R: Programming and Looping Functions

140.776 Statistical Computing

September 29, 2011

Recursive functions

Functions can be recursive. For example, suppose $x = 2^d$. Now given an integer x, we want to compute $d = log_2(x)$. You can implement using a loop:

```
g<-function(x) {
        d<-0
        while(x>=2) {
                x<-x/2
                d<-d+1
        }
}

> y<-g(32)
> y
[1] 5
```

Recursive functions

But you can also implement it using recursive function calls:

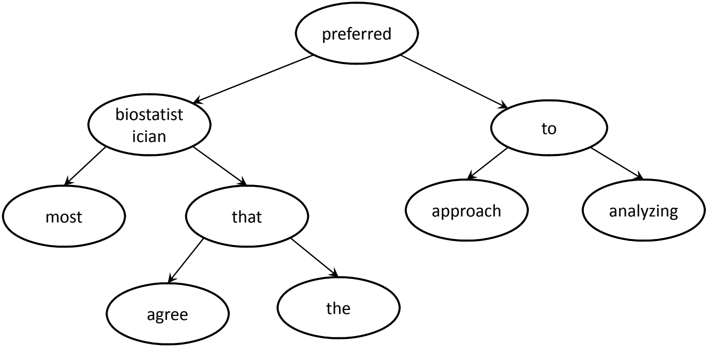
```
f<-function(x) {
        if(x>2) {
                d<-1+f(x/2)
        } else {
                d<-1
        }
        d
}

> y<-f(32)
> y
[1] 5
```

The function f() calls itself within the body of the function.

Tree

```
> load("tree.rda")
```

Tree


preferred
biostatist ician
to
most
that
approach
analyzing
agree
the

Tree traversal

```
scantree<-function(t) {
   leftn<-t$left
   rightn<-t$right

   if(is.list(leftn) == TRUE) {
      strl<-scantree(leftn)
   } else {
      strl<-""
   }

   if(is.list(rightn) == TRUE) {
      strr<-scantree(rightn)
   } else {
      strr<-""
   }

   str<-c(strl, t$key, strr)
}

mystr<-scantree(mytree)
print(paste(mystr, collapse= " "))
```

Looping functions

The for, while loops can often be replaced by looping functions:

- **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

lapply

```
lapply(X, FUN, ...)
```

lapply takes three arguments: a list X, a function FUN, and other arguments ... If X is not a list, it will be converted to a list using as.list().

It returns a list of the same length as X, each element of which is the result of applying FUN to the corresponding element of X.

lapply

Examples:

```
> u<-list(x=1:10,y=rnorm(100))
> lapply(u,mean)
$x
[1] 5.5

$y
[1] -0.06615078

> v<-c("bio","stat","comput")
> lapply(v,nchar)
[[1]]
[1] 3

[[2]]
[1] 4

[[3]]
[1] 6
```

lapply

```
> lapply(1:4, runif)
[[1]]
[1] 0.7082681

[[2]]
[1] 0.1966707 0.3025155

[[3]]
[1] 0.1872824 0.1093319 0.1641600

[[4]]
[1] 0.29028286 0.74228311 0.03167801 0.44816463
```

lapply

lapply makes 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 is a user-friendly version of lapply.

- 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 cannot figure things out, a list is returned.

sapply

Examples:

```
> v<-c("bio","stat","comput")
> lapply(v,nchar)
[[1]]
[1] 3

[[2]]
[1] 4

[[3]]
[1] 6

> sapply(v,nchar)
   bio   stat comput
     3      4      6
```

apply

```
apply(X, MARGIN, FUN, ...)
```

Applying a function to margins of an array X.

- If X is not an array but has a dimension attribute, apply attempts to coerce it to an array via as.matrix if it is two-dimensional (e.g., data frames) or via as.array
- MARGIN is an integer vector indicating which margins should be "retained".
- FUN is a function to be applied
- ... is for arguments to be passed to FUN

apply

- If each call to FUN returns a vector of length n, then apply returns an array of dimension c(n, dim(X)[MARGIN]) if n>1. If n equals 1, apply returns a vector if MARGIN has length 1 and an array of dimension dim(X)[MARGIN] otherwise.
- If the calls to FUN return vectors of different lengths, apply returns a list of length prod(dim(X)[MARGIN]) with dim set to MARGIN if this has length greater than one.

apply

```
> x<-matrix(1:6,3,2)
> x
     [,1] [,2]
[1,]    1    4
[2,]    2    5
[3,]    3    6

> apply(x,1,function(u) sum(u))
[1] 5 7 9

> apply(x,1,mean)
[1] 2.5 3.5 4.5
```

apply

Quantiles of the rows of a matrix.

```
> x<-matrix(rnorm(100),5,20)

> apply(x,1,quantile,probs=c(0.25,0.75))
          [,1]       [,2]       [,3]       [,4]
25% -0.7463242 -0.1705673 -0.6468663 -0.7671974
75%  0.4318116  0.9564692  0.4955044  0.4381032
          [,5]
25% -0.9612553
75%  1.4259372
```

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.

col/row sums and means

```
> x<-array(rnorm(2*2*10),c(2,2,10))
> apply(x,c(1,2),sum)
           [,1]     [,2]
[1,]  4.2774538 2.407804
[2,] -0.5435999 3.988917

> rowSums(x,dims=2)
           [,1]     [,2]
[1,]  4.2774538 2.407804
[2,] -0.5435999 3.988917

> rowSums(x)
[1] 6.685258 3.445317
```

tapply

We've already seen tapply before:

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

Applying a function to each (non-empty) group of values given by a unique combination of the levels of certain factors.

- X: an atomic object, typically a vector
- INDEX: list of factors, each of same length as X. The elements are coerced to factors by as.factor()
- FUN: the function to be applied
- ...: optional arguments to FUN
- simplify: if FALSE, returns a list. If TRUE, then if FUN always returns a scalar, tapply returns an array with the mode of the scalar.

tapply

```
> x<-c(rnorm(5),rnorm(5,1),rnorm(5,2),rnorm(5,3))
> f1<-factor(rep(1:2,each=10))
> f1
 [1] 1 1 1 1 1 1 1 1 1 1 2 2 2 2 2 2 2 2 2 2
Levels: 1 2
> f2<-factor(rep(rep(3:4,each=5),times=2))
> f2
 [1] 3 3 3 3 3 4 4 4 4 4 3 3 3 3 3 4 4 4 4 4
Levels: 3 4
> f<-list(f1,f2)
> tapply(x,f,mean)
       3         4
1 0.4687781 0.9727993
2 1.7442365 3.4148615
```

tapply

```
> x<-c(rnorm(10),rnorm(10,1),rnorm(10,2))
> 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 3 3 3
[27] 3 3 3 3
Levels: 1 2 3

> tapply(x,f,mean)
        1         2         3
0.3104300 0.9665058 2.0069397

> tapply(x,f,mean,simplify=FALSE)
$‘1‘
[1] 0.3104300
$‘2‘
[1] 0.9665058
$‘3‘
[1] 2.006940
```

tapply

Find group ranges.

```
> tapply(x,f,range)
$‘1‘
[1] -1.087020  1.801051

$‘2‘
[1] -0.3175924  2.4043049

$‘3‘
[1] 0.9338877 3.4817331
```

mapply

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

mapply is a multivariate version of sapply. mapply applies FUN to the first elements of each ... argument, the second elements, the third elements, and so on. Arguments are recycled if necessary.

- FUN: the function to be applied
- ...: arguments to apply over
- MoreArgs: a list of other arguments to FUN
- SIMPLIFY: logical; whether the result should be simplified to a vector or matrix.

mapply

Example:

```
## tedious to type
> list(rep(1,4),rep(2,3),rep(3,2),rep(4,1))

## use mapply instead
> 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(3,1,2)
[1]  5.164179  1.353838 -2.573485

> noise(1:3,1:3,2)
[1] -3.8190429  1.6455998  0.4092931
```

Instant vectorization

```
> mapply(noise,1:3,1:3,2)
[[1]]
[1] 3.619997

[[2]]
[1]  5.641030 -2.344175

[[3]]
[1]  0.7557551 -0.4642377  4.8742734
```

which is the same as

```
list(noise(1,1,2),noise(2,2,2),noise(3,3,2))
```

split

```
split(x, f, drop = FALSE, ...)
```

split divides the data in the x into the groups defined by a factor or list of factors. It is often followed by lapply.

- x: a vector or data frame
- f: a factor or a list of factors
- drop: logical; whether empty levels should be dropped

split

```
> x<-c(rnorm(4),runif(4),rgamma(4,1,1))
> f<-gl(3,4)
> split(x,f)
$‘1‘
[1] -2.03109144 -0.08146077 -0.17701322 -0.78487670

$‘2‘
[1] 0.1401723 0.6657537 0.6366146 0.7639057

$‘3‘
[1] 0.4280483 0.6125946 1.6261508 1.6642573
```

split

```
> lapply(split(x,f),mean)
$‘1‘
[1] -0.7686105

$‘2‘
[1] 0.5516116

$‘3‘
[1] 1.082763
```

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
Levels: 1.1 2.1 1.2 2.2 1.3 2.3 1.4 2.4 1.5 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] 0.23 0.862
 $ 2.1: num(0)
 $ 1.2: num [1:2] -0.849 0.511
 $ 2.2: num(0)
 $ 1.3: num -1.33
 $ 2.3: num -3.12
 $ 1.4: num(0)
 $ 2.4: num [1:2] 1.3 -2.11
 $ 1.5: num(0)
 $ 2.5: num [1:2] -0.726 0.839
```

Splitting on more than one level

Empty levels can be dropped.

```
> str(split(x,list(f1,f2), drop=TRUE))
List of 6
 $ 1.1: num [1:2] 0.23 0.862
 $ 1.2: num [1:2] -0.849 0.511
 $ 1.3: num -1.33
 $ 2.3: num -3.12
 $ 2.4: num [1:2] 1.3 -2.11
 $ 2.5: num [1:2] -0.726 0.839
```