Lecture 3: Data Manipulation

October 10, 2017

Contents

apply family

apply, lapply, sapply functions

- The `apply` family functions, are **functions which manipulate slices of data** stored as matrices, arrays, lists and data-frames **in a repetitive way**.
- These functions **avoid the explicit use of loops**, and might be **more computationally efficient**, depending on how big a dataset is. For more details on runtimes see this link.
- `apply` allow you to perform operations with **very few lines of code.**
- The family comprises: **apply, lapply , sapply, vapply, mapply, rapply, and tapply**. The difference lies in the structure of input data and the desired format of the output).

apply function

`apply` operates on arrays/matrices.

In the example below we obtain column sums of matrix X.

```
(X <- matrix(sample(30), nrow = 5, ncol = 6))
```

```
##      [,1] [,2] [,3] [,4] [,5] [,6]
## [1,]   23   25   29    1   13    8
## [2,]    3    4    6   12   22    2
## [3,]    5   21   26   17   19   14
## [4,]    7   10   15   27   16   28
## [5,]   24   18   20    9   30   11
```

```
apply(X, MARGIN = 2 , FUN = sum)
```

```
## [1]  62  78  96  66 100  63
```

Note: that in a matrix `MARGIN = 1` indicates rows and `MARGIN = 2` indicate columns.

apply function

- `apply` can be used with **user-defined functions:**

```
print(X)
```

```
##      [,1] [,2] [,3] [,4] [,5] [,6]
## [1,]   23   25   29    1   13    8
## [2,]    3    4    6   12   22    2
## [3,]    5   21   26   17   19   14
## [4,]    7   10   15   27   16   28
## [5,]   24   18   20    9   30   11
```

```
# number entries < 15
apply(X, 2, function(x) 10*x + 2)
```

```
##      [,1] [,2] [,3] [,4] [,5] [,6]
## [1,]  232  252  292   12  132   82
## [2,]   32   42   62  122  222   22
## [3,]   52  212  262  172  192  142
## [4,]   72  102  152  272  162  282
## [5,]  242  182  202   92  302  112
```

- The function can be defined outsid `apply()`,

```
logColMeans <- function(x, eps = NULL)
  if (!is.null(eps)) x <- x + eps
  return(mean(x))
}
apply(X, 2, logColMeans)
```

```
## [1] 12.4 15.6 19.2 13.2 20.0 12.6
```

```
apply(X, 2, logColMeans, eps = 0.1)
```

```
## [1] 12.5 15.7 19.3 13.3 20.1 12.7
```

lapply/sapply functions

- `lapply()` is used to **repeatedly apply a function to elements of a sequential object** such as a vector, list, or data-frame (applies to columns).
- The **output is a list** with the same number of elements as the input object.
- `sapply` is the same as `lapply` but **returns a "simplified" output.**
- user-defined functions can be used with `sapply/lapply`

```
# lapply returns a list
lapply(1:3, function(x) x^2)
```

```
## [[1]]
## [1] 1
##
## [[2]]
## [1] 4
##
## [[3]]
## [1] 9
```

```
# which you can 'simplify' with unlist(
unlist(lapply(1:3, function(x) x^2))
```

```
## [1] 1 4 9
```

```
# Or you could use sapply() instead
sapply(1:3, function(x) x^2)
```

```
## [1] 1 4 9
```

mapply functions

- `mapply` stands for 'multivariate' apply. It **applies a function to a multiple list or multiple vectors as arguments**.
- The goal is to vectorize arguments to a function which usually does not accept vectors as arguments.

```
# function word() returns a string of character C repeated k times.
word <- function(C,k) paste(rep.int(C,k), collapse='')
mapply(word, LETTERS[1:6], 6:1, SIMPLIFY = FALSE)
```

```
## $A
## [1] "AAAAAA"
##
## $B
## [1] "BBBBB"
##
## $C
## [1] "CCCC"
##
## $D
## [1] "DDD"
##
## $E
## [1] "EE"
##
## $F
## [1] "F"
```

Exercise 1

- Go to the “Lec3_Exercises.Rmd” file, which can be downloaded from the class website under the Lecture tab.
- Complete Exercise 1.

`dplyr` package

`dplyr`

- Introduces **a grammar of data manipulation.**
- **Code-efficient** for data exploration and transformation.
- **Fast on data frames** (written in C++): has speed of C and ease of R.
- **Intuitive to write and easy to read**, esp. when using the *chaining* syntax.
- You should use `dplyr` even as a beginner R user, and here is why.

```r
# To install dplyr with latest updates
install.packages("devtools")
devtools::install_github("tidyverse/dplyr")

# Or you could use CRAN
install.packages("dplyr")
```

tibbles

> *Tibbles are a modern take on data frames. They keep the features that have stood the test of time, and drop the features that used to be convenient but are now frustrating (i.e. converting character vectors to factors).*

- A tibble, `tbl`, is **a wrapper for a data frame that prints nicely**.
- The print method for `tbl` shows only the **first 10 rows, and all the columns that fit on screen**.
- Each column is also reported together its type.
- Tibbles (and `dplyr`) **do NOT preserve the row names**.
- **Subsetting `tbl` is strickter** than subsetting `data.frames`, and ALWAYS returns objects with expected class, i.e. with a single `[` you get back a tibble, and with double `[[` you get a vector.

Movie industry dataset

`movies.csv` contains information on last three decades of movies. The data h
been scraped from the IMDb website and can be accessed from a github repo.

```r
url <- "https://raw.githubusercontent.com/Juanets/movie-stats/master/movies.csv"
movies.df <- read.csv(url)
rownames(movies.df) <- paste0("M", 1:nrow(movies.df))
dim(movies.df)
```

```
## [1] 6820   15
```

```r
colnames(movies.df)
```

```
##  [1] "budget"   "company"  "country"  "director" "genre"    "gross"
##  [7] "name"     "rating"   "released" "runtime"  "score"    "star"
## [13] "votes"    "writer"   "year"
```

```r
head(movies.df)
```

```
##      budget                                company country       director
## M1  8000000          Columbia Pictures Corporation     USA     Rob Reiner
## M2  6000000                     Paramount Pictures     USA    John Hughes
## M3 15000000                     Paramount Pictures     USA     Tony Scott
## M4 18500000 Twentieth Century Fox Film Corporation     USA  James Cameron
## M5  9000000                   Walt Disney Pictures     USA Randal Kleiser
## M6  6000000                                Hemdale      UK   Oliver Stone
##        genre     gross                     name rating   released runtime scor
## M1 Adventure  52287414              Stand by Me      R 1986-08-22      89   8.
## M2    Comedy  70136369 Ferris Bueller's Day Off  PG-13 1986-06-11     103   7.
## M3    Action 179800601                  Top Gun     PG 1986-05-16     110   6.
## M4    Action  85160248                   Aliens      R 1986-07-18     137   8.
## M5 Adventure  18564613  Flight of the Navigator     PG 1986-08-01      90   6.
## M6     Drama 138530565                  Platoon      R 1987-02-06     120   8.
##                  star  votes        writer year
## M1       Wil Wheaton 299174  Stephen King 1986
## M2 Matthew Broderick 264740   John Hughes 1986
## M3        Tom Cruise 236909      Jim Cash 1986
## M4  Sigourney Weaver 540152 James Cameron 1986
## M5       Joey Cramer  36636 Mark H. Baker 1986
## M6     Charlie Sheen 317585  Oliver Stone 1986
```

Convert to tibble

```r
library(dplyr)

# convert to tibble
movies <- tbl_df(movies.df)
class(movies)
```

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

```r
# printing only shows 10 rows and as many columns as can fit on your screen
movies
```

```
## # A tibble: 6,820 x 15
##      budget                                company country          director
##  *    <dbl>                                 <fctr>  <fctr>            <fctr>
##  1  8000000            Columbia Pictures Corporation     USA        Rob Reiner
##  2  6000000                       Paramount Pictures     USA       John Hughes
##  3 15000000                       Paramount Pictures     USA        Tony Scott
##  4 18500000  Twentieth Century Fox Film Corporation     USA     James Cameron
##  5  9000000                     Walt Disney Pictures     USA    Randal Kleiser
##  6  6000000                                 Hemdale      UK      Oliver Stone
##  7 25000000                    Henson Associates (HA)      UK        Jim Henson
##  8  6000000 De Laurentiis Entertainment Group (DEG)     USA       David Lynch
##  9  9000000                       Paramount Pictures     USA     Howard Deutch
## 10 15000000                     SLM Production Group     USA David Cronenberg
## # ... with 6,810 more rows, and 11 more variables: genre <fctr>, gross <dbl>,
## #   name <fctr>, rating <fctr>, released <fctr>, runtime <int>, score <dbl>,
## #   star <fctr>, votes <int>, writer <fctr>, year <int>
```

Note: Tibbles and dplyr **do NOT preserve the row names**, you need to create an "id" column instead.

```r
str(movies)
```

```
## Classes 'tbl_df', 'tbl' and 'data.frame':	6820 obs. of  15 variables:
##  $ budget  : num  8000000 6000000 15000000 18500000 9000000 6000000 25000000 6
##  $ company : Factor w/ 2179 levels "101st Street Films",..: 663 1683 1683 2068
##  $ country : Factor w/ 57 levels "Argentina","Aruba",..: 56 56 56 56 56 54 54
##  $ director: Factor w/ 2759 levels "Aamir Khan","Aaron Blaise",..: 2246 1295 2
##  $ genre   : Factor w/ 17 levels "Action","Adventure",..: 2 5 1 1 2 7 2 7 5 7
##  $ gross   : num  5.23e+07 7.01e+07 1.80e+08 8.52e+07 1.86e+07 ...
##  $ name    : Factor w/ 6731 levels "10,000 BC","101 Dalmatians",..: 4667 1819
##  $ rating  : Factor w/ 13 levels "B","B15","G",..: 9 8 7 9 7 9 7 9 8 9 ...
##  $ released: Factor w/ 2403 levels "1986-01-10","1986-01-17",..: 40 28 24 34 3
##  $ runtime : int  89 103 110 137 90 120 101 120 96 96 ...
##  $ score   : num  8.1 7.8 6.9 8.4 6.9 8.1 7.4 7.8 6.8 7.5 ...
##  $ star    : Factor w/ 2504 levels "50 Cent","Aaliyah",..: 2474 1605 2348 2195
##  $ votes   : int  299174 264740 236909 540152 36636 317585 102879 146768 60565
##  $ writer  : Factor w/ 4199 levels "A.A. Milne","Aaron Guzikowski",..: 3723 19
##  $ year    : int  1986 1986 1986 1986 1986 1986 1986 1986 1986 1986 ...
```

Data manipulation functions

`dplyr` verbs

The most commonly used `dplyr` functions (or basic verbs) are:

- `filter()`: keep rows matching criteria,
- `select()`: pick columns by name,
- `arrange()`: reorder rows,
- `mutate()`: add new variables,
- `summarise()`: reduce variables to values

Operations performed with the above functions can be done using **base R functions, but they would be less computationally efficient, and require writi more lines of (ugly) code.**

Learn about `dplyr` from the turtorial written by its creator, Hadley Wickham

Structure of `dplyr` functions

- the first argument is a data frame
- subsequent argument specify what to do
- always return a data frame

filter(): keep rows matching criteria

```r
# base R approach to find all comedies by Woody Allen
movies[movies$genre == "Comedy" & movies$director == "Woody Allen", ]
```

```r
# dplyr approach
# note: both comma or ampersand represent AND condition
filter(movies, genre == "Comedy", director == "Woody Allen")
```

```
## # A tibble: 27 x 15
##      budget                                     company country    director
##       <dbl>                                      <fctr>  <fctr>      <fctr>
##  1  6400000                             Orion Pictures     USA Woody Allen
##  2 16000000                             Orion Pictures     USA Woody Allen
##  3 19000000 Jack Rollins & Charles H. Joffe Productions     USA Woody Allen
##  4 15000000                        Touchstone Pictures     USA Woody Allen
##  5 12000000                             Orion Pictures     USA Woody Allen
##  6 14000000                             Orion Pictures     USA Woody Allen
##  7 20000000                           TriStar Pictures     USA Woody Allen
##  8 13500000                           TriStar Pictures     USA Woody Allen
##  9 20000000                                    Miramax     USA Woody Allen
## 10 15000000                            Sweetland Films     USA Woody Allen
## # ... with 17 more rows, and 11 more variables: genre <fctr>, gross <dbl>,
## #   name <fctr>, rating <fctr>, released <fctr>, runtime <int>, score <dbl>,
## #   star <fctr>, votes <int>, writer <fctr>, year <int>
```

```r
# use pipe for OR condition
filter(movies, country == "Greece" | country == "Chile")
```

```
## # A tibble: 9 x 15
##    budget                  company country                  director     genre
##     <dbl>                   <fctr>  <fctr>                    <fctr>    <fctr>
## 1 0.0e+00            Paradis Films  Greece Theodoros Angelopoulos     Drama
## 2 0.0e+00          Boo Productions  Greece          Yorgos Lanthimos     Drama
## 3 0.0e+00                Haos Film  Greece Athina Rachel Tsangari     Drama
## 4 0.0e+00                Haos Film  Greece          Yorgos Lanthimos     Drama
## 5 0.0e+00        Participant Media   Chile      "Pablo Larra\xedn"     Drama
## 6 0.0e+00                    Film4  Greece          Yorgos Lanthimos    Comedy
## 7 2.6e+07      Alcon Entertainment   Chile          Patricia Riggen Biography
## 8 9.0e+06 Fox Searchlight Pictures   Chile      "Pablo Larra\xedn" Biography
## 9 0.0e+00                 AZ Films   Chile      "Pablo Larra\xedn" Biography
## # ... with 10 more variables: gross <dbl>, name <fctr>, rating <fctr>,
## #   released <fctr>, runtime <int>, score <dbl>, star <fctr>, votes <int>,
## #   writer <fctr>, year <int>
```

```r
# you can also use %in% operator
print(filter(movies, country %in% c("Argentina", "Colombia", "Chile")), n = Inf
```

```
## # A tibble: 19 x 15
##     budget                                                 company   country
##      <dbl>                                                  <fctr>    <fctr>
##  1 0.0e+00                                              Cinequanon Argentina
##  2 0.0e+00                                "GEA Cinematogr\xe1fica" Argentina
##  3 0.0e+00                                           Not specified Argentina
##  4 0.0e+00                                Aleph Producciones S.A. Argentina
##  5 1.5e+06                                                FX Sound Argentina
##  6 0.0e+00 Instituto Nacional de Cine y Artes Audiovisuales (INCAA) Argentina
##  7 0.0e+00                                                4k Films Argentina
##  8 0.0e+00                                                FilmFour Argentina
##  9 3.0e+06                                               HBO Films  Colombia
## 10 0.0e+00                                                Cinefarm Argentina
## 11 0.0e+00                                              Aura Films Argentina
## 12 0.0e+00                    Historias Cinematograficas Cinemania Argentina
## 13 2.0e+06                                          Tornasol Films Argentina
## 14 0.0e+00                                       Participant Media     Chile
## 15 3.3e+06                                     Corner Producciones Argentina
## 16 2.6e+07                                     Alcon Entertainment     Chile
## 17 1.4e+06                                           Buffalo Films  Colombia
## 18 9.0e+06                                Fox Searchlight Pictures     Chile
## 19 0.0e+00                                                AZ Films     Chile
## # ... with 12 more variables: director <fctr>, genre <fctr>, gross <dbl>,
## #   name <fctr>, rating <fctr>, released <fctr>, runtime <int>, score <dbl>,
## #   star <fctr>, votes <int>, writer <fctr>, year <int>
```

`select()`: pick columns by name

```r
# base R approach to select columns
movies[, c("name", "year", "genre")]
```

```r
# dplyr approach
movies.sub <- select(movies, name, country, year, genre)
movies.sub
```

```
## # A tibble: 6,820 x 4
##                        name country  year     genre
##   *                  <fctr>  <fctr> <int>    <fctr>
##   1             Stand by Me     USA  1986 Adventure
##   2 Ferris Bueller's Day Off    USA  1986    Comedy
##   3                 Top Gun     USA  1986    Action
##   4                  Aliens     USA  1986    Action
##   5  Flight of the Navigator    USA  1986 Adventure
##   6                 Platoon      UK  1986     Drama
##   7               Labyrinth      UK  1986 Adventure
##   8             Blue Velvet     USA  1986     Drama
##   9          Pretty in Pink     USA  1986    Comedy
## 10                  The Fly     USA  1986     Drama
## # ... with 6,810 more rows
```

```r
# use colon to select multiple contiguous columns,
select(movies, name, genre:score)
```

```
## # A tibble: 6,820 x 7
##                         name     genre     gross rating   released runtime scor
##   *                   <fctr>    <fctr>     <dbl> <fctr>     <fctr>   <int> <dbl
##  1               Stand by Me Adventure  52287414      R 1986-08-22      89   8.
##  2 Ferris Bueller's Day Off    Comedy  70136369  PG-13 1986-06-11     103   7.
##  3                   Top Gun    Action 179800601     PG 1986-05-16     110   6.
##  4                    Aliens    Action  85160248      R 1986-07-18     137   8.
##  5  Flight of the Navigator Adventure  18564613     PG 1986-08-01      90   6.
##  6                   Platoon     Drama 138530565      R 1987-02-06     120   8.
##  7                 Labyrinth Adventure  12729917     PG 1986-06-27     101   7.
##  8               Blue Velvet     Drama   8551228      R 1986-10-23     120   7.
##  9            Pretty in Pink    Comedy  40471663  PG-13 1986-02-28      96   6.
## 10                   The Fly     Drama  40456565      R 1986-08-15      96   7.
## # ... with 6,810 more rows
```

`select()` helpers

You can use the following functions to help select the columns:

- `starts_with()`
- `ends_with()`
- `contains()`
- `matches()` (matches a regular expression)

```
select(movies, starts_with("r"))
```

```
## # A tibble: 6,820 x 3
##    rating   released runtime
##  * <fctr>     <fctr>   <int>
##  1      R 1986-08-22      89
##  2  PG-13 1986-06-11     103
##  3     PG 1986-05-16     110
##  4      R 1986-07-18     137
##  5     PG 1986-08-01      90
##  6      R 1987-02-06     120
##  7     PG 1986-06-27     101
##  8      R 1986-10-23     120
##  9  PG-13 1986-02-28      96
## 10      R 1986-08-15      96
## # ... with 6,810 more rows
```

```r
select(movies, ends_with("e"))
```

```
## # A tibble: 6,820 x 4
##         genre                         name runtime score
##  *     <fctr>                       <fctr>   <int> <dbl>
##  1 Adventure                  Stand by Me      89   8.1
##  2    Comedy Ferris Bueller's Day Off     103   7.8
##  3    Action                      Top Gun     110   6.9
##  4    Action                       Aliens     137   8.4
##  5 Adventure  Flight of the Navigator      90   6.9
##  6     Drama                      Platoon     120   8.1
##  7 Adventure                    Labyrinth     101   7.4
##  8     Drama                  Blue Velvet     120   7.8
##  9    Comedy               Pretty in Pink      96   6.8
## 10     Drama                      The Fly      96   7.5
## # ... with 6,810 more rows
```

```r
select(movies, contains("re"))
```

```
## # A tibble: 6,820 x 4
##             director     genre   released score
##  *            <fctr>    <fctr>     <fctr> <dbl>
##  1        Rob Reiner Adventure 1986-08-22   8.1
##  2       John Hughes    Comedy 1986-06-11   7.8
##  3        Tony Scott    Action 1986-05-16   6.9
##  4     James Cameron    Action 1986-07-18   8.4
##  5    Randal Kleiser Adventure 1986-08-01   6.9
##  6      Oliver Stone     Drama 1987-02-06   8.1
##  7        Jim Henson Adventure 1986-06-27   7.4
##  8       David Lynch     Drama 1986-10-23   7.8
##  9     Howard Deutch    Comedy 1986-02-28   6.8
## 10 David Cronenberg     Drama 1986-08-15   7.5
## # ... with 6,810 more rows
```

Dropping columns

```r
# remove budget and company columns
print(select(movies, -budget, -company),  n = 6)
```

```
## # A tibble: 6,820 x 13
##   country        director     genre     gross                          name rating
## *  <fctr>          <fctr>    <fctr>     <dbl>                        <fctr> <fctr>
## 1     USA      Rob Reiner Adventure  52287414                   Stand by Me      R
## 2     USA     John Hughes    Comedy  70136369 Ferris Bueller's Day Off   PG-13
## 3     USA      Tony Scott    Action 179800601                       Top Gun     PG
## 4     USA   James Cameron    Action  85160248                        Aliens      R
## 5     USA Randal Kleiser Adventure  18564613   Flight of the Navigator     PG
## 6      UK    Oliver Stone     Drama 138530565                       Platoon      R
## # ... with 6,814 more rows, and 7 more variables: released <fctr>,
## #   runtime <int>, score <dbl>, star <fctr>, votes <int>, writer <fctr>,
## #   year <int>
```

```r
# Selecting and renaming in one
print(select(movies, name, gross_revenue = gross), n = 6)
```

```
## # A tibble: 6,820 x 2
##                       name gross_revenue
## *                   <fctr>         <dbl>
## 1              Stand by Me      52287414
## 2 Ferris Bueller's Day Off      70136369
## 3                  Top Gun     179800601
## 4                   Aliens      85160248
## 5  Flight of the Navigator      18564613
## 6                  Platoon     138530565
## # ... with 6,814 more rows
```

arrange(): reorder rows

```r
# dplyr approach
print(arrange(movies.sub, name), n = 6)
```

```
## # A tibble: 6,820 x 4
##                        name country  year     genre
##                      <fctr>  <fctr> <int>    <fctr>
## 1                 10,000 BC     USA  2008    Action
## 2            101 Dalmatians     USA  1996 Adventure
## 3            102 Dalmatians     USA  2000 Adventure
## 4       10 Cloverfield Lane     USA  2016     Drama
## 5 10 Things I Hate About You    USA  1999    Comedy
## 6                  10 Years     USA  2011    Comedy
## # ... with 6,814 more rows
```

```r
# use `desc` for descending
print(arrange(movies.sub, desc(year)), n = 6)
```

```
## # A tibble: 6,820 x 4
##                                    name country  year     genre
##                                  <fctr>  <fctr> <int>    <fctr>
## 1                         The Bad Batch     USA  2016     Drama
## 2                      Assassin's Creed     USA  2016    Action
## 3                           La La Land     USA  2016    Comedy
## 4                         Suicide Squad     USA  2016    Action
## 5                                  Sing     USA  2016 Animation
## 6 Fantastic Beasts and Where to Find Them      UK  2016 Adventure
## # ... with 6,814 more rows
```

`mutate()`: add new variables

```r
# base R approach to create a new variable 'profit'
movies$profit <- movies$gross - movies$budget
```

```r
# dplyr approach
movies <- mutate(movies, profit = gross - budget)
select(movies, name, gross, budget, profit)
```

```
## # A tibble: 6,820 x 4
##                          name     gross   budget    profit
##                        <fctr>     <dbl>    <dbl>     <dbl>
##  1                Stand by Me  52287414  8000000  44287414
##  2 Ferris Bueller's Day Off  70136369  6000000  64136369
##  3                    Top Gun 179800601 15000000 164800601
##  4                     Aliens  85160248 18500000  66660248
##  5  Flight of the Navigator  18564613  9000000   9564613
##  6                    Platoon 138530565  6000000 132530565
##  7                  Labyrinth  12729917 25000000 -12270083
##  8                Blue Velvet   8551228  6000000   2551228
##  9             Pretty in Pink  40471663  9000000  31471663
## 10                    The Fly  40456565 15000000  25456565
## # ... with 6,810 more rows
```

Generating multiple new variables

```r
movies <- mutate(movies,
                 profit = gross - budget,
                 gross_in_mil = gross/10^6,
                 budget_in_mil = budget/10^6,
                 profit_in_mil = profit/10^6)
select(movies, name, contains("_in_mil"))
```

```
## # A tibble: 6,820 x 4
##                        name gross_in_mil budget_in_mil profit_in_mil
##                      <fctr>        <dbl>         <dbl>         <dbl>
##  1               Stand by Me    52.287414           8.0     44.287414
##  2 Ferris Bueller's Day Off    70.136369           6.0     64.136369
##  3                  Top Gun   179.800601          15.0    164.800601
##  4                   Aliens    85.160248          18.5     66.660248
##  5   Flight of the Navigator    18.564613           9.0      9.564613
##  6                  Platoon   138.530565           6.0    132.530565
##  7                Labyrinth    12.729917          25.0    -12.270083
##  8              Blue Velvet     8.551228           6.0      2.551228
##  9           Pretty in Pink    40.471663           9.0     31.471663
## 10                  The Fly    40.456565          15.0     25.456565
## # ... with 6,810 more rows
```

summarise(): reduce variables to value

- `summarize()` can be used to aggregate data or to compute a summarizing value of interest.

```
# Total gross revenue for all movies in 
summarise(movies,
          tot_gross_in_bil = sum(gross)/
```

```
## # A tibble: 1 x 1
##   tot_gross_in_bil
##              <dbl>
## 1         228.4552
```

- `summarize()` is **primarily useful data previously grouped by one o more variables** using `group_by(`

```
by_genre <-  group_by(movies, genre)
summarize(by_genre, total = sum(gross)
```

```
## # A tibble: 17 x 2
##          genre        total
##         <fctr>        <dbl>
##  1      Action 74.792634664
##  2   Adventure 20.895092830
##  3   Animation 25.342203262
##  4   Biography  8.617526666
##  5      Comedy 53.543423603
##  6       Crime 10.217836159
##  7       Drama 25.204622256
##  8      Family  0.118110208
##  9     Fantasy  0.644653115
## 10      Horror  7.117846856
## 11     Musical  0.008094993
## 12     Mystery  1.379951556
## 13     Romance  0.145764206
## 14      Sci-Fi  0.307801697
## 15    Thriller  0.099600218
## 16         War  0.001509775
## 17     Western  0.018519094
```

Useful summary functions

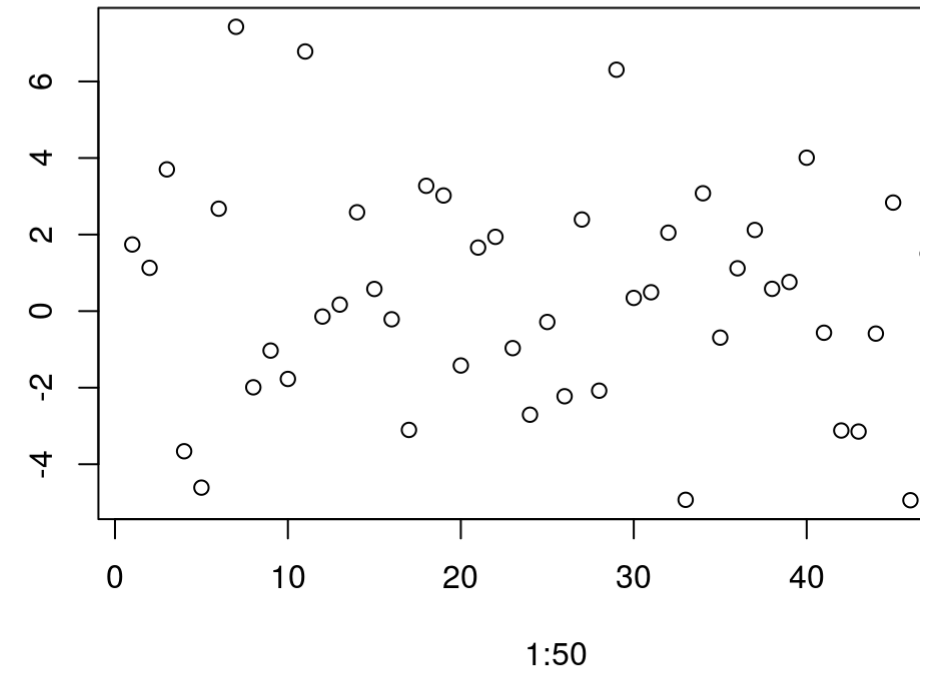
- `min(x)`, `median(x)`, `max(x)`, `quantile(x, p)`
- `n()`, `n_distinct()`, `sum(x)`, `mean(x)`
- `sum(x > 10)`, `mean(x > 0)`
- `sd(x)`, `var(x)`

Chaining operations

Pipe operator: %>%

- The `%>%` operator was intoduced in `magrittr` package to **pipe values forward into an expression or function call.**
- In the pipe notation we have something like `x %>% f(y)`, rather than `f(x, y)`
- This is similar to the Unix pipes: | used to **send the output of one program to another program for further processing.**

```r
rnorm(500) %>%
  matrix(ncol = 50) %>%
  colSums() %>%
  plot(x = 1:50)
```



Chaining operations

- Pipe operators used together with `dplyr` functions make a large difference as they semantically change your code in a way that **makes it more intuitive to both read and write**.
- The pipes allow users to chain operators which reflects the **sequential nature of data-processing tasks**.
- **Chaining increases readability** significantly when there are many commands
- `%>%` operator is automatically imported into `dplyr`

Find movies from USA produced after 2010. Group by genre and compute the group mean gross revenue in million dollars. Then pr
genre mean 'gross' revenue arranged in a descending order:

```r
# nesting
arrange(
  summarise(
    group_by(
      filter(movies,
             year > 2010, country == "US
      ),
      genre
    ),
    mean_gross = mean(gross)/10^6
  ),
  mean_gross
)
```

```
## # A tibble: 13 x 2
##         genre mean_gross
##        <fctr>      <dbl>
##  1  Thriller   0.016458
##  2     Drama  23.252067
##  3    Horror  27.714873
##  4    Sci-Fi  29.169033
##  5   Fantasy  30.657051
##  6     Crime  32.128370
##  7    Comedy  35.152773
##  8 Biography  40.552788
##  9   Mystery  49.457150
## 10   Romance  62.495645
## 11 Adventure  81.227901
## 12    Action  97.285930
## 13 Animation 151.960486
```

```r
# chaining
movies %>%
  filter(year > 2010, country == "USA"
  group_by(genre) %>%
  summarise(mean_gross = mean(gross)/1
  arrange(mean_gross)
```

```
## # A tibble: 13 x 2
##         genre mean_gross
##        <fctr>      <dbl>
##  1  Thriller   0.016458
##  2     Drama  23.252067
##  3    Horror  27.714873
##  4    Sci-Fi  29.169033
##  5   Fantasy  30.657051
##  6     Crime  32.128370
##  7    Comedy  35.152773
##  8 Biography  40.552788
##  9   Mystery  49.457150
## 10   Romance  62.495645
## 11 Adventure  81.227901
## 12    Action  97.285930
## 13 Animation 151.960486
```

Exercises 2

- Go to the “Lec3_Exercises.Rmd” file, which can be downloaded from the class website under the Lecture tab.
- Complete Exercise 2.

Joining & appending datasets

Merging two tables

```
x <- data.frame(
  item = c("cherries", "orange",
           "broccoli", "blueberries",
           "cabbage", "lemon", "spinach"
           "eggplants"),
  color = c("red", "orange", "green",
            "blue", "green", "yellow",
            "green", "purple"),
  stringsAsFactors = FALSE)

y <-  data.frame(
  item = c("carrot", "cherries",
           "broccoli", "blueberries",
           "cabbage", "lemon", "tomato")
  class = c("vegetable", "fruit",
            "vegetable", "fruit",
            "vegetable", "fruit", "fruit
  stringsAsFactors = FALSE)
```

item	color
cherries	red
orange	orange
broccoli	green
blueberries	blue
cabbage	green
lemon	yellow
spinach	green
eggplants	purple

item	class
carrot	vegetable
cherries	fruit
broccoli	vegetable
blueberries	fruit
cabbage	vegetable
lemon	fruit
tomato	fruit

inner_join(x, y)

- Include only rows in both x and y

```
inner_join(x, y) # or x %>% inner_join(y)
```

```
## Joining, by = "item"
```

x	
item	**color**
cherries	red
orange	orange
broccoli	green
blueberries	blue
cabbage	green
lemon	yellow
spinach	green
eggplants	purple

y	
item	**class**
carrot	vegetable
cherries	fruit
broccoli	vegetable
blueberries	fruit
cabbage	vegetable
lemon	fruit
tomato	fruit

inner_join(x, y)		
item	**color**	**class**
cherries	red	fruit
broccoli	green	vege
blueberries	blue	fruit
cabbage	green	vege
lemon	yellow	fruit

`left_join(x, y)`:

- Include all of x, and matching rows of y

```r
left_join(x, y) # or x %>% left_join(y)
```

```
## Joining, by = "item"
```

x	
item	**color**
cherries	red
orange	orange
broccoli	green
blueberries	blue
cabbage	green
lemon	yellow
spinach	green
eggplants	purple

y	
item	**class**
carrot	vegetable
cherries	fruit
broccoli	vegetable
blueberries	fruit
cabbage	vegetable
lemon	fruit
tomato	fruit

left_join(x, y)		
item	**color**	**class**
cherries	red	fruit
orange	orange	NA
broccoli	green	vege
blueberries	blue	fruit
cabbage	green	vege
lemon	yellow	fruit
spinach	green	NA
eggplants	purple	NA

`semi_join(x, y)`:

- Include rows of x that match y

```r
semi_join(x, y) # or x %>% semi_join(y)
```

```
## Joining, by = "item"
```

x	
item	**color**
cherries	red
orange	orange
broccoli	green
blueberries	blue
cabbage	green
lemon	yellow
spinach	green
eggplants	purple

y	
item	**class**
carrot	vegetable
cherries	fruit
broccoli	vegetable
blueberries	fruit
cabbage	vegetable
lemon	fruit
tomato	fruit

semi_join(x,	
item	**co**
cherries	re
broccoli	gr
blueberries	bl
cabbage	gr
lemon	ye

anti_join(x, y):

- Include rows of x that don’t match y

```r
anti_join(x, y) # or x %>% anti_join(y)
```

```
## Joining, by = "item"
```

x	
item	**color**
cherries	red
orange	orange
broccoli	green
blueberries	blue
cabbage	green
lemon	yellow
spinach	green
eggplants	purple

y	
item	**class**
carrot	vegetable
cherries	fruit
broccoli	vegetable
blueberries	fruit
cabbage	vegetable
lemon	fruit
tomato	fruit

anti_join(x,	
item	**co**
orange	or
spinach	gr
eggplants	pu

Extra functions

Renaming

```r
movies.sub <- movies %>% select(name, director, year, score, gross)
print(movies.sub, n = 3)
```

```
## # A tibble: 6,820 x 5
##                       name    director  year score     gross
##                     <fctr>      <fctr> <int> <dbl>     <dbl>
## 1               Stand by Me  Rob Reiner  1986   8.1  52287414
## 2 Ferris Bueller's Day Off John Hughes  1986   7.8  70136369
## 3                   Top Gun  Tony Scott  1986   6.9 179800601
## # ... with 6,817 more rows
```

```r
# Renaming variable
movies.sub %>% rename(gross_revenue = gross)
```

```
## # A tibble: 6,820 x 5
##                         name          director  year score gross_revenue
##                       <fctr>            <fctr> <int> <dbl>         <dbl>
##  1               Stand by Me        Rob Reiner  1986   8.1      52287414
##  2 Ferris Bueller's Day Off       John Hughes  1986   7.8      70136369
##  3                   Top Gun        Tony Scott  1986   6.9     179800601
##  4                    Aliens     James Cameron  1986   8.4      85160248
##  5  Flight of the Navigator    Randal Kleiser  1986   6.9      18564613
##  6                   Platoon      Oliver Stone  1986   8.1     138530565
##  7                 Labyrinth       Jim Henson  1986   7.4      12729917
##  8               Blue Velvet      David Lynch  1986   7.8       8551228
##  9            Pretty in Pink    Howard Deutch  1986   6.8      40471663
## 10                   The Fly David Cronenberg  1986   7.5      40456565
## # ... with 6,810 more rows
```

Distinct values

```
# Unique values
movies %>% distinct(rating)
```

```
## # A tibble: 13 x 1
##            rating
##            <fctr>
##  1              R
##  2          PG-13
##  3             PG
##  4        UNRATED
##  5 Not specified
##  6              G
##  7          NC-17
##  8      NOT RATED
##  9          TV-PG
## 10          TV-MA
## 11              B
## 12            B15
## 13          TV-14
```

Note that can take on multiple variables, and would return distinct variable combinations.

Group counts

Use a `tally()` function to generate a group frequency table:

```
movies %>% group_by(genre) %>% tally()
```

```
## # A tibble: 17 x 2
##          genre     n
##         <fctr> <int>
##  1      Action  1331
##  2   Adventure   392
##  3   Animation   277
##  4   Biography   359
##  5      Comedy  2080
##  6       Crime   522
##  7       Drama  1444
##  8      Family    14
##  9     Fantasy    32
## 10      Horror   277
## 11     Musical     4
## 12     Mystery    38
## 13     Romance    15
## 14      Sci-Fi    13
## 15    Thriller    18
## 16         War     2
## 17     Western     2
```

Window Functions

- Aggregation functions such as `mean()`, `n()` return 1 value per group.
- **Window functions return multiple values per group.** Examples include: ranking and ordering functions (like `min_rank`, `top_n()`), offset functions (`lead` and `lag`), and cumulative aggregates (like `cummean`).

```
# rewrite more simply with the `top_n` function
movies %>%
  select(name, genre, year, score) %>%
  group_by(genre) %>%
  top_n(2, wt = score) %>%       # if 'wt' argument in top_n() is not specified
  arrange(genre, year, score)    # the last variable is taken for ordering
```

```
## # A tibble: 35 x 4
## # Groups:   genre [17]
##                                                  name     genre  year score
##                                                <fctr>    <fctr> <int> <dbl>
##  1                                    The Dark Knight    Action  2008   9.0
##  2                                          Inception    Action  2010   8.8
##  3 The Lord of the Rings: The Fellowship of the Ring Adventure  2001   8.8
##  4     The Lord of the Rings: The Return of the King Adventure  2003   8.9
##  5                                      The Lion King Animation  1994   8.5
##  6                                     Spirited Away Animation  2001   8.6
##  7                                          Your name Animation  2016   8.5
##  8                                   Schindler's List Biography  1993   8.9
##  9                                  The Intouchables Biography  2011   8.6
## 10                                       Forrest Gump    Comedy  1994   8.8
## # ... with 25 more rows
```

Sampling functions

```
# randomly sample a fixed number of rows, without replacement
movies %>% sample_n(15)
```

```
## # A tibble: 15 x 19
##       budget                        company country              director     genr
##        <dbl>                         <fctr>  <fctr>                <fctr>    <fctr
##  1 4.50e+06       Keystone Family Pictures  Canada         Robert Vince    Comec
##  2 0.00e+00 Raajkamal Films International   India          Kamal Haasan     Crin
##  3 1.75e+07               United Artists      UK         Terry George Biograph
##  4 1.60e+07              New Line Cinema     USA   Jonathan Liebesman     Horrc
##  5 0.00e+00                 Warner Bros.     USA            John Gray Adventur
##  6 2.00e+08                   DreamWorks     USA          Michael Bay    Actic
##  7 3.20e+06                  ContentFilm     USA         Wayne Kramer     Crin
##  8 0.00e+00               Orion Pictures     USA             Jim Kouf    Actic
##  9 1.05e+08                 Warner Bros.     USA       Roland Emmerich    Actic
## 10 1.70e+06            Magnolia Pictures     USA    Steven Soderbergh     Dran
## 11 1.50e+07                  Fox Atomic     USA         Martin Weisz    Actic
## 12 1.60e+07             DC Entertainment     USA       Kenneth Johnson    Actic
## 13 0.00e+00      Colorado Film Production   Italy Gabriele Salvatores     Crin
## 14 0.00e+00            Caravan Pictures     USA       Martha Coolidge    Comec
## 15 2.00e+07            Magnolia Pictures      UK       Michael Radford     Crin
## # ... with 14 more variables: gross <dbl>, name <fctr>, rating <fctr>,
## #   released <fctr>, runtime <int>, score <dbl>, star <fctr>, votes <int>,
## #   writer <fctr>, year <int>, profit <dbl>, gross_in_mil <dbl>,
## #   budget_in_mil <dbl>, profit_in_mil <dbl>
```

```r
# randomly sample a fraction of rows, with replacement
movies %>% sample_frac(0.01, replace=TRUE)
```

```
## # A tibble: 68 x 19
##     budget                       company country           director     genre
##      <dbl>                        <fctr>  <fctr>             <fctr>    <fctr>
##  1 2.5e+07           Exodus Film Group     USA      Tony Leondis Animation
##  2 0.0e+00      Chroma III Productions     USA    Mark Griffiths    Comedy
##  3 0.0e+00                 Marble Hall     USA James Glickenhaus    Action
##  4 1.2e+05           Chango Productions     USA     Bryan Johnson     Crime
##  5 1.0e+08       Beacon Communications     USA       Peter Hyams    Action
##  6 7.4e+07 Illumination Entertainment     USA        Kyle Balda Animation
##  7 1.1e+08           Columbia Pictures     USA     Morten Tyldum Adventure
##  8 0.0e+00           Fox 2000 Pictures     USA       Adam Collis    Comedy
##  9 1.8e+07    Morgan Creek Productions     USA       John Warren    Comedy
## 10 4.9e+07            Carolco Pictures  France    Paul Verhoeven     Drama
## # ... with 58 more rows, and 14 more variables: gross <dbl>, name <fctr>,
## #   rating <fctr>, released <fctr>, runtime <int>, score <dbl>, star <fctr>,
## #   votes <int>, writer <fctr>, year <int>, profit <dbl>, gross_in_mil <dbl>,
## #   budget_in_mil <dbl>, profit_in_mil <dbl>
```