Introduction to the R Language

Loop Functions

Biostatistics 140.776

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

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

lapply

`lapply` takes three arguments: a list `X`, a function (or the name of a function) `FUN`, and 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))
}
```

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] 0.0296824
```

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] 0.06082667

$c
[1] 1.467083

$d
[1] 5.074749
```

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(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
```

apply

`apply` is used to a 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]
25% -0.2502935 -0.7488003 -0.7100923 -0.638243
```

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
```

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
```

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

$`8`
   Ozone  Solar.R     Wind
```

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
```

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
```

Summary

- The various apply functions can be used to compactly loop over objects
- Paradigm is that you loop over a single object, map a function to each element, and return an object of the same length
- Sometimes a bit more readable than using a ‘for‘ loop
- Not necessarily faster than a ‘for‘ loop