(A bit of) Advanced R

Part 3 - a tour of the `tidyverse`

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https://github.com/jchiquet/CourseAdvancedR

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Outline

1. Introduction

2. tibble

3. readr

4. tidyr

5. magrittr

6. dplyr

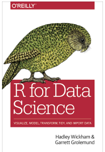
7. purrr

8. ggplot2

References

Many ideas/examples inspired/stolen there:

R for data science (Wickham & Grolemund, 2016), http://r4ds.had.co.nz


O'REILLY
R for Data Science
VISUALIZE, MODEL, TRANSFORM, TIDY, AND IMPORT DATA
Hadley Wickham & Garrett Grolemund

Tidyverse website, https://www.tidyverse.org/

Prerequisites

Data Structures in base R

1. Atomic vector (integer, double, logical, character)
2. Recursive vector (list)
3. Factor
4. Matrix and array
5. Data Frame

R base programming

1. Control Statements
2. Functions
3. Functionals
4. Input/output
5. Rstudio API (application programming interface)

Outline

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2. tibble
3. readr
4. tidyr
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6. dplyr
7. purrr
8. ggplot2

Tidy data: motivation

Collected data are (never) under a proper canonical format

> *"Happy families are all alike; every unhappy family is unhappy in its own way." – Leo Tolstoy*

> *"Tidy datasets are all alike, but every messy dataset is messy in its own way." – Hadley Wickham*[1]

[1] Rstudio's chief scientific advisor

Tidy data: motivation

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> *"Happy families are all alike; every unhappy family is unhappy in its own way." – Leo Tolstoy*
>
> *"Tidy datasets are all alike, but every messy dataset is messy in its own way." – Hadley Wickham*[1]

[1] Rstudio's chief scientific advisor

Tidy data: what?

First, a subjective question

What is the *observation/statistical unit* in your data?

Definition

Tidy data is a standard way of mapping the meaning of a dataset to its structure. A dataset is messy or tidy depending on how rows, columns and tables are matched up with observations, variables and types.

In tidy data,

1. each variable forms a column,
2. each observation forms a row,
3. each type of observational unit forms a table.

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In tidy data,

1. each variable forms a column,
2. each observation forms a row,
3. each type of observational unit forms a table.

Tidy data: why?

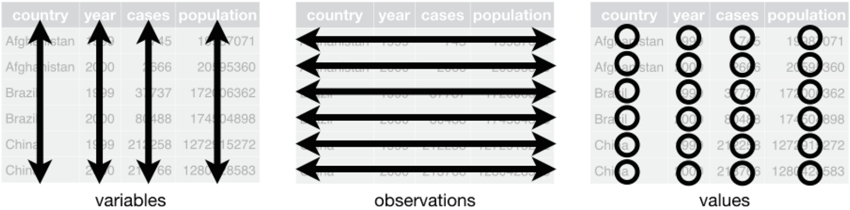

Figure 1: Tidy data

- make manipulation, visualization and modelling easier
- a common structure for all packages
- a philosophy for data representation (beyond the R framework)

Tidy or not ?

```r
tidyr::table3
```

```
## # A tibble: 6 x 3
##   country      year rate
## * <chr>       <int> <chr>
## 1 Afghanistan  1999 745/19987071
## 2 Afghanistan  2000 2666/20595360
## 3 Brazil       1999 37737/172006362
## 4 Brazil       2000 80488/174504898
## 5 China        1999 212258/1272915272
## 6 China        2000 213766/1280428583
```

Tidy or not ?

```
tidyr::table2
```

```
## # A tibble: 12 x 4
##    country      year type            count
##    <chr>       <int> <chr>           <int>
##  1 Afghanistan  1999 cases             745
##  2 Afghanistan  1999 population   19987071
##  3 Afghanistan  2000 cases            2666
##  4 Afghanistan  2000 population   20595360
##  5 Brazil       1999 cases           37737
##  6 Brazil       1999 population  172006362
##  7 Brazil       2000 cases           80488
##  8 Brazil       2000 population  174504898
##  9 China        1999 cases          212258
## 10 China        1999 population 1272915272
## 11 China        2000 cases          213766
## 12 China        2000 population 1280428583
```

Tidy or not ?

```
tidyr::table1
```

```
## # A tibble: 6 x 4
##   country      year  cases population
##   <chr>       <int>  <int>      <int>
## 1 Afghanistan  1999    745   19987071
## 2 Afghanistan  2000   2666   20595360
## 3 Brazil       1999  37737  172006362
## 4 Brazil       2000  80488  174504898
## 5 China        1999 212258 1272915272
## 6 China        2000 213766 1280428583
```

The process of data analysis

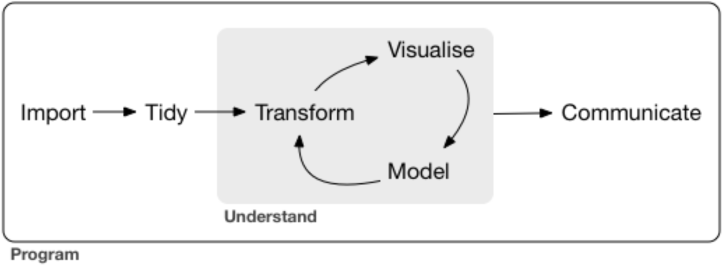

Figure 2: scheme for data analysis process

- **import:** read/load the data
- **tidy:** formating (individuals/variables data frame)
- **transform:** suppression/creation/filtering/selection
- **visualization:** representation and validation
- **model**: statistical fits
- **communication**: diffusion (web/talk/article)

The tidyverse

Definition

- contraction of ‘tidy’ (“well arranged) and ‘universe’.
- an *opinionated collection* of `R` packages designed for data science.
- all packages share an underlying *design philosophy*, *grammar*, and *data structures*

Phylosophy

allows the user to focus on the important statistical questions rather than focusing on the technical aspects of data analysis

Let's have a look

The core tidyverse loads ggplot2, tibble, tidyr, readr, purrr, stringr, forecats, dplyr and others in a fancy and unconflicted way.

```
library(tidyverse)
tidyverse:::tidyverse_conflicts()
```

```
## -- Conflicts -------------------------------------------------------------------------------
## x dplyr::filter() masks stats::filter()
## x dplyr::lag()    masks stats::lag()
```

```
tidyverse:::tidyverse_deps()
```

```
## # A tibble: 25 x 4
##    package cran  local behind
##    <chr>   <chr> <chr> <lgl>
##  1 broom   0.4.4 0.4.4 FALSE
##  2 cli     1.0.0 1.0.0 FALSE
##  3 crayon  1.3.4 1.3.4 FALSE
##  4 dbplyr  1.2.1 1.2.1 FALSE
##  5 dplyr   0.7.5 0.7.4 TRUE
##  6 forcats 0.3.0 0.3.0 FALSE
##  7 ggplot2 2.2.1 2.2.1 FALSE
##  8 haven   1.1.1 1.1.1 FALSE
##  9 hms     0.4.2 0.4.2 FALSE
## 10 httr    1.3.1 1.3.1 FALSE
## # ... with 15 more rows
```

Packages roles and overview I

tibble

a modern re-imagining of the data frame

tidyr

a set of functions that help you get to tidy data

dplyr

a consistent set of verbs that solve the most common data manipulation challenges

readr

Packages roles and overview II

a fast and friendly way to read rectangular data (like csv, tsv, and fwf)

stringr

a cohesive set of functions designed to make working with strings as easy as possible

forcats

a suite of useful tools that solve common problems with factors

ggplot2

a system for declaratively creating graphics, based on The Grammar of Graphics

Packages roles and overview III

purrr

enhances R's functional programming (FP) toolkit

magrittr

offers a set of operators which make your code more readable

Data analysis with the tidyverse

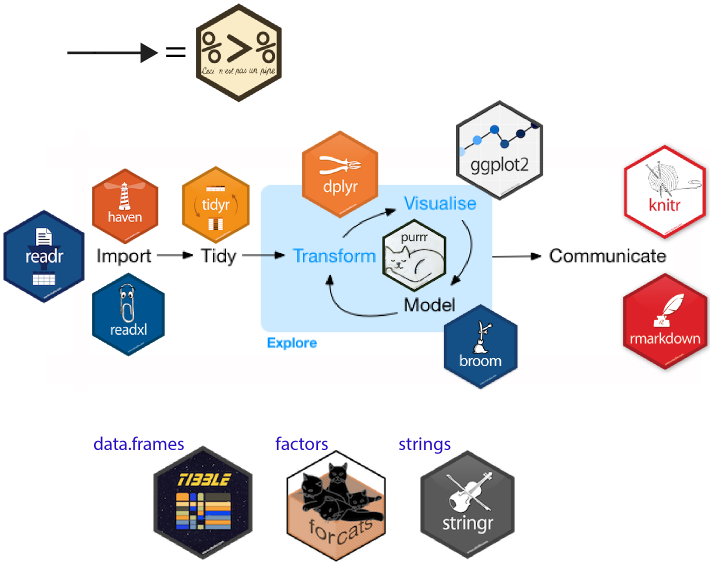

Figure 3: Updated scheme for data analysis process

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{tibble}

Figure 4: a modern re-imagining of the data frame

`tibble` versus `data.frame`

`tibbles` (or `tbl_df`) are modern reimagining of the `data.frame`,

- *lazy*: do less (e.g. do not change variable names, types, no partial matching)
- *surly*: complain more (e.g. when a variable does not exist)

Conversion from a data.frame

```
head(iris)
```

```
##   Sepal.Length Sepal.Width Petal.Length Petal.Width Species
## 1          5.1         3.5          1.4         0.2  setosa
## 2          4.9         3.0          1.4         0.2  setosa
## 3          4.7         3.2          1.3         0.2  setosa
## 4          4.6         3.1          1.5         0.2  setosa
## 5          5.0         3.6          1.4         0.2  setosa
## 6          5.4         3.9          1.7         0.4  setosa
```

```
as_tibble(iris)
```

```
## # A tibble: 150 x 5
##    Sepal.Length Sepal.Width Petal.Length Petal.Width Species
##           <dbl>       <dbl>        <dbl>       <dbl> <fct>
##  1          5.1         3.5          1.4         0.2 setosa
##  2          4.9         3            1.4         0.2 setosa
##  3          4.7         3.2          1.3         0.2 setosa
##  4          4.6         3.1          1.5         0.2 setosa
##  5          5           3.6          1.4         0.2 setosa
##  6          5.4         3.9          1.7         0.4 setosa
##  7          4.6         3.4          1.4         0.3 setosa
##  8          5           3.4          1.5         0.2 setosa
##  9          4.4         2.9          1.4         0.2 setosa
## 10          4.9         3.1          1.5         0.1 setosa
## # ... with 140 more rows
```

Conversion from a data.frame

```
head(iris)
```

```
##   Sepal.Length Sepal.Width Petal.Length Petal.Width Species
## 1          5.1         3.5          1.4         0.2  setosa
## 2          4.9         3.0          1.4         0.2  setosa
## 3          4.7         3.2          1.3         0.2  setosa
## 4          4.6         3.1          1.5         0.2  setosa
## 5          5.0         3.6          1.4         0.2  setosa
## 6          5.4         3.9          1.7         0.4  setosa
```

```
as_tibble(iris)
```

```
## # A tibble: 150 x 5
##    Sepal.Length Sepal.Width Petal.Length Petal.Width Species
##           <dbl>       <dbl>        <dbl>       <dbl> <fct>
##  1          5.1         3.5          1.4         0.2 setosa
##  2          4.9         3            1.4         0.2 setosa
##  3          4.7         3.2          1.3         0.2 setosa
##  4          4.6         3.1          1.5         0.2 setosa
##  5          5           3.6          1.4         0.2 setosa
##  6          5.4         3.9          1.7         0.4 setosa
##  7          4.6         3.4          1.4         0.3 setosa
##  8          5           3.4          1.5         0.2 setosa
##  9          4.4         2.9          1.4         0.2 setosa
## 10          4.9         3.1          1.5         0.1 setosa
## # ... with 140 more rows
```

Creating a tibble

```
tibble(
  x = 1:5,
  y = 1,
  z = x ^ 2 + y
)
```

```
## # A tibble: 5 x 3
##       x     y     z
##   <int> <dbl> <dbl>
## 1     1     1     2
## 2     2     1     5
## 3     3     1    10
## 4     4     1    17
## 5     5     1    26
```

Column names of a tibble

Names can start by any character. To refer such variables, use the backticks

```
tibble(`:)` = "smile", ` ` = "space", `2000` = "number")
```

```
## # A tibble: 1 x 3
##   `:)`  ` `   `2000`
##   <chr> <chr> <chr>
## 1 smile space number
```

Creating a tibble

```
tibble(
  x = 1:5,
  y = 1,
  z = x ^ 2 + y
)
```

```
## # A tibble: 5 x 3
##       x     y     z
##   <int> <dbl> <dbl>
## 1     1     1     2
## 2     2     1     5
## 3     3     1    10
## 4     4     1    17
## 5     5     1    26
```

Column names of a tibble

Names can start by any character. To refer such variables, use the backticks

```
tibble(`:)` = "smile", ` ` = "space", `2000` = "number")
```

```
## # A tibble: 1 x 3
##   `:)`  ` `   `2000`
##   <chr> <chr> <chr>
## 1 smile space number
```

Row names

Row do not have names in a tibble

Solution

- one can use name by adding a specfic column
- rownames_to_column () can help

Example

```
as_tibble(swiss, rownames = "Province")
```

```
## # A tibble: 47 x 7
##    Province     Fertility Agriculture Examination Education Catholic
##    <chr>            <dbl>       <dbl>       <int>     <int>    <dbl>
##  1 Courtelary        80.2        17            15        12     9.96
##  2 Delemont          83.1        45.1           6         9    84.8
##  3 Franches-Mnt      92.5        39.7           5         5    93.4
##  4 Moutier           85.8        36.5          12         7    33.8
##  5 Neuveville        76.9        43.5          17        15     5.16
##  6 Porrentruy        76.1        35.3           9         7    90.6
##  7 Broye             83.8        70.2          16         7    92.8
##  8 Glane             92.4        67.8          14         8    97.2
##  9 Gruyere           82.4        53.3          12         7    97.7
## 10 Sarine            82.9        45.2          16        13    91.4
## # ... with 37 more rows, and 1 more variable: Infant.Mortality <dbl>
```

Consistency in subsetting

```r
df <- data.frame(x = 1:9, y = LETTERS[1:9])
tbl <- tibble(x = 1:9, y = LETTERS[1:9])
```

```r
class(df[, 1:2])
```

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

```r
class(tbl[, 1:2])
```

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

```r
class(df[, 1])
```

```
## [1] "integer"
```

```r
class(tbl[, 1])
```

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

Consistency in subsetting

```r
df <- data.frame(x = 1:9, y = LETTERS[1:9])
tbl <- tibble(x = 1:9, y = LETTERS[1:9])
```

```r
class(df[, 1:2])
```

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

```r
class(tbl[, 1:2])
```

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

```r
class(df[, 1])
```

```
## [1] "integer"
```

```r
class(tbl[, 1])
```

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

Consistency in subsetting

```
df <- data.frame(x = 1:9, y = LETTERS[1:9])
tbl <- tibble(x = 1:9, y = LETTERS[1:9])
```

```
class(df[, 1:2])
```

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

```
class(tbl[, 1:2])
```

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

```
class(df[, 1])
```

```
## [1] "integer"
```

```
class(tbl[, 1])
```

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

List-column

The type `list` is available for a column in `tibble`

- a `tibble` allows cells containing lists
- a `tibble` allows cells containing data frames.

```
subset(starwars, select = c('name', 'height', 'mass', 'hair_color', 'films', 'vehicles'))
```

```
## # A tibble: 87 x 6
##    name               height  mass hair_color    films     vehicles
##    <chr>               <int> <dbl> <chr>         <list>    <list>
##  1 Luke Skywalker        172    77 blond         <chr [5]> <chr [2]>
##  2 C-3PO                 167    75 <NA>          <chr [6]> <chr [0]>
##  3 R2-D2                  96    32 <NA>          <chr [7]> <chr [0]>
##  4 Darth Vader           202   136 none          <chr [4]> <chr [0]>
##  5 Leia Organa           150    49 brown         <chr [5]> <chr [1]>
##  6 Owen Lars             178   120 brown, grey   <chr [3]> <chr [0]>
##  7 Beru Whitesun lars    165    75 brown         <chr [3]> <chr [0]>
##  8 R5-D4                  97    32 <NA>          <chr [1]> <chr [0]>
##  9 Biggs Darklighter     183    84 black         <chr [1]> <chr [0]>
## 10 Obi-Wan Kenobi        182    77 auburn, white <chr [6]> <chr [1]>
## # ... with 77 more rows
```

List-column: put a vector in each case

```
head(starwars$films, 4)
```

```
## [[1]]
## [1] "Revenge of the Sith"     "Return of the Jedi"
## [3] "The Empire Strikes Back" "A New Hope"
## [5] "The Force Awakens"
##
## [[2]]
## [1] "Attack of the Clones"    "The Phantom Menace"
## [3] "Revenge of the Sith"     "Return of the Jedi"
## [5] "The Empire Strikes Back" "A New Hope"
##
## [[3]]
## [1] "Attack of the Clones"    "The Phantom Menace"
## [3] "Revenge of the Sith"     "Return of the Jedi"
## [5] "The Empire Strikes Back" "A New Hope"
## [7] "The Force Awakens"
##
## [[4]]
## [1] "Revenge of the Sith"     "Return of the Jedi"
## [3] "The Empire Strikes Back" "A New Hope"
```

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readr

Figure 5: a fast and friendly way to read rectangular data (like csv, tsv, and fwf)

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{tidyr}

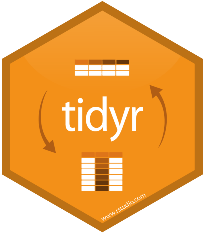

Figure 6: a set of functions that help you get to tidy data

```
library(tidyr)
```

⇝ `tidyr` is a package which helps you to transform messy datasets into tidy datasets.

- evolution of base function `reshape`
- available functions are `spread`, `gather`, `unite`, `separate`

Grades dataset

```
grades <- tibble(
  Name = c("Tommy", "Mary", "Gary", "Cathy"),
  Sexage = c("m.15", "f.15", "m.16", "f.14"),
  Test1 = c(10, 15, 16, 14),
  Test2 = c(11, 13, 10, 12),
  Test3 = c(12, 13, 17, 10)
  )
grades
```

```
## # A tibble: 4 x 5
##   Name  Sexage Test1 Test2 Test3
##   <chr> <chr>  <dbl> <dbl> <dbl>
## 1 Tommy m.15      10    11    12
## 2 Mary  f.15      15    13    13
## 3 Gary  m.16      16    10    17
## 4 Cathy f.14      14    12    10
```

Name	Sexage	Test1	Test2	Test3
Tommy	m.15	10	11	12
Mary	f.15	15	13	13
Gary	m.16	16	10	17
Cathy	f.14	14	12	10

separate()

Separate one column into multiple columns

```
grades <- separate(grades, Sexage, into = c("Sex", "Age"))
grades
```

```
## # A tibble: 4 x 6
##   Name  Sex   Age   Test1 Test2 Test3
##   <chr> <chr> <chr> <dbl> <dbl> <dbl>
## 1 Tommy m     15       10    11    12
## 2 Mary  f     15       15    13    13
## 3 Gary  m     16       16    10    17
## 4 Cathy f     14       14    12    10
```

Name	Sex	Age	Test1	Test2	Test3
Tommy	m	15	10	11	12
Mary	f	15	15	13	13
Gary	m	16	16	10	17
Cathy	f	14	14	12	10

Remark

The inverse of separate() is unite()

separate()

Separate one column into multiple columns

```
grades <- separate(grades, Sexage, into = c("Sex", "Age"))
grades
```

```
## # A tibble: 4 x 6
##   Name  Sex   Age   Test1 Test2 Test3
##   <chr> <chr> <chr> <dbl> <dbl> <dbl>
## 1 Tommy m     15       10    11    12
## 2 Mary  f     15       15    13    13
## 3 Gary  m     16       16    10    17
## 4 Cathy f     14       14    12    10
```

Name	Sex	Age	Test1	Test2	Test3
Tommy	m	15	10	11	12
Mary	f	15	15	13	13
Gary	m	16	16	10	17
Cathy	f	14	14	12	10

Remark

The inverse of `separate()` is `unite()`

gather()

Gather Columns Into Key-Value Pairs

```r
grades <- gather(grades, Test1, Test2, Test3, key = Test, value = Grade)
head(grades)
```

```
## # A tibble: 6 x 5
##   Name  Sex   Age   Test  Grade
##   <chr> <chr> <chr> <chr> <dbl>
## 1 Tommy m     15    Test1    10
## 2 Mary  f     15    Test1    15
## 3 Gary  m     16    Test1    16
## 4 Cathy f     14    Test1    14
## 5 Tommy m     15    Test2    11
## 6 Mary  f     15    Test2    13
```

Name	Sex	Age	Test	Grade
Tommy	m	15	Test1	10
Mary	f	15	Test1	15
Gary	m	16	Test1	16
Cathy	f	14	Test1	14
Tommy	m	15	Test2	11
Mary	f	15	Test2	13

Remark

The inverse of gather() is spread()

gather()

Gather Columns Into Key-Value Pairs

```r
grades <- gather(grades, Test1, Test2, Test3, key = Test, value = Grade)
head(grades)
```

```
## # A tibble: 6 x 5
##   Name  Sex   Age   Test  Grade
##   <chr> <chr> <chr> <chr> <dbl>
## 1 Tommy m     15    Test1    10
## 2 Mary  f     15    Test1    15
## 3 Gary  m     16    Test1    16
## 4 Cathy f     14    Test1    14
## 5 Tommy m     15    Test2    11
## 6 Mary  f     15    Test2    13
```

Name	Sex	Age	Test	Grade
Tommy	m	15	Test1	10
Mary	f	15	Test1	15
Gary	m	16	Test1	16
Cathy	f	14	Test1	14
Tommy	m	15	Test2	11
Mary	f	15	Test2	13

Remark

The inverse of `gather()` is `spread()`

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{magrittr}

Figure 7: a set of operators which make your code more readable

```r
library(magrittr)
```

Provides the following operators

- Pipe %>%
- Reassignment pipe %<>%
- T-Pipe %T>%

Motivation: make Tom eat an apple

Everyday language

Tom eats an apple

Subject - Verb - Complement

Programming language

```
eat(Tom, apple)
```

Verb - Subject - Complement

Pipes

⇝ get closer to everyday language in your code
⇝ clearly expressing a sequence of multiple operations

Pipe %>%

- when you read code, %>% is pronounced "then"
- the keybord shortcut for %>% is Ctrl + shift + M

Objective

- Helps writing `R` code which is easy to read (and thus, easy to understand)
- `x %>% f()` is equivalent to `f(x)`
- `x %>% f(y)` is equivalent to `f(x, y)`
- `x %>% f(y,.)` is équivalent to `f(y,x)`

Example

```
2^mean(log(seq_len(10), base = 2), na.rm = TRUE)
```

```
## [1] 4.528729
```

```
10 %>%
  seq_len() %>%
  log(base = 2) %>%
  mean(na.rm = TRUE) %>%
  {2^.}
```

```
## [1] 4.528729
```

Pipe %>%

- when you read code, %>% is pronounced “then”
- the keybord shortcut for %>% is Ctrl + shift + M

Objective

- Helps writing `R` code which is easy to read (and thus, easy to understand)
- `x %>% f()` is equivalent to `f(x)`
- `x %>% f(y)` is equivalent to `f(x, y)`
- `x %>% f(y,.)` is équivalent to `f(y,x)`

Example

```
2^mean(log(seq_len(10), base = 2), na.rm = TRUE)
```

```
## [1] 4.528729
```

```
10 %>%
  seq_len() %>%
  log(base = 2) %>%
  mean(na.rm = TRUE) %>%
  {2^.}
```

```
## [1] 4.528729
```

Pipe %>%

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Example

```r
2^mean(log(seq_len(10), base = 2), na.rm = TRUE)
```

```
## [1] 4.528729
```

```r
10 %>%
  seq_len() %>%
  log(base = 2) %>%
  mean(na.rm = TRUE) %>%
  {2^.}
```

```
## [1] 4.528729
```

Exercise

Consider

```
x <- c(0.109, 0.359, 0.63, 0.996, 0.515, 0.142, 0.017, 0.829, 0.907)
```

Compute the logarithm of `x`, return suitably lagged and iterated differences, compute the exponential function and round the result

1. In base `R`
2. Using %>%

(Re)assignment pipe %<>%

For affectation, magrittr provides the operator %<>% which allows to replace code like

```
mtcars <- mtcars%>% transform(cyl = cyl * 2)
```

by

```
mtcars %<>% transform(cyl = cyl * 2)
```

T-pipe %T>%

Problem with functions requiring early side effects along succession of %>%

- you might want to plot or print and object
- such function do not send back anything and break the pipe

Solution

- to overcome such an issue, use the "tee" pipe %T>%
- works like %>% except that it sends left side in place of right side of the expression
- "tee"because it looks like a pipe with a T shape

T-pipe %T>%: example without T

```
    rnorm (100) %>%
      matrix(ncol = 2) %>%
      plot() %>%
      str()
```

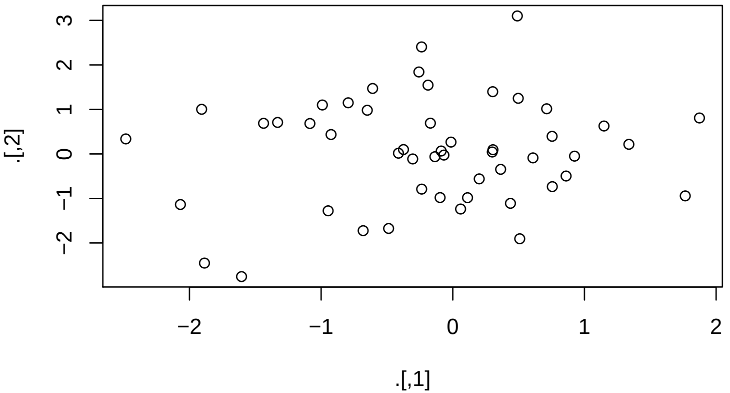

Figure 8: plot of bivariate Gaussian sample

```
## NULL
```

T-pipe %T>%: example with T

```
    rnorm (100) %>%
      matrix(ncol = 2) %T>%
      plot() %>%
      str()
```

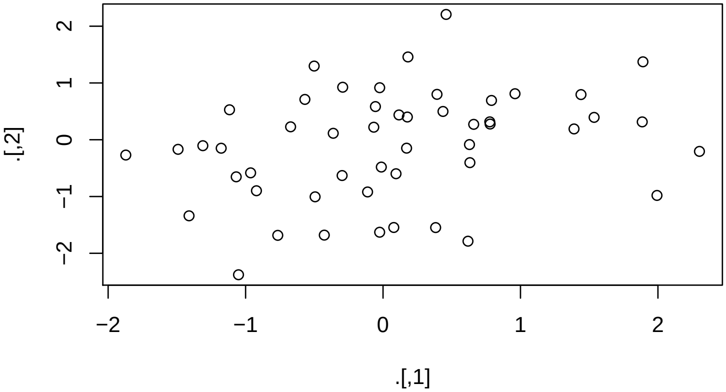

Figure 9: plot of bivariate Gaussian sample

```
##  num [1:50, 1:2] 1.44 -1.411 0.789 0.177 -0.298 ...
```

Exposition Operator %$%

When working with functions that do not take data argumentbut still useful in a pipeline, e.g., when your data is first processed and then passed into the function.

Example

```r
iris %>%
  subset(Sepal.Length > mean(Sepal.Length)) %$%
  cor(Sepal.Length, Sepal.Width)
```

```
## [1] 0.3361992
```

When not to use the pipe

Consider other solutions when

Pipes contain too many steps

Create *intermediate* objects with meaningful names

Multiple inputs or outputs are required

E.g., when several objects need to *combine* together

Complex dependance structures exists between your entries

Pipes are fundamentally *linear*: expressing complex relationships with them yield confusing code.

Outline

1. Introduction
2. tibble
3. readr
4. tidyr
5. magrittr
6. dplyr
7. purrr
8. ggplot2

dplyr

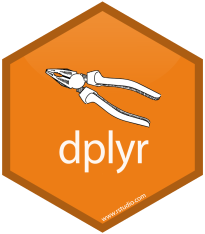

Figure 10: a consistent set of verbs that solve the most common data manipulation challenges

Outline

1. Introduction
2. tibble
3. readr
4. tidyr
5. magrittr
6. dplyr
7. purrr
8. ggplot2

{purrr}

Figure 11: enhances R's functional programming (FP) toolkit

Outline

1. Introduction
2. tibble
3. readr
4. tidyr
5. magrittr
6. dplyr
7. purrr
8. ggplot2

ggplot2

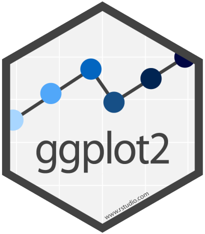

Figure 12: a system for declaratively creating graphics, based on The Grammar of Graphics

References

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Wickham, H., & Grolemund, G. (2016). *R for data science: Import, tidy, transform, visualize, and model data*. " O'Reilly Media, Inc." Retrieved from http://r4ds.had.co.nz