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Introduction to the R language

Biological Networks – Mod 1
Academic year 2021/2022
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Credits: Arin Basu, Tyler Perrachione

TOPICS

What is R

How to obtain and install R

How to read and export data

How to do basic statistical analyses

Data analysis packages in R

WHAT IS R

- Software for Statistical Data Analysis
- Based on S
- Programming Environment
- Interpreted Language
- Data Storage, Analysis, Graphing
- Free and Open Source Software

STRENGTHS AND WEAKNESSES

- Strengths
  - Free and Open Source
  - Strong User Community
  - Highly extensible, flexible
  - Implementation of high end statistical methods
  - Flexible graphics and intelligent defaults
- Weakness
  - Steep learning curve
  - Slow for large datasets

OBTAINING R

- Current Version: R-4.1.2
- Comprehensive R Archive Network:

  http://cran.r-project.org
- Binary and source codes
- Windows executables
- Compiled RPMs for Linux
- Can be obtained on a CD

INSTALLING R

- Binary (Windows/Linux): One step process
  - exe, rpm (Red Hat/Mandrake), apt-get (Debian)

- Linux, from sources:

```
$ tar –zxvf “filename.tar.gz”
$ cd filename
$ ./configure
$ make
$ make check
$ make install
```

STARTING R

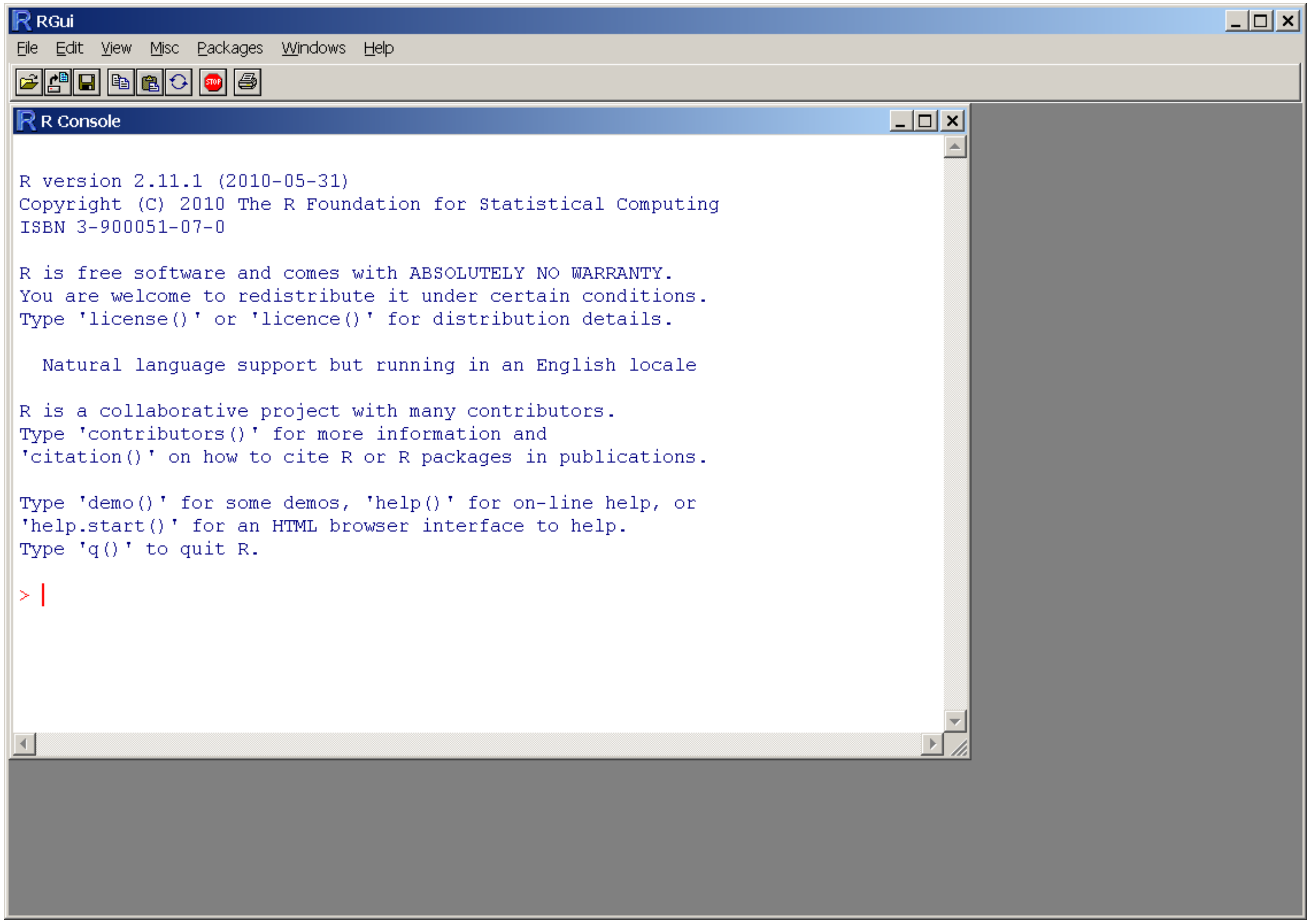
Windows, Double-click on Desktop Icon

```
$ R
```

Linux, type R at command prompt

RUNNING AND INTERACTING WITH R

Reference implementation of R includes a minimal programming environment – a console and no editor



```
R version 2.11.1 (2010-05-31)
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ISBN 3-900051-07-0

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Type 'license()' or 'licence()' for distribution details.

  Natural language support but running in an English locale

R is a collaborative project with many contributors.
Type 'contributors()' for more information and
'citation()' on how to cite R or R packages in publications.

Type 'demo()' for some demos, 'help()' for on-line help, or
'help.start()' for an HTML browser interface to help.
Type 'q()' to quit R.

> 
```

RUNNING R

- An R program is created using an editor
  - Notepad++, WinEdt, Tinn-R: Windows
  - Xemacs, ESS (Emacs speaks Statistics)
- To run a program in the console:
  - source(“filename.R”)
  - Outputs can be diverted by using sink(“filename.Rout”)

RUNNING R

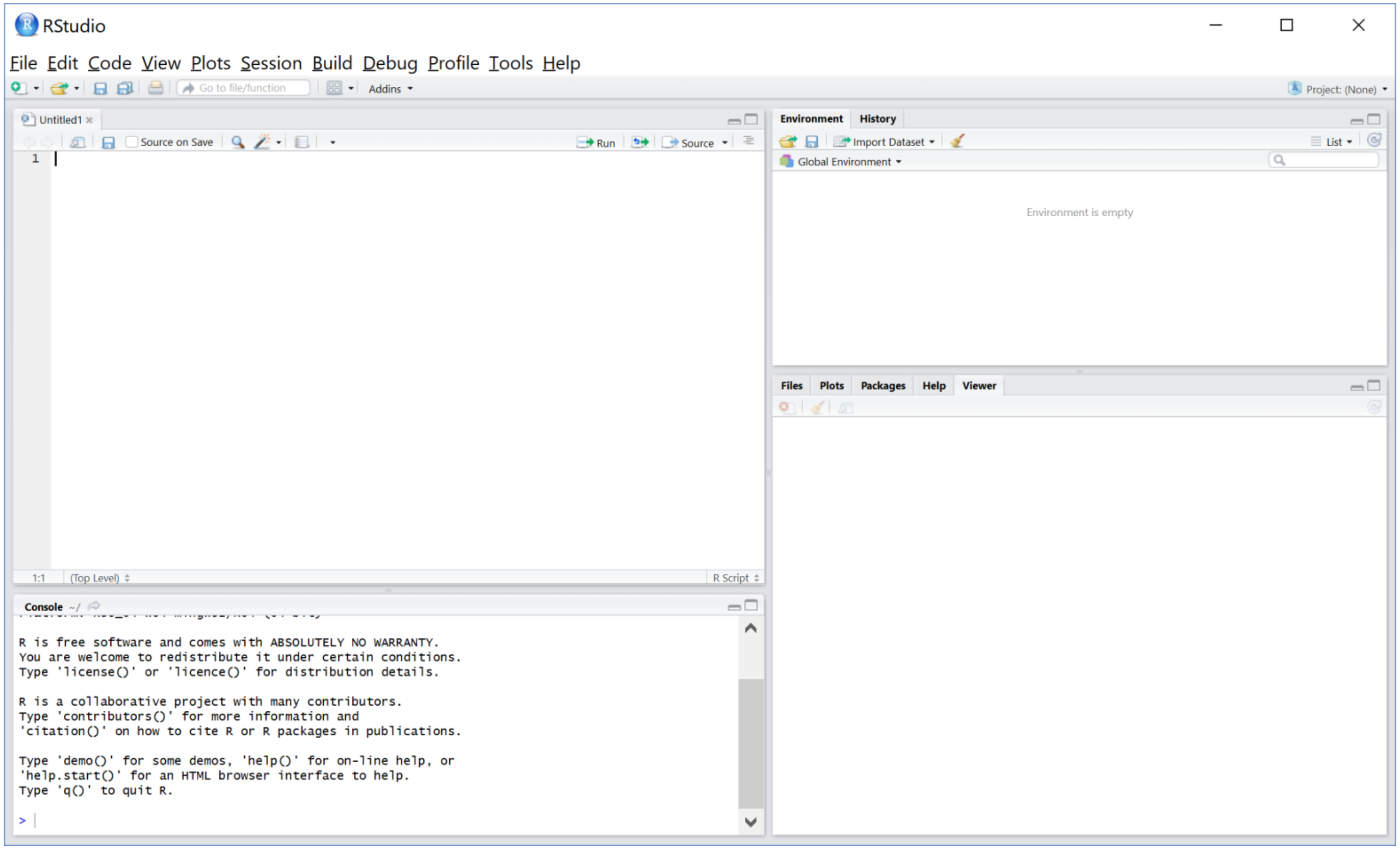
- What makes R so useful is the ease of installation of additional libraries
  - Libraries are called ‘packages’ in R parlance
  - Packages add functionality to the basic R installation
  - Hundreds packages are available in open online repositories

- Several IDEs are available for R to facilitate code development
  - a very popular one is Rstudio - available at http://www.rstudio.com

```
#
# basic code example
#

# install the XLConnect package
install.packages("XLConnect")
library("XLConnect")

# see what libraries are installed
library()

# change working directory
setwd("C:/Users/Mario/Documents")
getwd()

# load internal toy data set
data(iris)

# let’s inspect the iris data set
?iris          # same as: help(iris)
class(iris)
dim(iris)
head(iris)
tail(iris)

q()
```

RUNNING R WITH A IDE

- IDE: Integrated Development Environment
- RStudio: an open source IDE for R



```
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'help.start()' for an HTML browser interface to help.
Type 'q()' to quit R.

>
```

GETTING HELP IN R

- From built-in documentation:
  - ?WhatIWantToKnow
  - help(“WhatIWantToKnow”)
  - help.search(“WhatIWantToKnow”)
  - help.start()
  - getAnywhere(“WhatIWantToKnow”)
  - example(“WhatIWantToKnow”)

- Reference manual: “An Introduction to R”
  - https://cran.r-project.org/doc/manuals/r-release/R-intro.pdf

- Many active mailing lists and blogs
  - typically found by using the right keywords in Google

DATA STRUCTURES

- Supports virtually any type of data
- Numbers, characters, logicals (TRUE/ FALSE)
- Arrays of virtually unlimited sizes and number of dimensions
- Simplest data structures: Vectors and Matrices
- Lists: Can Contain mixed type variables
- Data Frame: Rectangular Data Set

SYNOPSIS OF OPERATORS

Operator	Usually means	In Formula means
+ or -	add or subtract	add or remove terms
*	multiplication	main effect and interactions
/	division	main effect and nesting
:	sequence	interaction only
^	exponentiation	limiting interaction depths
%in%	no specific	nesting only

EXPRESSIONS IN R

Math:

```
> 1 + 1
[1] 2

> 1 + 1 * 7
[1] 8

> (1 + 1) * 7
[1] 14
```

Variables:

```
> x <- 1
> x
[1] 1
> y = 2
> y
[1] 2
> 3 -> z
> z
[1] 3
> (x + y) * z
[1] 9
```

EXPRESSIONS IN R

Arrays:

```
> x <- c(0,1,2,3,4)
> x
[1] 0 1 2 3 4

> y <- 1:5
> y
[1] 1 2 3 4 5

> z <- 1:50
> z
 [1]  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15
[16] 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
[31] 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45
[46] 46 47 48 49 50
```

EXPRESSIONS IN R

Math on arrays:

```
> x <- c(0,1,2,3,4)
> y <- 1:5
> z <- 1:50
> x + y
[1] 1 3 5 7 9
> x * y
[1]  0  2  6 12 20
> x * z
 [1]   0   2   6  12  20   0   7  16  27  40   0
[12]  12  26  42  60   0  17  36  57  80   0  22
[23]  46  72 100   0  27  56  87 120   0  32  66
[34] 102 140   0  37  76 117 160   0  42  86 132
[45] 180   0  47  96 147 200
```

DATA STRUCTURES IN R

	Linear	Rectangular
All Same Type	VECTORS	MATRIX
Mixed	LIST	DATA FRAME

VECTORS AND MATRICES

```
# The c() function can be used to create vectors
> x <- c(0,1,2,3,4)
> x
[1] 0 1 2 3 4

# Use the vector() function to create empty vectors
> y <- vector(”numeric”, length = 10)
> y
[1] 0 0 0 0 0 0 0 0 0 0

> z <- 1:25
> z
 [1]  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15
[16] 16 17 18 19 20 21 22 23 24 25

# There is a matrix() function too
> m <- matrix(0, 2,3)
> m
     [,1] [,2] [,3]
[1,]    0    0    0
[2,]    0    0    0
>
```

ACCESSING MATRIX AND VECTOR ELEMENTS

- Subscripts are an essential tool
  - x[1] identifies first element in vector x
  - x[-1] identifies all elements in vector x except the first
  - x[2:4] identifies elements from the 2nd to the 4th in vector x
  - x[c(2,4,5)] identifies specific elements in vector x
  - x[x > 3] identifies all the elements grater than 3 in vector x
  - y[2,3] identifies the element in row 2, column 3 in matrix y
  - y[1,] identifies first row in matrix y
  - y[,1] identifies first column in matrix y
  - y[1:5,] gives first 5 rows of data

- To inspect a data object:
  - edit(<mydataobject>)

THE INFAMOUS NA

- R uses NA to represent data that is "not available"
- The function **`is.na()`** tests for NA
- NA’s are often an annoyance, see here an example of how to deal with them

```
> x <- c(1,2,NA,4,NA,5)
> x
[1]  1  2 NA  4 NA  5

> bad <- is.na(x)
> bad
[1] FALSE FALSE  TRUE FALSE  TRUE FALSE

> !bad
[1]  TRUE  TRUE FALSE  TRUE FALSE  TRUE

> x[!bad]
[1] 1 2 4 5
```

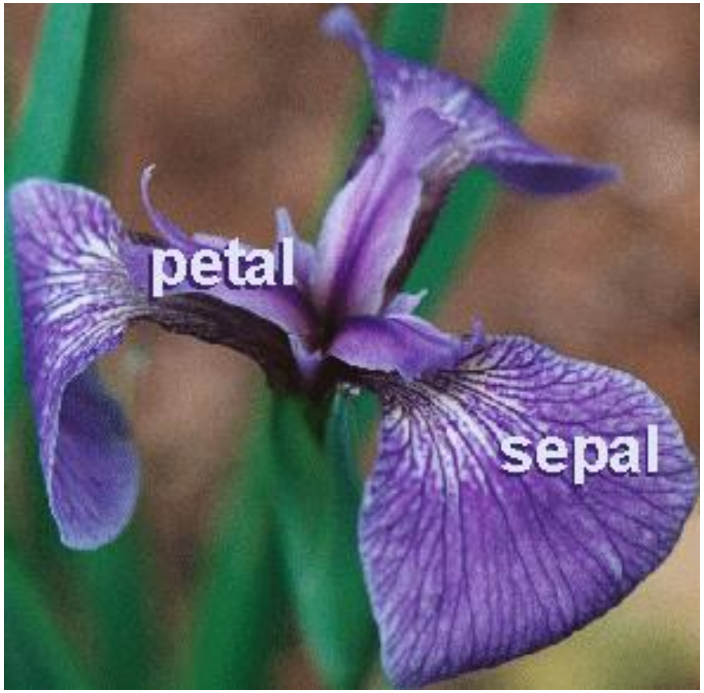
DATA FRAMES

- Data frames are R’s fundamental data structures
- They are used to store data in a table format
- Unlike matrices, data frames can store different type of data
- Data frames are usually created by calling the `read.table()` or `read.csv()` functions
- They can be converted to a matrix by calling `data.matrix()`

BUILT-IN DATA SETS

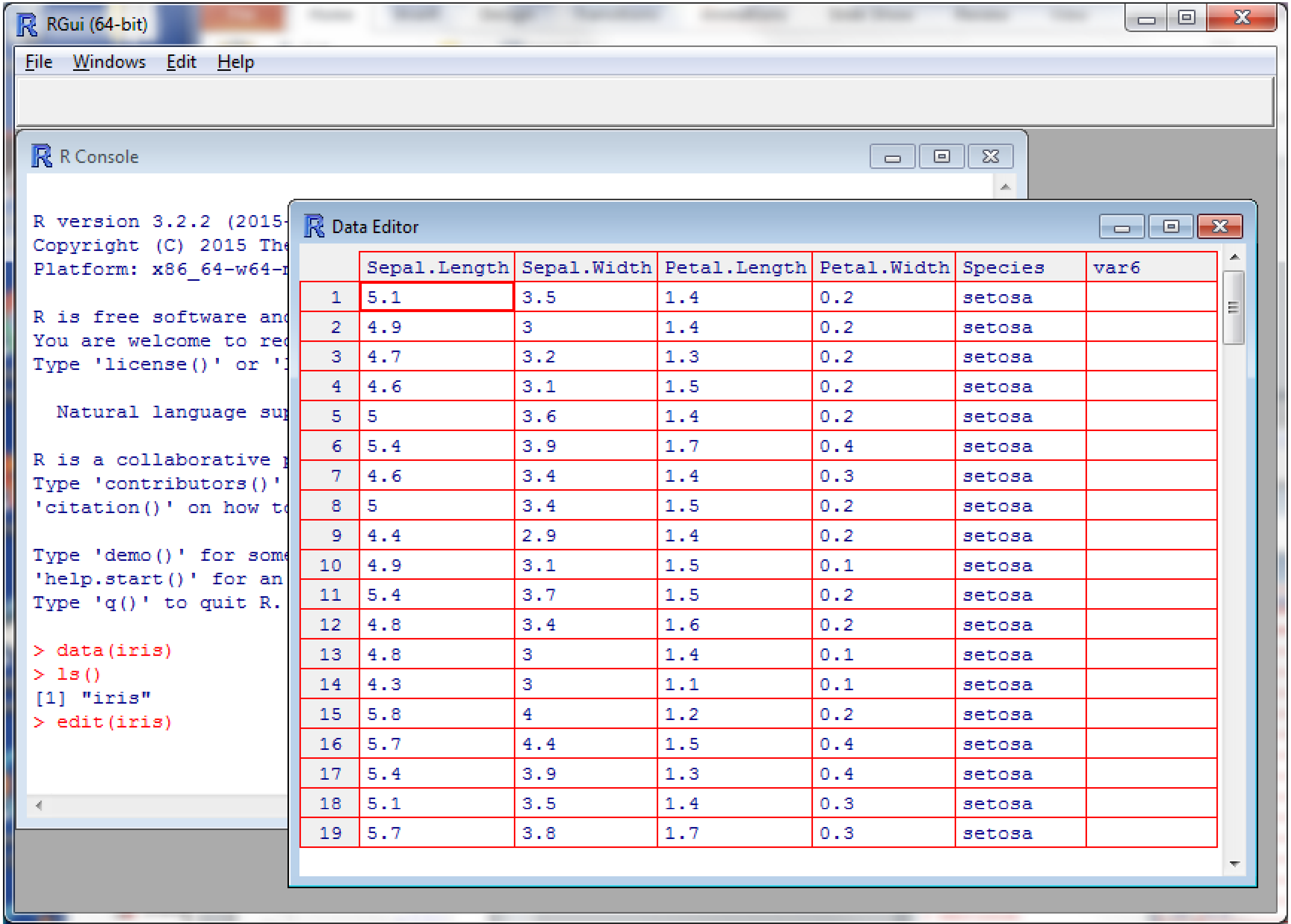
- You can practice the use of data frames by importing some of the built-in data sets available in R
- `data()` lists the built-in data sets
- `Iris` is a nice one

Iris virginica



Iris setosa

IRIS DATA SET



```
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Platform: x86_64-w64-m

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Type 'q()' to quit R.

> data(iris)
> ls()
[1] "iris"
> edit(iris)
```

	Sepal.Length	Sepal.Width	Petal.Length	Petal.Width	Species	var6
1	5.1	3.5	1.4	0.2	setosa	
2	4.9	3	1.4	0.2	setosa	
3	4.7	3.2	1.3	0.2	setosa	
4	4.6	3.1	1.5	0.2	setosa	
5	5	3.6	1.4	0.2	setosa	
6	5.4	3.9	1.7	0.4	setosa	
7	4.6	3.4	1.4	0.3	setosa	
8	5	3.4	1.5	0.2	setosa	
9	4.4	2.9	1.4	0.2	setosa	
10	4.9	3.1	1.5	0.1	setosa	
11	5.4	3.7	1.5	0.2	setosa	
12	4.8	3.4	1.6	0.2	setosa	
13	4.8	3	1.4	0.1	setosa	
14	4.3	3	1.1	0.1	setosa	
15	5.8	4	1.2	0.2	setosa	
16	5.7	4.4	1.5	0.4	setosa	
17	5.4	3.9	1.3	0.4	setosa	
18	5.1	3.5	1.4	0.3	setosa	
19	5.7	3.8	1.7	0.3	setosa	

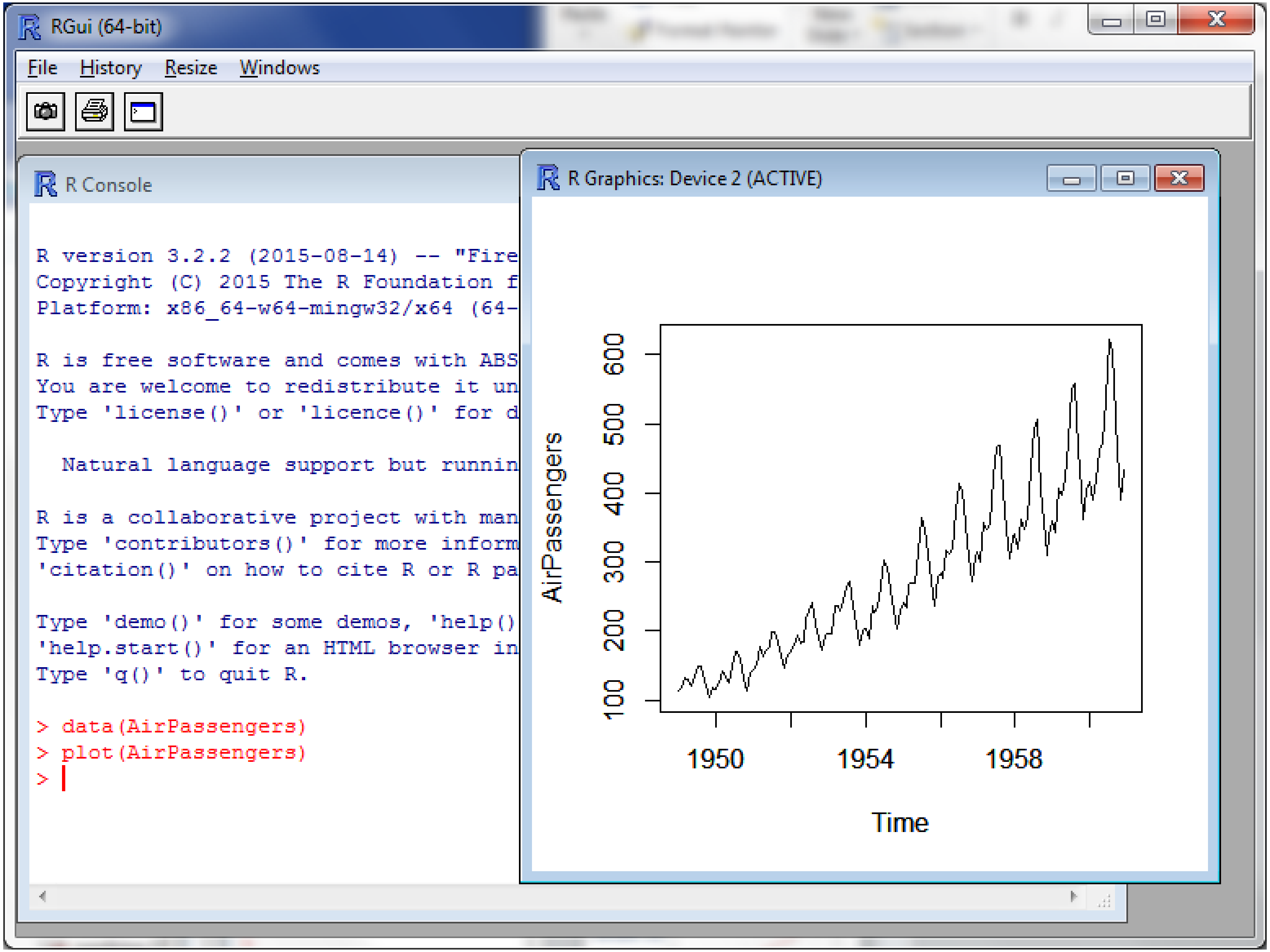
SUBSETTING DATA

- Using subset function
  - subset() will subset the dataframe
- Subscripting from data frames
  - myframe[,1] gives first column of myframe
- Using logical expressions
  - myframe[myframe[,1] < 5,] gets all rows that contain a value less than 5 in the first column
- Use the $ sign for lists and data frames
  - myframe$age gets age variable of myframe
  - attach(dataframe) -> make visible in the R environment the row/column names of the dataframe

GRAPHICS

- Plot an object, like: plot(num.vec)
  - here plots against index numbers
- Plot sends to graphic devices
  - can specify which graphic device you want
  - postscript, gif, jpeg, etc…
- Two types of plotting commands
  - high level: graphs drawn with one call (R does all the work, good results most of the time)
  - Low Level: add additional information to existing graph (i.e. a graph title, a smoothing curve, etc.) to improve quality of the graph

HIGH LEVEL: GENERATED WITH PLOT()



```
R version 3.2.2 (2015-08-14) -- "Fire
Copyright (C) 2015 The R Foundation f
Platform: x86_64-w64-mingw32/x64 (64-

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'help.start()' for an HTML browser in
Type 'q()' to quit R.

> data(AirPassengers)
> plot(AirPassengers)
> 
```
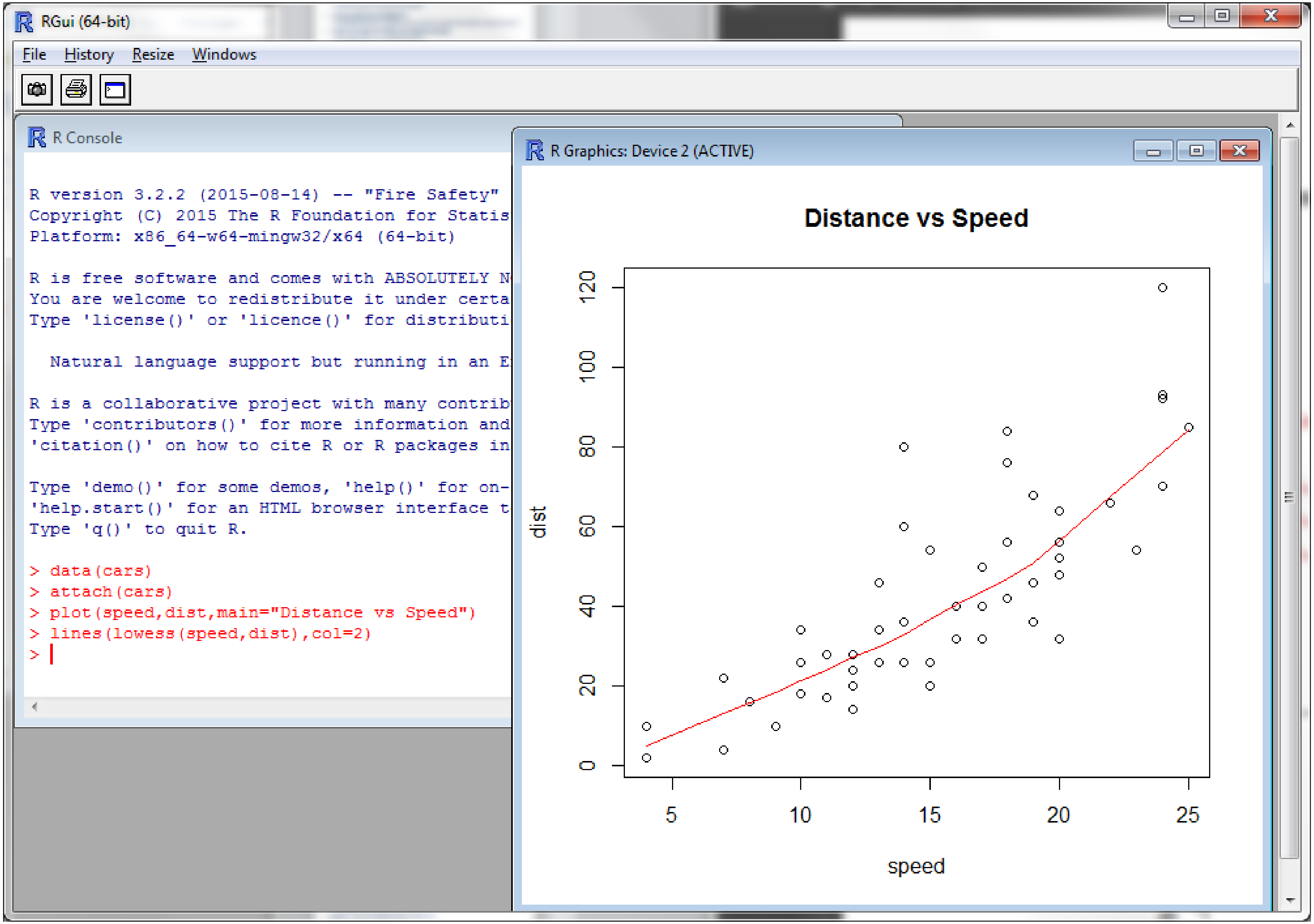

LOW LEVEL: SCATTERGRAM WITH LOWESS



```
R version 3.2.2 (2015-08-14) -- "Fire Safety"
Copyright (C) 2015 The R Foundation for Statis
Platform: x86_64-w64-mingw32/x64 (64-bit)

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Type 'demo()' for some demos, 'help()' for on-
'help.start()' for an HTML browser interface t
Type 'q()' to quit R.

> data(cars)
> attach(cars)
> plot(speed,dist,main="Distance vs Speed")
> lines(lowess(speed,dist),col=2)
> 
```

READING DATA INTO R

- R not well suited for data preprocessing
- Preprocess data elsewhere (SPSS, etc…)
- Easiest form of data to input: text file
- Spreadsheet like data:
  - Small/medium size: use read.table()
  - Large data: use scan()
- Use specialized packages to read from other systems:
  - Use the library “foreign” to read files from other statistical tools: library(“foreign”)
    - Can import from SAS, SPSS, Epi Info, can export to STATA format
  - Use the library “XLConnect” to read Excel files: library(“XLConnect”)

MORE BASIC R

```
#
# code example showing how to read/write data
#


# load internal toy data set
data(iris)

#create own copy
my.copy.of.iris <- iris

# how to extract columns from a data.frame
my.iris <-
data.frame(SepLen=iris$Sepal.Length,
           SepWid=iris$Sepal.Width,
           Species=iris$Species)

# quicker ways of extracting/removing cols
my.iris <- iris[,c(1,2,5)]
my.iris <- iris[,-c(3,4)]

# how to save/load a data set (R format)
save(my.copy.of.iris, file="mydata.RData")
mydata <- load(file="mydata.RData")
```

```
# how to save/load a data set (TAB sep. format)
write.table(iris, "myfile.dat", quote = FALSE,
             sep = "\t")
my.data <- read.table("myfile.dat",header = TRUE,
                      sep = “\t”, row.names = 1 )


# how to save/load a data set (CSV format)
write.csv(iris, "myfile.dat")
my.data <- read.csv("myfile.dat", row.names = 1)

# sometimes data is available in Excel format
# many packages can be used for this purpose
# install the XLCoonect package
install.packages("XLConnect")
library("XLConnect")

wb1 <- loadWorkbook("TP-Function.xlsx")
f1 <- readWorksheet(wbf1, sheet="F1_48")


q()
```

R PROGRAMMING STYLE

- Functions & Operators typically work on entire vectors
  - You are encouraged to write your own functions and use them

- Codes separated by newlines
  - “;” not necessary, sometimes useful to improve code clarity

- You are highly encouraged to use a lot of explicative comments to make your code easier to maintain!
  - Anything following a “#” is a comment and ignored by R

STATISTICAL FUNCTIONS IN R

- Descriptive Statistics
- Statistical Modeling
  - Regressions: Linear and Logistic
  - Probit, Tobit Models
  - Time Series
- Multivariate Functions
- A large and diverse mix of built-in packages and contributed packages

DESCRIPTIVE STATISTICS

- R has functions for all common statistics
- summary() gives lowest, mean, median, first, third quartiles, highest for numeric variables
- stem() gives stem-leaf plots
- table() gives tabulation of categorical variables

STATISTICAL MODELING

- Over 400 functions
  - lm, glm, aov, ts
- Numerous libraries & packages
  - survival, coxph, tree (recursive trees), nls, …
- Distinction between factors and regressors
  - factors: categorical, regressors: continuous
  - you must specify factors unless they are obvious to R
  - dummy variables for factors created automatically
- Use of data.frame makes life easy

HOW TO MODEL

Specify your model like this:

- y ~ x_i+c_i, where
- y = outcome variable, x_i = main explanatory variables, c_i = covariates, + = add terms
- Operators have special meanings

+ = add terms, : = interactions, / = nesting, so on…

Modeling -- object oriented

- each modeling procedure produces objects
- classes and functions for each object

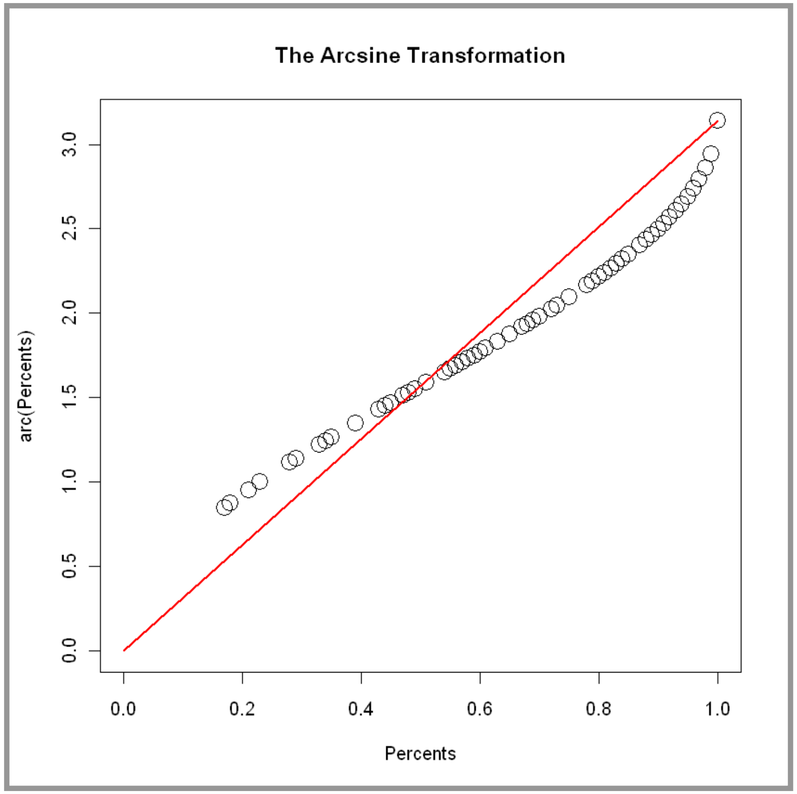
MODELING EXAMPLE: REGRESSION

```
carReg <- lm(speed~dist, data=cars)
# carReg becomes an object
# to get summary of this regression, we type
summary(carReg)

# to get only coefficients, we type
coef(carReg), or carReg$coef
# don’t want intercept? add 0, so
carReg <- lm(speed~0+dist, data=cars)
```

Functions:

```
> arc <- function(x) 2*asin(sqrt(x))
> arc(0.5)
[1] 1.570796
> x <- c(0,1,2,3,4)
> x <- x / 10
> arc(x)
[1] 0.0000000 0.6435011 0.9272952
[4] 1.1592795 1.3694384
```

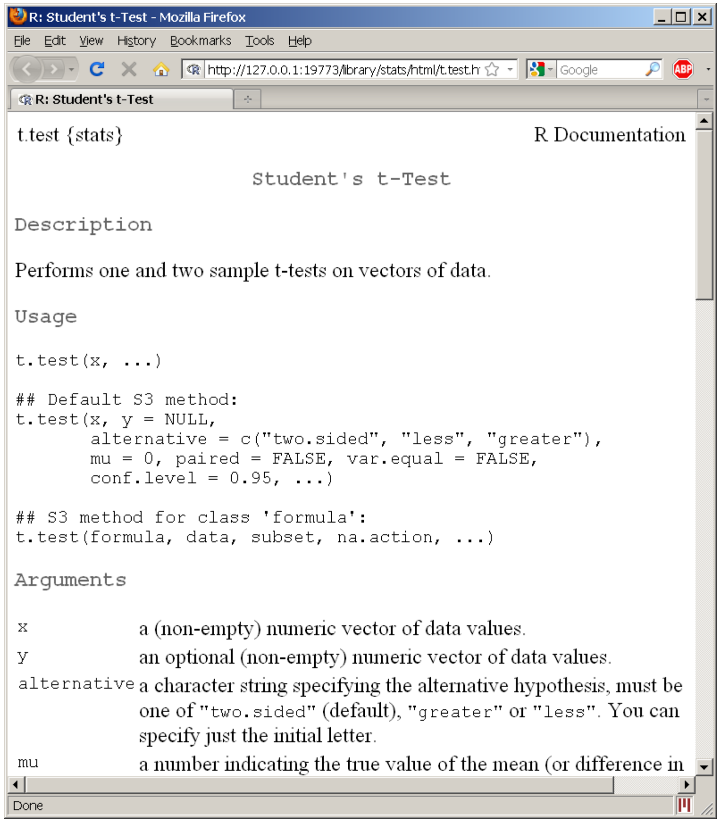


```
> plot(arc(Percents)~Percents,
+ pch=21,cex=2,xlim=c(0,1),ylim=c(0,pi),
+ main="The Arcsine Transformation")
> lines(c(0,1),c(0,pi),col="red",lwd=2)
```

INSTALLING, RUNNING, AND INTERACTING WITH R

Getting help:

```
> help(t.test)
> help.search("standard deviation")
```


R: Student's t-Test - Mozilla Firefox
File Edit View History Bookmarks Tools Help
http://127.0.0.1:19773/library/stats/html/t.test.h
Google
R: Student's t-Test
Done

t.test {stats} R Documentation

Student's t-Test

Description

Performs one and two sample t-tests on vectors of data.

Usage

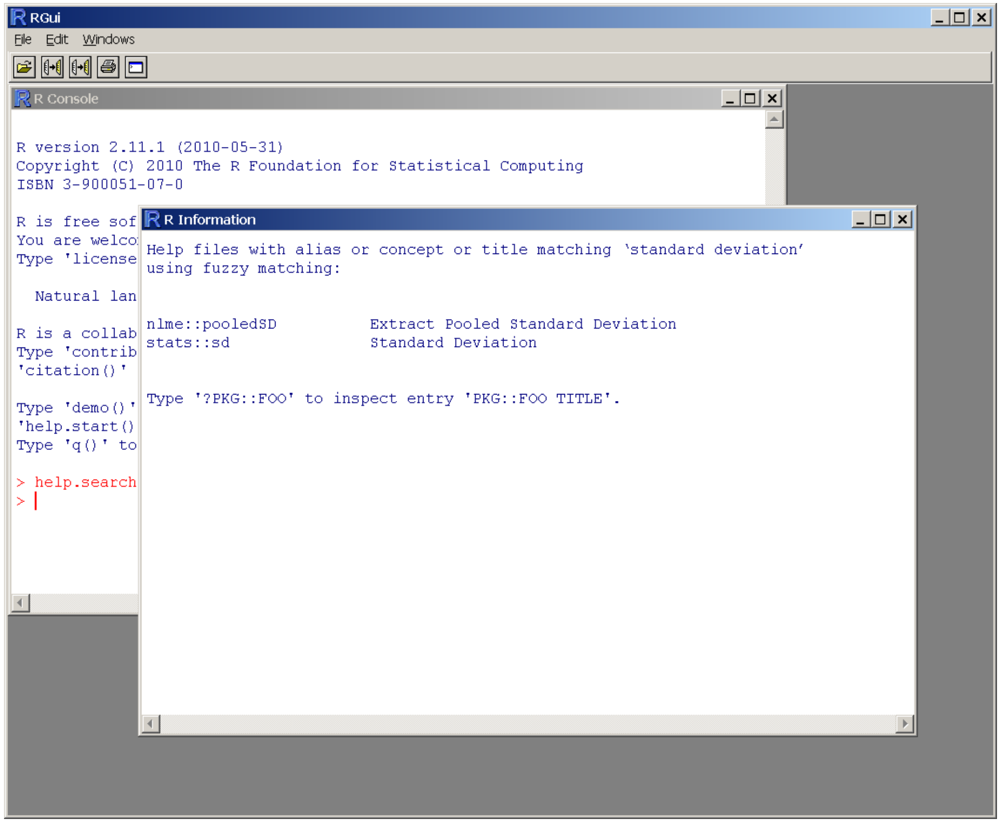
```
t.test(x, ...)

## Default S3 method:
t.test(x, y = NULL,
       alternative = c("two.sided", "less", "greater"),
       mu = 0, paired = FALSE, var.equal = FALSE,
       conf.level = 0.95, ...)

## S3 method for class 'formula':
t.test(formula, data, subset, na.action, ...)
```

Arguments

x	a (non-empty) numeric vector of data values.
y	an optional (non-empty) numeric vector of data values.
alternative	a character string specifying the alternative hypothesis, must be one of "two.sided" (default), "greater" or "less". You can specify just the initial letter.
mu	a number indicating the true value of the mean (or difference in



```
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Type 'contrib
'citation()'

Type 'demo()'
'help.start()
Type 'q()' to

> help.search
> |
```
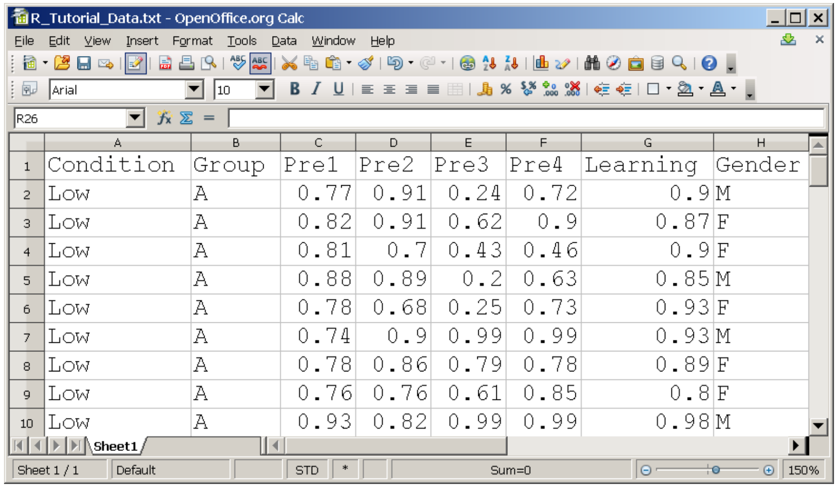
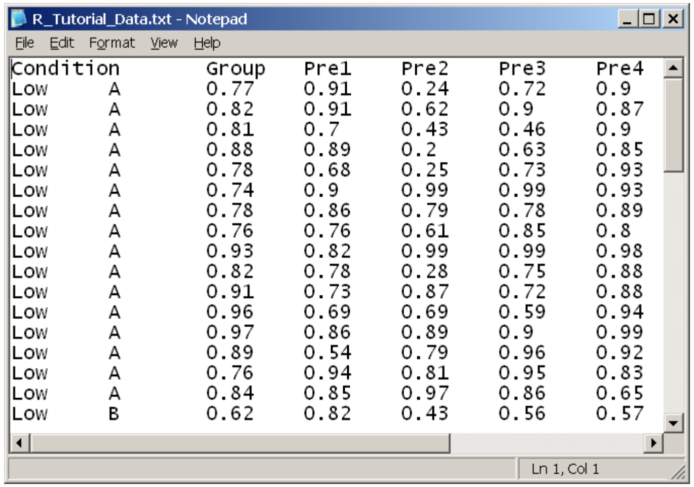

```
Help files with alias or concept or title matching 'standard deviation'
using fuzzy matching:

nlme::pooledSD          Extract Pooled Standard Deviation
stats::sd               Standard Deviation

Type '?PKG::FOO' to inspect entry 'PKG::FOO TITLE'.
```

Reading data from files:

```
> myData <- read.table("R_Tutorial_Data.txt",
+ header=TRUE, sep="\t")
> myData
   Condition Group Pre1 Pre2 Pre3 Pre4 Learning
1        Low     A 0.77 0.91 0.24 0.72     0.90
2        Low     A 0.82 0.91 0.62 0.90     0.87
3        Low     A 0.81 0.70 0.43 0.46     0.90
. . .
61      High     B 0.44 0.41 0.84 0.82     0.29
62      High     B 0.48 0.56 0.83 0.85     0.48
63      High     B 0.61 0.82 0.88 0.95     0.28
```


R_Tutorial_Data.txt - OpenOffice.org Calc
File Edit View Insert Format Tools Data Window Help
Arial
10
R26
Sheet1
Sheet 1 / 1
Default
STD
*
Sum=0
150%

	A	B	C	D	E	F	G	H
1	Condition	Group	Pre1	Pre2	Pre3	Pre4	Learning	Gender
2	Low	A	0.77	0.91	0.24	0.72	0.9	M
3	Low	A	0.82	0.91	0.62	0.9	0.87	F
4	Low	A	0.81	0.7	0.43	0.46	0.9	F
5	Low	A	0.88	0.89	0.2	0.63	0.85	M
6	Low	A	0.78	0.68	0.25	0.73	0.93	F
7	Low	A	0.74	0.9	0.99	0.99	0.93	M
8	Low	A	0.78	0.86	0.79	0.78	0.89	F
9	Low	A	0.76	0.76	0.61	0.85	0.8	F
10	Low	A	0.93	0.82	0.99	0.99	0.98	M

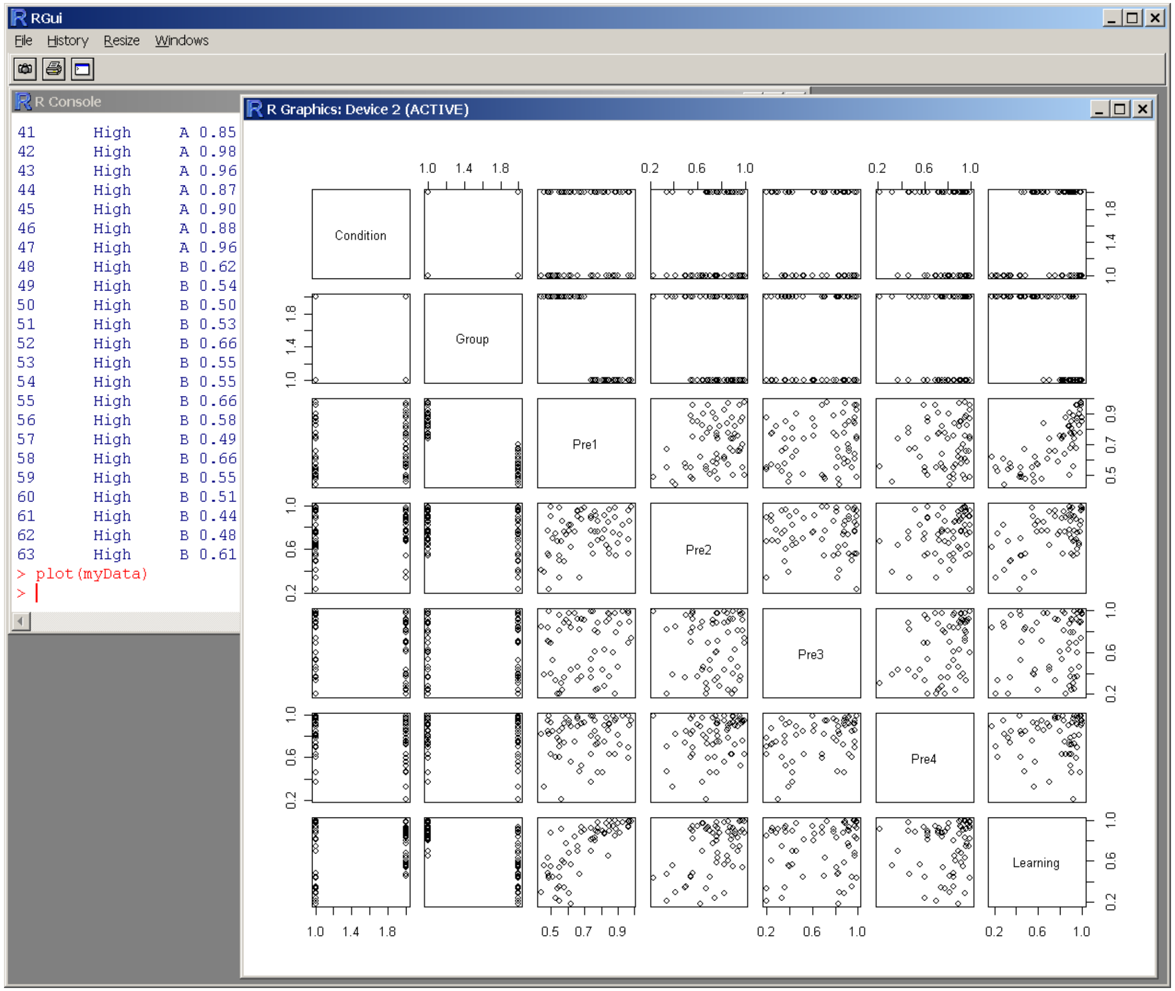


```
Condition       Group   Pre1    Pre2    Pre3    Pre4
Low     A       0.77    0.91    0.24    0.72    0.9
Low     A       0.82    0.91    0.62    0.9     0.87
Low     A       0.81    0.7     0.43    0.46    0.9
Low     A       0.88    0.89    0.2     0.63    0.85
Low     A       0.78    0.68    0.25    0.73    0.93
Low     A       0.74    0.9     0.99    0.99    0.93
Low     A       0.78    0.86    0.79    0.78    0.89
Low     A       0.76    0.76    0.61    0.85    0.8
Low     A       0.93    0.82    0.99    0.99    0.98
Low     A       0.82    0.78    0.28    0.75    0.88
Low     A       0.91    0.73    0.87    0.72    0.88
Low     A       0.96    0.69    0.69    0.59    0.94
Low     A       0.97    0.86    0.89    0.9     0.99
Low     A       0.89    0.54    0.79    0.96    0.92
Low     A       0.76    0.94    0.81    0.95    0.83
Low     A       0.84    0.85    0.97    0.86    0.65
Low     B       0.62    0.82    0.43    0.56    0.57
```

INSTALLING, RUNNING, AND INTERACTING WITH R

Examining datasets:

```
> plot(myData)
```



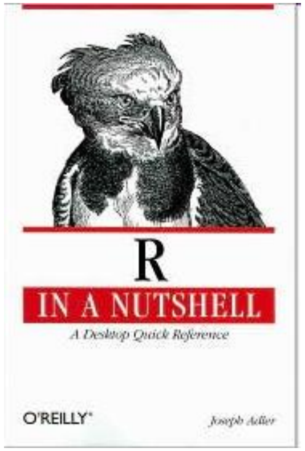
```
41          High      A 0.85
42          High      A 0.98
43          High      A 0.96
44          High      A 0.87
45          High      A 0.90
46          High      A 0.88
47          High      A 0.96
48          High      B 0.62
49          High      B 0.54
50          High      B 0.50
51          High      B 0.53
52          High      B 0.66
53          High      B 0.55
54          High      B 0.55
55          High      B 0.66
56          High      B 0.58
57          High      B 0.49
58          High      B 0.66
59          High      B 0.55
60          High      B 0.51
61          High      B 0.44
62          High      B 0.48
63          High      B 0.61
> plot(myData)
> 
```

HOW TO FIND R HELP AND RESOURCES ON THE INTERNET

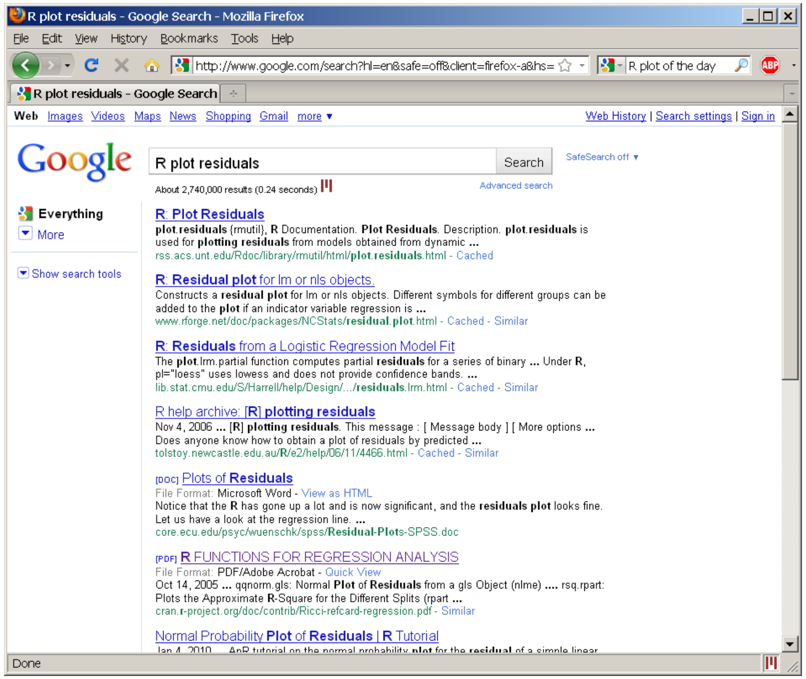
R wiki:
http://rwiki.sciviews.org/doku.php

R graph gallery:
http://addictedtor.free.fr/graphiques/thumbs.php

Kickstarting R:
http://cran.r-project.org/doc/contrib/Lemon-kickstart/



ISBN: 9780596801700


R plot residuals - Google Search - Mozilla Firefox
File Edit View History Bookmarks Tools Help
http://www.google.com/search?hl=en&safe=off&client=firefox-a&hs=
R plot of the day
R plot residuals - Google Search
Web Images Videos Maps News Shopping Gmail more ▾
Web History | Search settings | Sign in
Google
Search
SafeSearch off ▾
Advanced search
Everything
More
Show search tools
Done

R plot residuals

About 2,740,000 results (0.24 seconds)

R: Plot Residuals
plot.residuals {rmutil}, R Documentation. Plot Residuals. Description. plot.residuals is used for plotting residuals from models obtained from dynamic ...
rss.acs.unt.edu/Rdoc/library/rmutil/html/plot.residuals.html - Cached

R: Residual plot for lm or nls objects.
Constructs a residual plot for lm or nls objects. Different symbols for different groups can be added to the plot if an indicator variable regression is ...
www.rforge.net/doc/packages/NCStats/residual.plot.html - Cached - Similar

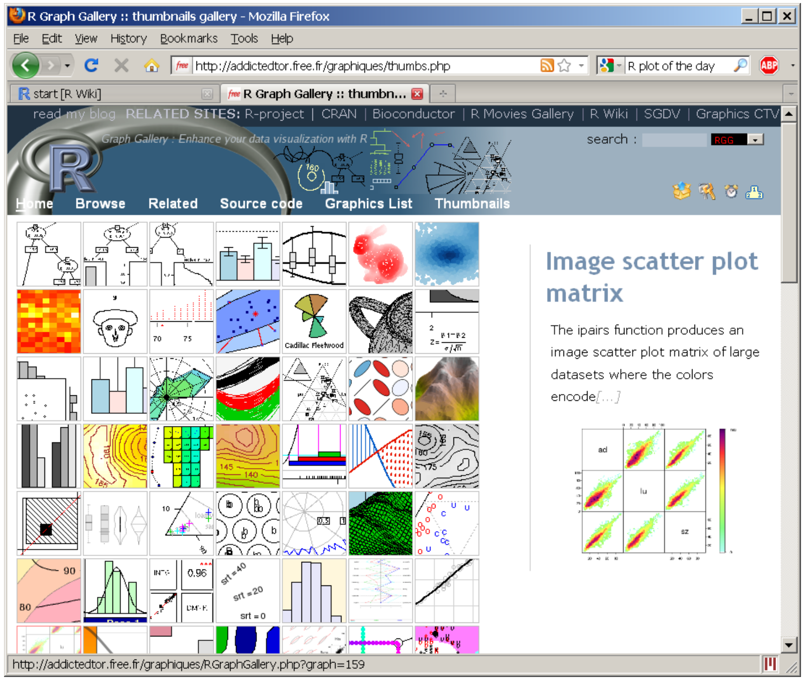
R: Residuals from a Logistic Regression Model Fit
The plot.lrm.partial function computes partial residuals for a series of binary ... Under R, pl="loess" uses lowess and does not provide confidence bands. ...
lib.stat.cmu.edu/S/Harrell/help/Design/.../residuals.lrm.html - Cached - Similar

R help archive: [R] plotting residuals
Nov 4, 2006 ... [R] plotting residuals. This message : [Message body] [More options ... Does anyone know how to obtain a plot of residuals by predicted ...
tolstoy.newcastle.edu.au/R/e2/help/06/11/4466.html - Cached - Similar

[DOC] Plots of Residuals
File Format: Microsoft Word - View as HTML
Notice that the R has gone up a lot and is now significant, and the residuals plot looks fine. Let us have a look at the regression line. ...
core.ecu.edu/psyc/wuenschk/spss/Residual-Plots-SPSS.doc

[PDF] R FUNCTIONS FOR REGRESSION ANALYSIS
File Format: PDF/Adobe Acrobat - Quick View
Oct 14, 2005 ... qqnorm.gls: Normal Plot of Residuals from a gls Object (nlme) .... rsq.rpart: Plots the Approximate R-Square for the Different Splits (rpart ...
cran.r-project.org/doc/contrib/Ricci-refcard-regression.pdf - Similar

Normal Probability Plot of Residuals | R Tutorial
Jan 4, 2010 ... AnR tutorial on the normal probability plot for the residual of a simple linear


R Graph Gallery :: thumbnails gallery - Mozilla Firefox
File Edit View History Bookmarks Tools Help
http://addictedtor.free.fr/graphiques/thumbs.php
R plot of the day
start [R Wiki]
R Graph Gallery :: thumbn...
read my blog RELATED SITES: R-project | CRAN | Bioconductor | R Movies Gallery | R Wiki | SGDV | Graphics CTV
Graph Gallery : Enhance your data visualization with R
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RGG
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lu
sz

Image scatter plot matrix

The ipairs function produces an image scatter plot matrix of large datasets where the colors encode[...]

http://addictedtor.free.fr/graphiques/RGraphGallery.php?graph=159

FOR MORE RESOURCES, CHECK OUT…

- R home page
  - http://www.r-project.org
- R discussion group
  - http://www.stat.math.ethz.ch/mailman/listinfo/r-help
- Cheat sheets:
  - https://www.rstudio.com/resources/cheatsheets/
- Search Google for R and Statistics
  - Typically the most useful hits are those from the www.stackoverflow.com blog