

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



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BSDS 100 - Intro to Data Science with R



- Lists
- Matrices and Arrays
- Data Frames

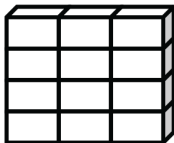
# Recall: Data Structures



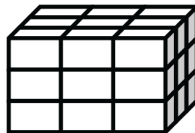
(a) Vector



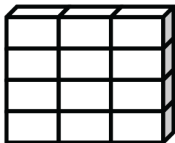
(b) Matrix



(c) Array

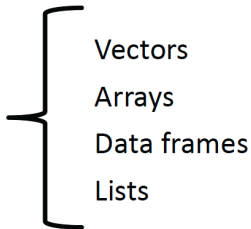


(d) Data frame



Columns can be different modes

(e) List



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

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Function	Action
<code>is.list()</code>	test if list
<code>as.list()</code>	coerce to list
<code>unlist()</code>	convert to atomic vector + coercion

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- 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



## 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



- 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()`



```
> 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



```
> 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
```



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## 1-D Function    n-D Functions

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<code>length()</code>	<code>nrow()</code> , <code>ncol()</code> , <code>dim()</code>
<code>names()</code>	<code>rownames()</code> , <code>colnames()</code> , <code>dimnames()</code>
<code>c()</code>	<code>cbind()</code> , <code>rbind()</code> , <code>abind()</code>

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**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



- 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
```



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`



- 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"
```



- **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()`



- **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, qq = -1:-3))
```

```
  x    y    z
1  1   98 1000
2  2   99 1001
3  3  100 1002
qq -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))`





```
> 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**



- 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, qq = -1:-3))
```

```
  x    y    z qq
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))`



```
> 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)



- Complete the Computational Assignment [here](#).

**Due:** Next Tuesday at the beginning of class.