CS&SS 321 - Data Science and Statistics for Social Sciences

Module II - Data management and exploratory visual analysis

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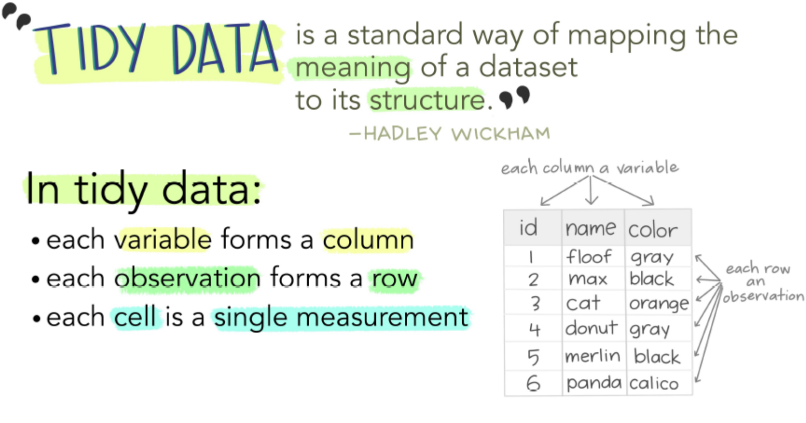
Module II

- This model will equip students with essential data science skills in `R`.
- In the next quiz sections, we will cover the following topics:
  - **Data frames**, **logical** relations, and **subsetting.**
  - **Quantile** and `NA` data.
  - Base `R` graphics.
  - **Pivoting** and **merging** data.
  - Introduction to `ggplot2`.

Creating and manipulating `data frames`.

- Think about *data* in terms of **data** *frame*.



Wickham, H. (2014). Tidy Data. Journal of Statistical Software 59 (10). DOI: 10.18637/jss.v059.i10

Creating and manipulating `data frames`.

- A data frame is a special type of object in R that can store **multiple vectors** of data.
- We can create data frames using the function `data.frame()`.

```
# vectors with student's names and grades
student <- c("Alice", "Bob", "Charlie","Sean","Brandy")
grades_M <- c(76, 82, 94, 45, 75)
grades_F <- c(82, 90, 89, NA, 64)

# create a df with grades
(df_new <- data.frame(student,grades_M,grades_F))
```

```
##   student grades_M grades_F
## 1   Alice       76       82
## 2     Bob       82       90
## 3 Charlie       94       89
## 4    Sean       45       NA
## 5  Brandy       75       64
```

Creating and manipulating `data frames`.

- We can create data frames by directly writing the vectors/columns as separate elements within the `data.frame()` function:

```
df_new <- data.frame(student=c("Alice", "Bob", "Charlie",
                               "Sean","Brandy"),
                     grades_M=c(76, 82, 94, 45, 75),
                     grades_F=c(82, 90, 89, NA, 64))

df_new
```

```
##   student grades_M grades_F
## 1   Alice       76       82
## 2     Bob       82       90
## 3 Charlie       94       89
## 4    Sean       45       NA
## 5  Brandy       75       64
```

Creating and manipulating `data frames`.

- To select a specific column from a data frame, use the $ operator followed by the *name* of the column.

```
df_new$grades_M
```

```
## [1] 76 82 94 45 75
```

- To select specific rows and/or columns from a data frame, we use brackets `[]`.
- If the object is a single vector, we use a single numeric value in the brackets to select an element within the vector.

```
# select element 2 from vector grade_M:
grades_M[2]
```

```
## [1] 82
```

Creating and manipulating `data frames`.

- If the object is a matrix or data frame, we can select elements by their row and column positions.
  - **Note**: we input two different values separated by a **comma** to select the row and column

```
# select row 2 from object df:
df_new[2,]
```

```
##   student grades_M grades_F
## 2     Bob       82       90
```

```
# select column 2 from object df:
df_new[,2]
```

```
## [1] 76 82 94 45 75
```

```
# select element in row 2 and column 2:
df_new[2,2]
```

Creating and manipulating `data frames`.

- We can also use **characters** to select columns by their names, for example:

```
# select column name "grade_M" from object df:

df_new[,c("grades_M")]
```

```
## [1] 76 82 94 45 75
```

```
# select columns name "student" and "grade_M":

df_new[,c("student","grades_M")]
```

```
##   student grades_M
## 1   Alice       76
## 2     Bob       82
## 3 Charlie       94
## 4    Sean       45
## 5  Brandy       75
```

tibbles are data frames too!

- Another type of data frame are **tibbles**.
  - `tibble()` is a fancy version of `data.frame()`.
  - All `dplyr` functions provide outputs `as_tibbles`.

```
as_tibble(df_new) ; class(as_tibble(df_new))
```

```
## # A tibble: 5 x 3
##   student grades_M grades_F
##   <chr>      <dbl>    <dbl>
## 1 Alice         76       82
## 2 Bob           82       90
## 3 Charlie       94       89
## 4 Sean          45       NA
## 5 Brandy        75       64
```

```
## [1] "tbl_df"     "tbl"        "data.frame"
```

Logical relations

- **Logical Data Class:**
  - Represents binary values: `TRUE` or `FALSE`.
  - Can be transformed into numeric form: `TRUE` becomes 1, and `FALSE` becomes 0.
  - Useful for relational analyses and evaluating proportions of `TRUE` within a vector using the `mean()` function.
  - Used to set **conditional tests**; useful for **subsetting** or create new variables.

```
3 + 5 < 10 # is 3 + 5 less than 10?
```

```
## [1] TRUE
```

Logical relations

```
# select column name "grade_M" from object df:
df_new$grades_M
```

```
## [1] 76 82 94 45 75
```

```
# Is each value greater or equal to 80?
df_new$grades_M >= 80 # the condition ">= 80" sets a logical tes
```

```
## [1] FALSE  TRUE  TRUE FALSE FALSE
```

```
# What proportion of TRUEs are in this vector?
mean(df_new$grades_M >= 80) # `TRUE` == 1, and `FALSE` == 0
```

```
## [1] 0.4
```

Subsetting: `ifelse()`.

- We can use the `ifelse()` function to create new variables based on *conditions* from other variables.
  1 - We set a *logical test* that evaluates to `TRUE` or `FALSE`.
  2 - We specify what value to assign if the test is `TRUE`, and a different value if the test is `FALSE`.

```r
# if test is TRUE, then "pass", otherwise, then "fail"
df_new$midterm <- ifelse(df_new$grades_M > 60, "pass", "fail")

df_new
```

```
##   student grades_M grades_F midterm
## 1   Alice       76       82    pass
## 2     Bob       82       90    pass
## 3 Charlie       94       89    pass
## 4    Sean       45       NA    fail
## 5  Brandy       75       64    pass
```

Subsetting: Base R.

- We can use *logical tests* in **vectors** within the **row element** of an object `x[ test , ]` to subset those cases that are `TRUE`.

```
# In the vector midterm, what values are "pass"?
df_new$midterm=="pass"
```

```
## [1]  TRUE  TRUE  TRUE FALSE  TRUE
```

```
# subset those rows where this test is TRUE
df_new[ df_new$midterm=="pass" , ]
```

```
##   student grades_M grades_F midterm
## 1   Alice       76       82    pass
## 2     Bob       82       90    pass
## 3 Charlie       94       89    pass
## 5  Brandy       75       64    pass
```

Subsetting: subset()/filter().

- To subset data, we can use the functions subset() or filter().
  - The subset() function is part of base R, while filter() is a function from the dplyr package.
  - If you plan to use filter(), you need to load the tidyverse or dplyr package first.

```r
# subset the df into a new one with final exam grades of above 85

subset(df_new, grades_F > 85)
```

```
##   student grades_M grades_F midterm
## 2     Bob       82       90    pass
## 3 Charlie       94       89    pass
```

```r
filter(df_new, grades_F > 85) # from dplyr package
```

```
##   student grades_M grades_F midterm
## 1     Bob       82       90    pass
## 2 Charlie       94       89    pass
```

Processing NA data.

- An initial step in data science project analysis is to examine the NA values.

```
dat
```

```
##      name age gender score
## 1   Alice  20      F    85
## 2     Bob  30      M    62
## 3 Charlie  NA      M    75
## 4    Dave  28      M    80
## 5     Eve  22      F    95
## 6   Marta  21      F    NA
```

Processing `NA` data.

- The function `is.na()` will return a vector of logical values

```r
is.na(dat)
```

```
##       name   age gender score
## [1,] FALSE FALSE  FALSE FALSE
## [2,] FALSE FALSE  FALSE FALSE
## [3,] FALSE  TRUE  FALSE FALSE
## [4,] FALSE FALSE  FALSE FALSE
## [5,] FALSE FALSE  FALSE FALSE
## [6,] FALSE FALSE  FALSE  TRUE
```

```r
mean(is.na(dat))
```

```
## [1] 0.08333333
```

Processing `NA` data.

- Several packages have functions to assists the analysis of `NA` values.
  - function `freq.na()` from package `questionr` is an example:

```r
library(questionr)
freq.na(dat)
```

```
##        missing  %
## age          1 17
## score        1 17
## name         0  0
## gender       0  0
```

Processing `NA` data.

- We already know that some functions have the argument `na.rm`, but this is not the norm.

```r
dat$score
```

```
## [1] 85 62 75 80 95 NA
```

```r
mean(dat$score)
```

```
## [1] NA
```

```r
mean(dat$score, na.rm = TRUE)
```

```
## [1] 79.4
```

Processing NA data.

- The `na.omit()` function in base R removes all rows with any NA value.

```
dat
```

```
##      name age gender score
## 1   Alice  20      F    85
## 2     Bob  30      M    62
## 3 Charlie  NA      M    75
## 4    Dave  28      M    80
## 5     Eve  22      F    95
## 6   Marta  21      F    NA
```

```
na.omit(dat)
```

```
##    name age gender score
## 1 Alice  20      F    85
## 2   Bob  30      M    62
```

Processing NA data.

- The drop_na() function from dplyr removes all rows with any NA value of a specific column.

```
drop_na(dat, score)
```

```
##      name age gender score
## 1   Alice  20      F    85
## 2     Bob  30      M    62
## 3 Charlie  NA      M    75
## 4    Dave  28      M    80
## 5     Eve  22      F    95
```

```
drop_na(dat, age)
```

```
##    name age gender score
## 1 Alice  20      F    85
## 2   Bob  30      M    62
## 3  Dave  28      M    80
## 4   Eve  22      F    95
## 5 Marta  21      F    NA
```

Processing `NA` data.

- We can use `ifelse()` function to substitute `NA` values.

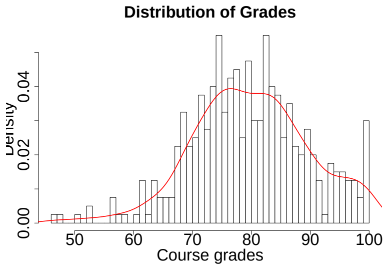
```
dat$score <- ifelse( is.na( dat$score ),
                     0, # if TRUE
                     dat$score) # if FALSE

dat
```

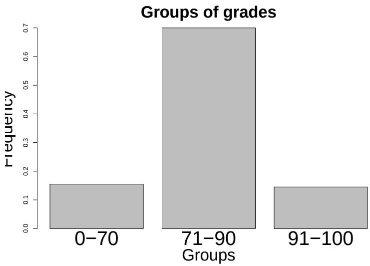
```
##      name age gender score
## 1   Alice  20      F    85
## 2     Bob  30      M    62
## 3 Charlie  NA      M    75
## 4    Dave  28      M    80
## 5     Eve  22      F    95
## 6   Marta  21      F     0
```

Distributions

- A **distribution** describes how variable values are **spread across** possible outcomes.
  - A **probability** distribution represents the **likelihood** of specific outcomes.
  - A **frequency** distribution summarizes counts of **distinct** values or ranges in dataset.
- **Continuous vs. Discrete Distributions:**
  - **Continuous** distributions involve numerical variables that can take any value within a range (e.g., height, weight), while
  - **Discrete** distributions involve variables that take distinct, separate values (e.g., number of cars, number of people).

Continuous vs. Discrete Distributions





Data Generating Process

- A **Data Generating Process** (DGP) refers to the hypothetical or real mechanism that generates a dataset.
  - It is a conceptual model that describes **how** the observed data is generated or produced.
- **Distributions** represent **systematic behavior** (aka, DGP).
- When looking at a distributions:
  - think in terms of a **DGP**, and
  - **how** the data was generated.

Reporting distributions

- When analyzing data, always report **descriptive statistics**.
  - *Mean.*
  - *Median.*
  - *Standard deviation.*
  - *Minimum.*
  - *Maximum.*
  - *Quartiles.*
- Note:
  - When comparing distributions of the same quantities, use the **median** instead of the **mean** as the reference point. **Why?**

quantile and data distribution.

- The quantile function in R can be used to calculate the values that separate a distribution into different quantiles.

```
quantile(df$grades)
```

```
##     0%    25%    50%    75%   100%
##  46.00  74.00  80.00  86.25 100.00
```

```
quantile(df$grades, probs = c(0.25, 0.5, 0.75))
```

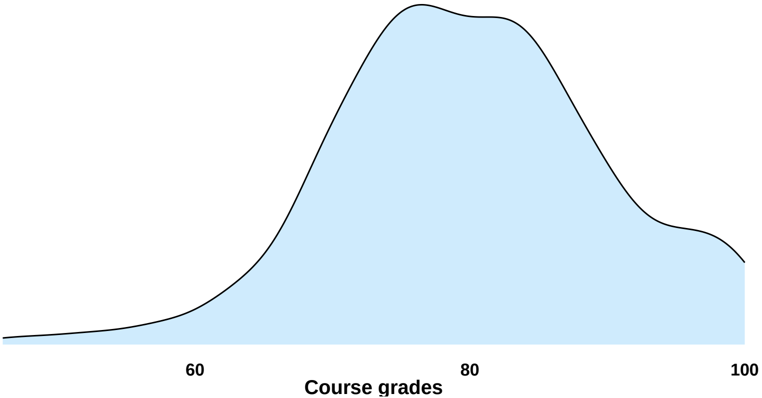
```
##   25%   50%   75%
## 74.00 80.00 86.25
```

```
summary(df$grades)
```

```
##    Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
##   46.00   74.00   80.00   79.98   86.25  100.00
```

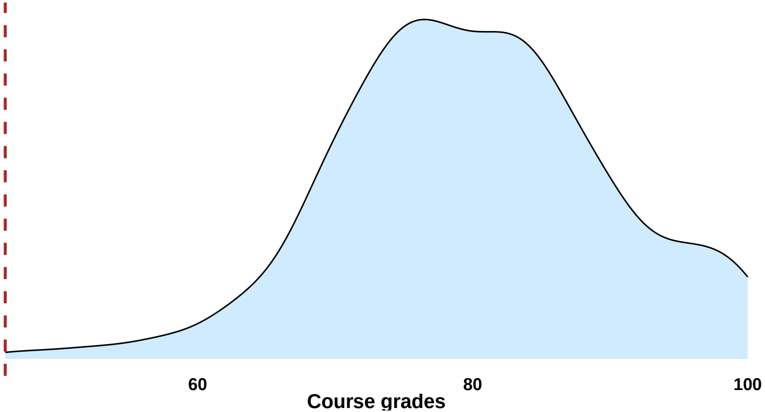
`quantile` and data distribution.

- Visualizing quantiles.
- Use the argument `probs` to specify segments of the data.



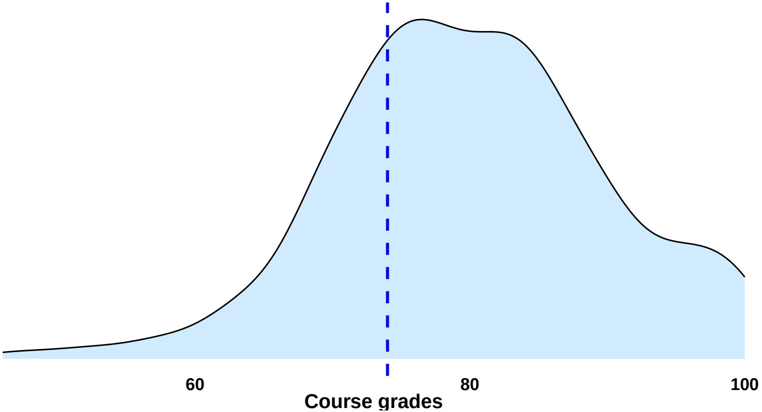
`quantile` and data distribution.

- Visualizing quantiles: **minimum**.
- `quantile(df$x, probs = 0)`



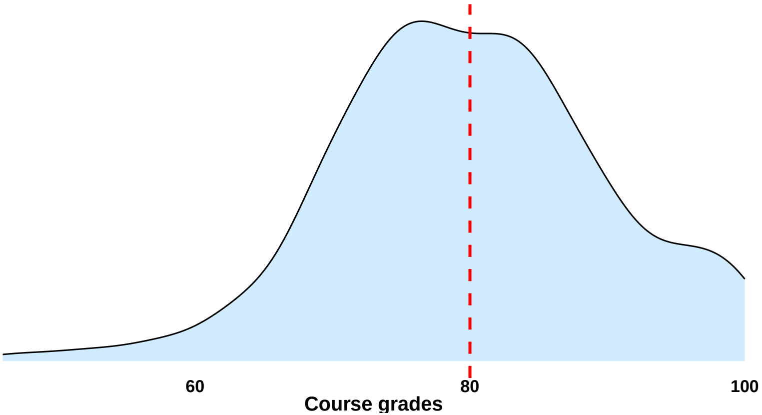
`quantile` and data distribution.

- Visualizing quantiles: **1st Quartile (Q1)** or **25th Percentile**.
- `quantile(df$x, probs = 0.25)`



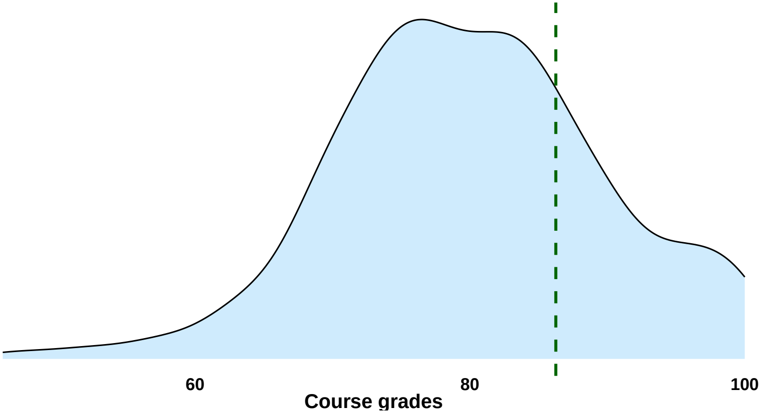
`quantile` and data distribution.

- Visualizing quantiles: **2st Quartile (Q2)** or **50th Percentile** or **median** or **5th Decile**.
- `quantile(df$x, probs = 0.5)`



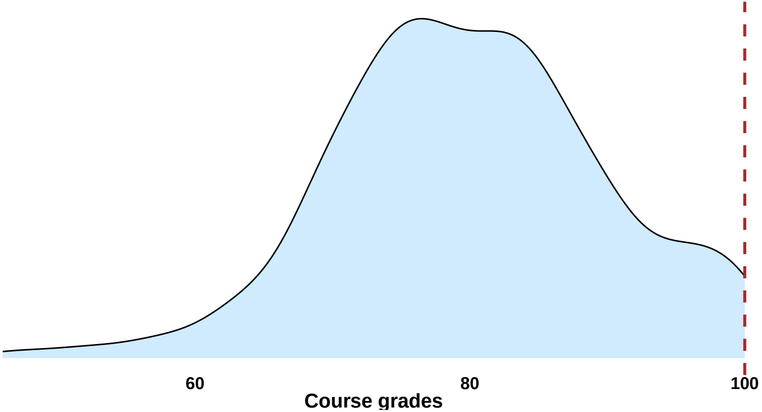
`quantile` and data distribution.

- Visualizing quantiles: **3st Quartile (Q3)** or **75th Percentile**.
- `quantile(df$x, probs = 0.75)`



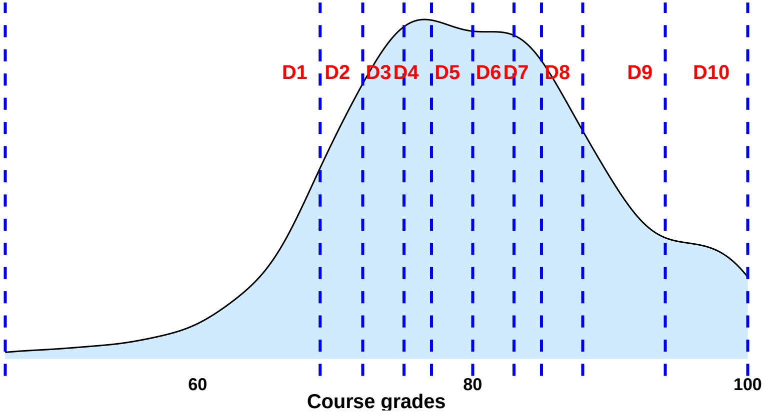
`quantile` and data distribution.

- Visualizaing quantiles: **maximum** or **100th percentile** or **10th decile**.
- `quantile(df$x, probs = 1)`



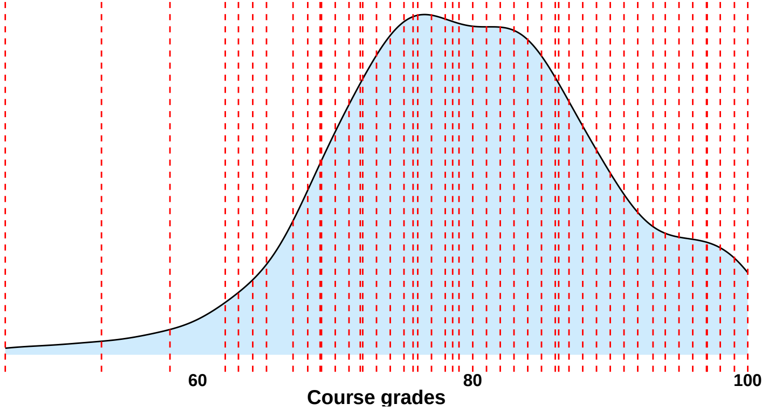
`quantile` and data distribution.

- Visualizing quantiles: **deciles** (1-10).
- `quantile(df$x, probs = seq(from=0,to=1,by=0.1))`



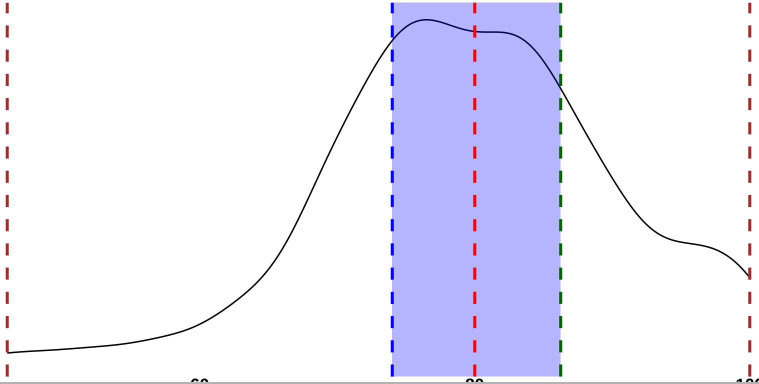
`quantile` and data distribution.

- Visualizing quantiles: **percentiles** (1-100).
- `quantile(df$x, probs = seq(from=0,to=1,by=0.01))`



`quantile` and data distribution.

- The **interquartile range** (IQR) is a measure of variability that represents the difference between the **first** and the **third** quartiles.
- It provides information about the spread of the middle 50% of the data.



More: nested `ifelse`.

- Notice that `ifelse` function can be nested on itself for multiple tests.

```
dat$letter <- ifelse(dat$score < 70,
                     "C",NA)
dat
```

```
##      name age gender score letter
## 1   Alice  20      F    85   <NA>
## 2     Bob  30      M    62      C
## 3 Charlie  NA      M    75   <NA>
## 4    Dave  28      M    80   <NA>
## 5     Eve  22      F    95   <NA>
## 6   Marta  21      F     0      C
```

More: nested `ifelse`.

- Notice that `ifelse` function can be nested on itself for multiple tests.

```
dat$letter <- ifelse(dat$score >= 70 & dat$score < 85,
                     "B",NA)
dat
```

```
##      name age gender score letter
## 1   Alice  20      F    85   <NA>
## 2     Bob  30      M    62   <NA>
## 3 Charlie  NA      M    75      B
## 4    Dave  28      M    80      B
## 5     Eve  22      F    95   <NA>
## 6   Marta  21      F     0   <NA>
```

More: nested `ifelse`.

- Notice that `ifelse` function can be nested on itself for multiple tests.

```
dat$letter <- ifelse(dat$score >= 85,
                     "A",NA)
dat
```

```
##      name age gender score letter
## 1   Alice  20      F    85      A
## 2     Bob  30      M    62   <NA>
## 3 Charlie  NA      M    75   <NA>
## 4    Dave  28      M    80   <NA>
## 5     Eve  22      F    95      A
## 6   Marta  21      F     0   <NA>
```

More: nested `ifelse`.

- Notice that `ifelse` function can be nested on itself for multiple tests.

```
dat$letter <- ifelse(dat$score < 70,
                     "C",ifelse(dat$score >= 70 &
                                  dat$score < 85,
                                "B",ifelse(dat$score >= 85,
                                           "A",NA)))
dat
```

```
##      name age gender score letter
## 1   Alice  20      F    85      A
## 2     Bob  30      M    62      C
## 3 Charlie  NA      M    75      B
## 4    Dave  28      M    80      B
## 5     Eve  22      F    95      A
## 6   Marta  21      F     0      C
```

More: nested `ifelse`.

- You can use the `case_when` function from the `dplyr` package to produce the same output.

```
dat$letter <- case_when(dat$score < 70 ~ "C",
                        dat$score >= 70 & dat$score < 85 ~ "B",
                        dat$score >= 85 ~ "A",
                        TRUE ~ NA_character_)
dat
```

```
##      name age gender score letter
## 1   Alice  20      F    85      A
## 2     Bob  30      M    62      C
## 3 Charlie  NA      M    75      B
## 4    Dave  28      M    80      B
## 5     Eve  22      F    95      A
## 6   Marta  21      F     0      C
```

In-lab exercise using `R-Markdown`.

reshaping data with `dplyr`

- **Reshaping** a data frame is a crucial skill in data science that enables you to perform various necessary tasks efficiently.
- There are two main types of data structures: **long** and **wide** formats.
- **Long format** is the preferred structure for most R functions and packages, including ggplot2. It is **tidy data** that is easy to manipulate and analyze.
- Although not tidy, **wide format** can be useful for presenting tables to audiences as it conveys more information in a smaller space. However, it is not ideal for data analysis.

long vs wide

country	year	metric
x	1960	10
x	1970	13
x	2010	15
y	1960	20
y	1970	23
y	2010	25
z	1960	30
z	1970	33
z	2010	35

```
pivot_wider(names_from = "year",
            names_prefix = "yr",
            values_from = "metric")
```

country	yr1960	yr1970	yr2010
x	10	13	15
y	20	23	25
z	30	33	35

```
pivot_longer(cols = yr1960:yr2010,
             names_to = "year",
             names_prefix = "yr"
             values_to = "metric")
```

reshaping data with `dplyr`

- The `pivot_` functions allow you to **reshape** data frames from long to wide or vice versa, which can be useful for data wrangling and visualization purposes.

```
# Create example data
(df <- data.frame(
  id = c(1, 2, 3),
  treatment = c("A", "B", "C"),
  day1 = c(10, 15, 12),
  day2 = c(12, 16, 18),
  day3 = c(8, 14, 10)
))
```

```
##   id treatment day1 day2 day3
## 1  1         A   10   12    8
## 2  2         B   15   16   14
## 3  3         C   12   18   10
```

reshaping data with dplyr

- `pivot_longer()` is used to convert a wide data frame to a **long format** by stacking columns into rows.
- You must specify which **columns** to pivot, the **names** for the new columns, and the name of the column to store the **values**.

```
# Use pivot_longer() to reshape
# the data from wide to long

df_long <-
  pivot_longer(df,
               cols = starts_with("day"),
               names_to = "day",
               values_to = "result")
df_long
```

```
## # A tibble: 9 x 4
##      id treatment day   result
##   <dbl> <chr>     <chr>  <dbl>
## 1     1 A         day1      10
## 2     1 A         day2      12
## 3     1 A         day3       8
## 4     2 B         day1      15
## 5     2 B         day2      16
## 6     2 B         day3      14
## 7     3 C         day1      12
## 8     3 C         day2      18
## 9     3 C         day3      10
```

reshaping data with `dplyr`

- while pivot_wider() does the opposite by spreading rows into columns.

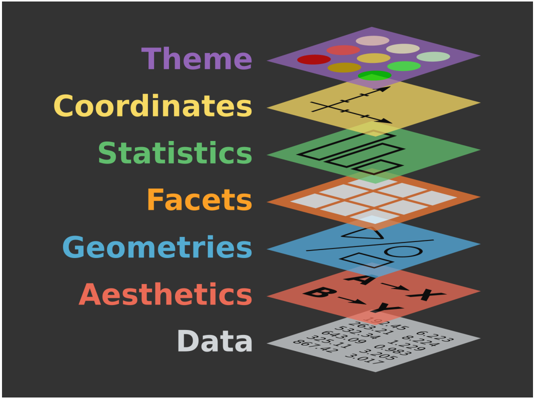
pivot_wider() takes similar arguments, but also requires specifying which column to use for the column names and which column to use for the values in the new columns.

```r
# Use pivot_wider() to reshape
# the data from long to wide

df_wide <-
  pivot_wider(df_long,
              names_from = "day",
              values_from = "result")
df_wide
```

```
## # A tibble: 3 x 5
##      id treatment  day1  day2  day3
##   <dbl> <chr>     <dbl> <dbl> <dbl>
## 1     1 A            10    12     8
## 2     2 B            15    16    14
## 3     3 C            12    18    10
```

Grammar of graphics

- A statistical graphic is a `mapping` of `data` variables to `aes`thetic attributes of `geom`etric objects. (Wilkinson 2005)



Grammar of graphics in `ggplot2`

- `ggplot2`: A *layered* grammer of graphics (Wickham 2009).
  - Build a graphic from multiple layers; each consists of some geometric objects or transformation
  - Use + to stack up layers
- *What* data do you want to visualize?
  - **`ggplot(data = ...)`**
- *How* are variables mapped to specific aesthetic attributes?
  - **`aes(... = ...)`**
    - positions (`x`, `y`), `shape`, `colour`, `size`, `fill`, `alpha`, `linetype`, `label`...
    - If the value of an attribute do not vary w.r.t. some variable, don't wrap it within `aes(...)`
- *Which* geometric shapes do you use to represent the data?
  - **`geom_{}`**:
    - `geom_point`, `geom_line`, `geom_ribbon`, `geom_polygon`, `geom_label`...

Tidy data

- `ggplot2` works well only with tidy data
  - *Tidy data*:
    - Each **variable** must have its own **column**
    - Each **observation** must have its own **row**
    - Each value must have its own cell