Writing your own functions

Statistics 133 – Spring 2015 – Feb 17

Writing Functions

So far we have relied on the built-in functionality of R to carry out our analyses. In the next several lectures, we'll cover

- How to write your own functions
- How to use flow control mechanisms like if and for
- Debugging your code when something goes wrong
- The meaning of "environments" and "variable scope"
- Timing and speeding up your code

What should be a function?

- Things you're going to re-run, especially if it will be re-run with changes
- Chunks of code you keep highlighting and hitting return on
- Chunks of code which are small parts of bigger analyses
- Chunks which are very similar to other chunks

Writing your own functions in R

Think about the code we have been writing so far in R. It has been

- made up of a sequence of commands, one after another
- specific to the particular dataset we're working with.

Functions allow us to

- organize our code into tasks
- reuse the same code on different datasets by making the data an *argument* to the function.

First Function

Our task is to convert inches into centimeters for family height:

family$height * 2.54

We can make a conversion function convert that looks like:

```
convert = function(x) x*2.54
```

To call it do convert(x) or maybe convert(family$height)

This function *encapsulates* the multiplication of each element by 2.54 for *any* x vector, not just the family$height.

Anatomy of a function

The syntax for writing a function is

```
function ( arguments ) body
```

Typically we assign the function to a particular name. This should describe what the function does.

```
myFunction = function (arguments) body
```

A function without a name is called an “orphan” function. These can be very powerfully used with the apply mechanism. Stay tuned....

```
function ( arguments ) body
```

The keyword `function` just tells R that you want to create a function.

Recall that the *parameters* to a function are its inputs, which may have default values.

```
> args(median)
function (x, na.rm = FALSE)
```

Here, if we do not explicitly specify `na.rm` when we call `median`, it will be assigned the default value of `FALSE`.

A few notes on specifying the arguments:

When you're writing your own function, it's good practice to put the most important arguments first. Often these will not have default values.

This allows the user of your function to easily specify the arguments by position, eg. `plot(xvec, yvec)` rather than `plot(x = xvec, y = yvec)`.

Next we have the *body* of the function, which typically consists of expressions surrounded by curly brackets. Think of these as performing some operations on the input values given by the arguments.

```
{
    expression 1
    expression 2
    return(value)
}
```

The `return` expression hands control back to the caller of the function and returns a given `value`. If the function returns more than one thing, this is done using a named list, for example

```
return(list(total = sum(x), avg = mean(x))).
```

In the absence of a return expression, a function will return the *last* evaluated expression. This is particularly common if the function is short.

That is the case for our simple function:

```
convert = function(x) x * 2.54
```

Here we don't need brackets `{}`, since there is only one expression.

A return expression anywhere in the function will cause the function to return control to the user *immediately*, without evaluating the rest of the function. This is often used in conjunction with `if` statements, which we'll come to later.

Considerations when writing a function:

- What will the function do?
- What should we call it? (Relate the name to what it does)
- What will be the arguments?
- Which arguments have default values and what are they?
- What (if anything) should the function return?

Control Flow

Computing in R consists of sequentially evaluating statements. *Flow control* structures allow us to control which statements are evaluated and in what order.

In R the primary ones consist of

- if/else statements and the ifelse function
- for and while loops

Expressions can be grouped together using curly braces "`{`" and "`}`". A group of expressions is called a *block*. For today's lecture, the word *statement* will refer to either a single expression or a block.

The basic syntax for an if/else statement is

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

First, `condition` is evaluated. If the first element of the result is `TRUE` then `statement1` is evaluated. If the first element of the result is `FALSE` then `statement2` is evaluated. *Only the first element of the result is used.*

If the result is numeric, `0` is treated as `FALSE` and any other number as `TRUE`. If the result is not logical or numeric, or if it is `NA`, you will get an error.

When we discussed Boolean algebra before, we met the operators `&` (AND) and `|` (OR).

Recall that these are both *vectorized* operators.

If/else statements, on the other hand, are based on a single, "global" condition. So we often see constructions using `any` or `all` to express something related to the whole vector, like

```
if ( any(x < -1 | x > 1) )
  warning("Value(s) in x outside the interval [-1,1]")
```

(We'll discuss error handling more later.)

The result of an if/else statement can be assigned. For example,

```
> if ( any(x <= 0) ) y = log(1+x) else y = log(x)
```

is the same as

```
> y = if ( any(x <= 0) ) log(1+x) else log(x)
```

Also, the else clause is optional. Another way to do the above is

```
> if( any(x <= 0) ) x = 1+x
> y = log(x)
```

Note that this version this changes `x` as well.

If/else statements can be nested.

```
if (condition1 )
  statement1
else if (condition2)
  statement2
else if (condition3)
  statement3
else
  statement4
```

The conditions are evaluated, in order, until one evaluates to `TRUE`. The the associated statement/block is evaluated. The statement in the final else clause is evaluated if none of the conditions evaluates to `TRUE`.

A note about formatting if/else statements:

When the if statement is not in a block, the else (if present) must appear on the same line as `statement1` or immediately following the closing brace. For example,

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

will be an error if not part of a larger block and/or function. I suggest using the format

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

Some common uses of if/else clauses

1. With logical arguments to tell a function what to do

```
corplot = function(x, y, plotit = TRUE){
  if ( plotit == TRUE ) plot(x, y)
  cor(x,y)
}
```

2. To verify that the arguments of a function are as expected

```
if ( !is.matrix(m) )
  stop("m must be a matrix")
```

3. To handle common numerical errors

```
ratio = if ( x!=0 ) y/x else NA
```

4. In general, to control which block of code is executed

```
normt = function(n, dist){
  if ( dist == “normal” ){
    return( rnorm(n) )
  } else if (dist == “t”){
    return(rt(n, df = 1, ncp = 0))
  } else stop(“distribution not implemented”)
}
```

These if/else constructions are useful for global tests, not tests applied to individual elements of a vector.

However, there is a vectorized function called `ifelse`.

```
> args(ifelse)
function (test, yes, no)
```

R object that can be coerced to logical

R objects of the same size as `test`

For each element of `test`, the corresponding element of `yes` is returned if the element is `TRUE`, and the corresponding element of `no` is returned if it is `FALSE`.

Some examples of `ifelse`

```
ratio = ifelse(x!=0, y/x, NA) # (Compare with earlier)

US.indicator = ifelse(country == “USA”, 1, 0)

plot(Income, Donations,
     col = ifelse(party == “Republican”, “red”, “blue”)
```

Anonymous functions

Recall

We wrote an expression to calculate the number of years that a weather station had been in operation

```
> length(unique(floor(rain[[1]])))
```

We can wrap this expression into a function:

```
numYears = function(y) {
  length(unique(floor(y)))
}
```

Apply this function to `rain`

```
sapply(rain, numYears)
```

We don't actually have to go through the hassle of writing a function definition.

We can use an anonymous function:

```
sapply(rain, function(y)
  length(unique(floor(y))))
```

Distance

We compute the distance from a vector of xs and a vector of ys to a point with the expression:

```
sqrt( (x - pt[1])^2 + (y - pt[2])^2 )
```

Can you wrap this into a function?

```
distToPoint =
 function(x, y, pt = c(0, 0)){
  sqrt( (x - pt[1])^2 + (y - pt[2])^2 )
}
```

Apply this function

Now we have two input argument that we would like to apply the function too

We can do this with mapply:

```
mapply(distToPoint, 1:10, 10:1)
```

But, what if we want to specify the parameter pt?

```
mapply(distToPoint, 1:10, 10:1,
       MoreArgs = list(pt = c(1, 0)))
```

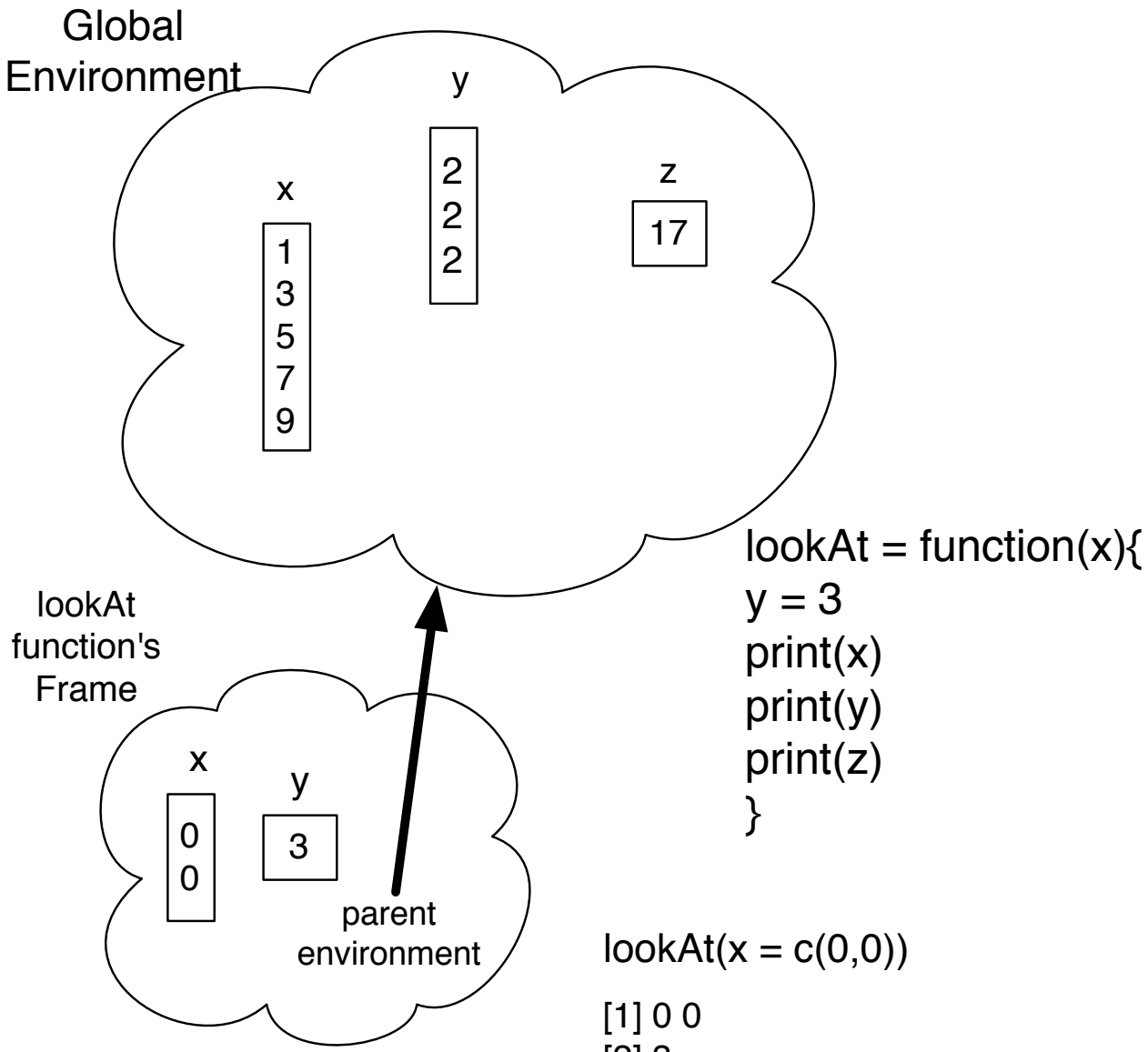
Environments and Scope

Environments and variable scope

R has a special mechanism for allowing you to use the same name in different places in your code and have it refer to different objects.

For example, you want to be able to create new variables in your functions and not worry if there are variables with the same name already in the workspace.

The solution relies on *environments* and the *variable scoping rules*.




```
lookAt = function(x){
y = 3
print(x)
print(y)
print(z)
}
```

```
lookAt(x = c(0,0))

[1] 0 0
[2] 3
[3] 17
```

When you call a function, R creates a new workspace containing just the variables defined by the arguments of that function. This space is called a *frame*.

```
> x = c(1, 3, 5, 7, 9); y = rep(2, 3); z = 17
> lookAt = function(x) {
+  y = 3
+  print(x); print(y); print(z)
}
> lookAt(x = c(0, 0))
```

x exists in the lookAt frame and so does y. However, z is not. R has a way of accessing variables that are not in the frame created by the function.

What is happening is that R is looking for variables with that name in a sequence of environments. An *environment* is just a frame (collection of variables) plus a pointer to the next environment to look in.

In our example, R didn't find the variable z in the environment defined by the function `lookAt`, so it went on to the next one. In this case, this was our main workspace, which is called the *Global Environment*.

The "next environment to look in" is called the parent environment.

If R reaches the Global Environment and still can't find the variable, it looks in something called the *search path*. This is a list of additional environments, which is used for packages of functions and user attached data. You can see the search path by typing `search()`.

This helps explain why we can write over built-in objects in R. What we're really doing is creating that object in the Global Environment, and then when we refer to it by name, R finds it here before it finds the predefined one.

```
> help(pi)
> Pi = 3
> pi
> rm(pi)
> pi
```

CRAN: http://cran.r-project.org/

CRAN
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Task Views
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R Homepage
The R Journal

Software
R Sources
R Binaries
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Contributed

Contributed Packages

Installation of Packages

Please type `help("INSTALL")` or `help("install.packages")` in R for information on how to install packages from this directory. The manual R Installation and Administration (also contained in the R base sources) explains the process in detail.

CRAN Task Views allow you to browse packages by topic and provide tools to automatically install all packages for special areas of interest. Currently, 28 views are available.

Daily Package Check Results

All packages are tested regularly on machines running Debian GNU/Linux, Fedora and Solaris. Packages are also checked under MacOS X and Windows, but typically only at the day the package appears on CRAN.

The results are summarized in the check summary (some timings are also available). Additional details for Windows checking and building can be found in the Windows check summary.

Writing Your Own Packages

The manual Writing R Extensions (also contained in the R base sources) explains how to write new packages and how to contribute them to CRAN.

Available Packages

Currently, the CRAN package repository features 2523 available packages.

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

ACCLMA	ACC & LMA Graph Plotting
ADGofTest	Anderson-Darling GoF test
ADaCGH	Analysis of data from aCGH experiments
AER	Applied Econometrics with R
AGSDest	Estimation in adaptive group sequential trials

If a particular package is already installed on your system, you can access its contents by typing

```
> library("nameofpackage")
```

The authors of the package write documentation for the functions and datasets included in it, which you can read as usual using `help()`.

All packages come with a reference manual, which you can access by visiting CRAN. Go to http://cran.r-project.org/, click on "Packages," then scroll down for the particular package. This is just a hard copy of the help pages. A few packages also come with a tutorial.

Search path

- As we load packages into our session, they get added to the search path.

```
> search()
 [1] ".GlobalEnv"         "tools:rstudio"
 [3] "package:stats"      "package:graphics"
 [5] "package:grDevices" "package:utils"
 [7] "package:datasets"  "package:methods"
 [9] "Autoloads"          "package:base"
> library(RColorBrewer)
> search()
 [1] ".GlobalEnv"            "package:RColorBrewer"
 [3] "tools:rstudio"          "package:stats"
 [5] "package:graphics"       "package:grDevices"
 [7] "package:utils"          "package:datasets"
 [9] "package:methods"        "Autoloads"
[11] "package:base"
```

objects()

Show objects in global environment

```
> objects()
 [1] "AP"           "Convert"      "age"
 [4] "annualQuant" "bmi"          "day"
 [7] "deltaWt"      "desiredWt"    "distToPt"
[10] "gender"       "height"       "numInts"
[13] "qqunif"       "rain"         "timesWt"
[16] "weight"       "wifi"
```

Display objects in RColorBrewer package

```
> objects(2)
[1] "brewer.pal"          "brewer.pal.info"
[3] "display.brewer.all" "display.brewer.pal"
```

Catching Errors

Catching errors

1. The function `stop` stops execution of the current expression and prints a specified error message.

```
> showstop = function(x){
+   if(any(x < 0)) stop("x must be >= 0")
+   return("ok")
+ }

> showstop(1)
[1] "ok”

> showstop(c(-1, 1))
Error in showstop(c(-1, 1)) : x must be >= 0
```

2. A similar function is `stopifnot`. It has the advantage of being able to take multiple conditions.

```
> Showstopifnot = function(x){
+   stopifnot(x >= 0, x %% 2 == 1)
+   return("ok")
+ }

> showstopifnot(1)
[1] "ok”

> showstopifnot(c(1, -1))
Error: all(x >= 0) is not TRUE

> showstopifnot(c(1,2))
Error: x %%2 == 1 is not all TRUE
```

3. Finally, `warning` just prints a warning message without stopping the execution of the function.

```
> ratio.warn = function(x, y){
+   if(any(y == 0))
+     warning("Dividing by zero")
+   return(x/y)
+ }

> ratio.warn(x = 1, y = c(1, 0))
[1]   1 Inf
Warning message:
In ratio.warn(x = 1, y = c(1, 0)) : Dividing by zero

> ratio.warn(x = 1:3, y = 1:2)
[1] 1 1 3
Warning message:
In x/y : longer object length is not a multiple of shorter
object length
```

The for statement

Looping is the repeated evaluation of a statement or block of statements.

Much of what is handled using loops in other languages can be more efficiently handled in R using vectorized calculations or one of the apply mechanisms.

However, certain algorithms, such as those requiring recursion, can only be handled by loops.

There are two main looping constructs in R: `for` and `while`.

For loops

A *for loop* repeats a statement or block of statements a predefined number of times.

The syntax in R is

```
for ( var in vector ){
  statement
}
```

For each element in `vector`, the variable `var` is set to the value of that element and `statement` is evaluated.

`vector` often contains integers, but can be any valid type.

While loops

A *while loop* repeats a statement or block of statements for as many times as a particular condition is `TRUE`.

The syntax in R is

```
while (condition){
  statement
}
```

`condition` is evaluated, and if it is `TRUE`, statement is evaluated. This process continues until condition evaluates to `FALSE`.

Exercise:

The expression

```
sample(1:0, size = 1, prob = c(p, 1-p))
```

simulates a random coin flip, where the coin has probability `p` of coming up heads, represented by a `1`.

Write a function that simulates flipping a coin until a fixed number of heads are obtained. It should take the probability `p` and the total number of heads `total` and return the trial on which the final head was obtained. This produces a single sample from the *negative binomial distribution*.

The break statement causes a loop to exit. This is particularly useful with while loops, which, if we're not careful, might loop indefinitely (or until we kill R).

```
myRNG = function(total, p = 0.5){
# Simulate number of tosses to get 10 Heads

 x = 0
 steps = 0
 max.iter = 1000

 while(x < total){
  x = x + sample(1:0, size = 1, prob = c(p, 1-p))
  steps = steps + 1
  if(steps >= max.iter){
    warning("Maximum iteration reached")
    break
  }
 }
 return(steps)
}
```