Intro to DS
Week 2

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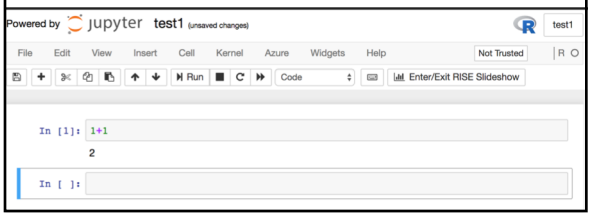
Objectives for This Week

- Explain/use basic concepts and techniques of data modeling
- Explain and use data frames in R
  - Data organization to facilitate R analysis
  - Rows and columns
  - Consistent mode type by attribute/variable

What are Markdown files and Notebooks?

- Provide Code, Comments and outputs in a single file
- Cells are code and output or markdown (comments)
- The most popular notebooks are Jupyter Notebooks
- Rmarkdown is part of RStudio



Integrated Code & Output

Powered by jupyter test1 (autosaved)

File Edit View Insert Cell Kernel Azure Widgets Help Trusted

Run Code Enter/Exit RISE Slideshow

Explore MPG, but round the values first

In [8]:
```
myCars <- mtcars
myCars$roundMPG <- round(myCars$mpg, -1)
str(myCars)
```

```
'data.frame':   32 obs. of  12 variables:
 $ mpg     : num  21 21 22.8 21.4 18.7 18.1 14.3 24.4 22.8 19.2 ...
 $ cyl     : num  6 6 4 6 8 6 8 4 4 6 ...
 $ disp    : num  160 160 108 258 360 ...
 $ hp      : num  110 110 93 110 175 105 245 62 95 123 ...
 $ drat    : num  3.9 3.9 3.85 3.08 3.15 2.76 3.21 3.69 3.92 3.92 ...
 $ wt      : num  2.62 2.88 2.32 3.21 3.44 ...
 $ qsec    : num  16.5 17 18.6 19.4 17 ...
 $ vs      : num  0 0 1 1 0 1 0 1 1 1 ...
 $ am      : num  1 1 1 0 0 0 0 0 0 0 ...
 $ gear    : num  4 4 4 3 3 3 3 4 4 4 ...
 $ carb    : num  4 4 1 1 2 1 4 2 2 4 ...
 $ roundMPG: num  20 20 20 20 20 20 10 20 20 20 ...
```

How to use the concept of cells & code?

- Break logical code into different cells
- Use markdown cells as comments / explanation

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Explore MPG, but round the values first

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```
'data.frame':   32 obs. of  12 variables:
 $ mpg     : num  21 21 22.8 21.4 18.7 18.1 14.3 24.4 22.8 19.2 ...
 $ cyl     : num  6 6 4 6 8 6 8 4 4 6 ...
```

Not a Good Notebook

Use Cells!!!

```
In [6]: library(tidyverse)
        value <- df %>%
          #only look at Thursday, ignore spaces
          filter(str_trim(day_of_week)=="THURSDAY") %>%

          #look at vehicle count
          pull(vehicle_count) %>%

          #take the mean, store it in value
          mean(na.rm=TRUE)

        paste("mean vehicle count", value)
        'mean vehicle count 1.90728476821192'

In [7]: #an alternative way to calculate the mean
        mean( df$vehicle_count[str_trim(df$day_of_week)=="THURSDAY"], na.rm=TRUE)
        1.90728476821192
        #Step 2: Investigating the data frame by answering the following questions with explicit R code:

In [9]: #  A.   What was the total number of accidents with injuries?
        df %>% filter (injury=="YES") %>% summarize( count=n()) %>% pull(count)
        301

In [11]: #  B.   How many accidents happen on Friday?
         df %>%
           filter (str_trim(df$day_of_week)=="FRIDAY") %>%
           summarize( count=n()) %>%
           pull(count)
         151

In [15]: #  H.   Use hist( ) to make a histogram of the number of vehicles
         #       in accidents on Friday.
         df %>%
           filter(str_trim(df$day_of_week)=="FRIDAY") %>%
           pull(vehicle_count) %>%
           hist(main="# of vehicles in Accidencts on Friday")
```

Output PDF in RStudio?

- Knit to PDF
- Might need to do the following commands in R:

  install.packages("tinytex")
  library(tinytex)
  tinytex::install_tinytex()

Data Frames in R

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Rows and Columns

One of the most basic and widely used methods of representing data is to use rows and columns, where each row is a case/instance and each column is a variable/attribute. Most spreadsheets arrange their data in rows and columns, although spreadsheets don't usually refer to these as cases or variables. R represents rows and columns in an object called a *data frame*.

- Data frames
  - Context: What is the data set about?
  - Content: What is contained in the columns?
  - Mode/Type: What are the data types of the columns
- Data frames facilitate analysis in R
  - Enforcement of rectangle
  - Row and column naming
  - Single mode/type by attribute/variable

An Example Dataset: Context

Name	Age	Gender	Weight
Dad	43	Male	188
Mom	42	Female	136
Sis	12	Female	83
Bro	8	Male	61
Dog	5	Female	44

An Example Dataset: Characteristics

Two-dimensions: rows and columns

Name	Age	Gender	Weight
Dad	43	Male	188
Mom	42	Female	136
Sis	12	Female	83
Bro	8	Male	61
Dog	5	Female	44

An Example Dataset: Characteristics

- Rows (data)
  - Cases
  - Instances
  - Observations

Name	Age	Gender	Weight
Dad	43	Male	188
Mom	42	Female	136
Sis	12	Female	83
Bro	8	Male	61
Dog	5	Female	44

Note: Name Age Gender Weight is **not** a data row.

An Example Dataset: Characteristics

- Columns (data)
  - **Variable name**
  - Attributes
  - Variables

Name	Age	Gender	Weight
Dad	43	Male	188
Mom	42	Female	136
Sis	12	Female	83
Bro	8	Male	61
Dog	5	Female	44

An Example Dataset: Characteristics

- Columns (data)
  - **Attributes**
  - **Variables**
  - Variable name

Name	Age	Gender	Weight
Dad	43	Male	188
Mom	42	Female	136
Sis	12	Female	83
Bro	8	Male	61
Dog	5	Female	44

- Note: Name Age Gender Weight are **not** data

An Example Dataset: Characteristics

- In a well-structured data set, each row has a unique identifier (case label).
- R supports "row names" or you can build in a data field to serve as unique ID
- R does NOT enforce the uniqueness of a row, as some DBs do

Name	Age	Gender	Weight
Dad	43	Male	188
Mom	42	Female	136
Sis	12	Female	83
Bro	8	Male	61
Dog	5	Female	44

An Example Dataset: Characteristics

- Each column has the same type/mode of data.
- Each column has the same number of entries.

Name	Age	Gender	Weight
Dad	43	Male	188
Mom	42	Female	136
Sis	12	Female	83
Bro	8	Male	61
Dog	5	Female	44

Creating a dataset in R

- Data set: How does this get built in R?
  - Create a vector for each variable (column).
  - Create a data frame to combine individual vectors.

Name	Age	Gender	Weight
Dad	43	Male	188
Mom	42	Female	136
Sis	12	Female	83
Bro	8	Male	61
Dog	5	Female	44

Question:

- How would you represent the following data in a data frame?
  - Students in a class
    - For each student, we have a student ID and a GPA.
    - Student 1: ID: N1; GPA: 3.8
    - Student 2: ID: N2; GPA: 4.0
    - Student 3: ID: N3; GPA: 3.3
    - Student 4: ID: N4; GPA: 3.5
    - Student 5: ID: N5; GPA: 3.9

→Create a grid (table) to show this information

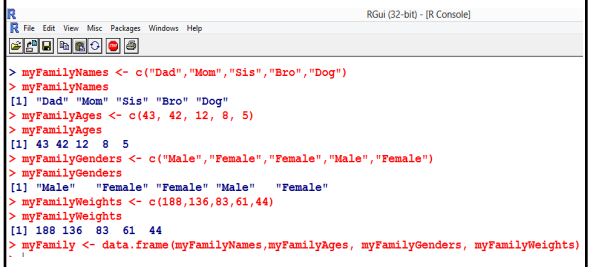
Answer:

- How would you represent the following data in a data frame?

Student ID	Student GPA
N1	3.8
N2	4.0
N3	3.3
N4	3.5
N5	3.9

Creating a Dataframe in R

1) Create Vectors
2) Use the data.frame function



Viewing a Dataframe

Display the contents of the data object MyFamily.

```
> myFamily <- data.frame(myFamilyNames,myFamilyAges, myFamilyGenders, myFamilyWeights)
> myFamily
  myFamilyNames myFamilyAges myFamilyGenders myFamilyWeights
1           Dad           43            Male            188
2           Mom           42          Female            136
3           Sis           12          Female             83
4           Bro            8            Male             61
5           Dog            5          Female             44
>
```

Using the R "Str" (Structure) Command

```
> myFamily
  myFamilyNames myFamilyAges myFamilyGenders myFamilyWeights
1           Dad           43            Male            188
2           Mom           42          Female            136
3           Sis           12          Female             83
4           Bro            8            Male             61
5           Dog            5          Female             44
> str(myFamily)
'data.frame':   5 obs. of  4 variables:
 $ myFamilyNames  : Factor w/ 5 levels "Bro","Dad","Dog",..: 2 4 5 1
 $ myFamilyAges   : num  43 42 12 8 5
 $ myFamilyGenders: Factor w/ 2 levels "Female","Male": 2 1 1 2 1
 $ myFamilyWeights: num  188 136 83 61 44
```

What does the structure function tell us about the data object myFamily?

- Confirmation that MyFamily is a data frame;
- MyFamily has five observations (cases/instances) and four variables.
- "$" for each variable/component column with descriptive information.
- Each of the variables has a mode or type (same mode within a variable/column).
- Variable is either a "factor" or "num".
- "Factor" variable has a "level".
- "Level" describes the options within a variable.
- "num" variable indicates "numeric".

Using the R Summary Command

```
> summary(myFamily)
 myFamilyNames  myFamilyAges myFamilyGenders myFamilyWeights
 Bro:1         Min.   : 5    Female:3        Min.   : 44.0
 Dad:1         1st Qu.: 8    Male  :2        1st Qu.: 61.0
 Dog:1         Median :12                    Median : 83.0
 Mom:1         Mean   :22                    Mean   :102.4
 Sis:1         3rd Qu.:42                    3rd Qu.:136.0
               Max.   :43                    Max.   :188.0
```

What does the summary function tell us about the data object myFamily?

- "Factor" variables list variable names (e.g., MyFamilyNames) along with the number of occurrences of cases that are coded within that factor.
- Numeric variables have six different calculated quantities that help summarize the variable:
  - Min / Max—minimum (or maximum) value of all cases
  - 1st Qu—dividing line at the top of the 1st quartile
  - Median—value of the case that splits the whole group in half
  - Mean—numeric average
  - 3rd Qu—3rd quartile

Accessing Dataframes

Accessing Dataframes as a vector:

```
#returns the second element in myFamilyAges
myFamily$myFamilyAges[2]
```

Accessing Dataframes as a matrix:

```
#returns the data element in the first row and first column
myFamily[1,1]

#returns the first row
myFamily[1,]

#returns the first column
myFamily[,1]

#returns everything but the 1st row  (i.e. deletes the 1st  row)
myFamily[-1,]

#returns everything but the first
> myFamily[,-1]
```

Sorting a Dataframe

Why doesn't 'sort' work?

> sort(mtcars)

Error in `[.data.frame`(x, order(x, na.last = na.last, decreasing = decreasing)) :

undefined columns selected

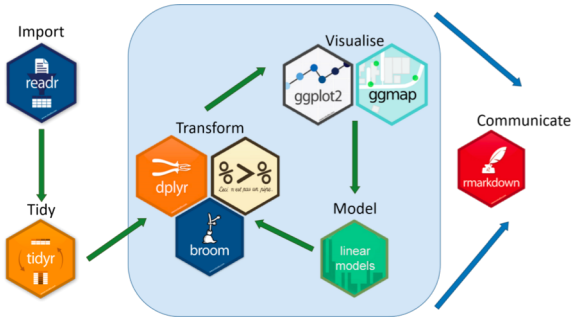
Sorting a Dataframe

```
#sorting
indexes <- order(mtcars[,"mpg"])
indexes[1]
[15]

mtcars[15,]
                    mpg cyl disp  hp drat   wt  qsec vs am gear carb
Cadillac Fleetwood 10.4   8  472 205 2.93 5.25 17.98  0  0    3    4

sortedDF <- mtcars[indexes,]
```

The Tidyverse (partial view)



Tibbles vs. DataFrames

- A "tibble" updates the behavior of a dataframe to make the structure more useful.
- Tibbles are part of the "tidyverse."
- Try 'glimpse' (vs 'str')

```
#> # A tibble: 1,000 x 5
#>   a                   b             c     d e
#>   <dttm>              <date>      <int> <dbl> <chr
#> 1 2019-01-08 17:33:11 2019-01-15      1 0.368 h
#> 2 2019-01-09 11:38:20 2019-01-20      2 0.612 n
#> 3 2019-01-09 06:02:00 2019-01-30      3 0.415 l
#> 4 2019-01-08 19:23:17 2019-01-29      4 0.212 x
#> 5 2019-01-08 15:47:33 2019-01-26      5 0.733 a
#> 6 2019-01-09 02:48:30 2019-01-22      6 0.460 v
#> # … with 994 more rows
```

Tibbles:

- Print nicely on the console
- Provide type information
- Tibbles avoid unnecessary type conversions and support improved column naming

Exploring a DataFrame

How to explore a dataframe

```
#Base R
str(mtcars)
```

'data.frame': 32 obs. of 11 variables:
$ mpg : num 21 21 22.8…
$ cyl : num 6 6 4 6 8 6…

```
#The tidyverse way
library(tidyverse)
glimpse(mtcars)
```

Rows: 32
Columns: 11
$ mpg <dbl> 21.0, 21.0, 22.8, 21.4…
$ cyl <dbl> 6, 6, 4, 6, 8, 6, 8, 4, 4…

Selecting a Column

How to select one column

```
#Base R
mtcars[ , "mpg"]
mtcars[ , 1]
mtcars$mpg
```

[1] 21.0 21.0 22.8 21.4 18.7...

```
#The tidyverse way
select(mtcars, "mpg")
select(mtcars, mpg)
```

	mpg
Mazda RX4	21.0
Mazda RX4 Wag	21.0
Datsun 710	22.8

Selecting Columns

How to select more than one column

```
#Base R
mtcars[ , c("mpg", "hp")]
mtcars[ ,c( 1,4)]
```

	mpg	hp
Mazda RX4	21.0	110
Mazda RX4 Wag	21.0	110
Datsun 710	22.8	93

```
#The tidyverse way
select(mtcars, c("mpg", "hp"))
select(mtcars, mpg, hp)
```

	mpg	hp
Mazda RX4	21.0	110
Mazda RX4 Wag	21.0	110
Datsun 710 2	2.8	93

Selecting Rows

How to select one or more rows

```
#Base R
mtcars[ 1:3,]
```

	mpg	cyl	disp	hp
Mazda RX4	21.0	6	160	110
Mazda RX4 Wag	21.0	6	160	110

```
#The tidyverse way
slice(mtcars,1:3)
```

	mpg	cyl	disp	hp
Mazda RX4	21.0	6	160	110
Mazda RX4 Wag	21.0	6	160	110

Tidyverse Pipes

Passes data from the command before to the one after
- Data flows left to right

Allows the code read more like a sentence

"%>%" is the "symbol" for a pipe

Example: min(x) is the same as:

#(x data get passed to "min" function)

```
x %>% min
```

#Simple example

```
x <- c(4,1,10,5)
x %>% min
[1] 1
```

#Dataframes example

```
mtcars %>% slice(1:3)
```

	mpg	cyl	disp	hp
Mazda RX4	21.0	6	160	110
Mazda RX4 Wag	21.0	6	160	110

Filtering DataFrames

(i.e., Subset Rows Based on a Condition)

How to create a subset of rows based on a condition for a column

#Base R

```
mtcars[mtcars$mpg > 28, ]
```

	mpg	cyl	disp	hp	drat
Fiat 128	32.4	4	78.7	66	4.08
Honda Civic	30.4	4	75.7	52	4.93

#The tidyverse way

```
mtcars %>% filter(mpg > 28)
```

	mpg	cyl	disp	hp	drat
Fiat 128	32.4	4	78.7	66	4.08
Honda Civic	30.4	4	75.7	52	4.93

Adding a Column

How to create a subset of rows based on a condition for a column

#Base R

```
myCars <- mtcars
carName=rownames(myCars)
myCars$carName <- carName
myCars [1,
  c("mpg", "cyl", "carName", "hp")]
```

	mpg	cyl	carName	hp
Mazda RX4	21	6	Mazda RX4	110

#The tidyverse way

```
myCars <- mtcars
myCars <-
rownames_to_column(myCars, var =
"carName")
myCars %>%
  slice(1) %>%
  select(mpg, cyl, carName, hp)
```

	mpg	cyl	carName	hp
1	21	6	Mazda RX4	110

Grouping Information

Do a summary-type report

```
#Base R
mean(myCars[myCars$cyl==4,"mpg"])
[1] 26.66364

mean(myCars[myCars$cyl==6,"mpg"])
[1] 19.74286

mean(myCars[myCars$cyl==8,"mpg"])
[1] 15.1
```

```
#The tidyverse way
myCars %>%
    group_by(cyl) %>%
        summarize(mpg=mean(mpg),
                  hp=mean(hp),
                  .groups = 'drop')
# A tibble: 3 x 3
  cyl   mpg   hp
  <dbl> <dbl> <dbl>
1 4     26.7  82.6
2 6     19.7  122
3 8     15.1  209
```

Sorting a DataFrame

```
#Base R
indexes <- order(mtcars[,"mpg"])
sortedDF <- mtcars[indexes,]
str(sortedDF)

"data.frame": 32 obs. of 11 variables:
 $ mpg : num 10.4 10.4 13.3…
 $ cyl : num 8 8 8 8 8 8…
```

```
#The tidyverse way
sortedDF <- mtcars %>%
                arrange(mpg)
glimpse(sortedDF)

Rows: 32
Columns: 11
$ mpg  <dbl> 10.4, 10.4, 13.3,…
$ cyl  <dbl> 8, 8, 8, 8, 8, 8, 8,…
```

Sample Questions

#Given the following lines of code were executed

```
names <- c("Jeff", "Pat", "Joe")
height <- c(100,103,120)
myFamily <- data.frame(names, height)
```

#What is returned from the following commands?

```
myFamily[1,1]
myFamily[1,]
select(myFamily, height)
myFamily %>% slice( c(1,3) )
```

Sample Answers

myFamily[1,1]
[1] "Jeff"

myFamily[1,]
names height
1 Jeff 100

select(myFamily, height)
height
1 100
2 103
3 120

myFamily %>% slice(c(1,3))
names height
1 Jeff 100
2 Joe 120

Data Science in the Real World

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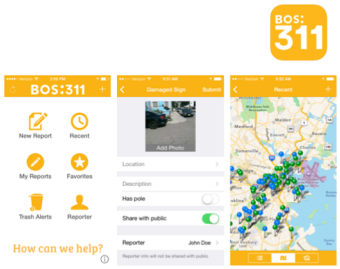
Boston Potholes: Discussion

The BOS:311 app helps residents and visitors improve City neighborhoods. You can report non-emergency issues, like potholes and graffiti.



Questions

- Example Focus – Fix potholes
- Where's the data science?
- What might be an issue?