R dplyr

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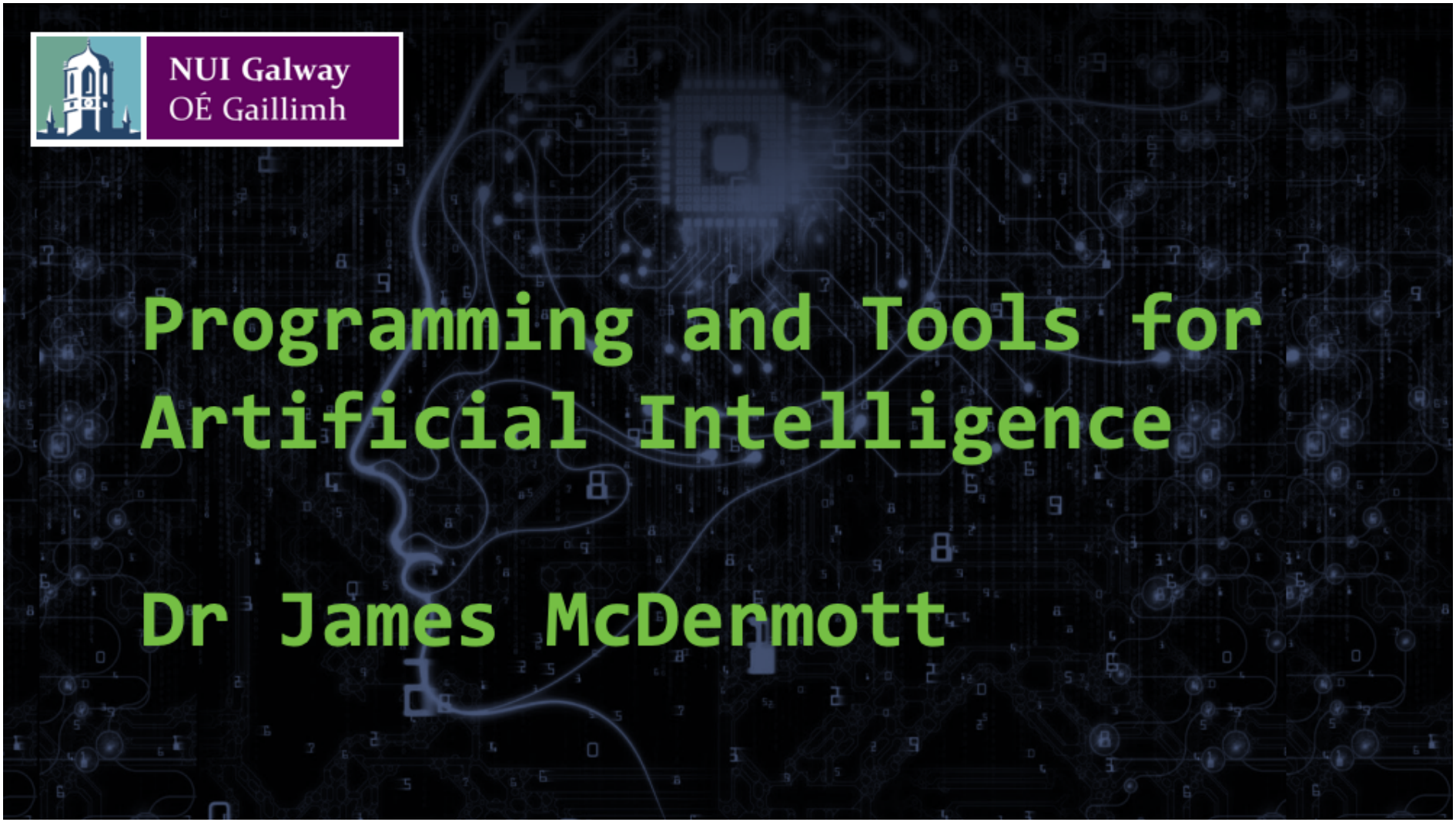
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dplyr

dplyr

dplyr is a package for relational operations on data. That is, it does stuff similar to SQL, which many students will be familiar with (also comparable to Excel and Pandas). In particular:

- `filter` (choose rows, like SQL `where`)
- `arrange` (sort rows)
- `select` (choose columns, like SQL `select`)
- `mutate` (add columns)
- `summarise` (condense multiple values)
- `sample_n`, `sample_frac` (for taking a quick look at a sub-sample, see also `head`)
- `inner_join`, `left_join`, `right_join`, `full_join` (join two tables, like SQL `join`)

`dplyr` and the pipe operator

All the `dplyr` verbs (`select`, etc.) have three things in common (from https://cran.r-project.org/web/packages/dplyr/vignettes/dplyr.html):

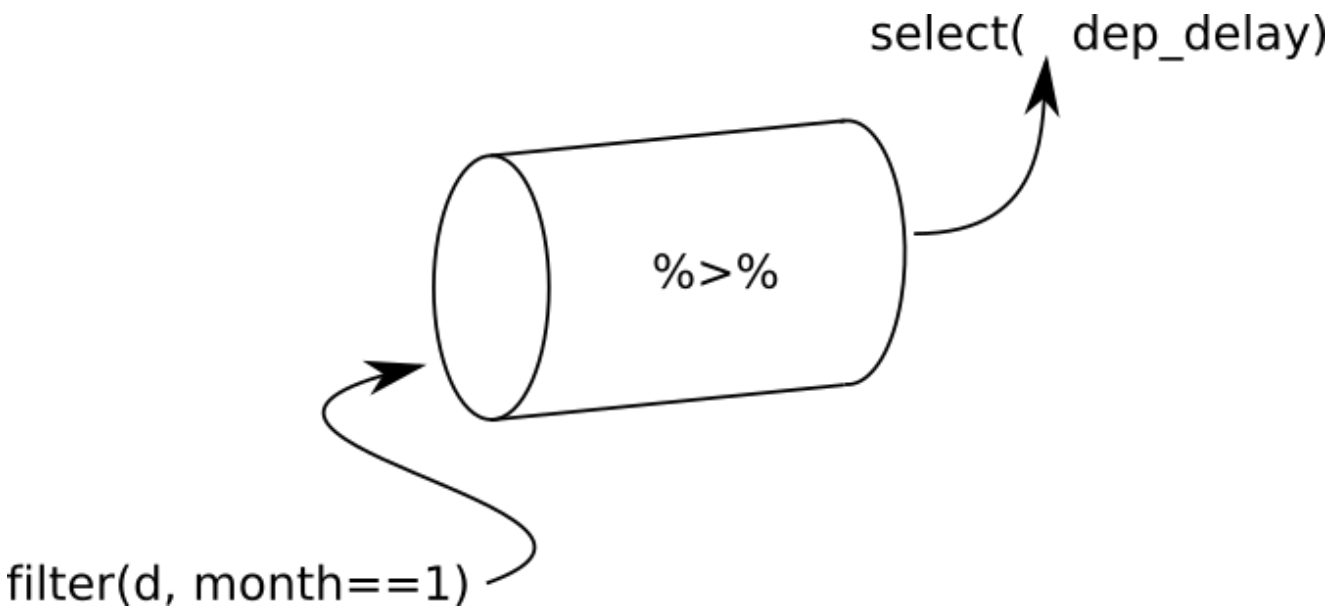
1. The first argument is a data frame [actually, a tibble].
2. The subsequent arguments describe what to do with the data frame. You can refer to columns in the data frame directly without using $.
3. The result is a new data frame

Therefore, it is natural to *chain* operations. That is where the *pipe* operator comes in.

The pipe %>%

- In Unix, the *pipe* symbol | is used to pass data from one command to another, e.g. `ls | grep -v "#"`
- In `magrittr`, the pipe %>% passes the output of its left-hand side to become the first argument of its right-hand side.

The pipe %>%




```
filter(d, month==1) %>% select(dep_delay)
```

The pipe %>%

In R, special operators are often named with double % symbols. The *pipe* operator %>% is an example.

`t %>% f()` means precisely `f(t)`, i.e. the output of the LHS becomes the first argument of the RHS.

It is useful to avoid complicated nested expressions:

`t %>% f("abc") %>% g("x", "y")` is easier to read than

```
g(f(t, "abc"), "x", "y")
```

(isn't it?)

Example: NYC Flights

```
# uncomment if not already installed
# install.packages("nycflights13")
library(nycflights13)
library(tidyverse)
```

```
## -- Attaching packages ---------------------------------

## v ggplot2 3.2.1       v purrr   0.3.2
## v tibble  2.1.1       v dplyr   0.8.0.1
## v tidyr   0.8.3       v stringr 1.4.0
## v readr   1.3.1       v forcats 0.4.0

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

Take a quick look at data

```
flights
```

```
## # A tibble: 336,776 x 19
##      year month   day dep_time sched_dep_time dep_delay arr_
##     <int> <int> <int>    <int>          <int>     <dbl>    <
##  1  2013     1     1      517            515         2
##  2  2013     1     1      533            529         4
##  3  2013     1     1      542            540         2
##  4  2013     1     1      544            545        -1
##  5  2013     1     1      554            600        -6
##  6  2013     1     1      554            558        -4
##  7  2013     1     1      555            600        -5
##  8  2013     1     1      557            600        -3
##  9  2013     1     1      557            600        -3
## 10  2013     1     1      558            600        -2
## # ... with 336,766 more rows, and 12 more variables: sched_
## #   arr_delay <dbl>, carrier <chr>, flight <int>, tailnum <
```

filter

Let's see just flights on Jan 1:

```
flights %>% filter(month == 1, day == 1)
```

```
## # A tibble: 842 x 19
##     year month   day dep_time sched_dep_time dep_delay arr_
##    <int> <int> <int>    <int>          <int>     <dbl>    <
##  1  2013     1     1      517            515         2
##  2  2013     1     1      533            529         4
##  3  2013     1     1      542            540         2
##  4  2013     1     1      544            545        -1
##  5  2013     1     1      554            600        -6
##  6  2013     1     1      554            558        -4
##  7  2013     1     1      555            600        -5
##  8  2013     1     1      557            600        -3
##  9  2013     1     1      557            600        -3
## 10  2013     1     1      558            600        -2
## # ... with 832 more rows, and 12 more variables: sched_arr
```

filter

Remember, this is internally translated to:

```
filter(flights, month == 1, day == 1)
```

```
## # A tibble: 842 x 19
##      year month   day dep_time sched_dep_time dep_delay arr_
##     <int> <int> <int>    <int>          <int>     <dbl>    <
##  1  2013     1     1      517            515         2
##  2  2013     1     1      533            529         4
##  3  2013     1     1      542            540         2
##  4  2013     1     1      544            545        -1
##  5  2013     1     1      554            600        -6
##  6  2013     1     1      554            558        -4
##  7  2013     1     1      555            600        -5
##  8  2013     1     1      557            600        -3
##  9  2013     1     1      557            600        -3
## 10  2013     1     1      558            600        -2
## #     with 832 more rows, and 12 more variables: sched_arr
```

filter

Which flight departure was delayed the longest? We can use `filter` again:

```
flights %>% filter(dep_delay == max(dep_delay, na.rm=TRUE))
```

```
## # A tibble: 1 x 19
##    year month   day dep_time sched_dep_time dep_delay arr_t
##   <int> <int> <int>    <int>          <int>     <dbl>    <i
## 1  2013     1     9      641            900      1301     1
## # ... with 12 more variables: sched_arr_time <int>, arr_del
## #   carrier <chr>, flight <int>, tailnum <chr>, origin <chr
## #   air_time <dbl>, distance <dbl>, hour <dbl>, minute <dbl
## #   time_hour <dttm>
```

Notice that `na.rm=TRUE` *inside* `max()` is essential: consider `max(flights$dep_delay)` to see why.

Syntax notes

1. `na.rm` argument
2. We can refer to columns with no special syntax (not even quotes)
3. Remember == for equality (I put spaces), but = for passing keyword arguments (I don't put spaces, as in Python).

filter examples

Boolean AND: use comma as we already saw

```
flights %>% filter(month == 1, day == 1)
```

```
## # A tibble: 842 x 19
##      year month   day dep_time sched_dep_time dep_delay arr_
##     <int> <int> <int>    <int>          <int>     <dbl>    <
##  1  2013     1     1      517            515         2
##  2  2013     1     1      533            529         4
##  3  2013     1     1      542            540         2
##  4  2013     1     1      544            545        -1
##  5  2013     1     1      554            600        -6
##  6  2013     1     1      554            558        -4
##  7  2013     1     1      555            600        -5
##  8  2013     1     1      557            600        -3
##  9  2013     1     1      557            600        -3
## 10  2013     1     1      558            600        -2
## #     with 832 more rows, and 12 more variables: sched_arr
```

filter examples

Boolean OR: use |

```
flights %>% filter(month == 1 | month == 12)
```

```
## # A tibble: 55,139 x 19
##     year month   day dep_time sched_dep_time dep_delay arr_
##    <int> <int> <int>    <int>          <int>     <dbl>    <
##  1  2013     1     1      517            515         2
##  2  2013     1     1      533            529         4
##  3  2013     1     1      542            540         2
##  4  2013     1     1      544            545        -1
##  5  2013     1     1      554            600        -6
##  6  2013     1     1      554            558        -4
##  7  2013     1     1      555            600        -5
##  8  2013     1     1      557            600        -3
##  9  2013     1     1      557            600        -3
## 10  2013     1     1      558            600        -2
## #     with 55,129 more rows, and 12 more variables: sched_a
```

filter examples

%in% operator does the same as above:

```
flights %>% filter(month %in% c(1, 12))
```

```
## # A tibble: 55,139 x 19
##     year month   day dep_time sched_dep_time dep_delay arr_
##    <int> <int> <int>    <int>          <int>     <dbl>    <
##  1  2013     1     1      517            515         2
##  2  2013     1     1      533            529         4
##  3  2013     1     1      542            540         2
##  4  2013     1     1      544            545        -1
##  5  2013     1     1      554            600        -6
##  6  2013     1     1      554            558        -4
##  7  2013     1     1      555            600        -5
##  8  2013     1     1      557            600        -3
##  9  2013     1     1      557            600        -3
## 10  2013     1     1      558            600        -2
## #     with 55,129 more rows, and 12 more variables: sched_a
```

arrange

dplyr becomes like a programmatic interface to Excel,
e.g. sort-by-column:

```
arrange(flights, dep_delay) # sort-by-column
```

```
## # A tibble: 336,776 x 19
##      year month   day dep_time sched_dep_time dep_delay arr_
##     <int> <int> <int>    <int>          <int>     <dbl>  <
##  1  2013    12     7     2040           2123       -43
##  2  2013     2     3     2022           2055       -33
##  3  2013    11    10     1408           1440       -32
##  4  2013     1    11     1900           1930       -30
##  5  2013     1    29     1703           1730       -27
##  6  2013     8     9      729            755       -26
##  7  2013    10    23     1907           1932       -25
##  8  2013     3    30     2030           2055       -25
##  9  2013     3     2     1431           1455       -24
## 10  2013     5     5      934            958       -24
```

arrange

Descending order:

```
arrange(flights, desc(dep_delay))
```

```
## # A tibble: 336,776 x 19
##     year month   day dep_time sched_dep_time dep_delay arr_
##    <int> <int> <int>    <int>          <int>     <dbl>    <
##  1  2013     1     9      641            900      1301
##  2  2013     6    15     1432           1935      1137
##  3  2013     1    10     1121           1635      1126
##  4  2013     9    20     1139           1845      1014
##  5  2013     7    22      845           1600      1005
##  6  2013     4    10     1100           1900       960
##  7  2013     3    17     2321            810       911
##  8  2013     6    27      959           1900       899
##  9  2013     7    22     2257            759       898
## 10  2013    12     5      756           1700       896
## # ... with 336,766 more rows, and 12 more variables: sched
```

`select` chooses columns

```
select(flights, day, month, year)
```

```
## # A tibble: 336,776 x 3
##      day month  year
##    <int> <int> <int>
##  1     1     1  2013
##  2     1     1  2013
##  3     1     1  2013
##  4     1     1  2013
##  5     1     1  2013
##  6     1     1  2013
##  7     1     1  2013
##  8     1     1  2013
##  9     1     1  2013
## 10     1     1  2013
## # ... with 336,766 more rows
```

`select` chooses columns

Select all columns from year to day (behind the scenes, the columns are *numbers*):

```
select(flights, year:day)
```

```
## # A tibble: 336,776 x 3
##     year month   day
##    <int> <int> <int>
##  1  2013     1     1
##  2  2013     1     1
##  3  2013     1     1
##  4  2013     1     1
##  5  2013     1     1
##  6  2013     1     1
##  7  2013     1     1
##  8  2013     1     1
##  9  2013     1     1
## 10  2013     1     1
```

Using `select` to deselect

```
select(flights, -(month:minute))
```

```
## # A tibble: 336,776 x 2
##      year time_hour
##     <int> <dttm>
##  1  2013 2013-01-01 05:00:00
##  2  2013 2013-01-01 05:00:00
##  3  2013 2013-01-01 05:00:00
##  4  2013 2013-01-01 05:00:00
##  5  2013 2013-01-01 06:00:00
##  6  2013 2013-01-01 05:00:00
##  7  2013 2013-01-01 06:00:00
##  8  2013 2013-01-01 06:00:00
##  9  2013 2013-01-01 06:00:00
## 10  2013 2013-01-01 06:00:00
## # ... with 336,766 more rows
```

More ways to select columns

```
select(flights, starts_with("d"))
```

```
## # A tibble: 336,776 x 5
##      day dep_time dep_delay dest  distance
##    <int>    <int>     <dbl> <chr>    <dbl>
##  1     1      517         2 IAH       1400
##  2     1      533         4 IAH       1416
##  3     1      542         2 MIA       1089
##  4     1      544        -1 BQN       1576
##  5     1      554        -6 ATL        762
##  6     1      554        -4 ORD        719
##  7     1      555        -5 FLL       1065
##  8     1      557        -3 IAD        229
##  9     1      557        -3 MCO        944
## 10     1      558        -2 ORD        733
## # ... with 336,766 more rows
```

mutate

```
select(flights, year:day, ends_with("delay"),
               distance, air_time) %>%
  mutate(gain=dep_delay - arr_delay) %>%
  mutate(speed=distance / air_time * 60)
```

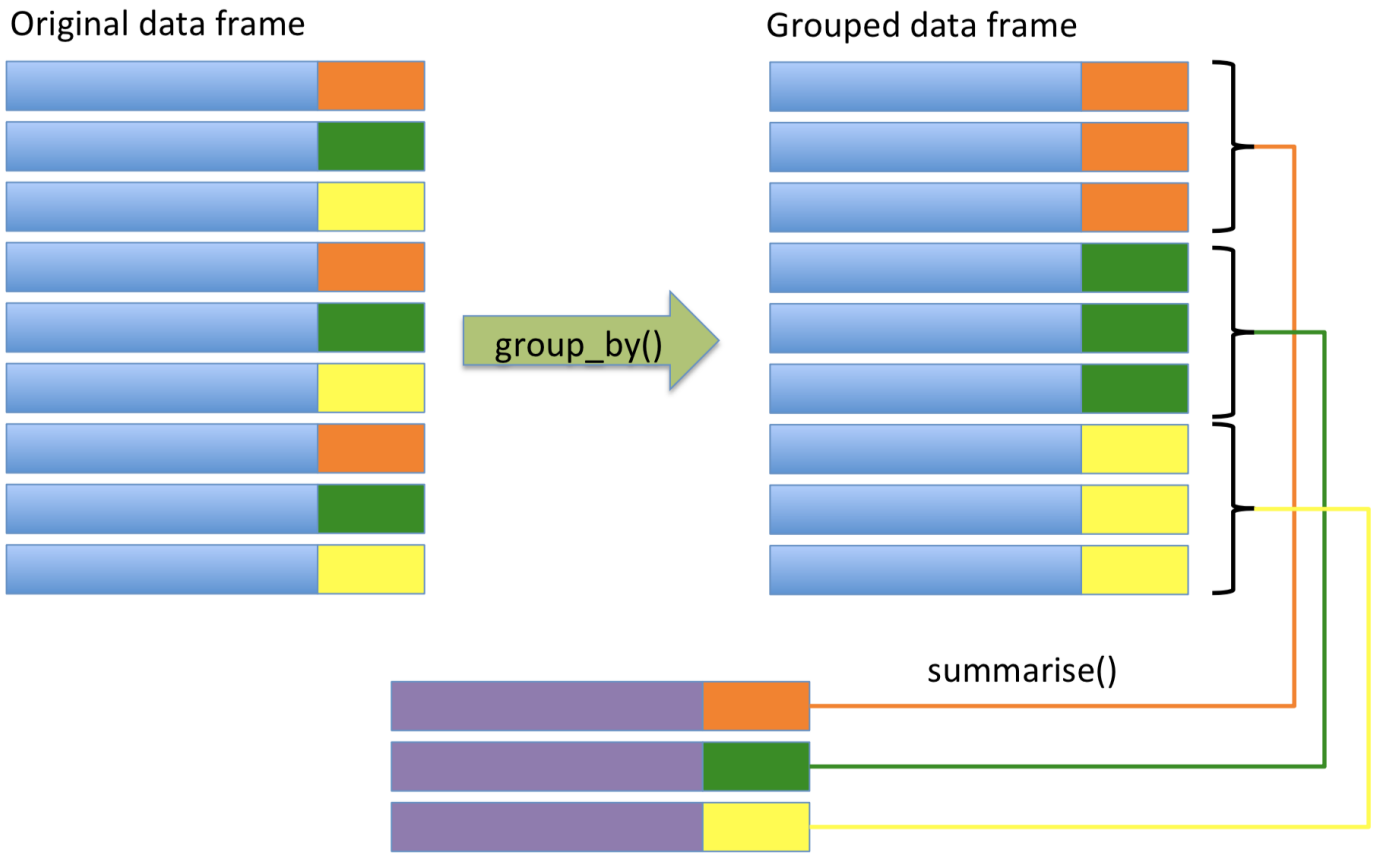
```
## # A tibble: 336,776 x 9
##      year month   day dep_delay arr_delay distance air_time
##     <int> <int> <int>     <dbl>     <dbl>    <dbl>    <dbl>
##  1  2013     1     1         2        11     1400      227
##  2  2013     1     1         4        20     1416      227
##  3  2013     1     1         2        33     1089      160
##  4  2013     1     1        -1       -18     1576      183
##  5  2013     1     1        -6       -25      762      116
##  6  2013     1     1        -4        12      719      150
##  7  2013     1     1        -5        19     1065      158
##  8  2013     1     1        -3       -14      229       53
##  9  2013     1     1        -3        -8      944      140
```

mutate

Remember none of these operations change the tibble itself, just return a new one. So we may decide to save the result in a new variable.

```
sml <- select(flights, year:day, ends_with("delay"),
              distance, air_time) %>%
  mutate(gain=dep_delay - arr_delay) %>%
  mutate(speed=distance / air_time * 60)
```

group_by



(R4DS)

group_by and summarise go well together

```
group_by(flights, carrier) %>%
  summarise(dep_delay=mean(dep_delay, na.rm=TRUE))
```

```
## # A tibble: 16 x 2
##    carrier dep_delay
##    <chr>       <dbl>
##  1 9E          16.7
##  2 AA           8.59
##  3 AS           5.80
##  4 B6          13.0
##  5 DL           9.26
##  6 EV          20.0
##  7 F9          20.2
##  8 FL          18.7
##  9 HA           4.90
## 10 MQ          10.6
## 11 OO          12.6
```

A bigger example: `who`

`who` is a dataset from the World Health Organisation which needs a lot of cleaning:

```
who %>%
  # gather many columns to 1
  gather(key, value, new_sp_m014:newrel_f65,
         na.rm = TRUE) %>%
  # fix inconsistent spelling
  mutate(key = stringr::str_replace(key, "newrel", "new_rel")) %>%
  # split eg "new_sp_m014" -> "new", "sp", "m014"
  separate(key, c("new", "var", "sexage")) %>%
  # remove redundant/unneeded columns
  select(-new, -iso2, -iso3) %>%
  # split eg "m014" -> "m", "014"
  separate(sexage, c("sex", "age"), sep = 1)
```

```
## # A tibble: 76,046 x 6
```

A bigger example: `who`

See https://r4ds.had.co.nz/tidy-data.html for detailed explanation.
Exercise: look at the output of each step of this transformation, starting at `who` itself, to understand the need for the next.

Some more handy functions (some from `dplyr`)

- Offset a vector of values: `lead` and `lag`
- Cumulative calculations: `cumsum`, `cummax`, etc.
- Where does each value come in a sort? `min_rank`
- Counts: `n`, `n_distinct`

Functional programming in R

- `dplyr` and the pipe are already examples of functional programming! E.g. all these operations don't change their input, just return a new version.
- Our friend `map` also exists in R. It makes a list.
- `map_dbl` and friends may be more useful since they return `vectors`. Compare `map` and `map_dbl` in the following.

```
d = 1:5
# R uses the opposite argument ordering, compared to Python
map(d, sqrt)
```

```
d = 1:5
map_dbl(d, sqrt)
```

Functional programming in R

```
d %>% map_dbl(sqrt) # equivalent, using pipe
```

Functional programming in R

`map` and friends come from the `purrr` package, well-documented here: https://r4ds.had.co.nz/iteration.html#the-map-functions

- The Joy of Functional Programming ACM Tech Talk webcast with Hadley Wickham can be viewed here: https://learning.acm.org/techtalks/functionalprogramming (Prerequisites: basic R, tibbles, distinction between lists, vectors, dataframes)

Summary

- tidy data: columns are variables, rows are observations
- tibbles
- pipe %>%
- verbs including `select`, `filter`, `mutate`, `arrange`, `rename`, `gather`, `spread`

Let's look at a cheatsheet for `dplyr`:
https://rstudio.com/wp-content/uploads/2015/02/data-wrangling-cheatsheet.pdf

Exercises

- Exercise 1: Our sort times data is available in tidy format as `sort_times_tidy.csv`. Use `group_by` and `summarise` to get the mean and the standard deviation for each `n`, and then for each `run_number`.
- A dataset of characters in *Star Wars* is available as `dplyr::starwars`. Exercise 2: Find all the human females. Exercise 3: Find the characters who are human *or* Wookiee. Exercise 4: Find the shortest character. Hint: recall we might need `na.rm`. Exercise 5: Add a new column called `BMI` giving the body mass index, where the formula is BMI $= m/h^2$ for mass m in kg and height h in metres. https://en.wikipedia.org/wiki/Body_mass_index. Exercise 6: Which character has the highest BMI?

Solutions

Exercise 1

```
d <- read_csv("data/sort_times_tidy.csv")
```

```
## Parsed with column specification:
## cols(
##   n = col_double(),
##   run_number = col_double(),
##   run_time = col_double()
## )
```

```
d %>% group_by(n) %>% summarise(mean_run_time=mean(run_time),
```

```
## # A tibble: 10 x 3
##           n mean_run_time sd_run_time
##       <dbl>         <dbl>       <dbl>
##  1   1000000         0.105     0.00654
##  2   2000000         0.209     0.0269
##  3   3000000         0.334     0.0387
```

Exercise 1

Notice that the mean and stddev for $n = 7$ million are anomalously high. One way this could occur is if our computer had a spike in CPU usage during the experiment, e.g. due to a browser loading a video.

Exercise 1

```
d %>% group_by(run_number) %>%
  summarise(mean_run_time=mean(run_time),
            sd_run_time=sd(run_time))
```

```
## # A tibble: 5 x 3
##   run_number mean_run_time sd_run_time
##        <dbl>         <dbl>       <dbl>
## 1          0         0.754       0.512
## 2          1         0.644       0.368
## 3          2         0.604       0.353
## 4          3         0.648       0.369
## 5          4         0.678       0.416
```

No major anomalies this time.

Exercise 2

```
sw <- dplyr::starwars
sw %>% filter(species == "Human", gender == "female") # human
```

```
## # A tibble: 9 x 13
##   name  height  mass hair_color skin_color eye_color birth_
##   <chr>  <int> <dbl> <chr>      <chr>       <chr>           <
## 1 Leia~    150    49 brown      light       brown
## 2 Beru~    165    75 brown      light       blue
## 3 Mon ~    150    NA auburn     fair        blue
## 4 Shmi~    163    NA black      fair        brown
## 5 Cordé    157    NA brown      light       brown
## 6 Dormé    165    NA brown      light       brown
## 7 Joca~    167    NA white      fair        blue
## 8 Rey       NA    NA brown      light       hazel
## 9 Padm~    165    45 brown      light       brown
## # ... with 5 more variables: homeworld <chr>, species <chr>
## #   vehicles <list>, starships <list>
```

Exercise 3

```
sw %>% filter(species == "Human" | species == "Wookiee") # hu
```

```
## # A tibble: 37 x 13
##    name  height  mass hair_color skin_color eye_color birth
##    <chr>  <int> <dbl> <chr>      <chr>      <chr>
##  1 Luke~    172    77 blond      fair       blue
##  2 Dart~    202   136 none       white      yellow
##  3 Leia~    150    49 brown      light      brown
##  4 Owen~    178   120 brown, gr~ light      blue
##  5 Beru~    165    75 brown      light      blue
##  6 Bigg~    183    84 black      light      brown
##  7 Obi-~    182    77 auburn, w~ fair       blue-gray
##  8 Anak~    188    84 blond      fair       blue
##  9 Wilh~    180    NA auburn, g~ fair       blue
## 10 Chew~    228   112 brown      unknown    blue
## # ... with 27 more rows, and 5 more variables: homeworld <c
## #   species <chr>  films <list>  vehicles <list>  starships
```

Exercise 4

```
sw %>% filter(height == max(height, na.rm=TRUE))
```

```
## # A tibble: 1 x 13
##   name  height  mass hair_color skin_color eye_color birth_
##   <chr>  <int> <dbl> <chr>      <chr>       <chr>           <
## 1 Yara~    264    NA none       white       yellow
## # ... with 5 more variables: homeworld <chr>, species <chr>
## #   vehicles <list>, starships <list>
```

Exercise 5

```
# NB convert height from cm to metres before squaring
BMI <- function(h, m) {m / (h / 100)^2}
sw <- sw %>% mutate(bmi=BMI(height, mass))
```

Exercise 6

```
sw %>% filter(bmi == max(bmi, na.rm=TRUE))
```

```
## # A tibble: 1 x 14
##   name  height  mass hair_color skin_color eye_color birth_
##   <chr>  <int> <dbl> <chr>      <chr>       <chr>           <
## 1 Jabb~    175  1358 <NA>       green-tan~ orange
## # ... with 6 more variables: homeworld <chr>, species <chr>
## #   vehicles <list>, starships <list>, bmi <dbl>
```