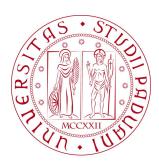
R flow of control and conditional execution

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AA 2021/2022 - R lecture 3



what we have learned so far

R is a dynamically-typed language

```
x <- 1L
y <- 2
x + y
# [1] 3
y <- 5.6
x + y
# [1] 6.6
```

→ Dynamic typing allows us to assign a value of a different data type to the same variable at any time

```
y <- "Test"
x + y
# Error in x + y : non-numeric argument to binary operator</pre>
```

→ But the operation is acknowledged with an error if the data types of the two variables are not compatible

Variables do not need to be declared

more key points ...

- variables do not need to be declared
- all types are vectors
- there is no "scalar" type in R
- but sometimes you have vectors of length one

Internal data representation

- floating point numbers are stored as double (64-bit)
- numbers and sequences are represented as ingeter

Inspecting data

Function	Description
class()	
<pre>typeof()</pre>	show the R type or storage mode of an object
${\tt storage.mode()}$	get/set the storage mode of an object
length()	get/set the length of a vector
attributes()	access object's attributes
str()	compactly display the internal structure of an R object

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Floating point precision limits

only operations among integers are exact

```
u <- sqrt(2)
u * u == 2
# [1] FALSE

u * u - 2
# [1] 4.440892e-16

print(u * u)
# [1] 2

print(u * u, digits = 18)
# [1] 2.000000000000000044</pre>
```

- the all.equal() function compares R objects testing 'near equality
- the identical() function tests two R objects for being exactly equal

```
identical(u * u, 2)
# [1] FALSE
all.equal(u * u, 2)
# [1] TRUE
```

→ check R FAQ 7.31 - Why doesn't R think these numbers are equal?

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Overview

```
- if / else
```

- switch()
- for loops
- while
- ifelse()
- function()

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if statement

• if is the typical conditional execution in many programming languages

```
x <- 35
y <- 45
if (x > y) cat("xuisubigger\n")
if (y > x) cat("yuisubigger\n")
# y is bigger
```

• with else we can build an alternative branch

```
if (x > y) {
   cat("x_{\sqcup}is_{\sqcup}bigger\n")
} else {
   cat("yuisubigger\n")
# y is bigger
```

always us the { brackets to delimit the body

and if statements can be nested

```
if (x > y) {
    cat("xuisubigger\n")
} else if (y > x) {
    cat("y_{\sqcup}is_{\sqcup}bigger\n")
    cat("x_{\sqcup}and_{\sqcup}y_{\sqcup}are_{\sqcup}equal \n")
# y is bigger
```

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switch (expression, list) conditional statement

- switch() can be used for multiple alternatives, instead of nested if / else
- expression can be a number:

```
switch(1, "red", "green", "blue", "yellow")
# [1] "red"
switch(4, "red", "green", "blue", "yellow")
# [1] "yellow"
switch(0, "red", "green", "blue", "yellow")
                                                         expression out of range
switch(5, "red", "green", "blue", "yellow")
# NULL
or a string \rightarrow the matching named item's value is returned
x < -35
y < -45
msg <- switch(as.character(sign(x - y)),</pre>
                 "1" = "x_{\sqcup}is_{\sqcup}bigger",
                 "0" = x_{\perp}andy_{\perp}are\thetaequal",
                                                 named list
                 "-1" = "y_{\sqcup}is_{\sqcup}bigger")
cat(msg, "\n")
y is bigger
as.character(sign(x - y))
# [1] "-1"
```

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for loops

Basic usage: for (j in set_or_sequence)

```
x <- c(1, 2, 7, 9)

for (i in x) cat(i, "u|u")
# 1 | 2 | 7 | 9 |
```

• we can use a sequence 1:5

```
for (i in 1:5) cat(i, "|_{\sqcup}")
1 | 2 | 3 | 4 | 5 |
```

but also a decreasing sequence

```
for (i in 1:-1) cat(i, "_{\sqcup}|_{\sqcup}") # 1 | 0 | -1 |
```

we can loop over a sequence generate along a vector

```
for (i in seq_along(x)) cat("(", i, ",", x[i],")")
# (1,1)(2,2)(3,7)(4,9)
```

- it's another possible construct for loops
- while tests a condition and enters the expression only if the condition is TRUE syntax:

```
while (some_expression_is_true) { do_something }

i <- 1
while (i<6) {
   cat(i,"_| | ")
   i <- i + 1
}
# 1 | 2 | 3 | 4 | 5 |</pre>
```

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do - while loops in R?

- the do while construct does not exist in R
- it can be simulated with a repeat statement
- while tests a condition and executes block only if the condition is TRUE: 0 to MANY
- do while executes at least once, and tests the condition at the end: 1 TO MANY

syntax:

```
repeat {
   statements
   if (!condition) { break }
}
```

condition is a logical expression to remain in the block

• Here is and example

```
i <- 1
repeat {
   cat(i,""")
   i <- i + 1
   if ( !(i < 6) ) { break }
}
# 1 | 2 | 3 | 4 | 5 | >
```

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Problem

- given an integer number n, compute the factorial:
- $n! = n \cdot (n-1) \cdot (n-2) \cdot \ldots \cdot 2 \cdot 1$

Using a for loop

```
n <- 5
fac <- 1
for (j in 2:n) {
    fac <- fac * j
}
cat(paste(n, "!=", fac, "\n"))
# 5 ! = 120</pre>
```

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Example: compute the factorial

Problem

- given an integer number *n*, compute the factorial:
- $n! = n \cdot (n-1) \cdot (n-2) \cdot \ldots \cdot 2 \cdot 1$

Using a while loop

```
n <- 5
fac <- 1
tmp <- n
while (tmp > 1) {
    fac <- fac * tmp
    tmp <- tmp - 1
}

cat(paste0(n, "! = ", fac, "\n"))
# 5! = 120</pre>
```

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Problem

- given an integer number n, compute the factorial:
- $n! = n \cdot (n-1) \cdot (n-2) \cdot \ldots \cdot 2 \cdot 1$

Using a repeat loop

```
n <- 5
fac <- 1
tmp <- n
repeat {
    fac <- fac * tmp
    tmp <- tmp - 1
    if (tmp < 1) {
        break
    }
}
cat(paste0(n, "! = ", fac, "\n"))
# 5! = 120</pre>
```

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Example: compute the factorial

Problem

- given an integer number *n*, compute the factorial:
- $n! = n \cdot (n-1) \cdot (n-2) \cdot \ldots \cdot 2 \cdot 1$
- we could compute the factorial using built-in functions that operate on the entire vector, avoiding the need of loops or repeats

R implements a built-in factorial() function

```
factorial(5)
# [1] 120
factorial(0)
# [1] 1
factorial(-3)
# [1] NaN
# Warning message:
# In gamma(x + 1) : NaNs produced
```

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• functions are the most important bulding block in R

```
f <- function(x, y, z) { statement(s) }</pre>
```

- a function in R can have (a variable number of) arguments
- that may have names
- and default values
- in a call, arguments are given by position or name

```
fsum <- function(x = 1, y = 2) { x + y }

fsum()
# [1] 3

fsum(2,3)
# [1] 5
fsum(2)
# [1] 4
fsum(y=2)
# [1] 3
fsum(y=2, x=4)
# [1] 6</pre>
fsum
# function(x = 1, y = 2) { x + y }
```

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R lazy evaluation

What is it?

- it's a programming strategy, used mainly in functional languages
- → only necessary symbols are evaluated → only the needed objects will be loaded in memory and/or looked for

Examples

```
plaz <- function(a, b) { return 10; }

plaz()
# [1] 10
plaz(1)
# [1] 10
plaz(1, 2)
# [1] 10

play <- function(a, b) { a * 10 }

play()
# Error in play() : argument "a" is missing, with no default play(1)
# [1] 10
play(1, 2)
# [1] 10</pre>
```

More examples

→ and expression is evaluated not at the time the call is made, but only when the expression is used

```
# Here, only TRUE is evaluated
if (TRUE || no_variable) {
    12
}
# [1] 12

ping <- function(a = Sys.time(), b = Sys.time(), c = Sys.time()){
    print(a)
        Sys.sleep(1)
    print(b)
        Sys.sleep(1)
    print(c)
}

ping()
# [1] "2022-03-16 16:44:07 CET"
# [1] "2022-03-16 16:44:08 CET"
# [1] "2022-03-16 16:44:09 CET"</pre>
```

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ifelse(): vectorized conditional execution

```
y <- log(rpois(20,1.5))
y
# [1]     -Inf 1.0986123 0.0000000 0.0000000 0.0000000 0.6931472
# [7] 0.6931472     -Inf 1.3862944 0.6931472 1.3862944     -Inf
# [13]     -Inf 0.0000000 0.0000000 1.0986123 0.0000000 0.0000000
# [19]     -Inf 1.0986123</pre>
mean(y)
# [1] -Inf
```

we need to replace -Inf with NA

ifelse() allows to perform conditional execution on the whole vector

Problem

- we generate a vector of 10⁷ random numbers from a uniform distribution
- we want to serch for the maximum value in the vector, using the R max() function and conventional loops

```
library(microbenchmark)
fm1 <- function(x) { max(x) }</pre>
fm2 <- function(x) {</pre>
 cmax <- x[1]
  for (i in 2:length(x)) {
   if (x[i] > cmax) cmax <- x[i]
}
u <- runif(10^7)
microbenchmark(max(u), fm1(u), fm2(u))
Unit: milliseconds
 expr min
                     lq
                           mean median
                                               uq
                                                     max neval cld
max(u) 13.8899 14.0255 15.0040 14.3078 15.753 18.1426 100 a
fm1(u) 13.8918 13.9899 14.8993 14.4838 15.186 21.7245 100 a
fm2(u) 237.0996 238.9029 243.2218 240.7945 246.097 259.4658 100 b
```

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Good/Bad practice in building vectors

Problem

- we want to build a vector containing 10^n elements in the sequence $1:10^n$
- three ways are analyzed

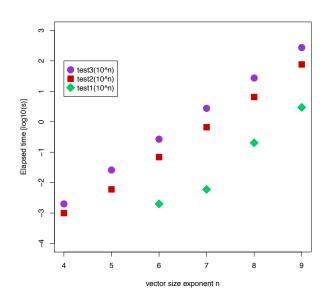
```
test1 <- function(n){
    y <- 1:n
}

test2 <- function(n){
    y <- numeric(n)
    for (i in 1:n)
        y[i] <- i
}

test3 <- function(n){
    y <- NULL
    for (i in 1:n)
        y <- c(y,i)
}</pre>
```

Good/Bad practice in building vectors (2)

- the first method (test1) is the best
- the loop using a pre-determined vector length is reasonably fast
- the last method (test3) is the slowest
- Moral: never grow vectors by repeated concatenation



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