A bird-eye view of R

Yufeng Huang

Assistant Professor of Marketing, Simon Business School

July 25/26, 2022

A bird-eye view of R

- We need to learn R from the basics, but before that let me give a quick, but general introduction
- It's like learning a language
  - you don't start with the alphabet
  - you start by hearing others talk
  - but at some point you should formally know that there are 26 letters, basic grammar, how to write a sentense, how to give a speech, how to write a report, etc.
- You might find some of today's examples difficult
  - not design for us to understand all details, but hopefully we can build some general ideas from these examples
  - it's like first time you hear people speak English, you want to get a feeling of it

Things we want to learn in this lecture note

- Calculato**R**
- Variables and expressions
- Functions and packages
- Help and error code
- Throughout: readability and style

CalculatoR

CalculatoR

You can type numeric expressions in R and it will evaluate it for you

```
2 + 3
```

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

```
3 * 4
```

```
## [1] 12
```

```
3^3
```

```
## [1] 27
```

```
sqrt(9) # square root
```

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

CalculatoR

Functions, and expressions involving more than one function

```
sqrt(9)
log(12)
exp(-1)
```

```
# pi is a built-in constant
(1.2 - exp(2))^2 + (log(3) / pi)
```

Comments

The hash symbol # indicates a comment. Anything to the right of a # is ignored in execution.

```
# this is a comment

but this is not a comment
```

```
## Error:  <text>:3:5:  unexpected symbol
## 2:
## 3:  but this
##         ^
```

Use comments to talk to human readers

```
sqrt(9)          # simple comment here

# but sometimes it's good to write multiple
#    lines of comments for readability

# -----------------
# and you can use it to section your code
# -----------------
```

Use comments to talk to human readers

```
# write a header section if needed

# illustration.R
# ---------------------------
# This function illustrates the purpose of a header
#    and unfortunately has no other purposes
# Author: Yufeng Huang
# Version: 0.0.0.2
# Date: 07-25-2022
# Bug report to: yufeng.huang@simon.rochester.edu
# ---------------------------
```

Remark

- Also note that all the code on these lecture notes are actual R code
  - they run and produce results when I compile the slides
  - so you do not have to verify the results
- That means, we can focus on understanding the code and results (and take extra notes if needed) rather than typing all the code yourselves
- Also, feel *completely free* to ask any questions if you do not understand anything

Variables

Use assignment to create variables

```
# assignment with 'arrow' (standard in R)
a <- 2 + 3

# assignment with 'equal' (standard in many languages)
b = 2 - 3

# double equal '==' is for comparison
a == b

## [1] FALSE
```

Let's spend a second to think about this

- Human language "a is equal to b" might mean:
  - create a and make it equal to b
  - I assert that a is equal to b and tell me if I'm right or wrong
- For the computer, these two are completely different!
  - differentiated by "=" (or "<-") and "=="
- Machine only understands literal statements and cannot tolerate any ambiguities

One word on single equal vs arrow

```
# totally fine for assignment
a = 2 + 3

# another use of single equal is to call an argument in the function
rm(list = ls()) # "list" is the name of an argument

# try not to mix assignment expressions
b <- 2
b = b + 2
```

R is case sensitive

```
# Z is different from z
Z <- 2
z <- 1
Z + z
```

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

```
# but note that human eyes are not good at distinguishing cases
```

Your turn: what are a and b?

```
a <- 2
a <- 1
a    # what is a?

b <- 1
b <- b + b
b <- b + b
b    # what is b?
```

- Point: top-to-bottom order in executing simple expressions

Objects

- Everything in R in an object
  - variables, functions, ...
- To list all objects in the current session, you can either use objects() or ls()
  - to be specific it lists data, variables and user-defined functions
  - also available in the environment tab in RStudio

```
# current objects
objects()

## [1] "a" "b" "z" "Z"

# alternatively
ls()

## [1] "a" "b" "z" "Z"
```

Reserved variables

certain variable/function names are reserved: c, F, T, sum, pi, ...

```
# reserved variables are the ones that are pre-defined
F

## [1] FALSE

pi

## [1] 3.141593

# you CAN use those but you SHOULD NOT
pi <- 1 + 1
pi

## [1] 2
```

Expressions

Expressions

```
# expressions as assignment
a <- log(1)    # log() in R is natural log

# or to print
print(a)    # equivalent to just 'a'
```

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

```
# semi-colon ends an expression, not required...
a;    # still prints a
```

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

```
# ...unless multiple expressions in the same line
a <- 1 + 1; a <- a + 1; a    # hard to read, not adviced
```

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

Your turn: what are the outputs in the R console?

```
# expression 1
1 + 1

# expression 2
a = 1 + 1

# expression 3
a == 1 + 1
```

Your turn: why different output?

```
# expressions can be multi-line

a <- log(132) + exp(4)/log(2) +
sqrt(log(2 + 5)^3)
a

## [1] 86.36575
```

```
# but easy to make mistake this way

a <- log(132) + exp(4)/log(2)
+ sqrt(log(2 + 5)^3)

## [1] 2.714465

a

## [1] 83.65128
```

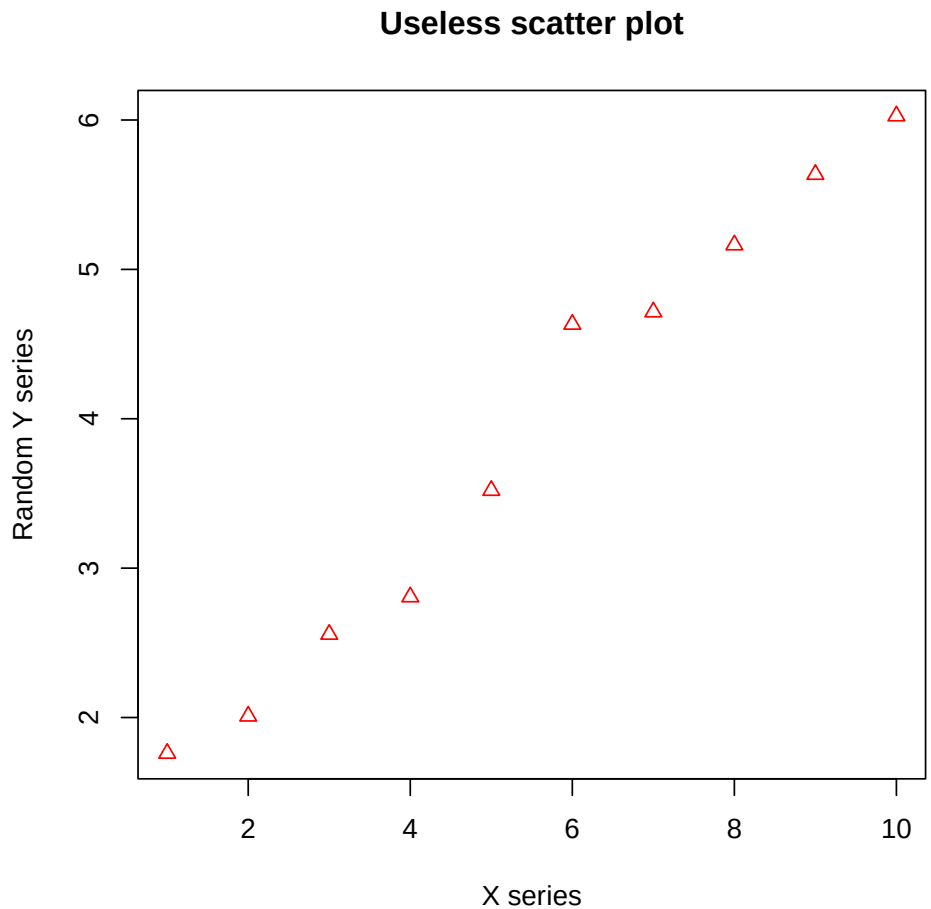
Indentation[1]

```r
# consider indenting the statement

a <- log(132) + exp(4)/log(2) +
    sqrt(log(2 + 5)^3)
```

```r
# indentation makes things readable

x.series <- 1:10
y.series <- NA
for (i in 1:length(x.series)) {
    y.series[i] <- 1 + 0.5*x.series[i] + rnorm(1)/5
}
```

[1] The second part is the "for-loop" that we saw yesterday and we'll these in Week 3

```r
# often multi-line expressions for plots
plot(x.series, y.series,
    xlab = "X series", ylab = "Random Y series",
    main = "Useless scatter plot", col = "red", pch = 24)
```



Your turn: What is y?

```
x <- 1
y <- x^2
x <- 2
print(y)          # what is y?
```

Expressions are evaluated at the spot

```
x <- 1
y <- x^2
x <- 2
print(y)
```

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

Q: What if we want to evaluate the general $y = x^2$ for any x?

Taking stock

- Variables, assigning variables, and simple expressions that involve variables
- Programming languages (including R) are literal
  - cannot understand things that are ambiguous
  - practical note to beginners: the code that you write down are usually clear to the computer but they might not be what you mean
- Expressions are executed according to fixed order of precedence

```
# conventional order of precedence in math
x + y * z

# functions: always evaluate the argument (or: input) before the function itself
f(g(x + 1))

# top to bottom when it comes to multiple expressions; exceptions in Week 3
a <- b + 1
b <- a + 1
```

R is free both as in “free beer”

and as in “free speech”

Functions (= free speech)

User-defined functions

```
# define a function squared(x)
squared <- function(x) {
    y <- x^2              # body of the function
    return(y)             # returns y as output
}
```

User-defined functions (con'd)

```
# squared(x) is defined for any x
squared(1)
```

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

```
squared(2)
```

```
## [1] 4
```

User-defined functions (con'd)

```
# squared(x) is defined for any x
squared(1)
```

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

```
squared(2)
```

```
## [1] 4
```

```
# even if the operation "^" is illegal
squared("today is sooo sunny")
```

```
## Error in x^2:  non-numeric argument to binary operator
```

Built-in functions

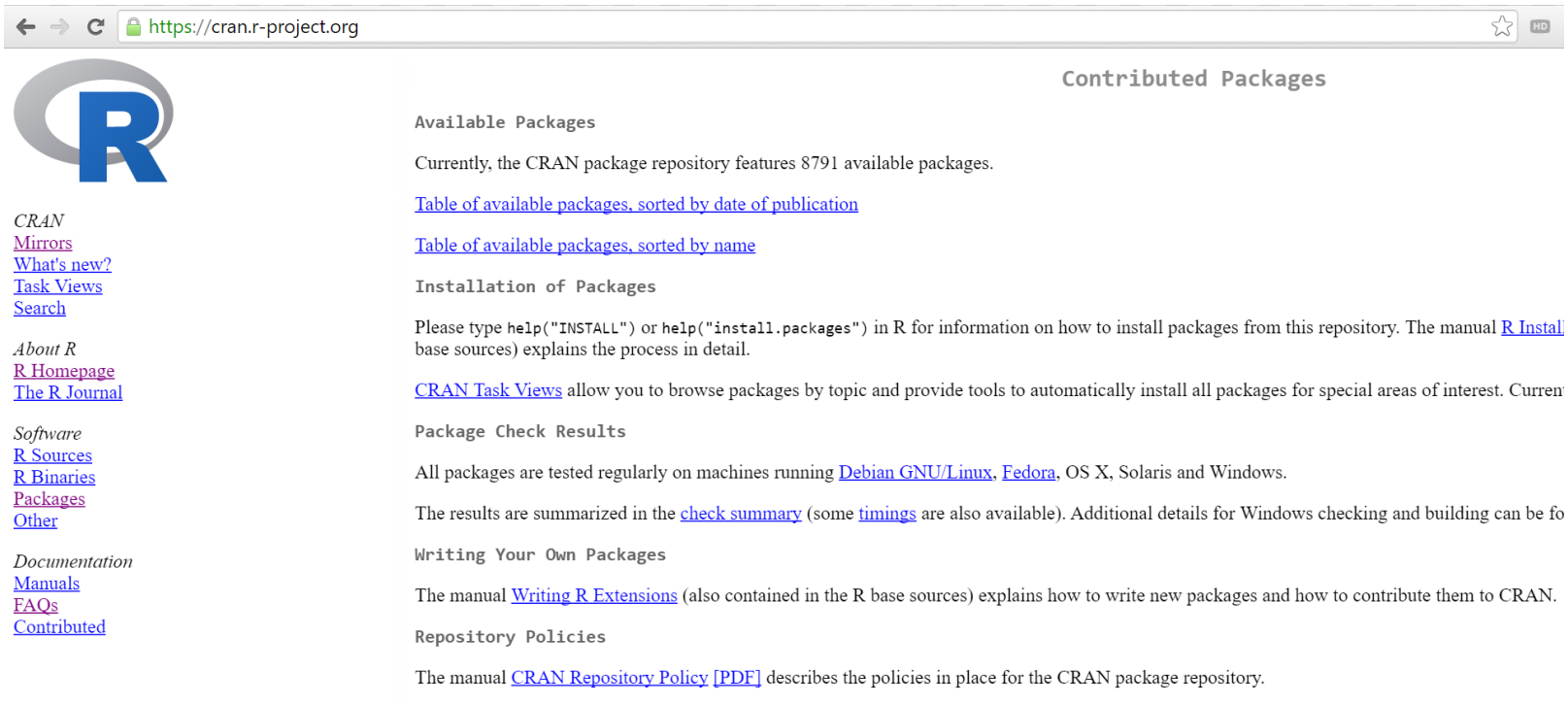
```
# sqrt() comes from the 'base' package
sqrt(4)

## [1] 2

sqrt(1)

## [1] 1
```

Packages (= free beer)[2]

[2] For the users; free speech for the authors.

Packages

- A package is an organized collection of functions (and datasets/other stuff)
- Written by developers and users (free speech for them)
  - distributed on the Comprehensive R Archive Network (CRAN)
  - downloadable via install.packages() (free beer for you)



Example: to fit a line[3]

```
# I want to run a linear regression
linear.fit <- lm(y.series ~ x.series)

## Error in lm(y.series ~ x.series):  could not find function "lm"
```

[3]Note: lm() comes from 'stats' package which usually comes preloaded; for illustration purposes I unloaded 'stats' in the background

Example: to fit a line[3]

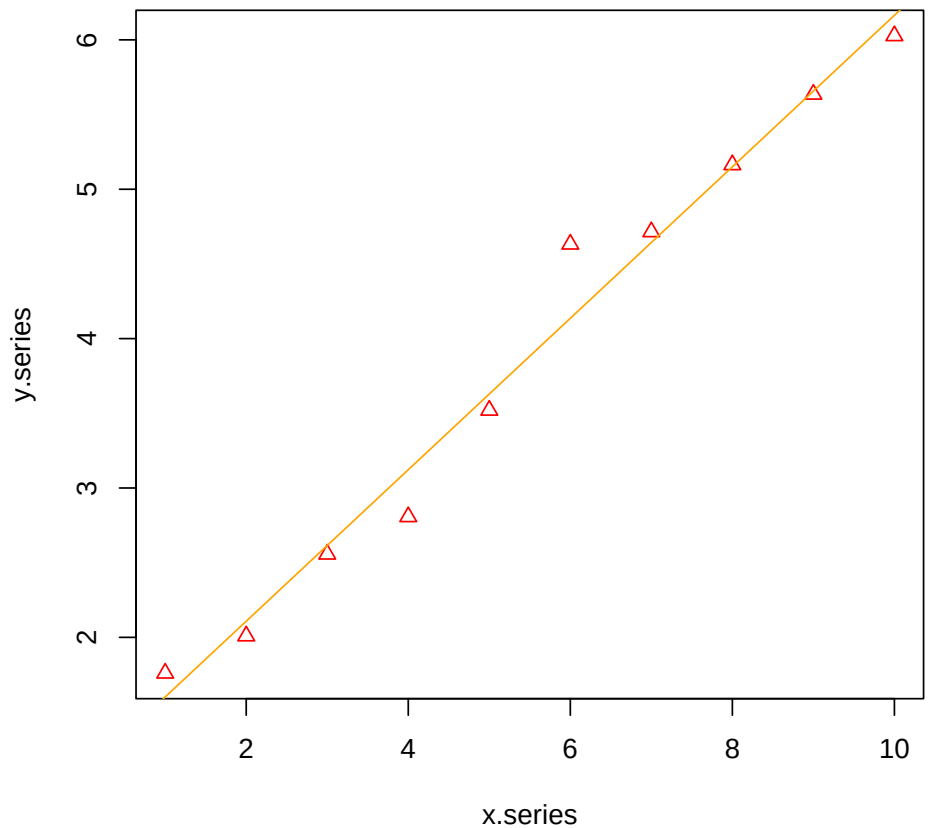
```
# I want to run a linear regression
linear.fit <- lm(y.series ~ x.series)

## Error in lm(y.series ~ x.series):  could not find function "lm"
```

```
# but I need to load 'stats' first
library('stats')
```

[3] Note: lm() comes from 'stats' package which usually comes preloaded; for illustration purposes I unloaded 'stats' in the background

Example: to fit a line (con'd)

```
# we can run the regression after 'stats' is loaded
linear.fit <- lm(y.series ~ x.series)
plot(x.series, y.series, col = "red", pch = 24)
abline(linear.fit, col = "orange")      # add line
```

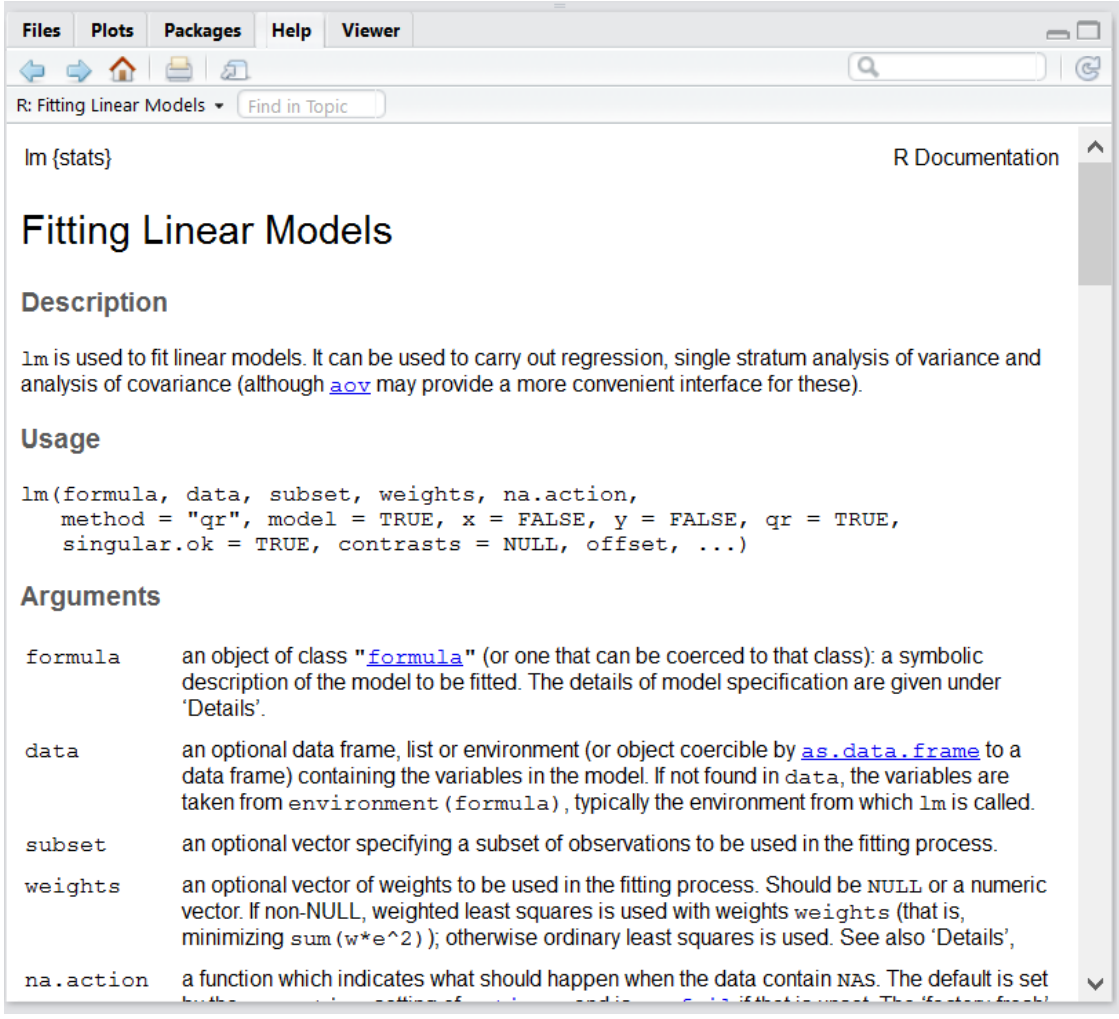


Help

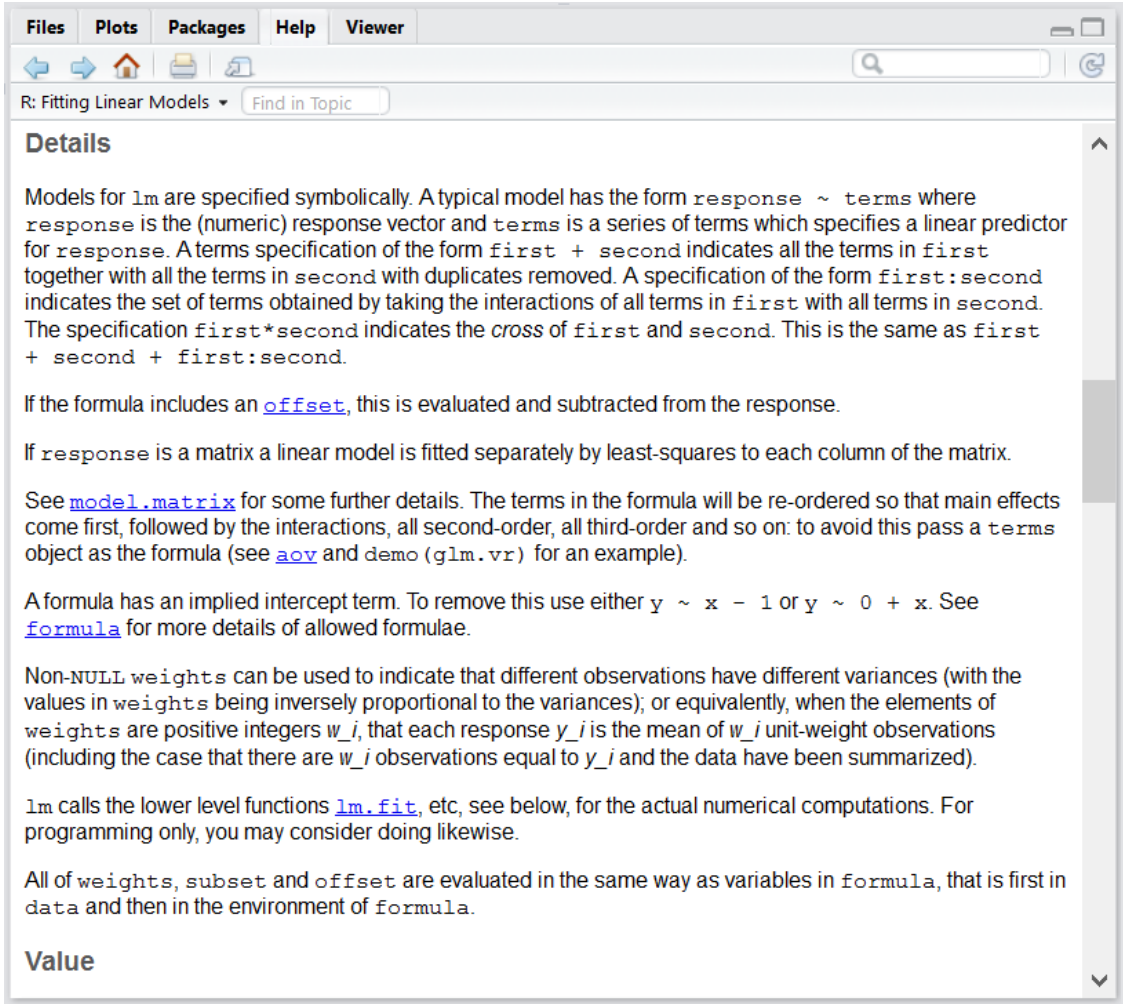
Help

```
# '?function_name' seeks help
?lm

# equivalent
help(lm)

# double '??' searches for the generic term 'lm'
??lm
```

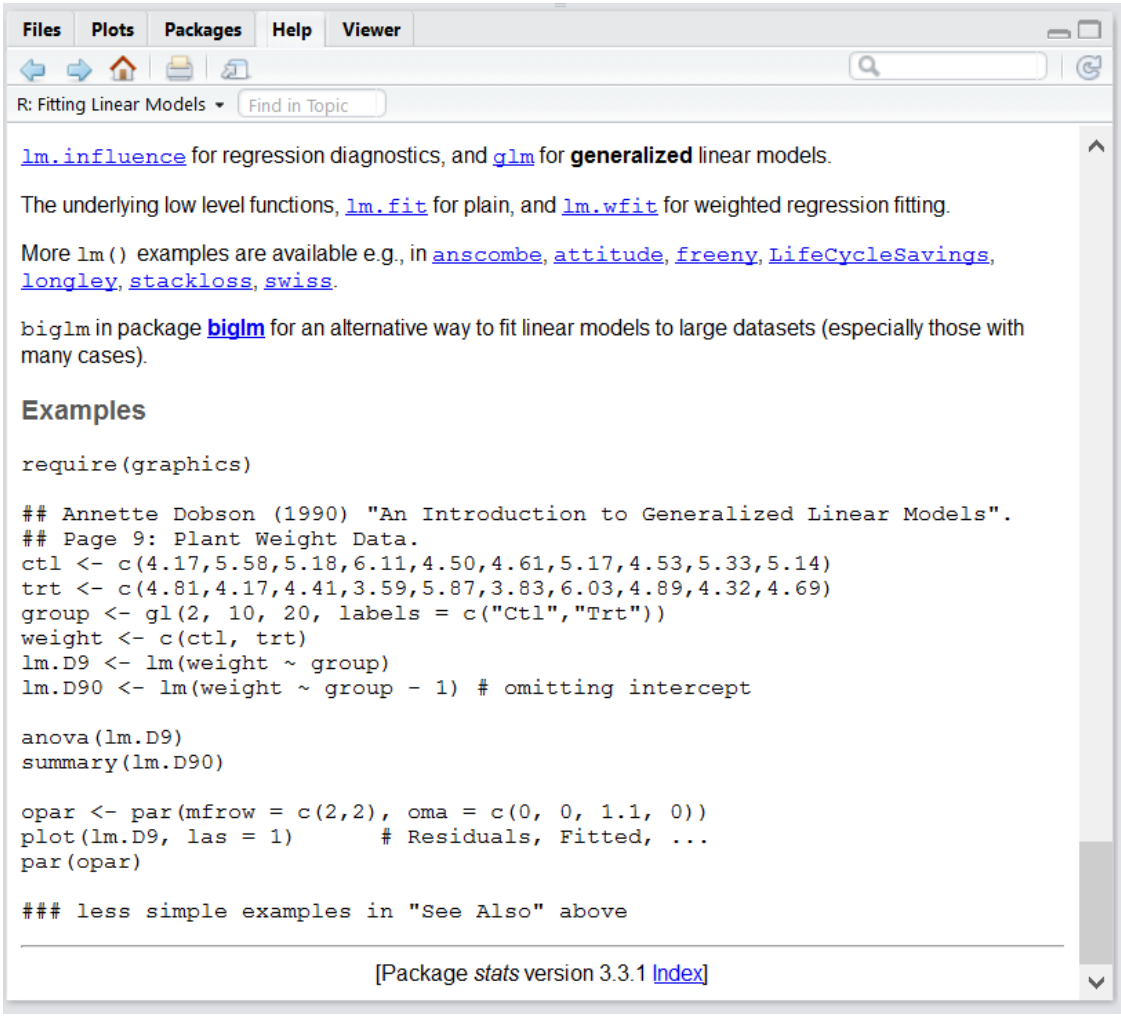
Reading help



Reading help (con'd)

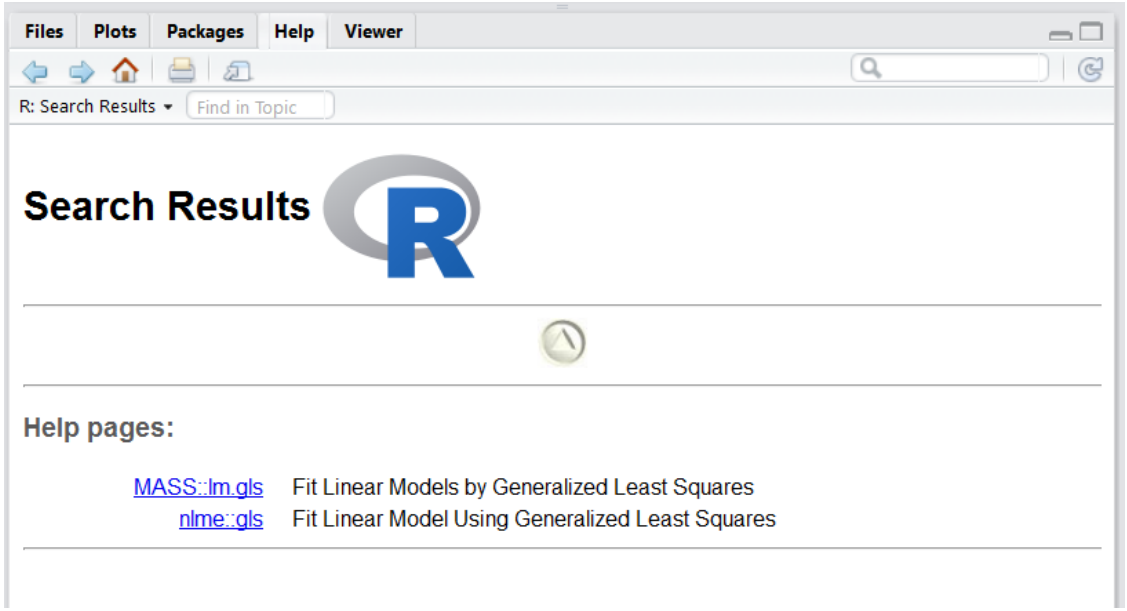


Reading help (con'd)



Help: general search

```
# '??' to search for a specific purpose
??'fit a linear model'

# can also Google
```



Error code (and how to use them as diagnostics)

```
# no such function (a message rather than an error code)
?cool

## No documentation for 'cool' in specified packages and libraries:
## you could try '??cool'

# wrong data type on the power function (within function squared())
squared("today is sunny")

        ## Error in x^2:  non-numeric argument to binary operator

# within the object (data) 'cars', no variable 'dits'
lm(formula = speed ~ dits, data = cars)

     ## Error in eval(predvars, data, env):  object 'dits' not found

# no object 'car', should be 'cars'; note that error is not on 'dits'
lm(formula = speed ~ dits, data = car)

         ## Error in is.data.frame(data):  object 'car' not found
```

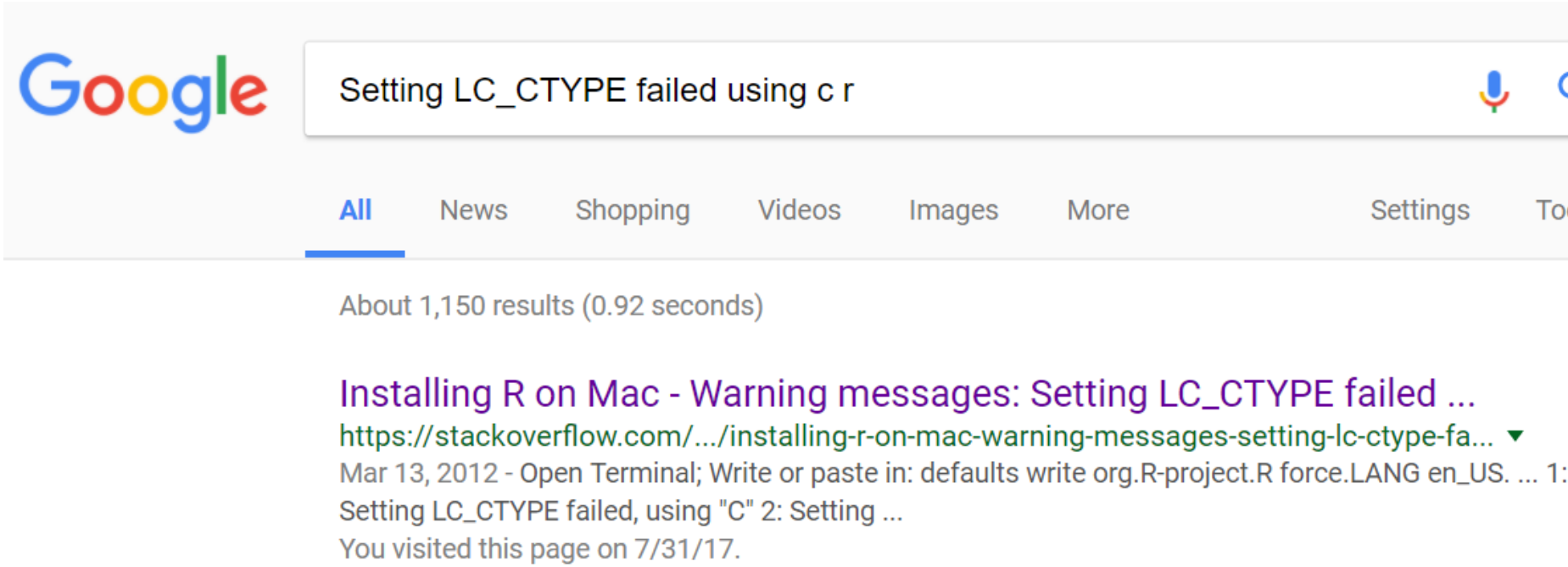
But what if we can't understand an error code?

- Some of you might encounter this when you install R

```
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.

  Natural language support but running in an English locale

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.

During startup - Warning messages:
1: Setting LC_CTYPE failed, using "C"
2: Setting LC_COLLATE failed, using "C"
3: Setting LC_TIME failed, using "C"
4: Setting LC_MESSAGES failed, using "C"
5: Setting LC_MONETARY failed, using "C"
[R.app GUI 1.70 (7375) x86_64-apple-darwin15.6.0]

WARNING: You're using a non-UTF8 locale, therefore only ASCII characters will work.
Please read R for Mac OS X FAQ (see Help) section 9 and adjust your system preferences accordingly.
> help.start()
starting httpd help server ... done
If the browser launched by '/usr/bin/open' is already running, it is *not* restarted, and you must switch to
    its window.
Otherwise, be patient ...
> 3^3
[1] 27
> Sys.getlocale()
[1] "C"
> defaults write org.R-project.R force.LANG en_US.UTF-8
Error: unexpected symbol in "defaults write"
```

- I really don't understand what "Setting LC_CTYPE failed" means, what do I do?

Google


Google
Setting LC_CTYPE failed using c r
All
News
Shopping
Videos
Images
More
Settings
About 1,150 results (0.92 seconds)
Installing R on Mac - Warning messages: Setting LC_CTYPE failed ...
https://stackoverflow.com/.../installing-r-on-mac-warning-messages-setting-lc-ctype-fa...
Mar 13, 2012 - Open Terminal; Write or paste in: defaults write org.R-project.R force.LANG en_US. ... 1:
Setting LC_CTYPE failed, using "C" 2: Setting ...
You visited this page on 7/31/17.

Taking stock

- R is free both as in "free beer" and as in "free speech"
  - you can define virtually any function on your own
  - you can use functions that others have defined and built
- There are so many functions out there and you will have to read a lot of help files
  - help files are in fixed format so it is reasonably easy to get used to understanding them
- Code running into error is a daily thing
  - many times you can figure out these errors reasonably quickly
  - but also many times it is much easier to seek others (including Google) for help
  - and remember to ask questions in (and out of) class!

House-keeping

Good house-keeping

Bad house-keeping

House-keeping

- We talked about coding style, indentation, read-ability, spacing throughout this class
- The point is that the machine can read your code if it's correct
- But humans cannot
  - easier to make mistakes
  - easier to be mis-interpreted by others
  - ignored by others
- Just like writing a bad article
- This is important and I will dedicate more time on this later on

Bad example earlier

```
# for the computer these are 3 separate expressions
a <- log(132) + exp(4)/log(2)    # assignment, no output
 + sqrt(log(2 + 5)^3)            # evaluate and print
a                                # then prints a

## [1] 2.714465
## [1] 83.65128
```

Bad example earlier

```
# for the computer these are 3 separate expressions
a <- log(132) + exp(4)/log(2)    # assignment, no output
 + sqrt(log(2 + 5)^3)            # evaluate and print
a                                # then prints a
```

```
## [1] 2.714465
## [1] 83.65128
```

```
# for a human, easily confused with this
a <- log(132) + exp(4)/log(2) + # assignment; code continues
sqrt(log(2 + 5)^3)
a                                # then prints a
```

```
## [1] 86.36575
```

Another example

- Suppose I want to evaluate the root x of quadratic equations with the general form

$$a \cdot x^2 + b \cdot x + c = 0$$

where a, b and c are parameters

- Mathematically there are two solutions of x, jointly expressed as

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

- Suppose there are 3 such equations:
  - $-x^2 + 2x + 1 = 0$
  - $x^2 - 2x + 1 = 0$
  - $x^2 - 4x + 3 = 0$

Poor house-keeping

```
# approach I: brute-force calculatoR

x11<-(-2+sqrt(2^2-4*(-1)*1))/(2*(-1))
x12<-(-2-sqrt(2^2-4*(-1)*1))/(2*(-1))
x21<-(2+sqrt((-2)^2-4*1*1))/(2*1)
x22<-(2-sqrt((-2)^2-4*1*1))/(2*1)
x31<-(4+sqrt((-4)^2-4*1*3))/(2*1)
x32<-(4-sqrt((-4)^2-4*1*3))/(2*1)

# was there a typo?
```

Wrong approach (but good intention)

```
# approach II: write down a "generic" expression

x1<-(-b+sqrt(b^2-4*a*c))/(2*a)
x2<-(-b-sqrt(b^2-4*a*c))/(2*a)

# let's only look at one case
a<--1;b<-2;c<-1
print(x1);print(x2)

# your turn: what's wrong?
```

Good approach[4]

```
# approach III: write a function

quadratic <- function(a, b, c) {
    root <- sqrt(b^2 - 4*a*c)    # used more than once
    x1 <- (-b + root) / (2*a)
    x2 <- (-b - root) / (2*a)
    list(x1, x2)
}

# evaluate the function at the same case
x <- quadratic(-1, 2, 1)
x

## [[1]]
## [1] -0.4142136
##
## [[2]]
## [1] 2.414214
```

[4] Also note indentation and spacing

Summary: important points

- Simple expressions
- Comment
- Single vs double equal
- Order of precedence and order of executing multi-line code (top to bottom)
- Variables, assign value to variables, replace value (by re-assigning)
- General understanding of the R environment
  - indentation
  - multi-line expressions
  - functions (preview) and packages
  - help
  - error code, warning messages