109-1: EE4052

通識課程：計算機程式設計之旅

Computer Programming

Unit 08: 多維度資料格式

連　豊　力

臺大電機系

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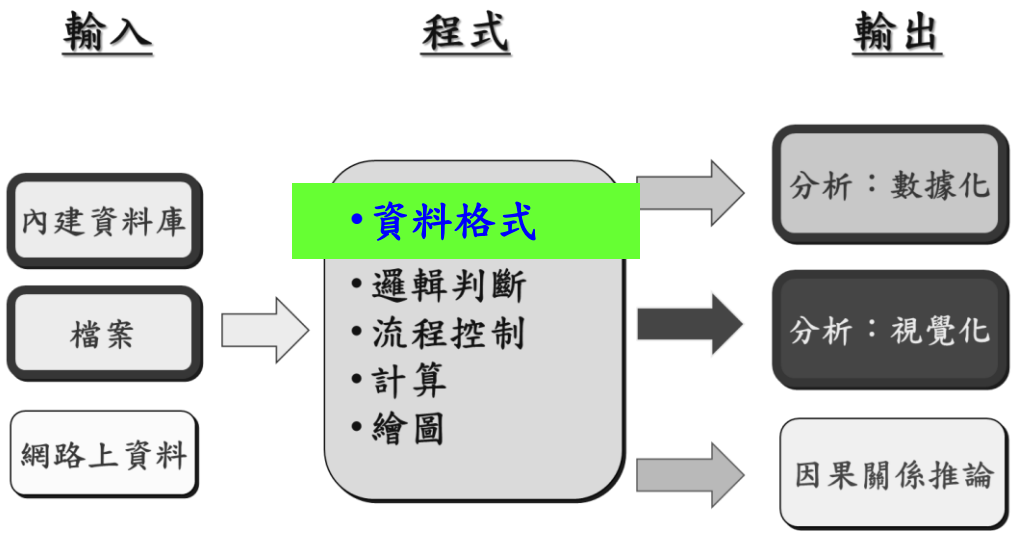
課程主題進度

- **U01:** 課程介紹：討論主題，作業，報告，進行方式
- **U02:** 主題，案例，程式，演算法，資源
- **U03:** 設定軟體 R 與 Rstudio
- **U04:** 數據處理與繪圖指令功能
- **U05:** 資料類別與基本運算
- **U06:** 邏輯判斷與流程控制
- **U07:** 函數：計算與排序
- **U08:** 多維度資料格式
- **U09:** 檔案資料輸入與輸出
- **U10:** 繪圖功能與文字
- **U11:** 多重繪圖與顏色
- **U12:** 函數：動畫與動作
- **U13:** 探索性資料分析
- **U14:** 資料間的相關性
- **U15:** 資料連結分析



簡介

- 一維的數據

10

70	84	39	32	60	31	78	77	61	79

10

70
84
39
32
60
31
78
77
61
79

- 二維的數據

3

16

70	19	65
84	71	56
39	79	19
32	76	33
60	90	82
31	81	71
78	10	84
77	82	76
61	48	76
79	60	46
81	29	79
33	60	65
76	60	38
69	33	83
71	39	83
70	56	33

8

3

70	84	39	32	60	31	78	77
19	71	79	76	90	81	10	82
65	56	19	33	82	71	84	76

簡介

- 三維以上的數據

3

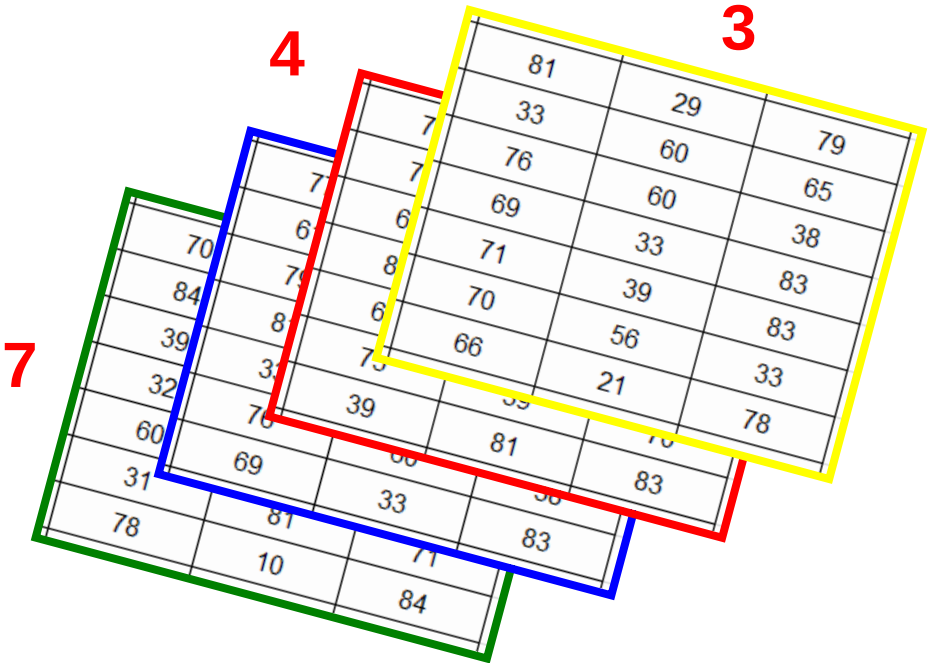
7

70	19	65
84	71	56
39	79	19
32	76	33
60	90	82
31	81	71
78	10	84

77	82	76
61	48	76
79	60	46
81	29	79
33	60	65
76	60	38
69	33	83

71	39	83
70	56	33
66	21	78
83	57	19
67	13	69
75	39	70
39	81	83

81	29	79
33	60	65
76	60	38
69	33	83
71	39	83
70	56	33
66	21	78



簡介

- 不同類型的資料

	Sepal.Length	Sepal.Width	Petal.Length	Petal.Width	Species
45	5.1	3.8	1.9	0.4	setosa
46	4.8	3.0	1.4	0.3	setosa
47	5.1	3.8	1.6	0.2	setosa
48	4.6	3.2	1.4	0.2	setosa
49	5.3	3.7	1.5	0.2	setosa
50	5.0	3.3	1.4	0.2	setosa
51	7.0	3.2	4.7	1.4	versicolor
52	6.4	3.2	4.5	1.5	versicolor
53	6.9	3.1	4.9	1.5	versicolor
54	5.5	2.3	4.0	1.3	versicolor
55	6.5	2.8	4.6	1.5	versicolor

	District	Group	Age	Holders	Claims
1	1	<1l	<25	197	38
2	1	<1l	25-29	264	35
3	1	<1l	30-35	246	20
4	1	<1l	>35	1680	156
5	1	1-1.5l	<25	284	63
6	1	1-1.5l	25-29	536	84
7	1	1-1.5l	30-35	696	89
8	1	1-1.5l	>35	3582	400
9	1	1.5-2l	<25	133	19
10	1	1.5-2l	25-29	286	52
11	1	1.5-2l	30-35	355	74
12	1	1.5-2l	>35	1640	233
13	1	>2l	<25	24	4
14	1	>2l	25-29	71	18
15	1	>2l	30-35	99	19
16	1	>2l	>35	452	77
17	2	<1l	<25	85	22
18	2	<1l	25-29	139	19
19	2	<1l	30-35	151	22
20	2	<1l	>35	931	87

大綱

作業

HW06：多維度資料格式

- 假設您預計購買一個手機，
  從網路上找到一些手機的資料，
  如下表所示：

廠牌	Brand	Apple	HTC	HTC	ASUS	ASUS
型號	Model	iPhone7	OneM8	OneS9	ZenFoneDeluxe	ZenFoneZoom
價格（元）	Price	24500	21900	9990	8990	15990
螢幕（吋）	Screen	4.7	5	5	5.5	5.5
重量（克）	Weight	138	160	158	170	185
記憶體（GB）	GB	32	16	32	16	64
日期（年月日）	Date	20160916	20140328	20160617	20150827	20151201

HW06：多維度資料格式

- 編輯一個程式於 .R 檔，完成下面的工作：
  - 建立一個數列：Brand，放置五個手機的廠牌資料
  - 建立一個數列：Model，放置五個手機的型號資料
  - 建立一個數列：Price，放置五個手機的價格資料
  - 建立一個數列：Screen，放置五個手機的螢幕資料
  - 建立一個數列：Weight，放置五個手機的重量資料
  - 建立一個數列：GB，放置五個手機的記憶體資料
  - 建立一個數列：Date，放置五個手機的日期資料
  - 建立一個 5x3 的矩陣 (matrix)：Number，
    放置五個手機的價格，螢幕，重量三種資料
  - 建立一個 資料框 (data.frame)：Phone，放置這五個手機的七種資料
  - 建立一個 資料框 (data.frame)：PhoneCheap，
    放置這五個手機，其價格小於10000元的手機的所有資料
- 您可以從一個一個數列慢慢建立起，
  也可以先建立一個資料框，再指定出個別的數列或矩陣
- 把編寫程式指令的想法或過程等，直接用註解在程式檔 (.R)。

HW06：多維度資料格式

- 繳交下面檔案，檔案名稱：HW06_學號_關鍵字.xxx
  - 主要指定檔案： HW06_B01921001_Phone.R
  - 不用編輯報告，直接把想法註解在程式檔 (.R) 之中，
  - 或者使用 (.Rmd) 格式編輯程式與結果，
  - 可以繳交下面格式的檔案： (.R) or (.Rmd) or (.html) 。

- 繳交方式與期限：
  - 上傳檔案到：https://cool.ntu.edu.tw
  - 繳交期限：11/16 (Mon), 11pm 以前

- 學習方式：
  - 請至下面網址輸入此次的學習方式所花的時間：
  - https://forms.gle/TGYXj2uLoL4HwqLHA

大綱

- 矩陣 matrix
- 陣列 array
- 列表 list
- 資料框 data.frame
- 因子 factor

大綱

16 × 3

70	19	65
84	71	56
39	79	19
32	76	33
60	90	82
31	81	71
78	10	84
77	82	76
61	48	76
79	60	46
81	29	79
33	60	65
76	60	38
69	33	83
71	39	83
70	56	33

3 × 8

70	84	39	32	60	31	78	77
19	71	79	76	90	81	10	82
65	56	19	33	82	71	84	76

矩陣 – matrix

建立矩陣與性質

- A <- matrix(c(1, -5, 4, 3, 6, -2), nrow = 2, ncol = 3)
- # by column

- B <- matrix(c(1, -5, 4, 3, 6, -2), nrow = 2, ncol = 3, byrow = TRUE)
- # by row

- class(A)
- dim(A)
- attributes(A)
- nrow(A)
- dim(A)[1]
- ncol(A)
- dim(A)[2]

```
> class(A)
[1] "matrix"

> dim(A)
[1] 2 3

> attributes(A)
$dim
[1] 2 3

> nrow(A)
[1] 2

> dim(A)[1]
[1] 2

> ncol(A)
[1] 3

> dim(A)[2]
[1] 3
```

```
> A
     [,1] [,2] [,3]
[1,]    1    4    6
[2,]   -5    3   -2
```

```
> B
     [,1] [,2] [,3]
[1,]    1   -5    4
[2,]    3    6   -2
```

矩陣與向量

- A <- matrix(c(1, -5, 4, 3, 6, -2), nrow = 2, ncol = 3)
- u <- as.numeric(A)
- v <- c(A)
- dim(v)
- length(v)
- nrow(A) * ncol(A)
- length(A)

```
> A
     [,1] [,2] [,3]
[1,]    1    4    6
[2,]   -5    3   -2

> u
[1]  1 -5  4  3  6 -2

> v
[1]  1 -5  4  3  6 -2

> dim(v)
NULL

> length(v)
[1] 6

> nrow(A) * ncol(A)
[1] 6

> length(A)
[1] 6
```

零矩陣與單位矩陣

- matrix(0, nrow = 2, ncol = 3)
- matrix(0, nrow = 3, ncol = 3)
- diag(0, nrow = 3)
- diag(3)
- diag(2.5, nrow = 3)
- diag(c(1, 2, 3), nrow = 3)
- diag(c(1, 2, 3))

```
> matrix( 0, nrow = 2, ncol = 3 )
     [,1] [,2] [,3]
[1,]    0    0    0
[2,]    0    0    0


> matrix( 0, nrow = 3, ncol = 3 )
     [,1] [,2] [,3]
[1,]    0    0    0
[2,]    0    0    0
[3,]    0    0    0


> diag( 0, nrow = 3 )
     [,1] [,2] [,3]
[1,]    0    0    0
[2,]    0    0    0
[3,]    0    0    0


> diag( 3 )
     [,1] [,2] [,3]
[1,]    1    0    0
[2,]    0    1    0
[3,]    0    0    1


> diag( 2.5, nrow = 3 )
     [,1] [,2] [,3]
[1,]  2.5  0.0  0.0
[2,]  0.0  2.5  0.0
[3,]  0.0  0.0  2.5


> diag( c(1, 2, 3), nrow = 3 )
     [,1] [,2] [,3]
[1,]    1    0    0
[2,]    0    2    0
[3,]    0    0    3


> diag( c(1, 2, 3) )
     [,1] [,2] [,3]
[1,]    1    0    0
[2,]    0    2    0
[3,]    0    0    3>
```

矩陣的 加 減 乘

- A <- matrix(1:9, nrow = 3, ncol = 3)
- B <- matrix(1:9, nrow = 3, ncol = 3, byrow = TRUE)
- A + B
- A - B
- A %*% B

```
     [,1] [,2] [,3]
[1,]    1    4    7
[2,]    2    5    8
[3,]    3    6    9
```

```
     [,1] [,2] [,3]
[1,]    1    2    3
[2,]    4    5    6
[3,]    7    8    9
```

- A * B

```
     [,1] [,2] [,3]
[1,]    1    4    7
[2,]    2    5    8
[3,]    3    6    9
```

```
     [,1] [,2] [,3]
[1,]    1    2    3
[2,]    4    5    6
[3,]    7    8    9
```

用指標的方式取出某個分量

- A <- matrix(1:9, nrow = 3, ncol = 3)
- B <- matrix(1:9, nrow = 3, ncol = 3, byrow = TRUE)
- A[2, 3]
- A[1, 2]
- A[4]
- c(A)[4]

- R1 <- A[1,]
- class(R1)

- R1[1, 2]

```
[1] 1 4 7
```

- R1 * B

- R1 %*% B

```
[1] 1 4 7
```

```
     [,1] [,2] [,3]
[1,]    1    2    3
[2,]    4    5    6
[3,]    7    8    9
```

```
     [,1] [,2] [,3]
[1,]    1    2    3
[2,]    4    5    6
[3,]    7    8    9
```

成為一個矩陣

- A <- matrix(1:9, nrow = 3, ncol = 3)
- B <- matrix(1:9, nrow = 3, ncol = 3, byrow = TRUE)

- R2 <- A[1, , drop = FALSE]
- class(R2)

- R2[1, 2]

- R2 %*% B

```
> R1 <- A[ 1, ]
> class(R1)
[1] "integer"
> R2 <- A[ 1,  , drop = FALSE ]
> class( R2 )
[1] "matrix"
```

形成另外一個矩陣或向量

- A <- matrix(1:9, nrow = 3, ncol = 3)
- E <- A[c(1, 3),]
- class(E)
- F <- A[c(1, 3), 2]
- class(F)

```
> E <- A[ c(1, 3), ]

> E
     [,1] [,2] [,3]
[1,]    1    4    7
[2,]    3    6    9

> class( E )

[1] "matrix"


> F <- A[ c(1, 3), 2 ]

> F

[1] 4 6

> class( F )

[1] "integer"
```

結合矩陣

- C <- matrix(1:4, nrow = 2, ncol = 2)
- D <- matrix(1:6, nrow = 2, ncol = 3)

- cbind(C, D)

- E <- matrix(1:4, nrow = 2, ncol = 2)
- F <- matrix(1:6, nrow = 3, ncol = 2)

- rbind(E, F)

```
> cbind( C, D )

     [,1] [,2] [,3] [,4] [,5]
[1,]    1    3    1    3    5
[2,]    2    4    2    4    6


> rbind(E, F)

     [,1] [,2]
[1,]    1    3
[2,]    2    4
[3,]    1    4
[4,]    2    5
[5,]    3    6
```

轉置矩陣

- A <- matrix(1:9, nrow = 3, ncol = 3)
- t(A)
- t(A) %*% A
- diag(A)
- sum(diag(A))

```
> t( A )

     [,1] [,2] [,3]
[1,]    1    2    3
[2,]    4    5    6
[3,]    7    8    9

> t( A ) %*% A

     [,1] [,2] [,3]
[1,]   14   32   50
[2,]   32   77  122
[3,]   50  122  194

> diag( A )

[1] 1 5 9

> sum( diag( A ) )

[1] 15
```

矩陣的行列式值與反矩陣

- A <- matrix(c(1, 0, 0, 3, 0.5, 0, 2, 1, 0.25), nrow = 3, ncol = 3)
- det(A)
- Ainv <- solve(A)
- Ainv
- Ainv %*% A

A^(-1)

```
> det(A)

[1] 0.125

> Ainv <- solve(A)

> Ainv

     [,1] [,2] [,3]
[1,]    1   -6   16
[2,]    0    2   -8
[3,]    0    0    4

> Ainv %*% A

     [,1] [,2] [,3]
[1,]    1    0    0
[2,]    0    1    0
[3,]    0    0    1
```

線性方程式：Ax = b

- A <- matrix(c(1, 0, 0, 3, 0.5, 0, 2, 1, 0.25), nrow = 3, ncol = 3)
- b <- c(2, 1, 3)
- solve(A, b)

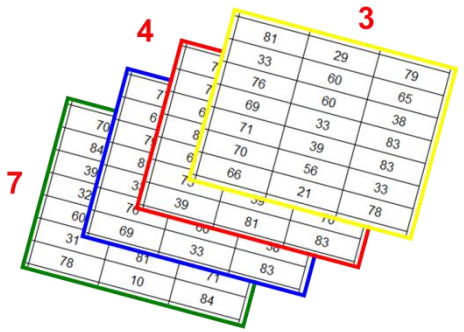
A x = b

x = A^(-1) b

```
  x +   3*y +    2*z   =   2
      0.5*y +      z   =   1
                0.25*z   =   3


[  1  3    2    ] [ x ]   [ 2 ]
[  0  0.5  1    ] [ y ] = [ 1 ]
[  0  0    0.25 ] [ z ]   [ 3 ]


[ x ]     [  1  3.   2    ]^(-1) [ 2 ]
[ y ]  =  [  0  0.5  1    ]      [ 1 ]
[ z ]     [  0  0    0.25 ]      [ 3 ]
```

```
> A

     [,1] [,2] [,3]
[1,]    1  3.0 2.00
[2,]    0  0.5 1.00
[3,]    0  0.0 0.25

> b

[1] 2 1 3

> solve( A, b )

[1]  44 -22  12
```

大綱



陣列 – array

定義一個陣列

- ?array
- array(data = NA, dim = length(data), dimnames = NULL)
  - data: 陣列內容的資料，預設值為 NA
  - dim: 維度，陣列的一個屬性
  - dimnames: 維度的名稱
- array(1:12)
- array(, c(3, 4))
- array(1:12, c(3, 4))
- array(data = 1:12, dim = c(3, 4))
- array(data = 1:60, dim = c(3, 4, 5))
- args(array)

```
> array( 1:12 )

 [1]  1  2  3  4  5  6  7  8  9 10 11 12

> array(  , c(3, 4) )

     [,1] [,2] [,3] [,4]
[1,]   NA   NA   NA   NA
[2,]   NA   NA   NA   NA
[3,]   NA   NA   NA   NA

> array( 1:12, c(3, 4) )

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

> array( data = 1:60, dim = c(3, 4, 5) )

, , 1

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

, , 2

     [,1] [,2] [,3] [,4]
[1,]   13   16   19   22
[2,]   14   17   20   23
[3,]   15   18   21   24

, , 3
.....
```

大綱

列表

```
> camera

$brand
[1] "Leica"   "Pentax"  "Olympus"
"Nikon"

$real.number
[1] 1.2 3.4

$color
[1] "red"   "green" "blue"
```

列表

- camera <- list(c("Leica", "Pentax", "Olympus", "Nikon"), c(1.2, 3.4), c("red", "green", "blue"))

```
> camera

[[1]]
[1] "Leica"   "Pentax"  "Olympus" "Nikon"

[[2]]
[1] 1.2 3.4

[[3]]
[1] "red"   "green" "blue"
```

- camera <-
  list(c("Leica", "Pentax", "Olympus", "Nikon"),
        c(1.2, 3.4),
        c("red", "green", "blue")
)

```
> camera

$brand
[1] "Leica"   "Pentax"  "Olympus" "Nikon"

$real.number
[1] 1.2 3.4

$color
[1] "red"   "green" "blue"
```

- camera <- list(brand = c("Leica", "Pentax", "Olympus", "Nikon"), real.number = c(1.2, 3.4), color = c("red", "green", "blue"))

- camera <-
  list(brand = c("Leica", "Pentax", "Olympus", "Nikon"),
        real.number = c(1.2, 3.4),
        color = c("red", "green", "blue")
)

索引方式 1 – 使用 [ ]

- a1 <- camera[1]
- a1

- camera["brand"]

- class(a1)

```
> a1

$brand
[1] "Leica"   "Pentax"  "Olympus" "Nikon"


> camera[ "brand" ]

$brand
[1] "Leica"   "Pentax"  "Olympus" "Nikon"

> class( a1 )

[1] "list"
```

索引方式 2 – 使用 [[ ]]

- a2 <- camera[[1]]
- a2

- camera[["brand"]]

- class(a2)

```
> a2
[1] "Leica"   "Pentax"  "Olympus" "Nikon"

> camera[[ "brand" ]]
[1] "Leica"   "Pentax"  "Olympus" "Nikon"
> class( a2 )
[1] "character"
```

索引方式 3 – 使用 $

- a3 <- camera$brand
- a3

- class(a3)

```
> a3
[1] "Leica"   "Pentax"  "Olympus" "Nikon"
> class( a3 )
[1] "character"
```

索引方式 的比較

- a1 # a1 是列表
- a2 # a2 是向量
- a3 # a3 是向量

- class(a1)
- class(a2)
- class(a3)

- camera[1][1]
- a1[1]

- a2[c(1, 2)]

- a3[2]

```
> a1                          # a1 是列表
$brand
[1] "Leica"   "Pentax"  "Olympus" "Nikon"

> a2                          # a2 是向量
[1] "Leica"   "Pentax"  "Olympus" "Nikon"

> a3                          # a3 是向量
[1] "Leica"   "Pentax"  "Olympus" "Nikon"

> class( a1 )
[1] "list"

> class( a2 )
[1] "character"

> class( a3 )
[1] "character"

> camera[ 1 ][ 1 ]
$brand
[1] "Leica"   "Pentax"  "Olympus" "Nikon"

> a1[ 1 ]
$brand
[1] "Leica"   "Pentax"  "Olympus" "Nikon"

> a2[ c(1, 2) ]
[1] "Leica"  "Pentax"

> a3[ 2 ]
[1] "Pentax"
```

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資料框

```
> camera

   member   brand color amount
1  father   Leica  gold      2
2  mother  Pentax   red      1
3 brother Olympus green      1
4  sister   Nikon  blue      2
```

資料框 (data frame)

- x1 <- c("father", "mother", "brother", "sister")
- x2 <- c("Leica", "Pentax", "Olympus", "Nikon")
- x3 <- c("gold", "red", "green", "blue")
- x4 <- c(2, 1, 1, 2)

```
> x
[1] "R" "G" "B" "R" "R" "B" "R" "G" "G"

> x2
[1] "Leica"   "Pentax"  "Olympus" "Nikon"

> x3
[1] "gold"  "red"   "green" "blue"

> x4
[1] 2 1 1 2
```

- camera <- data.frame(member = x1, brand = x2, color = x3, amount = x4)
- camera

```
> camera

   member   brand color amount
1  father   Leica  gold      2
2  mother  Pentax   red      1
3 brother Olympus green      1
4  sister   Nikon  blue      2
```

資料框 – 特徵

- camera
- class(camera)
- names(camera)
- colnames(camera) # column names
- rownames(camera) # row names

```
> camera
   member   brand color amount
1  father   Leica  gold      2
2  mother  Pentax   red      1
3 brother Olympus green      1
4  sister   Nikon  blue      2

> class(camera)
[1] "data.frame"

> names(camera)
[1] "member" "brand"  "color"  "amount"

> colnames(camera)
[1] "member" "brand"  "color"  "amount"

> rownames(camera)
[1] "1" "2" "3" "4"
```

資料框 – 內容

- camera
- camera$brand
- camera[, 2]
- camera[, "brand"]

```
> camera
   member   brand color amount
1  father   Leica  gold      2
2  mother  Pentax   red      1
3 brother Olympus green      1
4  sister   Nikon  blue      2

> camera$brand
[1] Leica   Pentax  Olympus Nikon
Levels: Leica Nikon Olympus Pentax

> camera[, 2]
[1] Leica   Pentax  Olympus Nikon
Levels: Leica Nikon Olympus Pentax

> camera[, "brand"]
[1] Leica   Pentax  Olympus Nikon
Levels: Leica Nikon Olympus Pentax
```

資料框 – 加入一行數據

- x5 <- c(8, 3, 2, 2)
- camera$cost <- x5
- camera

```
> camera
   member   brand color amount cost
1  father   Leica  gold      2    8
2  mother  Pentax   red      1    3
3 brother Olympus green      1    2
4  sister   Nikon  blue      2    2
```

資料框 – 改變名稱

- test <- camera
- colnames(test)[c(4, 5)] <- c("number", "money")
- test

```
> test

   member   brand color number money
1  father   Leica  gold      2     8
2  mother  Pentax   red      1     3
3 brother Olympus green      1     2
4  sister   Nikon  blue      2     2
```

資料框 – 捉取某一欄位的數據

- # 品牌 (brand) 為 Leica 的資料

- camera[camera$brand == "Leica",]
- subset(camera, brand == "Leica")

```
member brand color amount cost
1 father Leica  gold      2    8

member brand color amount cost
1 father Leica  gold      2    8
```

- # 品牌 (brand) 為 Leica 或 Nikon 的資料

- camera[camera$brand %in% c("Leica", "Nikon"),]
- subset(camera, brand %in% c("Leica", "Nikon"))

```
  member brand color amount cost
1 father Leica  gold      2    8
4 sister Nikon  blue      2    2

  member brand color amount cost
1 father Leica  gold      2    8
4 sister Nikon  blue      2    2
```

- # 價格 (cost) 大於 2 的資料

- camera[camera$cost > 2,]
- subset(camera, cost > 2)

```
member  brand color amount cost
1 father  Leica  gold      2    8
2 mother Pentax   red      1    3

  member  brand color amount cost
1 father  Leica  gold      2    8
2 mother Pentax   red      1    3
```

資料框 – 把矩陣轉為資料框

- A <- matrix(c(1, -5, 4, 3, 6, -2), nrow = 2, ncol = 3)

- rownames(A) # row names
- colnames(A) # column names

- D <- as.data.frame(A)

- names(D)
- colnames(D)
- rownames(D)

- D$V1

```
> A
     [,1] [,2] [,3]
[1,]    1    4    6
[2,]   -5    3   -2

> rownames( A )
NULL

> colnames( A )
NULL

> D

  V1 V2 V3
1  1  4  6
2 -5  3 -2

> names( D )
[1] "V1" "V2" "V3"

> colnames( D )
[1] "V1" "V2" "V3"

> rownames( D )
[1] "1" "2"

> D$V1
[1]  1 -5
```

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因子

```
> y
[1] R G B R R B R G G
Levels: B G R
```

因子 (factor)

- 因子是用來描述舉有等級與類別屬性的資料，例如：性別，階級等
- x <- c("R", "G", "B", "R", "R", "B", "R", "G", "G")
- class(x)
- y <- factor(x)
- class(y)

```
> x
[1] "R" "G" "B" "R" "R" "B" "R" "G" "G"
> class(x)
[1] "character“
```

```
> y
[1] R G B R R B R G G
Levels: B G R
> class(y)
[1] "factor"
```

因子 (factor)

- # 這些等級可以用整數來表示
- as.integer(y)
- levels(y)
- levels(y)[2]
- nlevels(y)
- levels(y)[as.integer(y)]

```
> as.integer( y )
[1] 3 2 1 3 3 1 3 2 2

> levels( y )
[1] "B" "G" "R"

> levels( y )[2]
[1] "G"

> nlevels( y )
[1] 3

> levels( y )[ as.integer(y) ]
[1] "R" "G" "B" "R" "R" "B" "R" "G" "G"
```

因子案例 – iris, CO2

- iris[,5]
- class(iris[, 5])
- summary(iris)
- class(CO2[, 1])
- class(CO2[, 2])
- class(CO2[, 3])
- summary(CO2)

iris[, 5] - Levels: setosa versicolor virginica

```
> iris[,5]
  [1] setosa     setosa     setosa
…
 [56] versicolor versicolor versicolor
…
[144] virginica  virginica  virginica
virginica  virginica  virginica  virginica
Levels: setosa versicolor virginica

> class( iris[,5] )
[1] "factor"

> class( CO2[,3] )
[1] "factor"

> class( CO2[,2] )
[1] "factor“

> class( CO2[,1] )
[1] "ordered" "factor"

> CO2[,1]
 [1] Qn1 Qn1 Qn1 Qn1 …… Mc3 Mc3 Mc3
Levels: Qn1 < Qn2 < Qn3 < Qc1 < Qc3 < Qc2 <
Mn3 < Mn2 < Mn1 < Mc2 < Mc3 < Mc1

>
```

產生因子 – 5的等級，3個分量

- gl(5, 3) # factor levels up to 5 with repeats of 3
- gl(n = 5, k = 3)
- class(gl(5, 3))
- gl(5, 2, 13)
- gl(n = 5, k = 2, length = 13)
- is.factor(gl(5, 2, 13))

```
> gl( 5, 3 )

 [1] 1 1 1 2 2 2 3 3 3 4 4 4 5 5 5
Levels: 1 2 3 4 5

> gl( n = 5, k = 3 )

 [1] 1 1 1 2 2 2 3 3 3 4 4 4 5 5 5
Levels: 1 2 3 4 5

> class( gl( 5, 3 ) )

[1] "factor"

> gl( 5, 2, 13 )

 [1] 1 1 2 2 3 3 4 4 5 5 1 1 2
Levels: 1 2 3 4 5

> gl( n = 5, k = 2, length = 13 )

 [1] 1 1 2 2 3 3 4 4 5 5 1 1 2
Levels: 1 2 3 4 5

> is.factor( gl(5, 2, 13) )

[1] TRUE
```

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下課了