MFE R Programming Workshop

Week 1

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Fall 2016

Overview

Goals

- Learn to program in R.
- What does programming mean?
  - Language syntax.
  - Debugging.
  - Finding solutions.
  - Translating math to code.
- This is just the beginning, you'll develop these skills throughout the program.

R as a language

- R is object oriented.
  - Everything is an object and functions operate differently when passed different types of objects.
- R is functional.
  - You write fewer loops.
  - You write cleaner code.

R vs C++

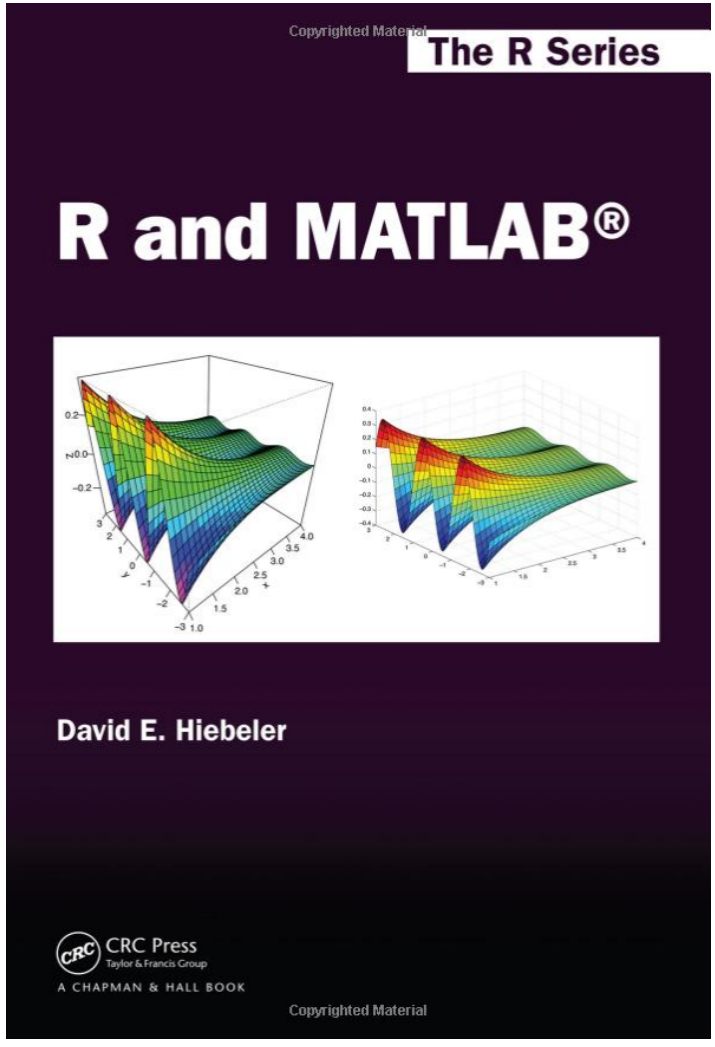
- Both are useful, and you will use both in the MFE program.
- R is an interpreted language.
  - Low programmer time.
  - A great tool for data munging, statistics, regressions, etc.
  - However, certain tasks in R can be slow (e.g. loops).
- C++ is very fast, but it takes longer to write programs.
- We can use both together!
- A good workflow:
  1. Write your program in R.
  2. If the program is too slow, benchmark your code.
  3. Try to speedup any bottlenecks in R.
  4. Convert any remaining bottlenecks to C++.

Jack of All Trades, Master of None

- You are better served by learning R and C++ very well, rather than trying to learn R, C++, MATLAB, Python, Julia, SAS, etc.
- The MFE program is just too short.
  - You also need to learn finance!
- Once you are proficient with R and C++, learning other languages is easy.
- Don't become a master of none!

MATLAB

- If you want to learn MATLAB after learning R, take a look at R and MATLAB by David Hiebeler.



Structure

- I will talk at the beginning of each class.
- For the remainder of the time you will break into your study groups and work on programming tasks.
- Tasks are designed to introduce you to the building blocks that will be used for course assignments throughout the MFE program.
- This course is a programming course with emphasis on methods for finance:
  - You will see finance terms and math.
  - You *may* not understand all of the finance, but you will learn it throughout the program.
- The key skills will be translating mathematical algorithms into code and developing the ability to find helpful resources.

Questions

Any questions before we start?

R Resources: Books

- Introductory:
  - R for Everyone by Jared P. Lander
  - R Cookbook by Paul Teetor (free at UCLA LearnIT)
  - R for Data Science by Hadley Wickham (free as well)
- Intermediate:
  - The Art of R Programming by Norman Matloff
- Advanced:
  - Software for Data Analysis by John Chambers
  - Extending R by John Chambers
  - Advanced R by Hadley Wickham

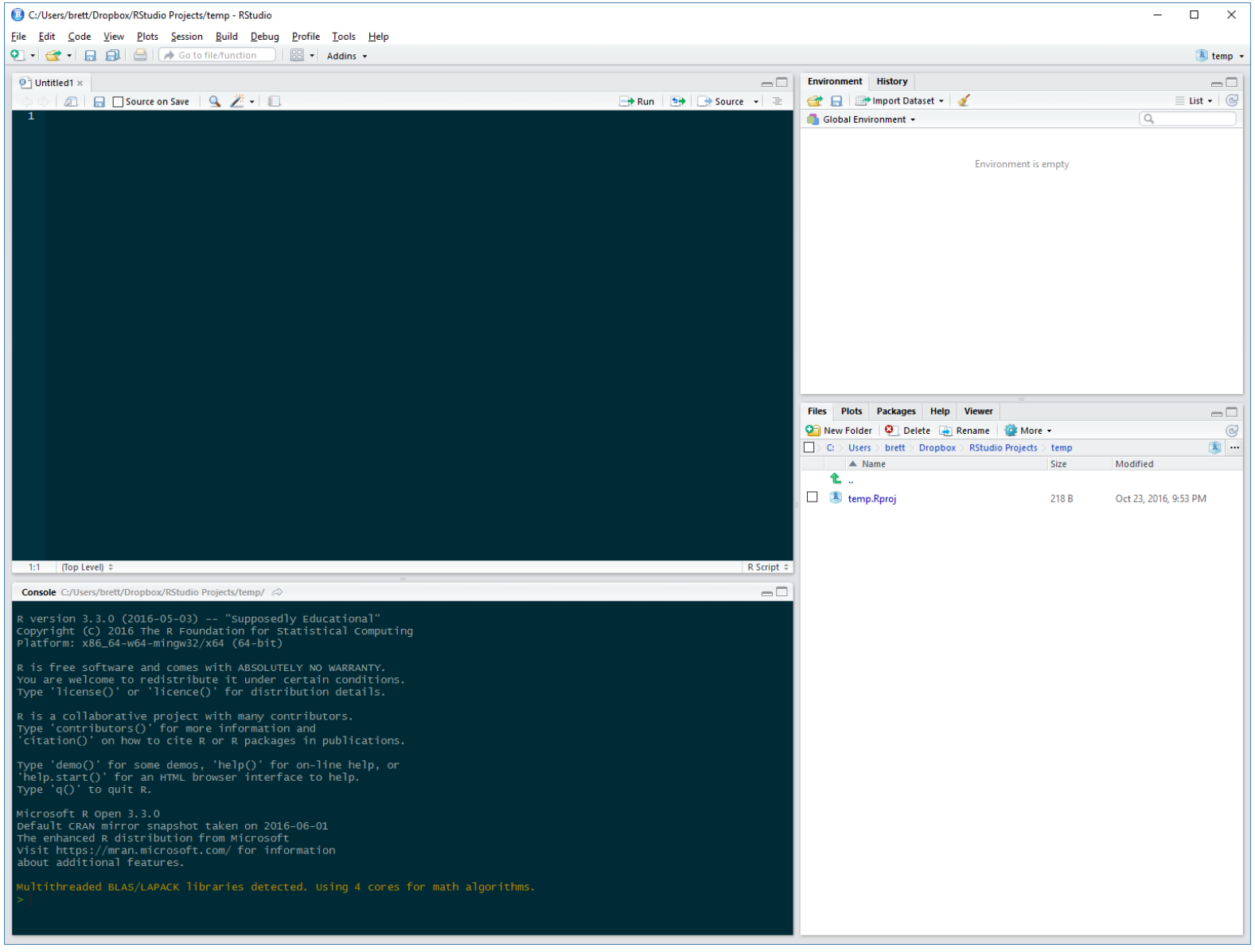
Other Resources

- Book series:
  - Use R! Springer series
    - FYI: Many Springer textbooks are just $25 through `http://link.springer.com/`. You need to be on campus or signed into the UCLA VPN. You can download the pdfs for free.
  - O'Reilly R Books (free at UCLA LearnIT)
- Built in documentation!
  - `?funcname`
- Journal of Statistical Software
- Data science courses on Coursera
- Data Camp
- `https://www.r-bloggers.com/`
- `https://twitter.com/rstudiotips`
- Google, Stack Overflow, etc.

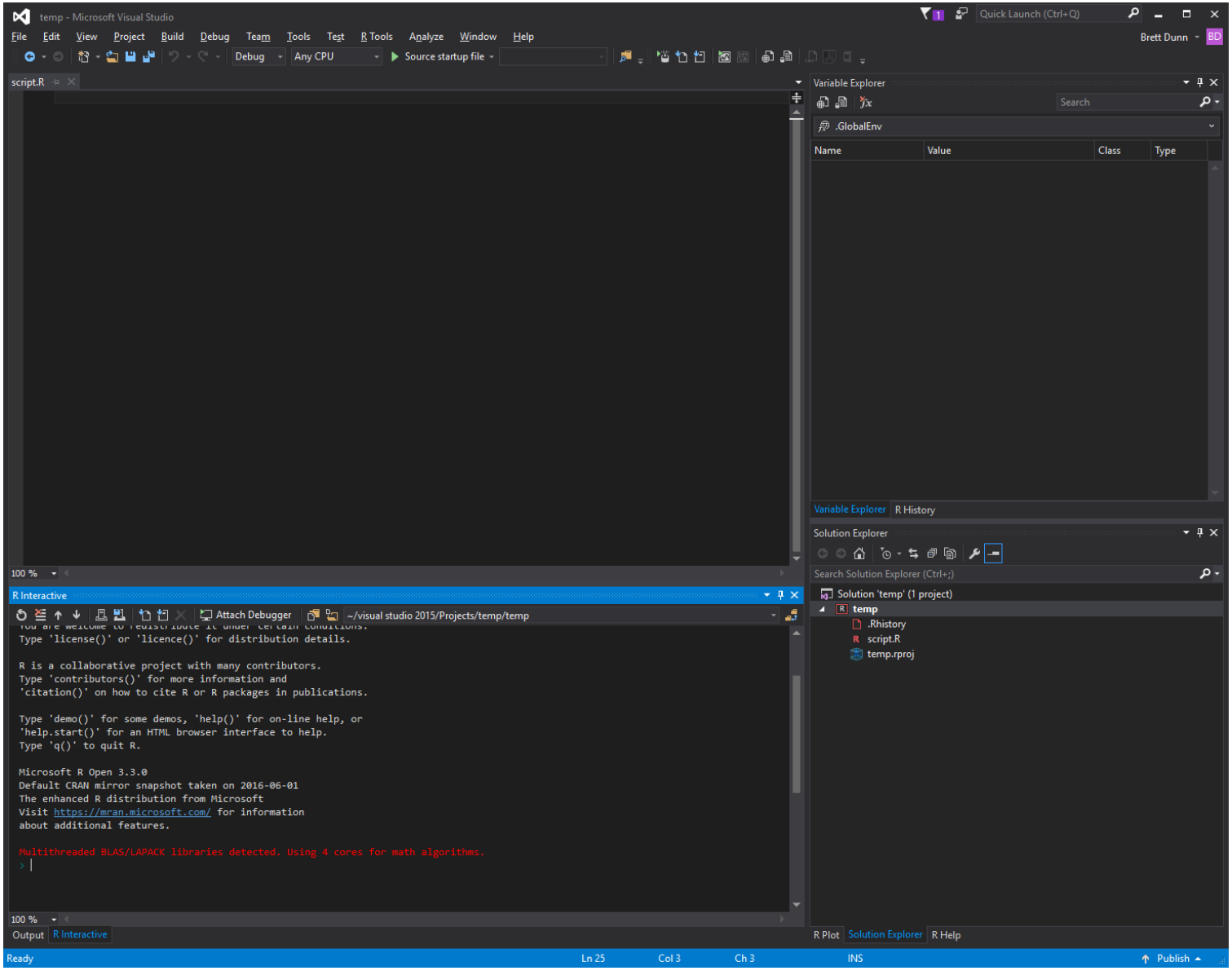
R Environment

- First, you need an R distribution.
  - I recommend Microsoft R Open.
  - https://mran.revolutionanalytics.com/download/
- Second, you need an integrated development environment (IDE) for R.
  - R Studio is a fantastic environment to interact with R.
  - Other options:
    - R Tools for Visual Studio if you use Visual Studio.
    - Emacs Speaks Statistics (ESS) if you use Emacs.
- I am going to assume that you have a working installation of R Studio and that you have a basic understanding of how it works.
- I will show you some Visual Studio.
- My focus is going to be on R programming.

RStudio

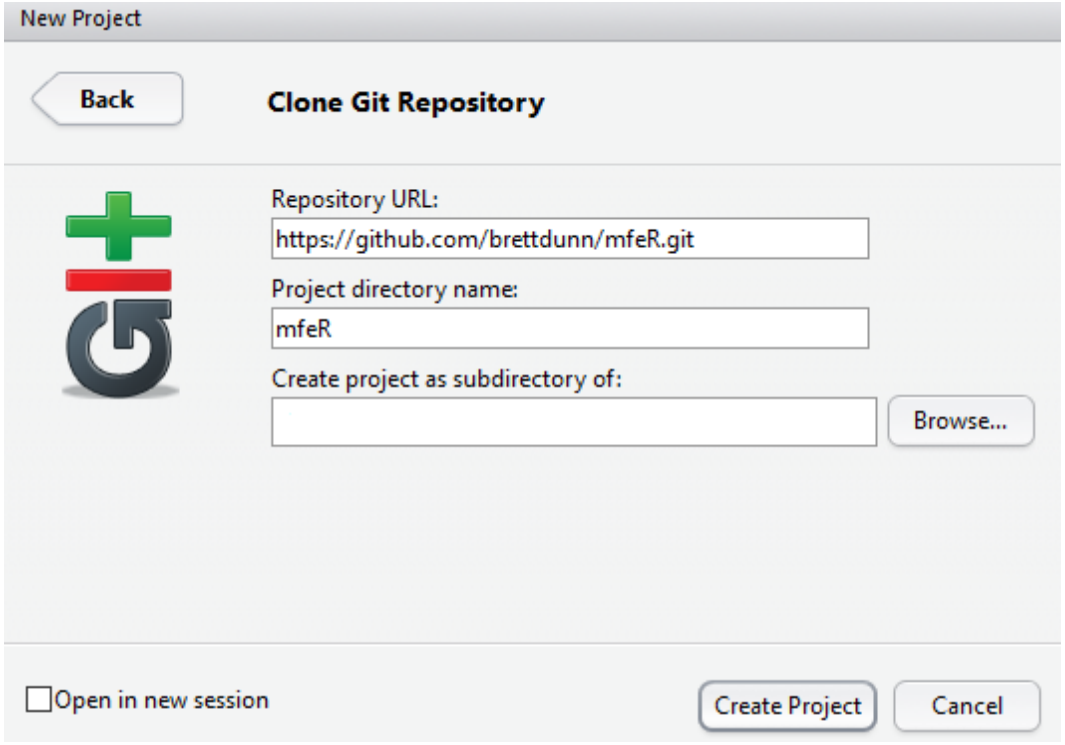

C:/Users/brett/Dropbox/RStudio Projects/temp - RStudio
File Edit Code View Plots Session Build Debug Profile Tools Help
Go to file/function
Addins
temp
Untitled1
Source on Save
Run
Source
1
1:1
(Top Level)
R Script
Console C:/Users/brett/Dropbox/RStudio Projects/temp/
R version 3.3.0 (2016-05-03) -- "Supposedly Educational"
Copyright (C) 2016 The R Foundation for Statistical Computing
Platform: x86_64-w64-mingw32/x64 (64-bit)
R is free software and comes with ABSOLUTELY NO WARRANTY.
You are welcome to redistribute it under certain conditions.
Type 'license()' or 'licence()' for distribution details.
R is a collaborative project with many contributors.
Type 'contributors()' for more information and
'citation()' on how to cite R or R packages in publications.
Type 'demo()' for some demos, 'help()' for on-line help, or
'help.start()' for an HTML browser interface to help.
Type 'q()' to quit R.
Microsoft R Open 3.3.0
Default CRAN mirror snapshot taken on 2016-06-01
The enhanced R distribution from Microsoft
Visit https://mran.microsoft.com/ for information
about additional features.
Multithreaded BLAS/LAPACK libraries detected. Using 4 cores for math algorithms.
>
Environment History
Import Dataset
List
Global Environment
Environment is empty
Files Plots Packages Help Viewer
New Folder Delete Rename More
C: Users brett Dropbox RStudio Projects temp
Name Size Modified
..
temp.Rproj 218 B Oct 23, 2016, 9:53 PM

R Tools for Visual Studio



Course Materials

- https://github.com/brettdunn/mfeR
- The materials for this course were created in RStudio, using R Markdown.
- To create your own RStudio project:
  - File / New Project / Version Control / Git
  - Enter the URL



R Basics

Command Line Interface

- To run a command in R, type it into the console next to the > symbol and press the Enter key.

```
2 + 3
```

```
## [1] 5
```

- Up Arrow + Enter repeats the line of code.
- Esc (Windows/Mac) or Ctrl-C (Linux) interrupts a command.

RStudio

- To start, create a new R Script file.
  - File/New File/R Script
- You can type your commands in the R Script file and run them on the Console.
  - Easy way to save your work.
  - `Ctrl+Enter` sends the line at the cursor to the console.
  - `Ctrl+Shift+S` runs the entire file.
  - Help/Keyboard Shortcuts lists all the available shortcuts.
    - Check out the multiple cursors.
- For larger tasks with many files, create an R project.
- Visual Studio is similar.

General Comments

- Make your code easy to read.
- Check out Google's R Style Guide
- Comment your code!

Google's R Style Guide

R is a high-level programming language used primarily for statistical computing and graphics. The goal of the R Programming Style Guide is to make our R code easier to read, share, and verify. The rules below were designed in collaboration with the entire R user community at Google.

Summary: R Style Rules

1. File Names: end in `.R`
2. Identifiers: `variable.name` (or `variableName`), `FunctionName`, `kConstantName`
3. Line Length: maximum 80 characters
4. Indentation: two spaces, no tabs
5. Spacing
6. Curly Braces: first on same line, last on own line
7. else: Surround else with braces
8. Assignment: use `<-`, not `=`
9. Semicolons: don't use them
10. General Layout and Ordering
11. Commenting Guidelines: all comments begin with # followed by a space; inline comments need two spaces before the #
12. Function Definitions and Calls
13. Function Documentation
14. Example Function
15. TODO Style: `TODO(username)`

R Packages

- A package is essentially a library of prewritten code designed to accomplish some task or a collection of tasks.
- R has a huge collection of user-contributed packages.
  - Warning: Not all packages are of the same quality.

CRAN
Mirrors
What's new?
Task Views
Search

About R
R Homepage
The R Journal

Software
R Sources
R Binaries
Packages
Other

Documentation
Manuals
FAQs
Contributed

CRAN Task Views

Bayesian	Bayesian Inference
ChemPhys	Chemometrics and Computational Physics
ClinicalTrials	Clinical Trial Design, Monitoring, and Analysis
Cluster	Cluster Analysis & Finite Mixture Models
DifferentialEquations	Differential Equations
Distributions	Probability Distributions
Econometrics	Econometrics
Environmetrics	Analysis of Ecological and Environmental Data
ExperimentalDesign	Design of Experiments (DoE) & Analysis of Experimental Data
ExtremeValueTheory	Extreme Value Theory
Finance	Empirical Finance
Genetics	Statistical Genetics
Graphics	Graphic Displays & Dynamic Graphics & Graphic Devices & Visualization
HighPerformanceComputing	High-Performance and Parallel Computing with R
MachineLearning	Machine Learning & Statistical Learning
MedicalImaging	Medical Image Analysis
MetaAnalysis	Meta-Analysis
Multivariate	Multivariate Statistics
NaturalLanguageProcessing	Natural Language Processing
NumericalMathematics	Numerical Mathematics
OfficialStatistics	Official Statistics & Survey Methodology

R Packages

- Installing a packages:
  - `Ctrl+7` in RStudio accesses the packages pane
  - You can also type `install.packages("packageName")`
- Uninstalling a package:
  - `remove.packages("packageName")`
- Loading packages:
  - `require(packageName)` or `library(packageName)` loads a package into R
  - The difference is that `require` returns `TRUE` if the package loads or `FALSE` if it doesn't.
- Unloading packages
  - `detach(package:packageName)`
- If two packages have the same function name use two colons:
  -`package1::func` or `package2::func`

Variables

- Unlike C++, R does not require variable types to be declared.
- A variable can take on any data type.
- A variable can also hold any R object such as a function, the result of an analysis, a plot, etc.
- Variable assignment is done with <-.
  - = works, but there are reasons to prefer <-.
- We can remove variables (e.g. to free up memory) with the `rm` function. `gc()` runs garbage collection.

```
x <- 2  # x is a pointer
x  # the same output as print(x)
```

```
## [1] 2
```

```
rm(x)  # removes x
```

Data Types

- There are many different data types in R.
- The four main types of data most likely to be used are:
  1. `numeric`
  2. `character` (string)
  3. `Date/POSIXct` (time-based)
  4. `logical (TRUE/FALSE)`
- The data type can be checked with the `class` function

```
x <- as.Date("2010-12-21")
class(x)
```

```
## [1] "Date"
```

Casting

```
x <- "2010-12-21"
class(x)
```

```
## [1] "character"
```

```
x
```

```
## [1] "2010-12-21"
```

```
x <- as.Date(x)
class(x)
```

```
## [1] "Date"
```

```
x
```

```
## [1] "2010-12-21"
```

More Casting

```
x <- as.numeric(x)
class(x)
```

```
## [1] "numeric"
```

```
is.numeric(x)
```

```
## [1] TRUE
```

```
x  # number of days since Jan 1, 1970
```

```
## [1] 14964
```

Even More Casting

```
x <- as.integer(x)  # x <- 14964L assigns an integer
class(x)
```

```
## [1] "integer"
```

```
is.integer(x)
```

```
## [1] TRUE
```

```
is.numeric(x)  # R promotes int to numeric as needed
```

```
## [1] TRUE
```

```
4L / 5L
```

```
## [1] 0.8
```

Logicals

```
# TRUE == 1 and FALSE == 0
x <- TRUE  # TRUE, FALSE, T, F are logicals
is.logical(x)
```

```
## [1] TRUE
```

```
5 == 5  # != tests for inequality
```

```
## [1] TRUE
```

```
"a" < "b"  # works on characters as well
```

```
## [1] TRUE
```

Vectors

Vectors

- A `vector` is a collection of elements, all of the same type.
- We will learn about:
  - Recycling
    - The automatic lengthening of vectors.
  - Filtering
    - The extraction of subsets of vectors.
  - Vectorization
    - Where functions are applied element-wise to vectors.

Vectors and Assignment

- Assigning values to variables can be done with <-
- Create vectors of numbers using the function c()

```
myvector <- c(1,2,3,4)
samevector <- 1:4
vectorsubset <- myvector[1:3]
vectorsubset
```

```
## [1] 1 2 3
```

c() function

- `c()`, which stands for concatenate is a very flexible function.

```
myvec1 <- 2:4
myvec2 <- c(1,3,5,myvec1)
myvec2
```

```
## [1] 1 3 5 2 3 4
```

Accesing elements of vectors

- Elements can be accessed using []

```
myvec <- c(2,4,6,8)
myvec[4]
```

```
## [1] 8
```

```
myvec[c(1,3)]
```

```
## [1] 2 6
```

Length

- `length()` returns the vector length

```
myvec <- 1:23
length(myvec)
```

```
## [1] 23
```

Recycling

- Vectors are recycled when an operation acts element-wise
- Be careful with and aware of this behavior!
- In some cases it is useful, others confusing

```
vec1 <- 1
vec2 <- 1:4
vec3 <- 1:2
vec2+vec1
```

```
## [1] 2 3 4 5
```

```
vec2+vec3
```

```
## [1] 2 4 4 6
```

seq and rep

- Useful functions for generating vectors
- See `?seq` and `?rep` for details

```
myvec1 <- seq(1,10,2)
myvec1
```

```
## [1] 1 3 5 7 9
```

```
myvec2 <- rep(c(1,2),3)
myvec2
```

```
## [1] 1 2 1 2 1 2
```

```
rep(c(1,2), each=2)
```

```
## [1] 1 1 2 2
```

NULL and NA

- `NULL` is the non-existent value in R
- `NA` is the missing place hold

```
myvec1 <- 5:8
myvec1[2] <- NA
myvec1
```

```
## [1]  5 NA  7  8
```

```
myvec2 <- NULL
length(myvec2)
```

```
## [1] 0
```

Filtering (1)

- Select subsets using vectors of logicals

```
vec1 <- 1:5
vec2 <- c(TRUE,FALSE,TRUE,FALSE,TRUE)
vec1[vec2]
```

```
## [1] 1 3 5
```

Filtering (2)

- Select subsets using vectors of logical

```
vec1 <- 1:6
vec2 <- vec1 > 3
vec2
```

```
## [1] FALSE FALSE FALSE  TRUE  TRUE  TRUE
```

```
vec1[vec2]
```

```
## [1] 4 5 6
```

```
vec1[vec1>3]
```

```
## [1] 4 5 6
```

Assigning to filter

- You can assign to the subsets

```
vec1 <- 1:6
vec1[vec1<2] <- NA
vec1
```

```
## [1] NA  2  3  4  5  6
```

Functions on vectors

- Functions typically operate on vectors

```
x <- 1:1000
mean(x)
```

```
## [1] 500.5
```

names

- You can give names to elements of vectors

```
myvec <- 1:3
names(myvec) <- c("A","B","C")
myvec["B"]
```

```
## B
## 2
```

Matrices

Intro

- Matrices are vectors with a number of rows and number of columns attribute

```
myvec <- 1:10
mymat <- matrix(myvec, nrow=2, ncol=5)
mymat
```

```
##      [,1] [,2] [,3] [,4] [,5]
## [1,]    1    3    5    7    9
## [2,]    2    4    6    8   10
```

```
mymat[1,3]
```

```
## [1] 5
```

Matrix operations

- Many matrix operations are surrounded by % signs

```
mymat1 <- matrix(1:4, nrow=2)
mymat2 <- matrix(5:8, nrow=2)
mymat1 %*% mymat2
```

```
##      [,1] [,2]
## [1,]   23   31
## [2,]   34   46
```

```
mymat1 + mymat2
```

```
##      [,1] [,2]
## [1,]    6   10
## [2,]    8   12
```

apply

- apply allows you to apply a function across a dimension of a matrix
- The third argument is a function!

```
mymat1 <- matrix(1:10, nrow=2)
# mean across rows
apply(mymat,1,mean)
```

```
## [1] 5 6
```

cbind and rbind

- Column bind and Row bind

```
mymat1 <- matrix(1:4,nrow=2)
mymat2 <- matrix(6:9,nrow=2)
mymat3 <- matrix(10:11,ncol=2)
cbind(mymat1,mymat2)
```

```
##      [,1] [,2] [,3] [,4]
## [1,]    1    3    6    8
## [2,]    2    4    7    9
```

```
rbind(mymat1,mymat3)
```

```
##      [,1] [,2]
## [1,]    1    3
## [2,]    2    4
## [3,]   10   11
```

Lists

Intro

- Lists are where you really start to see the advantages of R as a statistics and data manipulation language

```
element1 <- 1:5
element2 <- matrix(1:6,nrow=3)
mylist <- list(el1=element1,el2=element2)
mylist[["el1"]]
```

```
## [1] 1 2 3 4 5
```

```
mylist[["el2"]]
```

```
##      [,1] [,2]
## [1,]    1    4
## [2,]    2    5
## [3,]    3    6
```

Subsetting lists

- Subsets of lists are with single []

```
mylist <- list(A=1,B=2,C=3,D=4)
# this returns a list because of the single []
mylist[c(1,3)]
```

```
## $A
## [1] 1
##
## $C
## [1] 3
```

lapply

- `lapply` implicitly loops over each list element and applies a function

```
mylist <- list(A=1:10,B=2:17,C=745:791)
lapply(mylist,mean)
```

```
## $A
## [1] 5.5
##
## $B
## [1] 9.5
##
## $C
## [1] 768
```

lapply example

```
g <- c("M","F","F","I","M","M","F")
lapply(c("M","F","I"),function(gender) which(g==gender))
```

```
## [[1]]
## [1] 1 5 6
##
## [[2]]
## [1] 2 3 7
##
## [[3]]
## [1] 4
```

Data Frames

Intro

- In my mind, `data.frame` is the core data type in R
- The nicest part is that they can hold different types
- Each column must be the same length

```
dat1 <- 1:4
dat2 <- rep(c("A","B"),each=2)
myframe <- data.frame(col1=dat1,col2=dat2)
myframe
```

```
##   col1 col2
## 1    1    A
## 2    2    A
## 3    3    B
## 4    4    B
```

Subsets

- Subsetting is just like a matrix

```
myframe[1,2]
```

```
## [1] A
## Levels: A B
```

```
myframe[1,]
```

```
##   col1 col2
## 1    1    A
```

```
myframe[,2]
```

```
## [1] A A B B
## Levels: A B
```

Reading in data

- Reading in data typically gives you a `data.frame`
- `read.table` is the basic function to read in tabular data
- `read.csv` is a special cast of `read.table`
- As usual see `?read.table`
- Often you want to set `stringsAsFactors = FALSE`

Adding columns

```
dat1 <- 1:4
dat2 <- rep(c("A","B"),each=2)
myframe <- data.frame(col1=dat1,col2=dat2)
myframe$col3 <- 5:8
myframe
```

```
##   col1 col2 col3
## 1    1    A    5
## 2    2    A    6
## 3    3    B    7
## 4    4    B    8
```

names

- column names in data.frames are specified by `names()`
- this is because data.frames are actually lists with special attributes
- that means that the usual list functions work on data.frames
- lapply, etc

Long example

```
all2006 <- read.csv("2006.csv",header=TRUE,as.is=TRUE)

# exclude hourly-wagers
all2006 <- all2006[all2006$Wage_Per=="Year", ]

# exclude weird cases
all2006 <- all2006[all2006$Wage_Offered_From > 20000,]

all2006$rat <- all2006$Wage_Offered_From
                    / all2006$Prevailing_Wage_Amount

se2006 <- all2006[grep("Software Engineer", all2006),]
```

Control Statements

For loops (1)

```
x <- c(1:5)
y <- NULL
for(i in 1:length(x)) {
   y[i] <- x[i] + 2
}
y
```

```
## [1] 3 4 5 6 7
```

For loops (2)

- or another nice way to make a for loop

```
x <- c(1:3)
for(element in x) {
   print(element + 2)
}
```

```
## [1] 3
## [1] 4
## [1] 5
```

While loops

```
x <- c(1:5)
y <- NULL
i <- 1
while(i<=length(x)) {
   y[i] <- x[i] + 2
   i <- i+1
}
y
```

```
## [1] 3 4 5 6 7
```

Conditional Statements

```
x <- -10
myabs <- x
if(x<0) {
    myabs <- -x
}
myabs
```

```
## [1] 10
```

Functions

Function definitions

- Note that the last value evaluated is what is returned by the function

```
myfunc <- function(x) x^2
myfunc(10)
```

```
## [1] 100
```

Scope rules

- Variables defined inside a function are local to that function

```
myfunc <- function(x) {
    N <- 10
    N*x^2
}
myfunc(10)
```

```
## [1] 1000
```

```
# You can't access N out here
```

Lab 1

Let's work on Lab 1.