R

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Outline

1. Overview
2. Quick Get Started
3. Object-Oriented Programming
4. Input and Output
5. Data Visualization

Next

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   - Data Aanlysis and R
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Data Analysis

Wikipedia

Analysis of data is a process of inspecting, cleaning, transforming, and modeling data with the goal of discovering useful information, suggesting conclusions, and supporting decision making.

Data Analysis

Collecting → cleaning → transforming → modeling → visualizing

Biological Data Analysis

NGS and Complex Diseases

Sequencing → QC → Alignment and Variant Calling→ GWAS, EWAS ...→ Manhattan Plot, Q-Q plot ...

Biological Data Analysis

NGS and Complex Diseases

Sequencing → QC → Alignment and Variant Calling→ GWAS, EWAS ...→ Manhattan Plot, Q-Q plot ...
→ paper

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What is R?

R

R is a free software environment for statistical computing and graphics.
----R-project.org

History

- April 1st, 1997, R0.16，奥克兰大学的Ihaka和Gentleman发布了第一版本的R
- 1997年4月23日，0.49，CRAN网站发布，提供12个R的扩展包
- 1997年12月5日，0.60，R成文GNU项目的一部分
- 2000年2月29日，1.0，第一个可用于生产环境的版本发布
- 2010年4月22日，2.11，支持64位Windows操作系统
- 2011年10月31日，2.14，提供全新的并行计算包
- 2013年4月，3.0.0
- Now, 3.1.2

R语言在中国

- 2004年，国内专业人员开始翻译R语言官方文档
- 2006年，国内开始出版R语言书籍
- 2008年，在北京中国人民大学召开第一届中国R语言会议
- 2009年-2012年，每年分别在北京和上海举办中国R语言会议，迄今已举办五届
- 2012年，国人开发的Knitr包几乎成为R语言文档自动化的新标准，同时大量R语言畅销书籍被引进到国内翻译出版。
- 2013年，《R语言实战》、《ggplot2》、《R in a nutshell》 …

R语言的现状

- 使用领域囊括统计分析、数据挖掘、生命科学、商业智能、数据可视化、社交网络分析、电子商务、集成电路、金融、烟草、传媒、咨询等
- 赞助R语言开发工作的机构包括AT&T、默沙东、Google、新西兰电信，以及诸多大学及科研机构。
- 在商业产品中提供R语言支持的企业包括SAP、甲骨文、Teredata、IBM、Revolution、Matlab、SAS、SPSS等。
- 2012第五届中国R语言会议（上海会场）获得大量赞助，吸引了400多人注册，到会人员几乎涉及R所有应用领域的国内知名企业。
- 2013年第六届中国R语言会议（北京，5月；上海，1112月）。

Pros and Cons

The best thing about R is that it was developed by statisticians. The worst thing about R is that...it was developed by statisticians.
--- Bo Cowgill

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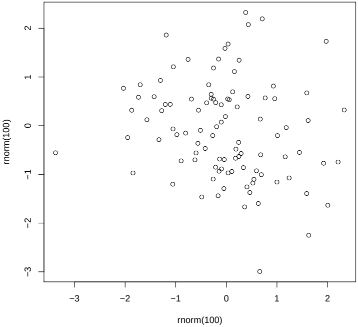
Hello R!

```
print("Hello R!")

## [1] "Hello R!"
```

Hello Plot

```
plot(rnorm(100),rnorm(100))
```



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Download and Installation

Download

CRAN

Installation

- R: Linux, Mac OS, Windows
- Rtools: Windows
- packages: CRAN, devtools, github, local file

Editors and IDEs

Editors

- R terminal
- Rgui
- VIM + Vim-R-plugin
- Emacs + ESS
- Notepad++ + NppToR
- ...

R Terminal and Rgui

R

- Ctrl + R: run
- Tab: auto complete
- arrow up and down: history

R and Texteditor

- copy and paste
- `source("source.R")`

source

```
sourceDir <- function(path, trace = TRUE, ...) {
       for (nm in list.files(path, pattern = "[.][RrSsQq]$")) {
          if(trace) cat(nm,":")
          source(file.path(path, nm), ...)
          if(trace) cat("\n")
       }
    }
```

VIM + Vim-R-plugin

Notepad++ + NppToR

Emacs + ESS

What is ESS?

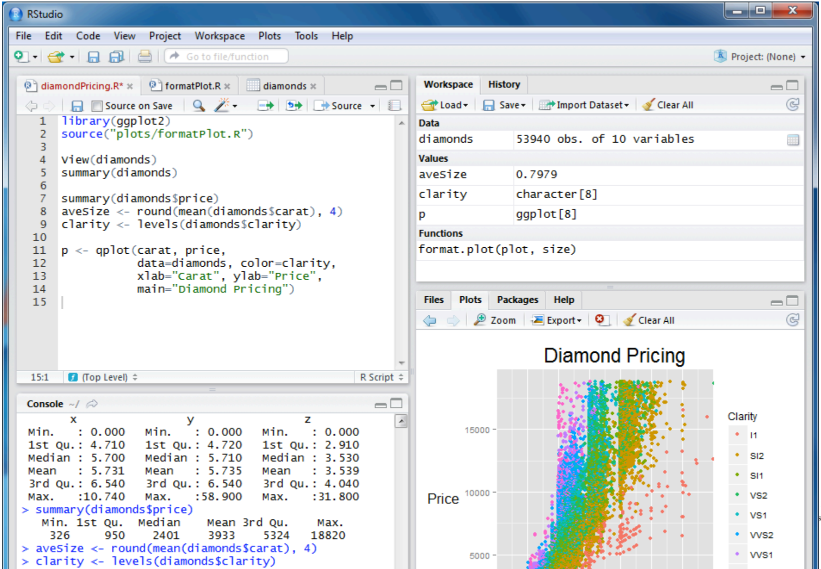
ESS: Emacs Speak Statistics

IDEs

IDEs

- RStudio: local and cloud-based
- TinnR
- StatET: eclipse for R
- ...

RStudio



RStudio
File Edit Code View Project Workspace Plots Tools Help
Go to file/function
Project: (None)
diamondPricing.R* formatPlot.R diamonds
Source on Save
Source
15:1 (Top Level) R Script
Workspace History
Load Save Import Dataset Clear All
Files Plots Packages Help
Zoom Export Clear All
Console ~/
Diamond Pricing
Price
15000
10000
5000
Clarity
I1
SI2
SI1
VS2
VS1
VVS2
VVS1

```r
library(ggplot2)
source("plots/formatPlot.R")

View(diamonds)
summary(diamonds)

summary(diamonds$price)
aveSize <- round(mean(diamonds$carat), 4)
clarity <- levels(diamonds$clarity)

p <- qplot(carat, price,
           data=diamonds, color=clarity,
           xlab="Carat", ylab="Price",
           main="Diamond Pricing")
```

Data

diamonds	53940 obs. of 10 variables

Values

aveSize	0.7979
clarity	character[8]
p	ggplot[8]

Functions

format.plot(plot, size)

```
        x                 y                 z
 Min.   : 0.000   Min.   : 0.000   Min.   : 0.000
 1st Qu.: 4.710   1st Qu.: 4.720   1st Qu.: 2.910
 Median : 5.700   Median : 5.710   Median : 3.530
 Mean   : 5.731   Mean   : 5.735   Mean   : 3.539
 3rd Qu.: 6.540   3rd Qu.: 6.540   3rd Qu.: 4.040
 Max.   :10.740   Max.   :58.900   Max.   :31.800
> summary(diamonds$price)
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
    326     950    2401    3933    5324   18820
> aveSize <- round(mean(diamonds$carat), 4)
> clarity <- levels(diamonds$clarity)
```

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Books

- R in action (also in Chinese)
- Introduction to R (also in Chinese)
- R for beginner (also in Chinese)
- R in a Nutshell (Chinese version is in press)
- The art of R programming (also in Chinese)
- ggplot2. Elegant Graphics for Data Analysis (also in Chinese)

Websites

- R-project and CRAN
- COS.name (Chinese)
- Quick-R
- http://had.co.nz/, Hadley Wickham
- Twitter, github, RForge
- Google

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- Quick-R
- http://had.co.nz/, Hadley Wickham
- Twitter, github, RForge
- Google Baidu?

Journals

- The R Journal
- Journal of Statistical Software

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Class, Type and Dimension

Class, Type and Dimension

Everything in R is a object, every object has class, type and dimension.

```r
class(obj)
typeof(obj)
dim(obj)
```

Data Types

```
## Error in library(GenomicRanges): there is no
package called 'GenomicRanges'
```

```
obj <- 1
class(obj)
```

```
## [1] "numeric"
```

```
obj <- "Gang Chen"
class(obj)
```

```
## [1] "character"
```

```
obj <- 1:3
class(obj)
```

```
## [1] "integer"
```

```
ranges <- GRanges(seqnames = c("chr1", "chr2"),
ranges = IRanges(start = c(1013, 4351),
end = c(2314, NA), width = c(NA, 1)),
strand = c("+", "-"))
```

```
class(list(a = 1, b = 2))
```

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

```
class(matrix(1:16, ncol=4))
```

```
## [1] "matrix"
```

```
class(array(1:64, c(4,4,4)))
```

```
## [1] "array"
```

```
obj <- as.data.frame(obj)
class(obj)
```

```
## [1] "data.frame"
```

```
obj <- as.factor(c("male", "female"))
```

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Types

```
 obj <- 1
 class(obj)
## [1] "numeric"
 obj <- 1:3
 class(obj)
## [1] "integer"
 obj <- 1+2i
 class(obj)
## [1] "complex"
```

Operations

Operators

- `+, -, *, /, ==, =, <-`
- `^`
- `exp(), log(), log10(), log2()`
- `sqrt(), abs(), sin(), cos()`
- `round(), floor(), ceriling()`
- `factorial()`

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Character

A character object is used to represent string values in R.

```
fname <- "Gang"
lname <- "Chen"
class(fname)

## [1] "character"
```

```
myPI <- 3.14
class(myPI)

## [1] "numeric"

myPI <- as.character(myPI)
class(myPI)

## [1] "character"
```

Character Operators

```
paste(fname, lname)

## [1] "Gang Chen"

substr("I am learning R", start=6, stop=13)

## [1] "learning"

sub("I am", "We are", "I am learning R")

## [1] "We are learning R"
```

Regular Expression

Regular Expressions == Problem

Some people,
when confronted with a problem,
think "I know, I'll use regular expressions."
Now they have two problems.

Regular Expression in R

Regular Expression Functions

```
help(regex)
grep(), grepl(), regexpr(), gregexpr(), sub(), gsub()
```

Example

```
grep("a.", c("Gang","Chen","aab", "Ag","ga"))
```

```
## [1] 1 3
```

Logical

```
 u = TRUE; v = FALSE
 u & v # u AND v

## [1] FALSE

 u | v # u OR v

## [1] TRUE

 !u # negation of u

## [1] FALSE
```

?

```
4.3 - 0.7

## [1] 3.6

4.3 - 0.7 == 3.6

## [1] FALSE

0.7 + 3.6 == 4.3

## [1] TRUE
```

```
4.2 / 6

## [1] 0.7

0.7 * 6

## [1] 4.2

4.2 / 6 == 0.7

## [1] FALSE
```

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Vector

A vector is a sequence of data elements of the same basic type.

```
a = c(1,2,3)
b = c(T, F, F, T)
chars = c("Gang", "Chen", "AA", "Aa","aB")
```

Arithmetic operations of vectors are performed memberwise.

All operators are applied to vectors

```
 a^2

## [1] 1 4 9

 !b

## [1] FALSE  TRUE  TRUE FALSE

 grep("a.",chars)

## [1] 1 5
```

Vector Arithmetic

```
 a = c(1,2,3,4,5)
 b = c(5,4,3,2,1)
 c(a, b)

##  [1] 1 2 3 4 5 5 4 3 2 1

 a + b

## [1] 6 6 6 6 6

 a * b

## [1] 5 8 9 8 5
```

Recycling Rule:

```
 d = c(1,2)
 a + d

## Warning in a + d:


## [1] 2 4 4 6 6
```

Vector Index

```
a = c("one", "two", "three", "four", "five")
a[3]

## [1] "three"

a[2:4]

## [1] "two"   "three" "four"

a[-3]

## [1] "one"  "two"  "four" "five"

a[8]

## [1] NA
```

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Matrix Construction

```
mat = matrix(1:24, ncol=6, nrow=4, byrow=T)
mat
```

```
##      [,1] [,2] [,3] [,4] [,5] [,6]
## [1,]    1    2    3    4    5    6
## [2,]    7    8    9   10   11   12
## [3,]   13   14   15   16   17   18
## [4,]   19   20   21   22   23   24
```

Matrix Index

```
mat[3,3]

## [1] 15

mat[2,]

## [1]  7  8  9 10 11 12

mat[,4]

## [1]  4 10 16 22
```

```
mat[2:3, 3:4]

##      [,1] [,2]
## [1,]    9   10
## [2,]   15   16

dim(mat)

## [1] 4 6

ncol(mat)

## [1] 6

nrow(mat)
```

Matrix Arithmetic

```
A
```

```
##      [,1] [,2] [,3] [,4]
## [1,]    1    5    9   13
## [2,]    2    6   10   14
## [3,]    3    7   11   15
## [4,]    4    8   12   16
```

```
A * B
```

```
##      [,1] [,2] [,3] [,4]
## [1,]    1   25   81  169
## [2,]    4   36  100  196
## [3,]    9   49  121  225
## [4,]   16   64  144  256
```

```
B
```

```
##      [,1] [,2] [,3] [,4]
## [1,]    1    5    9   13
## [2,]    2    6   10   14
## [3,]    3    7   11   15
## [4,]    4    8   12   16
```

```
A %*% B
```

```
##      [,1] [,2] [,3] [,4]
## [1,]   90  202  314  426
## [2,]  100  228  356  484
## [3,]  110  254  398  542
## [4,]  120  280  440  600
```

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List

A list is a generic vector containing other objects.

```
n = c(2, 3, 5)
s = c("aa", "bb", "cc", "dd", "
b = c(TRUE, FALSE, TRUE, FALSE,
x = list(n, s, b, 3)
```

```
x

## [[1]]
## [1] 2 3 5
##
## [[2]]
## [1] "aa" "bb" "cc" "dd" "ee"
##
## [[3]]
## [1]  TRUE FALSE  TRUE FALSE FA
##
## [[4]]
## [1] 3
```

List Slice

```
 x[1]

## [[1]]
## [1] 2 3 5

 x[c(2,4)]

## [[1]]
## [1] "aa" "bb" "cc" "dd" "ee"
##
## [[2]]
## [1] 3
```

List Member

```
 x[[3]]

## [1]  TRUE FALSE  TRUE FALSE FALSE

 x[3]

## [[1]]
## [1]  TRUE FALSE  TRUE FALSE FALSE
```

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Data Frame

A data frame is used for storing data tables. It is a list of vectors of equal length.

```
head(mtcars)
```

```
##                    mpg cyl disp  hp drat    wt  qsec vs am gear car
## Mazda RX4         21.0   6  160 110 3.90 2.620 16.46  0  1    4
## Mazda RX4 Wag     21.0   6  160 110 3.90 2.875 17.02  0  1    4
## Datsun 710        22.8   4  108  93 3.85 2.320 18.61  1  1    4
## Hornet 4 Drive    21.4   6  258 110 3.08 3.215 19.44  1  0    3
## Hornet Sportabout 18.7   8  360 175 3.15 3.440 17.02  0  0
## Valiant           18.1   6  225 105 2.76 3.460 20.22  1  0    3
```

Data Frame

```
 mtcars[1,2]

## [1] 6

 mtcars["Mazda RX4", "wt"]

## [1] 2.62

 ncol(mtcars)

## [1] 11

 nrow(mtcars)

## [1] 32
```

Factor

```
 gender <- c("male", "female")
 class(gender)

## [1] "character"

 gender <- as.factor(gender)
 class(gender)

## [1] "factor"
```

Factor

```
 group <- c(1, 2)
 group[1] < group[2]

## [1] TRUE

 class(group)

## [1] "numeric"

 group <- as.factor(group)
 group[1] < group[2]

## Warning in Ops.factor(group[1], group[2]): '<' not
meaningful for factors

## [1] NA
```

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If else

```
 if(something){
       # do something
 }else if(something){
       # do something
}else{
       # do something
}
```

ifelse

```
ifelse(test, yes, no)
```

```
a <- c(2,3,4,2,5,6,7,12)
ifelse(a%%2==0, a+1, 0)

## [1]  3  0  5  3  0  7  0 13
```

Loop

```r
for (var in seq) expr
while(cond) expr
repeat
break
next
```

Loop

```r
for(i in a){
  if(i %% 2 == 0){
    print(i + 1)
  }else{
    print(0)
  }
}
```

```
## [1] 3
## [1] 0
## [1] 5
## [1] 3
## [1] 0
## [1] 7
## [1] 0
```

apply functions

```
apply()
lapply()
sapply()
tapply()
```

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Function

```
 add <- function(a, b){
   a+b
}
 add(1, 2)

## [1] 3

 sapply(1:8, add, 3)

## [1]  4  5  6  7  8  9 10 11
```

Anonymous Function

```
sapply(1:8, function(a, b){a+b}, 3)

## [1]  4  5  6  7  8  9 10 11
```

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S4 Classes and methods

History

- 1976, Rick Becker and John Chambers, S on Honeywell OS
- Ported to UNIX, S2
- Around 1986, functional programming and object self-description, S3
- 1992, concept of classes and methods, S4
- 2010, Reference Classes (RC), R 2.12

appendix in Software for Data Analysis by Chambers

S4 Classes and methods

OO Systems in R

- S3
- S4
- RC
- Base Types

Best Reference: http://adv-r.had.co.nz/OO-essentials.html

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S4 Classes and methods

S4 in R

```
 library(stats4)
 library(pryr)

## Error in library(pryr): there is no package called 'pryr'

 y <- c(26, 17, 13, 12, 20, 5, 9, 8, 5, 4, 8)
 nLL <- function(lambda) -sum(dpois(y, lambda, log = TRUE))
 fit <- mle(nLL, start = list(lambda = 5), nobs = length(y))
 isS4(fit)

## [1] TRUE

 otype(fit)

## Error in eval(expr, envir, enclos):  "otype"

 isS4(nobs)

## [1] TRUE
```

S4 Classes and methods

Defining classes and creating objects

```r
setClass("Person",
 slots = list(name = "character", age = "numeric"))
setClass("Employee",
 slots = list(boss = "Person"),
 contains = "Person")

alice <- new("Person", name = "Alice", age = 40)
john <- new("Employee", name = "John", age = 20, boss = alice)
```

S4 Classes and methods

access slots of an S4 object

```
alice@age
slot(john, "boss")
```

S4 Classes and methods

Creating new methods and generics

```
setGeneric("union")
setMethod("union",
 c(x = "data.frame", y = "data.frame"),
 function(x, y) {
   unique(rbind(x, y))
 }
)
setGeneric("myGeneric", function(x) {
 standardGeneric("myGeneric")
})
```

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Standard I/O

```
scan()
print()
cat()
```

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File I/O

Input

```
read.table()
readLines()
readChar()
readBin()
scan()
```

Output

```
write.table()
write()
```

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Database I/O

```r
library(RMySQL) # for MySQL
library(RPostgreSQL) # for PostgreSQL
library(XLConnect) # for Excel
```

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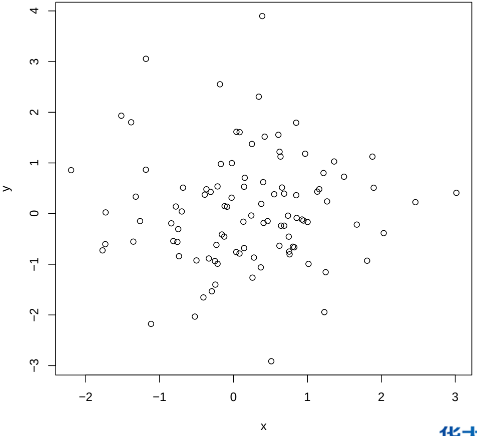
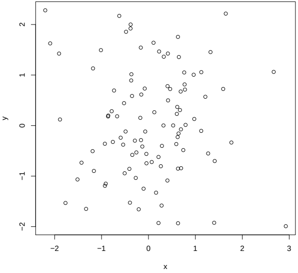
plot



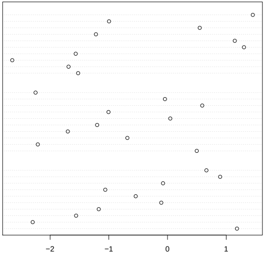
plot

```
x = rnorm(100)
y = rnorm(100)
plot(x, y)
```



dotchart

```
x = rnorm(30)
dotchart(x, groups = rep(1:3,10))
```



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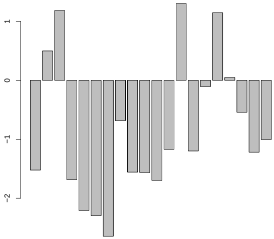
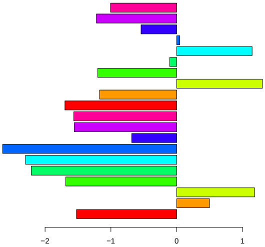
barplot

```r
barplot(x[1:20])
```



barplot

```
barplot(x[1:20], width=2, horiz=T, col=rainbow(10))
```



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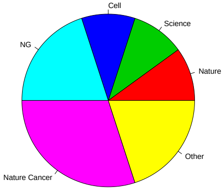
pie

```
pie(c(10,10,10,20,30,20), c("Nature","Science","Cell","NG",
Cancer","Other"),col=2:7)
```



pie

```
library(plotrix)

## Error in library(plotrix):  there is no package
called 'plotrix'

pie3D(c(10,10,10,20,30,20), labels=c("Nature","Science","Ce
Cancer","Other"),col=2:7)

## Error in eval(expr, envir, enclos):   "pie3D"
```

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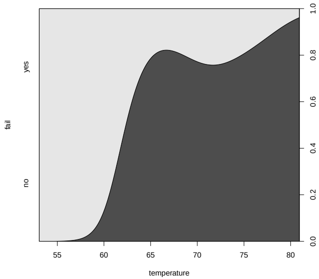
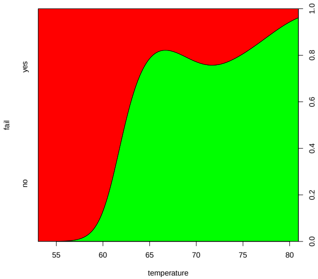
cdplot

```
cdplot(temperature, fail)
```



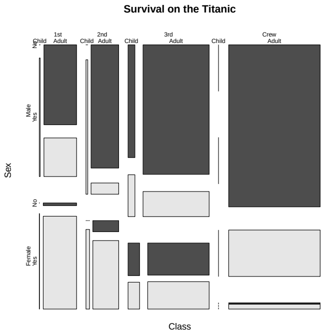
cdplot

```
cdplot(temperature, fail, col=c("green", "red"))
```



mosaicplot

```
require(stats)
mosaicplot(Titanic, main = "Survival on the Titanic",
color = TRUE)
```



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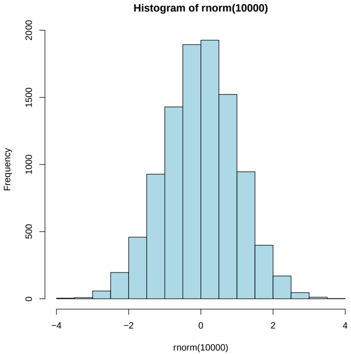
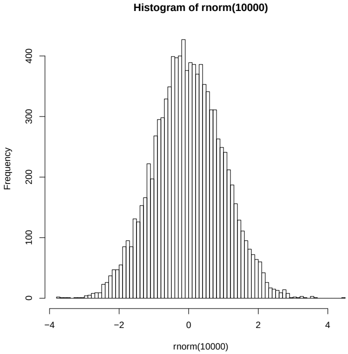
hist

```
hist(rnorm(10000), col="lightblue")
```



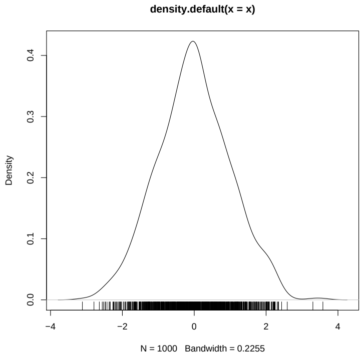
hist

```
hist(rnorm(10000), breaks=100)
```



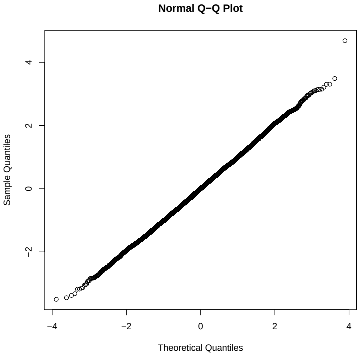
density + rug

```
x = rnorm(1000)
plot(density(x))
rug(x)
```



Q-Q plot

```
qqnorm(rnorm(10000))
```



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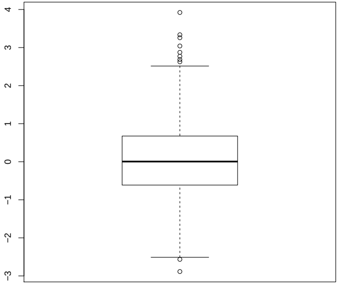
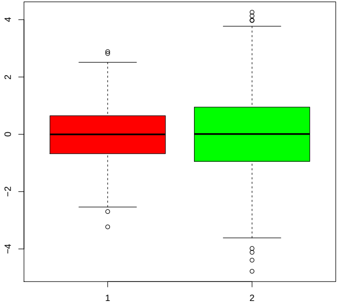
boxplot

```
boxplot(rnorm(1000))
```



boxplot

```
boxplot(cbind(rnorm(1000),rnorm(1000)+rnorm(1000)), col=c("
```



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