R TUTORIAL

BUSINESS ANALYTICS (SOSE 2014)

Martin Wistuba

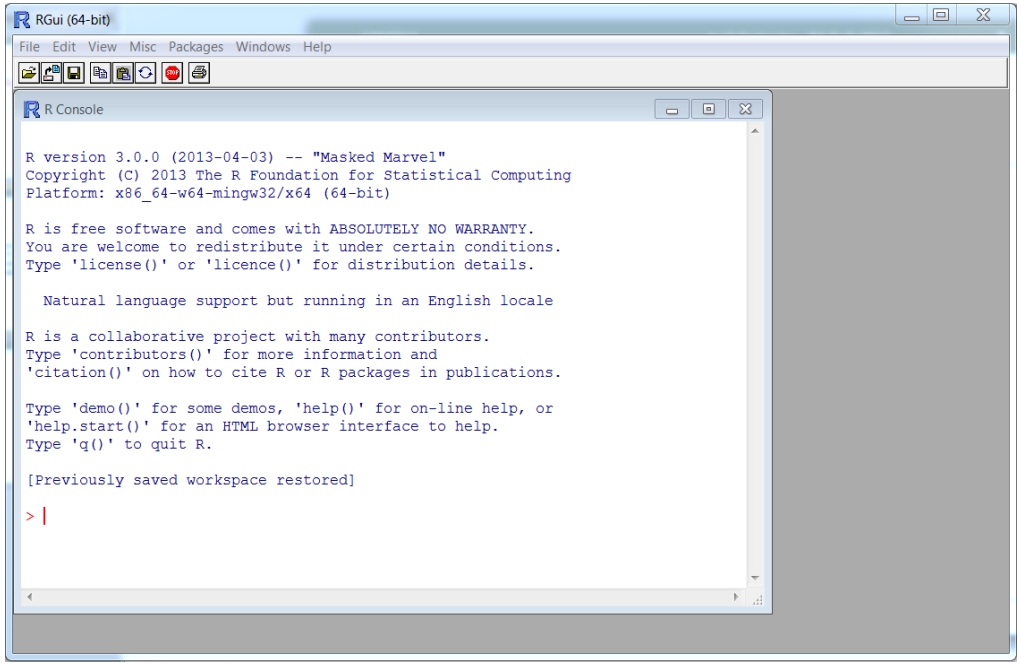
29/04/2014

What is R?

- Programming language
- Software environment
- Used by Statisticians and Data Miners
- Open Source version of “S”
- Large number of built-in statistical functions
- Easily configurable via packages

Getting R

- Download it from:
  - http://cran.r-project.org/
- Manual:
  - http://cran.r-project.org/doc/manuals/R-intro.pdf
- Includes RGui - IDE



Basics – Math Operations

- Type an expression into the console, while R computes the result

```
> 1+1
[1] 2
> pi
[1] 3.141593
> sqrt(2)
[1] 1.414214
```

Basics - Variables

- Variables are created and initialized via “name” <- “value”
- A function in R is called as “functionname”()

```
> x <- 23
> y <- 4
> z <- log( sqrt(x) + y )
> print(z)
[1] 2.174278
> z
[1] 2.174278
```

Basics - Printing

- print() : prints a single variable or data structure
- cat(): prints concatenated content

```
> x <- 5
> y <- 4
> z <- sqrt(x+y)
> print(z)
[1] 3
> cat("Square root of", x, " plus ", y, " is ", z, "\n")
Square root of 5  plus  4  is  3
```

Basics – Workspace

- The R session workspace stores all the created variables and functions in primary memory (RAM)
- In order to see all the created variables in your workspace use the list command

```
> ls()
[1] "x"  "y"      "z"
```

Basics – Workspace - Deleting Variables

- Delete through the rm() function

```
> ls()
[1] "x" "y" "z"
> rm(x)
> ls()
[1] "y" "z"
> rm(y,z)
> ls()
character(0)
```

Basics - Vectors

- A vector is a list of numeric values and is created as
- “name” <- c(“list of numbers”)

```
> v1 <- c(1,4,7,10,13)
> v2 <- c(3,23,2,-1,4)
> mean(v1)
[1] 7
> sd(v2)
[1] 9.576012
> cor(v1,v2)
[1] -0.363252
> cor(v2,v2)
[1] 1
```

Basics – Comparing Vectors

- Vectors can be compared (like variables) for equality ==, inequality !=, greater > or smaller <
- The outcome is a logical value TRUE/FALSE

```
> v <- c(3, pi, 4)
> w <- c(pi,pi,pi)
> v == w
[1] FALSE  TRUE FALSE
> w > v
[1]  TRUE FALSE FALSE
```

Basics - Sequences

- Create a sequence of numbers via
- “n”:”m”, for “n”,”n”+1,”n”+2,…,”m”
- seq(“n”,”m”,”k”), for “n”, “n”+”k”, “n”+2”k”, “n”+3”k”, …, “m”

```
> 1:14
 [1]  1  2  3  4  5  6  7  8  9 10 11 12 13 14
> seq(-1, 2, 0.3)
 [1] -1.0 -0.7 -0.4 -0.1  0.2  0.5  0.8  1.1  1.4  1.7  2.0
```

Basics – Selecting Vector Elements (1)

- Use square brackets to access element at a desired position, e.g. v[3] accesses the third element of v
- Use a negative sign to exclude, e.g. v[-2] is all except the second element
- Use a vector of indices to select multiple values
- Use a logical operator to access based on a condition

Basics – Selecting Vector Elements (2)

```
> fib <- c(0,1,1,2,3,5,8,13,21,34)
> fib[2]
[1] 1
> fib[7]
[1] 8
> fib[2:5]
[1] 1 1 2 3
> fib[ c(1,3,5,7) ]
[1] 0 1 3 8
> fib[ -(7:10) ]
[1] 0 1 1 2 3 5
```

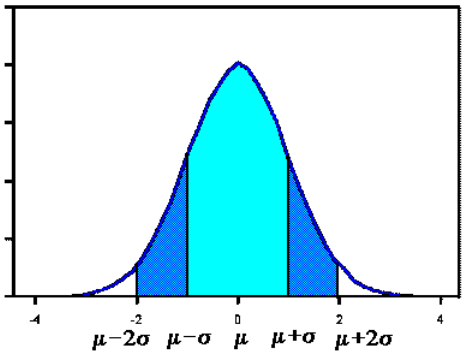
Basics – Selecting Vector Elements (3)

```
> fib <- c(0,1,1,2,3,5,8,13,21,34)
> mean(fib)
[1] 8.8
> fib[ fib > mean(fib) ] # fib > mean(fib) vec. of TRUE/FALSE
[1] 13 21 34
> fib[ fib %% 2 == 0 ]
[1]  0  2  8 34
```

Basics – Vector Arithmetic

```
> v <- c(11,12,13,14,15)
> w <- c(1,2,3,4,5)
> v+w
[1] 12 14 16 18 20
> v/w
[1] 11.000000  6.000000  4.333333  3.500000  3.000000
> v ^ 2
[1] 121 144 169 196 225
> mean(w)
[1] 3
> sd(w)
[1] 1.581139
> (w-mean(w))/sd(w)
[1] -1.2649111 -0.6324555  0.0000000  0.6324555  1.2649111
```

Normalization



Basics - Functions

```
function(param1,param2,…..,paramN)
{
  “expression 1”
  “expression 2”
  …
}
```

```
> gcd <- function(a,b){
+           if(b == 0) return(a)
+           else return( gcd(b, a %% b))
+   }
gcd(10,20)
[1] 10
```

Conditional Execution
if(“cond”) “expr” **else** “expr”

Termination
return(“value”)

Basics - Loops

- **while**(“condition”) “expression”

```
> z <- 0
> while(z < 5){
+    z <- z + 2
+    print(z)
+ }
[1] 2
[1] 4
[1] 6
```

- **Homework: Search for and learn the “for” loop**

Basics – Getting Help

> help.start() opens a local website on your browser which provides free tutorials, documentation, etc …

For a specific function:

> help(“functionname”)
> args(“functionname”)
> example(“functionname”)

Always ask Google if you get stuck!

Data Structures - Lists

- List is a vector whose elements are allowed to represent different modes/data types, i.e. numbers, strings, vectors, other lists …
- Lists are created using the **list**(“data”) function

```
> lst <- list(3, "A", 4.5 )
> print(lst)
[[1]]
[1] 3
[[2]]
[1] "A“
[[3]]
[1] 4.5
> length(lst)
[1] 3
> lst[[2]]
[1] "A"
```

```
> mode(lst[[2]])
[1] “character”
> lst2 <- list("Z", c(-21,5,7), list(3,"C"))
> print(lst2)
[[1]]
[1] "Z"
[[2]]
[1] -21   5   7
[[3]]
[[3]][[1]]
[1] 3
[[3]][[2]]
[1] "C"
```

Data Structures – Remove List Elements

- “listname”[“indices”] <- NULL

```
> lst <- list("A",100,90,"B",80,70,"C",60,50,"D",40,30)
> lst[ seq(2,length(lst),3)] <- NULL
> print(lst)
[[1]]
[1] "A"
[[2]]
[1] 90
[[3]]
[1] "B"
[[4]]
[1] 70
[[5]]
[1] "C"
[[6]]
[1] 50
[[7]]
[1] "D"
[[8]]
[1] 30
```

length(“data”): length of vector/list

Data Structures - Names

- Names can be set to vector and list elements

```
> grades <- c(5,4,3,2,1)
> names(grades) <- c("very bad", "bad", "normal", "good", "very good")
> grades["good"]
good
   2
```

Data Structures - Matrices

- Matrix is a vector which has two dimensions, set via **dim()**

```
> A <- 1:6
> print(A)
[1] 1 2 3 4 5 6
> dim(A)
NULL
> dim(A) <- c(3,2)
> print(A)
     [,1] [,2]
[1,]    1    4
[2,]    2    5
[3,]    3    6
```

Access: [“row”,”col”]

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

(“content”,”rows”,”cols”)

Data Structure – Matrix Selection

- Select one column/row, or a sub-matrix

```
> A <- matrix(1:16,4,4);
> print(A)
     [,1] [,2] [,3] [,4]
[1,]    1    5    9   13
[2,]    2    6   10   14
[3,]    3    7   11   15
[4,]    4    8   12   16
> A[2,]
[1]  2  6 10 14
> A[,3]
[1]  9 10 11 12
```

```
> A[1:2,3:4]
     [,1] [,2]
[1,]    9   13
[2,]   10   14
```

Data Structures - Arrays

- N-dimensional data structures

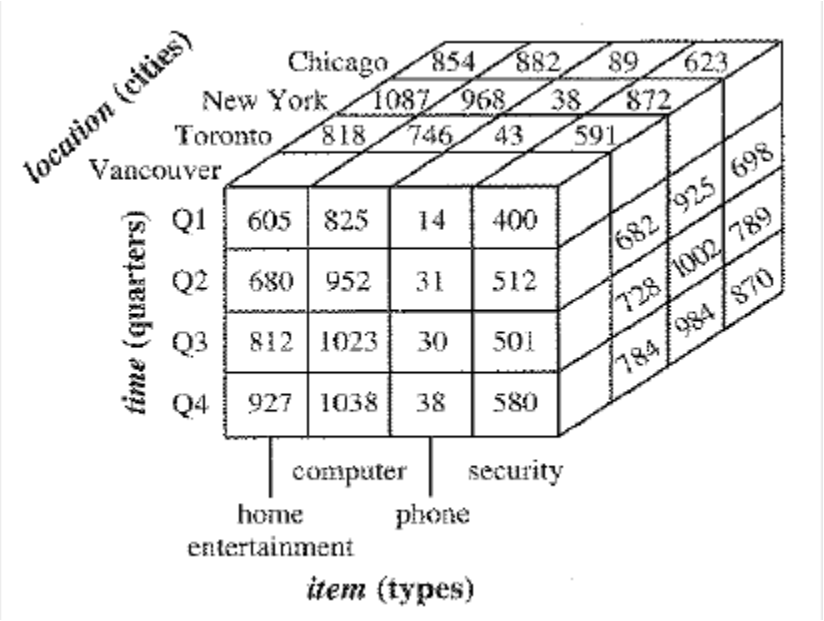
```
> D <- 1:12
> dim(D) <- c(2,3,2)
> print(D)
, , 1

     [,1] [,2] [,3]
[1,]    1    3    5
[2,]    2    4    6

, , 2

     [,1] [,2] [,3]
[1,]    7    9   11
[2,]    8   10   12
```

Three dimensional data cube, e.g.:



Source: http://timkienthuc.blogspot.de

Data Structures - Data Frames

- A tabular (2d) data structure which is a list whose elements are vectors. It is created using **data.frame**(“vec1”,”vec2”, …, “vecn”)
- Vectors are columns of the data frame and must have same length.
- For simplicity, think of the data frame like an Excel spreadsheet where each column has a unique data type.

```
> names <- c("hans", "tim", "lukas", "jorg")
> grades <- c(1.7, 2.0, 3.0, 1.3)
> scores <- data.frame(names,grades)
> print(scores)
  names grades
1  hans    1.7
2   tim    2.0
3 lukas    3.0
4  jorg    1.3
```

Data Structure – Append Data

Vectors

```
> v <- c(1,2,3,4)
> v <- c(v,5)
> print(v)
[1] 1 2 3 4 5
> w <- c(6,7,8,9)
> w <- c(v,w)
> print(w)
[1] 1 2 3 4 5 6 7 8 9
```

Frames

```
> newRow <- data.frame(
    names="josif", grades=2.0)
> scores <- rbind(scores,newRow)
> print(scores)
 names grades
1  hans    1.7
2  tim     2.0
3  lukas   3.0
4  jorg    1.3
5  josif   2.0
```

I/O – Read Tabular Files (1)

- Each line one record
- Within a record, each field is delimited by a special character such as comma, space, tab or colon.
- Each record contains the same number of fields

```
Fisher R.A. 1890 1962
Pearson Karl 1857 1936
Cox Gertrude 1900 1978
Yates Frank 1902 1994
Smith Kirstine 1878 1939
```

File “statisticians.txt”

I/O – Read Tabular Files (2)

- **read.table**(“filepath”) reads the file under the path and returns a data frame with the read content

```
> statisticians <- read.table("statisticians.txt")
> print(statisticians)
      V1        V2          V3    V4
1  Fisher      R.A.        1890  1962
2  Pearson   Karl          1857  1936
3  Cox         Gertrude 1900  1978
4  Yates       Frank     1902  1994
5  Smith       Kirstine  1878  1939
> statisticians$V1
[1] Fisher  Pearson Cox     Yates   Smith
Levels: Cox Fisher Pearson Smith Yates
```

I/O – Read CSV Files

- Simple CSV file “table.csv” (with a header line)

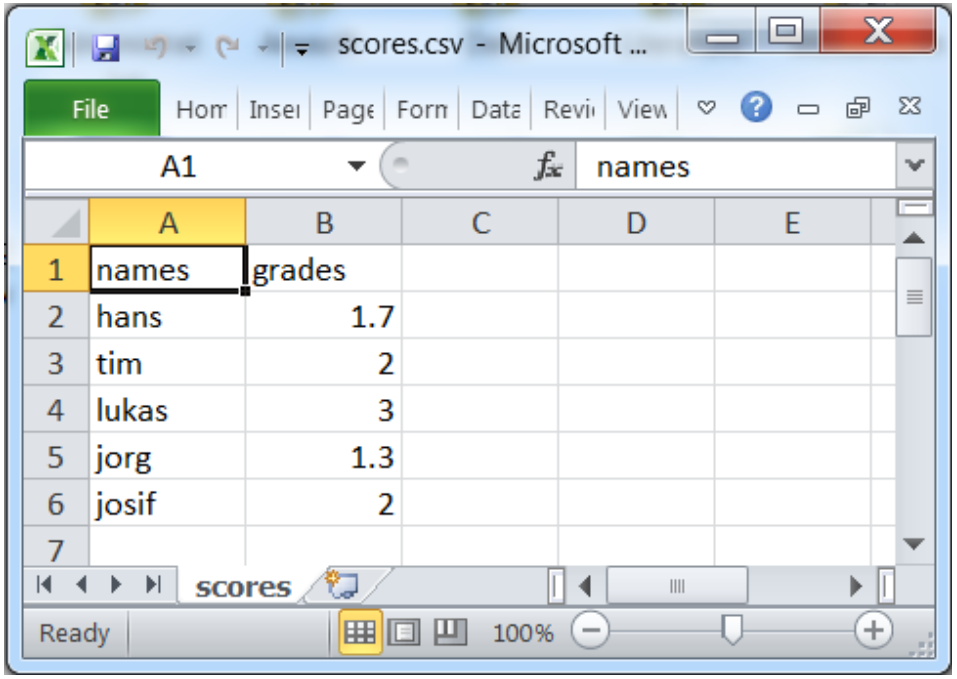
```
label,lbound,ubound
low,0,0.674
mid,0.674,1.64
high,1.64,2.33
```

```
> tbl <- read.csv("table.csv")
> print(tbl)
  label lbound ubound
1   low  0.000  0.674
2   mid  0.674  1.640
3  high  1.640  2.330
```

I/O – Write Data Frame to CSV File

```
> print(scores)
  names grades
1  hans    1.7
2   tim    2.0
3 lukas    3.0
4  jorg    1.3
5 josif    2.0
```

```
> write.csv(scores, "scores.csv",
            row.names=F)
```



Strings

```
> name <- "josif"
> surname <- "grabocka"
> fullname <- paste(name,surname)
> print(fullname)
[1] "josif grabocka"
> nchar(fullname)
[1] 14
> substr(fullname,7,10)
[1] "grab“
> sub("a", "$", fullname)
[1] "josif gr$bocka"
> gsub("a", "$", fullname)
[1] "josif gr$bock$"
```

Dates

```
> Sys.Date()
[1] "2013-04-28"
> format(Sys.Date(), "%m/%d/%Y")
[1] "04/28/2013“

> s <- as.Date("2013-04-23")
> e <- as.Date("2013-04-30")
> seq(s,e,1)
[1] "2013-04-23" "2013-04-24" "2013-04-25" "2013-04-26"
"2013-04-27" "2013-04-28" "2013-04-29" "2013-04-30"
```

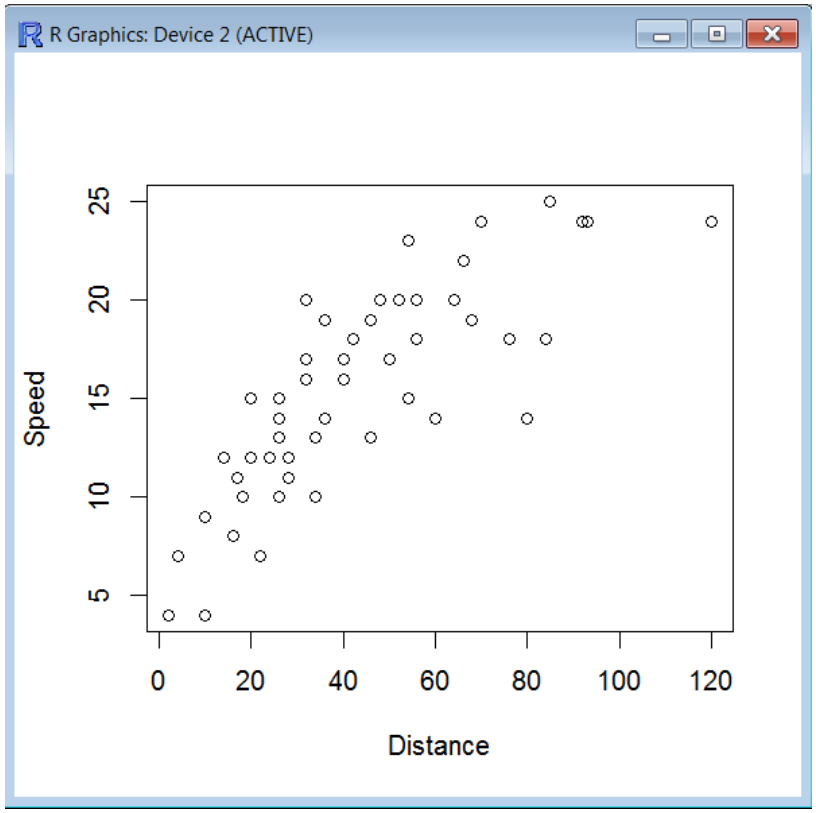
Graphics - Introduction

- Creating plots, charts and visual presentation of results
- High-level graphics functions
  - **plot** – generic plotting
  - **boxplot** – a box plot
  - **histogram** – histogram visualization of data
  - **curve** – display a function
- Low-level graphics functions (inside high-level containers)
  - **lines** – add lines to the plot
  - **points** – add points to the high level function
  - **polygon** – addition of polygon data
  - **text** – insertion of text annotation inside plot
- Title, Legend, Colors, Line-Styles, etc …

Graphics – Scatter Plot

- Packages :: Load Package :: Datasets (default datasets)

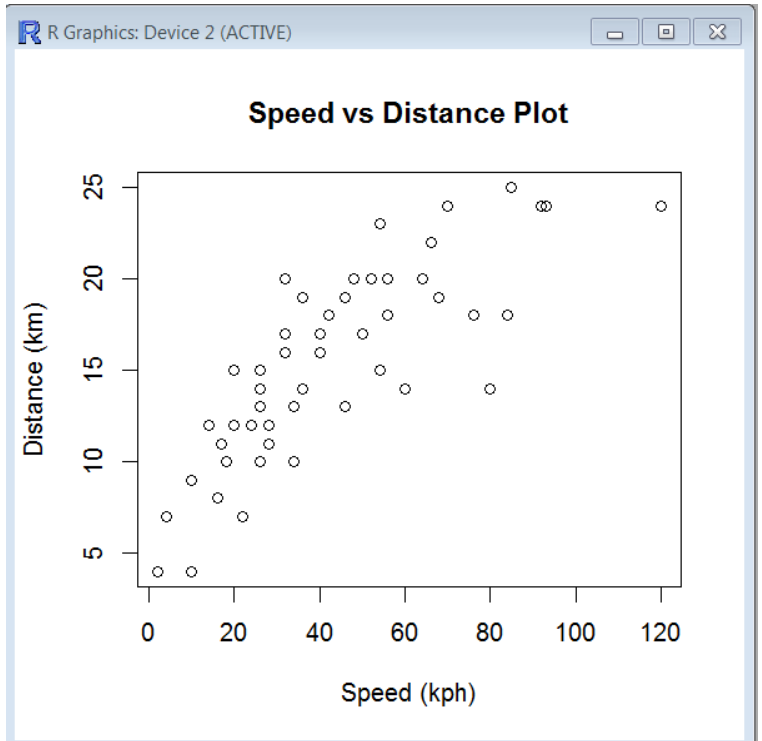
```
> ds <- cars
> print(ds)
speed dist
1     4    2
2     4   10
…
50    25   85
> Distance <- ds$dist #ds[,1]
> Speed <- ds$speed #ds[,2]
> plot(Distance,Speed)
```



Graphics – Title and Axis Labels

plot(D, main="title", xlab="X-axis label", ylab="Y-axis label")

> plot(Distance,Speed, main="Speed vs Distance Plot", xlab="Speed (kph)", ylab="Distance (km)")



Graphics – Multiple Plots (1)

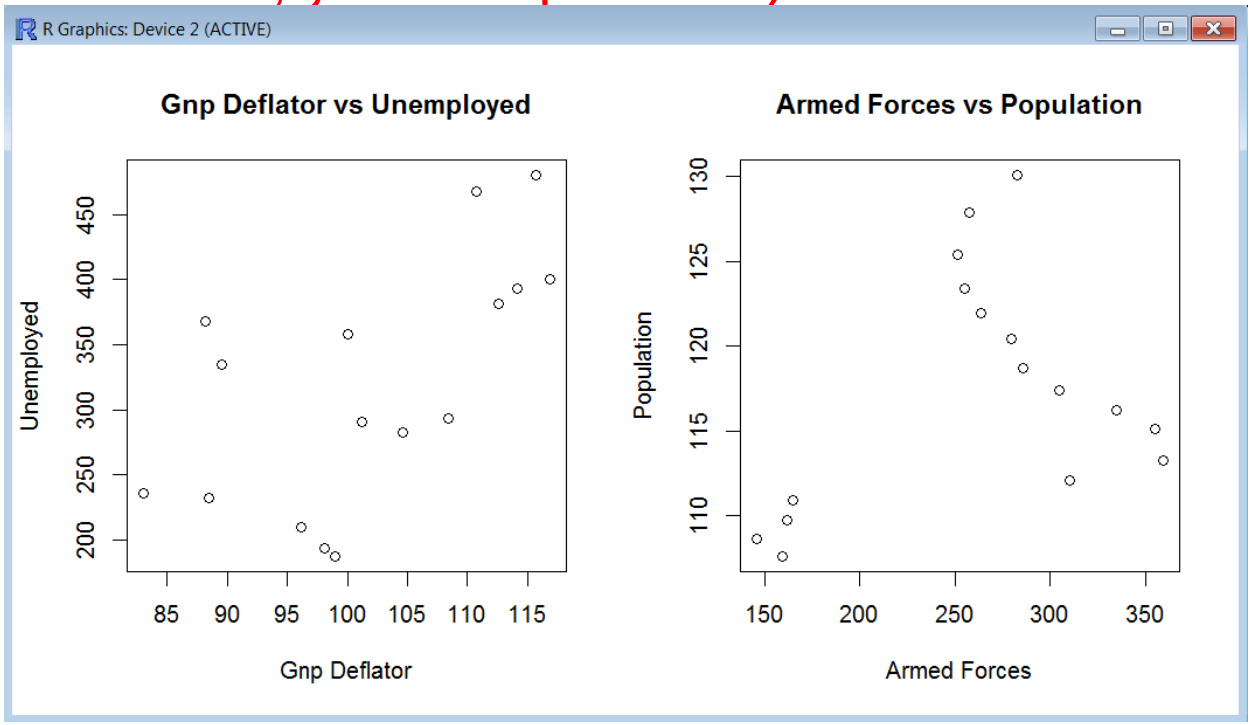
- Set the parameter **mfrow** before calling plot
- *par(mfrow=c("numRows","numCols"))*

```
> ds <- longley
> print(ds)
     GNP.deflator     GNP Unemployed Armed.Forces Population Year Employed
1947         83.0 234.289      235.6        159.0    107.608 1947   60.323
1948         88.5 259.426      232.5        145.6    108.632 1948   61.122
1949         88.2 258.054      368.2        161.6    109.773 1949   60.171
1950         89.5 284.599      335.1        165.0    110.929 1950   61.187
1951         96.2 328.975      209.9        309.9    112.075 1951   63.221
1952         98.1 346.999      193.2        359.4    113.270 1952   63.639
1953         99.0 365.385      187.0        354.7    115.094 1953   64.989
1954        100.0 363.112      357.8        335.0    116.219 1954   63.761
1955        101.2 397.469      290.4        304.8    117.388 1955   66.019
1956        104.6 419.180      282.2        285.7    118.734 1956   67.857
1957        108.4 442.769      293.6        279.8    120.445 1957   68.169
1958        110.8 444.546      468.1        263.7    121.950 1958   66.513
1959        112.6 482.704      381.3        255.2    123.366 1959   68.655
1960        114.2 502.601      393.1        251.4    125.368 1960   69.564
1961        115.7 518.173      480.6        257.2    127.852 1961   69.331
1962        116.9 554.894      400.7        282.7    130.081 1962   70.551
```

Plot together "GNP.Deflator (col 1) vs Unemployed (col 2)" and "Armed. (col 4) vs Pop. (col 5)"?

Graphics – Multiple Plots (2)

```
> par(mfrow=c(1,2))
> plot(ds[,1],ds[,3], main="Gnp Deflator vs Unemployed", xlab="Gnp Deflator", ylab="Unemployed")
> plot(ds[,4],ds[,5], main="Armed Forces vs Population", xlab="Armed Forces", ylab="Population")
```



Data Transformations – lapply, sapply

- Apply a “function” to every element of a “list” or vector
- R strategy against iterations!

```
lst <- lapply(“list”, “function”)          # output is a list
vec <- sapply(“list”, “function”)          # output is a vector
```

```
> funStuff <- c("Beer", "Football", "Love", "Statistics")
> greatify <- function(str){ return ( paste(str,"is great!") ) }
> funStuffGreatified <- sapply(funStuff, greatify)
> print(funStuffGreatified)
```

Beer	Football	Love	Statistics
"Beer is great!"	"Football is great!"	"Love is great!"	"Statistics is great!"

Data Transformation – Matrix apply (1)

- apply("matrix", "1-row or 2-column", "function")
- Example: Compute the product of each row?

```
> M <- matrix(1:16, 4, 4)
> print(M)
     [,1] [,2] [,3] [,4]
[1,]    1    5    9   13
[2,]    2    6   10   14
[3,]    3    7   11   15
[4,]    4    8   12   16
> apply(M, 1, prod)
[1]  585 1680 3465 6144
> 1*5*9*13
[1] 585
```

Data Transformation – Matrix apply (2)

- Compute the factorial of each cell of a matrix!
- “for every column -> for every row element of that column”?

```
> M <- matrix(1:9, 3, 3)
> print(M)
     [,1] [,2] [,3]
[1,]    1    4    7
[2,]    2    5    8
[3,]    3    6    9
> factorial <- function(x) { if(x < 1) return(1) else return( x*factorial(x-1) ) }
> apply(M, 2, function(row){ return( sapply(row,factorial) ) })
     [,1] [,2]   [,3]
[1,]    1   24   5040
[2,]    2  120  40320
[3,]    6  720 362880
```

Data Transformation – Data Frames

- By default a function is applied to columns, which are vectors
- lst <- **lapply**(“matrix”, “function”) # output is list
- vec <- **sapply**(“matrix”, “function”) # output is vector
- Also **apply** can be used for data frames similar to matrices, however the data frame columns must have identical modes/data types