trace, 289
- startup and shutdown, 19–20
- static task assignment, 348–350
- stationary distributions, Markov chains, 199–201
- statistical distributions, functions for, 193–194
- str() function, 14
- string-manipulation functions, 11, 251–254
 - gregexpr(), 254
 - grep(), 252
 - nchar(), 252
 - paste(), 252–253
 - regexpr(), 253–254
 - sprintf(), 253
 - strsplit(), 253
 - substr(), 253
- stringsAsFactors argument, data.frame() function, 102
- string utilities, in `edtdbg` debugging tool, 257–259
- strsplit() function, 253
- subdeterminants, 199
- submatrices, assigning values to, 62–63
- subnames argument, subtable() function, 132
- subscripting operations, 183
- subset() function, 47, 105
- subsetting, vector, 4–5
- substr() function, 253
- subtable() function, 132
- suffix, testing filename for given, 255–256
- sum() function, 190, 337
- summary() function, 15, 18
- summaryRprof() function, 319
- summing contents of many files, 245–246
- superassignment operator (`<<-`), 9
 - simplifying code, 174
 - writing to nonlocals with, 161–162
- sweep() linear algebra function, 197–198
- symmetric matrix, 77
- syntax errors, 303

T

- tabdom() function, 134
- tables, 127–130
 - extracting subtable example, 131–134
 - finding largest cells in, 134
 - functions, 136–137
 - aggregate(), 136
 - cut(), 136–137
 - matrix/array-like operations, 130–131
- tags, 86
- tapply() function
 - vs. by() function, 126–127
 - factors, 123–124
 - vs. split() function, 124
- tbl argument, subtable() function, 132
- tblarray array, 133
- TCP/IP, 247
- termination condition, 177
- testing vector equality, 54–55
- text, adding to graphs with text() function, 270–271
- text concordance, 90–93, 95–98
- text editors, 186
- text files, reading, 237
- text() function, adding text to graphs with, 270–271
- t() function, 71, 119, 197
- threaded code, 171
- threads, 341
- three-dimensional tables, 129–130
- Tierney, Luke, 334
- tolcol parameter, mapsound() function, 116
- tools
 - for composing function code, 186–187
 - edit() function, 186–187
 - text editors and IDEs, 186
 - debugging, 287–288, 300–302

- top-level environment, 152
- traceback() function, 291–292
- trace() function, 291
- tracemem() function, 314–315
- training set, 37
- transcendental functions, 40
- transition probability, 200
- treelike data structures, 177

U

- Ubuntu, installing R on, 353–354
- unclass() function, 229
- union() set operation, 202
- unlist() function, 93
- unname() function, 94
- unserialize() function, 248
- upn argument, showframe() function, 158
- upper-triangular matrices, class for storing, 214–219
- URLs, accessing files on remote machines via, 243
- u variable, 162

V

- values
 - assigning to submatrices, 62–63
 - Boolean, 145–146
 - list, accessing, 93–95
 - NA, 43, 105–106
 - NULL, 44
 - return, 147–149
- vanilla option, startup/shutdown, 20
- variables
 - assessing statistical relation of two, 49–51
 - categorical, 121
 - global, 9, 171–174
 - nominal, 121
- variable scope, 9
- vector assignment issues, 314
- vector cross product, 198–199
- vector filtering, 307
- vector-filtering capability, 176
- vector functions, 311
- vectorization
 - defined, 25
 - for speedup, 306–308
- vectorized operations, 40
- vector/matrix distinction, 78–79

- vectors, 10, 25–57
 - all() and any() functions, 35–39
 - finding runs of consecutive ones example, 35–37
 - predicting discrete-valued time series example, 37–39
 - c() function, 56–57
 - common operations, 30–34
 - arithmetic and logical operations, 30–31
 - colon operator (:), 32–33
 - generating vector sequences with seq() function, 33–34
 - repeating vector constants with rep() function, 34
 - vector indexing, 31–32
 - computing inner product of two, 196
 - declarations, 28–29
 - defined, 4
 - elements
 - adding and deleting, 26
 - naming, 56
 - filtering, 45–48
 - generating indices for, 45–47
 - with subset() function, 47
 - with which() function, 47–48
 - ifelse() function, 48–54
 - assessing statistical relation of two variables example, 49–51
 - recoding abalone data set example, 51–54
 - linear algebra operations on, 196–201
 - matrices and arrays as, 28
 - NA value, 43
 - NULL value, 44
 - obtaining length of, 27
 - recycling, 29–30
 - scalars, 26
 - testing vector equality, 54–55
 - vectorized operations, 39–43
 - vector in, matrix out, 42–43
 - vector in, vector out, 40–42
 - vertices, graph, finding, 75–78

W

- Web, downloading packages from, 356–358
 - installing automatically, 356–357
 - installing manually, 357–358

- where browser command, 289
- `which.max()` function, 73, 190
- `which.min()` function, 190
- `which()` function, 47–48
- whitespace, 233
- Wickham, Hadley, 136
- `wireframe()` function, 282–283
- `wmins` matrix, 77
- workers, `snow` package, 335
- working directory, 19–20
- `writeBin()` function, 248
- `writelnLines()` function, 248
- `write.table()` function, 244
- writing, 161
 - binary operations, 187
 - C/C++ functions to be called from R, 323–324
 - compiling and running code, 325
 - debugging R/C code, 326–327
 - extracting subdiagonals from
 - square matrix example, 324–325
 - prediction of discrete-valued time series example, 327–330
 - closures, 174–175
 - discrete-event simulation in R
 - example, 164–171
 - getting files and directory information, 245
 - to nonlocals
 - with `assign()` function, 163
 - with superassignment operator, 161–162
 - S3 classes, 212–213
 - S4 classes, 223–225
 - summing contents of many files
 - example, 245–246
 - when to use global variables, 171–174

X

- `xlim` option, 273–275
- x variable, 162

Y

- `ylim` option, 273–275

Z

- z variable, 162