



Introduction to the R Language

Loop Functions

Roger D. Peng, Associate Professor of Biostatistics
Johns Hopkins Bloomberg School of Public Health

Looping on the Command Line

Writing `for`, `while` loops is useful when programming but not particularly easy when working interactively on the command line. There are some functions which implement looping to make life easier.

- `lapply`: Loop over a list and evaluate a function on each element
- `sapply`: Same as `lapply` but try to simplify the result
- `apply`: Apply a function over the margins of an array
- `tapply`: Apply a function over subsets of a vector
- `mapply`: Multivariate version of `lapply`

An auxiliary function `split` is also useful, particularly in conjunction with `lapply`.

lapply

`lapply` takes three arguments: (1) a list `x`; (2) a function (or the name of a function) `FUN`; (3) other arguments via its `...` argument. If `x` is not a list, it will be coerced to a list using `as.list`.

```
lapply
```

```
## function (X, FUN, ...)  
## {  
##     FUN <- match.fun(FUN)  
##     if (!is.vector(X) || is.object(X))  
##         X <- as.list(X)  
##     .Internal(lapply(X, FUN))  
## }  
## <bytecode: 0x7ff7a1951c00>  
## <environment: namespace:base>
```

The actual looping is done internally in C code.

lapply

`lapply` always returns a list, regardless of the class of the input.

```
x <- list(a = 1:5, b = rnorm(10))  
lapply(x, mean)
```

```
## $a  
## [1] 3  
##  
## $b  
## [1] 0.4671
```

lapply

```
x <- list(a = 1:4, b = rnorm(10), c = rnorm(20, 1), d = rnorm(100, 5))  
lapply(x, mean)
```

```
## $a  
## [1] 2.5  
##  
## $b  
## [1] 0.5261  
##  
## $c  
## [1] 1.421  
##  
## $d  
## [1] 4.927
```

lapply

```
> x <- 1:4  
> lapply(x, runif)  
[[1]]  
[1] 0.2675082  
  
[[2]]  
[1] 0.2186453 0.5167968  
  
[[3]]  
[1] 0.2689506 0.1811683 0.5185761  
  
[[4]]  
[1] 0.5627829 0.1291569 0.2563676 0.7179353
```

lapply

```
> x <- 1:4
> lapply(x, runif, min = 0, max = 10)
[[1]]
[1] 3.302142

[[2]]
[1] 6.848960 7.195282

[[3]]
[1] 3.5031416 0.8465707 9.7421014

[[4]]
[1] 1.195114 3.594027 2.930794 2.766946
```

lapply

`lapply` and friends make heavy use of *anonymous* functions.

```
> x <- list(a = matrix(1:4, 2, 2), b = matrix(1:6, 3, 2))
> x
$a
      [,1] [,2]
[1,]    1    3
[2,]    2    4

$b
      [,1] [,2]
[1,]    1    4
[2,]    2    5
[3,]    3    6
```


lapply

An anonymous function for extracting the first column of each matrix.

```
> lapply(x, function(elt) elt[,1])  
$a  
[1] 1 2  
  
$b  
[1] 1 2 3
```

sapply

`sapply` will try to simplify the result of `lapply` if possible.

- If the result is a list where every element is length 1, then a vector is returned
- If the result is a list where every element is a vector of the same length (> 1), a matrix is returned.
- If it can't figure things out, a list is returned

sapply

```
> x <- list(a = 1:4, b = rnorm(10), c = rnorm(20, 1), d = rnorm(100, 5))  
> lapply(x, mean)  
$a  
[1] 2.5  
  
$b  
[1] 0.06082667  
  
$c  
[1] 1.467083  
  
$d  
[1] 5.074749
```

sapply

```
> sapply(x, mean)
      a      b      c      d
2.50000000 0.06082667 1.46708277 5.07474950

> mean(x)
[1] NA
Warning message:
In mean.default(x) : argument is not numeric or logical: returning NA
```



Introduction to the R Language

Loop Functions - apply

Roger Peng, Associate Professor
Johns Hopkins Bloomberg School of Public Health

apply

`apply` is used to evaluate a function (often an anonymous one) over the margins of an array.

- It is most often used to apply a function to the rows or columns of a matrix
- It can be used with general arrays, e.g. taking the average of an array of matrices
- It is not really faster than writing a loop, but it works in one line!

apply

```
> str(apply)
function (X, MARGIN, FUN, ...)
```

- **X** is an array
- **MARGIN** is an integer vector indicating which margins should be “retained”.
- **FUN** is a function to be applied
- ... is for other arguments to be passed to **FUN**

apply

```
> x <- matrix(rnorm(200), 20, 10)
> apply(x, 2, mean)
[1]  0.04868268  0.35743615 -0.09104379
[4] -0.05381370 -0.16552070 -0.18192493
[7]  0.10285727  0.36519270  0.14898850
[10]  0.26767260

> apply(x, 1, sum)
[1] -1.94843314  2.60601195  1.51772391
[4] -2.80386816  3.73728682 -1.69371360
[7]  0.02359932  3.91874808 -2.39902859
[10]  0.48685925 -1.77576824 -3.34016277
[13]  4.04101009  0.46515429  1.83687755
[16]  4.36744690  2.21993789  2.60983764
[19] -1.48607630  3.58709251
```


col/row sums and means

For sums and means of matrix dimensions, we have some shortcuts.

- `rowSums = apply(x, 1, sum)`
- `rowMeans = apply(x, 1, mean)`
- `colSums = apply(x, 2, sum)`
- `colMeans = apply(x, 2, mean)`

The shortcut functions are *much* faster, but you won't notice unless you're using a large matrix.

Other Ways to Apply

Quantiles of the rows of a matrix.

```
> x <- matrix(rnorm(200), 20, 10)
> apply(x, 1, quantile, probs = c(0.25, 0.75))
```

	[,1]	[,2]	[,3]	[,4]
25%	-0.3304284	-0.99812467	-0.9186279	-0.49711686
75%	0.9258157	0.07065724	0.3050407	-0.06585436
	[,5]	[,6]	[,7]	[,8]
25%	-0.05999553	-0.6588380	-0.653250	0.01749997
75%	0.52928743	0.3727449	1.255089	0.72318419
	[,9]	[,10]	[,11]	[,12]
25%	-1.2467955	-0.8378429	-1.0488430	-0.7054902
75%	0.3352377	0.7297176	0.3113434	0.4581150
	[,13]	[,14]	[,15]	[,16]
25%	-0.1895108	-0.5729407	-0.5968578	-0.9517069
75%	0.5326299	0.5064267	0.4933852	0.8868922
	[,17]	[,18]	[,19]	[,20]

apply

Average matrix in an array

```
> a <- array(rnorm(2 * 2 * 10), c(2, 2, 10))
> apply(a, c(1, 2), mean)
      [,1]      [,2]
[1,] -0.2353245 -0.03980211
[2,] -0.3339748  0.04364908

> rowMeans(a, dims = 2)
      [,1]      [,2]
[1,] -0.2353245 -0.03980211
[2,] -0.3339748  0.04364908
```



Introduction to the R Language

Loop Functions - `tapply`

Roger Peng, Associate Professor
Johns Hopkins Bloomberg School of Public Health

tapply

`tapply` is used to apply a function over subsets of a vector. I don't know why it's called `tapply`.

```
> str(tapply)
function (X, INDEX, FUN = NULL, ..., simplify = TRUE)
```

- `X` is a vector
- `INDEX` is a factor or a list of factors (or else they are coerced to factors)
- `FUN` is a function to be applied
- `...` contains other arguments to be passed `FUN`
- `simplify`, should we simplify the result?

tapply

Take group means.

```
> x <- c(rnorm(10), runif(10), rnorm(10, 1))
> f <- gl(3, 10)
> f
 [1] 1 1 1 1 1 1 1 1 1 1 2 2 2 2 2 2 2 2 2 2 3 3 3
[24] 3 3 3 3 3 3 3
Levels: 1 2 3
> tapply(x, f, mean)
      1      2      3
0.1144464 0.5163468 1.2463678
```

tapply

Take group means without simplification.

```
> tapply(x, f, mean, simplify = FALSE)
$'1'
[1] 0.1144464

$'2'
[1] 0.5163468

$'3'
[1] 1.246368
```

tapply

Find group ranges.

```
> tapply(x, f, range)
$'1'
[1] -1.097309  2.694970

$'2'
[1] 0.09479023 0.79107293

$'3'
[1] 0.4717443 2.5887025
```




Introduction to the R Language

Loop Functions - mapply

Roger Peng, Associate Professor
Johns Hopkins Bloomberg School of Public Health

mapply

`mapply` is a multivariate `apply` of sorts which applies a function in parallel over a set of arguments.

```
> str(mapply)
function (FUN, ..., MoreArgs = NULL, SIMPLIFY = TRUE,
         USE.NAMES = TRUE)
```

- `FUN` is a function to apply
- `...` contains arguments to apply over
- `MoreArgs` is a list of other arguments to `FUN`.
- `SIMPLIFY` indicates whether the result should be simplified

mapply

The following is tedious to type

```
list(rep(1, 4), rep(2, 3), rep(3, 2), rep(4, 1))
```

Instead we can do

```
> mapply(rep, 1:4, 4:1)
[[1]]
[1] 1 1 1 1

[[2]]
[1] 2 2 2

[[3]]
[1] 3 3

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

Vectorizing a Function

```
> noise <- function(n, mean, sd) {  
+   rnorm(n, mean, sd)  
+ }  
> noise(5, 1, 2)  
[1]  2.4831198  2.4790100  0.4855190 -1.2117759  
[5] -0.2743532  
  
> noise(1:5, 1:5, 2)  
[1] -4.2128648 -0.3989266  4.2507057  1.1572738  
[5]  3.7413584
```

split

`split` takes a vector or other objects and splits it into groups determined by a factor or list of factors.

```
> str(split)
function (x, f, drop = FALSE, ...)
```

- `x` is a vector (or list) or data frame
- `f` is a factor (or coerced to one) or a list of factors
- `drop` indicates whether empty factors levels should be dropped

split

```
> x <- c(rnorm(10), runif(10), rnorm(10, 1))
> f <- gl(3, 10)
> split(x, f)
$'1'
 [1] -0.8493038 -0.5699717 -0.8385255 -0.8842019
 [5]  0.2849881  0.9383361 -1.0973089  2.6949703
 [9]  1.5976789 -0.1321970

$'2'
 [1]  0.09479023  0.79107293  0.45857419  0.74849293
 [5]  0.34936491  0.35842084  0.78541705  0.57732081
 [9]  0.46817559  0.53183823

$'3'
 [1]  0.6795651  0.9293171  1.0318103  0.4717443
 [5]  2.5887025  1.5975774  1.3246333  1.4372701
```

split

A common idiom is `split` followed by an `lapply`.

```
> lapply(split(x, f), mean)
$'1'
[1] 0.1144464

$'2'
[1] 0.5163468

$'3'
[1] 1.246368
```

Splitting a Data Frame

```
> library(datasets)
```

```
> head(airquality)
```

	Ozone	Solar.R	Wind	Temp	Month	Day
1	41	190	7.4	67	5	1
2	36	118	8.0	72	5	2
3	12	149	12.6	74	5	3
4	18	313	11.5	62	5	4
5	NA	NA	14.3	56	5	5
6	28	NA	14.9	66	5	6

Splitting a Data Frame

```
> s <- split(airquality, airquality$Month)
> lapply(s, function(x) colMeans(x[, c("Ozone", "Solar.R", "Wind")]))
```

\$'5'

Ozone	Solar.R	Wind
NA	NA	11.62258

\$'6'

Ozone	Solar.R	Wind
NA	190.16667	10.26667

\$'7'

Ozone	Solar.R	Wind
NA	216.483871	8.941935

Splitting a Data Frame

```
> sapply(s, function(x) colMeans(x[, c("Ozone", "Solar.R", "Wind")]))
```

	5	6	7	8	9
Ozone	NA	NA	NA	NA	NA
Solar.R	NA	190.16667	216.483871	NA	167.4333
Wind	11.62258	10.26667	8.941935	8.793548	10.1800

```
> sapply(s, function(x) colMeans(x[, c("Ozone", "Solar.R", "Wind")],  
                                na.rm = TRUE))
```

	5	6	7	8	9
Ozone	23.61538	29.44444	59.115385	59.961538	31.44828
Solar.R	181.29630	190.16667	216.483871	171.857143	167.43333
Wind	11.62258	10.26667	8.941935	8.793548	10.18000

Splitting on More than One Level

```
> x <- rnorm(10)
> f1 <- gl(2, 5)
> f2 <- gl(5, 2)
> f1
[1] 1 1 1 1 1 2 2 2 2 2
Levels: 1 2
> f2
[1] 1 1 2 2 3 3 4 4 5 5
Levels: 1 2 3 4 5
> interaction(f1, f2)
[1] 1.1 1.1 1.2 1.2 1.3 2.3 2.4 2.4 2.5 2.5
10 Levels: 1.1 2.1 1.2 2.2 1.3 2.3 1.4 ... 2.5
```

Splitting on More than One Level

Interactions can create empty levels.

```
> str(split(x, list(f1, f2)))  
List of 10  
 $ 1.1: num [1:2] -0.378  0.445  
 $ 2.1: num(0)  
 $ 1.2: num [1:2] 1.4066 0.0166  
 $ 2.2: num(0)  
 $ 1.3: num -0.355  
 $ 2.3: num 0.315  
 $ 1.4: num(0)  
 $ 2.4: num [1:2] -0.907  0.723  
 $ 1.5: num(0)  
 $ 2.5: num [1:2] 0.732 0.360
```

split

Empty levels can be dropped.

```
> str(split(x, list(f1, f2), drop = TRUE))  
List of 6  
 $ 1.1: num [1:2] -0.378  0.445  
 $ 1.2: num [1:2]  1.4066 0.0166  
 $ 1.3: num -0.355  
 $ 2.3: num  0.315  
 $ 2.4: num [1:2] -0.907  0.723  
 $ 2.5: num [1:2]  0.732 0.360
```