Lecture 14: The Split-Apply-Combine Paradigm

Statistical Computing, 36-350

Monday November 9, 2015

Outline

- A quick reminder of what R can do
- How to make life easier with repeated tasks on large data sets

Refresher

We've used some tools for iterating over objects in R without `for()` loops:

- `subset()`: retrieve part of the data according to some condition
- `apply()`: takes a matrix and a margin, applies a function
- `sapply()` or `lapply()`: takes a list (or vector), applies a function
- `c()` or `rbind()` or `cbind()`: concatenate these objects in a known pattern

General strategy

Today we will learn a workflow that can be summmarized in three general steps:

- **Split** whatever data object we have into meaningful chunks
- **Apply** the function of interest to this division
- **Combine** the results into a new object

Sounds simple? It is, but it's powerful when combined with data structures (see Hadoop/MapReduce for how this makes you billions)

Why is this useful without the billions?

- This reinforces the pattern/function approach: **what you want to do** versus **how you want to do it**
- If the full data set is big, and we've already done the splitting, this makes it tractable on smaller machines

An important application: ragged data

Our previous functions work well with well-composed data: `apply()` on matrices, `sapply()` or `lapply()` on lists and vectors. What about *ragged data*—where the dimensions of each object aren't necessarily the same?

For this: start with data frames, though we'll be going beyond this eventually

A sociologial application

Politics and labor action: does having a friendlier government make labor action more or less likely?

Data: political economy of strikes

Compiled by Bruce Western, Sociology Dept., Harvard.

- Data frame of 8 columns: country, year, days on strike per 1000 workers, unemployment, inflation, left-wing share of governmentt, centralization of unions, union density
- 625 observations from 18 countries, 1951–1985
- Note that since $18 \times 35 = 630 > 625$, some years missing from some countries

```
strikes = read.csv("http://www.stat.cmu.edu/~ryantibs/statcomp/lectures/strikes.csv")
```

```
head(strikes)
```

```
##     country year strike.volume unemployment inflation left.parliament
## 1 Australia 1951           296          1.3      19.8            43.0
## 2 Australia 1952           397          2.2      17.2            43.0
## 3 Australia 1953           360          2.5       4.3            43.0
## 4 Australia 1954             3          1.7       0.7            47.0
```

```
## 5 Australia 1955           326          1.4       2.0            38.5
## 6 Australia 1956           352          1.8       6.3            38.5
##   centralization density
## 1      0.3748588      NA
## 2      0.3751829      NA
## 3      0.3745076      NA
## 4      0.3710170      NA
## 5      0.3752675      NA
## 6      0.3716072      NA
```

Research question

"Does having a friendlier government make labor action more or less likely?"

becomes

"Is there a relationship between a country's ruling party alignment (left versus right) and the volume of strikes?"

Lots of ways to approach this problem: simplest is to split it by country.

Functions `subset()`, `split()`, `tapply()`

Take Italy:

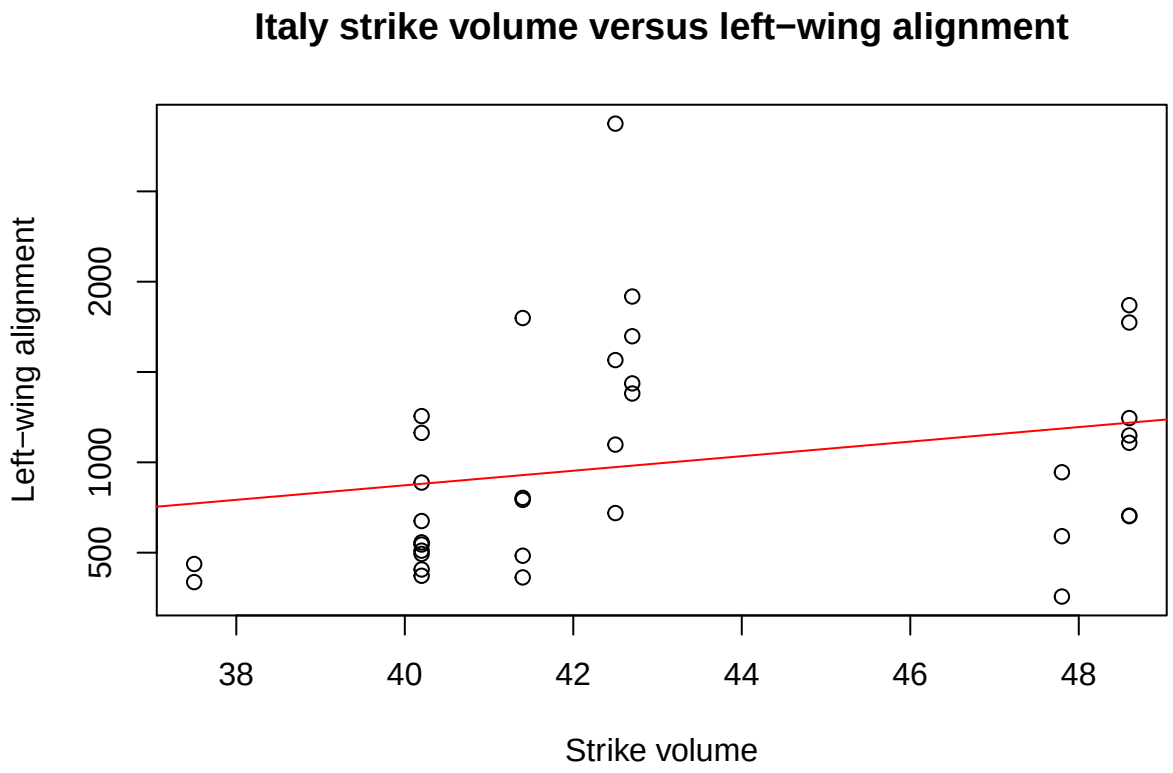
```
italy.strikes = subset(strikes, country=="Italy")
```

Or, if you prefer,

```
italy.strikes = strikes[strikes$country=="Italy",]
head(italy.strikes)
```

```
##     country year strike.volume unemployment inflation left.parliament
## 311   Italy 1951           437          8.8      14.3            37.5
## 312   Italy 1952           337          9.5       1.9            37.5
## 313   Italy 1953           545         10.0       1.4            40.2
## 314   Italy 1954           493          8.7       2.4            40.2
## 315   Italy 1955           511          7.5       2.3            40.2
## 316   Italy 1956           372          9.3       3.4            40.2
##     centralization density
## 311      0.2513799      NA
## 312      0.2489860      NA
## 313      0.2482739      NA
## 314      0.2466577      NA
## 315      0.2540366      NA
## 316      0.2457069      NA
```

```
italy.fit = lm(strike.volume ~ left.parliament, data=italy.strikes)
plot(italy.strikes$left.parliament, italy.strikes$strike.volume,
     main="Italy strike volume versus left-wing alignment",
     xlab="Strike volume", ylab="Left-wing alignment")
abline(italy.fit, col=2)
```



One down, seventeen to go

Tedious and dangerous to do this repeatedly—typos abound. How can we do this in an easier way?

First: we need subsets for every country. `split()` does this nicely:

```
strikes.split = split(strikes, strikes$country)
class(strikes.split)
```

```
## [1] "list"
```

```
names(strikes.split)
```

```
##  [1] "Australia"   "Austria"     "Belgium"     "Canada"      "Denmark"
##  [6] "Finland"     "France"      "Germany"     "Ireland"     "Italy"
## [11] "Japan"       "Netherlands" "New.Zealand" "Norway"      "Sweden"
## [16] "Switzerland" "UK"          "USA"
```

Now, let's generalize our function. We want the linear model coefficients:

```
my.strike.lm = function (country.df) {
  return(lm(strike.volume ~ left.parliament, data=country.df)$coefficients)
}
my.strike.lm(subset(strikes, country=="Italy"))
```

```
##     (Intercept) left.parliament
##      -738.74531        40.29109
```

We could use a `for()` loop ...

```
strike.coefs = NULL
my.countries = c("France", "Italy", "USA")
for (this.country in my.countries) {
  strike.coefs = cbind(strike.coefs,
    my.strike.lm (subset(strikes, country==this.country)))
}
colnames(strike.coefs) = my.countries
strike.coefs
```

```
##                      France      Italy        USA
## (Intercept)     202.4261408 -738.74531 111.440651
## left.parliament  -0.4255319   40.29109   5.918647
```

Easier if we've split!

```
strike.coefs = lapply (strikes.split[1:3], my.strike.lm)
strike.coefs
```

```
## $Australia
##     (Intercept) left.parliament
##     414.7712254      -0.8638052
##
## $Austria
##     (Intercept) left.parliament
##      423.077279       -8.210886
##
## $Belgium
##     (Intercept) left.parliament
##      -56.926780        8.447463
```

Combine step

```
do.call(cbind, strike.coefs)
```

```
##                   Australia    Austria    Belgium
## (Intercept)     414.7712254 423.077279 -56.926780
## left.parliament  -0.8638052  -8.210886   8.447463
```

Or, in one step:

```
strike.coefs = sapply(strikes.split[1:3], my.strike.lm)
strike.coefs
```

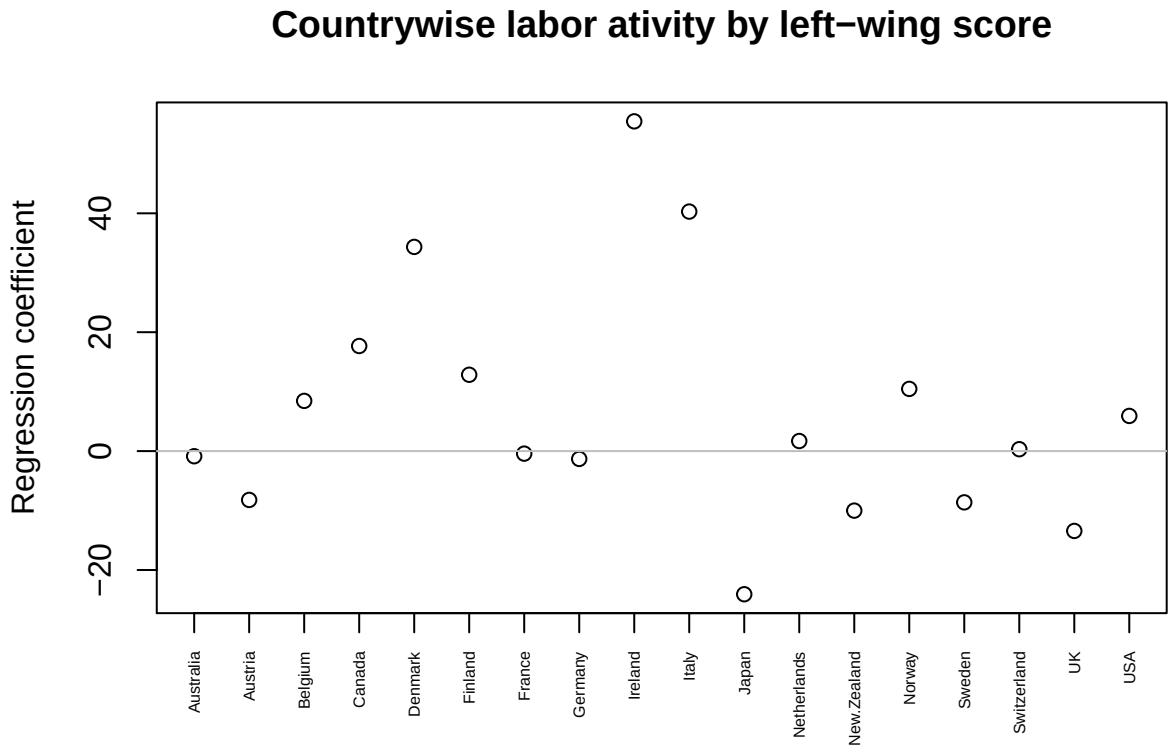
```
##                   Australia    Austria    Belgium
## (Intercept)     414.7712254 423.077279 -56.926780
## left.parliament  -0.8638052  -8.210886   8.447463
```

All together now

```
coefs = sapply(strikes.split, my.strike.lm)
coefs
```

```
##                   Australia    Austria    Belgium    Canada     Denmark
## (Intercept)     414.7712254 423.077279 -56.926780 -227.8218 -1399.35735
## left.parliament  -0.8638052  -8.210886   8.447463   17.6766    34.34477
##                   Finland      France   Germany   Ireland      Italy
## (Intercept)     108.2245 202.4261408 95.657134 -94.78661 -738.74531
## left.parliament  12.8422  -0.4255319 -1.312305  55.46721   40.29109
##                      Japan Netherlands New.Zealand     Norway    Sweden
## (Intercept)     964.73750  -32.627678    721.3464 -458.22397 513.16704
## left.parliament -24.07595    1.694387    -10.0106   10.46523  -8.62072
##                 Switzerland        UK        USA
## (Intercept)      -5.1988836 936.10154 111.440651
## left.parliament   0.3203399 -13.42792   5.918647
```

```
plot(coefs[2,],xaxt="n",xlab="",ylab="Regression coefficient",
     main="Countrywise labor ativity by left-wing score")
axis(side=1,at=seq(along=colnames(coefs)),labels=colnames(coefs),
     las=2,cex.axis=0.5)
abline(h=0,col="grey")
```

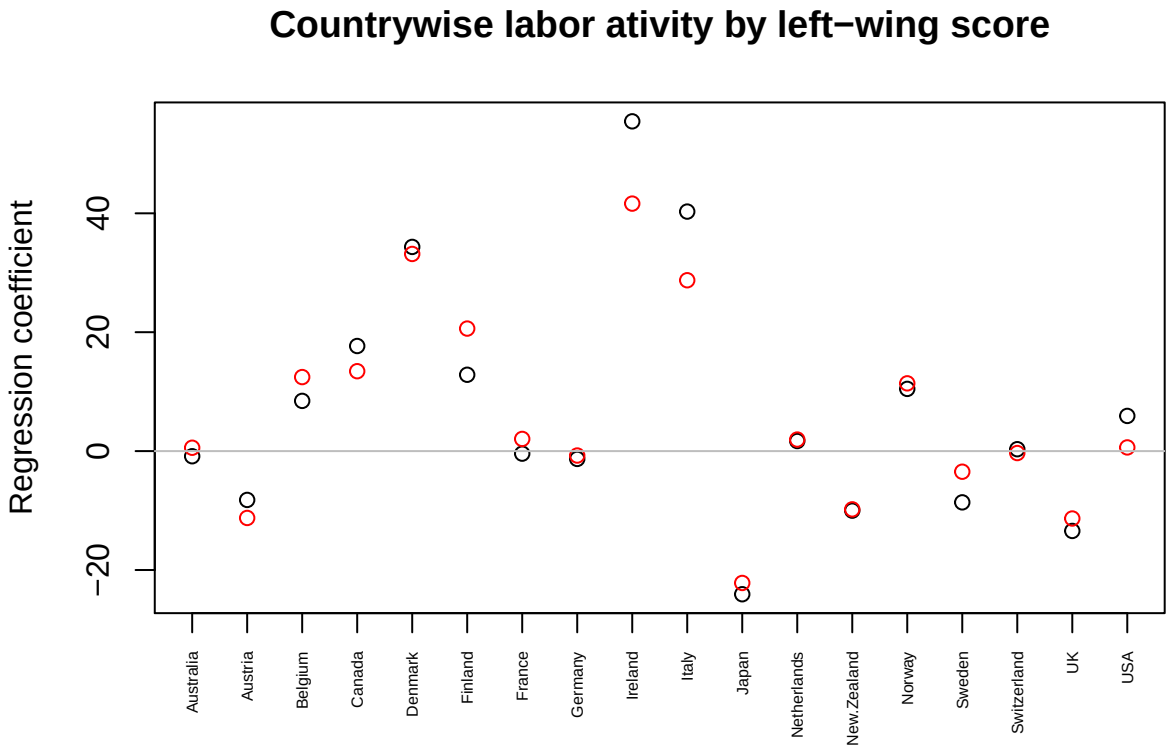


Add some more coefficients

```
my.strike.lm.better = function(country.df) {
  return(lm(strike.volume ~ left.parliament + unemployment + inflation,
            data=country.df)$coefficients)
}
coefs2 = sapply(strikes.split, my.strike.lm.better)
coefs2[,1:4]
```

```
##                   Australia     Austria      Belgium    Canada
## (Intercept)     157.9191118 600.6777769 -243.4822938 167.07123
## left.parliament   0.5658674 -11.2441604   12.4516118  13.43864
## unemployment     -1.1181489 -10.9216990    0.3578217 -48.17903
## inflation        30.4666061  -0.5923972   10.2673539  27.21807
```

```
plot(coefs[2,],xaxt="n",xlab="",ylab="Regression coefficient",
     main="Countrywise labor ativity by left-wing score")
axis(side=1,at=seq(along=colnames(coefs)),labels=colnames(coefs),
     las=2,cex.axis=0.5)
points(coefs2[2,], col="red")
abline(h=0,col="grey")
```



Summary

- Split-apply-combine is a commonly used strategy for dealing with repeated calculations over large data sets
- It is helpful conceptually (forces you to think: i. what are the main chunks of data, ii. what are the main functions to apply, iii. how to put things back together in a sensible way)
- It is also helpful computationally for large data sets
- Turns out there are a whole family of `apply()` like functions that will make your life even easier, and these are also extra helpful for large data sets (next time)