Introduction to computing in "R"

Practicum workshop February 6, 2008

R Console

Comments

"R" is in many ways comparable with SAS. The software is predominately syntax driven and relies on its user to known the "R" language (which in many ways resembles the "S" and UNIX programming languages). "R" is comparable in structure and conceptual arrangement to other syntax based software packages. Similarities and dissimilarities with other software packages will be pointed out to facilitate an easier transition into "R."

```
R version 2.5.1 (2007-06-27)
Copyright (C) 2007 The R Foundation for Statistical
Computing
ISBN 3-900051-07-0

R is free software and comes with ABSOLUTELY NO
WARRANTY.
You are welcome to redistribute it under certain
conditions.
Type 'license()' or 'licence()' for distribution details.
[…]
```

Upon running R the program will produce an introductory statement specifying the software version and basic helpful R commands.

```
> help( )
> search( )
> library( )
```

Several global "R" functions provide additional assistance. Such functions ending in "( )" call on all elements available in the environment.

Source R code: Saved R code
New Script: New syntax script (like .txt file)
Open script: Open a saved script
Display file(s): Open all saved "R" materials

Load Workspace: Load a previous workspace
Save Workspace: Save all your current content

Load History: Load previously saved syntax
Save History: Save all submitted syntax

Change dir: Changes the directory of temp. files, but resets to default after closing "R"

Print: Prints visible console content
Save to File: Saves visible console content

Click "Packages," then "Load package…" if the package is already installed or "Install package(s)…". Find "rgl", then click "OK".

or use the syntax

```
> install.packages("rgl")
> library(rgl)
```

"R" packages if they have already been downloaded from a CRAN mirror site can be loaded using this procedure. If the package has not been downloaded it can be installed using the "Install package(s)…" option. Also, an installed package can be loaded by specifying library(name of package).

```
> demo( )
> demo(lollipop3d)
> demo(bivar)
```

Most "R" packages will come with a demonstration of the included functions.

R Console

Comments

The "R" Environment contains the software's libraries with all the available datasets, expansion packages and macros. As compared to SAS the Log and Editor windows are consolidated into a single interface the "R" Console. "R" Environment controlling functions and options are not available over a separate window or through drop down menus as is the case in other software packages. Most, but not all, "R" Environment items must be called on using syntax.

```
> 2 + 2
[1] 4
> 2 +
+ 2
[1] 4
> 2 + (3xz
Error: syntax error, [...]
> z <- 2  # You can also type z = 2
> z
[1] 2
> 2 + (3*z)
[1] 8
```

"R" will provide intuitive error messages regarding the submitted syntax. Unlike in SPSS or SAS these comments are printed right in the console.

"R" treats all of its enetred elements as matrices and vectors, consequently, these must be conformable in order for operations to work. Also, each operation result should be stored into a new "R" object.

```
> library(MASS)
> data( )
> ?CO2
> CO2  # You can also call on CO2 [ ]
  Plant      Type  Treatment  conc uptake
1   Qn1    Quebec nonchilled  95  16.0
 [...]
```

Once a library is loaded all datasets within the library are dropped into the "R" Workspace. The Workspace is the underlying environment for the "R" Console, which acts as the temporary library catalog (like the "Work" folder in SAS).

```
> summary(CO2)
    Plant         Type       Treatment
 Qn1   : 7   Quebec   :42   nonchilled:42 [...]
> attach(CO2)
The following object(s) are masked...
> plot(CO2)
> fix (CO2)  # Change "Treatment" to "treat"
> attach(CO2)
> plot(treat, uptake)
```

General "R" operations to preliminary explore a loaded dataset. "R" will graph the loaded data intuitively or via the embedded plotting parameters.

```
> windows( )
> plot(uptake, pch=20); title("Grass Carbon Dioxide
Uptake", col.main="red")
> line(uptake)
Call:  line(uptake) [...]
> l.up <- line(uptake)
> abline( l.up, col="blue")
> abline( 30, 0, lty=4, col="green"); abline( v=60, lty=2,
col="orange")
> identify(uptake)
```

Graphs, tables, charts and all other "R" devices can only be manipulated using syntax. Also, once a graph is created added elements cannot be removed.

R Console	Comments

Objects and datasets can be imported into "R". Various forms of data can be loaded, including data files from specific statistical software packages such as SPSS, SAS etc. For the following exercise create a fictitious dataset in Notepad on your Desktop and save it as a ".txt" file.

```
> ?read.table
> example <- read.table(file="C:/Documents and
Settings/Desktop/example.txt", header=TRUE)
> example
   ID  age  GPA
1  1    23   4.0
2  2    21   3.8
[...]
> example[1,2] = 28
> example
   ID  age  GPA
1  1    28   4.0
2  2    21   3.8
[...]
```

Click "Packages," then "Load package..." and select "foreign" Click "OK".

```
> ?read.spss
```

Reading in datasets can problematic. Most issues can be resolved by knowing the dataset beforehand (i.e. how many variables are there, are variable labels included etc.).

```
> ?linear.model
No documentation for 'linear.model'  [...]
> help.search("linear model")
> ? lm
> lm
function (formula, data, subset, weights,
na.action, [...]
```

Any function documentation can be read by preceding the function with a "?." If the function is invalid, undefined or simply does not exists use the alternative help.search("") instead.

```
> length(uptake)
[1] 84
> s.pre <- sort ( sample (1:400, 84, replace=TRUE) )
> plot( s.pre )
> s.up <- sort(uptake)
> plot( s.pre, s.up, pch=20)
```

One of the most important steps in computing / programming in "R" is to ascribe the reults of operations to new "R" objects. In return these "R" objects are used in other operations building more complex and useful functions.

```
> lm.uptake <- lm( s.up ~ s.pre )
> lm.uptake
Call:
lm(formula = s.up ~ s.pre)  [...]
> summary (lm.uptake)
> lm.uptake [ ]

> abline(lm.uptake, lty=3, col="purple", lwd=3)
> plot (lm.uptake)
```

Functions which come from "R" packages usually have built in graphic, analtytic and output stipulations.

R Console

Comments

The "R" software packages deals quite differently with missing data than SPSS or SAS. In "R" a missing number is indicated with a "NA," Not Avaiable, and missing non-numbers with "NaN," Not a Number. It is vital to remember that once missing values are coded in a dataset it is very problematic operating with that particular dataset or reveresing the coding.

```
> up.res <- lm.uptake$residuals
> summary(up.res)
> plot(up.res)
> abline(0,0); abline(-2,0, col="red")
```

Individual variables from datasets or elements from output lists can be stored seperately into new "R" objects using the assign procedures and specifying the object (using the "$" sign).

```
> up.res
        1         2         3
-2.83362861 -1.33157849 -0.32747827  [...]
> res.trans <- function(x) { sqrt(x+2) }
> up.trans <- res.trans ( up.res )
 Warning message:
NaNs produced in: sqrt(x+2)
> up.trans
      1         2         3
    NaN 0.8175705 1.2932601  [...]
> windows ( )
> plot(up.trans)
```

When a called-on function produces NaNs or NAs "R" will complete the function but replace those values which have caused the error. "R" will also inform you with a warning message imbeded in the console.

```
> is.nan( up.trans )
   1     2     3        83    84
 TRUE FALSE FALSE  [...] TRUE  TRUE
> up.trans [1]
  1
NaN
> up.trans [1] <- 0
> up.trans
   1         2       3          84
 0.0000  0.8175  1.2932  [...]  NaN
> is.nan(up.trans)
   1     2     3        83    84
FALSE FALSE FALSE  [...] TRUE  TRUE
```

NaNs and NAs can be detected with logic functions. Infividual NaNs or NAs can be replaced by assigning a new number (scalar) to the particular spot in the vector or dataset.

```
> ?ifelse
> up.fix <- ifelse ( is.nan(up.trans), 3, up.trans )
> up.fix
   1         2       3          84
 0.0000  0.8175  1.2932  [...]  0.0000
> windows( )
> plot( up.fix )
> is.nan( up.fix )
   1     2     3         83    84
FALSE FALSE FALSE  [...] FALSE  FALSE
```

The replacement of NaNs and NAs in an entire vector/matrix has to be done by a conjunct work function (ifelse) and logic function (is.nan or is.na). As compared to individually exchanged integers "R" will remember in its registry (if the original dataset was a dataframe) that those NaNs and NAs replaced by such a function were once not a real number.

R Console Comments

"R" datasets and created objects are manipulated and managed through the "R" Workspace Image. These objects can be exported and saved into various target files.

```
> length(up.fix)
[1] 84
> fix.data <- matrix (up.fix, 12, 7)
> fix.data
          [,1]            [,2]
 [1,] 0.0000000    0.8709916
 [2,] 0.8175705    0.8191014  [...]
> fix(fix.data) # Assign some variable names
```

Data can be transformed into any desirable form. Matrix, dataframe and general data functions make such transformations from single vectors (or arrays) fairly simple.

```
> ?write.table
> write.table (fix.data, file="sample_data.txt")

or

> write.table (fix.data, file="C:/Documents and
Settings/Desktop/sample_data.txt", col.names = TRUE)
```

Data objects can be exported (saved) as one of many desirable formats such as ".txt", ".csv", or ".dbf" files all of which can be either comma, space or character seperated with or without variable and/or case labels included.

```
> ? ls
> ls ( )
[1] "a"         "age"
 [6] "Brand"   "calorie"[...]

> ? rm

> up.fix
   1      2      3
0.00  0.82  1.29 [...]
> rm (up.fix)
> up.fix
Error: object "up.fix" not found
> ls ( )

> rm ( list = ls( ) )
> ls ( )
character(0)
```

Objects in the Workspace Image can be monitored and managed using the *list objects* and *remove objects* function. However, objects removed from the Workspace Image will not be saved.

Last but not least your shouold try to save some of the created objects and syntax so as to learn how to save your workspace for "R" but also to get a sense for the nature of the saved files (see Appendix A). Remember, that unless you change the directory, either manually by designating a new temporary directory from the File menue, or by specifying a specific path to your exported files, "R" wil lsave everything to the defualt "R" system catalog.

Also, if you ever have a question regarding programming in "R" do not hesitate to use the "R" mailing list. Individuals contributing to this mailing list are not only highly knowledgable but also exceptionally helkpful. Often you will get new and imporved ideas (approaches) by interacting with others. That said, do not always take every piece of advice as absolute truth (in particular regarding statistics). To err is to be human. Verify and double check.

Appendix A
The "R" Environment
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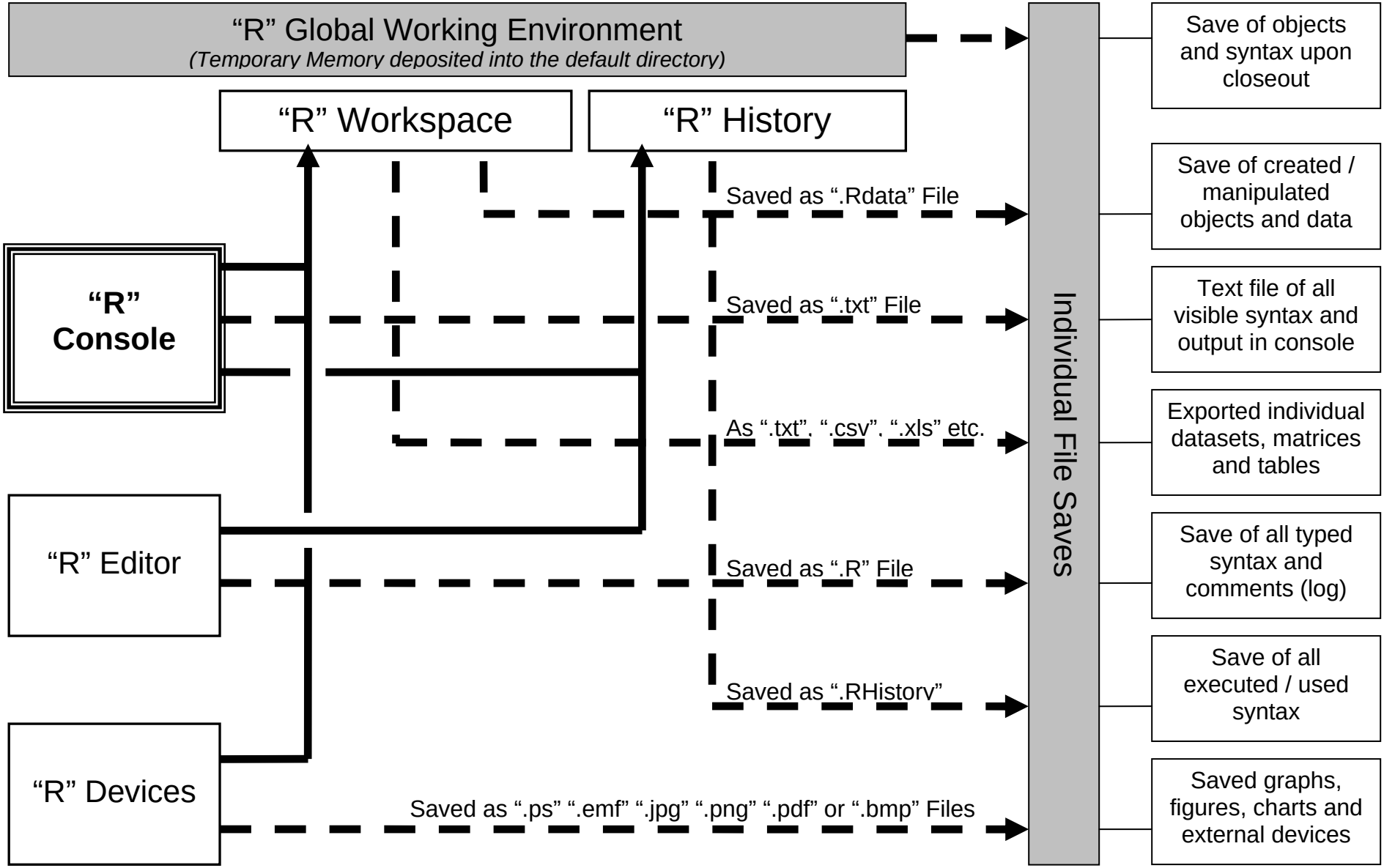

Appendix B
Useful Free "R" Manuals

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1) **R Installation and Administration** (60 pages)
By R Development Core Team

Available: http://cran.r-project.org/doc/manuals/R-admin.pdf

Content:
1 Obtaining R
2 Installing R under Unix-alikes
3 Installing R under Windows
4 Installing R under Mac OS X
5 Running R
6 Add-on packages
7 Internationalization and Localization
8 Choosing between 32- and 64-bit builds
9 The standalone Rmath library

2) **R Internals** (34 Pages)
By R Development Core Team

Available: http://cran.r-project.org/doc/manuals/R-ints.pdf

Content:
1 R Internal Structures
2 .Internal vs .Primitive
3 Internationaliation in the R sources
4 R coding standards
5 Testing R code

3) **The R Reference Index** (2667 pages)
By R Development Core Team

Available: http://cran.r-project.org/doc/manuals/fullrefman.pdf

Content:
1 The base package
2 The datasets package
3 The grDevices package
4 The graphics package
5 The grid package
6 The methods package
7 The stats package
8 The tools package
9 The utils package
10 The KernSmooth package
11 The MASS package
12 The boot package

13 The class package
14 The cluster package
15 The codetools package
16 The foreign package
17 The lattice package
18 The mgcv package
19 The nlme package
20 The nnet package
21 The rcompgen package
22 The rpart package
23 The spatial package
24 The splines package
25 The stats4 package
26 The survival package
27 The tcltk package

4) **An Introduction to R** (100 pages)
By W. N. Venables, D. M. Smith and the R Development Core Team

Available: http://cran.r-project.org/doc/manuals/R-intro.pdf

Content:
1 Introduction and preliminaries
2 Simple manipulations; numbers and vectors
3 Objects, their modes and attributes
4 Ordered and unordered factors
5 Arrays and matrices
6 Lists and data frames
7 Reading data from _les
8 Probability distributions
9 Grouping, loops and conditional execution
10 Writing your own functions
11 Statistical models in R

5) **R Language Definition** (60 pages)
By R Development Core Team

Available: http://cran.r-project.org/doc/manuals/R-lang.pdf

Content:
1 Introduction
2 Objects
3 Evaluation of expressions
4 Functions
5 Object-oriented programming
6 Computing on the language
7 System and foreign language interfaces
8 Exception handling
9 Debugging
10 Parser

6) **R Data Import / Export** (34 pages)
By R Development Core Team

Available: http://cran.r-project.org/doc/manuals/R-data.pdf

Content:
1 Introduction
2 Spreadsheet-like data
3 Importing from other statistical systems
4 Relational databases
5 Binary _les
6 Connections
7 Network interfaces
8 Reading Excel spreadsheets

7) **simpleR – Using R for Introductory Statistics** (114 pages)
By John Verzani

Available: http://cran.r-project.org/doc/contrib/Verzani-SimpleR.pdf

Content:
1 Introduction
2 Data
3 Univariate Data
4 Bivariate Data
5 Multivariate Data
6 Random Data
7 Simulations
8 Exploratory Data Analysis
9 Confidence Interval Estimation
10 Hypothesis Testing
11 Two-sample Test
12 Chi-square Test
13 Regression Analysis
14 Multiple Regression Analysis
15 Analysis of Variance

8) **Writing R Extensions** (125 pages)
By R Development Core Team

Available: http://cran.r-project.org/doc/manuals/R-exts.pdf

Content:
1 Creating R packages
2 Writing R documentation _les
3 Tidying and pro_ling R code
4 Debugging
5 System and foreign language interfaces
6 The R API: entry points for C code
7 Generic functions and methods
8 Linking GUIs and other front-ends to R

9) **Practical Regression and ANOVA using R** (213 pages)
Julian J. Faraway

Available: http://probability.ca/cran/doc/contrib/Faraway-PRA.pdf

Content:
1 Introduction
2 Estimation
3 Inference
4 Errors in Predictors
5 Generalized Least Squares
6 Testing for Lack of Fit
7 Diagnostics
8 Transformation
9 Scale Changes, Principal Components and Collinearity
10 Variable Selection
11 Statistical Strategy and Model Uncertainty
12 Chicago Insurance Redlining - a complete example
13 Robust and Resistant Regression
14 Missing Data
15 Analysis of Covariance
16 ANOVA

10) **R Manual to Accompany Agresti's Categorical Data Analysis (2002)** (278 pages)
By Laura A. Thompson

Available: https://home.comcast.net/~lthompson221/Splusdiscrete2.pdf

Content:
Introduction and Changes from First Edition
1 Distributions and Inference for Categorical Data
2 Describing Contingency Tables
3 Inference for Contingency Tables
4 Generalized Linear Models
5 Logistic Regression
6 Building and Applying Logistic Regression Models
7 Logit Models for Multinomial Responses
8 Loglinear Models for Contingency Tables
9 Building and Extending Loglinear Models
10 Models for Matched Pairs
11 Analyzing Repeated Categorical Response Data
12 Random Effects
13 Other Mixture Models for Categorical Data

Appendix C
Additional "R" Web Resources

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1) **The R Project for Statistical Computing**
R Development Core Team

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

2) **R-help – Main R Mailing List**
Community Contributed

https://www.stat.math.ethz.ch/mailman/listinfo/r-help

3) **R-Cookbook.com Delicious Statistical Recipes**
Creative Commons

http://www.r-cookbook.com/

4) **Using R for Psychological Research**
William Revelle, Northwestern University

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

5) **R Graphical Manuals**
Osamu Ogasawara and IMS Lab Inc. (designed by CMG Technologies)

http://cged.genes.nig.ac.jp/RGM2/index.php

6) **R Tutorials**
Kelley Black, Department of Mathematics, Union College

http://www.cyclismo.org/tutorial/R/

7) **Animated Statistics Using R**
Yihui Xie

http://r.yihui.name/intro/documentations/index.htm

8) **The Omega Project for Statistical Computing**
Omega Project and Doug Bates

http://www.omegahat.org/

9) **R Help @ MC**
Center for Mathematical Sciences, Lund University

http://www1.maths.lth.se/help/R/

Appendix D
Useful "R" Functions and Syntax

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R reference card, by Jonathan Baron

Parentheses are for functions, brackets are for indicating the position of items in a vector or matrix. (Here, items with numbers like x1 are user-supplied variables.)

Miscellaneous

q(): quit
<-: assign
INSTALL package1: install package1
m1[,2]: column 2 of matrix m1
m1[,2:5] or m1[,c(2,3,4,5)]: columns 2–5
m1$a1: variable a1 in data frame m1
NA: missing data
is.na: true if data missing
library(mva): load (e.g.) the mva package

Help

help(command1): get help with command1 (NOTE: USE THIS FOR MORE DETAIL THAN THIS CARD CAN PROVIDE.)
help.start(): start browser help
help(package=mva): help with (e.g.) package mva
apropos("topic1") and help.search("topic1"): commands relevant to topic1
example(command1): examples of command1

Input and output

source("file1"): run the commands in file1.
read.table("file1"): read in data from file1
data.entry(): spreadsheet
scan(x1): read a vector x1
download.file("url1"): from internet
url.show("url1"), read.table.url("url1"): remote input
sink("file1"): output to file1, until sink()
write(object1, "file1"): writes object1 to file1
write.table(dataframe1,"file1"): writes a table

Managing variables and objects

attach(x1) detach(x1): put (remove) x1 in search path
ls(): lists all the active objects.
str(object1): print useful information about object1
rm(object1): remove object1
dim(matrix1): dimensions of matrix1
dimnames(x1): names of dimensions of x1
length(vector1): length of vector1
1:3: the vector 1,2,3
c(1,2,3): creates the same vector
rep(x1,n1): repeats the vector x1 n1 times
cbind(a1,b1,c1), rbind(a1,b1,c1): binds columns or rows into a matrix
merge(df1,df2): merge data frames
matrix(vector1,r1,c1): make vector1 into a matrix with r1 rows and c1 columns
data.frame(v1,v2): make a data frame from vectors v1 and v2
as.factor(), as.matrix(), as.vector(): conversion
is.factor(), is.matrix(), is.vector(): what it is
t(): switch rows and columns
which(x1==a1): returns indices of x1 where x1==a1

Control flow

for (i1 in vector1): repeat what follows
if (condition1) ...else ...: conditional

Arithmetic

%*%: matrix multiplication
%/%, ^, %%, sqrt(): integer division, power, modulus, square root

Statistics

max(), min(), mean(), median(), sum(), var(): as named
summary(data.frame): prints statistics
rank(), sort() rank and sort
ave(x1,y1): averages of x1 grouped by factor y1
by(): apply function to data frame by factor
apply(x1,n1,function1): apply function1 (e.g. mean) to x by rows (n1=1) or columns (n2=2)
tapply(x1,list1,function1): apply function to x1 by list1
table(): make a table
tabulate(): tabulate a vector

basic statistical analysis

aov(), anova(), lm(), glm(): (generalized) linear models, anova
t.test(): t test
prop.test(), binom.test(): sign test
chisq.test(x1): chi-square test on matrix x1
fisher.test(): Fisher exact test
cor(a): show correlations
cor.test(a,b): test correlation
friedman.test(): Friedman test

some statistics in mva package

prcomp(): principal components
kmeans(): kmeans cluster analysis
factanal(): factor analysis
cancor(): canonical correlation

Graphics

plot(), barplot(), boxplot(), stem(), hist(): basic plots
matplot(): matrix plot
pairs(matrix): scatterplots
coplot(): conditional plot
stripplot(): strip plot
qqplot(): quantile-quantile plot
qqnorm(), qqline(): fit normal distribution