Data transformation

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Introduction

Visualisation is an important tool for insight generation, but it is rare that you get the data in exactly the right form you need. We may need to create, summarises, rename, reorder vairables.

Prerequisites

```
# install.packages("nycflights13")
library(nycflights13)
library(tidyverse)
```

```
## -- Attaching packages -------------- tidyverse 1.3.0 --
```

```
## v ggplot2 3.2.1     v purrr   0.3.3
## v tibble  2.1.3     v dplyr   0.8.3
## v tidyr   1.0.0     v stringr 1.4.0
## v readr   1.3.1     v forcats 0.4.0
```

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

nycflights13

```
flights
```

```
## # A tibble: 336,776 x 19
##     year month   day dep_time sched_dep_time dep_delay arr_time sched_arr_time
##    <int> <int> <int>    <int>          <int>     <dbl>    <int>          <int>
##  1  2013     1     1      517            515         2      830            819
##  2  2013     1     1      533            529         4      850            830
##  3  2013     1     1      542            540         2      923            850
##  4  2013     1     1      544            545        -1     1004           1022
##  5  2013     1     1      554            600        -6      812            837
##  6  2013     1     1      554            558        -4      740            728
##  7  2013     1     1      555            600        -5      913            854
##  8  2013     1     1      557            600        -3      709            723
##  9  2013     1     1      557            600        -3      838            846
## 10  2013     1     1      558            600        -2      753            745
## # ... with 336,766 more rows, and 11 more variables: arr_delay <dbl>,
## #   carrier <chr>, flight <int>, tailnum <chr>, origin <chr>, dest <chr>,
```

```
## #   air_time <dbl>, distance <dbl>, hour <dbl>, minute <dbl>, time_hour <dttm>
```

`int`: intergers

`dbl`: doubles, or real numbers

`chr`: character vectors, or strings

`dttm`: date-times (a date+ a time)

`lgl`: logical, vectors that contain only `TRUE` or `FALSE`

`fctr`: factors, which R uses to represent categorical variables with fixed possible values

`date`: dates

dplyr basics

`filter()`: pick observations by their values

`arrange()`: reorder the rows

`select()`: pick variables by their names

`mutate()`: create new variables with functions of existing variable

`summarise()`: collapse many values down to single summary

All verbs work similarly:

1. The first argument is a data frame.
2. The subsequent arguments describe what to do with the data frame, using the variable names (without quotes)
3. The result is a new data frame

Filter rows with filter()

`filter()` allows you to subset observations based on their values. The first argument is the name of the data frame. The second and subsequent arguments are the expressions that filter the data frame.

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

```
## # A tibble: 842 x 19
##     year month   day dep_time sched_dep_time dep_delay arr_time sched_arr_time
##    <int> <int> <int>    <int>          <int>     <dbl>    <int>          <int>
##  1  2013     1     1      517            515         2      830            819
##  2  2013     1     1      533            529         4      850            830
##  3  2013     1     1      542            540         2      923            850
##  4  2013     1     1      544            545        -1     1004           1022
##  5  2013     1     1      554            600        -6      812            837
##  6  2013     1     1      554            558        -4      740            728
##  7  2013     1     1      555            600        -5      913            854
##  8  2013     1     1      557            600        -3      709            723
##  9  2013     1     1      557            600        -3      838            846
## 10  2013     1     1      558            600        -2      753            745
## # ... with 832 more rows, and 11 more variables: arr_delay <dbl>,
## #   carrier <chr>, flight <int>, tailnum <chr>, origin <chr>, dest <chr>,
## #   air_time <dbl>, distance <dbl>, hour <dbl>, minute <dbl>, time_hour <dttm>
```

```
jan1<-filter(flights,month==1,day==1)

(dec25<-filter(flights,month==12,day==25))
```

```
## # A tibble: 719 x 19
##     year month   day dep_time sched_dep_time dep_delay arr_time sched_arr_time
##    <int> <int> <int>    <int>          <int>     <dbl>    <int>          <int>
##  1  2013    12    25      456            500        -4      649            651
##  2  2013    12    25      524            515         9      805            814
##  3  2013    12    25      542            540         2      832            850
##  4  2013    12    25      546            550        -4     1022           1027
##  5  2013    12    25      556            600        -4      730            745
##  6  2013    12    25      557            600        -3      743            752
##  7  2013    12    25      557            600        -3      818            831
##  8  2013    12    25      559            600        -1      855            856
##  9  2013    12    25      559            600        -1      849            855
## 10  2013    12    25      600            600         0      850            846
## # ... with 709 more rows, and 11 more variables: arr_delay <dbl>,
## #   carrier <chr>, flight <int>, tailnum <chr>, origin <chr>, dest <chr>,
## #   air_time <dbl>, distance <dbl>, hour <dbl>, minute <dbl>, time_hour <dttm>
```

```
# brackets that we can print the result
```

Comparisons

Comparison operator: `>`, `>=`, `<`,`<=`, `!=` and `==`

```
# filter(flights,month=1) This is false since we need to use ==
sqrt(2)^2==2
```

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

```
1/49*49==1
```

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

```
# This result is surprising, when we compare two numbers, one is floating, one is integer

#Instead of relying on `==`, we use near()

near(sqrt(2)^2,2)
```

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

```
near(1/49*49,1)
```

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

Logical operators

`&`: and

`|`: or

`!`: not

```r
filter(flights,month==11|month==12)
```

```
## # A tibble: 55,403 x 19
##     year month   day dep_time sched_dep_time dep_delay arr_time sched_arr_time
##    <int> <int> <int>    <int>          <int>     <dbl>    <int>          <int>
##  1  2013    11     1        5           2359         6      352            345
##  2  2013    11     1       35           2250       105      123           2356
##  3  2013    11     1      455            500        -5      641            651
##  4  2013    11     1      539            545        -6      856            827
##  5  2013    11     1      542            545        -3      831            855
##  6  2013    11     1      549            600       -11      912            923
##  7  2013    11     1      550            600       -10      705            659
##  8  2013    11     1      554            600        -6      659            701
##  9  2013    11     1      554            600        -6      826            827
## 10  2013    11     1      554            600        -6      749            751
## # ... with 55,393 more rows, and 11 more variables: arr_delay <dbl>,
## #   carrier <chr>, flight <int>, tailnum <chr>, origin <chr>, dest <chr>,
## #   air_time <dbl>, distance <dbl>, hour <dbl>, minute <dbl>, time_hour <dttm>
```

```r
# or

nov_dec<-filter(flights,month %in% c(11,12))
```

Missing values

```r
NA>5
```

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

```r
10==NA
```

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

```r
NA+10
```

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

```r
NA/2
```

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

```r
NA==NA
```

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

```r
X<-NA
Y<-NA
X==Y
```

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

```r
df<-tibble(x=c(1,NA,3))
filter(df,x>1)
```

```
## # A tibble: 1 x 1
##       x
##   <dbl>
## 1     3
```

```r
filter(df,is.na(x)|x>1)
```

```
## # A tibble: 2 x 1
##       x
##   <dbl>
## 1    NA
## 2     3
```

Exercises

1.Find all flights that had an arrival delay of two or more hours

Answer

```r
filter(flights,arr_delay>120)
```

```
## # A tibble: 10,034 x 19
##     year month   day dep_time sched_dep_time dep_delay arr_time sched_arr_time
##    <int> <int> <int>    <int>          <int>     <dbl>    <int>          <int>
##  1  2013     1     1      811            630       101     1047            830
##  2  2013     1     1      848           1835       853     1001           1950
##  3  2013     1     1      957            733       144     1056            853
##  4  2013     1     1     1114            900       134     1447           1222
##  5  2013     1     1     1505           1310       115     1638           1431
##  6  2013     1     1     1525           1340       105     1831           1626
##  7  2013     1     1     1549           1445        64     1912           1656
##  8  2013     1     1     1558           1359       119     1718           1515
##  9  2013     1     1     1732           1630        62     2028           1825
## 10  2013     1     1     1803           1620       103     2008           1750
## # ... with 10,024 more rows, and 11 more variables: arr_delay <dbl>,
## #   carrier <chr>, flight <int>, tailnum <chr>, origin <chr>, dest <chr>,
## #   air_time <dbl>, distance <dbl>, hour <dbl>, minute <dbl>, time_hour <dttm>
```

2. Find all flights that Flew to Houston (`IAH` or `HOU`)

Answer

```r
filter(flights,dest=="IAH"|dest=="HOU")
```

```
## # A tibble: 9,313 x 19
##     year month   day dep_time sched_dep_time dep_delay arr_time sched_arr_time
##    <int> <int> <int>    <int>          <int>     <dbl>    <int>          <int>
##  1  2013     1     1      517            515         2      830            819
##  2  2013     1     1      533            529         4      850            830
##  3  2013     1     1      623            627        -4      933            932
##  4  2013     1     1      728            732        -4     1041           1038
##  5  2013     1     1      739            739         0     1104           1038
##  6  2013     1     1      908            908         0     1228           1219
##  7  2013     1     1     1028           1026         2     1350           1339
##  8  2013     1     1     1044           1045        -1     1352           1351
##  9  2013     1     1     1114            900       134     1447           1222
## 10  2013     1     1     1205           1200         5     1503           1505
## # ... with 9,303 more rows, and 11 more variables: arr_delay <dbl>,
## #   carrier <chr>, flight <int>, tailnum <chr>, origin <chr>, dest <chr>,
## #   air_time <dbl>, distance <dbl>, hour <dbl>, minute <dbl>, time_hour <dttm>
```

3. Find all flights that were operated by United, American, or Delta

Answer

```
filter(flights,carrier=="UA"|carrier=="AA"|carrier=="DL")
```

```
## # A tibble: 139,504 x 19
##     year month   day dep_time sched_dep_time dep_delay arr_time sched_arr_time
##    <int> <int> <int>    <int>          <int>     <dbl>    <int>          <int>
##  1  2013     1     1      517            515         2      830            819
##  2  2013     1     1      533            529         4      850            830
##  3  2013     1     1      542            540         2      923            850
##  4  2013     1     1      554            600        -6      812            837
##  5  2013     1     1      554            558        -4      740            728
##  6  2013     1     1      558            600        -2      753            745
##  7  2013     1     1      558            600        -2      924            917
##  8  2013     1     1      558            600        -2      923            937
##  9  2013     1     1      559            600        -1      941            910
## 10  2013     1     1      559            600        -1      854            902
## # ... with 139,494 more rows, and 11 more variables: arr_delay <dbl>,
## #   carrier <chr>, flight <int>, tailnum <chr>, origin <chr>, dest <chr>,
## #   air_time <dbl>, distance <dbl>, hour <dbl>, minute <dbl>, time_hour <dttm>
```

4. Departed in summer (July, August, and September)

Answer

```
filter(flights,month==7|month==8|month==9)
```

```
## # A tibble: 86,326 x 19
##     year month   day dep_time sched_dep_time dep_delay arr_time sched_arr_time
##    <int> <int> <int>    <int>          <int>     <dbl>    <int>          <int>
##  1  2013     7     1        1           2029       212      236           2359
##  2  2013     7     1        2           2359         3      344            344
##  3  2013     7     1       29           2245       104      151              1
##  4  2013     7     1       43           2130       193      322             14
##  5  2013     7     1       44           2150       174      300            100
##  6  2013     7     1       46           2051       235      304           2358
##  7  2013     7     1       48           2001       287      308           2305
##  8  2013     7     1       58           2155       183      335             43
##  9  2013     7     1      100           2146       194      327             30
## 10  2013     7     1      100           2245       135      337            135
## # ... with 86,316 more rows, and 11 more variables: arr_delay <dbl>,
## #   carrier <chr>, flight <int>, tailnum <chr>, origin <chr>, dest <chr>,
## #   air_time <dbl>, distance <dbl>, hour <dbl>, minute <dbl>, time_hour <dttm>
```

5. Arrived more than two hours late, but didn't leave late

```
filter(flights,arr_delay>120|dep_delay<=0)
```

```
## # A tibble: 210,094 x 19
##     year month   day dep_time sched_dep_time dep_delay arr_time sched_arr_time
##    <int> <int> <int>    <int>          <int>     <dbl>    <int>          <int>
##  1  2013     1     1      544            545        -1     1004           1022
##  2  2013     1     1      554            600        -6      812            837
##  3  2013     1     1      554            558        -4      740            728
##  4  2013     1     1      555            600        -5      913            854
##  5  2013     1     1      557            600        -3      709            723
```

```
##  6  2013     1     1      557            600        -3      838            846
##  7  2013     1     1      558            600        -2      753            745
##  8  2013     1     1      558            600        -2      849            851
##  9  2013     1     1      558            600        -2      853            856
## 10  2013     1     1      558            600        -2      924            917
## # ... with 210,084 more rows, and 11 more variables: arr_delay <dbl>,
## #   carrier <chr>, flight <int>, tailnum <chr>, origin <chr>, dest <chr>,
## #   air_time <dbl>, distance <dbl>, hour <dbl>, minute <dbl>, time_hour <dttm>
```

6.Were delayed by at least an hours late, but made up over 30 minutes in flight

Answer

```
filter(flights,arr_delay<dep_delay-30|dep_delay>=60)
```

```
## # A tibble: 43,165 x 19
##     year month   day dep_time sched_dep_time dep_delay arr_time sched_arr_time
##    <int> <int> <int>    <int>          <int>     <dbl>    <int>          <int>
##  1  2013     1     1      701            700         1     1123           1154
##  2  2013     1     1      811            630       101     1047            830
##  3  2013     1     1      820            820         0     1249           1329
##  4  2013     1     1      826            715        71     1136           1045
##  5  2013     1     1      840            845        -5     1311           1350
##  6  2013     1     1      848           1835       853     1001           1950
##  7  2013     1     1      857            851         6     1157           1222
##  8  2013     1     1      909            810        59     1331           1315
##  9  2013     1     1      957            733       144     1056            853
## 10  2013     1     1     1025            951        34     1258           1302
## # ... with 43,155 more rows, and 11 more variables: arr_delay <dbl>,
## #   carrier <chr>, flight <int>, tailnum <chr>, origin <chr>, dest <chr>,
## #   air_time <dbl>, distance <dbl>, hour <dbl>, minute <dbl>, time_hour <dttm>
```

7. Departed between midnight and 6am (inclusive)

Answer

```
filter(flights,dep_time>=000&dep_time<=600)
```

```
## # A tibble: 9,344 x 19
##     year month   day dep_time sched_dep_time dep_delay arr_time sched_arr_time
##    <int> <int> <int>    <int>          <int>     <dbl>    <int>          <int>
##  1  2013     1     1      517            515         2      830            819
##  2  2013     1     1      533            529         4      850            830
##  3  2013     1     1      542            540         2      923            850
##  4  2013     1     1      544            545        -1     1004           1022
##  5  2013     1     1      554            600        -6      812            837
##  6  2013     1     1      554            558        -4      740            728
##  7  2013     1     1      555            600        -5      913            854
##  8  2013     1     1      557            600        -3      709            723
##  9  2013     1     1      557            600        -3      838            846
## 10  2013     1     1      558            600        -2      753            745
## # ... with 9,334 more rows, and 11 more variables: arr_delay <dbl>,
## #   carrier <chr>, flight <int>, tailnum <chr>, origin <chr>, dest <chr>,
## #   air_time <dbl>, distance <dbl>, hour <dbl>, minute <dbl>, time_hour <dttm>
```

8. Another useful dplyr filtering helper is `between()`. What does it do?

Answer

```
filter(flights,between(dep_time,000,600))
```

```
## # A tibble: 9,344 x 19
##     year month   day dep_time sched_dep_time dep_delay arr_time sched_arr_time
##    <int> <int> <int>    <int>          <int>     <dbl>    <int>          <int>
##  1  2013     1     1      517            515         2      830            819
##  2  2013     1     1      533            529         4      850            830
##  3  2013     1     1      542            540         2      923            850
##  4  2013     1     1      544            545        -1     1004           1022
##  5  2013     1     1      554            600        -6      812            837
##  6  2013     1     1      554            558        -4      740            728
##  7  2013     1     1      555            600        -5      913            854
##  8  2013     1     1      557            600        -3      709            723
##  9  2013     1     1      557            600        -3      838            846
## 10  2013     1     1      558            600        -2      753            745
## # ... with 9,334 more rows, and 11 more variables: arr_delay <dbl>,
## #   carrier <chr>, flight <int>, tailnum <chr>, origin <chr>, dest <chr>,
## #   air_time <dbl>, distance <dbl>, hour <dbl>, minute <dbl>, time_hour <dttm>
```

```
filter(flights,is.na(dep_time))
```

```
## # A tibble: 8,255 x 19
##     year month   day dep_time sched_dep_time dep_delay arr_time sched_arr_time
##    <int> <int> <int>    <int>          <int>     <dbl>    <int>          <int>
##  1  2013     1     1       NA           1630        NA       NA           1815
##  2  2013     1     1       NA           1935        NA       NA           2240
##  3  2013     1     1       NA           1500        NA       NA           1825
##  4  2013     1     1       NA            600        NA       NA            901
##  5  2013     1     2       NA           1540        NA       NA           1747
##  6  2013     1     2       NA           1620        NA       NA           1746
##  7  2013     1     2       NA           1355        NA       NA           1459
##  8  2013     1     2       NA           1420        NA       NA           1644
##  9  2013     1     2       NA           1321        NA       NA           1536
## 10  2013     1     2       NA           1545        NA       NA           1910
## # ... with 8,245 more rows, and 11 more variables: arr_delay <dbl>,
## #   carrier <chr>, flight <int>, tailnum <chr>, origin <chr>, dest <chr>,
## #   air_time <dbl>, distance <dbl>, hour <dbl>, minute <dbl>, time_hour <dttm>
```

Arrange rows with arrange()

`arrange()` works similarly to `filter()` except that instead of selecting rows, it cahnges their order.

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

```
## # A tibble: 336,776 x 19
##     year month   day dep_time sched_dep_time dep_delay arr_time sched_arr_time
##    <int> <int> <int>    <int>          <int>     <dbl>    <int>          <int>
##  1  2013     1     1      517            515         2      830            819
##  2  2013     1     1      533            529         4      850            830
##  3  2013     1     1      542            540         2      923            850
##  4  2013     1     1      544            545        -1     1004           1022
##  5  2013     1     1      554            600        -6      812            837
##  6  2013     1     1      554            558        -4      740            728
##  7  2013     1     1      555            600        -5      913            854
```

```
##  8  2013     1     1      557            600        -3      709            723
##  9  2013     1     1      557            600        -3      838            846
## 10  2013     1     1      558            600        -2      753            745
## # ... with 336,766 more rows, and 11 more variables: arr_delay <dbl>,
## #   carrier <chr>, flight <int>, tailnum <chr>, origin <chr>, dest <chr>,
## #   air_time <dbl>, distance <dbl>, hour <dbl>, minute <dbl>, time_hour <dttm>
```

Use `desc()` to re-order by a column in descending order:

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

```
## # A tibble: 336,776 x 19
##     year month   day dep_time sched_dep_time dep_delay arr_time sched_arr_time
##    <int> <int> <int>    <int>          <int>     <dbl>    <int>          <int>
##  1  2013     1     9      641            900      1301     1242           1530
##  2  2013     6    15     1432           1935      1137     1607           2120
##  3  2013     1    10     1121           1635      1126     1239           1810
##  4  2013     9    20     1139           1845      1014     1457           2210
##  5  2013     7    22      845           1600      1005     1044           1815
##  6  2013     4    10     1100           1900       960     1342           2211
##  7  2013     3    17     2321            810       911      135           1020
##  8  2013     6    27      959           1900       899     1236           2226
##  9  2013     7    22     2257            759       898      121           1026
## 10  2013    12     5      756           1700       896     1058           2020
## # ... with 336,766 more rows, and 11 more variables: arr_delay <dbl>,
## #   carrier <chr>, flight <int>, tailnum <chr>, origin <chr>, dest <chr>,
## #   air_time <dbl>, distance <dbl>, hour <dbl>, minute <dbl>, time_hour <dttm>
```

Missing values are always sorted at the end:

```
df<-tibble(x=c(5,2,NA))
arrange(df,x)
```

```
## # A tibble: 3 x 1
##       x
##   <dbl>
## 1     2
## 2     5
## 3    NA
```

```
arrange(df,desc(x))
```

```
## # A tibble: 3 x 1
##       x
##   <dbl>
## 1     5
## 2     2
## 3    NA
```

Exercises

1. How could you use `arrange()` to sort all missing values to the start? (hint: use `is.na()`)

Answer

```
arrange(df,desc(is.na(x)))
```

```
## # A tibble: 3 x 1
```

```
##       x
##   <dbl>
## 1    NA
## 2     5
## 3     2
```

2. Sort `flights` to find the most delayed flights. Find the flights that left earliest

Answer

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

```
## # A tibble: 336,776 x 19
##     year month   day dep_time sched_dep_time dep_delay arr_time sched_arr_time
##    <int> <int> <int>    <int>          <int>     <dbl>    <int>          <int>
##  1  2013     1     9      641            900      1301     1242           1530
##  2  2013     6    15     1432           1935      1137     1607           2120
##  3  2013     1    10     1121           1635      1126     1239           1810
##  4  2013     9    20     1139           1845      1014     1457           2210
##  5  2013     7    22      845           1600      1005     1044           1815
##  6  2013     4    10     1100           1900       960     1342           2211
##  7  2013     3    17     2321            810       911      135           1020
##  8  2013     6    27      959           1900       899     1236           2226
##  9  2013     7    22     2257            759       898      121           1026
## 10  2013    12     5      756           1700       896     1058           2020
## # ... with 336,766 more rows, and 11 more variables: arr_delay <dbl>,
## #   carrier <chr>, flight <int>, tailnum <chr>, origin <chr>, dest <chr>,
## #   air_time <dbl>, distance <dbl>, hour <dbl>, minute <dbl>, time_hour <dttm>
```

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

```
## # A tibble: 336,776 x 19
##     year month   day dep_time sched_dep_time dep_delay arr_time sched_arr_time
##    <int> <int> <int>    <int>          <int>     <dbl>    <int>          <int>
##  1  2013    12     7     2040           2123       -43       40           2352
##  2  2013     2     3     2022           2055       -33     2240           2338
##  3  2013    11    10     1408           1440       -32     1549           1559
##  4  2013     1    11     1900           1930       -30     2233           2243
##  5  2013     1    29     1703           1730       -27     1947           1957
##  6  2013     8     9      729            755       -26     1002            955
##  7  2013    10    23     1907           1932       -25     2143           2143
##  8  2013     3    30     2030           2055       -25     2213           2250
##  9  2013     3     2     1431           1455       -24     1601           1631
## 10  2013     5     5      934            958       -24     1225           1309
## # ... with 336,766 more rows, and 11 more variables: arr_delay <dbl>,
## #   carrier <chr>, flight <int>, tailnum <chr>, origin <chr>, dest <chr>,
## #   air_time <dbl>, distance <dbl>, hour <dbl>, minute <dbl>, time_hour <dttm>
```

3. Sort `flights` to find the fastest (highest speed) flights.

Answer

```
arrange(flights,desc(distance/air_time))
```

```
## # A tibble: 336,776 x 19
##     year month   day dep_time sched_dep_time dep_delay arr_time sched_arr_time
##    <int> <int> <int>    <int>          <int>     <dbl>    <int>          <int>
##  1  2013     5    25     1709           1700         9     1923           1937
```

```
##  2  2013     7     2     1558           1513        45     1745           1719
##  3  2013     5    13     2040           2025        15     2225           2226
##  4  2013     3    23     1914           1910         4     2045           2043
##  5  2013     1    12     1559           1600        -1     1849           1917
##  6  2013    11    17      650            655        -5     1059           1150
##  7  2013     2    21     2355           2358        -3      412            438
##  8  2013    11    17      759            800        -1     1212           1255
##  9  2013    11    16     2003           1925        38       17             36
## 10  2013    11    16     2349           2359       -10      402            440
## # ... with 336,766 more rows, and 11 more variables: arr_delay <dbl>,
## #   carrier <chr>, flight <int>, tailnum <chr>, origin <chr>, dest <chr>,
## #   air_time <dbl>, distance <dbl>, hour <dbl>, minute <dbl>, time_hour <dttm>
```

4. Which flights travelled the farthest? Which travelled the shortest?

Answer

```
arrange(flights,desc(distance))
```

```
## # A tibble: 336,776 x 19
##     year month   day dep_time sched_dep_time dep_delay arr_time sched_arr_time
##    <int> <int> <int>    <int>          <int>     <dbl>    <int>          <int>
##  1  2013     1     1      857            900        -3     1516           1530
##  2  2013     1     2      909            900         9     1525           1530
##  3  2013     1     3      914            900        14     1504           1530
##  4  2013     1     4      900            900         0     1516           1530
##  5  2013     1     5      858            900        -2     1519           1530
##  6  2013     1     6     1019            900        79     1558           1530
##  7  2013     1     7     1042            900       102     1620           1530
##  8  2013     1     8      901            900         1     1504           1530
##  9  2013     1     9      641            900      1301     1242           1530
## 10  2013     1    10      859            900        -1     1449           1530
## # ... with 336,766 more rows, and 11 more variables: arr_delay <dbl>,
## #   carrier <chr>, flight <int>, tailnum <chr>, origin <chr>, dest <chr>,
## #   air_time <dbl>, distance <dbl>, hour <dbl>, minute <dbl>, time_hour <dttm>
```

```
arrange(flights,distance)
```

```
## # A tibble: 336,776 x 19
##     year month   day dep_time sched_dep_time dep_delay arr_time sched_arr_time
##    <int> <int> <int>    <int>          <int>     <dbl>    <int>          <int>
##  1  2013     7    27       NA            106        NA       NA            245
##  2  2013     1     3     2127           2129        -2     2222           2224
##  3  2013     1     4     1240           1200        40     1333           1306
##  4  2013     1     4     1829           1615       134     1937           1721
##  5  2013     1     4     2128           2129        -1     2218           2224
##  6  2013     1     5     1155           1200        -5     1241           1306
##  7  2013     1     6     2125           2129        -4     2224           2224
##  8  2013     1     7     2124           2129        -5     2212           2224
##  9  2013     1     8     2127           2130        -3     2304           2225
## 10  2013     1     9     2126           2129        -3     2217           2224
## # ... with 336,766 more rows, and 11 more variables: arr_delay <dbl>,
## #   carrier <chr>, flight <int>, tailnum <chr>, origin <chr>, dest <chr>,
## #   air_time <dbl>, distance <dbl>, hour <dbl>, minute <dbl>, time_hour <dttm>
```

Select columns with select()

It is not uncommon to get datasets with hundreds or even thousands of variables. In this case, the first challenge is to narrowing in on the variables you are actually interested in. We use `select()`.

```
select(flights,year,month,day) #directly type columns that want to stay
```

```
## # 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
## # ... with 336,766 more rows
```

```
select(flights,year:day) # use : to select variables between left and right
```

```
## # 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
## # ... with 336,766 more rows
```

```
select(flights,-(year:day)) # delete the columns that dont want
```

```
## # A tibble: 336,776 x 16
##    dep_time sched_dep_time dep_delay arr_time sched_arr_time arr_delay carrier
##       <int>          <int>     <dbl>    <int>          <int>     <dbl> <chr>
##  1      517            515         2      830            819        11 UA
##  2      533            529         4      850            830        20 UA
##  3      542            540         2      923            850        33 AA
##  4      544            545        -1     1004           1022       -18 B6
##  5      554            600        -6      812            837       -25 DL
##  6      554            558        -4      740            728        12 UA
##  7      555            600        -5      913            854        19 B6
##  8      557            600        -3      709            723       -14 EV
##  9      557            600        -3      838            846        -8 B6
## 10      558            600        -2      753            745         8 AA
## # ... with 336,766 more rows, and 9 more variables: flight <int>,
## #   tailnum <chr>, origin <chr>, dest <chr>, air_time <dbl>, distance <dbl>,
```

```
## #   hour <dbl>, minute <dbl>, time_hour <dttm>
```

There are a number of helper functions you can see within `select()`:

1. `starts_with("abc")`: matches names that begin with "abc"
2. `ends_with("xyz")`: matches names that end with "xyz"
3. `contains("ijk")`:macthes names that contain "ijk"
4. `matches("(.)\\1")`: selects variables that match a regular expression. This one macthes any variables that contain repeated characters. You will learn more about regular expressions in strings.
5. `num_range("x",1:3)`: matches `x1`,`x2` and `x3`.

`select()` can be used to rename variables, but it is rarely useful because it drops all variables not explicitly mentioned. Instead, use`rename()`, which is a variant of `select()` that keeps all the variables that are not explicitly mentioned:

```
rename(flights,tail_num=tailnum)
```

```
## # A tibble: 336,776 x 19
##     year month   day dep_time sched_dep_time dep_delay arr_time sched_arr_time
##    <int> <int> <int>    <int>          <int>     <dbl>    <int>          <int>
##  1  2013     1     1      517            515         2      830            819
##  2  2013     1     1      533            529         4      850            830
##  3  2013     1     1      542            540         2      923            850
##  4  2013     1     1      544            545        -1     1004           1022
##  5  2013     1     1      554            600        -6      812            837
##  6  2013     1     1      554            558        -4      740            728
##  7  2013     1     1      555            600        -5      913            854
##  8  2013     1     1      557            600        -3      709            723
##  9  2013     1     1      557            600        -3      838            846
## 10  2013     1     1      558            600        -2      753            745
## # ... with 336,766 more rows, and 11 more variables: arr_delay <dbl>,
## #   carrier <chr>, flight <int>, tail_num <chr>, origin <chr>, dest <chr>,
## #   air_time <dbl>, distance <dbl>, hour <dbl>, minute <dbl>, time_hour <dttm>
```

Another option is to use `select()` in conjunction with the `everything()` helper.

```
select(flights,time_hour,air_time,everything())
```

```
## # A tibble: 336,776 x 19
##    time_hour           air_time  year month   day dep_time sched_dep_time
##    <dttm>                 <dbl> <int> <int> <int>    <int>          <int>
##  1 2013-01-01 05:00:00      227  2013     1     1      517            515
##  2 2013-01-01 05:00:00      227  2013     1     1      533            529
##  3 2013-01-01 05:00:00      160  2013     1     1      542            540
##  4 2013-01-01 05:00:00      183  2013     1     1      544            545
##  5 2013-01-01 06:00:00      116  2013     1     1      554            600
##  6 2013-01-01 05:00:00      150  2013     1     1      554            558
##  7 2013-01-01 06:00:00      158  2013     1     1      555            600
##  8 2013-01-01 06:00:00       53  2013     1     1      557            600
##  9 2013-01-01 06:00:00      140  2013     1     1      557            600
## 10 2013-01-01 06:00:00      138  2013     1     1      558            600
## # ... with 336,766 more rows, and 12 more variables: dep_delay <dbl>,
## #   arr_time <int>, sched_arr_time <int>, arr_delay <dbl>, carrier <chr>,
## #   flight <int>, tailnum <chr>, origin <chr>, dest <chr>, distance <dbl>,
## #   hour <dbl>, minute <dbl>
```

Exercises

1. Brainstorm as many ways as possible to select `dep_time`, `dep_delay`,`arr_time`, and `arr_delay` from `flights`

Answer

```
# 5!=5*4*3*2*1
```

2. What happens if you include the name of a variable multiple times in a `select()` call?

Answer

```
select(flights,distance,distance)
```

```
## # A tibble: 336,776 x 1
##    distance
##       <dbl>
##  1     1400
##  2     1416
##  3     1089
##  4     1576
##  5      762
##  6      719
##  7     1065
##  8      229
##  9      944
## 10      733
## # ... with 336,766 more rows
```

Only one column will be showed.

3. What does the `one_of()` function do? Why might it be helpful in conjunction with this vector?

Answer

```
vars<-c("year","month","day","dep_delay","arr_delay")
select(flights,one_of(vars))
```

```
## # A tibble: 336,776 x 5
##     year month   day dep_delay arr_delay
##    <int> <int> <int>     <dbl>     <dbl>
##  1  2013     1     1         2        11
##  2  2013     1     1         4        20
##  3  2013     1     1         2        33
##  4  2013     1     1        -1       -18
##  5  2013     1     1        -6       -25
##  6  2013     1     1        -4        12
##  7  2013     1     1        -5        19
##  8  2013     1     1        -3       -14
##  9  2013     1     1        -3        -8
## 10  2013     1     1        -2         8
## # ... with 336,766 more rows
```

```
# one_of(): Matches variable names in a character vector.
```

4. Does the result of running the following code surprise you? How do the select helpers deal with case by default? How can you change that default?

Answer

```
select(flights,contains("TIME"))
```

```
## # A tibble: 336,776 x 6
##    dep_time sched_dep_time arr_time sched_arr_time air_time time_hour
##       <int>          <int>    <int>          <int>    <dbl> <dttm>
##  1      517            515      830            819      227 2013-01-01 05:00:00
##  2      533            529      850            830      227 2013-01-01 05:00:00
##  3      542            540      923            850      160 2013-01-01 05:00:00
##  4      544            545     1004           1022      183 2013-01-01 05:00:00
##  5      554            600      812            837      116 2013-01-01 06:00:00
##  6      554            558      740            728      150 2013-01-01 05:00:00
##  7      555            600      913            854      158 2013-01-01 06:00:00
##  8      557            600      709            723       53 2013-01-01 06:00:00
##  9      557            600      838            846      140 2013-01-01 06:00:00
## 10      558            600      753            745      138 2013-01-01 06:00:00
## # ... with 336,766 more rows
```

Including all variables whcih name contains time.

Add new variables with mutate()

`mutate()`: building new variable with existing variables

```
flights_sml<-select(flights,year:day,
                    ends_with("delay"),
                    distance,
                    air_time)

mutate(flights_sml,
       gain=dep_delay-arr_delay,
       speed=distance/air_time*60)
```

```
## # A tibble: 336,776 x 9
##     year month   day dep_delay arr_delay distance air_time  gain speed
##    <int> <int> <int>     <dbl>     <dbl>    <dbl>    <dbl> <dbl> <dbl>
##  1  2013     1     1         2        11     1400      227    -9  370.
##  2  2013     1     1         4        20     1416      227   -16  374.
##  3  2013     1     1         2        33     1089      160   -31  408.
##  4  2013     1     1        -1       -18     1576      183    17  517.
##  5  2013     1     1        -6       -25      762      116    19  394.
##  6  2013     1     1        -4        12      719      150   -16  288.
##  7  2013     1     1        -5        19     1065      158   -24  404.
##  8  2013     1     1        -3       -14      229       53    11  259.
##  9  2013     1     1        -3        -8      944      140     5  405.
## 10  2013     1     1        -2         8      733      138   -10  319.
## # ... with 336,766 more rows
```

```
# You can refer to columns that you have just created
mutate(flights_sml,
       gain=dep_delay-arr_delay,
       hours=air_time/60,
       gain_per_hours=gain/hours)
```

```
## # A tibble: 336,776 x 10
```

```
##     year month   day dep_delay arr_delay distance air_time  gain hours
##    <int> <int> <int>     <dbl>     <dbl>    <dbl>    <dbl> <dbl> <dbl>
##  1  2013     1     1         2        11     1400      227    -9 3.78
##  2  2013     1     1         4        20     1416      227   -16 3.78
##  3  2013     1     1         2        33     1089      160   -31 2.67
##  4  2013     1     1        -1       -18     1576      183    17 3.05
##  5  2013     1     1        -6       -25      762      116    19 1.93
##  6  2013     1     1        -4        12      719      150   -16 2.5
##  7  2013     1     1        -5        19     1065      158   -24 2.63
##  8  2013     1     1        -3       -14      229       53    11 0.883
##  9  2013     1     1        -3        -8      944      140     5 2.33
## 10  2013     1     1        -2         8      733      138   -10 2.3
## # ... with 336,766 more rows, and 1 more variable: gain_per_hours <dbl>
```

If you only want to keep the new variables, use `transmute()`

```
transmute(flights,
          gain=dep_delay-arr_delay,
          hours=air_time/60,
          gain_per_hour=gain/hours)
```

```
## # A tibble: 336,776 x 3
##     gain hours gain_per_hour
##    <dbl> <dbl>         <dbl>
##  1    -9 3.78          -2.38
##  2   -16 3.78          -4.23
##  3   -31 2.67         -11.6
##  4    17 3.05           5.57
##  5    19 1.93           9.83
##  6   -16 2.5           -6.4
##  7   -24 2.63          -9.11
##  8    11 0.883         12.5
##  9     5 2.33           2.14
## 10   -10 2.3           -4.35
## # ... with 336,766 more rows
```

Useful creation functions

There are many functions for creating new variables that you can use with `mutate()`. The key property is that the function must be vectorised: it must take a vector of values as input, return a vector with the same number of values as output. There is no way to list every possible function that you might use, but there is a selection of functions that are frequently useful:

1. Arithmetic operators: `+`,`-`,`*`,`/`,`^`. These are all vectorised using the so called "recycling rules". `x/sum(x)`- calculate the proportion of a total, `y-mean(y)`- calculate the difference from the mean
2. Modular airthmetic: `%/%` (integer division) and `%%` (remainder), where `x==y*(x%/%y)+(x%%y)`. Modular arithmetic is a handy tool because it allows you to break integers up into pecies.

```
transmute(flights,
          dep_time,
          hour=dep_time%/% 100,
          minute=dep_time %%100)
```

```
## # A tibble: 336,776 x 3
##    dep_time  hour minute
```

```
##       <int> <dbl>  <dbl>
##  1      517     5     17
##  2      533     5     33
##  3      542     5     42
##  4      544     5     44
##  5      554     5     54
##  6      554     5     54
##  7      555     5     55
##  8      557     5     57
##  9      557     5     57
## 10      558     5     58
## # ... with 336,766 more rows
```

3. Cumulative and rolling aggregates: R provides functions for running sums, products, mins and maxes: `cumsum()`, `cumprod()`, `cummin()`, `cummax()`; and dplyr provides `cummean()` for cumulative means.

```
x<-c(1,2,3,4,5,6,7,8,9,10)
cumsum(x)
```

```
##  [1]  1  3  6 10 15 21 28 36 45 55
```

```
cummean(x)
```

```
##  [1] 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0 5.5
```

4. Logical comparisons, `<`,`<=`,`>`,`>=`,`!=`, and `==`, which you learned earlier.
5. Ranking: there are a number of ranking functions, but you should start with `min_rank()`, use desc to get largest to smallest.

```
y<-c(1,2,2,NA,3,4)
min_rank(y)
```

```
## [1]  1  2  2 NA  4  5
```

```
min_rank(desc(y))
```

```
## [1]  5  3  3 NA  2  1
```

Grouped summarises with summarise()

`summarise()`: It summarises the all information

```
summarise(flights,delay=mean(dep_delay,na.rm=T))
```

```
## # A tibble: 1 x 1
##   delay
##   <dbl>
## 1  12.6
```

`summarise` is often in pair with `group_by()`. This changes the unit of analysis from the complete dataset to individual groups.

```
by_day<-group_by(flights,year,month,day)
summarise(by_day,delay=mean(dep_delay,na.rm=T))
```

```
## # A tibble: 365 x 4
## # Groups:   year, month [12]
##     year month   day delay
##    <int> <int> <int> <dbl>
```

```
##  1  2013     1     1 11.5
##  2  2013     1     2 13.9
##  3  2013     1     3 11.0
##  4  2013     1     4  8.95
##  5  2013     1     5  5.73
##  6  2013     1     6  7.15
##  7  2013     1     7  5.42
##  8  2013     1     8  2.55
##  9  2013     1     9  2.28
## 10  2013     1    10  2.84
## # ... with 355 more rows
```

```
# We get average delay per day
```

Combining multiple operations with pipe

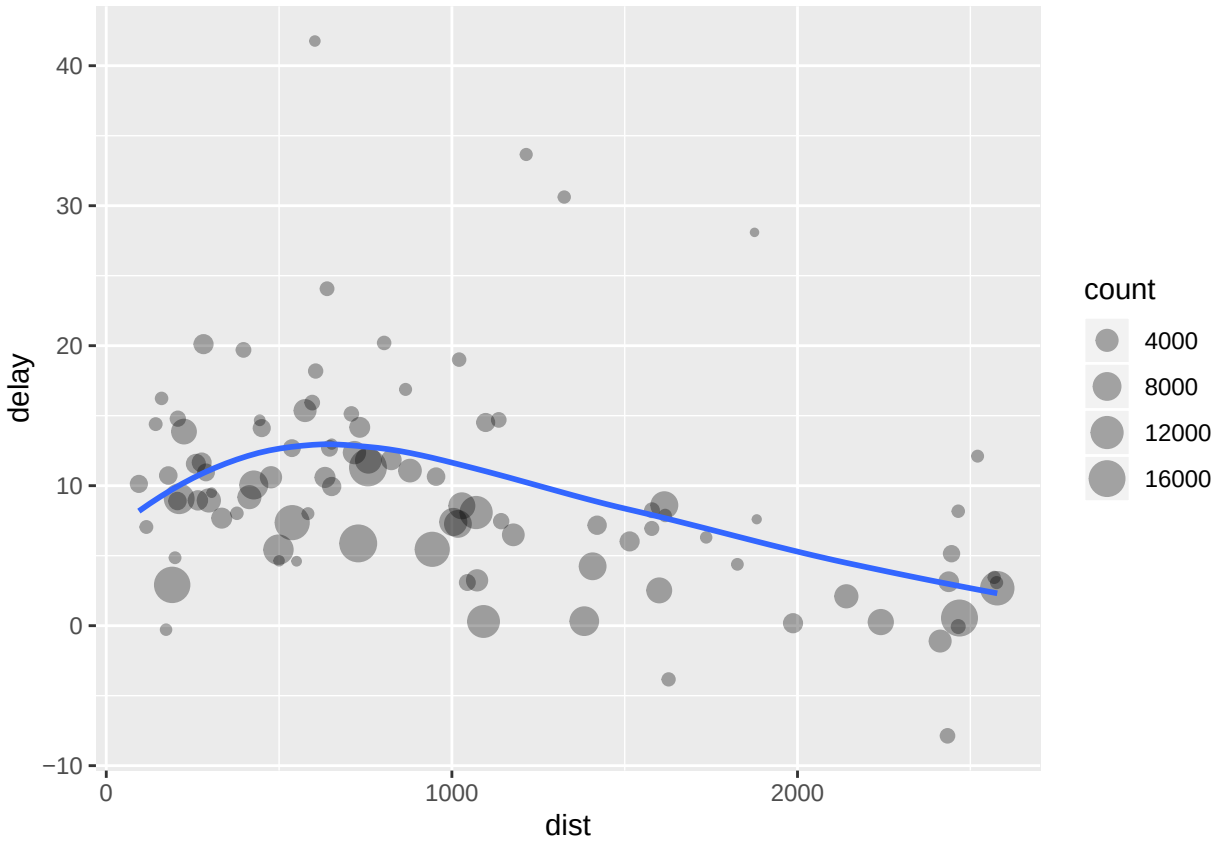
Imagine that we want to explore the relationship between the distance and average delay for each location. Using what you know about dplyr

```
by_dest<-group_by(flights,dest)
delay<-summarise(by_dest,
                 count=n(),
                 dist=mean(distance,na.rm=T),
                 delay=mean(arr_delay,na.rm=T))
delay<-filter(delay,count>20,dest!="HNL")

# It looks like delays increase with distance up to ~750 miles and then decrease.

ggplot(data=delay,mapping=aes(x=dist,y=delay))+
        geom_point(aes(size=count),alpha=1/3)+
        geom_smooth(se=FALSE)
```

```
## `geom_smooth()` using method = 'loess' and formula 'y ~ x'
```



There are three steps to prepare this data:

1. Group flights by destination
2. Summarise to compute distance, average delay, and number of flights
3. Filter to remove noisy points and Honolulu airport, which is almost twice as far away as the next closest airport

```
delays<-flights %>% group_by(dest) %>%
        summarise(
                count=n(),
                dist=mean(distance,na.rm=T),
                delay=mean(arr_delay,na.rm=T)
                ) %>%
        filter(count>20,dest!="HNL")
```

Step-by-Step analysis:

%>%: is then

`x %>% f(y)` turns into `f(x,y)`

Missing values

```
flights %>%
        group_by(year,month,day) %>%
        summarise(mean=mean(dep_delay))
```

```
## # A tibble: 365 x 4
## # Groups:   year, month [12]
##     year month   day  mean
##    <int> <int> <int> <dbl>
##  1  2013     1     1    NA
##  2  2013     1     2    NA
##  3  2013     1     3    NA
##  4  2013     1     4    NA
##  5  2013     1     5    NA
##  6  2013     1     6    NA
##  7  2013     1     7    NA
##  8  2013     1     8    NA
##  9  2013     1     9    NA
## 10  2013     1    10    NA
## # ... with 355 more rows
```

```
# We get a lot of missing values. Fortunately, all aggregation functions have an `na.rm` argument which

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

```
## # A tibble: 365 x 4
## # Groups:   year, month [12]
##     year month   day  mean
##    <int> <int> <int> <dbl>
##  1  2013     1     1 11.5
##  2  2013     1     2 13.9
##  3  2013     1     3 11.0
##  4  2013     1     4  8.95
##  5  2013     1     5  5.73
##  6  2013     1     6  7.15
##  7  2013     1     7  5.42
##  8  2013     1     8  2.55
##  9  2013     1     9  2.28
## 10  2013     1    10  2.84
## # ... with 355 more rows
```

```
# It removes the missing values represent cancelled flights.
```

```
not_cancelled<-flights %>%
        filter(!is.na(dep_delay),!is.na(arr_delay))
not_cancelled %>%
        group_by(year,month,day) %>%
        summarise(mean=mean(dep_delay))
```

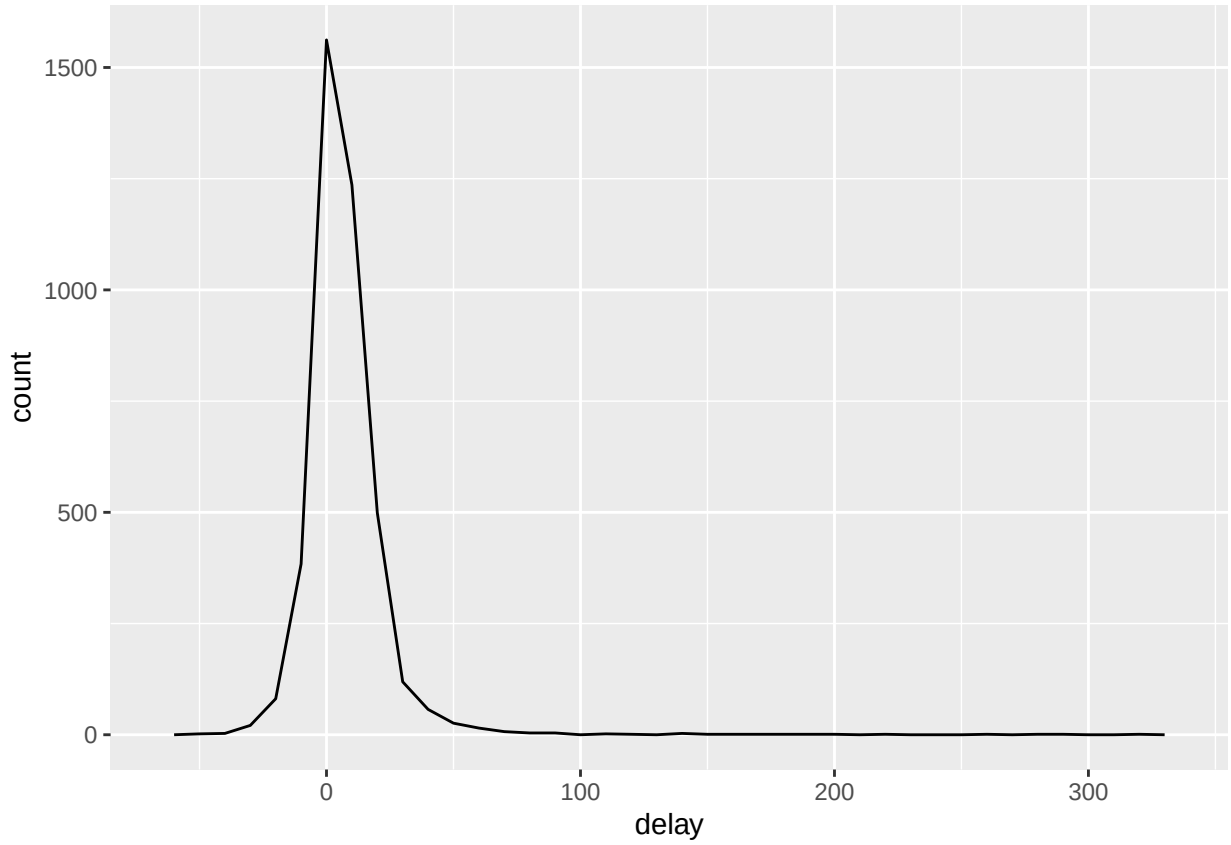
```
## # A tibble: 365 x 4
## # Groups:   year, month [12]
##     year month   day  mean
##    <int> <int> <int> <dbl>
##  1  2013     1     1 11.4
##  2  2013     1     2 13.7
##  3  2013     1     3 10.9
##  4  2013     1     4  8.97
##  5  2013     1     5  5.73
##  6  2013     1     6  7.15
```

```
##  7  2013     1     7  5.42
##  8  2013     1     8  2.56
##  9  2013     1     9  2.30
## 10  2013     1    10  2.84
## # ... with 355 more rows
```

Counts

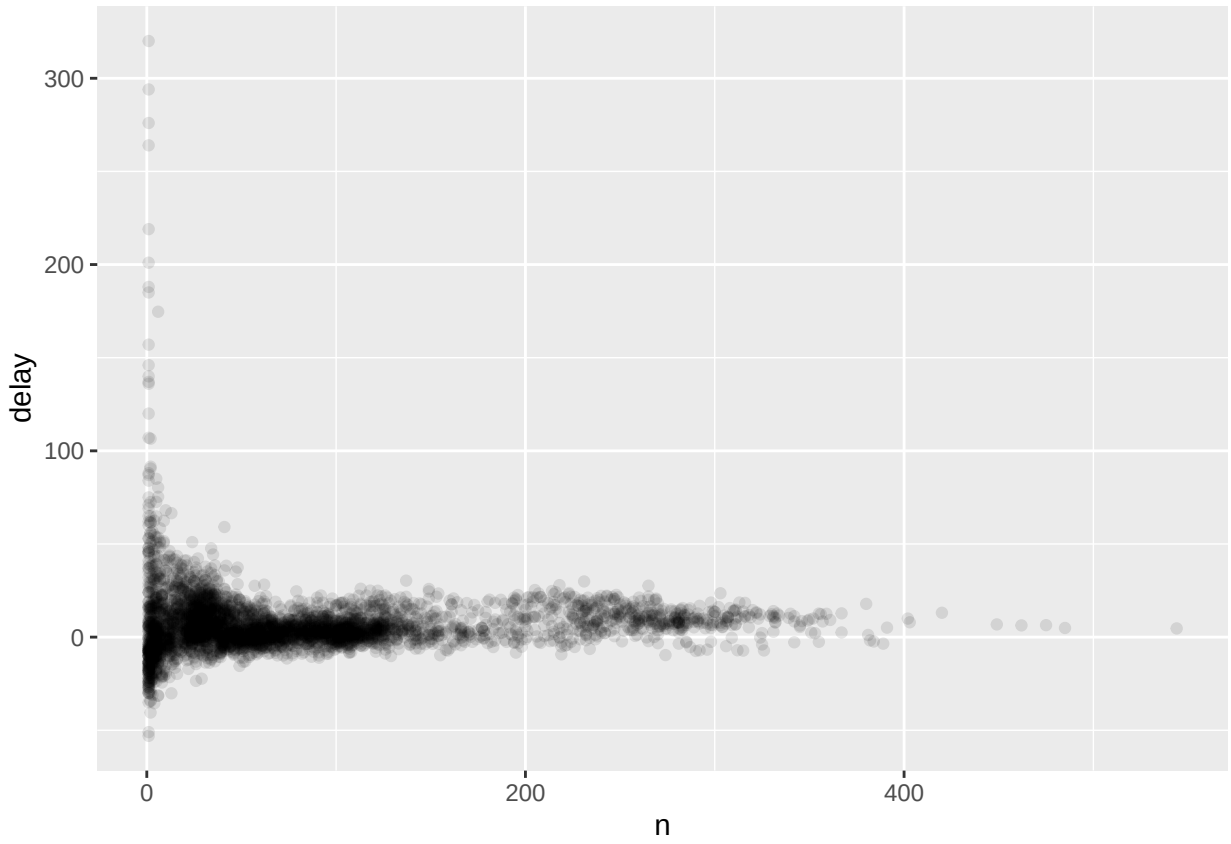
Whenever you do any aggregation, it is always a good idea to include either a count(`n()`), or a count of non-missing values (`sum(!is.na(x))`).

```
delays<-not_cancelled %>%
        group_by(tailnum) %>%
        summarise(delay=mean(arr_delay))
ggplot(data=delays,mapping=aes(x=delay))+
        geom_freqpoly(binwidth=10)
```



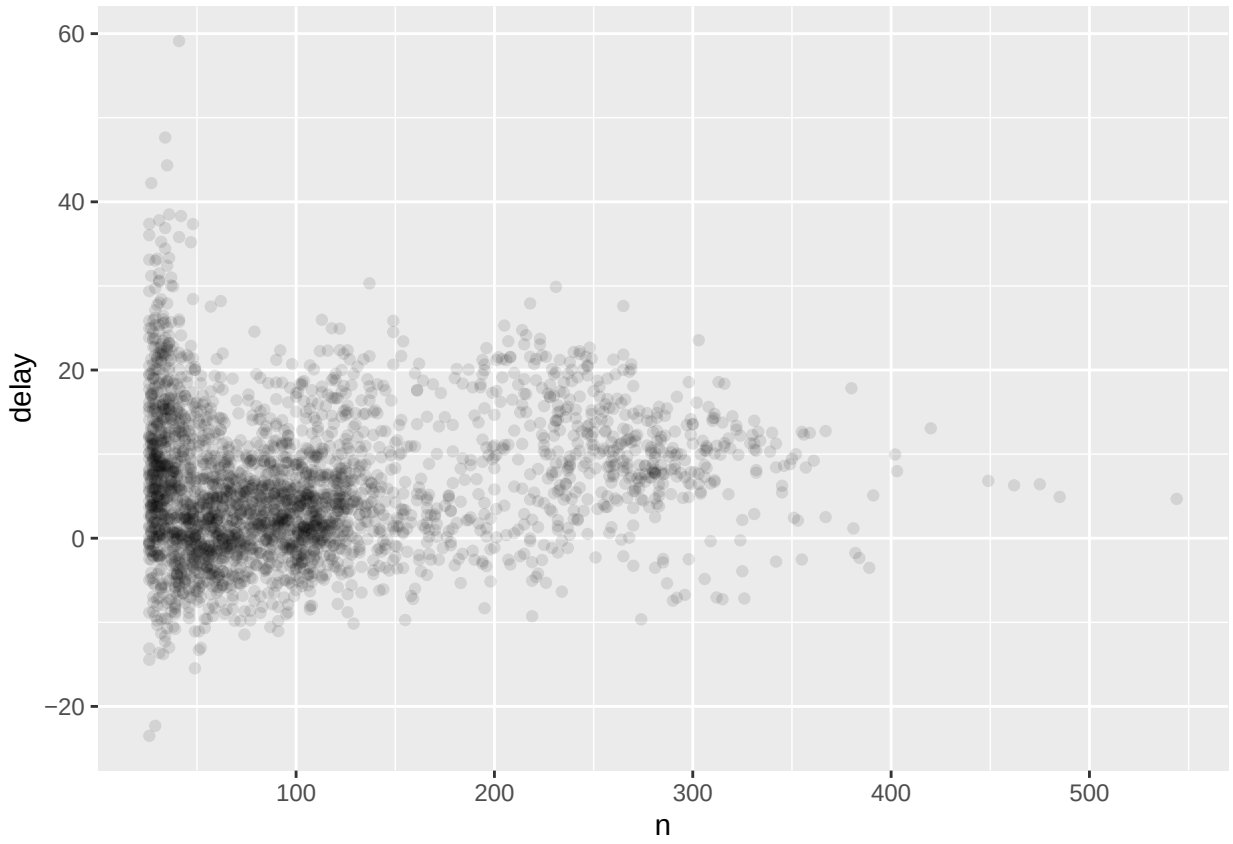
We get get more insight if we draw a scatterplot of number of flights vs average delay

```
delays<-not_cancelled %>%
        group_by(tailnum) %>%
        summarise(
                delay=mean(arr_delay,na.rm=T),
                n=n())
ggplot(data=delays,mapping=aes(x=n,y=delay))+geom_point(alpha=1/10)
```



Not surprisingly, this is much greater variation in the average delay when there are few flights. The shape of this plot is very characteristic: whenever you plot a mean vs group size, you will see that the variation decreases as the sample size increases

```
delays %>%
        filter(n>25) %>%
        ggplot(mapping=aes(x=n,y=delay))+
        geom_point(alpha=1/10)
```



Grouping by multiple variables

When you group by multiple variables, each summary peels off one level of the grouping. That makes it easy to progressively roll up a dataset:

```
daily<-group_by(flights,year,month,day)
(per_day<-summarise(daily,flights=n()))
```

```
## # A tibble: 365 x 4
## # Groups:   year, month [12]
##     year month   day flights
##    <int> <int> <int>   <int>
##  1  2013     1     1     842
##  2  2013     1     2     943
##  3  2013     1     3     914
##  4  2013     1     4     915
##  5  2013     1     5     720
##  6  2013     1     6     832
##  7  2013     1     7     933
##  8  2013     1     8     899
##  9  2013     1     9     902
## 10  2013     1    10     932
## # ... with 355 more rows
```

```
(per_month<-summarise(per_day,flights=sum(flights)))
```

```
## # A tibble: 12 x 3
```

```
## # Groups:   year [1]
##     year month flights
##    <int> <int>   <int>
##  1  2013     1   27004
##  2  2013     2   24951
##  3  2013     3   28834
##  4  2013     4   28330
##  5  2013     5   28796
##  6  2013     6   28243
##  7  2013     7   29425
##  8  2013     8   29327
##  9  2013     9   27574
## 10  2013    10   28889
## 11  2013    11   27268
## 12  2013    12   28135
```

```
(per_year<-summarise(per_month,flights=sum(flights)))
```

```
## # A tibble: 1 x 2
##    year flights
##   <int>   <int>
## 1  2013  336776
```

Ungrouping

If you need to remove grouping, and return to operations un ungrouped data, use `ungroup()`

```
daily %>%
        ungroup() %>%
        summarise(flights=n())
```

```
## # A tibble: 1 x 1
##   flights
##     <int>
## 1  336776
```

Grouped mutates (and filters)

Grouping is most useful in conjunction with `summarise()`, but you can also do convenient operations with `mutate()` and `filter()`:

Find the worst members of each group:

```
flights_sml%>%
        group_by(year,month,day) %>%
        filter(rank(desc(arr_delay))<10)
```

```
## # A tibble: 3,306 x 7
## # Groups:   year, month, day [365]
##     year month   day dep_delay arr_delay distance air_time
##    <int> <int> <int>     <dbl>     <dbl>    <dbl>    <dbl>
##  1  2013     1     1       853       851      184       41
##  2  2013     1     1       290       338     1134      213
##  3  2013     1     1       260       263      266       46
##  4  2013     1     1       157       174      213       60
```

```
##  5  2013     1     1       216       222      708      121
##  6  2013     1     1       255       250      589      115
##  7  2013     1     1       285       246     1085      146
##  8  2013     1     1       192       191      199       44
##  9  2013     1     1       379       456     1092      222
## 10  2013     1     2       224       207      550       94
## # ... with 3,296 more rows
```