

Basic Course on R: Programming Structures 1

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1 `if()`, `else`, and `ifelse()` Statements

1.1 Conditional Execution Using `if()` and (Optionally) `else`

- Sometimes we'll want R to execute a statement only if a certain condition is met. This can be accomplished via the `if()` and (optionally) `else` statements:

```
if()      # Used to execute a statement only if the given condition  
          # is met  
else     # Used to specify an alternative statement to be executed  
          # if the condition given in if() isn't met
```

- Such *conditional execution* commands have the forms:

```
if (condition) {  
  statement1  
}
```

and

```
if (condition) {  
  statement1  
} else {  
  statement2  
}
```

- In both cases above, if `condition` is `TRUE`, `statement1` is executed. If `condition` is `FALSE`, then in the first case nothing happens. In the second case, `statement2` is executed.
- Here's a simple example:

```
x <- 5  
if (x < 10) {  
  y <- 0  
}  
y  
  
## [1] 0
```

- Here's another:

```
if (x >= 10) {  
  y <- 1  
} else {  
  y <- 0  
}  
y  
  
## [1] 0
```

- There's actually an easier way to accomplish the above task:

```
y <- if(x >= 10) 1 else 0  
y  
  
## [1] 0
```

- When using such *conditional assignment* statements, in the absence of `else`, `if()` returns `NULL` if `condition` isn't met. So

```
y <- if(condition) 1
```

is equivalent to

```
y <- if(condition) 1 else NULL
```

- In the next example, `return()` is used to terminate a function call and return a value that depends on whether or not a condition is met:

```
mySign <- function(x) {  
  if(x < 0) {  
    return("Negative")  
  } else {  
    return("Non-negative")  
  }  
}
```

We get:

```
mySign(13)

## [1] "Non-negative"
```

1.2 Using if() and else with a Sequence of Statements

- if() and else can be used to conditionally execute whole *sequences* of statements, which we enclose in curly brackets { }. The general form of an if() command is:

```
if (condition) {
  statement11
  statement12
  .
  .
  .
  statement1q
}
```

which could be followed by else and another sequence of statements (in curly brackets) to be executed if condition isn't met.

1.3 Vectorized if-else: The ifelse() Function

- Sometimes we'll need to create a vector whose values depend on whether or not the values in another vector satisfies some condition. We use:

```
ifelse()      # Returns a vector whose values depend on whether or
               # not a given condition is met by the elements of
               # another vector
```

- ifelse() takes argument **test**, the condition to be met, **yes** the return value (or vector of values) when **test** is TRUE, and **no**, the return values (or vector of values) when **test** is FALSE.
- Here we convert the values in **ht** to “short” or “tall”:

```
ht <- c(69, 71, 67, 66, 72, 71, 61, 65, 73, 70, 68, 74)
htCategory <- ifelse(ht > 69, yes = "tall", no = "short")
htCategory
```

```
## [1] "short" "tall" "short" "short" "tall" "tall" "short" "short"
## [9] "tall" "tall" "short" "tall"
```

2 Looping

- **Loops** are used to *iterate* (repeat) an R statement (or set of statements). They're implemented in three ways, `for()`, `while()`, and `repeat`:

```
for()      # Repeat a set of statements a specified number of
           # times
while()    # Repeat a set of statements as long as a specified
           # condition is met
repeat     # Repeat a set of statements until a break command is
           # encountered
```

- Two other commands, `break` and `next`, are used, respectively, to terminate a loop's iterations and to skip ahead to the next iteration:

```
break      # Terminate a loop's iterations
next       # Skip ahead to the next iteration
```

- Here's an example in which each of the three loop types, `for()`, `while()`, and `repeat`, are used to perform a simple task, namely printing the numbers 1^2 , 2^2 , ..., 5^2 to the screen:

```
for(i in 1:5) {
  print(i^2)
}

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

i <- 1
while(i <= 5) {
  print(i^2)
  i <- i + 1
}
```

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

i <- 1
repeat {
  print(i^2)
  i <- i + 1
  if(i > 5) break
}

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

2.1 for() Loops

- `for()` loops are used when we know in advance how many iterations the loop should perform.
- The general form of a `for()` loop is:

```
for(i in sequence) {
  statement1
  statement2
  .
  .
  .
  statementq
}
```

where **sequence** is a vector, **i** (whose name you're free to change) assumes the values in **sequence** one after another, each time triggering another iteration of the loop during which **statements 1** through **q** are executed. The **statements** usually involve the variable **i**.

- Here's an example. Suppose we have the data frame describing someone's coin collection:

```
coins <- data.frame(Coin = c("penny", "quarter", "nickel",
                             "quarter", "dime", "penny"),
                    Year = c(1943, 1905, 1889, 1960, 1937, 1900),
                    Mint = c("Den", "SF", "Phil", "Den", "SF",
                             "Den"),
                    Condition = c("good", "fair", "excellent",
                                   "good", "poor", "good"),
                    Value = c(12.00, 55.00, 300.00, 40.00, 18.00,
                              28.00),
                    Price = c(15.00, 45.00, 375.00, 25.00, 20.00,
                              20.00))
```

```
coins
```

```
##      Coin Year Mint Condition Value Price
## 1  penny 1943  Den      good     12     15
## 2 quarter 1905  SF      fair     55     45
## 3  nickel 1889 Phil excellent    300    375
## 4 quarter 1960  Den      good     40     25
## 5   dime 1937  SF      poor     18     20
## 6  penny 1900  Den      good     28     20
```

- If we type:

```
colMeans(coins)
```

```
## Error in colMeans(coins): 'x' must be numeric
```

we get an error message because some of the columns are non-numeric.

- We can compute the means of the numeric columns by looping over the columns, each time checking whether it's numeric before computing it's mean:

```
means <- NULL
for(i in 1:ncol(coins)) {
  if (is.numeric(coins[, i])) {
    means <- c(means, mean(coins[, i]))
  }
}
```

The result is:

```
means
## [1] 1922.33333 75.50000 83.33333
```

2.2 while() Loops

- `while()` loops are used when we want the loop to iterate until some condition is no longer met.
- The general form of a `while()` loop is:

```
while(condition) {
  statement1
  statement2
  .
  .
  .
  statementq
}
```

where `condition` is a logical (TRUE or FALSE) expression involving a variable whose value changes over the course of the loop iterations.

- Prior to each iteration, R checks whether `condition` is TRUE or FALSE. If it's TRUE, the iteration proceeds, otherwise the iterations are terminated.

2.3 repeat Loops

- A `repeat` loop iterates a set of statements until a `break` statement is encountered. The general form is of a `repeat` loop is:

```
repeat {
  statement1
  statement2
  .
  .
  .
  statementq
}
```


where at least one of the **statements** should be of the form

```
if(condition) break
```

where **condition** is a logical (TRUE or FALSE) expression which may be updated during the loop's iterations.

2.3.1 Terminating an “Endless” Loop

- Once in a while we (mistakenly) write a loop that has no way of stopping, for example:

```
i <- 1
while(i <= 5) {
  print("I Cannot Stop by Myself")
}
```

- To terminate the iterations hit the **Escape** key or select **Terminate R...** in RStudio's **Session** pulldown menu.

2.4 Nested Loops

- Loops can be *nested*, with one inside the other.
- One use of this is to loop over rows and columns of a matrix (or over the dimensions of a higher-dimensional array).
- Suppose, for example, we want to create the matrix **X** with 0's below the main diagonal and the row number completing each row:

##	[,1]	[,2]	[,3]	[,4]	[,5]	[,6]
## [1,]	1	1	1	1	1	1
## [2,]	0	2	2	2	2	2
## [3,]	0	0	3	3	3	3
## [4,]	0	0	0	4	4	4
## [5,]	0	0	0	0	5	5
## [6,]	0	0	0	0	0	6

- We can construct this matrix using nested `for()` loops:

```
# First create a 6 by 6 matrix of all 0's
X <- matrix(0, nrow = 6, ncol = 6)
# Next fill in the upper right part using nested loops.
for(i in 1:6) { # i is the row number, ranging from 1 to 6
  for(j in i:6) { # j is the column number, ranging from i to 6
    X[i, j] <- i
  }
}
```

Above,

- During the first iteration of the outer loop, `i` is fixed at 1 and the inner loop is iterated with `j` ranging over the values 1, 2, ..., 6, during which time `X[1,1]`, `X[1,2]`, ... `X[1,6]` are replaced by 1's.
- Then in the second iteration of the outer loop, `i` is fixed at 2 and the inner loop is iterated with `j` ranging over the values 2, 3, ..., 6, during which time `X[2,2]`, `X[2,3]`, ... `X[2,6]` are replaced by 2's.
- This continues until `i` reaches 6 and `j` "ranges" from 6 to 6, during which time `X[6, 6]` is replaced by the value 6.

2.5 Looping Over List Elements

- In the next example, we loop over the elements of a list, printing a list element and recording its length during each iteration:

```
myList <- list(
  w = c(4, 4, 5, 5, 6, 6),
  x = c("a", "b", "c"),
  y = c(5, 10, 15),
  z = c("r", "s", "t", "u", "v")
)
lengths <- NULL
for(i in myList) {
  print(i)
  lengths <- c(lengths, length(i))
}

## [1] 4 4 5 5 6 6
## [1] "a" "b" "c"
```

```
## [1] 5 10 15
## [1] "r" "s" "t" "u" "v"

lengths

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

3 The Logical Operations “And”, “Or”, and “Not”

3.1 Logical Operations and Compound Logical Expressions

- R has *logical operators* (or *Boolean operators*) corresponding to “and” and “or”. They’re used to combine two logical expressions together to form a single *compound* logical expression. Another logical operator corresponding to “not” is used to negate a logical expression. These are written in R as:

```
&&      # "And" for logical scalars
||      # "Or" for logical scalars
!       # "Not" (for logical scalars or vectors)
&       # "And" for logical vectors
|       # "Or" for logical vectors
```

- These operate on logical (TRUE or FALSE) expressions and return TRUE or FALSE.
- The distinction between && and &, and between || and | is this:
 - && and || operate on logical *scalars* (single TRUE or FALSE values).
 - && and || are the preferred operators to use in if() statements.
 - & and | operate elementwise on logical *vectors*.
 - & and | are the preferred operators to use in ifelse() statements and in square brackets [] when extracting subsets from vectors or data frames.

3.2 Logical Operations on Scalar Logical Expressions

- && returns TRUE if both of the expressions are TRUE and it returns FALSE otherwise:

```
TRUE && TRUE

## [1] TRUE
```

```
TRUE && FALSE
```

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

- `||` returns `TRUE` if one or both of the expressions are `TRUE` and it returns `FALSE` otherwise:

```
FALSE || TRUE
```

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

```
FALSE || FALSE
```

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

- As a practical example, if we want to test whether a variable `x` lies *between* two numbers, say 60 and 70, we type:

```
x > 60 && x < 70
```

and to test whether it lies *outside* the range 60 to 70, we type:

```
x < 60 || x > 70
```

- Here's an example of using `&&` in an `if()` statement:

```
x <- 3
y <- 5
if(x < 10 && y < 10) {
  print("Both less than 10")
} else {
  print("Not both less than 10")
}
```

```
## [1] "Both less than 10"
```

- As a practical example, if we want to test whether a variable `x` lies *between* two numbers, say 60 and 70, we type:

```
x > 60 && x < 70
```

and to test whether it lies *outside* the range 60 to 70, we type:

```
x < 60 || x > 70
```

- Here's an example of using `&&` in an `if()` statement:

```
x <- 3
y <- 5
if(x < 10 && y < 10) {
  print("Both less than 10")
} else {
  print("Not both less than 10")
}

## [1] "Both less than 10"
```

- The negation operator, `!`, returns “the opposite” of a logical expression:

```
!TRUE

## [1] FALSE

!FALSE

## [1] TRUE

!(5 < 6)

## [1] FALSE
```

- Pay attention to the operator precedence for `&&`, `||`, and `!`. It can be found by typing:

```
?Syntax
```

but parentheses can be used to control the order of operations.

- If we try to apply `&&` or `||` to *vectors*, R only applies it to their first elements:

```
c(TRUE, FALSE, TRUE) && c(TRUE, TRUE, FALSE)

## [1] TRUE
```

3.3 Logical Operations on Logical Vectors

- To apply the operations “and” and “or” elementwise on two logical vectors, use `&` and `|`. For example:

```
c(TRUE, FALSE, TRUE) & c(TRUE, TRUE, FALSE)

## [1] TRUE FALSE FALSE
```

- `&` and `|` are useful in `ifelse()` statements. (Recall that `ifelse()` operates elementwise on vectors.). For example, consider the systolic and diastolic blood pressure readings:

```
systolic <- c(110, 119, 111, 113, 128)
diastolic <- c(70, 74, 88, 74, 83)
```

A blood pressure is classified as normal if the systolic level is less than 120 *and* the diastolic level is less than 80:

```
classification <- ifelse(systolic < 120 & diastolic < 80,
                          yes = "Normal",
                          no = "Abnormal")
classification

## [1] "Normal" "Normal" "Abnormal" "Normal" "Abnormal"
```

- In the next example, we use `&` in square brackets `[]` to extract rows from a data frame:

```
bpData <- data.frame(
  name = c("Joe", "Katy", "Bill", "Kim", "Mark"),
  systolic = c(110, 119, 111, 113, 128),
  diastolic = c(70, 74, 88, 74, 83))
bpData
```

##	name	systolic	diastolic
## 1	Joe	110	70
## 2	Katy	119	74
## 3	Bill	111	88
## 4	Kim	113	74
## 5	Mark	128	83

```
attach(bpData)
bpData[systolic < 120 & diastolic < 80, ]
```

##	name	systolic	diastolic
## 1	Joe	110	70
## 2	Katy	119	74
## 4	Kim	113	74

```
detach(bpData)
```

4 Variable Number of Arguments Using “...”

- Functions can be written to take a variable number of arguments. The argument name “...” in the function definition will match any number of arguments.
- For example, here’s a function that returns the mean of all the values in an arbitrary number of vectors:

```
meanOfAll <- function(...) {
  return(mean(c(...)))
}
```

The command

```
meanOfAll(usSales, europeSales, otherSales)
```

would combine the three vectors and take the mean of all the data. The effect of `c(...)` is as if `c()` were called with the same three arguments passed to `meanOfAll()`.

- Many of R's built-in functions take a variable number of arguments. For example look at the help files for `list()` and `c()`.

5 The `source()` Function

- `source()` is a nice function for reading in big chunks of R code, e.g. a set of functions that you want to use every time you start a new R session.

```
source()           # Read R commands from a text file.
```

- For example, suppose we have the following commands saved in a text file '`C:\myRcode.txt`':

```
myFun <- function(message) {  
  print(message)  
}
```

```
myFun("Hello World")
```

We can execute those commands using `source()` by typing:

```
source("C:/myRcode.txt")
```

```
## [1] "Hello World"
```