Stat 243

Control Flow Structures in R

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Expressions

Expressions

R code is composed of a series of expressions

- assignment statements
- arithmetic expressions
- function calls
- conditional statemetns
- loop statements
- etc

Simple Expressions

```r
#  assignment statement
a <- 12345

# arithmetic expression
525 + 34 - 280
```

```
## [1] 279
```

```r
# function call
median(1:10)
```

```
## [1] 5.5
```

Expressions

One way to separate expressions is with new lines:

```
a <- 12345
525 + 34 - 280
median(1:10)
```

Grouping Expressions

Constructs for grouping together expressions

- semicolons `;`
- curly braces `{ }`

Grouping Expressions

Grouping expressions with semicolons:

```
a <- 10; b <- 20; d <- 30
```

Using semicolons, although valid, it is not a common practice among the R community

Grouping Expressions

Grouping expressions with braces:

```
{
  a <- 10
  b <- 20
  d <- 30
}
```

Grouping Expressions

Grouping expressions in one line with semicolons within braces:

```
{a <- 10; b <- 20; d <- 30}
```

Compound Expressions

- Compound expressions consist of multiple simple expressions
- Compound expressions require braces
- Simple expressions in a compound expression can be separated by semicolons or newlines

Value of Expressions

The value of an expression is the last evaluated statement:

```r
# value of an expression
{5 + 3; 4 * 2; 1 + 1}
```

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

The result has the visibility of the last evaluation

Compound Expressions

It is possible to assign expressions to an object. Still, the variables inside the braces can be used in later expressions

```
z <- {x <- 4; y <- x^2; x + y}
x
```

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

```
z
```

```
## [1] 20
```

Compound Expressions

Instead of assigning a compound expression to z:

```
z <- {x <- 4; y <- x^2; x + y}
```

most R users would prefer something like this:

```
x <- 4
y <- x^2
z <- x + y
```

Using Expressions

Expressions are typically used in

- Flow control structures (e.g. `for` loop)
- Functions

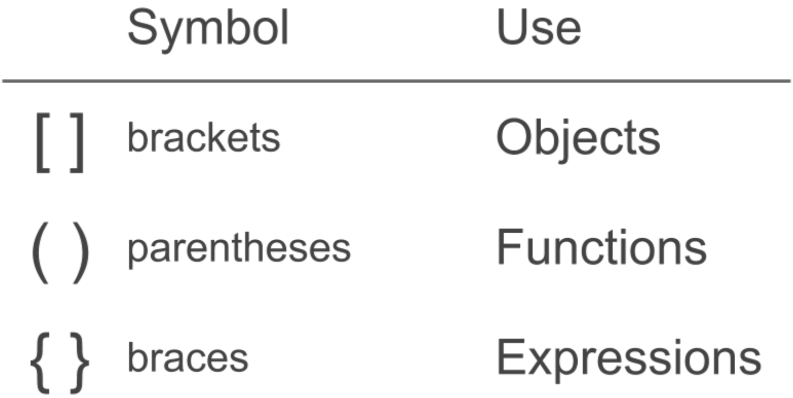
Brackets, Parentheses, and Braces

```r
# brackets for objects
dataset[1:10]

# parentheses for functions
some_function(dataset)

# braces for expressions
{
  1 + 1
  mean(1:5)
  tbl <- read.csv('datafile.csv')
}
```

Brackets and braces in R



	Symbol	Use
[ ]	brackets	Objects
( )	parentheses	Functions
{ }	braces	Expressions

Figure 1: brackets, parentheses, braces

Compound Expressions

Do not confuse a function call (having arguments in multiple lines) with a compound expression

```
# this is NOT a compound expression
plot(x = runif(10),
     y = rnorm(10),
     col = "#89F39A",
     main = "some plot",
     xlab = 'x',
     ylab = 'y')
```

Expressions

In summary

- A program is a set of instructions
- Programs are made up of expressions
- R expressions can be simple or compound
- Every expression in R has a value

Basic Functions

Motivation

R comes with many functions and packages that let us perform a wide variety of tasks.
Sometimes, however, there's no function to do what we want to achieve. In these cases we need to create our own functions.

Anatomy of a function

function() allows us to create a function. It has the following structure:

```
function_name <- function(arg1, arg2, etc)
{
  expression_1
  expression_2
  ...
  expression_n
}
```

Anatomy of a function

- Generally, we will give a name to a function
- A function takes one or more inputs (or none), known as *arguments*
- The expressions forming the operations comprise the **body** of the function
- Functions with simple expressions don't require braces
- Functions with compound expressions do require braces
- Functions return a single value

Function example

A function that squares its argument

```
square <- function(x) {
  x * x
}
```

- the function name is `"square"`
- it has one argument: `x`
- the function body consists of one simple expression
- it returns the value `x * x`

Function example

It works like any other function in R:

```r
square(10)
```

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

In this case, `square()` is also vectorized

```r
square(1:5)
```

```
## [1]  1  4  9 16 25
```

Why is `square()` vectorized?

Function example

Once defined, functions can be used in other functions definitions:

```
sum_of_squares <- function(x) {
  sum(square(x))
}

sum_of_squares(1:5)
```

```
## [1] 55
```

Function example

Functions with a body consisting of a simple expression can be written with no braces (in one single line!):

```r
square <- function(x) x * x

square(10)
```

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

However, we recommend you to always write functions using braces

More about functions?

We'll discuss more details about functions in the next unit

Control Flow Structures

Control Flow

There are many times where you don't just want to execute one statement after another; you need to control the flow of execution

Main Idea

Execute some code when a codition is fulfilled

Control Flow Structures

- if-then-else
- switch cases
- repeat loop
- while loop
- for loop

If-Then-Else

If-then-else

If-then-else statements make it possible to choose between two (possibly compound) expressions depending on the value of a logical condition

```r
# absolute value
num <- rnorm(1)
if (num >= 0) {
  num
} else {
  -num
}
```

```
## [1] 0.2066898
```

If-then-else

If-then-else statements make it possible to choose between two (possibly compound) expressions depending on the value of logical condition

```
if (condition) expression1 else expression2
```

If `condition` is true then `expression1` is evaluated otherwise `expression2` is executed

If-Then-Else

If-then-else with **simple** expressions (equivalent forms):

```
# no braces
if (condition) expression1 else expression2

# with braces
if (condition) {
  expression1
} else {
  expression2
}
```

Example: if-then-else

Equivalent forms:

```
# simple if-then-else
if (5 > 2) 5 * 2 else 5 / 2

# simple if-then-else
if (5 > 2) {
  5 * 2
} else {
  5 / 2
}
```

If-Then-Else

If-then-else with **compound** expressions

```
# compound expressions require braces
if (condition) {
  expression1
  expression2
  ...
} else {
  expression3
  expression4
  ...
}
```

Considerations

- `if()` takes a **logical** condition
- the condition must be a logical value of **length one**
- it executes the next statement if the condition is TRUE
- if the condition is FALSE, then it executes the false expression

If and Else

```r
y <- -5

if (y > 0) {
  print("it is positive")
} else {
  print("it is negative")
}
```

```
## [1] "it is negative"
```

The else statement must occur on the same line as the closing brace from the if clause!

If and Else

The logical condition must be of length one!

```r
if (c(TRUE, TRUE)) {
  print("it is positive")
} else {
  print("it is negative")
}
```

```
## Warning in if (c(TRUE, TRUE)) {: the condition has lengt
## first element will be used
```

```
## [1] "it is positive"
```

Just If

It is also possible to have the **if** clause (without *else*)

```
# just if
if (condition) {
  expression1
  ...
}
```

Equivalent to:

```
# just if
if (condition) {
  expression1
  ...
} else NULL
```

Just If

If there is a single statement, you can omit the braces:

```r
if (TRUE) { print("It is true") }

if (TRUE) print("It is true")

# valid but not recommended
if (TRUE)
  print("It is true")
```

Multiple If’s

Multiple conditions can be defined by combining `if` and `else` repeatedly:

```r
set.seed(9)
x <- round(rnorm(1), 1)

if (x > 0) {
  print("x is positive")
} else if (x < 0) {
  print("x is negative")
} else if (x == 0) {
  print("x is zero")
}
```

```
## [1] "x is negative"
```

Vectorized `ifelse()`

`if()` takes a single logical value. If you want to pass a logical vector of conditions, you can use `ifelse()`:

```r
true_false <- c(TRUE, FALSE)

ifelse(true_false, "true", "false")
```

```
## [1] "true"  "false"
```

Vectorized If

```r
# some numbers
numbers <- c(1, 0, -4, 9, -0.9)

# are they non-negative or negative?
ifelse(numbers >= 0, "non-neg", "neg")
```

```
## [1] "non-neg" "non-neg" "neg"     "non-neg" "neg"
```

Function `switch()`

When a condition has multiple options, combining several `if` and `else` can become cumbersome

Multiple if’s

```
first_name <- "harry"

if (first_name == "harry") {
  last_name <- "potter"
} else {
  if (first_name == "ron") {
    last_name <- "weasley"
  } else {
    if (first_name == "hermione") {
      last_name <- "granger"
    } else {
      last_name <- "not available"
    }
  }
}
```

Multiple selection with switch()

```r
first_name <- "ron"

last_name <- switch(
  first_name,
  harry = "potter",
  ron = "weasley",
  hermione = "granger",
  "not available")

last_name
```

```
## [1] "weasley"
```

Multiple selection with `switch()`

- the `switch()` function makes it possible to choose between various alternatives
- `switch()` takes a character string
- followed by several named arguments
- `switch()` will match the input string with the provided arguments
- a default value can be given when there's no match
- multiple expressions in a `switch()` can be enclosed by braces

Multiple selection with `switch()`

```
switch(expr,
       tag1 = rcode_block1,
       tag2 = rcode_block2,
       ...
       )
```

`switch()` selects one of the code blocks, depending on the value of `expr`

Switch example

```r
operation <- "add"

result <- switch(
  operation,
  add = 2 + 3,
  product = 2 * 3,
  division = 2 / 3,
  other = {
    a <- 2 + 3
    exp(1 / sqrt(a))
  }
)

result
```

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

Switch example

- `switch()` can also take an integer as first argument
- in this case the remaining arguments do not need names
- instead, they will have associated integers

```r
switch(
  4,
  "one",
  "two",
  "three",
  "four")
```

```
## [1] "four"
```

Empty code blocks in `switch()`

Empty code blocks can be used to make several tags match the same code block:

```
student <- "ron"

house <- switch(
  student,
  harry = ,
  ron = ,
  hermione = "gryffindor",
  draco = "slytherin")
```

In this case a value of `"harry"`, `"ron"`, or `"hermione"` will cause `"gryffindor"`

Loops

About Loops

- Many times we need to perform a procedure several times
- The main idea is that of **iteration**
- For this purpose we use loops
- We perform the same operation several times as long as some condition is fulfilled
- R provides three basic paradigms: `for`, `repeat`, `while`

For Loops

- Often we want to repeatedly carry out some computation a fixed number of times.
- For instance, repeat an operation for each element of a vector.
- In R this is done with a `for` loop.

Motivation example

```r
prices <- c(2.50, 2.95, 3.45, 3.25)

prices
```

```
## [1] 2.50 2.95 3.45 3.25
```

Printing prices

```r
cat("Price 1 is", prices[1])
cat("Price 2 is", prices[2])
cat("Price 3 is", prices[3])
cat("Price 4 is", prices[4])
```

```
## Price 1 is 2.5
```

```
## Price 2 is 2.95
```

```
## Price 3 is 3.45
```

```
## Price 4 is 3.25
```

Printing prices

```r
for (i in 1:4) {
  cat("Price", i, "is", prices[i], "\n")
}
```

```
## Price 1 is 2.5
## Price 2 is 2.95
## Price 3 is 3.45
## Price 4 is 3.25
```

Motivation example

```r
coffee_prices <- c(
  expresso = 2.50,
  latte = 2.95,
  mocha = 3.45,
  cappuccino = 3.25)

coffee_prices
```

```
##   expresso      latte      mocha cappuccino 
##       2.50       2.95       3.45       3.25 
```

Printing coffee prices

```r
cat("Expresso has a price of", coffee_prices[1])
cat("Latte has a price of", coffee_prices[2])
cat("Mocha has a price of", coffee_prices[3])
cat("Capuccino has a price of", coffee_prices[4])
```

```
## Expresso has a price of 2.5
```

```
## Latte has a price of 2.95
```

```
## Mocha has a price of 3.45
```

```
## Capuccino has a price of 3.25
```

Printing coffee prices

```r
for (i in 1:4) {
  cat(names(coffee_prices)[i], "has a price of",
      prices[i], "\n")
}
```

```
## expresso has a price of 2.5
## latte has a price of 2.95
## mocha has a price of 3.45
## cappuccino has a price of 3.25
```

For Loops

`for` loops are used when we know exactly how many times we want the code to repeat

```
for (iterator in times) {
  do_something
}
```

`for` takes an **iterator** variable and a vector of **times** to iterate through.

For Loops

```r
value <- 2
for (i in 1:5) {
  value <- value * 2
  print(value)
}
```

```
## [1] 4
## [1] 8
## [1] 16
## [1] 32
## [1] 64
```

For Loops

The vector of *times* does NOT have to be a numeric vector; it can be any vector

```r
value <- 2
times <- c('one', 'two', 'three', 'four')

for (i in times) {
  value <- value * 2
  print(value)
}
```

```
## [1] 4
## [1] 8
## [1] 16
## [1] 32
```

For Loops and Next statement

Sometimes we need to skip a loop iteration if a given condition is met, this can be done with a next statement

```
for (iterator in times) {
  expr1
  expr2
  if (condition) {
    next
  }
  expr3
  expr4
}
```

For Loops and Next statement

```r
x <- 2

for (i in 1:5) {
  y <- x * i
  if (y == 8) {
    next
  }
  print(y)
}
```

```
## [1] 2
## [1] 4
## [1] 6
## [1] 10
```

Nested Loops

It is common to have nested loops

```
for (iterator1 in times1) {
  for (iterator2 in times2) {
    expr1
    expr2
    ...
  }
}
```

Nested loops

```r
# some matrix
A <- matrix(1:12, nrow = 3, ncol = 4)

A
```

```
##      [,1] [,2] [,3] [,4]
## [1,]    1    4    7   10
## [2,]    2    5    8   11
## [3,]    3    6    9   12
```

Nested Loops

```r
# reciprocal of values less than 6
for (i in 1:nrow(A)) {
  for (j in 1:ncol(A)) {
    if (A[i,j] < 6) A[i,j] <- 1 / A[i,j]
  }
}

A
```

```
##           [,1] [,2] [,3] [,4]
## [1,] 1.0000000 0.25    7   10
## [2,] 0.5000000 0.20    8   11
## [3,] 0.3333333 6.00    9   12
```

For Loops and Vectorized Computations

- R `for` loops have bad reputation for being slow
- Experienced users will tell you “tend to avoid for loops in R” (me included)
- R provides a family of functions that are usually more efficient than loops (i.e. `apply()` functions)
- You can start solving a problem using `for` loops
- Once you solved it, try to see if you can find a vectorized alternative
- It takes practice and experience to find alternative solutions to `for` loops
- There are cases when using `for` loops is not that bad

Repeat Loop

`repeat` executes the same code over and over until a stop condition is met:

```
repeat {
  keep_doing_something
  if (stop_condition) break
}
```

The `break` statement stops the loops. If you enter an infinite loop, you can manually break it by pressing the `ESC` key.

Repeat Loop

```
value <- 2

repeat {
  value <- value * 2
  print(value)
  if (value >= 40) break
}
```

```
## [1] 4
## [1] 8
## [1] 16
## [1] 32
## [1] 64
```

Repeat Loop

To skip a current iteration, use `next`

```r
value <- 2

repeat {
  value <- value * 2
  print(value)
  if (value == 16) {
    value <- value * 2
    next
  }
  if (value > 80) break
}
```

```
## [1] 4
## [1] 8
## [1] 16
## [1] 64
## [1] 128
```

While Loops

It can also be useful to repeat a computation until a condition is false. A `while` loop provides this form of control flow.

```
while (condition) {
  keep_doing_something
}
```

About while loops

- `while` loops are backward `repeat` loops
- `while` checks first and then attempts to execute
- computations are carried out for as long as the condition is true
- the loop stops when the condition is FALSE
- If you enter an infinite loop, break it by pressing `ESC` key

While Loops

```r
value <- 2

while (value < 40) {
  value <- value * 2
  print(value)
}
```

```
## [1] 4
## [1] 8
## [1] 16
## [1] 32
## [1] 64
```

Repeat, While, For

- If you don't know the number of times something will be done, you can use either `repeat` or `while`
- `while` evaluates the condition at the beginning
- `repeat` executes operations until a stop condition is met
- If you know the number to times that something will be done, use `for`
- `for` needs an *iterator* and a vector of *times*

Questions

- What happens if you pass `NA` as a condition to `if()`?
- What happens if you pass `NA` as a condition to `ifelse()`?
- What types of values can be passed as the first argument to `switch()`?
- How do you stop a `repeat` loop executing?
- How do you jump to next iteration of a loop?