Data analysis and visualization using R

R basics

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R basics

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- Data types
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- Getting help
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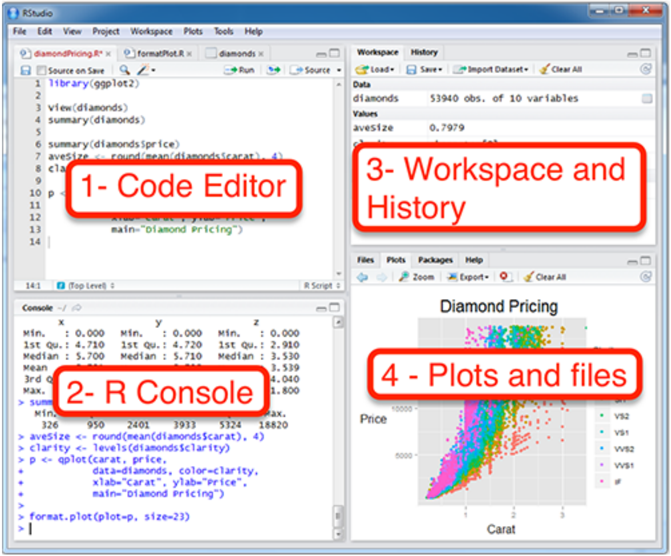
RStudio

The workbench



```
library(ggplot2)

view(diamonds)
summary(diamonds)

summary(diamonds$price)
aveSize <- round(mean(diamonds$carat), 4)
cla

p <


           main="Diamond Pricing")

```

Data	
diamonds	53940 obs. of 10 variables
Values	
aveSize	0.7979

```
       x                  y                  z
 Min.   : 0.000   Min.   : 0.000   Min.   : 0.000
 1st Qu.: 4.710   1st Qu.: 4.720   1st Qu.: 2.910
 Median : 5.700   Median : 5.710   Median : 3.530
 Mean                                         3.539
 3rd Q                                        4.040
 Max.                                         1.800
> summ
   Min.                                     Max.
    326      950     2401     3933     5324   18820
> aveSize <- round(mean(diamonds$carat), 4)
> clarity <- levels(diamonds$clarity)
> p <- qplot(carat, price,
+            data=diamonds, color=clarity,
+            xlab="Carat", ylab="Price",
+            main="Diamond Pricing")
>
> format.plot(plot=p, size=23)
> 
```

Panels of the workbench

You work with 4 panels in the workbench:

1. **Code editor** where you write your scripts: text file with code you want to execute more than once
2. **R console** where you execute lines of code one by one
3. **Workspace and history** See what data you have in memory, and what you have done so far
4. **Plots, Help & Files** . . .

The console vs code editor

- Use the console to do basic calculations, try pieces of code, develop a function, or load scripts (from the code editor) into memory.
- Use the code editor to work on stored code - analyses you may want to repeat, or develop further.
- In the code editor, you can edit data files, programs (scripts), and analytical notebooks (RMarkdown)

Basic Math

The console

- The prompt is the “greater than” symbol “$>$”
- R waits here for you to enter commands
- You can use the console as a calculator
- R supports all math operations in the way you would expect them:

`+`	is ‘plus’, as in $2 + 2 = 4$
`-`	ditto, subtract, as in 2 - 2 $= 0$
`*`	multiply
`/`	divide
`^`	exponent (identical to: `**`)

for the square root you can use $n^{0.5}$: `n**0.5`

use parentheses `()` for grouping parts of equations.

Operator Precedence

All “operators” adhere to the standard mathematrical **precedence** rules (PEMDAS):

```
Parentheses (simplify inside these)
Exponents
Multiplication and Division (from left to right)
Addition and Subtraction (from left to right)
```

- With complex statements you should be aware of operator precedence!
- If you are not sure: use parentheses ()
- If you are still uncertain, look at this reference page

–Practice 1–

In the console, calculate the following:

$31 + 11$

$66 - 24$

$\frac{126}{3}$

12^2

$\sqrt{256}$

$\frac{3*(4+\sqrt{8})}{5^3}$

Solutions

$31 + 11 = 42$

$66 - 24 = 42$

$\frac{126}{3} = 42$

$12^2 = 144$

$\sqrt{256} = 16$

$\frac{3 * (4 + \sqrt{8})}{5^3} = 0.1638823$

An expression dissected

When you type `21 / 3` this called an ***expression***.

The expression has three parts: an operator (/ in the middle) and two operands (left operand 21 and right operand 3).

Since there is no assignment, the result will be send to the console as output, giving `[1] 7`.

Because this expression is the sole contents of the current line in the console, it is also called a ***statement***.

Statement vs expression

A statement is a complete line of code that performs some action, while an expression is any section of code that evaluates to a value.

Functions

Definition

Simple mathematics is not the core business of R.

Going further than basic math, you will need functions.

A function is a piece of functionality that you can execute by typing its name, followed by a pair of parentheses. Within these parentheses, you can pass data for the function to work on. Functions often return a value but not always

Function usage has this general form:

$$function\_name(argument, argument, ...)$$

Example: Square root with `sqrt()`

You have already seen that the square root can be calculated as $n^{0.5}$.

However, there is also a function for it: `sqrt()`. It ***returns*** the square root of the given number, *e.g.* `sqrt(36)`

```
36^0.5
```

```
[1] 6
```

```
sqrt(36)
```

```
[1] 6
```

Another example: `paste()`

The `paste` function can take any number of arguments and returns them combined into a single text string. You can also specify a separator using `sep="<separator string>"`:

```r
paste(1, 2, 3, sep = "---")
```

```
[1] "1---2---3"
```

Note the use of quotes surrounding the dashes: `"---"`; they indicate it is text data.
Note also the use of a name for only the last argument. Not all arguments can be specified by name, but when possible this has preference, as in `sep = "---"`.

Getting help on a function

Type `?function_name` in the console to get help on a function. For instance, typing `?sqrt` will give the help page of the square root function.

Scroll down in the help to see example usages of the function.

–Practice 2–

1. View the help page for `paste`. There are two variants of this function.
   - Which? And what is the difference between them?
   - Use both variants to generate exactly this message `"welcome to R"` from these arguments: `"welcome "`, `"to "`, `"R"`
2. What does the `abs` function do?
   - What is returned by `abs(-20)` and what is `abs(20)`?
3. What does the `c` function do?
   - What is the difference in returned value of `c()` when you combine either `1`, `3` and `"a"` as arguments , or `1`, `2` and `3`?

Variables

What are variables?

- In math, you often use variables to label or name pieces of data, or a function.
- E.g., `x = 42` is used to define a variable `x`, with a value of `42`.
- In programming (and R) this is the same.
- Variables are really *variable* - their value can change!
- In R you can assign a value to a variable using "`<-`", so "`x <- 42`" is equivalent to "`x = 42`"

–Practice 3–

Create three variables with the given values - x=20, y=10 and z=3. Next, calculate the following with these variables:

1. $x + y$
2. x^z
3. $q = x \times y \times z$
4. $\sqrt{q}$
5. $\frac{q}{\pi}$ (pi is gewoon pi in R)
6. $\log_{10}(x \times y)$

Vectors

R is vector-based

- In R, ***all data lives inside vectors***.
- When you type '2 + 4', R wil do this:
    - create a vector of length 1 with its element having the value 2
    - create a vector of length 1 with its element having the value 4
    - add the value of the second vector to ALL the values of vector one, and recycle any shorter vector as many times as needed
- We'll revisit this behavior later.

Four types of data

R knows five basic types of data:

numeric: numbers with a decimal part: `3.123`, `5000.0`, `4.1E3`
integer: numbers without a decimal part: `1`, `0`, `2999`
logical: `true` or `false` (also called boolean values)
character: text, should be put within quotes: `"hello R"`
factor: nominal and ordinal scales (dealt with later)

Note 1: If you type a number on the console, it will always be a `numeric` value,decimal part or not.

Note 2: For character data, single and double quotes are equivalent but double are preferred.

Creating vectors

- The simplest way (there are many) to create a vector is to use the “Concatenate” function `c()`
- `c()` takes all its arguments and puts them behind each other in a vector

```r
> c(2, 4, 3)
```

```
[1] 2 4 3
```

```r
> c("a", "b", c("c", "d"))
```

```
[1] "a" "b" "c" "d"
```

```r
> c(0.1, 0.01, 0.001)
```

```
[1] 0.100 0.010 0.001
```

Vectors can hold only one data type

- A vector can hold only one type of data
- R tries very hard to **coerce** all data to one type

```
c(2, 4, "a") ## becomes a character vector
```

```
[1] "2" "4" "a"
```

Get the type

Using the function `class()`, you can get the data type of a vector.

```r
class(c(2, 4, "a"))
class(1:5)
class(c(2, 4, 0.3))
class(c(2, 4, 3))
```

```
[1] "character"
[1] "integer"
[1] "numeric"
[1] "numeric"
```

Comments

- Everything on a line after a hash sign “#” will be ignored by R

```r
## starting cool analysis
x <- c(T, F, T) # Creating a logical vector
y <- c(TRUE, FALSE, TRUE) # same
```

Ending statements

- You can optionally end statements with a semicolon ";"
- Only when you have more statements on one line they are mandatory

```r
x <- c(1, 2, 3); x; x <- 42; x
```

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

```
[1] 42
```

- *Rule*: Have one statement per line and don't use semicolons

Vector fiddling

Vector arithmetic

- Going back to the vector arithmetic
- Let's just look at some examples

```
x <- c(2, 4, 3, 5)
y <- c(6, 2)
x + y
x * 2
```

```
[1] 8 6 9 7
[1]  4  8  6 10
```

R works ***set based*** and will ***cycle*** the shorter of the two operands to be able to deal with all elements of the longer operand.

```r
x <- c(2, 4, 3, 5)
z <- c(1, 2, 3)
x - z
```

```
Warning in x - z: longer object length is not a multiple of
```

```
[1] 1 2 0 4
```

- As you see, this generates a warning that “longer object length is not a multiple of shorter object length”
- But R will proceed anyway, by cycling the shorter one!

Other operators

- Logical operators:
  - `&`: logical "and"
  - `|`: logical "or"
  - `!`: logical "not"
- Comparison operators (also logical):
  - `<` `<=` `>` `>=` `==`
- Modulo: `%%`
- Integer division: `%/%`
- The `%in%` operator

Modulo: %%

The modulo operator gives the remainder of a division:

```
10 %% 3
```

```
[1] 1
```

```
4 %% 2
```

```
[1] 0
```

```
11 %% 3
```

```
[1] 2
```

Integer division %/%

The integer division is the complement of modulo and gives the integer part of a division:

```
10 %/% 3
```

```
[1] 3
```

```
4 %/% 2
```

```
[1] 2
```

```
11 %/% 3
```

```
[1] 3
```

The %in% operator

The %in% operator is very handy when you want to know if the elements of one vector are present in another vector. An example explains best, as usual:

```
a <- c("one", "two", "three")
b <- c("zero", "three", "five", "two")
a %in% b
b %in% a
```

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

There is no positional evaluation, it simply reports if the corresponding element in the first is present *anywhere* in the second.

Vector creation methods

Creating vectors of specific type

- Often you want to be specific about what you create: use the class-specific constructor **OR** one of the conversion methods
- constructor methods have the name of the type
- conversion methods have “as.” prepended to the name

Method 1: Constructor functions

```r
integer(4)
```

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

```r
character(4)
```

```
[1] "" "" "" ""
```

```r
logical(4)
```

```
[1] FALSE FALSE FALSE FALSE
```

Method 2: Conversion functions

Conversion methods have the name `as.XXX()` where XXX is the desired type

```r
x <- c(1, 0, 2, 2.3)
class(x)
```

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

```r
as.logical(x)
```

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

```r
as.integer(x)
```

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

Limits to coersion

- R will not coerce types that are non-coercable: you get an `NA` value.

```r
x <- c(2, 3, "a")
y <- as.integer(x)
```

```
Warning: NAs introduced by coercion
```

```r
class(y)
```

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

```r
y
```

```
[1]  2  3 NA
```

Method 3: The colon operator

The colon operator *(:)* generates a series of integers

```
1 : 5
```

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

```
5 : 1
```

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

```
2 : 3.66
```

```
[1] 2 3
```

Method 4: The `rep()` function

```r
rep(1 : 3, times = 3)
```

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

```r
rep(1 : 3, each= 3)
```

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

```r
rep(1 : 3, times = 2, each = 3)
```

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

Method 5: The seq() function

```
seq(from = 1, to = 3, by = .2)
```

```
 [1] 1.0 1.2 1.4 1.6 1.8 2.0 2.2 2.4 2.6 2.8 3.0
```

```
seq(1, 2, 0.2) # same
```

```
[1] 1.0 1.2 1.4 1.6 1.8 2.0
```

```
seq(1, 0, length.out = 5)
```

```
[1] 1.00 0.75 0.50 0.25 0.00
```

```
seq(3, 0, by = -1)
```

```
[1] 3 2 1 0
```

Method 6: Through vector operations

This operation of two numeric vectors results in a logical vector:

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

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

Advanced vector fiddling

Operators and vectors in practice

Suppose you have vectors a and b and you want to know which values in a are greater than in b and also smaller than 3

```
a <- c(2, 1, 3, 1, 5, 1)
b <- c(1, 2, 4, 2, 3, 0)
a > b & a < 3 ## returns a logical vector with test results
```

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

Can you figure out this one?

```
6 - 2 : 5
```

```
[1] 4 3 2 1
```

Selecting vectors elements

Often, you want to get to know things about values in a vector

- what value is at the third position?
- what is the highest value?
- which positions have negative values?
- what are the last 5 values?

There are several ways to do this as we'll see

Selecting by index

- The `index` is the position of a value in a vector.
- R starts at 1
- Use brackets `[]` to specify one or more selected indices

```r
x <- c(2, 4, 6, 3, 5, 1)
x[4] ## fourth element
```

```
[1] 3
```

```r
x[3:5] ## elements 3 to 5
```

```
[1] 6 3 5
```

```r
x <- c(2, 4, 6, 3, 5, 1)
x[c(1, 2, 2, 5)] ## elements 1, 2, 2 and 5
```

```
[1] 2 4 4 5
```

```r
x[c(F, T, F)] ## select using booleans - cycled
```

```
[1] 4 5
```

```r
x[x %% 2 == 0] ## all even elements using modulo
```

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

```r
x <- c(2, 4, 6, 3, 5, 1)
x[(length(x) - 1) : length(x)] ## last 2 elements; note th
```

```
[1] 5 1
```

```r
x[length(x) - 1 : length(x)]
```

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

```r
x[x == max(x)]
```

```
[1] 6
```

Use `which()` to get an index instead of value

The function `which()` returns indices for which the logical test evaluates to `true`:

```
which(x >= 2) ## which positions have values 2 or greater?
```

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

```
which(x == max(x)) ## which positions have the maximum val
```

```
[1] 3
```

Calculations with logical vectors

- Often, you want to know how many cases fit some condition
- Logical values have a numeric counterpart:
  - TRUE == 1
  - FALSE == 0
- Use `sum()` to use this feature

```
x <- c(2, 4, 2, 1, 5, 3, 6)
x > 3 ## which values are greater than 3?
```

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

```
sum(x > 3) ## how many are greater than 3?
```

```
[1] 3
```

Some ground rules

Coding style rules

- Names of variables start with a lower-case letter
- Words are separated using underscores
- Be descriptive with names
- Function names are verbs
- Write all code and comments in English
- Preferentially use one statement per line
- Use spaces on both sides of ALL operators
- Use a space after a comma
- Indent code blocks -with {}- with 4 or 2 spaces, but be consistent

Follow Hadleys' style guide http://adv-r.had.co.nz/Style.html

Wrap-up of the basics

- help on function: `help(function)`
- or `?function`
- autocomplete/suggestions in RStudio: `tab` key
- help (in Rstudio): F1
- installing a library that is not in the core packages: `install.packages("ggplot2"")`
- loading a library that is not in the core packages: `library(ggplot2)`
- remove variable(s): `rm(x, y, z, myData)`

The best keyboar shortcuts

- `ctr + 1` go to code editor
- `ctr + 2` go to console
- `ctr + alt + i` insert code chunk (RMarkdown)
- `ctr + enter` run current line
- “