

SIAM: Getting Started with R

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March 6, 2014

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- ▶ Strategy 2: Run the first implementation 100 times and then run the second implementation 100 times. Compare the average run time.

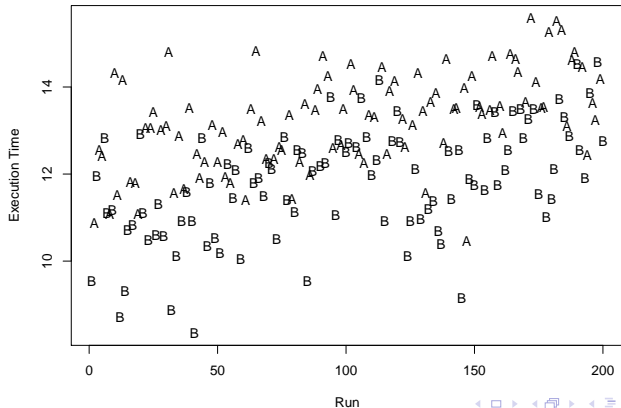
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- ▶ Strategy 1: Run each implementation once. Pick a winner based on that one run.
- ▶ Strategy 2: Run the first implementation 100 times and then run the second implementation 100 times. Compare the average run time.
- ▶ Strategy 3: Randomly assign order of tests. Perform Wilcoxon-Mann-Whitney test of hypothesis that there is no difference in the two implementations.

Running experiment

```
> # number of times to run each implementation
> replicates <- 100
> # if z is 1, run A then B, otherwise run B then A
> z <- rbinom(replicates, size = 1, p = 0.5)
> times <- sapply(z, function(i) {
  if (i == 1) {
    return(c(A(), B()))
  } else {
    return(c(B(), A()))
  }
})
```

Graphing the data



Hypothesis test: Two algorithms perform the same

```
> wilcox.test(times[1,], times[2,],  
              paired = TRUE, exact = TRUE)
```

Wilcoxon signed rank test

data: times[1,] and times[2,]

V = 2195, p-value = 0.2585

alternative hypothesis: true location shift is not equal to 0

What is R?

- ▶ A language for statistical analysis (data manipulation, modeling, visualization).
- ▶ S started at Bell Labs in 1970s and 1980s.
- ▶ GNU R is an open source port of the language.
- ▶ Currently in version 3.0.x.
- ▶ Interpreted language with bindings to C/C++, Fortran, other languages
- ▶ Available for Windows, Mac, UNIXes; extensive package repository

Variables

- ▶ Variables can be assigned using either `<-` or `=`

```
> a <- 7
```

```
> b = c(1, 2, 3, 4)
```

- ▶ The basic data type is a vector (with optional names)

```
> is.vector(c(a = 3, foo = 1, 4, last123 = 1))
```

```
[1] TRUE
```

```
> is.vector(3)
```

```
[1] TRUE
```

- ▶ Assigning via special functions like `names<-`:

```
> names(b) <- c("A", "B", "C", "D")
```

```
> b
```

```
A B C D
```

```
1 2 3 4
```

Objects

- ▶ Objects have a *class* and a *mode*

```
> m <- matrix(c(1,2,3,4,5,6,7,8,9), nrow = 3)
> class(m)
[1] "matrix"
> mode(m)
[1] "numeric"
```

- ▶ Usual suspects for modes:

- ▶ logical
- ▶ numeric (integer, double, complex, factor)
- ▶ character (strings)
- ▶ raw
- ▶ list

Exercise: Variables

- ▶ Create a vector with three numbers (use the `c` function).
- ▶ Create a vector with six numbers.
- ▶ Add them together. What happens?

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- ▶ R will “recycle” vectors to the length of the longer one.

Loops

The usual `for` and `while` constructs exist:

```
> a <- 0
> for (i in 1:5) {
  a <- a + i
}
> print(a)
[1] 15
```

The `*apply` family of functions perform maps over vectors:

```
> sapply(c(1,2,3,4), function(x) { x * x })
[1] 1 4 9 16
```

Vectorization

Many explicit loops can be avoided with “vectorization”:

```
> square <- function(x) { x * x }  
> square(c(1,2,3))  
[1] 1 4 9
```

There are some built in functions to “vectorize” other functions.

Functions: Creating and Passing

Functions are created like regular variables and can be treated like any other object:

```
> withfile <- function(fname, f) {  
  sink(fname)  
  f()  
  sink()  
}  
> withfile("myoutput.txt", function() {  
  print("hi")  
  print("bye")  
})
```


Functions: Arguments

Arguments can be named and given default values. Special ... argument captures any other passed arguments.

```
> f <- function(a, b, c = 0.5, ...) {  
  round(a:b * c, ...)  
}
```

```
> f(1, 3)
```

```
[1] 0 1 2
```

```
> f(b = 3, a = 1)
```

```
[1] 0 1 2
```

```
> f(c = 1/3, 1, 3, digits = 3)
```

```
[1] 0.333 0.667 1.000
```

Booleans and Comparisons

- ▶ Standard boolean operations:

```
> c(TRUE && TRUE, TRUE && FALSE, FALSE || TRUE)
[1] TRUE FALSE TRUE
```

- ▶ Single boolean if-else statements; switch function

- ▶ Elementwise boolean operations | and &:

```
> c(TRUE, TRUE, FALSE) | c(FALSE, TRUE, FALSE)
[1] TRUE TRUE FALSE
```

- ▶ Elementwise comparisons:

```
> ifelse(c(1,2,3,4,5) %% 2 == 0, "even", "odd")
[1] "odd" "even" "odd" "even" "odd"
```

Exercise: Function to compute multiples

From Project Euler Problem 1:

If we list all the natural numbers below 10 that are multiples of 3 or 5, we get 3, 5, 6 and 9. The sum of these multiples is 23.

Find the sum of all the multiples of 3 or 5 below 1000.

- ▶ Write a function `isThreeOrFive` that returns a boolean (hint: `%%` is modulo).
- ▶ Apply the function to all values from 1 to 1000 (hint: `1:1000`).
- ▶ Use the `sum` function to answer the question.

Example solutions

- ▶ Vectorization:

```
> isThreeOrFive <- function(x) {  
  # by using elementwise operation, this is vector  
  (x %% 3 == 0) | (x %% 5 == 0)  
}  
> sum((1:999)[isThreeOrFive(1:999)])  
[1] 233168
```

- ▶ Explicit looping:

```
> s <- 0  
> for (x in 1:999) {  
  if (isThreeOrFive(x)) s <- s + x  
}  
> s
```

Missing Values

- ▶ Missing values for any data type is notated with the special NA value.
- ▶ Missing values (NA) are neither true or false, but short circuiting can still occur:

```
> c(FALSE && NA, TRUE || NA)
```

```
[1] FALSE TRUE
```

```
> c(TRUE && NA, FALSE || NA)
```

```
[1] NA NA
```

- ▶ Many functions will have special NA handling arguments:

```
> nas <- c(1, 2, 3, NA, 5)
```

```
> mean(nas)
```

```
[1] NA
```

Matrices

The `matrix` class holds a single mode of data in a square format.

- ▶ Convenient subscripting notation style:
- ▶ Standard linear algebra tools available.
- ▶ The `array` class generalizes to dimensions > 2 .

```
> matrix <- matrix(1:12, nrow = 3)
```

```
> m[1:2, 2:3]
```

	[,1]	[,2]
[1,]	4	7
[2,]	5	8

Data Frames

The `data.frame` class holds multiple modes, `$` operator to get specific columns as vectors.

```
> df <- data.frame(nums = 1:10, letters = letters[1:10])
> df[1:3, ]
  nums letters
1    1      a
2    2      b
3    3      c
> df$letters
[1] a b c d e f g h i j
Levels: a b c d e f g h i j
```

Formulas

A common interface is a formula with a left and right hand side:

```
> y ~ x1 + x2 + x3 * x4 + log(x5)
```

- ▶ Used in many model fitting and plotting routines.
- ▶ Short hand notation for interactions (: and *).
- ▶ Many functions permitted.
- ▶ Can pull variables from the environment, but usually better to combine with a `data = mydata` argument.

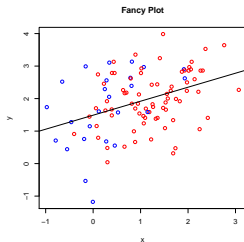
Plotting Basics

- ▶ Many objects have `plot` methods.
- ▶ These can be combined with other plotting primitives to create nice graphics.
- ▶ Output can be viewed interactively or saved as PDF, SVG, PNG, JPG, and others.

Example: Building a linear model

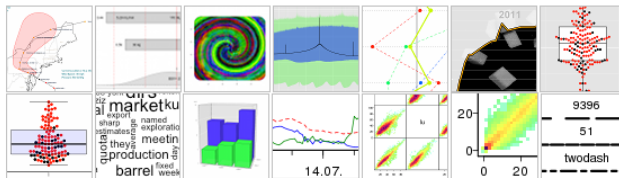
```
> library(MASS)
> randoms <- as.data.frame(
  mvrnorm(n = 100,
    mu = c(1,2),
    Sigma = matrix(c(1, 0.5, 0.5, 1),
      nrow = 2)))
> colnames(randoms) <- c("x", "y")
> randoms$w <- (randoms$x + rnorm(100)) > 0
> model <- lm(y ~ x, data = randoms)
```

Example: Plotting regression model



```
> plot(y ~ x,  
       data = randoms,  
       col = ifelse(randoms$w ==  
                     "red",  
                     "blue"),  
       main = "Fancy Plot")  
> cs <- model$coefficients  
> abline(a = cs[1],  
         b = cs[2])
```

More examples



» Random entries

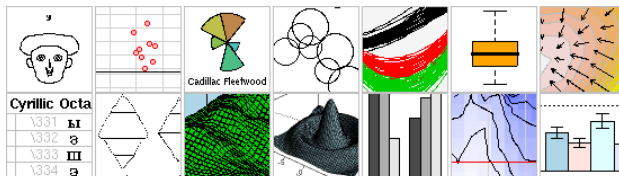
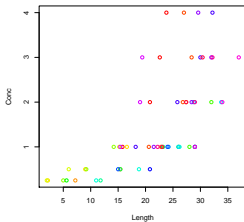


Figure : Mini examples from R Graphics Gallery

Exercise: Plotting Heart Muscle Experiment

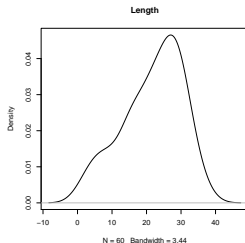
- ▶ Load the rat heart muscle experiment data: `data(muscle)`
- ▶ Plot `Conc` versus `Length`
- ▶ What is the distribution of the `Length` variable? (Hint: try plotting the results of `density` function)

Exercise: Plotting Heart Muscle Experiment



```
> cols <- rainbow(  
  nlevels(muscle$Strip))  
> plot(Conc ~ Length,  
  data = muscle,  
  col = cols[muscle$Strip])
```

Exercise: Length density plot



```
> plot(density(muscle$Length),  
       main = "Length")
```

CRAN

The Comprehensive R Archive Network(CRAN) is a repository for community packages.

- ▶ 5066 packages as of 2013-12-30
- ▶ Easy to use with `install.packages("packageName")`
- ▶ Packages for different statistical techniques, plotting/graphics, parsing, development tools.
- ▶ Pre-built binaries for Windows and OS X. Source builds for other platforms.

Installing and Using Packages

```
> install.packages("e1071")  
  
> library(e1071)  
> data(Titanic)  
> m <- naiveBayes(Survived ~ ., data = Titanic)  
> me <- list(class = "3rd", Sex = "Male", "Age" = "Adult")  
> predict(m, newdata = me)  
[1] No  
Levels: No Yes
```

Some recommend packages

- ▶ `caret`: Machine learning meta package
- ▶ `lattice` and `ggplot`: Advance plotting packages.
- ▶ `xtable`: Formats tables as \LaTeX and HTML
- ▶ `Rcpp`: Simplifies interfacing with C/C++.
- ▶ `plyr`: Data manipulation routines.

Sweave

- ▶ Embed R in \LaTeX (e.g. these slides)
- ▶ Chunks are evaluated and (optionally) output TeX.
- ▶ Figures can be generated as well

file.Rnw

```
<<chunkname, eval = TRUE>>=  
c(1, 2, 3) + c(4, 5, 6)  
@
```

file.tex

```
\begin{Schunk}  
\begin{Sinput}  
> c(1, 2, 3) + c(4, 5, 6)  
\end{Sinput}  
\begin{Soutput}  
[1] 5 7 9  
\end{Soutput}  
\end{Schunk}
```

Using R to Create Artifacts

- ▶ Projects with multiple languages, phases
- ▶ We use `make` to map out dependencies and run R
- ▶ The `save` function serializes most data types.
- ▶ Typical workflow:
 - ▶ Load data (usually a `.csv` or similar)
 - ▶ Process data using R and save `.rda` file
 - ▶ Analysis phases consume `data.rda` and produce more `.rda` files
 - ▶ Figures, tables, etc. rely on these items and are built via `Makefile`
 - ▶ Output documents (`paper.pdf`, `presentation.pdf`) depend on entire collection.

Interfacing R with Other Languages

- ▶ R is largely built on C and Fortran and interfacing is pretty straight forward.
- ▶ Rcpp and inline packages make it even easier (including compiling writing C++ as a string)
- ▶ RInside is a package to allow calling R from C++
- ▶ RPy2, RJava, RinRuby, statistics::R, probably others
- ▶ foreign library can read many formats
- ▶ RSQLite: interact with sqlite3 files, bindings for most languages

Books

- ▶ *The Art of R Programming* by Norman Matloff
- ▶ *Software for Data Analysis: Programming with R* by John Chambers
- ▶ *Reproducible Research in R and RStudio* by Christopher Gandrud
- ▶ O'Reilly R cookbooks
- ▶ Many books that teach specific statistical techniques with R demonstrations

Web

- ▶ `r-project.org`: downloads, introductory guides, packages
- ▶ Searching the web for “R” is an extreme frustration (get used to it)
- ▶ R Inferno: common pitfalls and workarounds
- ▶ Mailing lists: `r-help`, `r-devel`
- ▶ `stackoverflow.com` and `stats.stackexchange.com`
- ▶ `r-bloggers.com`

Editors

- ▶ R for Windows and OS X ship with REPL and editor
- ▶ Rcmdr and tinR attempt to add a full GUI
- ▶ emacs: *Emacs Speaks Statistics* is a set of modes, including a REPL and Sweave interaction
- ▶ vim: syntax highlighting, I was never able to get interactive stuff to work (I use emacs + EVIL + ESS)
- ▶ RStudio: commercial IDE freeware; available as Java app and in-browser interface