# Tutorial - Big Data Analyses with **R**

## O'Reilly Strata Conference London

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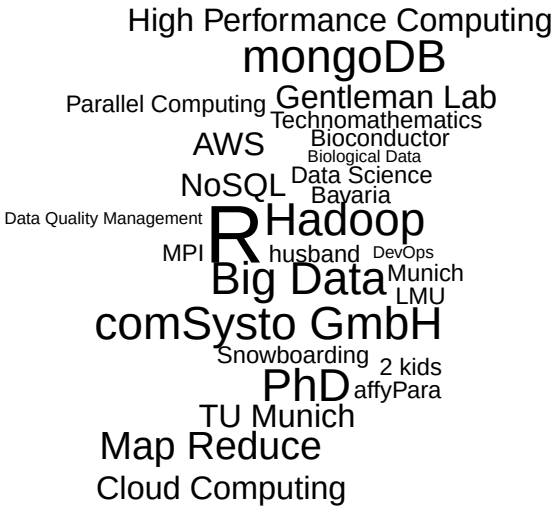
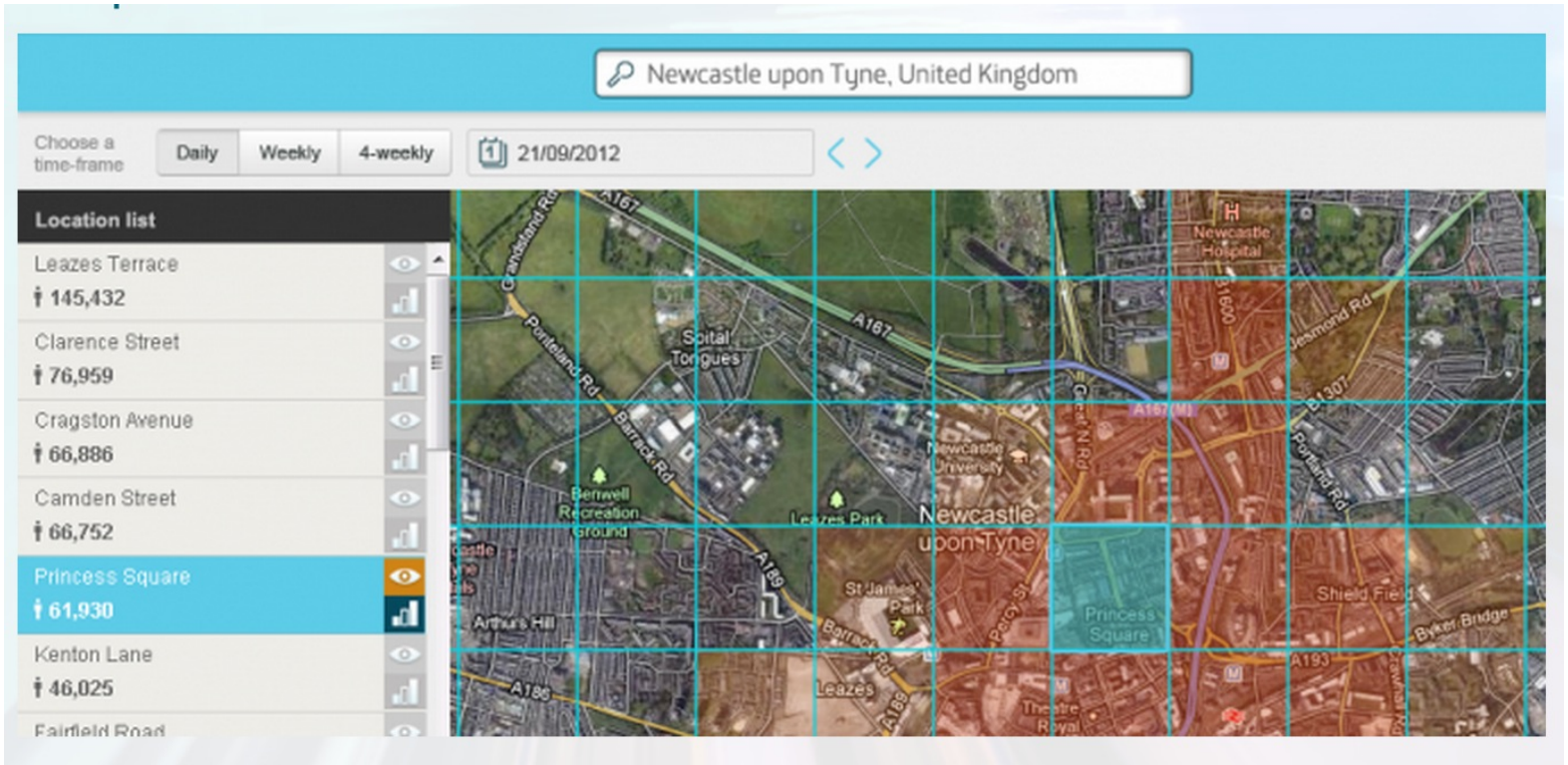



# comSysto GmbH

- based in Munich, Germany
- Lean Company. Great Chances!
- **software company** specialized in lean business, technology development and Big Data
- focuses on **open source frameworks**
- **Meetup organizer** for Munich
  - `http://www.meetup.com/Hadoop-User-Group-Munich/`
  - `http://www.meetup.com/Muenchen-MongoDB-User-Group/`
  - `http://www.meetup.com/munich-useR-group/`
- `http://www.comsysto.com`


# Project: Telefónica Dynamic Insights 'SmartSteps'

"Big decisions made Better"




http://dynamicinsights.telefonica.com/488/smart-steps

# Motivation and Goals

- Today, there exists a lot of data and a huge pool of analyses methods
- **R** is a great tool for your Big Data analyses

- Provide an **overview** of Big Data technologies in **R**
- **Hands-on code** and exercises to get started

# Outline

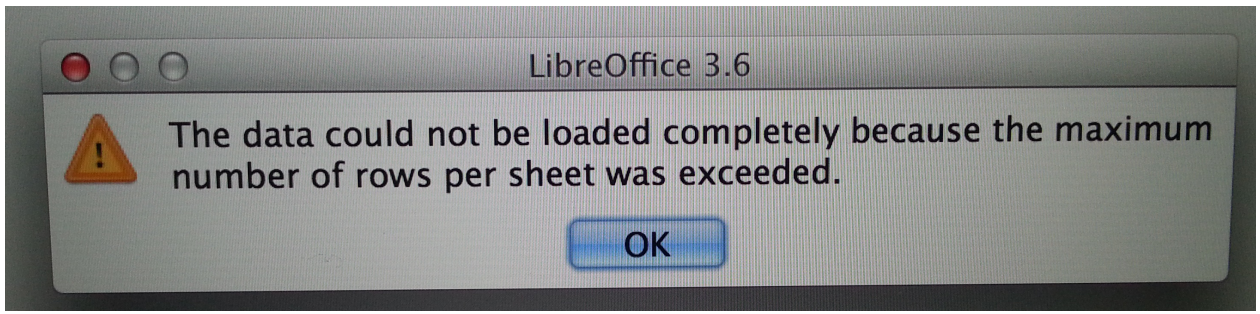


# Outline



# Big Data

- a big hype topic
- everything is big data
- everyone wants to work with big data
- Wikipedia: "... a collection of data sets **so large and complex** that it **becomes difficult** to process using on-hand database management tools or traditional data processing applications ..."




# Big Data

## my view on data

- access to many different data sources (Internet)
- storage is cheep - store everything
- today, CIOs get interested in the power of all their data
- $\Rightarrow$ a lot of different and **complex data** have to be stored
- $\Rightarrow$ **NoSQL**

# NoSQL - MongoDB

- NoSQL: databases with less constrained consistency models $\Rightarrow$ **schema-less**
- **MongoDB**:
  - open source, cross-platform document-oriented database system
  - most popular NoSQL database system
  - supported MongoDB Inc.
  - stores structured data as JSON-like documents with dynamic schemas
  - **MongoDB as a German / European Service**


`http://www.mongodb.org` `http://www.mongosoup.de`

# Big Data

## my view on processing

- more and more data have to be processed
- backward-looking analysis is outdated
- today, we are working on quasi real-time analysis
- but, CIOs are interested in **forward-looking predictive analysis**
- $\Rightarrow$ more **complex methods**, more processing time
- $\Rightarrow$ **Hadoop**, Super Computer and statistical tools

# Hadoop

- open-source software framework designed to support large scale data processing
- **Map Reduce**: a computational paradigm
  - application is divided into many small fragments of work
- **HDFS**: Hadoop Distributed File System
  - a distributed file system that stores data on the compute nodes
- **the Ecosystem**: Hive, Pig, Flume, Mahout, ...
- written in Java, opened up to alternatives by its Streaming API


`http://hadoop.apache.org`

# Big Data

## my view on resources

- computing resources are available to everyone and cheep
- man-power is expensive and it is difficult to hire Big Data experts
  - Java Programmer: good programming - bad statistical background
  - Statistician: good methodology - bad programming and database knowledge
  - Big Data Analyst: ?? - **skills shortage** or 'Fachkräftemangel'
- $\Rightarrow$ welcome to the **'Tutorial - R and Big Data'** to solve this problem

# Outline



# www.r-project.org

- open-source: **R** is a free software environment for statistical computing and graphics
- offers tools to **manage and analyze data**
- standard and many more **statistical methods** are implemented
- support via the **R** mailing list by members of the core team
  - **R**-announce, **R**-packages, **R**-help, **R**-devel, ...
  - `http://www.r-project.org/mail.html`
- support via several manuals and books:
  - `http://www.r-project.org/doc/bib/R-books.html`
  - `http://cran.r-project.org/manuals.html`

- huge online-libraries with **R**-packages:
  - CRAN: `http://cran.r-project.org/`
  - BioConductor (genomic data): `http://www.bioconductor.org/`
  - Omegahat: `http://www.omegahat.org/`
  - **R**-Forge: `http://r-forge.r-project.org/`
- possibility to **write personalized code** and to contribute new **packages**
- really famous since January 6, 2009: The New York Times, "Data Analysts Captivated by **R**'s Power"


# **R** vs. SAS vs. Julia vs. Pythong vs. ...

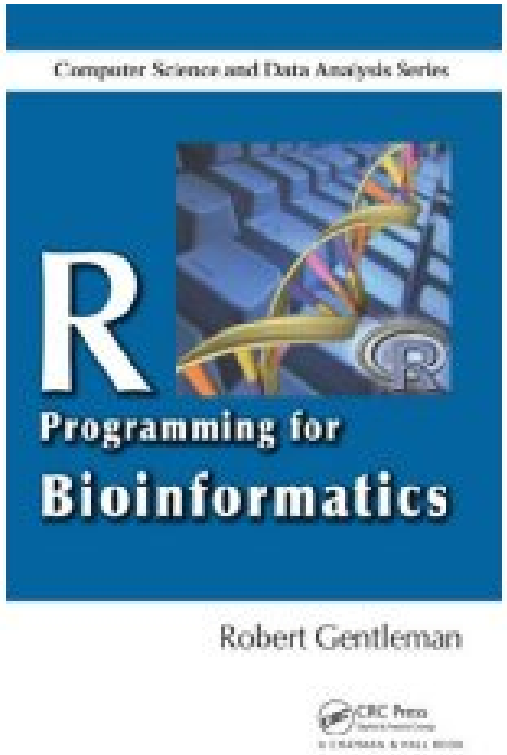
**R** is open source, SAS is a commercial product, Julia a very new dynamic programming language, ...

- **R** is free and available to everyone
- **R** code is open source and can be modified by everyone
- **R** is a complete and enclosed programming language
- **R** has a **big and active community**

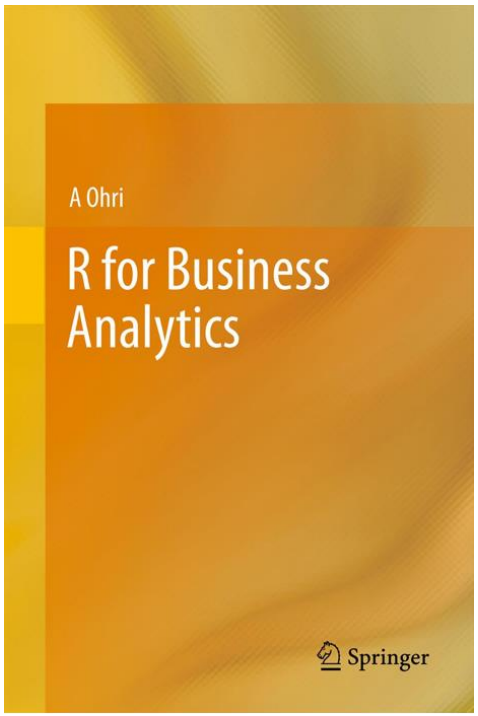




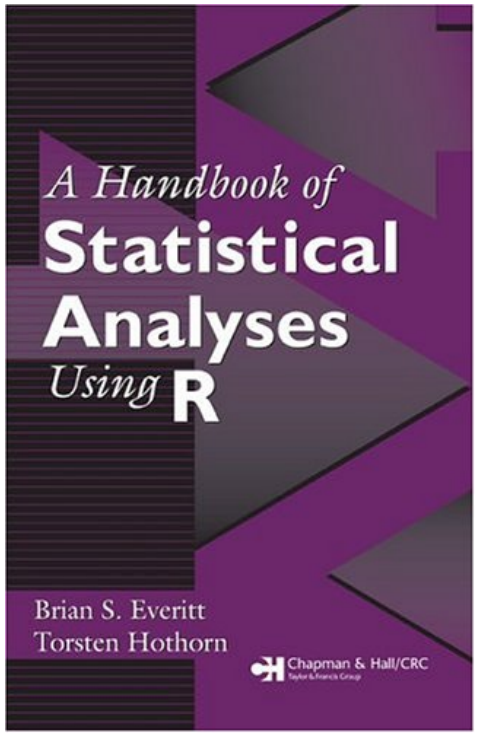
# R books


Computer Science and Data Analysis Series
R
Programming for
Bioinformatics
Robert Gentleman
CRC Press

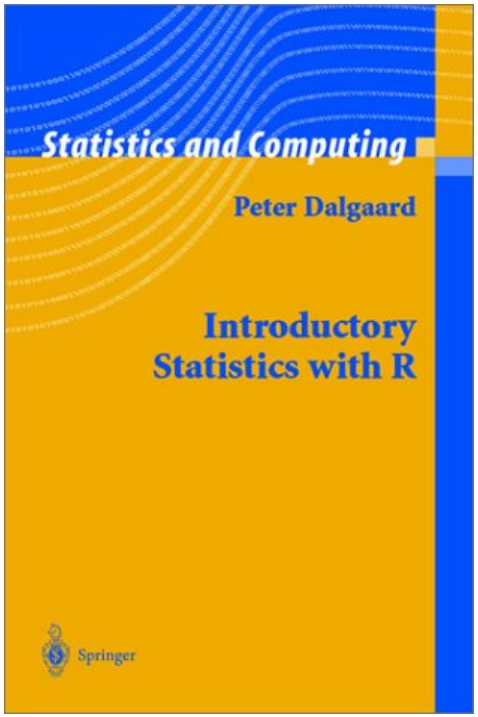
(a)


A Ohri
R for Business
Analytics
Springer

(b)


A Handbook of
Statistical
Analyses
Using R
Brian S. Everitt
Torsten Hothorn
Chapman & Hall/CRC

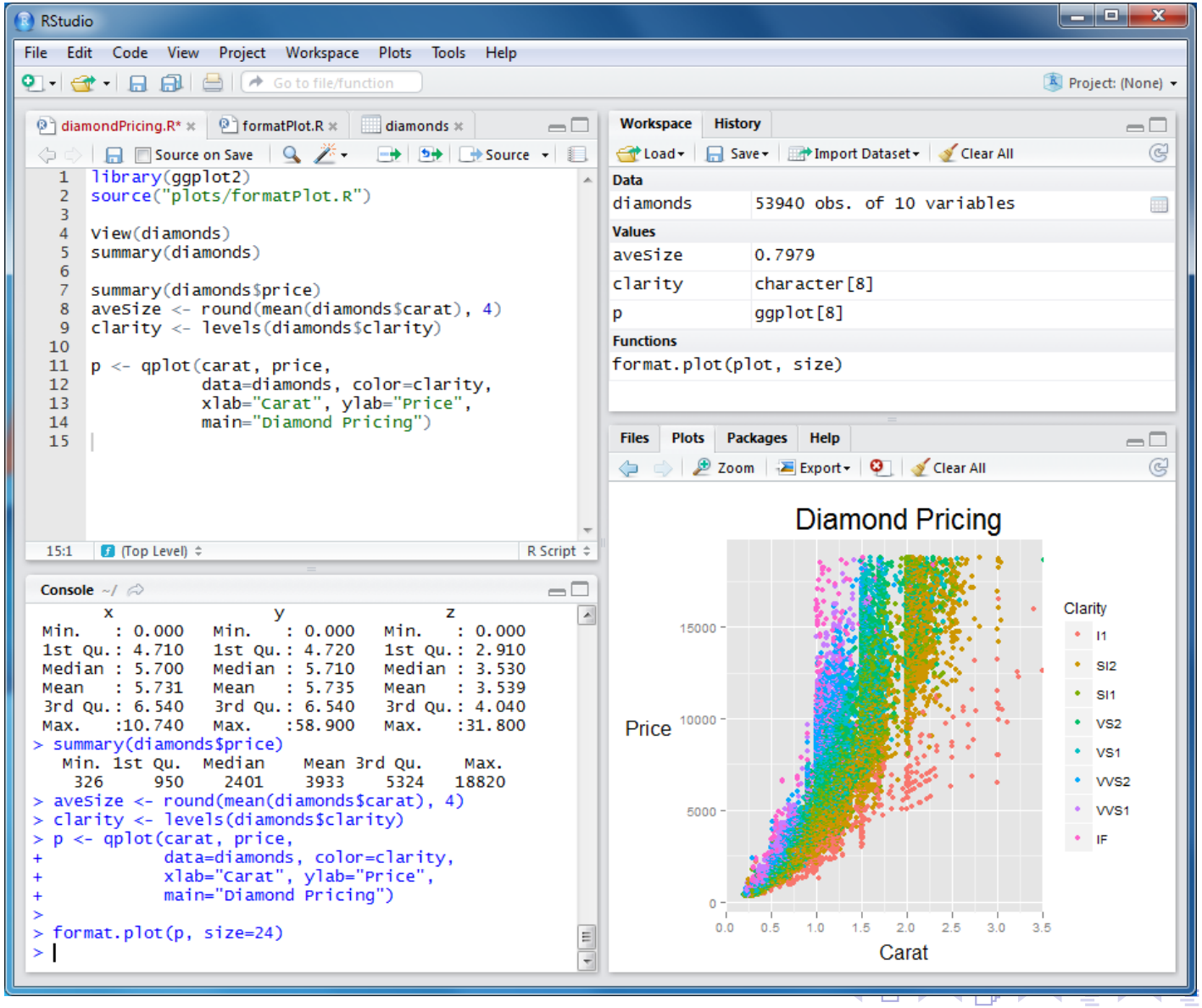
(c)

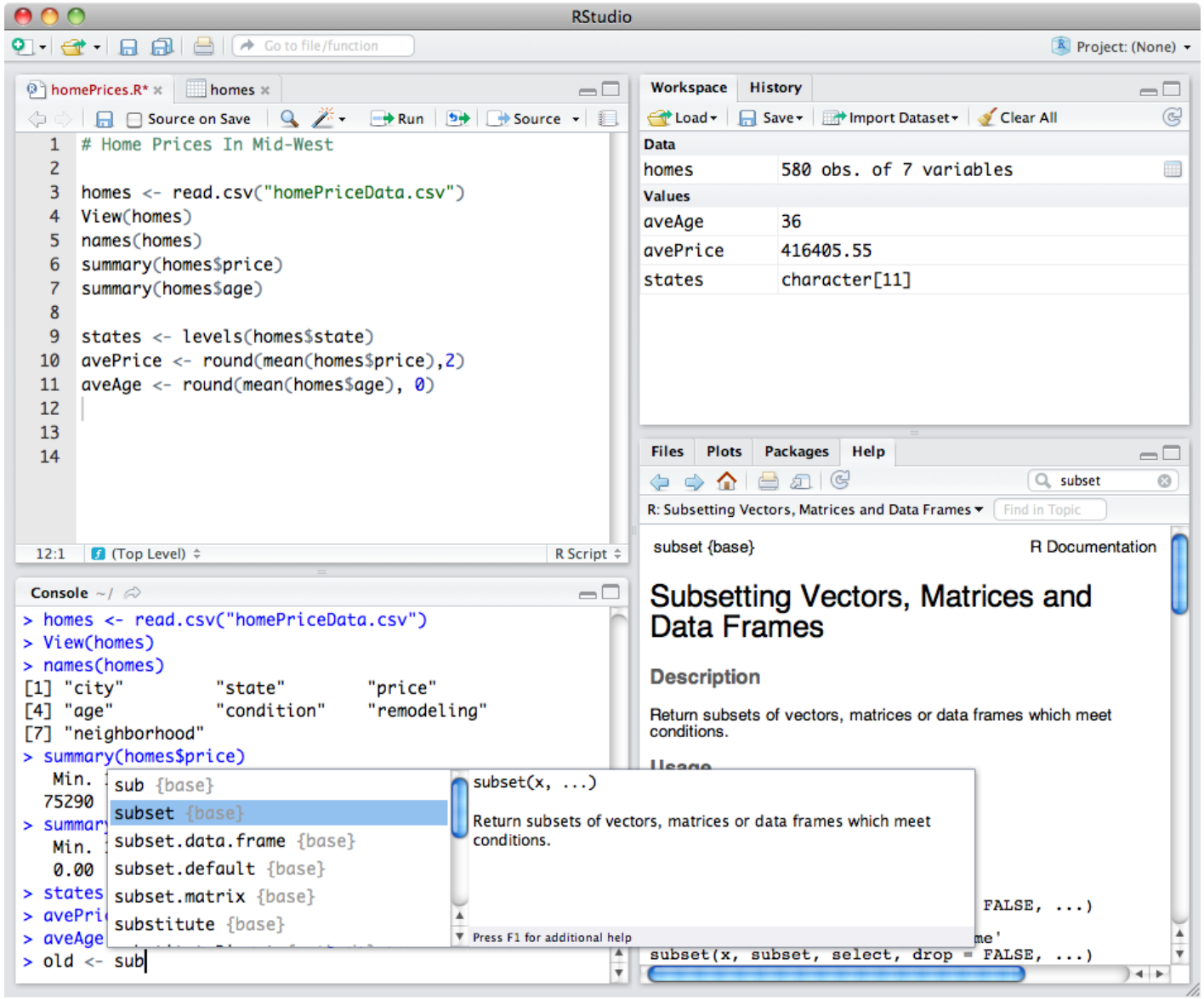

Statistics and Computing
Peter Dalgaard
Introductory
Statistics with R
Springer

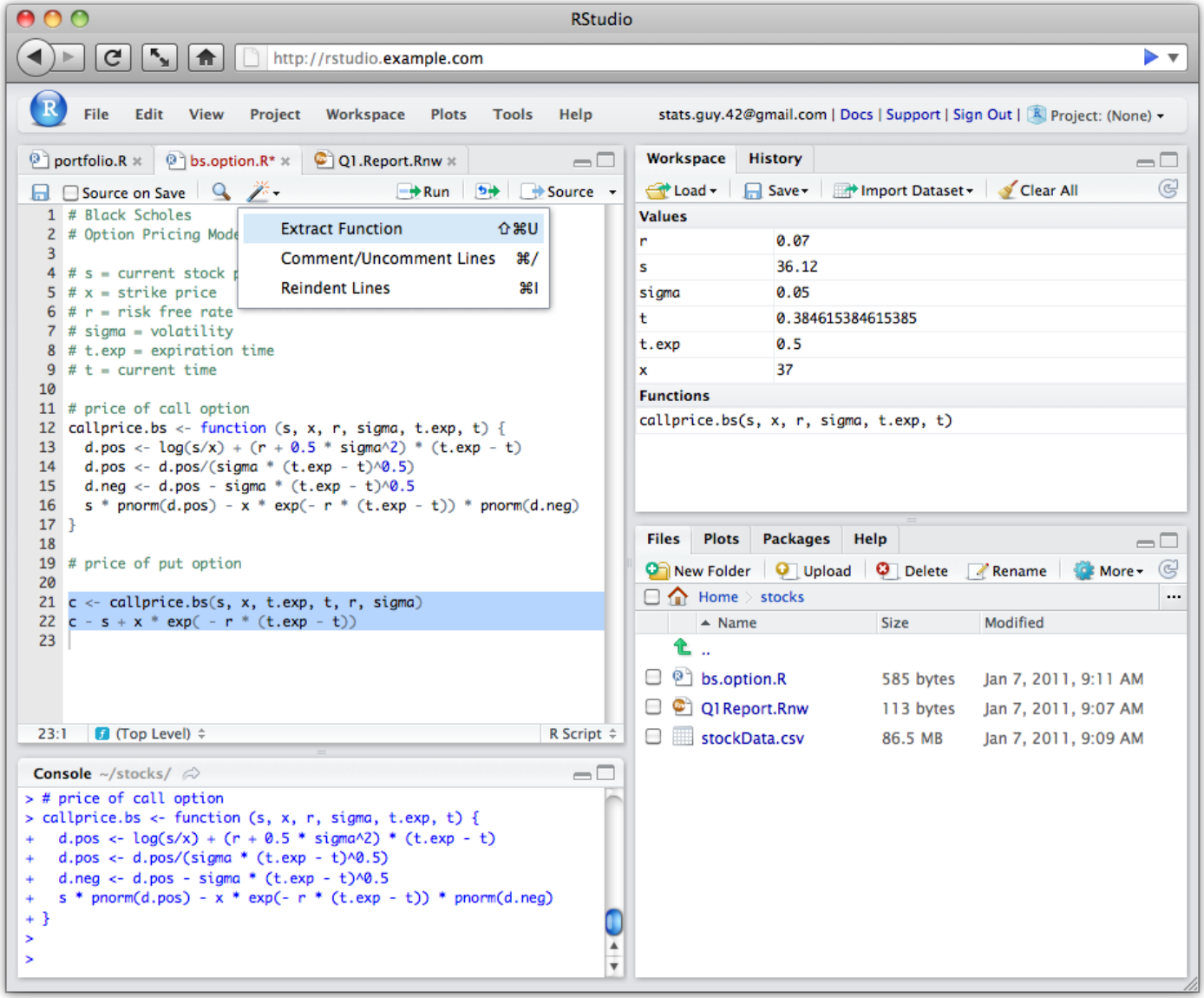
(d)

# RStudio IDE

http://www.rstudio.com




RStudio
Go to file/function
Project: (None)
homePrices.R*
homes
Source on Save
Run
Source
1 # Home Prices In Mid-West
2
3 homes <- read.csv("homePriceData.csv")
4 View(homes)
5 names(homes)
6 summary(homes$price)
7 summary(homes$age)
8
9 states <- levels(homes$state)
10 avePrice <- round(mean(homes$price),2)
11 aveAge <- round(mean(homes$age), 0)
12
13
14
12:1
(Top Level)
R Script
Workspace
History
Load
Save
Import Dataset
Clear All
Data
homes 580 obs. of 7 variables
Values
aveAge 36
avePrice 416405.55
states character[11]
Files
Plots
Packages
Help
subset
R: Subsetting Vectors, Matrices and Data Frames
Find in Topic
subset {base}
R Documentation
Subsetting Vectors, Matrices and Data Frames
Description
Return subsets of vectors, matrices or data frames which meet conditions.
Console ~/
> homes <- read.csv("homePriceData.csv")
> View(homes)
> names(homes)
[1] "city" "state" "price"
[4] "age" "condition" "remodeling"
[7] "neighborhood"
> summary(homes$price)
Min.
75290
> summar
Min.
0.00
> states
> avePri
> aveAge
> old <- sub
sub {base}
subset {base}
subset.data.frame {base}
subset.default {base}
subset.matrix {base}
substitute {base}
subset(x, ...)
Return subsets of vectors, matrices or data frames which meet conditions.
Press F1 for additional help
FALSE, ...)
me'
subset(x, subset, select, drop = FALSE, ...)


RStudio
http://rstudio.example.com
File Edit View Project Workspace Plots Tools Help
stats.guy.42@gmail.com | Docs | Support | Sign Out | Project: (None)
portfolio.R
bs.option.R*
Q1.Report.Rnw
Source on Save
Run
Source
Extract Function ⇧⌘U
Comment/Uncomment Lines ⌘/
Reindent Lines ⌘I
1 # Black Scholes
2 # Option Pricing Mode
3
4 # s = current stock p
5 # x = strike price
6 # r = risk free rate
7 # sigma = volatility
8 # t.exp = expiration time
9 # t = current time
10
11 # price of call option
12 callprice.bs <- function (s, x, r, sigma, t.exp, t) {
13 d.pos <- log(s/x) + (r + 0.5 * sigma^2) * (t.exp - t)
14 d.pos <- d.pos/(sigma * (t.exp - t)^0.5)
15 d.neg <- d.pos - sigma * (t.exp - t)^0.5
16 s * pnorm(d.pos) - x * exp(- r * (t.exp - t)) * pnorm(d.neg)
17 }
18
19 # price of put option
20
21 c <- callprice.bs(s, x, t.exp, t, r, sigma)
22 c - s + x * exp( - r * (t.exp - t))
23
23:1 (Top Level) R Script
Console ~/stocks/
> # price of call option
> callprice.bs <- function (s, x, r, sigma, t.exp, t) {
+ d.pos <- log(s/x) + (r + 0.5 * sigma^2) * (t.exp - t)
+ d.pos <- d.pos/(sigma * (t.exp - t)^0.5)
+ d.neg <- d.pos - sigma * (t.exp - t)^0.5
+ s * pnorm(d.pos) - x * exp(- r * (t.exp - t)) * pnorm(d.neg)
+ }
>
>
Workspace History
Load Save Import Dataset Clear All
Values
r 0.07
s 36.12
sigma 0.05
t 0.384615384615385
t.exp 0.5
x 37
Functions
callprice.bs(s, x, r, sigma, t.exp, t)
Files Plots Packages Help
New Folder Upload Delete Rename More
Home stocks
Name Size Modified
..
bs.option.R 585 bytes Jan 7, 2011, 9:11 AM
Q1Report.Rnw 113 bytes Jan 7, 2011, 9:07 AM
stockData.csv 86.5 MB Jan 7, 2011, 9:09 AM

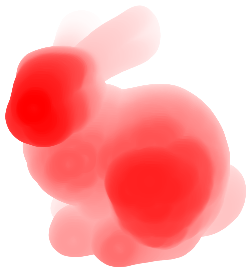
# R as Calculator

```
>  (5+5) - 1 * 3
[1] 7
>  abs(-5)
[1] 5
>  x <- 3
>  x
[1] 3
>  x^2 + 4
[1] 13
```

```
> help("mean")
> ?mean

> x <- 1:10
> x
 [1]  1  2  3  4  5  6  7  8  9 10

> x < 5
 [1]  TRUE  TRUE  TRUE  TRUE FALSE FALSE FALSE FALSE FALSE FAI

> x[3:7]
[1] 3 4 5 6 7

> x[-2]
[1]  1  3  4  5  6  7  8  9 10
```

# load packages and data

```
> # install.packages("onion")
> library(onion)
> data(bunny)
> head(bunny, n=3)
                x         y           z
[1,] -0.0378297 0.127940 0.00447467
[2,] -0.0447794 0.128887 0.00190497
[3,] -0.0680095 0.151244 0.03719530
> p3d(bunny,theta=3,phi=104,box=FALSE)
```



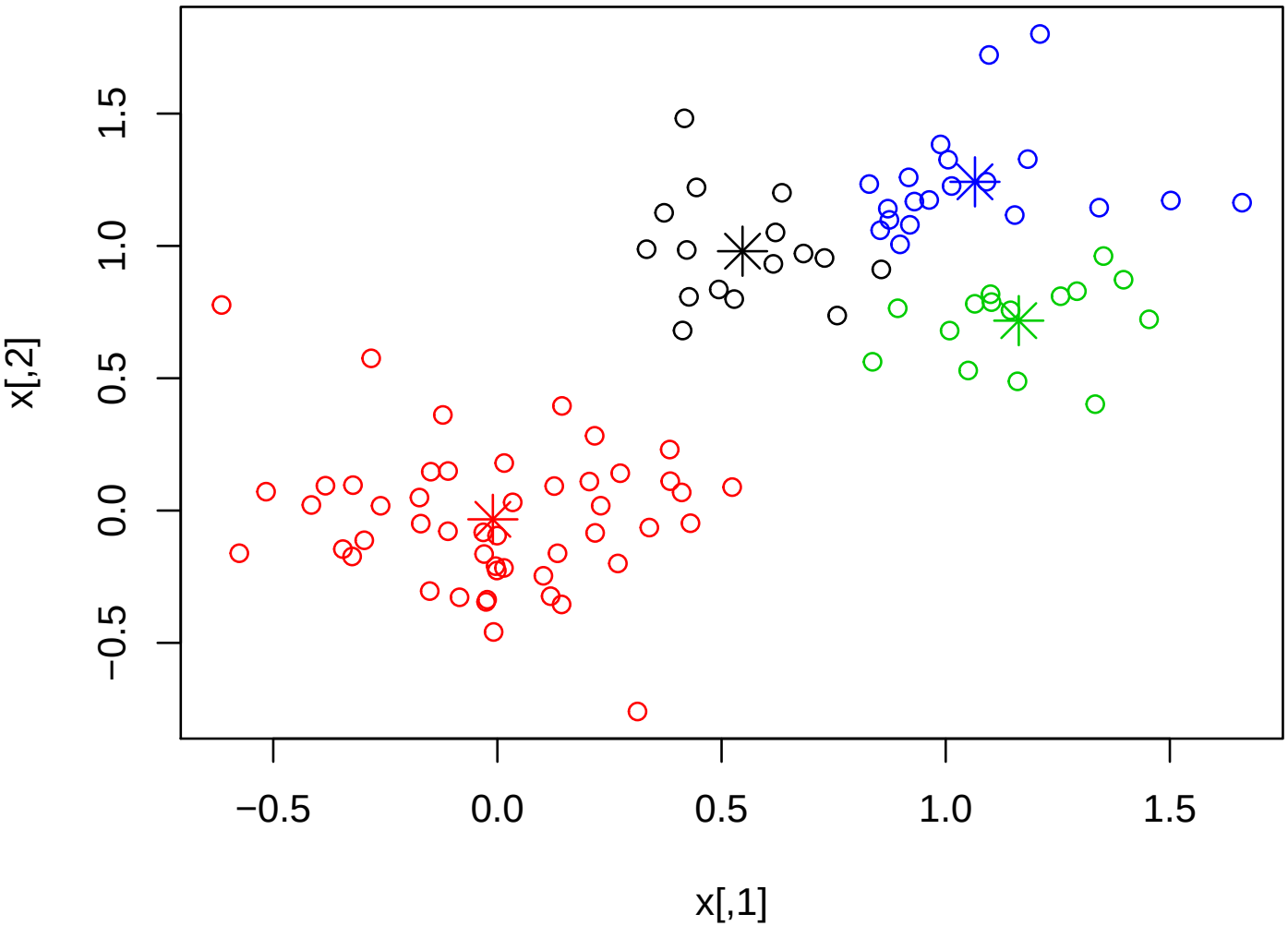
# functions

```
> myfun <- function(x,y){
+   res <- x+y^2
+   return(res)
+ }
> myfun(2,3)

[1] 11

> myfun

function(x,y){
  res <- x+y^2
  return(res)
}
```

# many statistical functions, e.g. k-means clustering

```
> x <- rbind(matrix(rnorm(100, sd = 0.3), ncol = 2),
+            matrix(rnorm(100, mean = 1, sd = 0.3), ncol = 2))
> head(x, n=3)
            [,1]       [,2]
[1,] -0.15097039 -0.3043468
[2,]  0.01462622 -0.2168538
[3,]  0.14398056  0.3953751
> dim(x)
[1] 100   2
> cl <- kmeans(x, 4)
> cl
K-means clustering with 4 clusters of sizes 16, 49, 15, 20

Cluster means:
         [,1]         [,2]
1  0.54676699  0.98002268
2  0.01015640  0.02316055
```

```
> plot(x, col = cl$cluster)
> points(cl$centers, col = 1:4, pch = 8, cex = 2)
```




# data types

**vector**: all elements same data type

```
> vector <- c(1,2,5.3,6,-2,4)
> vector
```

```
[1]  1.0  2.0  5.3  6.0 -2.0  4.0
```

**matrix**: all elements same data type

```
> matrix <- matrix(LETTERS[c(19,20,18,1,20,1)],
+                  nrow=2, ncol=3)
> matrix
```

```
     [,1] [,2] [,3]
[1,] "S"  "R"  "T"
[2,] "T"  "A"  "A"
```

**data frame**: different columns can have different data types

```
> vector2 <- c("red", "white", "red", NA, "blue", "orange")
> vector3 <- c(TRUE,TRUE,TRUE,FALSE,TRUE,FALSE)
> dataframe <- data.frame(vector,vector2,vector3)
> dataframe
```

```
  vector vector2 vector3
1    1.0     red    TRUE
2    2.0   white    TRUE
3    5.3     red    TRUE
4    6.0    <NA>   FALSE
5   -2.0    blue    TRUE
6    4.0  orange   FALSE
```

```
> typeof(dataframe)
```

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

**list**: ordered collection of elements

```
> mylist <- list(name="Fred", numbers=vector,
+                    matrix=matrix, age=5.3)
> mylist
```

```
$name
[1] "Fred"

$numbers
[1]  1.0  2.0  5.3  6.0 -2.0  4.0

$matrix
     [,1] [,2] [,3]
[1,] "S"  "R"  "T"
[2,] "T"  "A"  "A"

$age
[1] 5.3
```

# Package: **data.table**

- **extension of data.frame** for fast indexing, fast ordered joins, fast assignment, fast grouping and list columns

```
> library(data.table)
> datatable <- data.table(vector,vector2,vector3)
> datatable
```

```
   vector vector2 vector3
1:    1.0     red    TRUE
2:    2.0   white    TRUE
3:    5.3     red    TRUE
4:    6.0      NA   FALSE
5:   -2.0    blue    TRUE
6:    4.0  orange   FALSE
```

```
> datatable[2]

   vector vector2 vector3
1:      2   white    TRUE

> datatable[,vector]

[1]  1.0  2.0  5.3  6.0 -2.0  4.0

> datatable[,sum(vector),by=vector3]

   vector3   V1
1:    TRUE  6.3
2:   FALSE 10.0

> setkey(datatable,vector2)
> datatable["orange"]

   vector2 vector vector3
1:  orange      4   FALSE
```

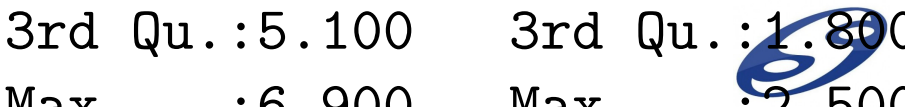
# Package: **plyr**

- **tools** for splitting, applying and combining data
- functions are named according to what sort of data structure used (a, l, d, m)
- provides a set of **helper** functions for common **data analysis**

```
> library(plyr)
> data(iris)
> count(iris, vars="Species")
```

```
     Species freq
1     setosa   50
2 versicolor   50
3  virginica   50
```

```
> head(iris, n=3)
  Sepal.Length Sepal.Width Petal.Length Petal.Width Species
1          5.1         3.5          1.4         0.2  setosa
2          4.9         3.0          1.4         0.2  setosa
3          4.7         3.2          1.3         0.2  setosa
> is.data.frame(iris)
[1] TRUE
> dim(iris)
[1] 150   5
> summary(iris)
  Sepal.Length    Sepal.Width     Petal.Length    Petal.Width
 Min.   :4.300   Min.   :2.000   Min.   :1.000   Min.   :0.100
 1st Qu.:5.100   1st Qu.:2.800   1st Qu.:1.600   1st Qu.:0.300
 Median :5.800   Median :3.000   Median :4.350   Median :1.300
 Mean   :5.843   Mean   :3.057   Mean   :3.758   Mean   :1.199
 3rd Qu.:6.400   3rd Qu.:3.300   3rd Qu.:5.100   3rd Qu.:1.800
 Max.   :7.900   Max.   :4.400   Max.   :6.900   Max.   :2.500
       Species
```



```
> summarise(iris, mean_petal_length=mean(Petal.Length),
+           max_petal_length=max(Sepal.Length))

  mean_petal_length max_petal_length
1             3.758              7.9

> ddply(iris, .(Species), summarise,
+       mean_petal_length=mean(Petal.Length),
+       max_petal_length=max(Sepal.Length))

     Species mean_petal_length max_petal_length
1     setosa             1.462              5.8
2 versicolor             4.260              7.0
3  virginica             5.552              7.9

> daply(iris[,c(1,2,5)], .(Species), colwise(mean))

Species      Sepal.Length Sepal.Width
  setosa     5.006        3.428
  versicolor 5.936        2.77
  virginica  6.588        2.974
```

# Package: **RJSONIO**

- Serialize **R** objects **to and from JSON**

```
> library(RJSONIO)
> json <- toJSON(list(a=c(1,2,3), name="Markus"))
> cat(json)

{
 "a": [      1,      2,      3 ],
"name": "Markus"
}

> robj <- fromJSON(json)
> robj

$a
[1] 1 2 3


$name
[1] "Markus"
```

# Package: **bigmemory** and **big...**

- http://www.bigmemory.org/
- manage massive matrices with **shared memory and memory-mapped files**

```
> library(bigmemory)
> x <- rbind(matrix(rnorm(100, sd = 0.3), ncol = 2),
+            matrix(rnorm(100, mean = 1, sd = 0.3), ncol = 2))
> dim(x)

[1] 100   2

> bigmatrix <- as.big.matrix(x)
> bigmatrix[1:3,]

             [,1]       [,2]
[1,] -0.10500752  0.1020906
[2,]  0.44259378  0.1069441
[3,]  0.01187035 -0.1730431
```

```
> library(biganalytics)
> require(foreach)
> res <- bigkmeans(bigmatrix, 3)
> res
K-means clustering with 3 clusters of sizes 35, 22, 43

Cluster means:
             [,1]        [,2]
[1,]  1.22053252 1.062299708
[2,]  0.59426347 0.707238489
[3,] -0.03341732 0.008253787

Clustering vector:
  [1] 3 3 3 3 3 2 3 3 3 3 3 3 3 3 2 2 3 3 3 3 2 3 3 3 3 2 3 3
 [38] 3 3 3 3 3 3 3 2 3 3 3 3 3 1 2 2 1 1 1 1 2 1 1 1 2 1 1 2
 [75] 1 2 2 2 1 1 1 1 1 2 1 1 2 1 1 1 1 1 2 1 1 1 2 1 2 1

Within cluster sum of squares by cluster:
[1] 3.954684 2.812699 7.952937
```

# Package: **parallel**

- first version was released with **R** 2.14.0
- contains functionality derived from and pretty much equivalent to the **multicore** and **snow** packages

```
> x <- list(a = 1:10, b = exp(-3:3))
> lapply(x, mean)

$a
[1] 5.5

$b
[1] 4.535125
```

```
> library(parallel)
> cl <- makeCluster(2)
> parLapply(cl, x, mean)

$a
[1] 5.5

$b
[1] 4.535125

> stopCluster(cl)

> mclapply(x, mean)

$a
[1] 5.5

$b
[1] 4.535125
```

# Package: **Rcpp**

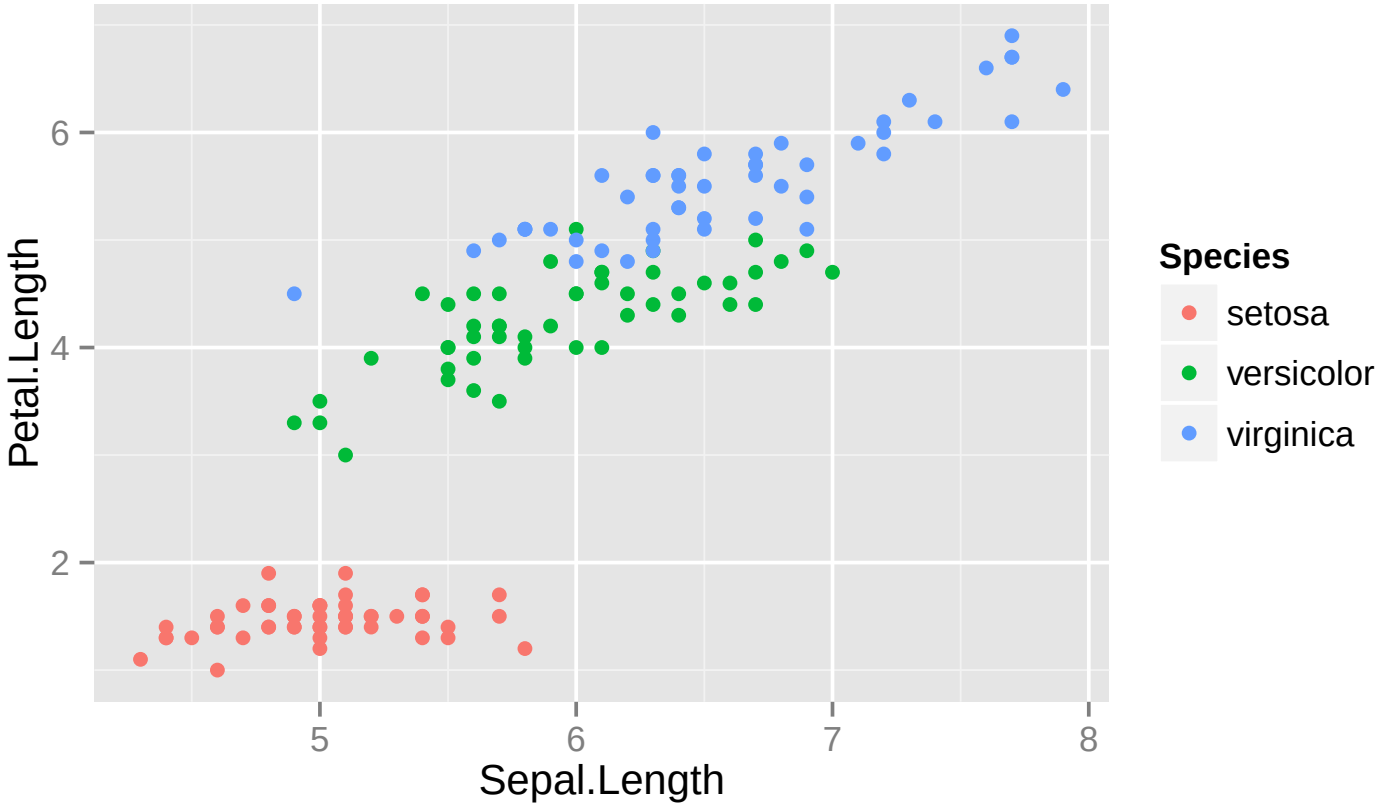
- provides a clean, approachable API that lets you **write high-performance code**
- can help with loops, recursive functions and functions with advanced data structures
- lead to a **2-3** order of magnitude speed up

```
> library(Rcpp)
> cppFunction('
+   int add(int x, int y, int z) {
+     int sum = x + y + z;
+     return sum;
+   }'
+ )
> add
function (x, y, z)
.Primitive(".Call")(<pointer: 0x1012bed80>, x, y, z)
> add(1, 2, 3)
[1] 6
```

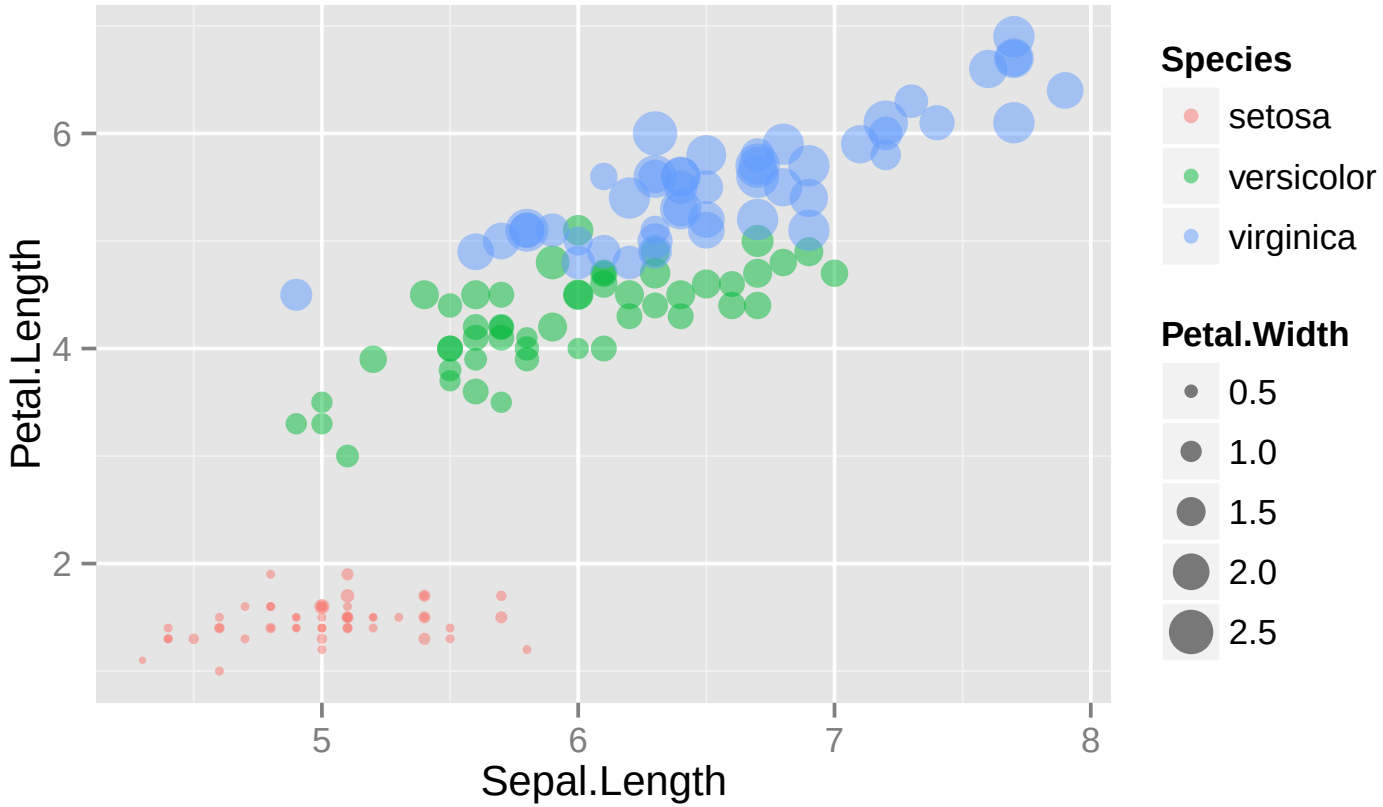
# Package: **ggplot2**

- useful for producing **complex graphics relatively simply**
- an implementation of the **Grammar of Graphics book** by Liland Wilkinson
  - the basic notion is that there is a **grammar to the composition of graphical components** in statistical graphics
  - by directly controlling that grammar, you can generate a large set of carefully constructed graphics from a relatively small set of operations
  - "A good grammar will allow us to gain insight into the composition of complicated graphics, and reveal unexpected connections between seemingly different graphics."

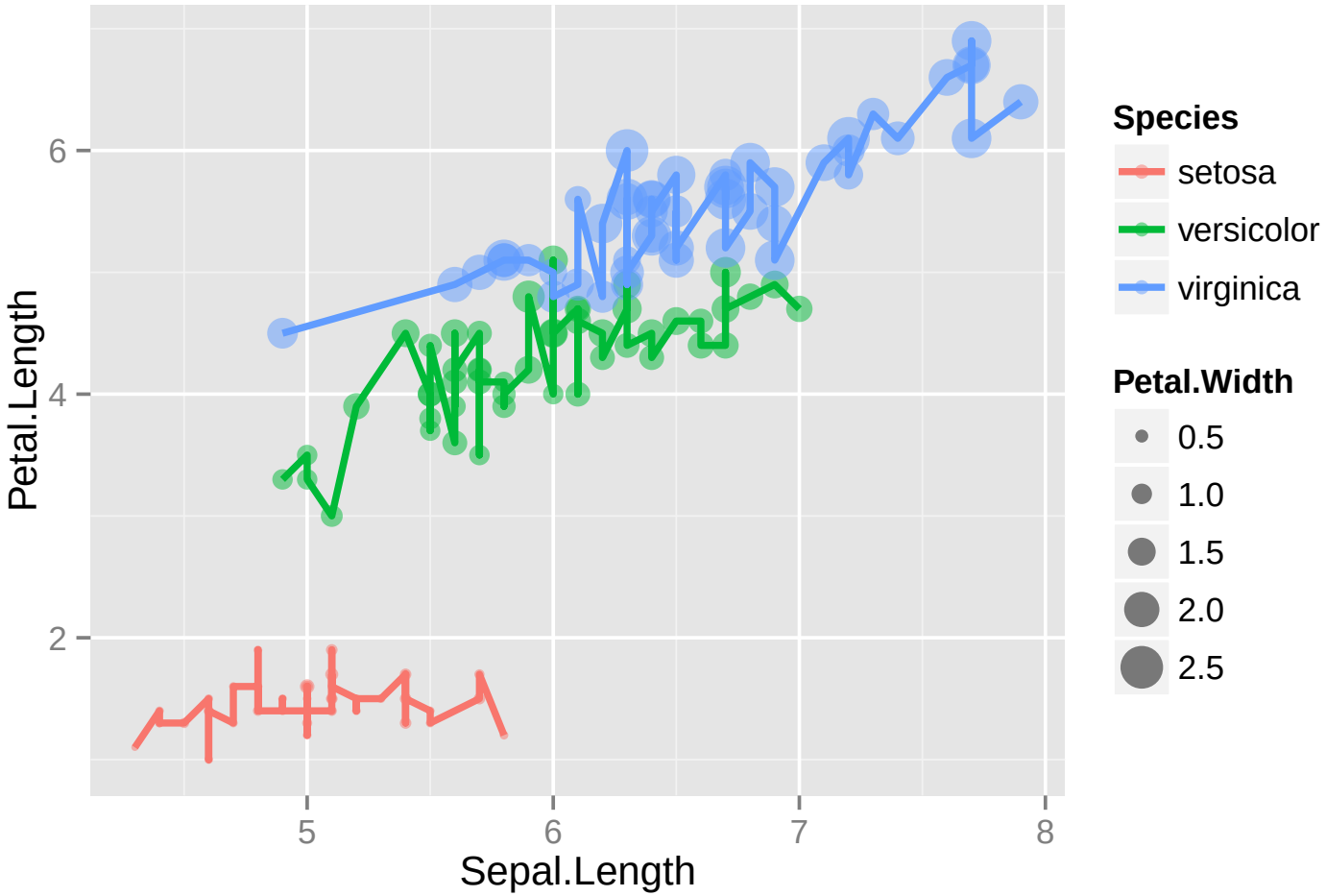
```
> library(ggplot2)
> qplot(Sepal.Length, Petal.Length, data = iris,
+       color = Species)
```



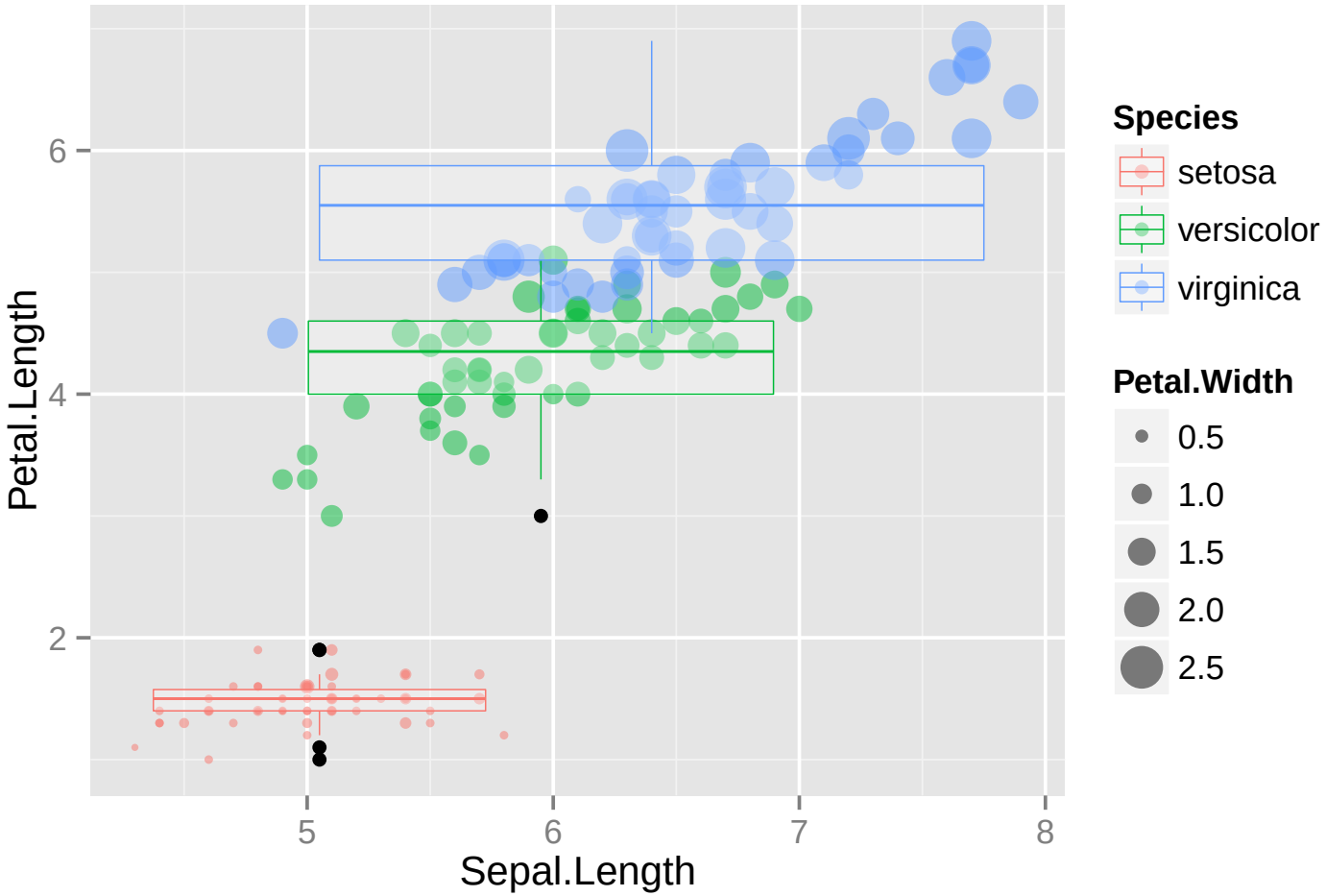

```
> res <- qplot(Sepal.Length, Petal.Length, data = iris,
+         color = Species, size = Petal.Width, alpha = I(0.5))
> res
```




```
> res + geom_line(size=1)
```




```
> res + geom_boxplot(size=0.2, alpha=I(0.3))
```




# Shiny - easy web application

- developed by **RStudio**
- turn analyses into **interactive web applications** that anyone can use
- let your users choose input parameters using friendly controls like sliders, drop-downs, and text fields
- easily incorporate any number of outputs like plots, tables, and summaries
- **no** HTML or JavaScript knowledge is necessary, **only R**

`http://www.rstudio.com/shiny/`

# Shiny - Server

- node.js based application to **host** Shiny Apps on web server
- developed by **RStudio**
- hosted beta service by RStudio: `https://rstudio.wufoo.com/forms/shiny-server-beta-program/`
- **RApache** package provides similar functionality to host and execute **R** code
- **RApache** more difficult to use, but more flexibility

# Hello World Shiny

- a simple application that generates a random distribution with a configurable number of observations and then plots it

```
> library(shiny)
> runExample("01_hello")
```

- Shiny applications have **two components**:
  - a user-interface definition: ui.R
  - a server script: server.R
- For more documentation check the tutorial:
  `http://rstudio.github.io/shiny/tutorial`

# Package: **bigvis**

- tools for exploratory data analysis of large data sets

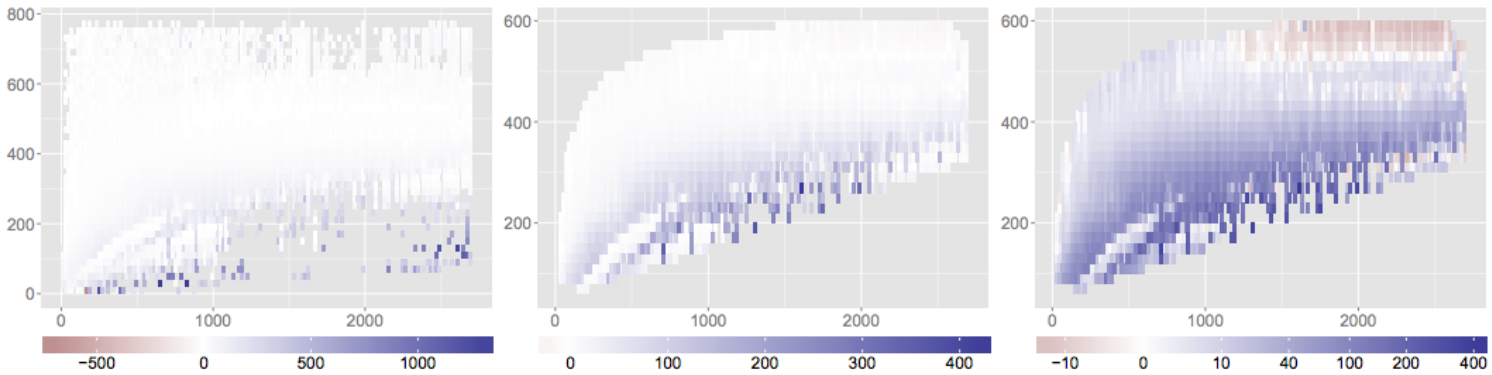



Fig. 1. Average delay (colour, in minutes) as a function of distance (x axis, in miles) and speed (y axis, in mph) for 76 million flights. The initial view (left) needs refinement to be useful: first we focus on the middle 99.5% of the data (centre) then transform average delay to shrink the impact of unusually high delays and focus on typical values (right). Flights with higher than average speeds (top-right) have shorter delays (red); more interestingly, a subset of shorter, slower flights (bottom-left) have average delays very close to 0 (white).

# Outline



# R and Databases

## Starting relational

- SQL provides a **standard language** to filter, aggregate, group, sort data
- SQL-like query languages showing up in new places (Hadoop Hive, Impala, ...)
- ODBC provides SQL interface to non-database data (Excel, CSV, text files)

- **R** stores relational data **in data frames**

# Package **sqldf**

- **sqldf** is an **R** package for **running SQL statements** on **R** data frames
- SQL statements in **R** using "data frame names" in place of "table names"
- a database with appropriate table layouts/schema is **automatically created**, the data frames are automatically loaded into the database
- the result is read back into **R**
- **sqldf** supports the SQLite back-end database (by default), the H2 java database, the PostgreSQL database and MySQL

```
> library(sqldf)
> sqldf("select * from iris limit 2")
  Sepal_Length Sepal_Width Petal_Length Petal_Width Species
1          5.1         3.5          1.4         0.2  setosa
2          4.9         3.0          1.4         0.2  setosa
> sqldf("select count(*) from iris")
  count(*)
1      150
> sqldf("select Species, count(*) from iris group by Species")
     Species count(*)
1     setosa       50
2 versicolor       50
3  virginica       50
```

```
> sqldf("select Species, avg(Sepal_Length) 'mean Sepal_Length'
+       variance(Sepal_Width) 'var Sepal_Width'
+       from iris group by Species")
     Species mean Sepal_Length var Sepal_Width
1     setosa              5.006      0.14368980
2 versicolor              5.936      0.09846939
3  virginica              6.588      0.10400408
```

# Other relational package

- **RMySQL** package provides an interface to MySQL.
- **RPostgreSQL** package provides an interface to PostgreSQL.
- **ROracle** package provides an interface for Oracle.
- **RJDBC** package provides access to databases through a JDBC interface.
- **RSQLite** package provides access to SQLite. The source for the SQLite engine is included.

**One big problem:**

- all packages **read the full result in R memory**
- with Big Data this will fail

# **R** and MongoDB

- on CRAN there are two packages to connect **R** with MongoDB
  - **rmongodb** supported by MongoDB Inc.
    - ★ powerful for big data
    - ★ ~~difficult to use due to BSON objects~~
  - **RMongo**
    - ★ is very similar to all the relational packages
    - ★ easy to use
    - ★ limited functionality
    - ★ reads full results in **R** memory
    - ★ difficult to install on MAC OS X

# Package: **RMongo**

- uses a **R** to Java bridge and the Java MongoDB driver

```
> library(RMongo)
> Sys.setenv(NOAWT=1) # for MAC OS X
> mongo <- mongoDbConnect("cc_JwQcDLJSYQJb",
+                         "dbs001.mongosoup.de", 27017)
> dbAuthenticate(mongo, username="JwQcDLJSYQJb",
+                password="RSXPkUkXXXXX")

> dbShowCollections(mongo)

[1] "zips"              "ccp"               "system.users"   "system
[5] "test"              "test_data"
```

```
> dbGetQuery(mongo, "zips", "{'state':'AL'}",
+            skip=0, limit=3)
   X_id state                          loc   pop        city
1 35004    AL  [ -86.51557 , 33.584132]  6055       ACMAR
2 35005    AL [ -86.959727 , 33.588437] 10616 ADAMSVILLE
3 35006    AL [ -87.167455 , 33.434277]  3205       ADGER

> dbInsertDocument(mongo, "test_data",
+                  '{"foo": "bar", "size": 5 }')

[1] "ok"

> dbDisconnect(mongo)
```

- supports the **aggregation framework**

```
> output <- dbAggregate(mongo, "zips",
+   c('{ "$group" : { "_id" : "$state", totalPop :
+                     { $sum : "$pop" } } } ',
+    ' { "$match" : {totalPop : { $gte : 10000 } } } ')
+   )
```

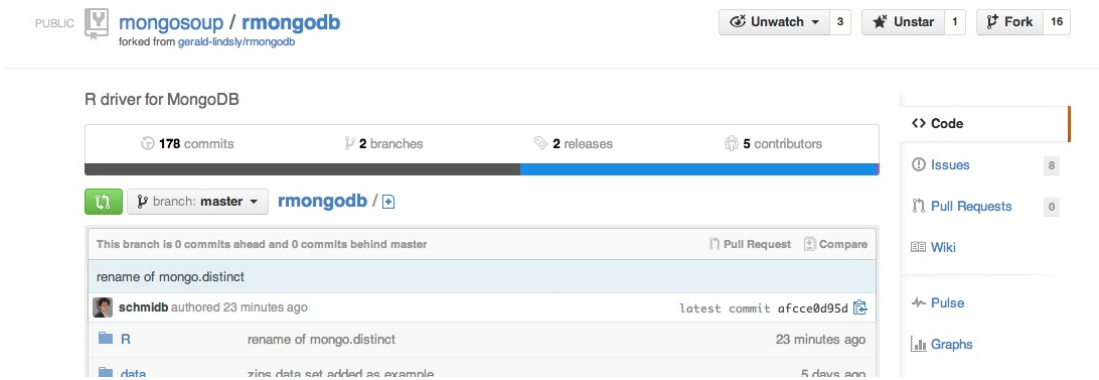
- in SQL: SELECT state, SUM(pop) AS pop FROM zips GROUP BY state HAVING pop $>$ (10000)

# Package: **rmongodb**

- developed on top of the MongoDB supported **C driver**
- runs almost entirely in native code, so you can expect high performance
- MongoDB and **rmongodb** use BSON documents to represent objects in the database and for network messages
- BSON is an **efficient binary representation of JSON**-like objects (http://www.mongodb.org/display/DOCS/BSON)
- there are numerous functions in **rmongodb** for serializing/deserializing data to/from BSON

# **rmongodb** NEWS:

- new maintainer: markus@mongosoup.de
- new repository: `https://github.com/mongosoup/rmongodb`
- resubmitted to CRAN and **back since end of October**: version 1.1.3
- new milestones and features are coming
- please provide **feedback**




```
> library(rmongodb)
> mongo <- mongo.create(host="dbs001.mongosoup.de",
+                       db="cc_JwQcDLJSYQJb",
+                       username="JwQcDLJSYQJb",
+                       password="RSXPkUXXXXXX")
> mongo
[1] 0
attr(,"mongo")
<pointer: 0x1090455c0>
attr(,"class")
[1] "mongo"
attr(,"host")
[1] "dbs001.mongosoup.de"
attr(,"name")
[1] ""
attr(,"username")
[1] "JwQcDLJSYQJb"
attr(,"password")
[1] "RSXPkUkxRdQX"
```

```
> mongo.get.database.collections(mongo, "cc_JwQcDLJSYQJb")

[1] "cc_JwQcDLJSYQJb.zips"      "cc_JwQcDLJSYQJb.ccp"
[3] "cc_JwQcDLJSYQJb.test"      "cc_JwQcDLJSYQJb.test_data"

> # creating BSON buffers
> buf <- mongo.bson.buffer.create()
> err <- mongo.bson.buffer.append(buf, "state", "AL")
> mongo.bson.from.buffer(buf)

state : 2   AL

> # creating BSON buffers from JSON - NEW
> mongo.bson.from.JSON('{"state":"AL"}')

state : 2   AL
```

```
> res <- mongo.find.one(mongo, "cc_JwQcDLJSYQJb.zips",
+                       mongo.bson.from.JSON('{"state":"AL"}'))
> res

city : 2    ACMAR
loc : 4
0 : 1    -86.515570
1 : 1    33.584132

pop : 16    6055
state : 2    AL
_id : 2    35004

> mongo.bson.value(res, "pop")

[1] 6055
```

```
> cursor <- mongo.find(mongo, "cc_JwQcDLJSYQJb.zips",
+             query=mongo.bson.from.JSON('{"state":"AL"}'))
> res <- NULL
> while (mongo.cursor.next(cursor)){
+     tmp <- mongo.bson.to.list(mongo.cursor.value(cursor))
+     res <- rbind(res, tmp)
+ }
> err <- mongo.cursor.destroy(cursor)
> head(res, n=4)
```

```
    city          loc         pop   state _id
tmp "ACMAR"       Numeric,2 6055  "AL"  "35004"
tmp "ADAMSVILLE" Numeric,2 10616 "AL"  "35005"
tmp "ADGER"       Numeric,2 3205  "AL"  "35006"
tmp "KEYSTONE"    Numeric,2 14218 "AL"  "35007"
```

```
> # NEW: find all in one batch
> res <- mongo.find.batch(mongo, "cc_JwQcDLJSYQJb.zips",
+         query=mongo.bson.from.JSON('{"state":"AL"}'))
> head(res, n=4)
```

```
    city           loc       pop   state _id
val "ACMAR"        Numeric,2 6055  "AL"  "35004"
val "ADAMSVILLE"   Numeric,2 10616 "AL"  "35005"
val "ADGER"        Numeric,2 3205  "AL"  "35006"
val "KEYSTONE"     Numeric,2 14218 "AL"  "35007"
```

```
> # OLD
> buf <- mongo.bson.buffer.create()
> err <- mongo.bson.buffer.start.object(buf, "pop")
> err <- mongo.bson.buffer.append(buf, "$gt", 100000)
> err <- mongo.bson.buffer.finish.object(buf)
> query <- mongo.bson.from.buffer(buf)
> #
> # NEW
> query <- mongo.bson.from.JSON('{"pop":{"$gt":100000}}')
> #
> mongo.count(mongo, "cc_JwQcDLJSYQJb.zips",
+             query )
[1] 4
```

```
> mongo.drop(mongo, "cc_JwQcDLJSYQJb.test_data")

[1] TRUE

> mongo.insert(mongo, "cc_JwQcDLJSYQJb.test_data",
+              list(foo="bar", size=5L))

[1] TRUE

> mongo.insert(mongo, "cc_JwQcDLJSYQJb.test_data",
+              mongo.bson.from.JSON('{"n1":10}'))

[1] TRUE

> mongo.count(mongo, "cc_JwQcDLJSYQJb.test_data",
+             mongo.bson.empty())

[1] 2
```

# Create BSON objects

- It WAS about creating BSON query or field objects:

```
> ?mongo.bson
> ?mongo.bson.buffer.append
> ?mongo.bson.buffer.start.array
> ?mongo.bson.buffer.start.object
```

# **rmongodb** coming soon

- check version 1.2.X on github

```
> mongo.get.keys(mongo, "cc_JwQcDLJSYQJb.ccp")
> # implemented
>
> mongo.apply(mongo, "cc_JwQcDLJSYQJb.people",
+             1, keys="age", mean)
> mongo.summary(mongo, "cc_JwQcDLJSYQJb.people")
> # implemented
>
> mongo.aggregate( ... )
> mongo.table( ... )
```

# Break and Time of Exercises

- Connect to the **R**Studio Server:
  - `http://rtraining.comsysto.com:8787`
  - Get your user and password at the front desk
- Use **R** as calculator:
  - In your exercise/home directory you can find a file "exercise_Rbasics.R". Run all the commands.
  - **R** experts will find small challenges in the file.
- Check the Shiny App running on:
  `http://rtraining.comsysto.com:3838/user01/01_hello`
  - In your home directory you can find a folder "ShinyApp". This folder holds all the code for several example ShinyApps.
  - There are 11 different ShinyApps. Go to the URL of one or two other ShinyApps from your user, e.g. :
    `http://rtraining.comsysto.com:3838/userXX/05_sliders`
  - Feel free to make changes and check the results in your browser.

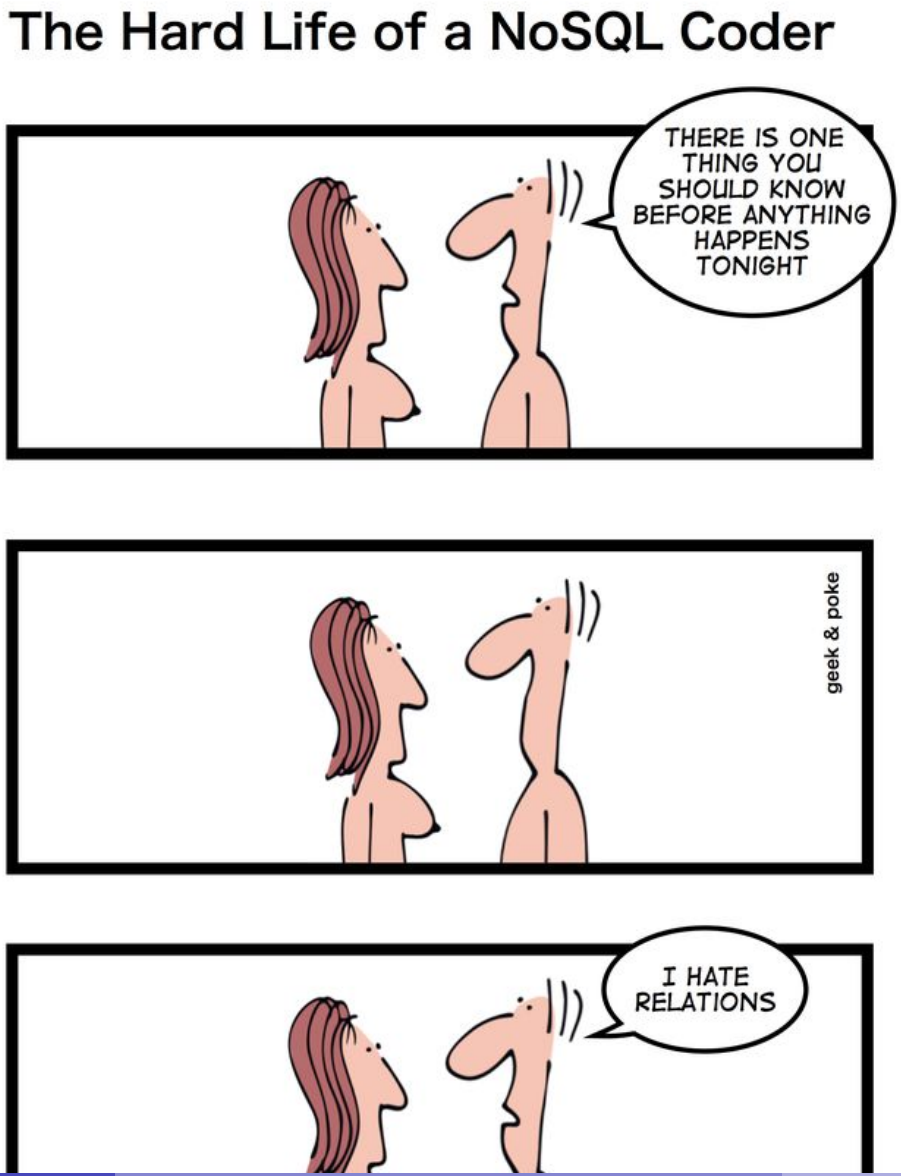
- Use **Rockmongo** to view content of mongodb:
  - `http://rtraining.comsysto.com/rockmongo`
  - User/pw : admin/admin
- or use **ShinyMongo** to view content of mongodb:
  `http://rtraining.comsysto.com:3838/schmidb/ShinyMongo`
- Use **R** to connect and query MongoDB
  - In your home directory you can find a file "exercise_Rmongodb.R". Run all the commands.
  - **R** experts will find small challenges in the file.

## BREAK

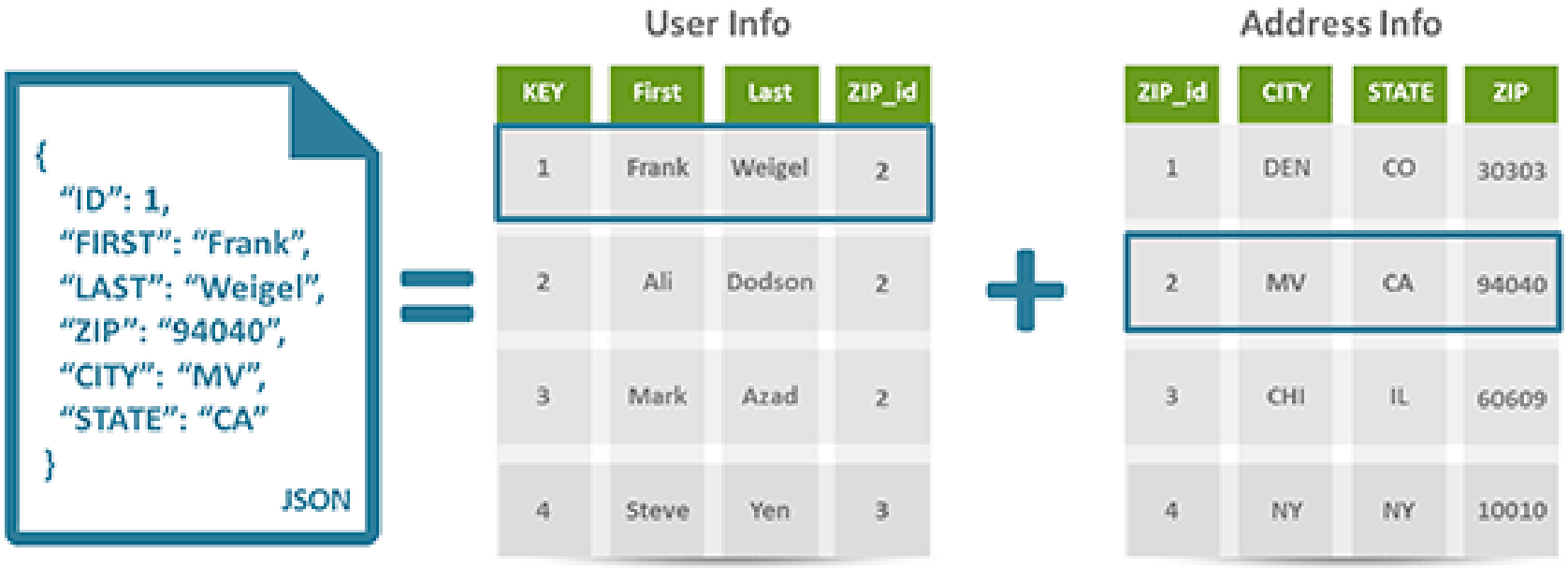
Slides available at

`http://rtraining.comsysto.com/slides/slides.pdf`

# NoSQL - schema-less



# NoSQL - all in one




# NoSQL - implicit schema

- **relational schema**: defines columns, their names, and their datatypes
  - **error** if insert of data doesn't fit in the schema
- schema-less database allows **any data**
  - structured with individual fields and structures
  - reduces ceremony and increases flexibility
- **implicit schema** in schema-less
  - code that manipulates the data needs to make some assumptions about its structure, such as the **name of fields**
  - data / commands that doesn't fit: leading to errors

# NoSQL - schema-less example

```
{'first':'martin', 'last':'fowler',
 'zip_id': {'city':'munich', 'zip':80883},
 'card_id':2334}
{'first':'peter', 'last':'sadalage',
 'zip_id':'Munich, Lindwurmstr. 97',
 'card_id':1333}
{'surname':'humble', 'first':'tom',
 'zip_id': {'zip':94104, 'city':'Munich'},
 'card_id':[2334, 6534]}
```

```
> library(RJSONIO)
> json1 <- fromJSON( '{"first":"martin", "last":"fowler",
+  "zip_id": {"city":"munich", "zip":80883},
+  "card_id":2334}')
> json2 <- fromJSON( '{"first":"peter", "last":"sadalage",
+  "zip_id":"Munich, 80892, Lindwurmstr. 97" ,
+  "card_id":1333}')
> json3 <- fromJSON( '{"surname":"humble", "first":"tom",
+  "zip_id": {"zip":94104, "city":"Munich"},
+  "card_id":[2334, 6534]}')
> data <- rbind(json1, json2, json3)
> dim(data)

[1] 3 4
```

```
> data
      first    last        zip_id                                  car
json1 "martin" "fowler"    List,2                                  233
json2 "peter"  "sadalage" "Munich, 80892, Lindwurmstr. 97" 133
json3 "humble" "tom"       List,2                                  Num
> data[3, "zip_id"]
[[1]]
[[1]]$zip
[1] 94104

[[1]]$city
[1] "Munich"
> data[3, "card_id"]
[[1]]
[1] 2334 6534
```

```
> summary(data)
 first.Length  first.Class  first.Mode last.Length  last.Class
 1            -none-     character       1           -none-     c
 1            -none-     character       1           -none-     c
 1            -none-     character       1           -none-     c
 zip_id.Length  zip_id.Class  zip_id.Mode
 2            -none-     list
 1            -none-     character
 2            -none-     list
 card_id.Length  card_id.Class  card_id.Mode
 1          -none-   numeric
 1          -none-   numeric
 2          -none-   numeric
```

**R** and NoSQL makes your analyses **difficult**

# Outline



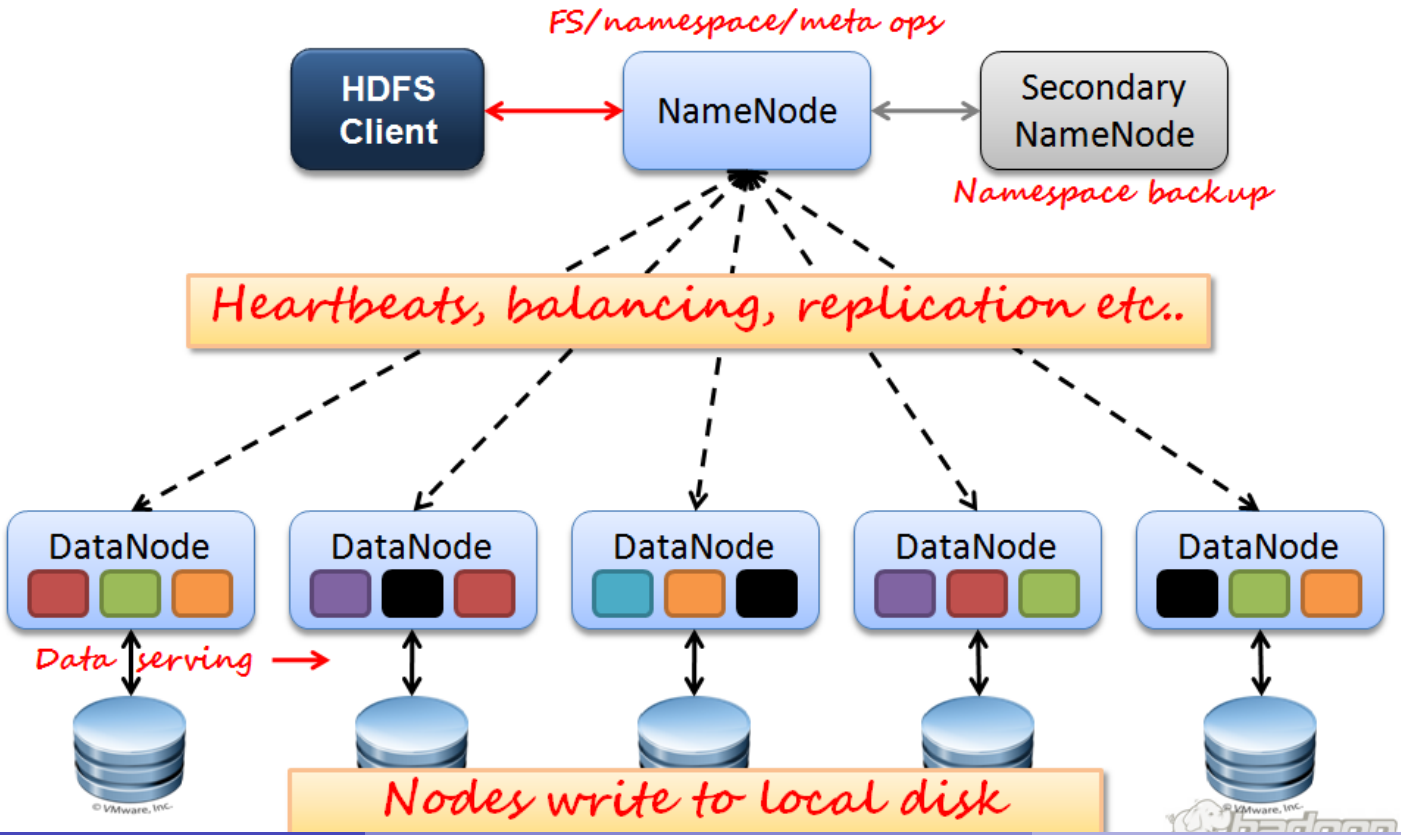
# RHadoop

- an open source project sponsored by **Revolution Analytics**
- package overview:
  - **rmr2** hosts all Map Reduce related functions
    - ⋆ uses Hadoop Streaming API
  - **rhdfs** for interaction with HDFS file system
  - **plyrmr** convenient processing on a Hadoop cluster of large data sets
  - **rhbase** connect with Hadoop's NoSQL database HBase
- **installation** is the biggest challenge
  - check web for installation guidelines
  - works with MapR, Cloudera, Hortonworks and Apache Hadoop distribution
  - so far there is no official AWS EMR support

`https://github.com/RevolutionAnalytics/RHadoop`

# HDFS and Hadoop cluster

- HDFS is a **block-structured file system**
  - blocks are stored across a cluster of one or more machines with data storage capacity: DataNode
  - data is accessed in a write once and read many model
- HDFS does come with its own utilities for file management
- HDFS file system stores its **metadata** reliably: NameNode



# Hadoop Distribution

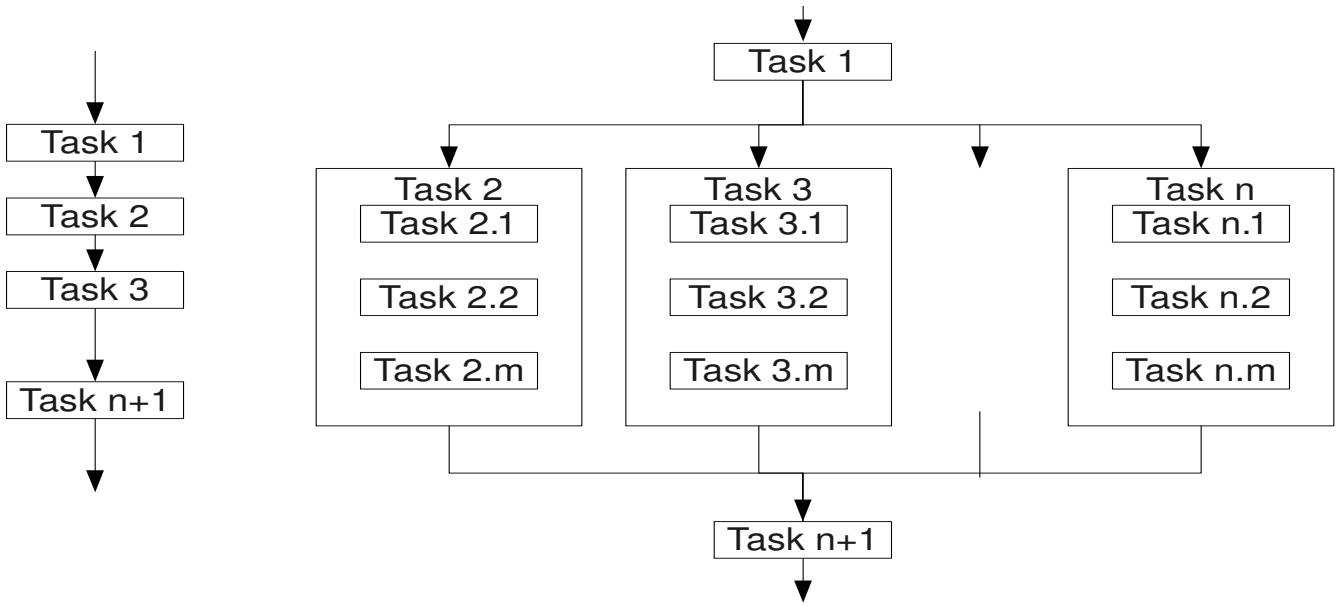
- the training system runs on MapR
  - a enterprise-grade platform for Hadoop
  - complete Hadoop distribution
  - comprehensive management suite
  - industry-standard interfaces
  - combines open source packages with Enterprise-grade dependability
  - higher performance
  - mount Hadoop with Direct Access **NFS**

MAPR TECHNOLOGIES

`http://www.mapR.com`

# Parallel Computing basics

- Serial and parallel tasks:




- Problem is broken into a **discrete series** of instructions and they are processed one after another.
- Problem is broken into discrete parts, that can be **solved concurrently**.

# Simple Parallel Computing with **R**

```
> x <- 1:5
> x
[1] 1 2 3 4 5
> lapply(x, function(y) y^2)
[1]  1  4  9 16 25
> library(parallel)
> mclapply(x, function(y) y^2)
[1]  1  4  9 16 25
```

# My first Map Reduce Job

```
> library(rmr2)
> rmr.options(backend=c("local"))

NULL

> small.ints <- to.dfs(keyval(1, 1:100))
> out <- mapreduce(
+      input = small.ints,
+      map = function(k, v) cbind(v, v^2))
> df <- from.dfs(out)
> head(df$val, n=5)

     v
[1,] 1  1
[2,] 2  4
[3,] 3  9
[4,] 4 16
[5,] 5 25
```

```
> library(rmr2)
> #small.ints <- to.dfs(1:100)
> small.ints <- to.dfs(keyval(1, 1:100))
> out <- mapreduce(
+     input = small.ints,
+     map = function(k, v) cbind(v, v^2))
> df <- from.dfs(out)
```

- **to.dfs** put the data into HDFS
  - not possible to write out big data, not in a scalable way
  - nonetheless very useful for a variety of uses like writing test cases, learning and debugging
  - can put the data in a file of your own choosing
  - if you don't specify one it will create temp files and clean them up when done
  - return value is something we call a "big data object"
  - it is a stub, that is the data is not in memory, only some information

```
> library(rmr2)
> small.ints <- to.dfs(keyval(1, 1:100))
> out <- mapreduce(
+     input = small.ints,
+     map = function(k, v) cbind(v, v^2))
> df <- from.dfs(out)
```

- **mapreduce** replaces lapply
- input is the variable small.ints which contains the output of to.dfs
- function to apply, which is called a "map function" is a regular **R** function with a few constraint
  - a function of two arguments, a collection of keys and one of values
  - returns key value pairs using the function `keyval`, which can have vectors, lists, matrices or data.frames as arguments
  - avoid calling `keyval` explicitly but the return value x will be converted with a call to `keyval(NULL,x)`
- (a reduce function, which we are not using here)
- we are not using the keys at all, only the values, but we still need both to support the general map reduce case

```
> library(rmr2)
> small.ints <- to.dfs(keyval(1, 1:100))
> out <- mapreduce(
+     input = small.ints,
+     map = function(k, v) cbind(v, v^2))
> df <- from.dfs(out)
```

- return value is big data object
- you can pass it as input to other jobs
- read it into memory with `from.dfs`
  - it will fail for big data!
  - from.dfs is complementary to to.dfs and returns a key-value pair collection

# Dealing with Input Formats

```
> air.in =
+     make.input.format(
+         "csv",
+         sep = ",",
+         col.names=c("iata", "airport", "city",
+                     "state", "country", "lat", "long"),
+         stringsAsFactors = FALSE
+         )
> air2007 <- from.dfs("../exercises/data/airports.csv",
+                     format = air.in)
> air2007$key
NULL
> head(air2007$val, n=3)
  iata                 airport             city state country
1  00M                Thigpen      Bay Springs    MS     USA 31.
2  00R Livingston Municipal       Livingston    TX     USA 30.
3  00V          Meadow Lake Colorado Springs    CO     USA 38.
```

```
> air.subs =
+     mapreduce(
+         "../exercises/data/airports.csv",
+         input.format = air.in)
> air.subs

function ()
{
    fname
}
<environment: 0x1045d6630>

> air.mem= from.dfs(air.subs)
> names(air.mem)

[1] "key" "val"

> air.df = values(air.mem)
```

```
> important.cols = c("airport", "city", "state")
> air.df = subset(air.df, select = important.cols)
> head(air.df, n=3)
```

```
                 airport              city state
1                Thigpen       Bay Springs    MS
2 Livingston Municipal        Livingston    TX
3          Meadow Lake Colorado Springs    CO
```

```
> air.subs =
+     mapreduce(
+         air.subs,
+         map =
+             function(k, v)
+                 subset(v, select = important.cols))
> head( values( from.dfs(air.subs) ), n=3)
```

| | airport | city | state |
|---|---|---|---|
| 1 | Thigpen | Bay Springs | MS |
| 2 | Livingston Municipal | Livingston | TX |
| 3 | Meadow Lake | Colorado Springs | CO |

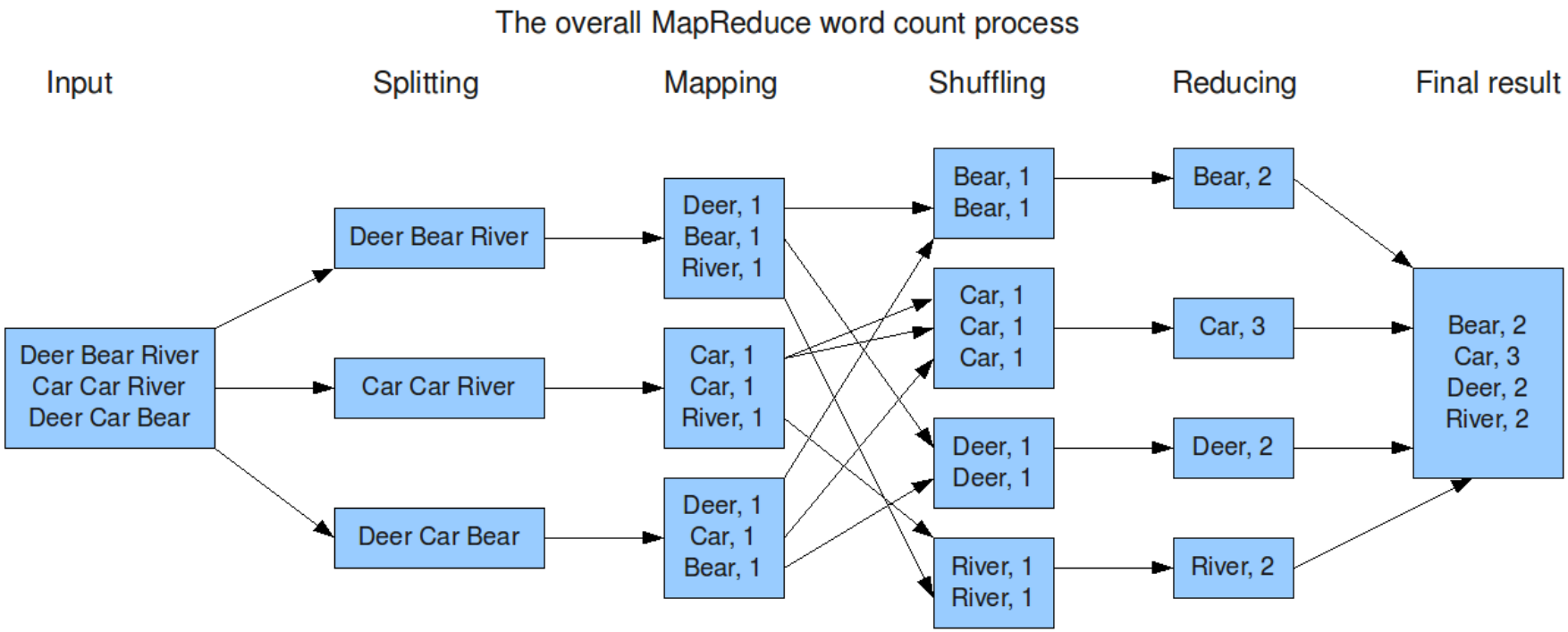
```
> air.subs =
+     mapreduce(
+         "../exercises/data/airports.csv",
+         input.format = air.in,
+         map =
+             function(k, v)
+                 subset(v, city=="Perry"))
> head( values( from.dfs(air.subs) ), n=3)
```

```
     iata          airport  city state country      lat       lo
4     01G    Perry-Warsaw Perry    NY     USA 42.74135 -78.052
382   40J     Perry-Foley Perry    FL     USA 30.06928 -83.580
1456  F22 Perry Municipal Perry    OK     USA 36.38560 -97.277
```

```
> air.subs =
+     mapreduce(
+         "../exercises/data/airports.csv",
+         input.format = air.in,
+         map =
+             function(k, v){
+                 v = v[!is.na(as.character(v$state)), ]
+                 keyval( as.character(v$state),
+                         as.integer(v$lat) ) },
+         reduce =
+           function(k, v)
+               cbind(state=k,
+                     lat_mean= mean(v, na.rm = TRUE) )
+
+         )
```

```
> head( values( from.dfs(air.subs) ), n=4)

     state lat_mean
[1,] "MS"  "32.375"
[2,] "TX"  "30.9808612440191"
[3,] "CO"  "38.7959183673469"
[4,] "NY"  "41.9587628865979"
```

# Hadoop Hello World - "Word - Count"




```
> wc.map =
+       function(., lines) {
+         key <- unlist(
+             strsplit(x = lines,
+               split = pattern))
+         keyval( key, 1 )
+       }
> wc.reduce =
+     function(word, counts) {
+         keyval( word, sum(counts) )
+     }
```

```
> rmr.options(backend=c("local"))

NULL

> pattern <- " +"
> out <- mapreduce(
+       input = "../exercises/data/faust.txt" ,
+       input.format = "text",
+       map = wc.map,
+       reduce = wc.reduce,
+       combine = T,
+       in.memory.combine = F)
> res <- from.dfs(out)
> id <- which(res$key=="Alle")
> res$val[id]

[1] 5
```

# Hadoop Environments Variables

- all RHadoop packages have to access hadoop
- in Linux they need the correct environment variables
- in **R** you have to set them explicitly

```
> Sys.setenv(HADOOP_CMD="/opt/mapr/hadoop/
+             hadoop-0.20.2/bin/hadoop")
> Sys.setenv(HADOOP_STREAMING="/opt/mapr/hadoop/
+             hadoop-0.20.2/contrib/streaming/
+             hadoop-0.20.2-dev-streaming.jar")
> library(rmr2)
> # rmr.options(backend=c("hadoop"))
> small.ints <- to.dfs(keyval(1, 1:100))
> out <- mapreduce(
+     input = small.ints,
+     map = function(k, v) cbind(v, v^2))
```

# Package **rhdfs**

- basic connectivity to the **Hadoop Distributed File System**
- can browse, read, write, and modify files stored in HDFS
- package has a dependency on **rJava**
- is dependent upon the HADOOP_CMD environment variable

```
> Sys.setenv(HADOOP_CMD="/opt/mapr/hadoop/
+             hadoop-0.20.2/bin/hadoop")
> library(rhdfs)
> hdfs.init()
> hdfs.ls()
> data <- 1:1000
> file <- hdfs.file("my_test", "w")
> hdfs.write(data, file)
> hdfs.close(file)
> hdfs.ls()
```

- with the MapR Hadoop distribution we basically **do not need** the package
- mount Hadoop with Direct Access **NFS**

```
> list.files(path = "/mnt/mapr/data")
> list.dir(path = "/mnt/mapr/")
> file.info("/mnt/mapr/data/zips.json")
> ?file.create
```

# Package **plyrmr**

- perform common **data manipulation** operations on very large data sets stored on Hadoop

```
> air.df = transform(air.df,
+                    aiport = airport == "Hilliard Airpark")
> head( air.df, n=5 )
```

| | airport | city | state | aiport |
|---|---|---|---|---|
| 1 | Thigpen | Bay Springs | MS | FALSE |
| 2 | Livingston Municipal | Livingston | TX | FALSE |
| 3 | Meadow Lake | Colorado Springs | CO | FALSE |
| 4 | Perry-Warsaw | Perry | NY | FALSE |
| 5 | Hilliard Airpark | Hilliard | FL | TRUE |

```
> library(plyrmr)
> air.subs =
+     transform(
+         input("../exercises/data/airports.csv",
+               format = air.in),
+         aiport = airport == "Hilliard Airpark")
> air.subs
[1] "Got it! To generate results call the functions output or
> air.df = as.data.frame(air.subs)
> head( air.df, n=5 )
  iata                 airport                city state country
1  00M                 Thigpen        Bay Springs    MS     USA 31.
2  00R Livingston Municipal          Livingston    TX     USA 30.
3  00V          Meadow Lake Colorado Springs    CO     USA 38.
4  01G        Perry-Warsaw                 Perry    NY     USA 42.
5  01J     Hilliard Airpark             Hilliard    FL     USA 30.
  aiport
1  FALSE
2  FALSE
```

```
> air.df = select(air.df, airport, city)
> head( air.df, n=3 )
```

```
                 airport              city
1                Thigpen       Bay Springs
2 Livingston Municipal        Livingston
3           Meadow Lake Colorado Springs
```

```
> air.subs =
+     select(air.subs,
+            airport, city)
> head( as.data.frame(air.subs), n=3 )
```

```
                 airport             city
1              Thigpen       Bay Springs
2 Livingston Municipal        Livingston
3          Meadow Lake Colorado Springs
```

- ... and many more commands: gather, merge, sample, summarize, where, ...

# RHadoop Advanced

- **rmr2** the easiest, most productive, most elegant way to write map reduce jobs
- with **rmr2** one-two orders of magnitude less code than Java
- with **rmr2** readable, reusable, extensible map reduce
- with **rmr2** is a great prototyping, executable spec and research language
- **rmr2** is a way to work on big data sets in a way that is '**R**-like'
- 'Simple things should be simple, complex things should be possible'

- **rmr2** is not Hadoop Streaming
  - it uses streaming
  - no support for every single option that streaming has
  - streaming is accessible from **R** with no additional packages because **R** can execute an external program and **R** scripts can read stdin and stdout
- map reduce programs written in **rmr2** are not going to be the most efficient

- Hive, Impala you can access via **RODBC**
- Hive you can access with the **R** package **RHive**
- HBASE you can access with the **R** package **rhbase**
- Want to learn more? Check **Revolution Analytics Webinars**

# RHadoop k-means clustering

- live demo

# Exercise for the Discussion Round

- Connect to the **R**Studio Server:
  - `http://rtraining.comsysto.com:8787`
- Use **R** to run MapReduce jobs and explore HDFS
  - In your home/exercise directory you can find a file "exercise_Rhadoop.R". Run all the commands.
  - **R** experts: check the hadoop-*.R files and start loving Hadoop.
  - You can access the MapR dashboard via `https://rtraining.comsysto.com:8443` (user: 'user', password:'comsysto')

# Summary

- **R** is a powerful statistical tool to analyse many different kind of data:

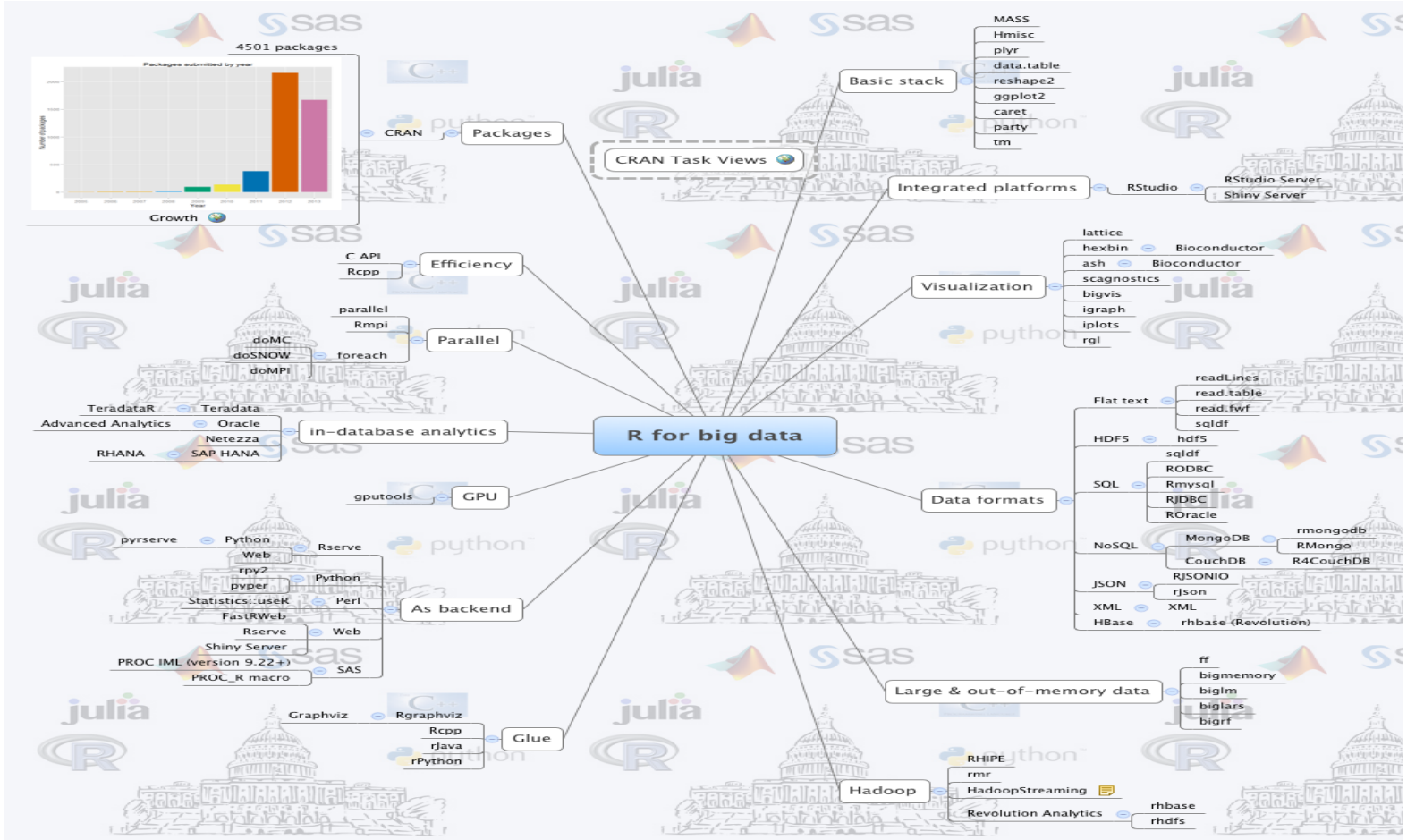
  **from small to big data**

- **R** can access databases
  - MongoDB and **rmongodb** support big data
- **R** can run Hadoop jobs
  - **rmr2** runs your Map Reduce jobs
  - **plyrmr** makes big data management on Hadoop easy
- **R** is open source and there is a lot of community driven development

`http://www.r-project.org/`

the tutorial did not cover ...

- the commercial **R** version: **Revolution R Enterprise**
  - RRE7 is coming
  - R functions to run directly on Hadoop
  - in-database analytics (Teradata)
  - `http://www.revolutionanalytics.com`
- Oracle **R** Advanced Analytics for Hadoop package: `http://www.oracle.com/technetwork/bdc/big-data-connectors/downloads/index.html`
- pbdR: programming with big data in **R**: `http://r-pbd.org/`




http://datacommunitydc.org/blog/2013/05/stepping-up-to-big-data-with-r-and-python

# How to go on

- start playing around with **R and Big Data**
- get part of the community
  - `http://www.r-bloggers.com`
  - `http://hadoop.comsysto.com`
- interested in more **R courses** hosted by comSysto GmbH in Munich, Germany?
  - two day **R** beginners training (05. - 06.12.2013)
  - one day **R** Data Handling and Graphics (12.12.2013)
  - one day **R** Big Data Analyses (13.12.2013)
  - `http://comsysto.com/events`
- **rmongodb** webinar in January 2014:
  `https://www3.gotomeeting.com/register/287023934`

# Goodbye

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