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(2) R程式語言的基礎: 物件

吳漢銘
淡江大學 數學系
資料科學與數理統計組

http://www.hmwu.idv.tw

本章大綱&學習目標

- R程式變數(Variables)命名法及語法
- R的物件(Object): Vectors, Character Strings, Array, Matrix, Forming Partitioned Matrices, List, Data Frame
- 查詢物件之模式，屬性，類別及可取用的元素。
- 存取資料的元素(例如: `iris[,1], iris$Species`)

變數命名法

- Case sensitive
  - `A` and `a` are different
- All alphanumeric symbols are allowed (`A-Z, a-z, 0-9`)
  - “`.`”, “`_`”.
- Name must start with “.” or a letter.

- 錯誤命名
  - `3x`
  - `3_x`
  - `3-x`
  - `3.x`
  - `.3variable`
- 正確命名
  - `x_3`
  - `x3`
  - `x.3`
  - `taiwan.taipei.x3`
  - `.variable`

R語法

- Assignments

```
> x <- 5
> x = 5
> x
> (x <- 5)
[1] 5
> assign("x", 2)
> 2 -> x

> a <- b <- c <- 6
```

- x <- expressions

```
> x <- 3+5
```

- ; or new line

```
> x <- 5 ; y <- 7
```

or

```
> x <- 5
> Y <- 7
```

- Comment

```
> # how are you?
```

- "+" : If a comment is not complete at the end of a line, R will give a different prompt.

```
> x <-
+ 5
```

R語法

- Recall previous commands
  - 上下鍵(Vertical arrow keys)
- 執行外部程式檔(Execute commands)

```
> source("commands.R")
```

- 把output存檔(Send R output to a file)

```
> sink("test.txt")
> x <- 5 + 3
> x
> sink()
> getwd()
```

物件(Objects)

- Variables, arrays of numbers, character strings, functions,...

```
> x <- 3+5
> y <- 7
> objects()
[1] "x" "y"

> ls()
[1] "x" "y"

> rm(x, y)
> rm(list = ls())

> objects()
character(0)
```

儲存R物件所佔用的記憶體估計:

```
object.size(x)
print(object.size(x), units = "Mb")
```

```
> n <- 10000
> p <- 200
> myData <- as.data.frame(matrix(rnorm(n*p),
ncol = p, nrow=n))
> print(object.size(myData), units = "Mb")
15.3 Mb
```

Rounding of Numbers

- ceiling: the **smallest integers** not less than the corresponding elements of x.
- floor: the **largest integers** not greater than the corresponding elements of x.
- trunc: **the integers** formed by truncating the values in x toward 0.
- round: rounds the values in its first argument to the specified number of decimal places (default 0).
- signif: rounds the values in its first argument to the specified number of significant digits.

```
> (x <- c(pi, 1/3, -1/3, -pi))
[1]  3.1415927  0.3333333 -0.3333333 -3.1415927
> ceiling(x)
[1]  4  1  0 -3
> floor(x)
[1]  3  0 -1 -4
> trunc(x)
[1]  3  0  0 -3
> round(x, 2)
[1]  3.14  0.33 -0.33 -3.14
> round(x, 5)
[1]  3.14159  0.33333 -0.33333 -3.14159
> signif(x, 2)
[1]  3.10  0.33 -0.33 -3.10
> signif(x, 5)
[1]  3.14160  0.33333 -0.33333 -3.14160
```

向量 (Vector)

- 向量(vector): 同樣屬性(數字或文字)的資料的集合
- `c()`: 串連多個字串 (combine values into a vector or list)

```
> x1 <- c(10, 5, 3, 6, 2.7)
> x1
[1] 10.0  5.0  3.0  6.0  2.7
>
> assign("x2", c(10, 5, 3, 6, 2.7))
> x2
[1] 10.0  5.0  3.0  6.0  2.7
>
> c(10, 5, 3, 6, 2.7) -> x3
> x3
[1] 10.0  5.0  3.0  6.0  2.7
>
> length(x1)
[1] 5
>
> c(1,7:9)
[1] 1 7 8 9
> c(1:5, 10.5, "next")
[1] "1" "2" "3" "4" "5" "10.5" "next"
```

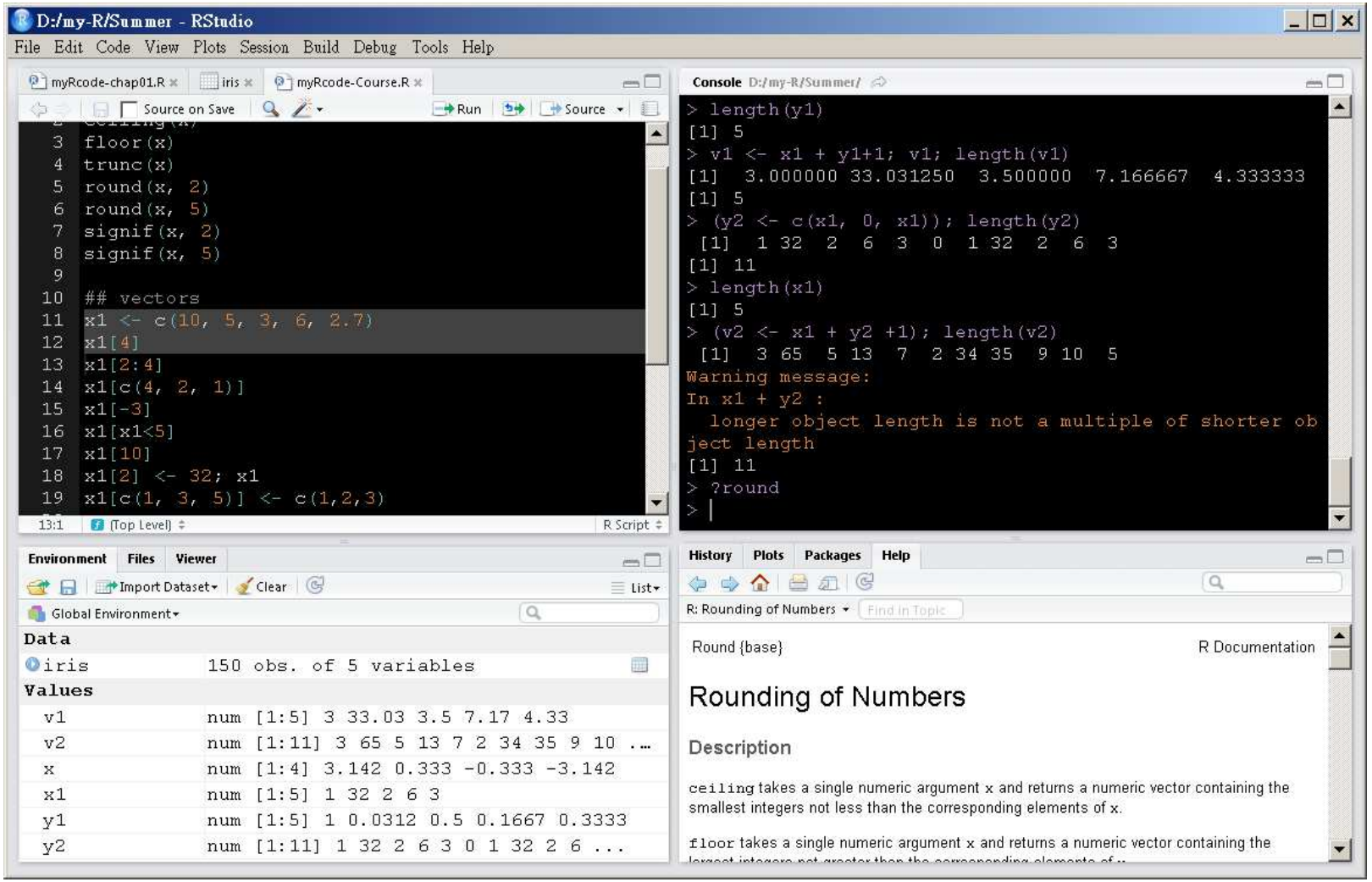
```
> x1[4]
[1] 6
> x1[2:4]
[1] 5 3 6
> x1[c(4, 2, 1)]
[1]  6  5 10
> x1[-3]
[1] 10.0  5.0  6.0  2.7
> x1[x1<5]
[1] 3.0 2.7
> x1[10]
[1] NA
> x1[2] <- 32; x1
[1] 10.0 32.0  3.0  6.0  2.7
> x1[c(1, 3, 5)] <- c(1,2,3)
> x1
[1]  1 32  2  6  3
```

向量 (Vectors)

```
> (y1 <- 1/x1)
[1] 0.1000000 0.2000000 0.3333333 0.1666667 0.3703704
> length(y1)
[1] 5
>
> v1 <- x1 + y1+1; v1; length(v1)
[1] 11.100000  6.200000  4.333333  7.166667  4.070370
[1] 5
>
> (y2 <- c(x1, 0, x1)); length(y2)
 [1] 10.0  5.0  3.0  6.0  2.7  0.0 10.0  5.0  3.0  6.0  2.7
 [1] 11
>
> length(x1)
[1] 5
> (v2 <- x1 + y2 + 1); length(v2)
 [1] 21.0 11.0  7.0 13.0  6.4 11.0 16.0  9.0 10.0  9.7 13.7
Warning message:
In x1 + y2 :
  longer object length is not a multiple of shorter object length
[1] 11
```

x1 repeated 2.2 times, y repeated one time, 1 repeated 11 times

課堂練習1: p4~p9



注意: 打完一行程式，就立刻執行，查看結果

向量運算 (Vector Arithmetic)

一些簡單的數學計算:

- +, -, *, /, ^
- log(x), logb(x, b)
- pi, exp(x),
- sin(pi/2), cos(pi), tan(pi/4),
- abs(x), sqrt(x),
- length(x)
- prod(x)
- choose(n, k)
- factorial(x)

一些簡單的統計運算:

- max(x), min(x)
- pmax(x), pmin(x)
- range(x)
  - c(min(x), max(x))
- mean(x)
  - sum(x)/length(x)
- var(x), cov(x)
  - sum((x-mean(x))^2)/(length(x)-1)
- sqrt(var(x))
- median(x)
- summary(x)
- cor(x, y)

其它函式應用

- sort(x)#排序，由小到大。
- rank(x)#排序等級。
- order(x)#排序後，各個元素的原始所在位置。

課堂練習2

```
> x <- c(1.58, -0.29,  0.59, -0.38,  0.72)
> max(x)
[1] 1.58
> min(x)
[1] -0.38
> range(x)
[1] -0.38  1.58
> c(min(x), max(x))
[1] -0.38  1.58
> mean(x)
[1] 0.444
> sum(x)/length(x)
[1] 0.444
```

```
> var(x)
[1] 0.65143
> sum( (x-mean(x))^2)/(length(x)-1)
[1] 0.65143
> sqrt(var(x))
[1] 0.8071121
> median(x)
[1] 0.59
> summary(x)
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
 -0.380  -0.290   0.590   0.444   0.720   1.580
> sort(x)
[1] -0.38 -0.29  0.59  0.72  1.58
> rank(x)
[1] 5 2 3 1 4
> order(x)
[1] 4 2 3 5 1
```

規律的序列 (Regular Sequences)


```
> x <-c(1,2,3,4,5,6,7,8,9,10)
> x <- 1:10
> y <- 10:2
> 2*1:10
 [1]  2  4  6  8 10 12 14 16 18 20
>
> n <- 10
> 1:n-1
 [1] 0 1 2 3 4 5 6 7 8 9
> 1:(n-1)
[1] 1 2 3 4 5 6 7 8 9
>
> width <- 1
> seq(from=2, to=5, by=width)
[1] 2 3 4 5
>
> 2:5
[1] 2 3 4 5
> s1<- seq(-5, 5, by=0.2)
> s2 <- seq(length=51, from=-5, by=0.2)
```

The colon operator has high priority with an expression

規律的序列 (Regular Sequences)


```
> rep(x, times=5)
 [1]  1  2  3  4  5  6  7  8  9 10  1  2  3  4  5  6  7  8
[19]  9 10  1  2  3  4  5  6  7  8  9 10  1  2  3  4  5  6
[37]  7  8  9 10  1  2  3  4  5  6  7  8  9 10
>
> rep(x, each=5)
 [1]  1  1  1  1  1  2  2  2  2  2  3  3  3  3  3  4  4  4
[19]  4  4  5  5  5  5  5  6  6  6  6  6  7  7  7  7  7  8
[37]  8  8  8  8  9  9  9  9  9 10 10 10 10 10
>
> rep(1:4, each=5)
 [1] 1 1 1 1 1 2 2 2 2 2 3 3 3 3 3 4 4 4 4 4

> rep(LETTERS[1:4], 3)
 [1] "A" "B" "C" "D" "A" "B" "C" "D" "A" "B" "C" "D"
>
> rep(LETTERS[1:4], length.out=3)
[1] "A" "B" "C"
```

課堂練習3: 造出規律的序列

- 1 2 2 3 3 3 4 4 4 4 5 5 5 5 5
- 5 4 4 3 3 3 2 2 2 2 1 1 1 1 1
- 1 2 3 1 2 3 1 2 3
- Fibonacci number:
0 1 1 2 3 5 8 13 21 34 55 ...
- 1 2 3 4 5 2 3 4 5 3 4 5 4 5 5
- 1 6 13 22 33 46 ...
- 1 2 3 4 9 8 27 16 ...

邏輯向量 (Logical Vectors)

- **TRUE, FALSE**
- **T, F**
- Logical operators
  - <, <=, >, >=, ==, !=
- c1,c2: logical expression
  - **c1&c2:** intersection “and”
  - **c1|c2:** union “or”

```
> x <- c(12, 4, 7, 20, 13)
> x < 15
[1]  TRUE  TRUE  TRUE FALSE  TRUE
> x <= 15
[1]  TRUE  TRUE  TRUE FALSE  TRUE
> x > 13
[1] FALSE FALSE FALSE  TRUE FALSE
> x >= 10
[1]  TRUE FALSE FALSE  TRUE  TRUE
> x == 12
[1]  TRUE FALSE FALSE FALSE FALSE
> x != 20
[1] TRUE TRUE TRUE FALSE TRUE
> (x = 3)
[1] 3
```

```
> (x > 10)
[1] TRUE FALSE FALSE  TRUE  TRUE
> x != 20
[1]  TRUE  TRUE  TRUE FALSE  TRUE
> (x > 10) & (x != 20)
[1]  TRUE FALSE FALSE FALSE  TRUE
> (x > 10) | (x != 20)
[1] TRUE TRUE TRUE TRUE TRUE
```

```
> (x >= 10)
[1]  TRUE FALSE FALSE  TRUE  TRUE
> 1*(x >= 10)
[1] 1 0 0 1 1
> (x >= 15)
[1] FALSE FALSE FALSE  TRUE FALSE
> 2*(x >= 15)
[1] 0 0 0 2 0
```

遺失值 (Missing Values)

- **NA**: not available, missing values

```
> z <- c(1:3, NA)
> z
[1]  1  2  3 NA
> ind <- is.na(z)
> ind
[1] FALSE FALSE FALSE  TRUE
```

- A vector of the same length as x all of whose values are NA

```
> x == NA
[1] NA NA NA NA NA
```

- **NaN**: not a number, missing values

```
> 0/0
[1] NaN
> Inf-Inf
[1] NaN
```

See also: `na.fail(x)`, `na.pass(x)`, `na.omit(x)`, `na.exclude(x)`

`is.na(xx)` is **TRUE** both for **NA** and **NaN** values
`is.nan(xx)` is only **TRUE** for **NaN**s

字元向量 (Character Vectors)

- Character strings are entered using either
  - double (") quotes or
  - single (') quotes
- Character strings are printed using double quotes.

```
> (x <- "x-values")
[1] "x-values"
> (y <- "New iteration results")
[1] "New iteration results"
> (answer1 <- c("a1", "a2", "b1", "b3"))
[1] "a1" "a2" "b1" "b3"
> (answer2 <- c('a1', 'a2', 'b1', 'b3'))
[1] "a1" "a2" "b1" "b3"
> (answer3 <- c('a', "a2", 3))
[1] "a"  "a2" "3"
```

```
> paste("A", 1:6, sep = "")
[1] "A1" "A2" "A3" "A4" "A5" "A6"
> paste("Today is", date())
[1] "Today is Wed Sep 24 13:26:20 2008"
> labs <- paste(c("X", "Y"), 1:10, sep="")
> labs
 [1] "X1"  "Y2"  "X3"  "Y4"  "X5"  "Y6"  "X7"  "Y8"  "X9"  "Y10"
```

跳脫字元 (Escape Character)

- Escape Character:
  - `\n`: new line.
  - `\t`: tab.
  - `\b`: backspace.

```
> cat("How are you?", "\n", "I'm fine.", "\n")
How are you?
 I'm fine.
> cat("How are you?", "\t", "I'm fine.", "\n")
How are you?     I'm fine.
> cat("How are you?", "\b\b\b", "I'm fine.")
How are yo I'm fine.>
```

NOTE: `"\"` is entered and printed as `"\\"`

```
> setwd("c:\\temp\\mydata")
```

索引向量: Index Vector [ ]

- A logical vector

```
> x <- c(7, 2, 4, 9, NA, 4)
> x[2]
[1] 2
> x[5]
[1] NA
> x[0]
numeric(0)
> x[10]
[1] NA
> y <- x[!is.na(x)]
> y
[1] 7 2 4 9 4
> (x+1)[(!is.na(x))&(x>0)] -> z
> z
[1]  8  3  5 10  5
```

- A vector of positive integral quantities

```
> rep(c(1,2,2,1), times=3)
 [1] 1 2 2 1 1 2 2 1 1 2 2 1
> c("x","y")[rep(c(1,2,2,1), times=3)]
 [1] "x" "y" "y" "x" "x" "y" "y" "x" "x" "y" "y" "x"
```

索引向量: Index Vector [ ]

- A vector of negative integral quantities

```
> x <- c(7, 2, 4, 9, NA, 4)
> x[-2]
[1]  7  4  9 NA  4
> x[-(1:3)]
[1]  9 NA  4
```

- A vector of character strings

```
> fruit <- c(5, 10, 1, 20)
> fruit
[1]  5 10  1 20
> names(fruit) <- c("orange", "banana", "apple", "peach")
> fruit
orange banana  apple  peach
     5     10      1     20
> lunch <- fruit[c("apple", "orange")]
> lunch
 apple orange
     1      5
```

More example

```
> x <- c(7, 2, 4, 9, NA, 4)
> x[is.na(x)] <- 0
> x
[1] 7 2 4 9 0 4
> y <- c(-7, 2, 4, 9, 0, -4)
> abs(y)
[1] 7 2 4 9 0 4
> y[y<0] <-  -y[y<0]
> y
[1] 7 2 4 9 0 4
```

課堂練習4

- 練習「字元向量，跳脫字元，向量索引」

```
> x <- c(A=5, B=3, third=10)
> x
    A     B third
    5     3    10
> x[1]
A
5
> x["A"]
A
5
> x[c("third", "B")]
third     B
   10     3
> x[c(3, 1)]
third     A
   10     5
> names(x)
[1] "A"     "B"     "third"
> names(x) <- c("AA", "BB", "CC")
> x
AA BB CC
 5  3 10
```

因子 (Factors)

- The levels of factors are stored in alphabetical order.

```
> scores <- c(60, 49, 90, 54, 54, 48, 61, 61, 51, 49, 49)
> gender <- c("f", "f", "m", "f", "m", "m", "m", "m", "f", "f", "m")
> levels(gender)
NULL
> gender.f <- factor(gender)
> gender.f
 [1] f f m f m m m m f f m
Levels: f m
> levels(gender.f)
[1] "f" "m“
> table(gender.f)
gender.f
f m
5 6
```

```
> levels(gender.f) <- c("女", "男")
> gender.f
 [1] 女 女 男 女 男 男 男 男 女 女 男
Levels: 女 男
> (scores.mean <- tapply(scores, gender.f, mean))
  女   男
52.6 60.5
```

```
> grade <- as.factor(c("B", "F", "A", "C", "A", "C", "B", "A", "F", "D"))
> levels(grade)
[1] "A" "B" "C" "D" "F"
> grade2 <- ordered(grade, levels=rev(levels(grade)))
> grade2
 [1] B F A C A C B A F D
Levels: F < D < C < B < A
```

```
> grade2[which(grade2 >= "B")]
[1] B A A B A
Levels: F < D < C < B < A
```

陣列 (Arrays)

- An array is a multiply subscripted collection of data entries.

```
> z <- 1:30
> z
 [1]  1  2  3  4  5  6  7  8  9 10 11
12 13 14 15 16 17 18 19 20 21 22 23 24
25 26 27 28
[29] 29 30
>
> dim(z) <- c(3,5,2)
> z
, , 1

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

, , 2

     [,1] [,2] [,3] [,4] [,5]
[1,]   16   19   22   25   28
[2,]   17   20   23   26   29
[3,]   18   21   24   27   30
```

```
> z[1,3,2]
[1] 22
>
> z[1,1,]
[1]  1 16
>
> z[1,,2]
[1] 16 19 22 25 28
>
> z[1,1:2,1]
[1] 1 4
>
> z[-1,,]
, , 1

     [,1] [,2] [,3] [,4] [,5]
[1,]    2    5    8   11   14
[2,]    3    6    9   12   15

, , 2

     [,1] [,2] [,3] [,4] [,5]
[1,]   17   20   23   26   29
[2,]   18   21   24   27   30
```

陣列 (Arrays)

```
> x <- array(1:20, dim=c(4,5))
> x
     [,1] [,2] [,3] [,4] [,5]
[1,]    1    5    9   13   17
[2,]    2    6   10   14   18
[3,]    3    7   11   15   19
[4,]    4    8   12   16   20
>
> i <- array(c(1:3, 3:1), dim=c(3,2))
> i
     [,1] [,2]
[1,]    1    3
[2,]    2    2
[3,]    3    1
>
> x[i] <- 0
> x
     [,1] [,2] [,3] [,4] [,5]
[1,]    1    5    0   13   17
[2,]    2    0   10   14   18
[3,]    0    7   11   15   19
[4,]    4    8   12   16   20
```

```
> x <- c(1,2,3,4,5)
> x
[1] 1 2 3 4 5
> z <- array(x, dim=c(3,4))
> z
     [,1] [,2] [,3] [,4]
[1,]    1    4    2    5
[2,]    2    5    3    1
[3,]    3    1    4    2
>
> t(z) #transpose
     [,1] [,2] [,3]
[1,]    1    2    3
[2,]    4    5    1
[3,]    2    3    4
[4,]    5    1    2
```

課堂練習5: interval data

```
> temperature
          January.a January.b February.a February.b
AnQing          1.8       7.1        2.1        7.2
BaoDing        -7.1       1.7       -5.3        4.8
BeiJing        -7.2       2.1       -5.9        3.8
BoKeTu        -23.4     -15.5      -24.0      -14.0
ChangChun     -16.9      -6.7      -17.6       -6.8
> tempArray <- array(0, dim=c(5,2,2))
> tempArray[,,1] <- as.matrix(temperature[,c(1,3)])
> tempArray[,,2] <- as.matrix(temperature[,c(2,4)])
> tempArray
, , 1

      [,1]  [,2]
[1,]   1.8   2.1
[2,]  -7.1  -5.3
[3,]  -7.2  -5.9
[4,] -23.4 -24.0
[5,] -16.9 -17.6

, , 2

      [,1]  [,2]
[1,]   7.1   7.2
[2,]   1.7   4.8
[3,]   2.1   3.8
[4,] -15.5 -14.0
[5,]  -6.7  -6.8
```

```
> colnames(tempArray) <- c("January", "February")
> rownames(tempArray) <- rownames(temperature)
> dimnames(tempArray)[[3]] <- c("min", "max")
> dimnames(tempArray)
[[1]]
[1] "AnQing"    "BaoDing"   "BeiJing"   "BoKeTu"
"ChangChun"

[[2]]
[1] "January"  "February"

[[3]]
[1] "min" "max"
> tempArray
, , min

          January February
AnQing        1.8      2.1
BaoDing      -7.1     -5.3
BeiJing      -7.2     -5.9
BoKeTu      -23.4    -24.0
ChangChun   -16.9    -17.6

, , max

          January February
AnQing        7.1      7.2
BaoDing       1.7      4.8
BeiJing       2.1      3.8
BoKeTu      -15.5    -14.0
ChangChun    -6.7     -6.8
```

矩陣 (Matrices)

- A matrix is an array with two subscripts.

```
> x <- 1:20
> A <- matrix(x, ncol=4)
> A
     [,1] [,2] [,3] [,4]
[1,]    1    6   11   16
[2,]    2    7   12   17
[3,]    3    8   13   18
[4,]    4    9   14   19
[5,]    5   10   15   20
> A.1 <- matrix(x, ncol=4, byrow=TRUE)
> A.1
     [,1] [,2] [,3] [,4]
[1,]    1    2    3    4
[2,]    5    6    7    8
[3,]    9   10   11   12
[4,]   13   14   15   16
[5,]   17   18   19   20
> nrow(A)
[1] 5
> ncol(A)
[1] 4
```

```
> dim(A)
[1] 5 4
> diag(A)
[1]  1  7 13 19
>
> B <- matrix(x+2, ncol=4)
> A * B #element by element product
     [,1] [,2] [,3] [,4]
[1,]    3   48  143  288
[2,]    8   63  168  323
[3,]   15   80  195  360
[4,]   24   99  224  399
[5,]   35  120  255  440
> A %*% t(B) #matrix product
     [,1] [,2] [,3] [,4] [,5]
[1,]  482  516  550  584  618
[2,]  524  562  600  638  676
[3,]  566  608  650  692  734
[4,]  608  654  700  746  792
[5,]  650  700  750  800  850
```

```
> x <- 4
> diag(x) #identity matrix
```

矩陣 (Matrices)

```
> apply(mat, 1, mean) # row means
[1]  9 10 11 12
> apply(mat, 2, mean) # column means
[1]  2.5  6.5 10.5 14.5 18.5
> apply(mat, 1, var) # row variances
[1] 40 40 40 40
> apply(mat, 2, var) # column variances
[1] 1.666667 1.666667 1.666667 1.666667 1.666667
>
> mean(mat)
[1] 10.5
> var(mat)
         [,1]     [,2]     [,3]     [,4]     [,5]
[1,] 1.666667 1.666667 1.666667 1.666667 1.666667
[2,] 1.666667 1.666667 1.666667 1.666667 1.666667
[3,] 1.666667 1.666667 1.666667 1.666667 1.666667
[4,] 1.666667 1.666667 1.666667 1.666667 1.666667
[5,] 1.666667 1.666667 1.666667 1.666667 1.666667
> summary(mat)
       V1              V2              V3              V4              V5
 Min.   :1.00   Min.   :5.00   Min.   : 9.00   Min.   :13.00   Min.   :17.00
 1st Qu.:1.75   1st Qu.:5.75   1st Qu.: 9.75   1st Qu.:13.75   1st Qu.:17.75
 Median :2.50   Median :6.50   Median :10.50   Median :14.50   Median :18.50
 Mean   :2.50   Mean   :6.50   Mean   :10.50   Mean   :14.50   Mean   :18.50
 3rd Qu.:3.25   3rd Qu.:7.25   3rd Qu.:11.25   3rd Qu.:15.25   3rd Qu.:19.25
 Max.   :4.00   Max.   :8.00   Max.   :12.00   Max.   :16.00   Max.   :20.00
```

```
> mat <- matrix(1:20, ncol=5)
> mat
     [,1] [,2] [,3] [,4] [,5]
[1,]    1    5    9   13   17
[2,]    2    6   10   14   18
[3,]    3    7   11   15   19
[4,]    4    8   12   16   20
> id <- mat[, 2] > 5
> id
[1] FALSE  TRUE  TRUE  TRUE
> mat[id, ]
     [,1] [,2] [,3] [,4] [,5]
[1,]    2    6   10   14   18
[2,]    3    7   11   15   19
[3,]    4    8   12   16   20
```

矩陣的索引

```
> (y <- array(1:15, dim=c(3, 5)))
> dim(y)
[1] 3 5

> x <- matrix(1:15, 3, 5)
> x
     [,1] [,2] [,3] [,4] [,5]
[1,]    1    4    7   10   13
[2,]    2    5    8   11   14
[3,]    3    6    9   12   15
> x[1]
[1] 1
> x[6]
[1] 6
>
> x <- matrix(1:15, 3, 5, byrow=TRUE)
> x
     [,1] [,2] [,3] [,4] [,5]
[1,]    1    2    3    4    5
[2,]    6    7    8    9   10
[3,]   11   12   13   14   15
> x[1]
[1] 1
> x[6]
[1] 12
```

```
> y[2, 4]
[1] 11
> y[1,]
[1]  1  4  7 10 13
> y[,1]
[1] 1 2 3
> y[2:3, ]
     [,1] [,2] [,3] [,4] [,5]
[1,]    2    5    8   11   14
[2,]    3    6    9   12   15
> y[-2,]
     [,1] [,2] [,3] [,4] [,5]
[1,]    1    4    7   10   13
[2,]    3    6    9   12   15
> y[,-2]
     [,1] [,2] [,3] [,4]
[1,]    1    7   10   13
[2,]    2    8   11   14
[3,]    3    9   12   15
> dimnames(y)
NULL
> rownames(y)
NULL
> colnames(y)
NULL
```

矩陣結合 (Forming Partitioned Matrices)

- **cbind()** and **rbind()**

```
> x <- c(1, 2, 3, 4, 5)
> y <- c(0.5, 0.4, 0.3, 0.2, 0.1)
> (z1 <- cbind(x,y))
     x   y
[1,] 1 0.5
[2,] 2 0.4
[3,] 3 0.3
[4,] 4 0.2
[5,] 5 0.1
> (z2 <- rbind(x,y))
  [,1] [,2] [,3] [,4] [,5]
x  1.0  2.0  3.0  4.0  5.0
y  0.5  0.4  0.3  0.2  0.1
```

```
> (A <- rbind(x,y))
     [,1] [,2] [,3] [,4]
[1,]    1    6   11   16
[2,]    2    7   12   17
[3,]    3    8   13   18
[4,]    4    9   14   19
[5,]    5   10   15   20
[6,]    3    5    7    9
[7,]    4    6    8   10
```

```
> (x <- matrix(1:20, ncol=4, nrow=5))
     [,1] [,2] [,3] [,4]
[1,]    1    6   11   16
[2,]    2    7   12   17
[3,]    3    8   13   18
[4,]    4    9   14   19
[5,]    5   10   15   20
> (y <- matrix(3:10, ncol=4))
     [,1] [,2] [,3] [,4]
[1,]    3    5    7    9
[2,]    4    6    8   10
> (z <- matrix(rep(1:5, 2),nrow=5))
     [,1] [,2]
[1,]    1    1
[2,]    2    2
[3,]    3    3
[4,]    4    4
[5,]    5    5
```

```
> (B <- cbind(x,z))
     [,1] [,2] [,3] [,4] [,5] [,6]
[1,]    1    6   11   16    1    1
[2,]    2    7   12   17    2    2
[3,]    3    8   13   18    3    3
[4,]    4    9   14   19    4    4
[5,]    5   10   15   20    5    5
```

表列 (List)

- List is an object consisting of an ordered collection of objects known as its components.
- A list could consist of a numeric vector, a logical value, a matrix, a complex vector, a character array, a function, and so on.
- 許多 R統計函式回傳值皆是 list。

```
> my.list <- list(name="George",
                  wife="Mary",
                  no.children=3,
                  child.ages=c(4,7,9))
> my.list
$name
[1] "George"

$wife
[1] "Mary"

$no.children
[1] 3

$child.ages
[1] 4 7 9
```

Construct list:

```
my.list <- list(name_1=object_1,…,name_m=object_m)
lst.ABC <- list(list.A, list.B, list.C)
```

表列 (List)

lst[1] vs **lst[[1]]**

- **[]:** a general subscripting.
- **[[]]:** the operator used to select a single element.
- **[1]:** a sublist of the **list** consisting of the first entry. (**name** are included in the sublist).
- **[[1]]:** first object in the list, **exclude name**.

```
> my.list
$name
[1] "George"

$wife
[1] "Mary"

$no.children
[1] 3

$child.ages
[1] 4 7 9
```

```
> my.list[[1]] #傳回向量
[1] "George"
> my.list[[2]]
[1] "Mary"
> my.list[[4]][1]
[1] 4
>
> my.list$name #my.list[[1]]
#my.list[["name"]]
[1] "George"
> my.list$wife #my.list[[2]]
[1] "Mary"
> my.list$child.ages[1] #my.list[[4]][1]
[1] 4
> x <- "name"
> my.list[[x]]
[1] "George"
>
> my.list[1] #傳回list
$name
[1] "George"
> my.list[2]
$wife
[1] "Mary"
```

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```
my.list <- list(name=c("George", "John", "Tom"),
                wife=c("Mary", "Sue", "Nico"),
                no.children=c(3, 2, 0),
                child.ages=list(c(4,7,9), c(2, 5), NA))
```

```
> my.list$name
[1] "George" "John"   "Tom"
> my.list$wife
[1] "Mary" "Sue"  "Nico"
> my.list$no.children
[1] 3 2 0
> my.list$name[3]
[1] "Tom"
> my.list$name=="John"
[1] FALSE  TRUE FALSE
> my.list$child.ages
[[1]]
[1] 4 7 9

[[2]]
[1] 2 5

[[3]]
[1] NA
```

```
> my.list$child.ages[2]
[[1]]
[1] 2 5
> my.list$child.ages[[2]]
[1] 2 5
> my.list$child.ages[2][1]
[[1]]
[1] 2 5
> my.list$child.ages[[2]][1]
[1] 2
> my.list$child.ages[[2]][2]
[1] 5
> length(my.list)
[1] 4
```

資料框 (Data Frame)

- A data frame is a list with class "**data.frame**" .
- Regarded as a matrix with column possibly of differing modes and attributes.

```
> my.matrix <- matrix(1:15, ncol=3)
> my.matrix
     [,1] [,2] [,3]
[1,]    1    6   11
[2,]    2    7   12
[3,]    3    8   13
[4,]    4    9   14
[5,]    5   10   15
> my.data <- data.frame(my.matrix)
> my.data
  X1 X2 X3
1  1  6 11
2  2  7 12
3  3  8 13
4  4  9 14
5  5 10 15
```

```
> my.data[1, ]
  X1 X2 X3
1  1  6 11
> my.data[2, 3]
[1] 12
> my.data$X1
[1] 1 2 3 4 5
> my.data[, "X1"]
[1] 1 2 3 4 5
> my.data["X1"]
  X1
1  1
2  2
3  3
4  4
5  5
> rownames(my.data)
[1] "1" "2" "3" "4" "5"
> row.names(my.data)
[1] "1" "2" "3" "4" "5"
> colnames(my.data)
[1] "X1" "X2" "X3"
> names(my.data)
[1] "X1" "X2" "X3"
```

資料框 (Data Frame)

```
> rownames(my.data) <- c(paste("s", 1:5, sep="."))
> colnames(my.data) <- c("A1", "A2", "A3")
> my.data
    A1 A2 A3
s.1  1  6 11
s.2  2  7 12
s.3  3  8 13
s.4  4  9 14
s.5  5 10 15
```

```
> attach(my.data)
> A1
[1] 1 2 3 4 5
> A2
[1]  6  7  8  9 10
> A3
[1] 11 12 13 14 15
> detach()
> A1
Error: object "A1" not found
```

列資料選取

```
> index.1 <- iris[, "Species"] == "virginica"
> iris[index.1, ]
    Sepal.Length Sepal.Width Petal.Length Petal.Width   Species
101          6.3         3.3          6.0         2.5 virginica
102          5.8         2.7          5.1         1.9 virginica
...

> iris[Species == "virginica",]
    Sepal.Length Sepal.Width Petal.Length Petal.Width   Species
101          6.3         3.3          6.0         2.5 virginica
102          5.8         2.7          5.1         1.9 virginica
...

> iris[!(Species=="virginica"),]
    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
...

> m <- mean(iris$Sepal.Length)
> index.3 <- iris[, "Sepal.Length"] > m
> iris[index.3, ]
    Sepal.Length Sepal.Width Petal.Length Petal.Width    Species
51           7.0         3.2          4.7         1.4 versicolor
52           6.4         3.2          4.5         1.5 versicolor
...
```

物件的模式(Modes)

- Mode: `"logical", "integer", "double", "complex", "raw", "character", "list", "expression", "name", "symbol" and "function".`

```
> mode(object)
```

- Vector must have their values all of the same mode.
  - Empty character string vector: `character(0)`.
  - Empty numeric vector: `numeric(0)`.

NOTE: Lists are of mode list. There are ordered sequences of objects which individually can be of any mode.

```
> (z <- 0:9)
 [1] 0 1 2 3 4 5 6 7 8 9
> mode(z)
[1] "numeric"
> (digits <- as.character(z))
 [1] "0" "1" "2" "3" "4" "5" "6" "7" "8" "9"
> mode(digits)
[1] "character"
> (d <- as.integer(digits))
 [1] 0 1 2 3 4 5 6 7 8 9
> mode(d)
[1] "numeric"
> (x <- z[1:5]>3)
 [1] FALSE FALSE FALSE FALSE  TRUE
> mode(x)
[1] "logical"
```

物件的屬性 (Attributes)

```
> attributes(object)
```

- Select a specific attribute

```
> attr(object, name)
```

- Set a specific attribute

```
> attr(z, “dim”) <- c(10, 10)
```

```
> x <- matrix(1:10, ncol=2)
> x
      [,1] [,2]
[1,]    1    6
[2,]    2    7
[3,]    3    8
[4,]    4    9
[5,]    5   10
> attributes(x)
$dim
[1] 5 2

> attr(x, "dim")
[1] 5 2
> dim(x)
[1] 5 2
```

```
> x <- data.frame(matrix(1:10, ncol=2))
> x
  X1 X2
1  1  6
2  2  7
3  3  8
4  4  9
5  5 10
> attributes(x)
$names
[1] "X1" "X2"

$row.names
[1] 1 2 3 4 5

$class
[1] "data.frame"

> attr(x, "names")
[1] "X1" "X2"
> names(x)
[1] "X1" "X2"
```

```
> gender.f
 [1] 女 女 男 女 男 男 男 男
女 女 男
Levels: 女 男
> str(gender.f)
 Factor w/ 2 levels "女","
男": 1 1 2 1 2 2 2 2 1 1 ...
> class(gender.f)
[1] "factor"
> attributes(gender.f)
$levels
[1] "女" "男"

$class
[1] "factor"
```

物件的長度

```
> beta <- c(1, 3, 5, 2, 4, 6, 11, NA, NA, 22)
> length(beta)
[1] 10
> length(beta[!is.na(beta)])
[1] 8
>
> e <- numeric() #empty object
> e[3] <- 17
> length(e)
[1] 3
> e
[1] NA NA 17
>
> alpha <- numeric(10)
> length(alpha)
[1] 10
> alpha <- alpha[2*1:5]
> length(alpha)
[1] 5
> length(alpha) <- 3
> alpha
[1] 0 0 0
```

```
> alpha
 [1] 0 0 0 0 0 0 0 0 0 0

> 2*1:5
[1]  2  4  6  8 10
```

物件的類別 (Class)

- All objects in R have a class.
  - For simple vector, mode=class: `numeric, logical, character, list`.
  - `matrix, array, factor, data.frame`

- R計算實數，是以雙倍精確度(double precision)來計算及儲存。

```
> (x <- pi)
[1] 3.141593
> is.double(x)
[1] TRUE
> is.numeric(x)
[1] TRUE
```

See also: `as.double`, `as.numeric`

```
> 4 + 5i
[1] 4+5i
> x <- complex(real=c(3, 4), imaginary=c(3, 4)); x
[1] 3+3i 4+4i
```

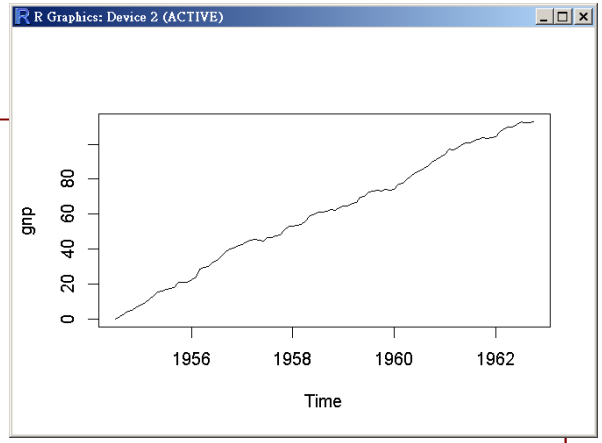
課堂練習7

```
> attach(iris)
> dim(iris)
[1] 150   5
> attributes(iris)
$names
[1] "Sepal.Length" "Sepal.Width"  "Petal.Length" "Petal.Width"  "Species"
$row.names
  [1]   1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16
..
$class
[1] "data.frame"
> str(iris)
'data.frame':   150 obs. of  5 variables:
 $ Sepal.Length: num  5.1 4.9 4.7 4.6 5 5.4 4.6 5 4.4 4.9 ...
..
 $ Species     : Factor w/ 3 levels "setosa","versicolor",..: 1 1 1 1 1 1 1 1 1 1 ...
> my.lm <- lm(Sepal.Length~Sepal.Width)
> my.lm
Call:
lm(formula = Sepal.Length ~ Sepal.Width)

Coefficients:
(Intercept)  Sepal.Width
     6.5262      -0.2234
> str(my.lm)
List of 12
 $ coefficients : Named num [1:2] 6.526 -0.223
  ..- attr(*, "names")= chr [1:2] "(Intercept)" "Sepal.Width"
...
```

時間物件變數: ts

```
ts(data = NA, start = 1, end = numeric(), frequency = 1,
   deltat = 1, ts.eps = getOption("ts.eps"), class = , names = )
as.ts(x, ...)
is.ts(x)
```




```
> ts(1:10, frequency = 4, start = c(1959, 2))
     Qtr1 Qtr2 Qtr3 Qtr4
1959         1    2    3
1960    4    5    6    7
1961    8    9   10
> my.ts <- ts(1:10, frequency = 7, start = c(12, 2))
> print(my.ts, calendar = TRUE)
   p1 p2 p3 p4 p5 p6 p7
12     1  2  3  4  5  6
13  7  8  9 10
> gnp <- ts(cumsum(1+round(rnorm(100), 2)), start = c(1954, 7), frequency = 12)
> gnp
        Jan     Feb     Mar     Apr     May     Jun     Jul     Aug     Sep     Oct     Nov     Dec
1954                                                   -0.12    1.62    3.13    4.36    4.78    6.81
1955    7.98    9.62   11.26   12.80   15.25   15.88   17.13   17.72   18.04   20.77   21.01   21.22
. . .
1962 104.41 106.88 108.87 109.82 109.62 111.52 112.70 112.29 112.48 112.84
> plot(gnp)
```

Multivariate ts

```
> z <- ts(matrix(rnorm(300), 100, 3), start = c(1961, 1), frequency = 12)
> head(z, 3)
         Series 1  Series 2   Series 3
[1,] -0.008998503 0.5389408 -0.9403586
[2,] -0.750712987 0.3026561 -0.1112974
[3,] -2.086179305 0.6752907  0.8359952
> tail(z, 3)
         Series 1   Series 2    Series 3
[98,]  1.6249153 -0.8999009  0.12837969
[99,]  0.6174681 -0.8451825  0.86245135
[100,] 0.5894715 -0.2738029 -0.05433789
>
> class(z)
[1] "mts"    "ts"     "matrix"
> plot(z)
> plot(z, plot.type = "single", lty = 1:3)
```