

Elements of a programming language – 3

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In several algorithms, the point is to repeat certain action several times. In a mathematical formulas language, we have for instance the following signs for repeating an action:

$$\Sigma_{i=1}^n(expression)$$

which denotes addition over elements with indices $1...n$ or

$$\Pi_{i=1}^n(expression)$$

which denotes multiplication.

It is important to learn how to translate these (and similar) formulas into the R language.

Repeating actions – for loop

One way to repeat an action is to use the **for-loop**

```
for (i in 1:5) {  
  cat(paste('Performing operation no.', i), '\n')  
}
```

```
## Performing operation no. 1  
## Performing operation no. 2  
## Performing operation no. 3  
## Performing operation no. 4  
## Performing operation no. 5
```

Repeating actions – for loop ctd.

A slight modification of the above example will skip odd indices.

```
for (i in c(2,4,6,8,10)) {  
  cat(paste('Performing operation no.', i), '\n')  
}
```

```
## Performing operation no. 2  
## Performing operation no. 4  
## Performing operation no. 6  
## Performing operation no. 8  
## Performing operation no. 10
```

Repeating actions – for loop external counter

Sometimes, we also want an external counter:

```
cnt <- 1
for (i in c(2,4,6,8,10)) {
  cat(paste('Performing operation no.', cnt,
            'on element', i), '\n')
  cnt <- cnt + 1
}
```

```
## Performing operation no. 1 on element 2
## Performing operation no. 2 on element 4
## Performing operation no. 3 on element 6
## Performing operation no. 4 on element 8
## Performing operation no. 5 on element 10
```

Repeating actions – for loop an example

Say, we want to add 1 to every element of a vector:

```
vec <- c(1:5)
vec
```

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

```
for (i in vec) {
  vec[i] <- vec[i] + 1
}
vec
```

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

Repeating actions – avoid loops and vectorize!

The above can be achieved in R by means of vectorization:

```
vec <- c(1:5)
vec + 1
```

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

Let us compare the time of execution of the vectorized version (vector with 10,000 elements):

```
##      user  system elapsed
##    0.038    0.002    0.040
```

to the loop version:

```
##      user  system elapsed
##    1.111    0.017    1.140
```


Repeating actions – the while loop

There is also another type of loop in R, the **while loop** which is executed until some condition is true.

```
x <- 1
while (x < 5) {
  cat(x, " ... ")
  x <- x + 1
}
```

```
## 1   ... 2   ... 3   ... 4   ...
```

When we explicitly repeat an action using a loop, we talk about **iteration**. We can also repeat actions by means of **recursion**, i.e. when a function calls itself. Let us implement a factorial !:

```
factorial.rec <- function(x) {  
  if (x == 0 || x == 1)  
    return(1)  
  else  
    return(x * factorial(x - 1)) # Recursive call!  
}  
factorial.rec(5)
```

```
## [1] 120
```

Recursion = iteration?

Yes, every iteration can be converted to recursion (Church-Turing conjecture) and vice-versa. It is not always obvious, but theoretically it is doable. Let's see how to implement *factorial* in iterative manner:

```
factorial.iter <- function(x) {  
  if (x == 0 || x == 1)  
    return(1)  
  else {  
    tmp <- 1  
    for (i in 2:x) {  
      tmp <- tmp * i  
    }  
    return(tmp)  
  }  
}  
  
factorial.iter(5)
```

Recursion == iteration, really?

More writing for the iterative version, right? What about the time efficiency?

The recursive version:

```
## [1] 2.432902e+18
```

```
##      user  system elapsed  
##    0.002    0.000    0.002
```

And the iterative one:

```
## [1] 2.432902e+18
```

```
##      user  system elapsed  
##    0.002    0.000    0.003
```

Loops – void growing data

Avoid changing dimensions of an object inside the loop:

```
v <- c() # Initialize
for (i in 1:100) {
  v <- c(v, i)
}
```

It is much better to do it like this:

```
v <- rep(NA, 100) # Initialize with length
for (i in 1:100) {
  v[i] <- i
}
```

Always try to know the size of the object you are going to create!

Decision taking – an if clause

Often, one has to take a different course of action depending on a flow of the algorithm. You have already seen the **if-else** block. Let's print only odd numbers [1, 10]:

```
v <- 1:10
for (i in v) {
  if (i %% 2 != 0) { # if clause
    cat(i, ' ')
  }
}
```

```
## 1 3 5 7 9
```

Decision taking – if-else

If we want to print 'o' for an odd number and 'e' for an even, we could write either:

```
v <- 1:10
for (i in v) {
  if (i %% 2 != 0) { # if clause
    cat('o ')
  }
  if (i %% 2 == 0) { # another if-clause
    cat('e ')
  }
}
```

```
## o e o e o e o e o e
```

Decision taking – if-else

or

```
v <- 1:10
for (i in v) {
  if (i %% 2 != 0) { # if clause
    cat('o ')
  } else { # another if-clause
    cat('e ')
  }
}
```

```
## o e o e o e o e o e
```


Decision taking – if-else

or else

```
v <- 1:10
for (i in v) {
  tmp <- 'e ' # set default to even
  if (i %% 2 != 0) { # if clause
    tmp <- 'o ' # change default for odd numbers
  }
  cat(tmp)
}
```

```
## o e o e o e o e o e
```

Each three are ways are good and are mainly the matter of style...

Decision taking – more alternatives

So far, so good, but we were only dealing with 3 alternatives. Let's say that we want to print '?' for zero, 'e' for even and 'o' for an odd number:

```
v <- 0:10
for (i in v) {
  if (i == 0) {
    cat('? ')
  } else if (i %% 2 != 0) { # if clause
    cat('o ')
  } else { # another if-clause
    cat('e ')
  }
}
```

```
## ? o e o e o e o e
```

Congratulations! You have just learned the **if-else if-else** clause.

Switch

If-else clauses operate on logical values. What if we want to take decisions based on non-logical values? Well, if-else will still work by evaluating a number of comparisons, but we can also use **switch**:

```
switch.demo <- function(x) {  
  switch(class(x),  
    logical = ,  
    numeric = cat('Numeric or logical.'),  
    factor = cat('Factor.'),  
    cat('Undefined')  
  )  
}  
switch.demo(x=TRUE)
```

Numeric or logical.

```
switch.demo(x=15)
```

Functions 1

Often, it is really handy to re-use some code we have written or to pack together the code that is doing some task. Functions are a really good way to do this in R:

```
add.one <- function(arg1) {  
  arg1 <- arg1 + 1  
  return(arg1)  
}  
add.one(1)
```

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

```
add.one()
```

```
## Error in add.one(): argument "arg1" is missing, with no
```

Anatomy of a function

A function consists of: formal arguments, function body and environment:

```
formals(ecdf)
```

```
## $x
```

```
body(plot.ecdf)
```

```
## {  
##     plot.stepfun(x, ..., ylab = ylab, verticals = verticals,  
##               pch = pch)  
##     abline(h = c(0, 1), col = col.01line, lty = 2)  
## }
```

```
environment(ecdf)
```

```
## <environment: namespace:stats>
```

Functions – default values

Sometimes, it is good to use default values for some arguments:

```
add.a.num <- function(arg, num=1) {  
  arg <- arg + num  
  return(arg)  
}  
add.a.num(1, 5)
```

```
## [1] 6
```

```
add.a.num(1) # skip the num argument?
```

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

```
add.a.num(num=1) # skip the num argument?
```

```
## Error in add.a.num(num = 1): argument "arg" is missing,
```

Functions – order of arguments

```
args.demo <- function(x, y, arg3) {  
  print(paste('x =', x, 'y =', y, 'arg3 =', arg3))  
}  
args.demo(1,2,3)
```

```
## [1] "x = 1 y = 2 arg3 = 3"
```

```
args.demo(x=1, y=2, arg3=3)
```

```
## [1] "x = 1 y = 2 arg3 = 3"
```

```
args.demo(x=1, 2, 3)
```

```
## [1] "x = 1 y = 2 arg3 = 3"
```

```
args.demo(a=3, x=1, y=2)
```

Functions – order of arguments 2

```
args.demo2 <- function(x, arg2, arg3) {  
  print(paste('x =', x, 'arg2 =', arg2, 'arg3 =', arg3))  
}  
args.demo2(x=1, y=2, ar=3)
```

```
## Error in args.demo2(x = 1, y = 2, ar = 3): argument 3 ma
```


Functions – variables scope

Functions 'see' not only what has been passed to them as arguments:

```
x <- 7
y <- 3
xyplus <- function(x) {
  x <- x + y
  return(x)
}
y <- xyplus(x)
y
```

```
## [1] 10
```

Functions – variables scope cted.

Everything outside the function is called **global environment**.

There is a special operator for working on global environment from within a function:

```
x <- 1
xplus <- function(x) {
  x <- x + 1
}
xplus(x)
x
```

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

```
xplus(x)
x
```

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

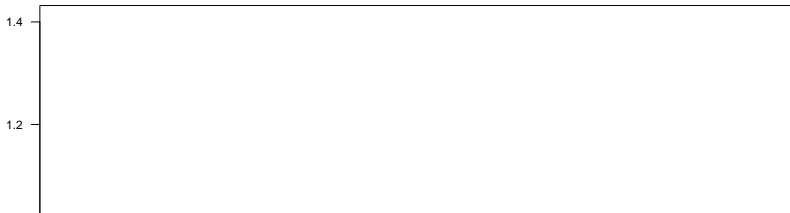
Functions – the dot-dot-dot argument

There is a special argument ... (ellipsis) which allows you to give any number of arguments or pass arguments downstream:

```
c # Any number of arguments
```

```
## function (... , recursive = FALSE) .Primitive("c")
```

```
my.plot <- function(x, y, ...) { # Passing downstream  
  plot(x, y, las=1, cex.axis=.8, ...)  
}  
my.plot(1,1)
```



Functions – the dot-dot-dot argument trick

What if the authors of, e.g. `plot.something` wrapper forgot about the dot-dot-dot?

```
c # Any number of arguments
```

```
## function (... , recursive = FALSE) .Primitive("c")
```

```
my.plot <- function(x, y) { # Passing downstream
  plot(x, y, las=1, cex.axis=.8, ...)
}
formals(my.plot) <- c(formals(my.plot), alist(... = ))
my.plot(1, 1, col='red', pch=19)
```



Lazy evaluation

In R, arguments are evaluated as late as possible, i.e. when they are needed. This is **lazy evaluation**:

```
h <- function(a = 1, b = d) {  
  d <- (a + 1) ^ 2  
  c(a, b)  
}  
h()
```

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

The above won't be possible in, e.g. C where values of both arguments have to be known before calling a function **eager evaluation**.

In R everything is a function

Because in R everything is a function, we can redefine things:

(

```
## .Primitive("(")
```

```
(` <- function(e1) {  
  if (is.numeric(e1) && runif(1) < 0.1) {  
    e1 + 1  
  } else {  
    e1  
  }  
}  
replicate(50, (1 + 2))
```

```
## [1] 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 4 3 3 3
```

```
rm("(")
```

Infix notation

Operators like '+', '-' or '*' are using the so-called **infix** functions, where the function name is between arguments. We can define our own:

```
`%p%` <- function(x, y) {  
  paste(x,y)  
}  
'a' %p% 'b'
```

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

Base functions

When we start R, the following packages are pre-loaded automatically:

```
.libPaths() # get library location
```

```
## [1] "/Library/Frameworks/R.framework/Versions/3.3/Resources
```

```
# library() # see all packages installed  
search() # see packages currently loaded
```

```
## [1] ".GlobalEnv" "package:stats" "package:gra
```

Check what basic functions are offered by packages: *base*, *utils* and we will soon work with package *graphics*. If you want to see what statistical functions are in your arsenal, check out package *stats*.