# Programming for Data Analytics

# 4. Data Frames

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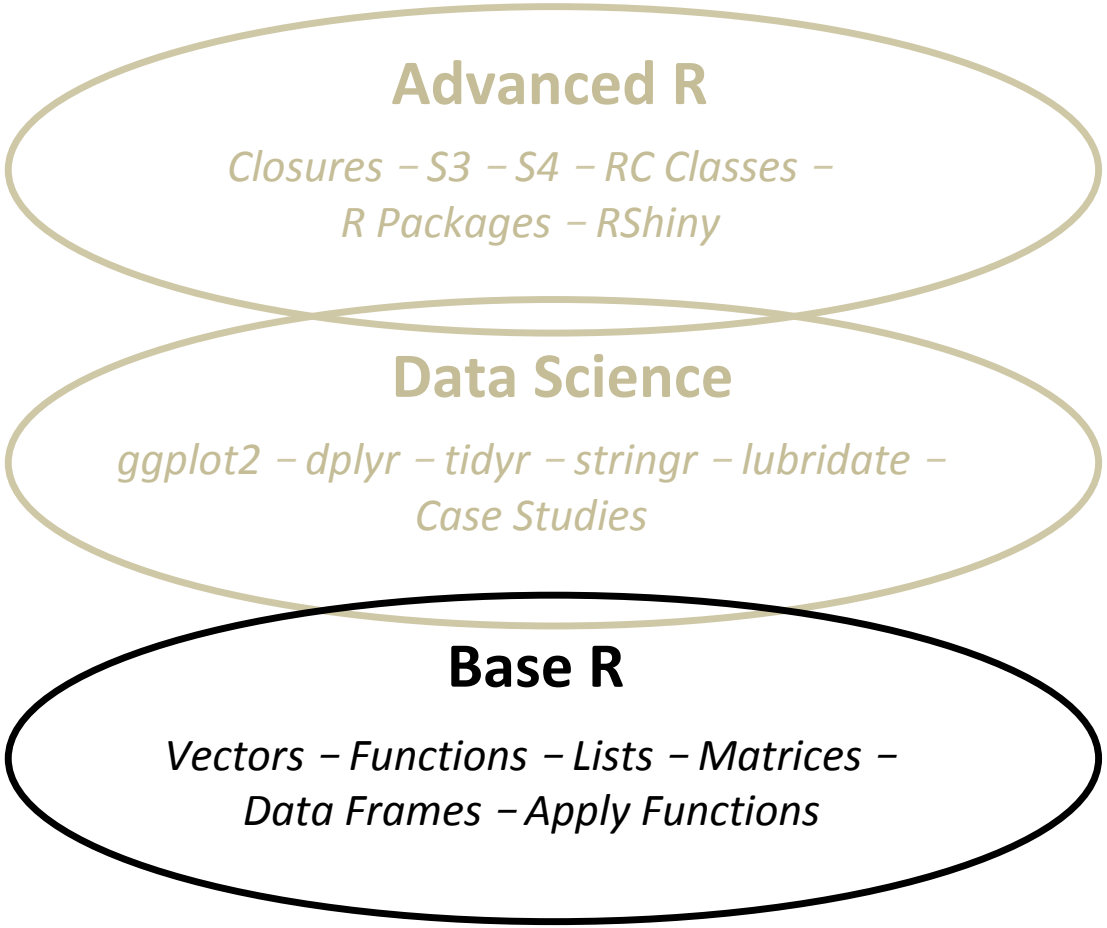
https://github.com/JimDuggan/CT5102

# Lecture 04 - Overview

1. Data Frames
2. Adding Columns
3. Incomplete Cases
4. Case Study



# (1) Data Frames

- The most common way of storing data in R
- Under the hood, a data frame is a list of equal-length vectors
- A two-dimensional structure, it shares properties of both a list and a matrix

| | Homogenous | Heterogenous |
|---|---|---|
| 1d | Atomic Vector | List |
| 2d | Matrix | **Data Frame** |
| nd | Array | |

# Creating a data frame…

```
> df <- data.frame(x=1:5,y=LETTERS[1:5],stringsAsFactors=F)
>
> str(df)
'data.frame':   5 obs. of  2 variables:
 $ x: int  1 2 3 4 5
 $ y: chr  "A" "B" "C" "D" ...
```

```
> df
  x y
1 1 A
2 2 B
3 3 C
4 4 D
5 5 E
```

# Sample Data Set (mtcars)

A data frame with 32 observations on 11 variables.

[, 1] mpg Miles/(US) gallon
[, 2] cyl Number of cylinders
[, 3] disp Displacement (cu.in.)
[, 4] hp Gross horsepower
[, 5] drat Rear axle ratio
[, 6] wt Weight (1000 lbs)
[, 7] qsec 1/4 mile time
[, 8] vs V/S
[, 9] am Transmission (0 = automatic, 1 = manual)
[,10] gear Number of forward gears
[,11] carb Number of carburetors

# Using head()

```
> head(mtcars)
                   mpg cyl disp  hp drat    wt  qsec vs am gear carb
Mazda RX4         21.0   6  160 110 3.90 2.620 16.46  0  1    4    4
Mazda RX4 Wag     21.0   6  160 110 3.90 2.875 17.02  0  1    4    4
Datsun 710        22.8   4  108  93 3.85 2.320 18.61  1  1    4    1
Hornet 4 Drive    21.4   6  258 110 3.08 3.215 19.44  1  0    3    1
Hornet Sportabout 18.7   8  360 175 3.15 3.440 17.02  0  0    3    2
Valiant           18.1   6  225 105 2.76 3.460 20.22  1  0    3    1
```

# Subsetting rows (note list operator $ can be used to identify column)

```
> mtcars[mtcars$gear == 5,]
                mpg cyl  disp  hp drat    wt qsec vs am gear carb
Porsche 914-2  26.0   4 120.3  91 4.43 2.140 16.7  0  1    5    2
Lotus Europa   30.4   4  95.1 113 3.77 1.513 16.9  1  1    5    2
Ford Pantera L 15.8   8 351.0 264 4.22 3.170 14.5  0  1    5    4
Ferrari Dino   19.7   6 145.0 175 3.62 2.770 15.5  0  1    5    6
Maserati Bora  15.0   8 301.0 335 3.54 3.570 14.6  0  1    5    8
>
> mtcars[mtcars$gear == 5 & mtcars$cyl == 8,]
                mpg cyl disp  hp drat   wt qsec vs am gear carb
Ford Pantera L 15.8   8  351 264 4.22 3.17 14.5  0  1    5    4
Maserati Bora  15.0   8  301 335 3.54 3.57 14.6  0  1    5    8
```

# Accessing rows via indices

```
> mtcars[1:8,]
                   mpg cyl  disp  hp drat    wt  qsec vs am gear carb
Mazda RX4         21.0   6 160.0 110 3.90 2.620 16.46  0  1    4    4
Mazda RX4 Wag     21.0   6 160.0 110 3.90 2.875 17.02  0  1    4    4
Datsun 710        22.8   4 108.0  93 3.85 2.320 18.61  1  1    4    1
Hornet 4 Drive    21.4   6 258.0 110 3.08 3.215 19.44  1  0    3    1
Hornet Sportabout 18.7   8 360.0 175 3.15 3.440 17.02  0  0    3    2
Valiant           18.1   6 225.0 105 2.76 3.460 20.22  1  0    3    1
Duster 360        14.3   8 360.0 245 3.21 3.570 15.84  0  0    3    4
Merc 240D         24.4   4 146.7  62 3.69 3.190 20.00  1  0    4    2
```

# Sampling from a data frame…

- Selecting n random observations from a data frame

```
> mtcars[sample(nrow(mtcars),2),]
                  mpg cyl  disp  hp drat    wt  qsec vs am gear carb
Chrysler Imperial 14.7   8 440.0 230 3.23 5.345 17.42  0  0    3    4
Merc 280          19.2   6 167.6 123 3.92 3.440 18.30  1  0    4    4
>
> mtcars[sample(nrow(mtcars),2),]
                mpg cyl  disp hp drat    wt qsec vs am gear carb
Merc 240D      24.4   4 146.7 62 3.69 3.190 20.0  1  0    4    2
Toyota Corolla 33.9   4  71.1 65 4.22 1.835 19.9  1  1    4    1
```

# Filtering rows and columns

```
> mtcars[mtcars$cyl==6,c("mpg","cyl")]
                  mpg cyl
Mazda RX4        21.0   6
Mazda RX4 Wag    21.0   6
Hornet 4 Drive   21.4   6
Valiant          18.1   6
Merc 280         19.2   6
Merc 280C        17.8   6
Ferrari Dino     19.7   6
```

# Filtering behaviour (> 1 column)

```
> mtcars[1:4,1:2]
                  mpg cyl
Mazda RX4        21.0   6
Mazda RX4 Wag    21.0   6
Datsun 710       22.8   4
Hornet 4 Drive   21.4   6
> str(mtcars[1:4,1:2])
'data.frame':   4 obs. of  2 variables:
 $ mpg: num  21 21 22.8 21.4
 $ cyl: num  6 6 4 6
```

# Filtering behaviour ( 1 column)

- This shows the difference between **simplifying** and **preserving**
- This also is a common source of programming errors, as R automatically converts a 1 column data frame result to a vector
- Use drop=FALSE to prevent
- tibbles (later) are designed to avoid this problem.

```
> mtcars[1:4,1]
[1] 21.0 21.0 22.8 21.4
>
> mtcars[1:4,1,drop=F]
                  mpg
Mazda RX4        21.0
Mazda RX4 Wag    21.0
Datsun 710       22.8
Hornet 4 Drive   21.4
```

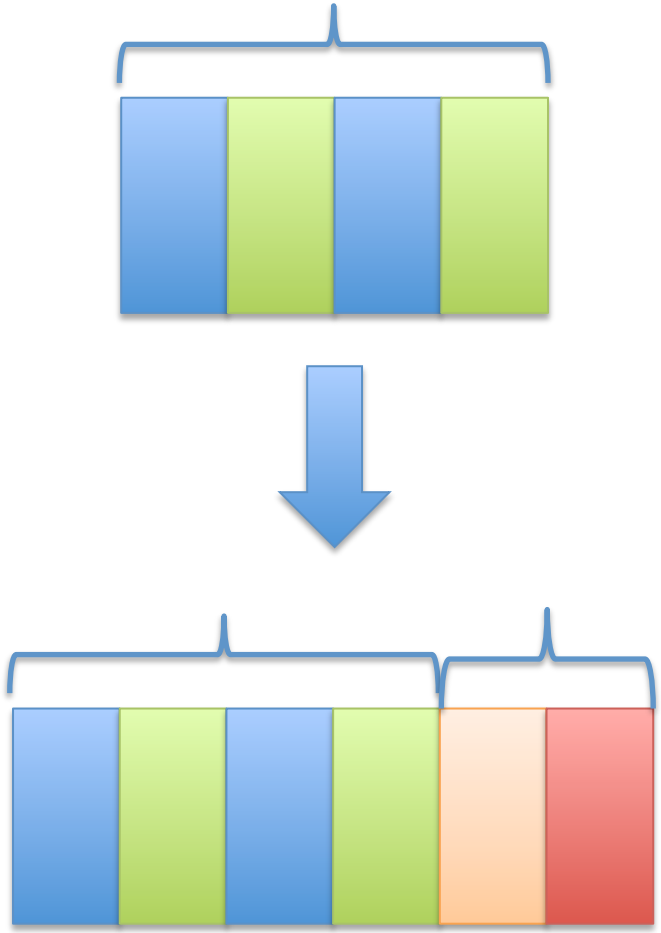
# Challenge 4.1

| | mpg | cyl | disp | hp | drat | wt | qsec | vs | am | gear | carb |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Mazda RX4 | 21.0 | 6 | 160.0 | 110 | 3.90 | 2.620 | 16.46 | 0 | 1 | 4 | 4 |
| Mazda RX4 Wag | 21.0 | 6 | 160.0 | 110 | 3.90 | 2.875 | 17.02 | 0 | 1 | 4 | 4 |
| Datsun 710 | 22.8 | 4 | 108.0 | 93 | 3.85 | 2.320 | 18.61 | 1 | 1 | 4 | 1 |
| Hornet 4 Drive | 21.4 | 6 | 258.0 | 110 | 3.08 | 3.215 | 19.44 | 1 | 0 | 3 | 1 |
| Hornet Sportabout | 18.7 | 8 | 360.0 | 175 | 3.15 | 3.440 | 17.02 | 0 | 0 | 3 | 2 |
| Valiant | 18.1 | 6 | 225.0 | 105 | 2.76 | 3.460 | 20.22 | 1 | 0 | 3 | 1 |
| Duster 360 | 14.3 | 8 | 360.0 | 245 | 3.21 | 3.570 | 15.84 | 0 | 0 | 3 | 4 |
| Merc 240D | 24.4 | 4 | 146.7 | 62 | 3.69 | 3.190 | 20.00 | 1 | 0 | 4 | 2 |
| Merc 230 | 22.8 | 4 | 140.8 | 95 | 3.92 | 3.150 | 22.90 | 1 | 0 | 4 | 2 |
| Merc 280 | 19.2 | 6 | 167.6 | 123 | 3.92 | 3.440 | 18.30 | 1 | 0 | 4 | 4 |

- List all the cars that have an mpg greater than the average
- List the car(s) with the greatest displacement

# (2) Adding Columns

- Often the initial data set may not contain sufficient information for analysis
- Adding new variables (columns) is an important feature to have
- Data frames support this: columns can be combined or new information used



# Adding new columns

- Create a new column that contains kilometers per gallon

| | mpg | cyl | disp | hp | drat | wt | qsec | vs | am | gear | carb |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Mazda RX4 | 21.0 | 6 | 160.0 | 110 | 3.90 | 2.620 | 16.46 | 0 | 1 | 4 | 4 |
| Mazda RX4 Wag | 21.0 | 6 | 160.0 | 110 | 3.90 | 2.875 | 17.02 | 0 | 1 | 4 | 4 |
| Datsun 710 | 22.8 | 4 | 108.0 | 93 | 3.85 | 2.320 | 18.61 | 1 | 1 | 4 | 1 |
| Hornet 4 Drive | 21.4 | 6 | 258.0 | 110 | 3.08 | 3.215 | 19.44 | 1 | 0 | 3 | 1 |
| Hornet Sportabout | 18.7 | 8 | 360.0 | 175 | 3.15 | 3.440 | 17.02 | 0 | 0 | 3 | 2 |
| Valiant | 18.1 | 6 | 225.0 | 105 | 2.76 | 3.460 | 20.22 | 1 | 0 | 3 | 1 |
| Duster 360 | 14.3 | 8 | 360.0 | 245 | 3.21 | 3.570 | 15.84 | 0 | 0 | 3 | 4 |
| Merc 240D | 24.4 | 4 | 146.7 | 62 | 3.69 | 3.190 | 20.00 | 1 | 0 | 4 | 2 |
| Merc 230 | 22.8 | 4 | 140.8 | 95 | 3.92 | 3.150 | 22.90 | 1 | 0 | 4 | 2 |
| Merc 280 | 19.2 | 6 | 167.6 | 123 | 3.92 | 3.440 | 18.30 | 1 | 0 | 4 | 4 |

# Solution

```
> mtcars$kpg <- mtcars$mpg * 8/5
>
> mtcars[1:8,]
                   mpg cyl  disp  hp drat    wt  qsec vs am gear carb   kpg
Mazda RX4         21.0   6 160.0 110 3.90 2.620 16.46  0  1    4    4 33.60
Mazda RX4 Wag     21.0   6 160.0 110 3.90 2.875 17.02  0  1    4    4 33.60
Datsun 710        22.8   4 108.0  93 3.85 2.320 18.61  1  1    4    1 36.48
Hornet 4 Drive    21.4   6 258.0 110 3.08 3.215 19.44  1  0    3    1 34.24
Hornet Sportabout 18.7   8 360.0 175 3.15 3.440 17.02  0  0    3    2 29.92
Valiant           18.1   6 225.0 105 2.76 3.460 20.22  1  0    3    1 28.96
Duster 360        14.3   8 360.0 245 3.21 3.570 15.84  0  0    3    4 22.88
Merc 240D         24.4   4 146.7  62 3.69 3.190 20.00  1  0    4    2 39.04
```

# Challenge 4.2

- Create a new column called “Model”, which contains the type of car. How is the model information currently stored?

| | mpg | cyl | disp | hp | drat | wt | qsec | vs | am | gear | carb |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Mazda RX4 | 21.0 | 6 | 160.0 | 110 | 3.90 | 2.620 | 16.46 | 0 | 1 | 4 | 4 |
| Mazda RX4 Wag | 21.0 | 6 | 160.0 | 110 | 3.90 | 2.875 | 17.02 | 0 | 1 | 4 | 4 |
| Datsun 710 | 22.8 | 4 | 108.0 | 93 | 3.85 | 2.320 | 18.61 | 1 | 1 | 4 | 1 |
| Hornet 4 Drive | 21.4 | 6 | 258.0 | 110 | 3.08 | 3.215 | 19.44 | 1 | 0 | 3 | 1 |
| Hornet Sportabout | 18.7 | 8 | 360.0 | 175 | 3.15 | 3.440 | 17.02 | 0 | 0 | 3 | 2 |
| Valiant | 18.1 | 6 | 225.0 | 105 | 2.76 | 3.460 | 20.22 | 1 | 0 | 3 | 1 |
| Duster 360 | 14.3 | 8 | 360.0 | 245 | 3.21 | 3.570 | 15.84 | 0 | 0 | 3 | 4 |
| Merc 240D | 24.4 | 4 | 146.7 | 62 | 3.69 | 3.190 | 20.00 | 1 | 0 | 4 | 2 |
| Merc 230 | 22.8 | 4 | 140.8 | 95 | 3.92 | 3.150 | 22.90 | 1 | 0 | 4 | 2 |
| Merc 280 | 19.2 | 6 | 167.6 | 123 | 3.92 | 3.440 | 18.30 | 1 | 0 | 4 | 4 |

# (3) Incomplete Records

```
> my_mtcars <- mtcars
>
> set.seed(0)
>
> rows <- sample(nrow(my_mtcars),3)
> col  <- sample(ncol(my_mtcars),1)
>
> my_mtcars[rows,col] <- NA
>
> rows
[1] 29  9 12
>
> col
[1] 7
```

# Resulting data frame (3 rows)

```
> my_mtcars[rows,]
                mpg cyl  disp  hp drat   wt qsec vs am gear carb
Ford Pantera L 15.8   8 351.0 264 4.22 3.17   NA  0  1    5    4
Merc 230       22.8   4 140.8  95 3.92 3.15   NA  1  0    4    2
Merc 450SE     16.4   8 275.8 180 3.07 4.07   NA  0  0    3    3
```

# Find rows that have incomplete cases in the data set

```
> !complete.cases(my_mtcars)
 [1] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE  TRUE FALSE FALSE
[12]  TRUE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
[23] FALSE FALSE FALSE FALSE FALSE FALSE  TRUE FALSE FALSE FALSE
>
> my_mtcars[!complete.cases(my_mtcars),]
                mpg cyl  disp  hp drat   wt qsec vs am gear carb
Merc 230       22.8   4 140.8  95 3.92 3.15   NA  1  0    4    2
Merc 450SE     16.4   8 275.8 180 3.07 4.07   NA  0  0    3    3
Ford Pantera L 15.8   8 351.0 264 4.22 3.17   NA  0  1    5    4
>
> rows
[1] 29  9 12
```

# Approximating missing values.

```
> mean(my_mtcars$qsec)
[1] NA
>
> mean(my_mtcars$qsec,na.rm = T)
[1] 17.80552
```

- Replace any missing values in the qsec column with the overall average value

# Changing the values…

```
> my_mtcars[rows,"qsec"] <- mean(my_mtcars$qsec,na.rm = T)
>
> my_mtcars[rows,]
                 mpg cyl  disp  hp drat   wt     qsec vs am gear carb
Ford Pantera L 15.8   8 351.0 264 4.22 3.17 17.80552  0  1    5    4
Merc 230       22.8   4 140.8  95 3.92 3.15 17.80552  1  0    4    2
Merc 450SE     16.4   8 275.8 180 3.07 4.07 17.80552  0  0    3    3
```

# Setting invalid values to NA

```
> my_mtcars <- mtcars
>
> rows <- sample(nrow(my_mtcars),3)
> col  <- sample(ncol(my_mtcars),1)
>
> my_mtcars[rows,col] <- -9000
>
> col  <- sample(ncol(my_mtcars),1)
>
> my_mtcars[rows,col] <- -1000
> my_mtcars[rows,]
                mpg cyl  disp  hp drat   wt  qsec vs am  gear carb
Ford Pantera L 15.8   8 351.0 264 4.22 3.17 -9000  0  1 -1000    4
Merc 230       22.8   4 140.8  95 3.92 3.15 -9000  1  0 -1000    2
Merc 450SE     16.4   8 275.8 180 3.07 4.07 -9000  0  0 -1000    3
```

# Removing invalid values…

```
> my_mtcars[rows,]
                 mpg cyl  disp  hp drat   wt  qsec vs am  gear carb
Ford Pantera L 15.8   8 351.0 264 4.22 3.17 -9000  0  1 -1000    4
Merc 230       22.8   4 140.8  95 3.92 3.15 -9000  1  0 -1000    2
Merc 450SE     16.4   8 275.8 180 3.07 4.07 -9000  0  0 -1000    3
>
> clean <- data.frame(apply(my_mtcars,2,
+                           function(x)ifelse(x<0,NA,x)))
>
> clean[rows,]
                 mpg cyl  disp  hp drat   wt qsec vs am gear carb
Ford Pantera L 15.8   8 351.0 264 4.22 3.17   NA  0  1   NA    4
Merc 230       22.8   4 140.8  95 3.92 3.15   NA  1  0   NA    2
Merc 450SE     16.4   8 275.8 180 3.07 4.07   NA  0  0   NA    3
```

# Challenge 3.3

- Extend the previous example so that the apply function returns the average of all valid values instead of NA.
- *Hint: Apply functions can have more than one statement, once the {} brackets are used.*

```
> my_mtcars[rows,]
                 mpg cyl  disp  hp drat   wt  qsec vs am  gear carb
Ford Pantera L 15.8   8 351.0 264 4.22 3.17 -9000  0  1 -1000    4
Merc 230       22.8   4 140.8  95 3.92 3.15 -9000  1  0 -1000    2
Merc 450SE     16.4   8 275.8 180 3.07 4.07 -9000  0  0 -1000    3
```

# (4) Case Study

- Install the package nycflights13
- Create a data frame from this data,
  ```
  df <- nycflights13::flights
  ```
- Select all the flights from 1st March 2013, and only the following columns
  - *dep_delay, arr_delay, origin, dest, distance*
- Create a new column that contains the text “On Time” or “Late” depending on the departure time
- Plot a histogram of the departure delays, distance for this date
- Find the average delay, average distance
- Compare the average departure delay for each airport, using an apply function.