# Using R – Foundation

MING-CHANG LEE

Department of Information Management
Yu Da College of Business

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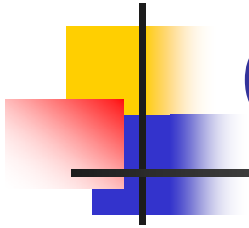
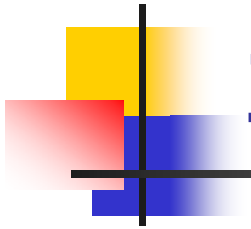
Email: alan9956@ydu.edu.tw
Web : http://web.ydu.edu.tw/~alan9956/



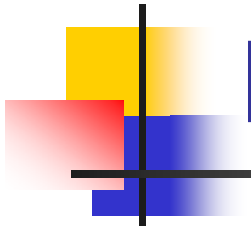
# Outline

1. Introduction
2. Data Manipulation
3. Descriptive Statistics
4. Graphics



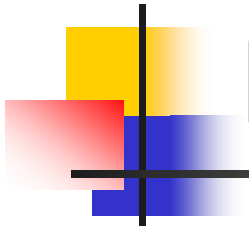
# 1. Introduction

- R for statistical analysis and graphics - Ihaka Gentleman, 1996.
- R is similar to the S language that was developed at AT&T Bell Laboratories by Rick Becker, John Chambers and Allan Wilks.
- Versions of R are available:
  - Microsoft Windows
  - Linux
  - Unix
  - Macintosh OS X (10.4.4)



# Features

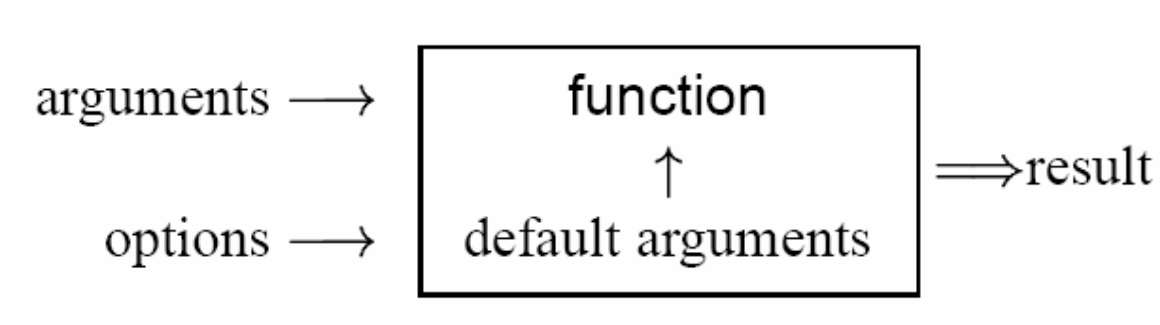
- An effective data handling and storage facility.
- A suite of operators for calculations on arrays, in particular matrices.
- A large, coherent, integrated collection of intermediate tools for data analysis.
- Graphical facilities for data analysis and display either on-screen or on hardcopy.
- A well-developed, simple and effective programming language which includes conditionals, loops, user-defined recursive functions and input and output facilities.



# How R works

- An interpreted language ( Not a complied language).
- An object-oriented language – variables, data, functions, result are stored in the forms of objects.

# R function



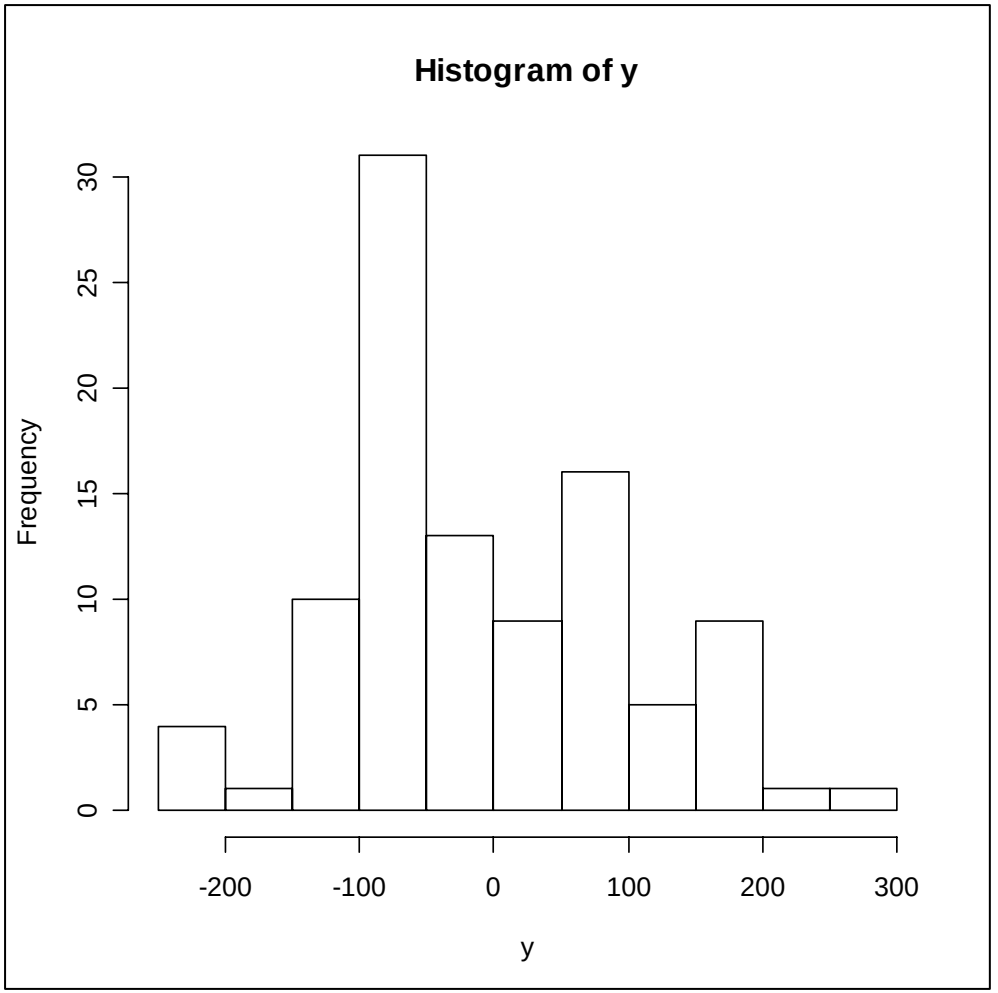

- Arguments:
  data, formulate, expressions.
- Packages of function:
  C:/Program Files/R/R-2.3.1/library
  C:/Program Files/R/R-2.3.1/library/base

# R - Environment

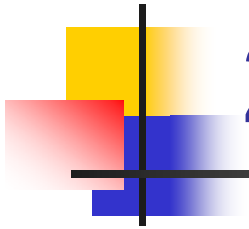

- > : The command line prompt

# Examples:

```
x <- c(1:100)
y <- rnorm(100)*100
hist(y)
test.model <- lm(y ~ x)
test.model
plot(x,y)
library(help="graphics")
```




```
# On-line help:
? ...
? rnorm
? plot
#Information on package 'base'
library(help="base")
```



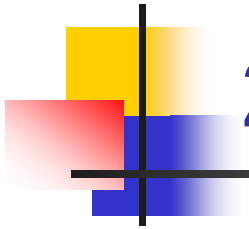
# 2. Data Manipulation

2.1 Data Manipulation Introduction

2.2 Generating Data

2.3 Creating Objects

2.4 Import/Export Data



# 2.1 Data Manipulation Introduction

- Objects have two intrinsic attributes:
  - mode - the basic type of the elements of the object.
    1. Numeric
    2. Character
    3. Logical (FALSE or TRUE).
    4. Complex
  - Length - the number of elements of the object.

```
x <- c(1:2)
mode (x)
# [1] "numeric"
length(x)
# [1] 2
```

# Name of object

- Assign operator:
  <-
- The name of an object must start with a letter (A-Z and a-z) and can include letters, digits (0-9), and dots (.).
- R discriminates for the names of the objects the uppercase letters from the lowercase ones.
  (i.e. x and X can name two distinct objects)
- TRY !

```
A <- “WEPA"; compar <- TRUE; z <- 3+4i
mode(A); mode(compar); mode(z)
[1] "character"
[1] "logical"
[1] "complex"
```

# Special number

- R correctly represents non-finite numeric values:
  - + ∞ : Inf
  - - ∞ : -Inf
- NaN : Not a number

```
x <- 5/0
x
[1] Inf
exp(x)
[1] Inf
exp(-x)
[1] 0
x - x
[1] NaN
```

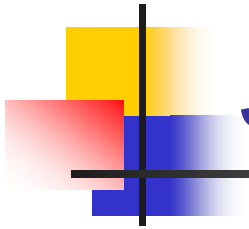
# Type of Objects

| object | modes | several modes possible in the same object? |
|---|---|---|
| vector | numeric, character, complex *or* logical | No |
| factor | numeric *or* character | No |
| array | numeric, character, complex *or* logical | No |
| matrix | numeric, character, complex *or* logical | No |
| data.frame | numeric, character, complex *or* logical | Yes |
| ts | numeric, character, complex *or* logical | Yes |
| list | numeric, character, complex, logical, function, expression, . . . | Yes |

PS: ts – time series

# 2.2 Generating Data

- Regular sequences
  - c( )
  - seq( )
  - scan( )
  - rep( )
  - sequence( )
  - gl( )
  - expand.grid( )
  - Constants
  - Missing values
- Random sequences
  – refer “4. Probability Distribution”



# Joining (concatenating) vectors: c

- c( … ) : Join these numbers together in to a vector.

```
x <- c(2,3,5,2,7,1)
x
[1] 2 3 5 2 7 1
y <- c(10,15,12)
y
[1] 10 15 12
z <- c(x, y)
z
[1] 2 3 5 2 7 1 10 15 12
```

# Subsets of Vectors

```
# Specify the numbers of the elements that are to be extracted:
x <- c(3,11,8,15,12) # Assign to x the values 3, 11, 8, 15, 12
x[c(2,4)] # Extract elements (rows) 2 and 4
[1] 11 15

# Use negative numbers to omit elements:
x[-c(2,3)]
[1] 3 15 12

x>10 # This generates a vector of logical (T or F)
[1] F T F T T
x[x>10]
[1] 11 15 12

# vectors have named elements:
c(ALAN=100, SERENA=2000, ANDY=300, ALPHA=400)[c("ALAN","ANDY")]
ALAN ANDY
 100  300
```

# Regular sequences: seq, scan

- Regular sequence of integers : seq(from, to, steps )
- Combine Values into a Vector or List function : c( )
- Using keyboard to input data: scan()

```
x1 <- 1:100
x2 <- 100:1
x3 <- seq(1,10, 0.5)
x4 <- seq(length=9, from=1, to=5)
x5 <- c(1,2,2.5,6,10)
x6 <- scan()
1: 1
2: 2
3: 3
4: 5
5:
Read 4 items
```

# Regular sequences : rep, sequence

- creates a vector with all its elements identical: rep( )
- creates a series of sequences of integers each ending by the numbers given as arguments: sequence( )

```
rep(1,30)
 [1] 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
 sequence(5)
[1] 1 2 3 4 5
 sequence(c(5,2))
[1] 1 2 3 4 5 1 2
 sequence(c(5,9))
 [1] 1 2 3 4 5 1 2 3 4 5 6 7 8 9
```

# Generate levels (factors): gl

- gl( ): Generating regular series of factors.
- gl(n, k, length = n*k, labels = 1:n, ordered = FALSE)

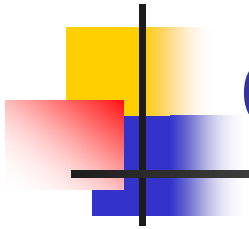
  **n**: An integer giving the number of levels(or glass).
  **k**: An integer giving the number of replications.
  **length**: An integer giving the length of the result.
  **labels**: An optional vector of labels for factor levels.
  **ordered**: The result is ordered or not.

# Example: gl( )

```
gl(3, 5)
 [1] 1 1 1 1 1 2 2 2 2 2 3 3 3 3 3
Levels: 1 2 3
gl(3, 5, length=30)
 [1] 1 1 1 1 1 2 2 2 2 2 3 3 3 3 3 1 1 1 1 1 2 2 2 2 2 3 3 3 3 3
Levels: 1 2 3
gl(2, 6, label=c("Male", "Female"))
 [1] Male   Male   Male   Male   Male   Male   Female Female Female
Female Female Female
Levels: Male Female
```

- TRY

```
x <- gl(3, 3, label=c("優良", "普通", "加油"), length=27)
x
class(x)
```

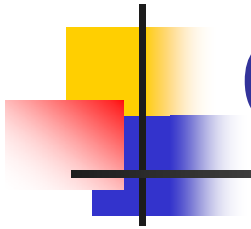


# Generate data frame: expand.grid

- expand.grid(arguments):
  arguments including:
  - Vectors
  - factors
  - list

# Example: expand.grid( )

```
x <- expand.grid(h=c(160, 165, 170), w=c(50, 60), sex=c("M", "F"))
print(x)
    h  w sex
1 160 50   M
2 165 50   M
3 170 50   M
4 160 60   M
5 165 60   M
6 170 60   M
…
12 170 60   F
class(x)
[1] "data.frame"
```



# Constants

- LETTERS
- letters
- month.abb
- month.name
- pi

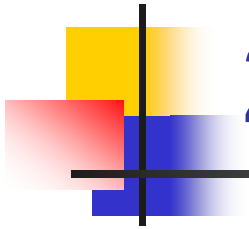
TRY

```
x <- LETTERS
y <- x[-c(2:10)]
length(x)
length(y)
z <- month.name
z
```

# Missing values - NA

- 'NA' is a logical constant of length 1 which contains a missing value indicator.

```
x <- c(pi, 1, 2)
x
[1] 3.141593 1.000000 2.000000
x[2] <- NA
x
[1] 3.141593       NA 2.000000
is.na(x[2])
[1] TRUE
is.na(x[1])
[1] FALSE
# To replace all NAs by 0, use
x[is.na(x)] <- 0
x
[1] 3.141593 0.000000 2.000000
```



# 2.3 Creating objects

- list
- vector
- factor
- array
- matrix
- data.frame

# Creating objects: list

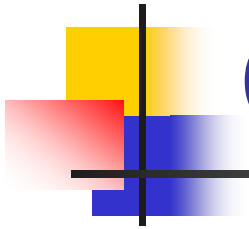
- Function to construct, coerce and check for all kinds of R lists.

```
data()  # list all available data sets
cars
   speed dist
1      4    2
2      4   10
3      7    4
...
49    24  120
50    25   85

pts <- list(x=cars[,1], y=cars[,2])
plot(pts)
```

# Creating objects: vector

- Vector produces a vector of the given length and mode.
- vector (mode , length)
  - mode specified as argument: numeric – 0 ; logical – FALSE ; character – “ “

```
x <- vector(mode="numeric", length=1000000)
is.vector(x)
[1] TRUE
x <- c("Taiwan", "China", "USA")
is.vector(x)
[1] TRUE
```

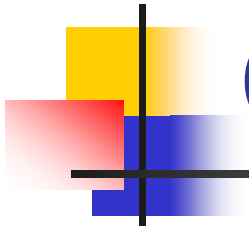


# Creating objects: factor

- A factor includes not only the values of the corresponding categorical variable, but also the different possible levels of that variable (even if they are present in the data).
- factor (x,
  levels = sort(unique(x), na.last = TRUE),
  labels = levels,
  exclude = NA,
  ordered = is.ordered(x) )
  - x: a vector of data, usually taking a small number of distinct values
  - levels specifies the possible levels of the factor (by default the unique values of the vector x),
  - labels defines the names of the levels,
  - exclude the values of x to exclude from the levels,
  - ordered is a logical argument specifying whether the levels of the factor are ordered.

# Example: factor

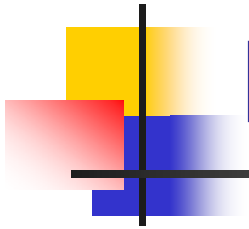
```
factor(1:3)
[1] 1 2 3
Levels: 1 2 3
factor(1:3, levels=1:5)
[1] 1 2 3
Levels: 1 2 3 4 5
factor(1:3, labels=c("A", "B", "C"))
[1] A B C
Levels: A B C
x <- factor(letters[1:6], label="YDU")
x
[1] YDU1 YDU2 YDU3 YDU4 YDU5 YDU6
Levels: YDU1 YDU2 YDU3 YDU4 YDU5 YDU6
class(x)
[1] "factor"
```



# Creating objects: arrary

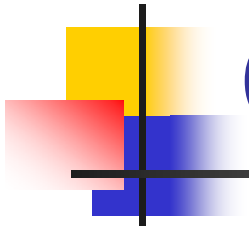
- Creates or tests for arrays.
  - array(data = NA, dim = length(data), dimnames = NULL)
  - as.array(x)
  - is.array(x)

```
x <- array(letters)
class(x)
[1] "array"
dim(x)
[1] 26
```



# Example: array

```
x <- array(letters)
class(x)
[1] "array"
dim(x)
[1] 26

x <- array(1:3, c(2,4))
x
     [,1] [,2] [,3] [,4]
[1,]    1    3    2    1
[2,]    2    1    3    2
dim(x)
[1] 2 4
length(x)
[1] 8
x[1, ] # select row 1
```



# Creating objects: matrix

- matrix(data = NA, nrow = 1, ncol = 1, byrow = FALSE, dimnames = NULL)
- as.matrix(x)
- is.matrix(x)

# Example: matrix

```
matrix.data <- matrix(
            c(1,2,3,4,5,6),
            nrow = 2,
            ncol = 3,
            byrow=TRUE,
            dimnames = list(c("row1", "row2"), c("C1", "C2",
                        "C3")) )
matrix.data
        C1 C2 C3
row1  1   2   3
row2  4   5   6
```

# Creating objects: data.frame

- A data frame is the type of object normally used in R to store a data matrix.
- A list of variables of the same length, but possibly of different types (numeric, factor, character, logical, . . . ).

- data.frame(..., row.names = NULL, check.rows = FALSE, check.names = TRUE)

POWERFUL FUNCTION

# Example1: data.frame

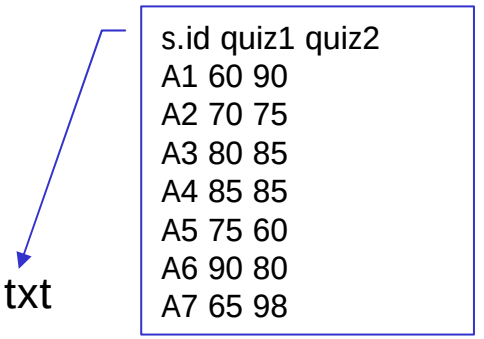
```
x <- 1:4; n <- 10; M <- c(10, 35); y <- 2:4
data.frame(x, n)
  x  n
1 1 10
2 2 10
3 3 10
4 4 10
data.frame(x, M)
  x  M
1 1 10
2 2 35
3 3 10
4 4 35
TRY !
data.frame(x, y)
z <- data.frame(var1= rnorm(5), var2=LETTERS[1:5])
```

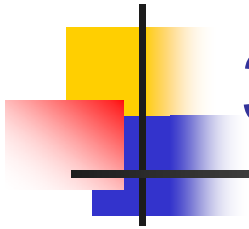
# Example2: data.frame

```
data(cars)
help(cars)
class(cars)
[1] "data.frame"
cars
   speed dist
1      4    2
2      4   10
…
# TRY ! How to add row names (e.g., Row1, Row2,…)
x
      speed dist
Row1      4    2
Row2      4   10
…
```

# 2.4 Import/Export Data

```
# Create a data directory C:\Program Files\R\R-2.3.1\data
# Set working directory
workpath <- "C:/Program Files/R/R-2.3.1/data"
setwd(workpath)
# Get working directory
getwd()
# Create a text file C:\Program Files\R\R-2.3.1\data\r_input.txt
# Import dataset
score1 <- read.table(file="r_input.txt", header= TRUE)
score1
# Add new column data for mid_term
mid_term <- matrix(c(60,80,65,85,80,90,99), nrow=7, ncol=1, byrow=FALSE,
            dimnames = list(c(),c("mid_term")))
mid_term
# Merge two data.frame( score1 and mid_term)
score2 <- data.frame(score1, mid_term)
score2
# Export dataset
write.table(score2 , file= "r_output.txt", sep = "\t", append=FALSE, row.names=
            FALSE, col.names = TRUE, quote= FALSE)
```





# 3. Descriptive Statistics

3.1 Operators

3.2 Mathematical Functions

3.3 Accessing Data

3.4 Descriptive Statistics

# 3.1 Operators

| Operators | | | | | |
|---|---|---|---|---|---|
| Arithmetic | | Comparison | | Logical | |
| + | addition | < | lesser than | ! x | logical NOT |
| - | subtraction | > | greater than | x & y | logical AND |
| * | multiplication | <= | lesser than or equal to | x && y | id. |
| / | division | >= | greater than or equal to | x \| y | logical OR |
| ^ | power | == | equal | x \|\| y | id. |
| %% | modulo | != | different | xor(x, y) | exclusive OR |
| %/% | integer division | | | | |

PS:The following characters are also operators for R:

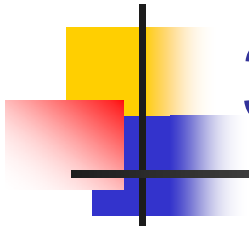
- $
- [
- [[
- :
- ?
- <-.

# 3.2 Mathematical Functions

| | |
|---|---|
| sum(x) | sum of the elements of x |
| prod(x) | product of the elements of x |
| max(x) | maximum of the elements of x |
| min(x) | minimum of the elements of x |
| which.max(x) | returns the index of the greatest element of x |
| which.min(x) | returns the index of the smallest element of x |
| range(x) | id. than c(min(x), max(x)) |
| length(x) | number of elements in x |
| mean(x) | mean of the elements of x |
| median(x) | median of the elements of x |
| var(x) or cov(x) | variance of the elements of x (calculated on *n* -1) |
| cor(x) | correlation matrix of x if it is a matrix or a data frame (1 if x is a vector) |
| var(x, y) or cov(x, y) | covariance between x and y, or between the columns of x and those of y if they are matrices or data frames |
| cor(x, y) | linear correlation between x and y, or correlation matrix if they are matrices or data frames |

# Mathematical Functions (cont.)

| | |
|---|---|
| round(x, n) | rounds the elements of x to n decimals. |
| ceiling(x) | returns a numeric vector containing the smallest integers not less than x. |
| floor(x) | returns a numeric vector containing the largest integers not greater than x. |
| rev(x) | reverses the elements of x. |
| sort(x) | sorts the elements of x in increasing order.<br>To sort in decreasing order: rev(sort(x)). |
| rank(x) | ranks of the elements of x |
| log(x, base) | computes the logarithm of x with base "base" |
| choose(n, k) | computes the combinations of *k* events among *n* repetitions<br>= *n*! / [(*n*-*k*)!**k*!] |
| sample(x, size) | resample randomly and without replacement. The option replace = TRUE allows to resample with replacement. |

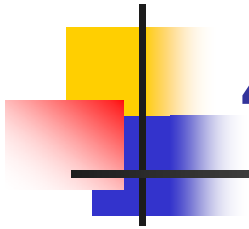


# 3.3 Accessing Data

| | |
|---|---|
| how many elements? | `length(x)` |
| $i$th element | `x[2]` ($i = 2$) |
| all *but* $i$th element | `x[-2]` ($i = 2$) |
| first $k$ elements | `x[1:5]` ($k = 5$) |
| last $k$ elements | `x[(length(x)-5):length(x)]` ($k = 5$) |
| specific elements. | `x[c(1,3,5)]` (First, 3rd and 5th) |
| all greater than some value | `x[x>3]` (the value is 3) |
| bigger than or less than some values | `x[ x< -2 \| x > 2]` |
| which indices are largest | `which(x == max(x))` |

# 3.4 Descriptive Statistics

```
summary(score2)
score2[2]
score2$Quiz1
quiz1 <- score2$Quiz1
mean(quiz1)
max(quiz1)
min(quiz1)
std(quiz1) # error function
# solution 1
sqrt( sum( (quiz1 - mean(quiz1))^2 /(length(quiz1)-1))) #
   std=10.80123
# solution 2
std = function(x) sqrt(var(x))
std(quiz1) # same as solution 1 # TRY sd(quiz1)
```



# 4. Graphics

4.1 Graphical device

4.2 Plot

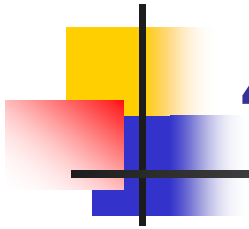
4.3 Bar charts

4.4 Pie charts

4.5 Box-and-whisker plot

4.6 Stem-and-Leaf plot

```
demo(graphics)
```



# 4.1 Graphical device

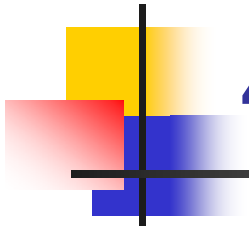
- The result of a graphical function is sent to a graphical device.
  - Graphical window
  - File.
- There are two kinds of graphical functions:
  1. *High-level plotting functions* which create a new graph.
  2. *Low-level plotting functions* which add elements to an already existing graph.

# Graphical devices

- Open a graphical window:
  x11() or windows()
- List of available graphical devices:
  dev.list()
- Show/Change the active device:
  dev.cur(), dev.set(3)
- Close the active device:
  dev.off(), dev.off(2)

"null device"' is always device 1.

cur: current



# 4.2 Plot( )

- plot(x, y) # Same as “plot(y ~ x)”
- type:
  - p :point,
  - l: line,
  - b: both
- pch: controls the type of symbol, either an integer between 1 and 25, or any single character within “ “
- col: controls the colour of symbols. e.g., “red”
- xlab = "string"
- ylab = "string“
- main = "string"
- sub = "string”
- cex: a value controlling the size of texts and symbols with respect to the default
- lwd: a numeric which controls the width of lines

# Plot - pch

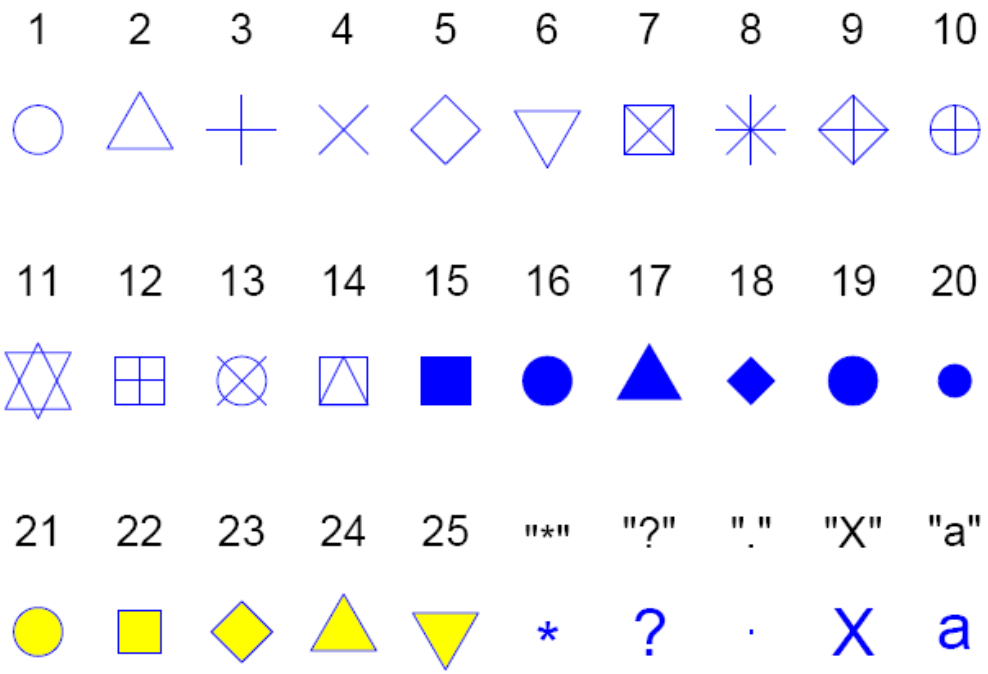
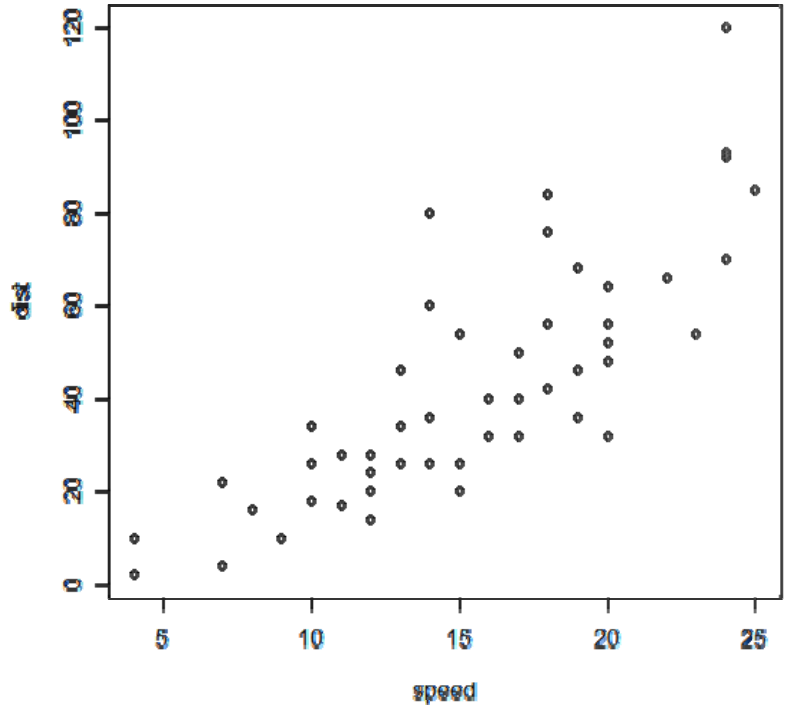



Figure 2: The plotting symbols in R (`pch=1:25`). The colours were obtained with the options `col="blue", bg="yellow"`, the second option has an effect only for the symbols 21–25. Any character can be used (`pch="*", "?", ".", ...`).

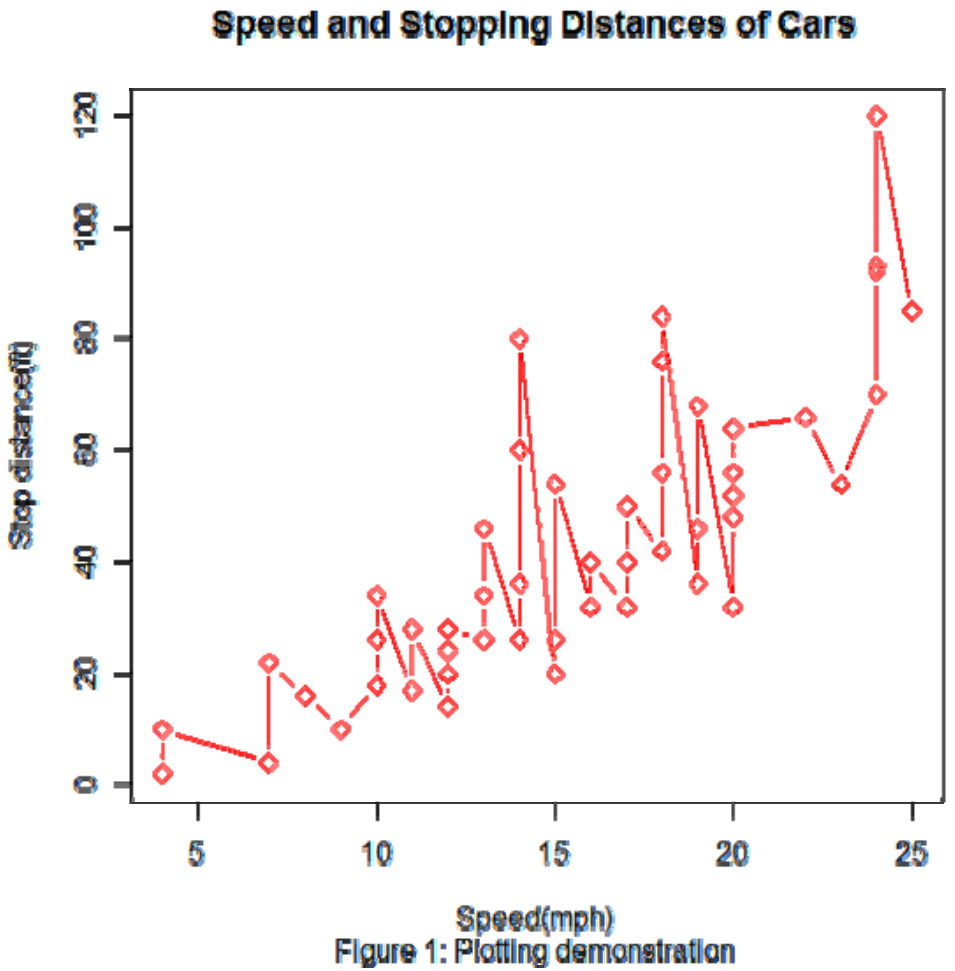
# Example: plot

```
data()
data(cars) #Speed and Stopping Distances of Cars
plot(cars) # x-axis:speed; y-axis: dist
plot(cars$dist, cars$speed)
plot(cars, type="b")
```



# Example: plot (cont.)

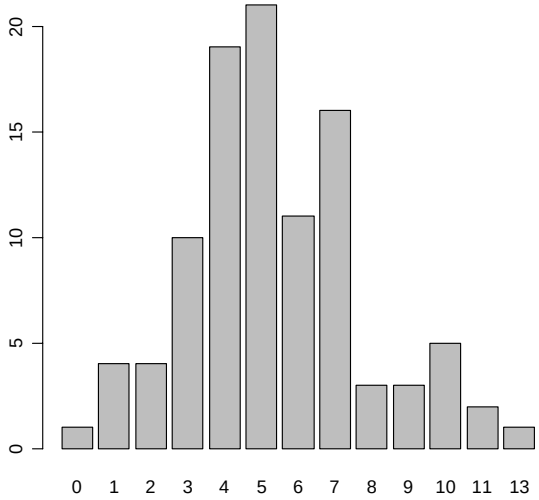
```
> cl <- colors()
> cl
  [1] "white“ …
```

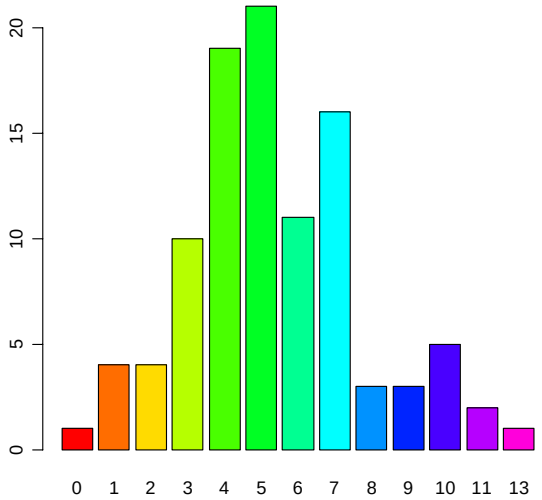



```
plot(cars,
type="b",
pch=5,
col="red",
xlab="Speed(mph)",
ylab="Stop distance(ft)",
main="Speed and Stopping Distances of Cars",
sub= "Figure 1: Plotting demonstration")
```

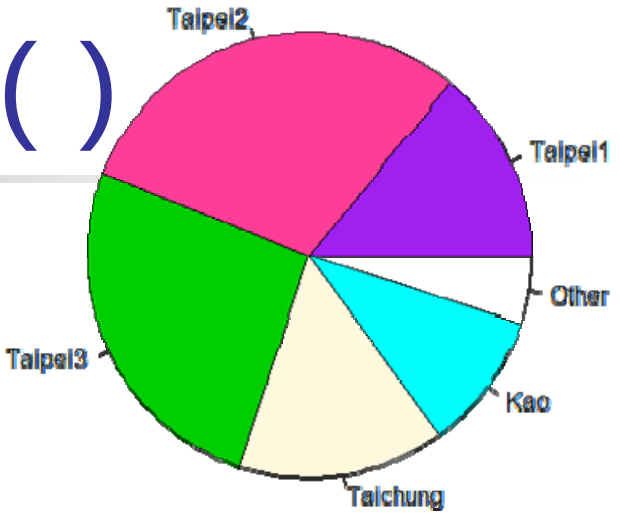
# 4.3 Bar charts – barplot( )

```
CarArrived <- table(NumberOfCar <- rpois(100, lambda=5))
CarArrived

 0  1  2  3  4  5  6  7  8  9 10 11 13
 1  4  4 10 19 21 11 16  3  3  5  2  1
barplot(CarArrived)
barplot(CarArrived, col=rainbow(14))
```



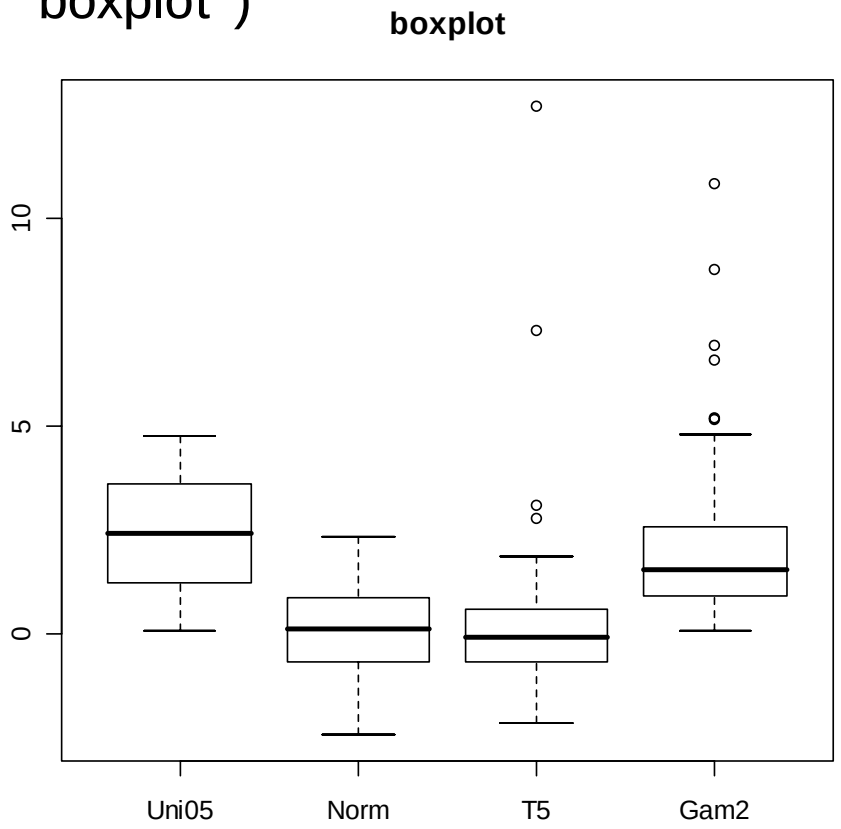
# 4.4 Pie charts – pie( )




```
pie.sales <- c(0.14, 0.30, 0.26, 0.15, 0.10, 0.05) # Sales ratio

names(pie.sales) <- c("Taipei1", "Taipei2", "Taipei3", "Taichung",
        "Kao", "Other") # Sales area

pie(pie.sales) # default colours

pie(pie.sales, col = c("purple", "violetred1", "green3", "cornsilk",
        "cyan", "white")) # set colour

pie(pie.sales, density = 10, clockwise=TRUE) # The density of
        shading lines
```

# 4.5 Box-and-whisker Plot – boxplot( )

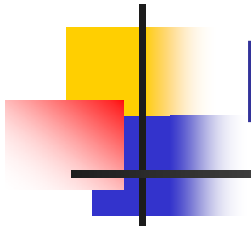
```
#  Produce box-and-whisker plot(s) of the given (grouped) values.
mat <- cbind(Uni05 = (1:100)/21, Norm = rnorm(100), T5 = rt(100, df
          = 5), Gam2 = rgamma(100, shape = 2))
boxplot(data.frame(mat), main = “boxplot")
```



# 4.6 Stem-and-Leaf Plot – stem( )

```
mat = scan()
1: 2 3 16 23 14 12 4 13 2 0 0 0 6 28 31 14 4 8 2 5
21:
Read 20 items
stem(mat)

  The decimal point is 1 digit(s) to the right of the |

  0 | 000222344568
  1 | 23446
  2 | 38
  3 | 1
```

Press ‘Enter’



# References


1. R. Ihaka & R. Gentleman (1996) R: a language for data analysis and graphics, Journal of Computational and Graphical Statistics 5: 299–314.
2. J H Maindonald (2004) Using R for Data Analysis and Graphics - Introduction, Examples and Commentary. http://cran.r-project.org/doc/contrib/usingR-2.pdf
3. E. Paradis (2002) R for Beginners. http://cran.r-project.org/doc/contrib/Paradis-rdebuts_en.pdf
4. W. N. Venables, D. M. Smith and the R Development Core Team (2006) An Introduction to R - Notes on R: A Programming Environment for Data Analysis and Graphics. http://cran.r-project.org/doc/manuals/R-intro.pdf
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# THANKS

## Q & A