Lecture 5: Data Structures II: Lists, Matrices, and Data Frames

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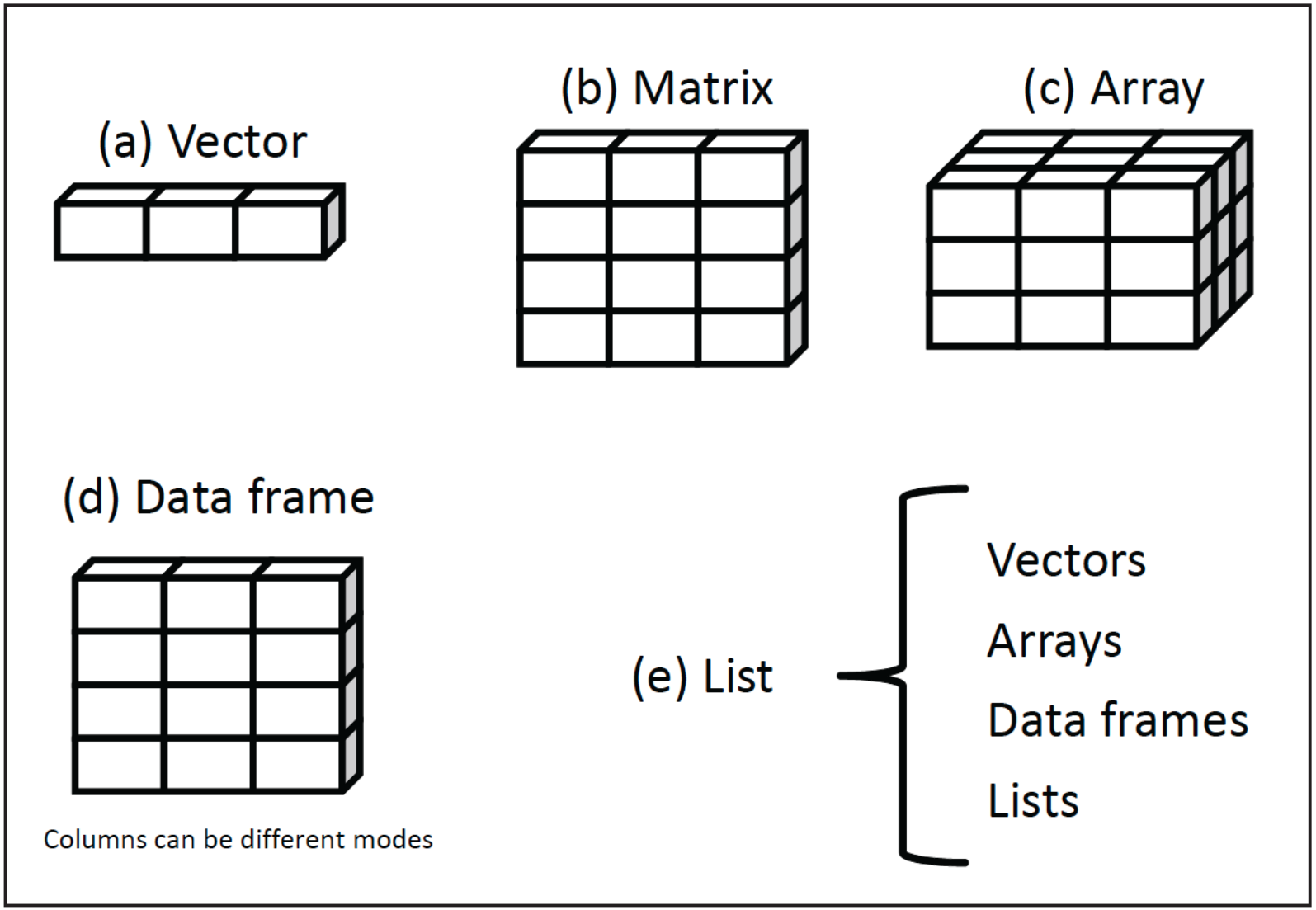
BSDS 100 - Intro to Data Science with `R`

Outline

- Lists
- Matrices and Arrays
- Data Frames

Recall: Data Structures



Part I: Lists

Lists

- Lists are different from atomic vectors as elements of a list can be of any type, including lists
- A list is constructed using `list()` instead of `c()`

```
> myList <- list(10:12, "abc", c(3.1415, 9), c(T, F, F, F))

> str(myList)
List of 4
 $ : int [1:3] 10 11 12
 $ : chr "abc"
 $ : num [1:2] 3.14 9
 $ : logi [1:4] TRUE FALSE FALSE FALSE
```

Lists

- Lists are recursive, i.e., a list can contain lists, making them fundamentally different from atomic vectors
- Handy functions

Function	Action
`is.list()`	test if list
`as.list()`	coerce to list
`unlist()`	convert to atomic vector + coercion

JSON Data

- JSON stands for JavaScript Object Notation
- JSON data is a list and is
  - light-weight
  - language-independent
  - easy to read and write
  - text-based, human readable data exchange format

JSON Data

Using `jsonlite` package:

```
> mtcars[1:2, 1:2]
              mpg cyl
Mazda RX4      21   6
Mazda RX4 Wag  21   6

> (json_01 <- toJSON(mtcars[1:2, 1:2]))
[
{"mpg":21, "cyl":6, "_row":"Mazda RX4"},
{"mpg":21, "cyl":6, "_row":"Mazda RX4 Wag"}
]
```

Part II: Matrices and Arrays

Matrices and Arrays

- By giving an atomic vector a dimension attribute, it behaves like a multi-dimensional array
- A special case of the array is a matrix, a two-dimensional array
- Matrices and arrays are created with `matrix()` and `array()`

Matrix Example

```
> x <- matrix(1:10, ncol = 5, nrow = 2)
 # can drop ncol and nrow to shorten

 > x
     [,1] [,2] [,3] [,4] [,5]
[1,]    1    3    5    7    9
[2,]    2    4    6    8   10
```

Array Example

```
> y <- array(1:12, c(2, 3, 2))
> y
, , 1

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

, , 2

     [,1] [,2] [,3]
[1,]    7    9   11
[2,]    8   10   12
```

Selected Functional Generalizations

1-D Function	n-D Functions
`length()`	`nrow()`, `ncol()`, `dim()`
`names()`	`rownames()`, `colnames()`, `dimnames()`
`c()`	`cbind()`, `rbind()`, `abind()`

Note: a matrix or array can also be one-dimensional, e.g., an object that is defined as a matrix is permitted to only have one column or one row; although they may look and behave alike, a vector and a one-dimensional matrix behave differently and may generate strange output when using certain functions, e.g., `tapply()`

Part III: Data Frames

Data Frames

- Most common way of storing data in R
- A data frame is a list with equal-length vectors
- Each vector must be of the same data type

This is why we use

Data Frame Summary Example

Summary of Data `ToothGrowth`: a data frame with 60 observations on 3 variables.

- [, 1] len numeric: Tooth length
- [, 2] supp factor: Supplement type (VC or OJ)
- [, 3] dose numeric: Dose in milligrams/day

```
> str(ToothGrowth)
'data.frame': 60 obs. of  3 variables:
 $ len : num  4.2 11.5 7.3 5.8 6.4 10 11.2 11.2 5.2 7 ...
 $ supp: Factor w/ 2 levels "OJ","VC": 2 2 2 2 2 2 2 2 2 2 ...
 $ dose: num  0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 ...

 > ?ToothGrowth
```

Creating Data Frames

Create a data frame using `data.frame()`

```
# this is sloppy coding etiquette and is only for exposition

> (xyz <- data.frame(1:3, c("a", "b", "c")))
  X1.3 c..a....b....c..
1    1                a
2    2                b
3    3                c

> str(xyz)
'data.frame': 3 obs. of  2 variables:
 $ X1.3            : int  1 2 3
 $ c..a....b....c..: Factor w/ 3 levels "a","b","c": 1 2 3
```

Creating Data Frames

Create a data frame using `data.frame()`

- Surround code with `()` to automatically print the result to the console
- After creating the data frame, the first column of untitled numbers are row numbers
- Observe that even though the entries in `letterColumn` are characters that an `str(letterColumn)` shows the column to be a `Factor`

Creating and Manipulating Data Frames

- If you want to suppress R's default behavior of turning strings into factors, use the options `stringsAsFactors = FALSE`

```
> (xyz <- data.frame(numberColumn = 1:3, letterColumn = c("a", "b", "c"),
    stringsAsFactors = F))

  numberColumn letterColumn
1            1            a
2            2            b
3            3            c

> str(xyz)

'data.frame': 3 obs. of  2 variables:
 $ numberColumn: int  1 2 3
 $ letterColumn: chr  "a" "b" "c"
```

Creating and Manipulating Data Frames

- **Note:** A data frame is a list, which means that `typeof(myDataFrame)` will output a list
- Instead use `class()` or `is.data.frame()`
- An object can be coerced to a data frame using `as.data.frame()`

Combine/Append Data Frames

- **When a data frame already exists**, you can easily combine/append another data frame or a vector to the original data frame

1. Use `cbind()` to column-bind two data frames
   - **Note**: the number of columns in each data frame must be equal, and row names are ignored
2. Use `rbind()` to row-bind two data frames
   - **Note**: the **number** and the **names** of columns must match

Examples: `cbind()`

```
> (myDataFrame_01 <- data.frame(x = 1:3, y = c("A", "B", "c")))
  x y
1 1 A
2 2 B
3 3 c

> (myDataFrame_02 <- cbind(myDataFrame_01, data.frame(z = -1:-3)))
  x y  z
1 1 A -1
2 2 B -2
3 3 c -3
```

Examples: `rbind()`

```
> (myDataFrame_05 <- data.frame(x = 1:3, y = 98:100, z = 1000:1002))
  x   y    z
1 1  98 1000
2 2  99 1001
3 3 100 1002

> (myDataFrame_06 <- rbind(myDataFrame_05, qqq = -1:-3))
     x   y    z
1    1  98 1000
2    2  99 1001
3    3 100 1002
qqq -1  -2   -3
```

Example: Try these

```
> myDataFrame_05 <- data.frame(x = 1:3, y = 98:100, z = 1000:1002)

> myDataFrame_06 <- rbind(myDataFrame_05, ???)
```

- Based on the `myDataFrame_06` code, what happens if we replace ??? with:
  - (a) `qqq = -1`
  - (b) `qqq = -1:-2`
  - (c) `qqq = -1:-99`
  - (d) `qqq = c(-1, -2)`
  - (e) `qqq = c("-1", -2)`
  - (f) `qqq = c("a", -2, -3)))`

Solution

```
> myDataFrame_05 <- data.frame(x = 1:3, y = 98:100, z = 1000:1002)

> myDataFrame_06 <- rbind(myDataFrame_05, ???)
```

(a) Entire additional row of −1's

(b) Entire additional row of repeating −1's and −2's

(c) Additional row: -1, -2, -3

(d) Entire additional row of repeating −1's and −2's

(e) Entire additional row of repeating −1's and −2's as characters (non numeric), thereby changing **all** all data frame column types to characters

(f) Additional row: a, -2, -3 as characters (non numeric), thereby changing **all** all data frame columns types to characters

Combine/Append Data Frames

- Use `cbind()` to column-bind a data frame with a vector
  - **Note**: This will only work if the vector has the same length as the number of rows in the data frame.

```
> (myDataFrame_07 <- data.frame(x = 1:3, y = 98:100, z = 1000:1002))
  x   y    z
1 1  98 1000
2 2  99 1001
3 3 100 1002

> (myDataFrame_08 <- cbind(myDataFrame_05, qqq = -1:-3))
  x   y    z qqq
1 1  98 1000  -1
2 2  99 1001  -2
3 3 100 1002  -3
```

Example: Try these

```
> myDataFrame_07 <- data.frame(x = 1:3, y = 98:100, z = 1000:1002)

> myDataFrame_08 <- cbind(myDataFrame_07, ???)
```

- Based on the `myDataFrame_08` code, what happens if we replace ??? with:
  (a) `qqq = -1`
  (b) `qqq = -1:-2`
  (c) `qqq = -1:-99`
  (d) `qqq = c("-1", -2)`
  (e) `qqq = c("a", -2, -3)))`

Solution

```
> myDataFrame_07 <- data.frame(x = 1:3, y = 98:100, z = 1000:1002)

> myDataFrame_08 <- cbind(myDataFrame_05, ???)
```

(a) Entire additional column of −1's

(b) `<arguments imply differing number of rows: 3, 2>`

(c) Extends the length of all other columns and repeats those values until −99

(d) `<arguments imply differing number of rows: 3, 2>`

(e) `<arguments imply differing number of rows: 3, 2>`

(f) Additional column: a, -2, -3 as factors (non numeric)

Assignment 5

- Complete the Computational Assignment here.

Due: Next Tuesday at the beginning of class.