R Notebook midterm: 419 Survey of Multivariate Methods

Contents

Top of the world

https://brand.wsu.edu/visual/colors/

TESTING PROCEDURE

This midterm exam (Rnotebook-midterm) is worth 150 points. For each question, review how much the item is worth in terms of points and plan your time wisely.

I would deem it "unwise" to spend hours on a question that is only worth 5 points.

Static/Existing Resources Are Allowed

This is an open-book examination. You can use your course notebooks (digital and old-school). You can use Internet resources (stackoverflow, Wikipedia, and Youtube).

Dynamic/Living Resources Are __ NOT__ Allowed

You cannot use a living resource on the exam. That would include a classmate, student, sibling, parent, a tutor, online forums (where you ask the question after the exam period has begun).

If you have questions that need clarifying, please **email the instructor** and he will try to answer them by email or ZOOM. He will be checking his email often during the week of the exam, to make himself available to you.

Levels of Mastery

- Do You **Remember**?
- Do You **Understand**?
- Can You **Apply** what you remember/understand to another similar problem?
- Can You **Analyze** and **Synthesize** Data?
- Can You **Evaluate** your analyses?
- Can You **Create** meaningful visualizations and summaries?

Rubric of Mastery

For every 10 points, this is the general breakdown.

Emerging	Developing	Mastering
0-4	5-7	8 - 10

EXPLORATORY DATA ANALYSIS (EDA)

Exploratory data analysis (EDA) is the process of analyzing data to summarize its main characteristics.

Confirmatory data analysis (CDA) is the process of applying specific statistical methods to analyze the data. The goal is also to summarize its main characteristics. We commonly refer to CDA as "statistical hypothesis

testing". CDA generally makes assumptions about how the data is distributed. Or wants to apply a specific model to the data.

So the two approaches have the same objective: summarize the main characteristics of the data. How they achieve that objective is very different.

Introduction

John Tukey

John Tukey is the father of "Exploratory Data Analysis" (EDA) https://en.wikipedia.org/wiki/John_Tukey. My favorite statistics book is his 1977 book (not surprising) entitled "Exploratory Data Analysis."

Exploratory vs Confirmatory

From Wikipedia (Accessed October 2020): Tukey "also contributed to statistical practice and articulated the important distinction between exploratory data analysis and confirmatory data analysis, **believing that much statistical methodology placed too great an emphasis on the latter**."

I belong to the "Tukey" camp. I believe too much emphasis is place on "formal statistical methods and tests". I believe more emphasis should be placed on the underlying nature of the data. These underlying principles are how the statistical methods developed.

As a data analyst, I believe that first and foremost, we should let the data speak. That is why the first half of the semester started in this form. The second half (confirmatory data analysis) will rely on what is labeled by many as "formal statistical methods".

Tukey and "Bell Labs"

In 1965, Tukey divided his time between working at Princeton University and working at Bell Labs (a research think tank).

Robust Statistics as Nonparametric Tukey proposed that five summary data are essential to understanding numerical data: `min`, `max`, `median` (technically `Q2`), and `Q1` and `Q3` (the quartiles). In `R`, the function `summary` has only added `mean` to Tukey's proposal from years ago.

Box and Whisker Plot In 1975, Tukey invented the "box and whisker" plot that identifies the median, inter-quartile range (IQR), and outliers of data. The visualization displays the data without making any assumptions about its statistical distribution. The boxplot is a working demonstration of EDA. **Let the data speak!**

John Chambers and `S` and `R`

At the same time ast John Tukey, three other men were also working at Bell Labs (John Chambers, Rick Becker, and Allan Wilks) on a statistical programming language `S` that emphasized EDA. This "statistical computing" language was programming mostly in `Fortran` with some `C` programming. Chambers published his first "statistical computing" text in 1977, titled "Computational methods for data analysis" https://archive.org/details/computationalmet0000cham/page/n11/mode/2up

Between 1988 and 1991, Chambers updated the engine of `S` to make it more robust. That same engine still powers much of `R` today. That is, much of the base code of `S` was written by Chambers himself. `R` today still uses much of that `S` codebase under the hood.

`R` was an open-source offshoot (a "fork") of `S` which occurred in the mid 1990s. Today, Chambers is still active in the `S`-now`R` community. My favorite book of his is titled (2008): "Software for data analysis programming with R". My second-favorite book of his is titled (1998): "Programming with data: a guide to the S language". In 2016, he authored another book that I still need to read "Extending R."

Modern `R` is written in `Fortran`, `C`, and `C++`.

Since its foundation is primarily `C`, we can use standard "make" and "make-install" tools to compile R or its packages from the source code. That is why we needed `Rtools` on Windows. The MacOS is now linux based, so no additional tools are required.

Summary

EDA as exploration is an iterative process.

Analogy: learning a foreign language

I like to use the analogy of learning a foreign language using the "immersion" approach. For example, I studied Spanish in high school, learned vocabulary and grammar, and really could not speak the language well.

I did learn to speak the language well by being dropped into a foreign country for nearly two years. Some key ingredients to learn a language in an "immersive" environment are listed below:

- surround yourself with others speaking the language to be learned [e.g., I did not spend a lot of time with other Americans speaking English].
- be present when engaged in the language. Listen intently and try to understand as much as you can, not worrying about what you don't fully understand.
- reflect after language engagement. Try to synthesize what "gaps" you have and then develop study habits to fill in those gaps.
- practice what you have learned.

To some degree, my success was likely accelerated because I had precursory training. Regardless, "immersive" practices benefit learning new languages.

Proficiency in Data Analytics

[As part of your journey, I have asked you to keep a "paper-and-pencil" notebook to write down words/phrases/ideas. For example, in this section, there may be words/terms/phrases/ideas you don't fully understand.]

Proficiency requires an iteration of these key features described above. But first, you have to understand what language you are trying to speak. Is it `R`? Is it Statistics? Mathematics? What exactly is the language?

In my opinion, the language is the "language of data".

The "language of data"

How do you think mathematics developed? It likely started with simple data, based on real-world experience: two hands, five fingers on each hand gives me the number ten. Counting in a base-10 system likely resulted. An entire domain of mathematics called "number theory" devotes its studies to these integer values.

How do you think statistics developed? People went out and started measuring things. One person would literally walk down the street in the late 1800s and ask if he could measure a person's proportions. Another person would study crop yields at different locations and tried to ascertain if they were different.

The foundation of mathematics and statistics is data. So I believe, we should let the data speak.

Let the data speak

So I am definitely an EDA-guy. Some people are, some people are not. I personally am a strong believer that we should **let the data speak**, learn how to describe the data without imposing any restrictions on it, and always think about the data first and foremost.

I also believe that we should use logic, intuition, and insight before we develop any formal "confirmatory" hypothesis testing. I have intentionally architected this course to emphasis EDA.

Quality data provenance

I am also very ademant about **data provenance** as I believe the "outputs" of any analysis (whether exploratory or confirmatory) is as only as good as the data quality. I call this `data intimacy`. You should care just as much about the process to get quality data as you do to analyze said data.

The term **GIGO** (garbage-in, garbage-out) in my estimation represents what happens when care for quality data is treated lightly.

Iterative Exploration

This full EDA approach is a multi-lens approach. View the data from as many different perspectives as possible before arriving at a conclusion. Base your conclusion on a synthesis of what you analyzed from those different perspectives.

- We do initial EDA (using mathematical foundations),
- then we may do confirmatory analyses (traditional statistical methods), and
- then we synthesize our findings and do a higher-ordered EDA using the original analysis and the confirmatory analysis to make final decisions using sound logic and intuition.
- this process will enlighten our understand and possibly help us formulate new suppositions and think about what additional data would inform the topic.

(10 points) YOUR "EDA" OPINION

[I have expressed my opinion about the study of data and the importance of EDA in that study. What is your opinion on this topic?

This is worth 10 points, a minimal answer should be at least 3 paragraphs. Agreeing/Disagreeing with my opinion is not how you will be evaluated. How well you express YOUR opinion is what is important.]

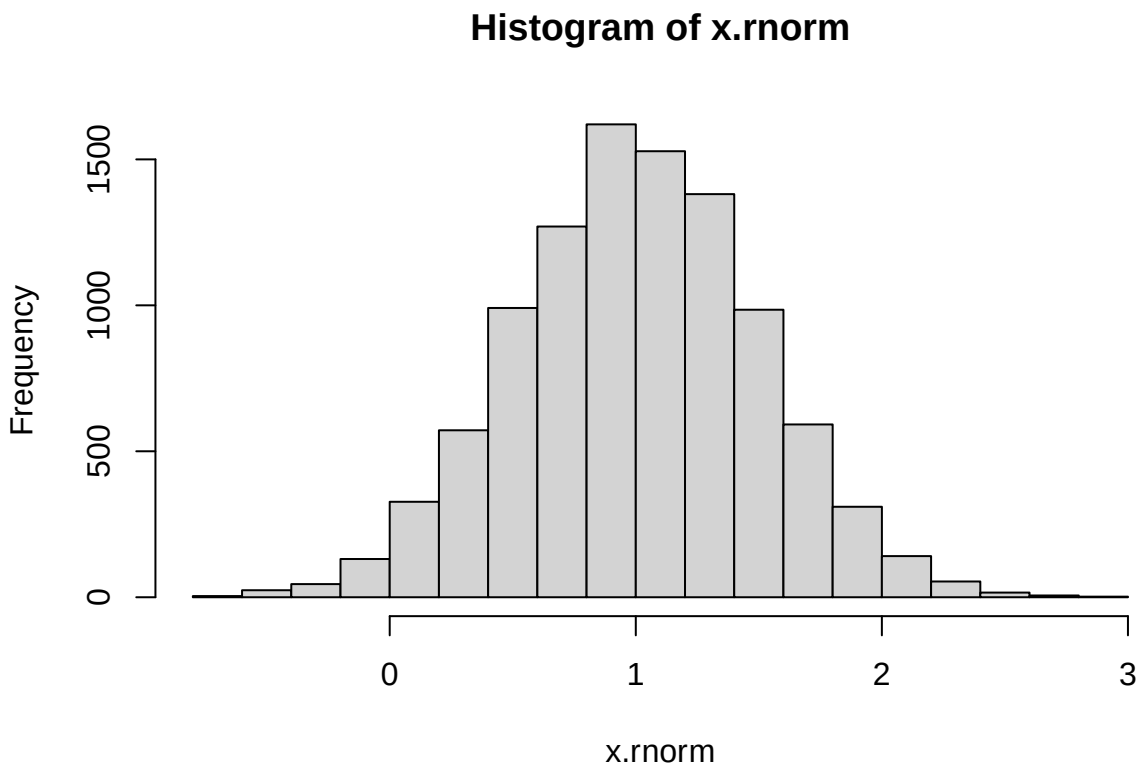
SIMULATING DATA

(10 points) Basic Simulation

- Pick a `set.seed` choice so the code is replicable. Verify that every time you run the commands, the data is not changing with the seed "you chose".
- Use the functions `rnorm`, `runif` to simulate data.
- Simulate `n=9999;` data for each.
- Call `x.rnorm` the data for the first and `x.runif` the data for the second.
- Plot a histogram `graphics::hist` and report the summary statistics '`base::summary` of each.
- Then, plot them using `plot(x.rnorm, x.runif);`.
- Finally, `plot(x.rnorm, sample(x.rnorm) );` and compare it to `plot(x.runif, sample(x.runif) );`.

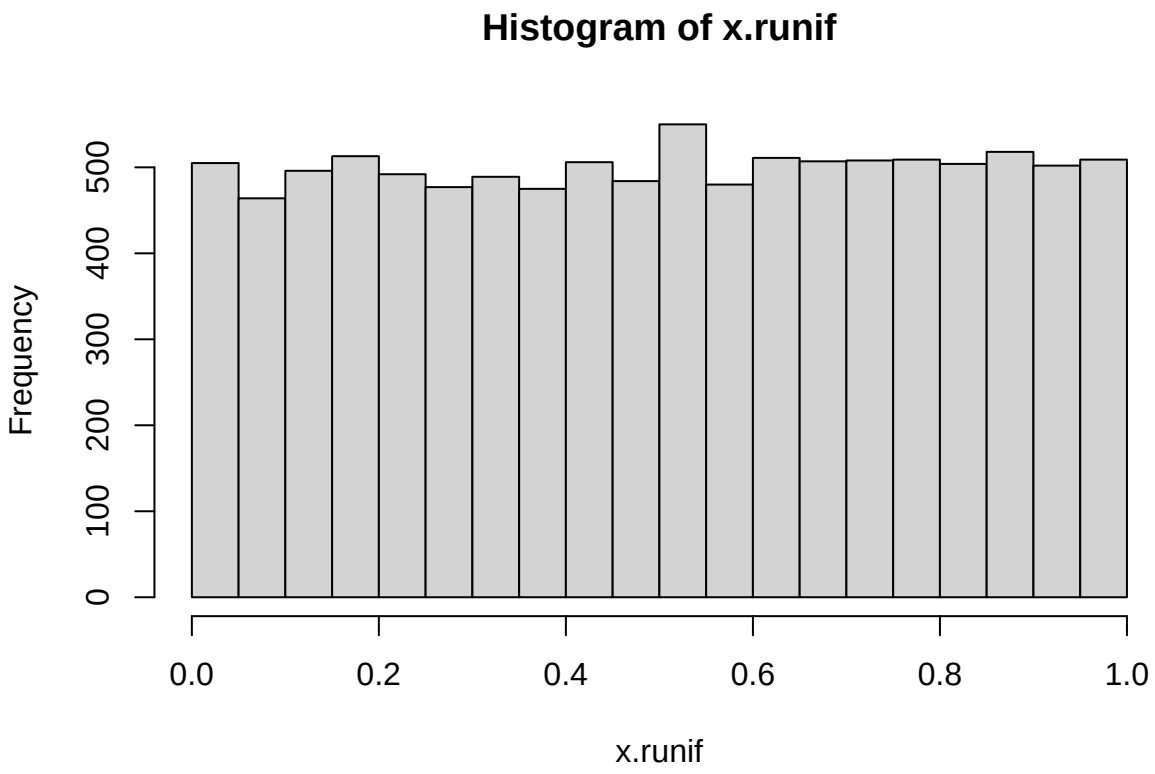
```
set.seed(1234);

x.rnorm = rnorm(n = 9999, 1, 0.5);
x.runif = runif(n = 9999, 0,1);
graphics::hist(x.rnorm);
```



Code of simulation

```
graphics::hist(x.runif);
```



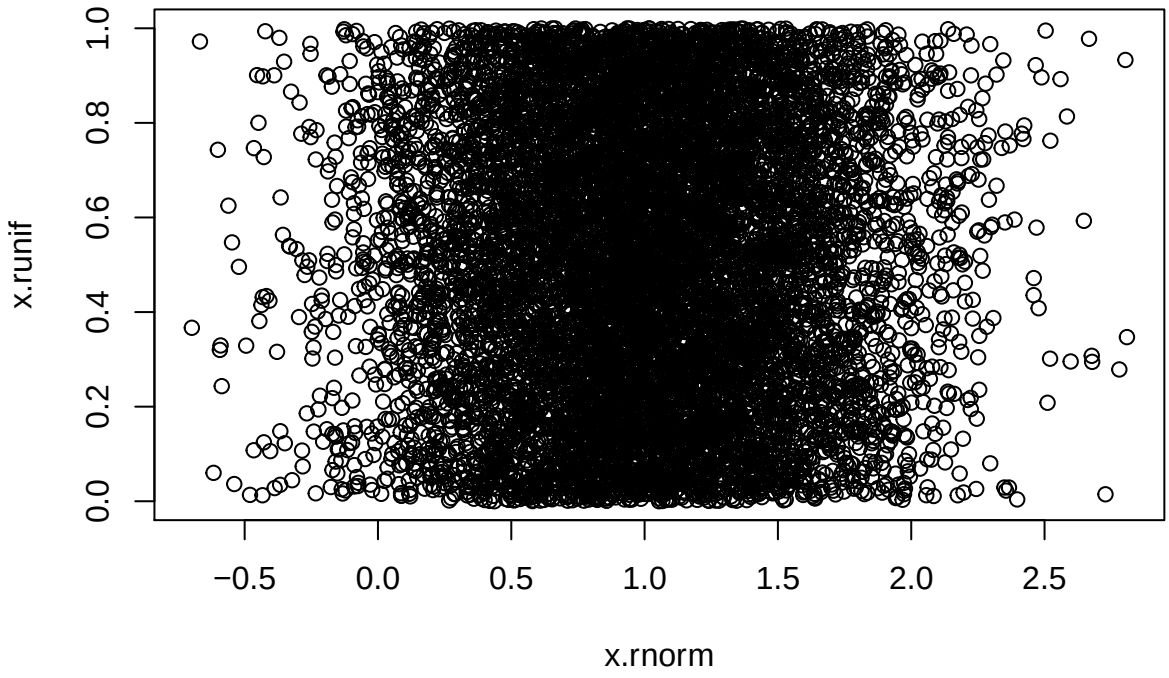

```
base::summary(x.rnorm);
```

```
##    Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
## -0.6980  0.6696  1.0023  1.0030  1.3347  2.8091
```

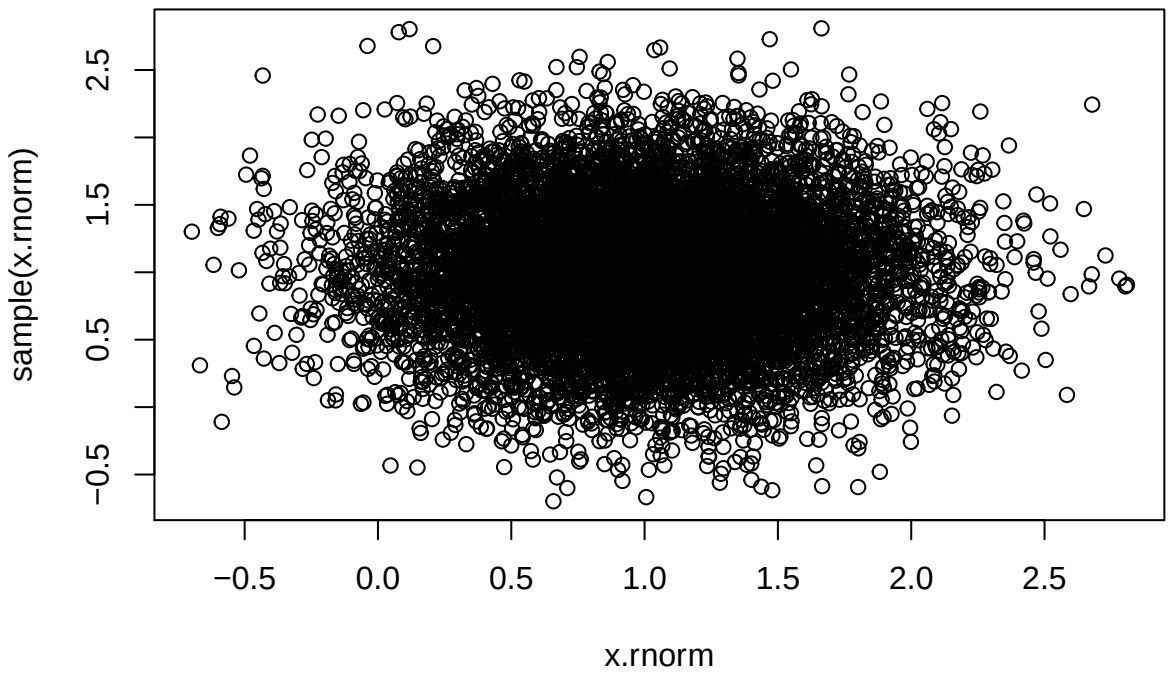
```
base::summary(x.runif);
```

```
##      Min.   1st Qu.    Median      Mean   3rd Qu.      Max.
## 0.0000315 0.2543541 0.5089181 0.5044548 0.7536124 0.9998502
```

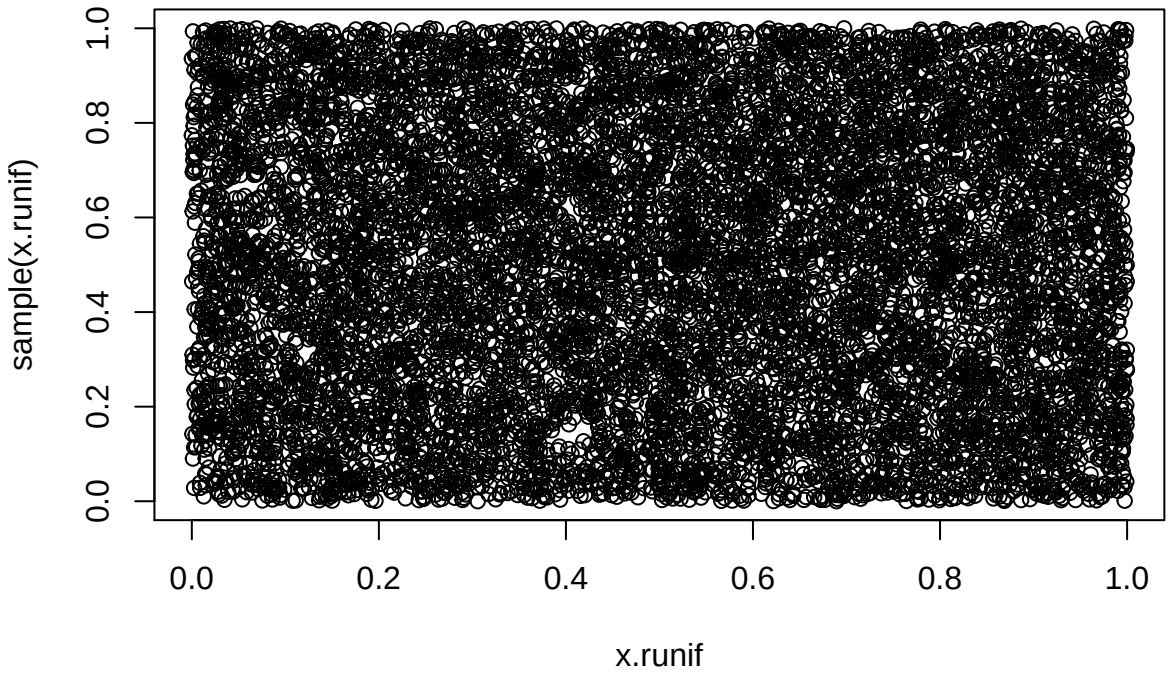
```
plot(x.rnorm, x.runif);
```




```
plot(x.rnorm, sample(x.rnorm));
```




```
plot(x.runif, sample(x.runif));
```



Describe `rnorm`, `runif`

- Describe what each function `rnorm` and `runif` does. How are they similar? How are they different?
- What does the `sample` function do?
- How was `plot(x.rnorm, x.runif);` different from `plot(x.rnorm, ( x.rnorm.sample = sample(x.rnorm) ) );` and `plot(x.runif, ( x.runif.sample = sample(x.runif) ) );`? How would you describe the shape of each of these plots?

(5 points) "Easter-Egg" Simulation

- There was an "Easter Egg" that related to setting the seed `set.seed` using `rbinom`. If you search in the BlackBoard discussion forum for `easter` you will see the discussion about August 25-27.
- In the "Easter Egg", the goal was to find a scenario using a specific `set.seed` that would simulate flipping a coin 100 times and getting one result (heads/tails) exactly 52 times.
- In this problem, the search criteria has changed. Simulate flipping a coin 1000 times and getting one result (heads/tails) exactly 555 times.
- You need to report 5 values for `set.seed` that achieves this objective. You can report more.

- You should explicitly have the code print `length(x)` where `x` is a vector of the values that meet the objective.

```
nsim = 500000;
y= 1:nsim;
ns = 0;
which = numeric(0);
for(i in y)
```

```
  {
  set.seed(i);
  res = rbinom(n = 1, 1000, 0.5);
  if(res == 555)
    {
    cat(i, sep = "\n");
    ns = 1 + ns;
    which = c(which, i);
    }
  }
```

```
## 49771
## 58927
## 63153
## 64693
## 74842
## 101575
## 103323
## 113838
## 121830
## 152054
## 168654
## 178390
## 211784
## 225908
## 253759
## 298626
## 303566
## 316746
## 317968
## 325175
## 400407
## 491595
## 492805
## 498906
```

```
x = which;
length(x);
```

```
## [1] 24
```

Rolling the Dice

- You have 3 dice.
- Each dice has the numbers `1:10` ... they are ten-sided die ("decader" die).
- Write the necessary `for-loops` to capture all possible outcomes of rolling the three dice at the same time.
- A dataframe `myrolls` should have three columns: `dice.1`, `dice.2`, `dice.3` plus a fourth column `roll.total` which is the sum `dice.1 + dice.2 + dice.3` of one iteration of the nested `for loop`.
- Report the dimensions `dim` of `myrolls`.
- Create a table `outcomes.table` that summarizes the counts of the `myrolls$roll.total`
- Transform the table to a dataframe `outcomes.df`. Name the columns: c("roll.total", "count");
- Report the sum of `outcome.df$count`
- Create a new column `outcomes.df$prob` (Probability) that determines the probability of that row given the total sum of the `count` column.

- Display the dataframe.

```
## your code goes here ...

dice.1 = dice.2 = dice.3 = 1:10;

myrolls = NULL;
for(d1 in dice.1)
  {
  for(d2 in dice.2)
    {
    for(d3 in dice.3)
      {
      roll.total = d1 + d2 + d3;
      row = c(d1, d2, d3, roll.total);
      myrolls = rbind(myrolls, row);
      }
    }
  }

myrolls = as.data.frame(myrolls);
colnames(myrolls) = c("dice.1", "dice.2", "dice.3", "roll.total");

myrolls;
```

Setting Up the Dice Scenario

```
##         dice.1 dice.2 dice.3 roll.total
## row          1      1      1          3
## row.1        1      1      2          4
## row.2        1      1      3          5
## row.3        1      1      4          6
## row.4        1      1      5          7
## row.5        1      1      6          8
## row.6        1      1      7          9
## row.7        1      1      8         10
## row.8        1      1      9         11
## row.9        1      1     10         12
## row.10       1      2      1          4
## row.11       1      2      2          5
## row.12       1      2      3          6
## row.13       1      2      4          7
## row.14       1      2      5          8
## row.15       1      2      6          9
## row.16       1      2      7         10
## row.17       1      2      8         11
## row.18       1      2      9         12
## row.19       1      2     10         13
## row.20       1      3      1          5
## row.21       1      3      2          6
## row.22       1      3      3          7
## row.23       1      3      4          8
## row.24       1      3      5          9
## row.25       1      3      6         10
```

```
## row.26       1      3      7         11
## row.27       1      3      8         12
## row.28       1      3      9         13
## row.29       1      3     10         14
## row.30       1      4      1          6
## row.31       1      4      2          7
## row.32       1      4      3          8
## row.33       1      4      4          9
## row.34       1      4      5         10
## row.35       1      4      6         11
## row.36       1      4      7         12
## row.37       1      4      8         13
## row.38       1      4      9         14
## row.39       1      4     10         15
## row.40       1      5      1          7
## row.41       1      5      2          8
## row.42       1      5      3          9
## row.43       1      5      4         10
## row.44       1      5      5         11
## row.45       1      5      6         12
## row.46       1      5      7         13
## row.47       1      5      8         14
## row.48       1      5      9         15
## row.49       1      5     10         16
## row.50       1      6      1          8
## row.51       1      6      2          9
## row.52       1      6      3         10
## row.53       1      6      4         11
## row.54       1      6      5         12
## row.55       1      6      6         13
## row.56       1      6      7         14
## row.57       1      6      8         15
## row.58       1      6      9         16
## row.59       1      6     10         17
## row.60       1      7      1          9
## row.61       1      7      2         10
## row.62       1      7      3         11
## row.63       1      7      4         12
## row.64       1      7      5         13
## row.65       1      7      6         14
## row.66       1      7      7         15
## row.67       1      7      8         16
## row.68       1      7      9         17
## row.69       1      7     10         18
## row.70       1      8      1         10
## row.71       1      8      2         11
## row.72       1      8      3         12
## row.73       1      8      4         13
## row.74       1      8      5         14
## row.75       1      8      6         15
## row.76       1      8      7         16
## row.77       1      8      8         17
## row.78       1      8      9         18
## row.79       1      8     10         19
```

```
## row.80       1      9      1         11
## row.81       1      9      2         12
## row.82       1      9      3         13
## row.83       1      9      4         14
## row.84       1      9      5         15
## row.85       1      9      6         16
## row.86       1      9      7         17
## row.87       1      9      8         18
## row.88       1      9      9         19
## row.89       1      9     10         20
## row.90       1     10      1         12
## row.91       1     10      2         13
## row.92       1     10      3         14
## row.93       1     10      4         15
## row.94       1     10      5         16
## row.95       1     10      6         17
## row.96       1     10      7         18
## row.97       1     10      8         19
## row.98       1     10      9         20
## row.99       1     10     10         21
## row.100      2      1      1          4
## row.101      2      1      2          5
## row.102      2      1      3          6
## row.103      2      1      4          7
## row.104      2      1      5          8
## row.105      2      1      6          9
## row.106      2      1      7         10
## row.107      2      1      8         11
## row.108      2      1      9         12
## row.109      2      1     10         13
## row.110      2      2      1          5
## row.111      2      2      2          6
## row.112      2      2      3          7
## row.113      2      2      4          8
## row.114      2      2      5          9
## row.115      2      2      6         10
## row.116      2      2      7         11
## row.117      2      2      8         12
## row.118      2      2      9         13
## row.119      2      2     10         14
## row.120      2      3      1          6
## row.121      2      3      2          7
## row.122      2      3      3          8
## row.123      2      3      4          9
## row.124      2      3      5         10
## row.125      2      3      6         11
## row.126      2      3      7         12
## row.127      2      3      8         13
## row.128      2      3      9         14
## row.129      2      3     10         15
## row.130      2      4      1          7
## row.131      2      4      2          8
## row.132      2      4      3          9
## row.133      2      4      4         10
```

```
## row.134      2      4      5         11
## row.135      2      4      6         12
## row.136      2      4      7         13
## row.137      2      4      8         14
## row.138      2      4      9         15
## row.139      2      4     10         16
## row.140      2      5      1          8
## row.141      2      5      2          9
## row.142      2      5      3         10
## row.143      2      5      4         11
## row.144      2      5      5         12
## row.145      2      5      6         13
## row.146      2      5      7         14
## row.147      2      5      8         15
## row.148      2      5      9         16
## row.149      2      5     10         17
## row.150      2      6      1          9
## row.151      2      6      2         10
## row.152      2      6      3         11
## row.153      2      6      4         12
## row.154      2      6      5         13
## row.155      2      6      6         14
## row.156      2      6      7         15
## row.157      2      6      8         16
## row.158      2      6      9         17
## row.159      2      6     10         18
## row.160      2      7      1         10
## row.161      2      7      2         11
## row.162      2      7      3         12
## row.163      2      7      4         13
## row.164      2      7      5         14
## row.165      2      7      6         15
## row.166      2      7      7         16
## row.167      2      7      8         17
## row.168      2      7      9         18
## row.169      2      7     10         19
## row.170      2      8      1         11
## row.171      2      8      2         12
## row.172      2      8      3         13
## row.173      2      8      4         14
## row.174      2      8      5         15
## row.175      2      8      6         16
## row.176      2      8      7         17
## row.177      2      8      8         18
## row.178      2      8      9         19
## row.179      2      8     10         20
## row.180      2      9      1         12
## row.181      2      9      2         13
## row.182      2      9      3         14
## row.183      2      9      4         15
## row.184      2      9      5         16
## row.185      2      9      6         17
## row.186      2      9      7         18
## row.187      2      9      8         19
```

```
## row.188      2      9      9         20
## row.189      2      9     10         21
## row.190      2     10      1         13
## row.191      2     10      2         14
## row.192      2     10      3         15
## row.193      2     10      4         16
## row.194      2     10      5         17
## row.195      2     10      6         18
## row.196      2     10      7         19
## row.197      2     10      8         20
## row.198      2     10      9         21
## row.199      2     10     10         22
## row.200      3      1      1          5
## row.201      3      1      2          6
## row.202      3      1      3          7
## row.203      3      1      4          8
## row.204      3      1      5          9
## row.205      3      1      6         10
## row.206      3      1      7         11
## row.207      3      1      8         12
## row.208      3      1      9         13
## row.209      3      1     10         14
## row.210      3      2      1          6
## row.211      3      2      2          7
## row.212      3      2      3          8
## row.213      3      2      4          9
## row.214      3      2      5         10
## row.215      3      2      6         11
## row.216      3      2      7         12
## row.217      3      2      8         13
## row.218      3      2      9         14
## row.219      3      2     10         15
## row.220      3      3      1          7
## row.221      3      3      2          8
## row.222      3      3      3          9
## row.223      3      3      4         10
## row.224      3      3      5         11
## row.225      3      3      6         12
## row.226      3      3      7         13
## row.227      3      3      8         14
## row.228      3      3      9         15
## row.229      3      3     10         16
## row.230      3      4      1          8
## row.231      3      4      2          9
## row.232      3      4      3         10
## row.233      3      4      4         11
## row.234      3      4      5         12
## row.235      3      4      6         13
## row.236      3      4      7         14
## row.237      3      4      8         15
## row.238      3      4      9         16
## row.239      3      4     10         17
## row.240      3      5      1          9
## row.241      3      5      2         10
```

```
## row.242      3      5      3         11
## row.243      3      5      4         12
## row.244      3      5      5         13
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```

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```

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## row.818      9      2      9         20
## row.819      9      2     10         21
## row.820      9      3      1         13
## row.821      9      3      2         14
## row.822      9      3      3         15
## row.823      9      3      4         16
## row.824      9      3      5         17
## row.825      9      3      6         18
## row.826      9      3      7         19
## row.827      9      3      8         20
## row.828      9      3      9         21
## row.829      9      3     10         22
## row.830      9      4      1         14
## row.831      9      4      2         15
## row.832      9      4      3         16
## row.833      9      4      4         17
## row.834      9      4      5         18
## row.835      9      4      6         19
```

```
## row.836      9      4      7         20
## row.837      9      4      8         21
## row.838      9      4      9         22
## row.839      9      4     10         23
## row.840      9      5      1         15
## row.841      9      5      2         16
## row.842      9      5      3         17
## row.843      9      5      4         18
## row.844      9      5      5         19
## row.845      9      5      6         20
## row.846      9      5      7         21
## row.847      9      5      8         22
## row.848      9      5      9         23
## row.849      9      5     10         24
## row.850      9      6      1         16
## row.851      9      6      2         17
## row.852      9      6      3         18
## row.853      9      6      4         19
## row.854      9      6      5         20
## row.855      9      6      6         21
## row.856      9      6      7         22
## row.857      9      6      8         23
## row.858      9      6      9         24
## row.859      9      6     10         25
## row.860      9      7      1         17
## row.861      9      7      2         18
## row.862      9      7      3         19
## row.863      9      7      4         20
## row.864      9      7      5         21
## row.865      9      7      6         22
## row.866      9      7      7         23
## row.867      9      7      8         24
## row.868      9      7      9         25
## row.869      9      7     10         26
## row.870      9      8      1         18
## row.871      9      8      2         19
## row.872      9      8      3         20
## row.873      9      8      4         21
## row.874      9      8      5         22
## row.875      9      8      6         23
## row.876      9      8      7         24
## row.877      9      8      8         25
## row.878      9      8      9         26
## row.879      9      8     10         27
## row.880      9      9      1         19
## row.881      9      9      2         20
## row.882      9      9      3         21
## row.883      9      9      4         22
## row.884      9      9      5         23
## row.885      9      9      6         24
## row.886      9      9      7         25
## row.887      9      9      8         26
## row.888      9      9      9         27
## row.889      9      9     10         28
```

```
## row.890      9     10      1         20
## row.891      9     10      2         21
## row.892      9     10      3         22
## row.893      9     10      4         23
## row.894      9     10      5         24
## row.895      9     10      6         25
## row.896      9     10      7         26
## row.897      9     10      8         27
## row.898      9     10      9         28
## row.899      9     10     10         29
## row.900     10      1      1         12
## row.901     10      1      2         13
## row.902     10      1      3         14
## row.903     10      1      4         15
## row.904     10      1      5         16
## row.905     10      1      6         17
## row.906     10      1      7         18
## row.907     10      1      8         19
## row.908     10      1      9         20
## row.909     10      1     10         21
## row.910     10      2      1         13
## row.911     10      2      2         14
## row.912     10      2      3         15
## row.913     10      2      4         16
## row.914     10      2      5         17
## row.915     10      2      6         18
## row.916     10      2      7         19
## row.917     10      2      8         20
## row.918     10      2      9         21
## row.919     10      2     10         22
## row.920     10      3      1         14
## row.921     10      3      2         15
## row.922     10      3      3         16
## row.923     10      3      4         17
## row.924     10      3      5         18
## row.925     10      3      6         19
## row.926     10      3      7         20
## row.927     10      3      8         21
## row.928     10      3      9         22
## row.929     10      3     10         23
## row.930     10      4      1         15
## row.931     10      4      2         16
## row.932     10      4      3         17
## row.933     10      4      4         18
## row.934     10      4      5         19
## row.935     10      4      6         20
## row.936     10      4      7         21
## row.937     10      4      8         22
## row.938     10      4      9         23
## row.939     10      4     10         24
## row.940     10      5      1         16
## row.941     10      5      2         17
## row.942     10      5      3         18
## row.943     10      5      4         19
```

```
## row.944     10      5      5         20
## row.945     10      5      6         21
## row.946     10      5      7         22
## row.947     10      5      8         23
## row.948     10      5      9         24
## row.949     10      5     10         25
## row.950     10      6      1         17
## row.951     10      6      2         18
## row.952     10      6      3         19
## row.953     10      6      4         20
## row.954     10      6      5         21
## row.955     10      6      6         22
## row.956     10      6      7         23
## row.957     10      6      8         24
## row.958     10      6      9         25
## row.959     10      6     10         26
## row.960     10      7      1         18
## row.961     10      7      2         19
## row.962     10      7      3         20
## row.963     10      7      4         21
## row.964     10      7      5         22
## row.965     10      7      6         23
## row.966     10      7      7         24
## row.967     10      7      8         25
## row.968     10      7      9         26
## row.969     10      7     10         27
## row.970     10      8      1         19
## row.971     10      8      2         20
## row.972     10      8      3         21
## row.973     10      8      4         22
## row.974     10      8      5         23
## row.975     10      8      6         24
## row.976     10      8      7         25
## row.977     10      8      8         26
## row.978     10      8      9         27
## row.979     10      8     10         28
## row.980     10      9      1         20
## row.981     10      9      2         21
## row.982     10      9      3         22
## row.983     10      9      4         23
## row.984     10      9      5         24
## row.985     10      9      6         25
## row.986     10      9      7         26
## row.987     10      9      8         27
## row.988     10      9      9         28
## row.989     10      9     10         29
## row.990     10     10      1         21
## row.991     10     10      2         22
## row.992     10     10      3         23
## row.993     10     10      4         24
## row.994     10     10      5         25
## row.995     10     10      6         26
## row.996     10     10      7         27
## row.997     10     10      8         28
```

```
## row.998     10     10      9         29
## row.999     10     10     10         30
```

```
print("Dimensions of myrolls");
```

```
## [1] "Dimensions of myrolls"
```

```
dim(myrolls);
```

```
## [1] 1000    4
```

```
outcomes.table = table(myrolls$roll.total);
outcomes.df = as.data.frame(outcomes.table);
  colnames(outcomes.df) = c("roll.total", "count");


total.sum = sum(outcomes.df$count);
print("Sum of outcomes.df$count");
```

```
## [1] "Sum of outcomes.df$count"
```

```
total.sum;
```

```
## [1] 1000
```

```
outcomes.df$prob = outcomes.df$count / total.sum;
outcomes.df;
```

```
##    roll.total count  prob
## 1           3     1 0.001
## 2           4     3 0.003
## 3           5     6 0.006
## 4           6    10 0.010
## 5           7    15 0.015
## 6           8    21 0.021
## 7           9    28 0.028
## 8          10    36 0.036
## 9          11    45 0.045
## 10         12    55 0.055
## 11         13    63 0.063
## 12         14    69 0.069
## 13         15    73 0.073
## 14         16    75 0.075
## 15         17    75 0.075
## 16         18    73 0.073
## 17         19    69 0.069
## 18         20    63 0.063
## 19         21    55 0.055
## 20         22    45 0.045
## 21         23    36 0.036
## 22         24    28 0.028
## 23         25    21 0.021
## 24         26    15 0.015
## 25         27    10 0.010
## 26         28     6 0.006
## 27         29     3 0.003
## 28         30     1 0.001
```

Viewing a subset of data to answer a question

- How many ways can I roll a 23 when I throw the dice at the same time? What is the probability that I roll a 23 on a single throw?

```
# if you don't have the latest version of humanVerseWSU, you can access the function as follows:
# library(devtools);
# source_url(paste0( path.github, "humanVerseWSU/R/functions-dataframe.R" ));

sub.myrolls = subsetDataFrame(myrolls, "roll.total", "==", 23);

sub.myrolls;
```

```
##         dice.1 dice.2 dice.3 roll.total
## row.299      3     10     10         23
## row.389      4      9     10         23
## row.398      4     10      9         23
## row.479      5      8     10         23
## row.488      5      9      9         23
## row.497      5     10      8         23
## row.569      6      7     10         23
## row.578      6      8      9         23
## row.587      6      9      8         23
## row.596      6     10      7         23
## row.659      7      6     10         23
## row.668      7      7      9         23
## row.677      7      8      8         23
## row.686      7      9      7         23
## row.695      7     10      6         23
## row.749      8      5     10         23
## row.758      8      6      9         23
## row.767      8      7      8         23
## row.776      8      8      7         23
## row.785      8      9      6         23
## row.794      8     10      5         23
## row.839      9      4     10         23
## row.848      9      5      9         23
## row.857      9      6      8         23
## row.866      9      7      7         23
## row.875      9      8      6         23
## row.884      9      9      5         23
## row.893      9     10      4         23
## row.929     10      3     10         23
## row.938     10      4      9         23
## row.947     10      5      8         23
## row.956     10      6      7         23
## row.965     10      7      6         23
## row.974     10      8      5         23
## row.983     10      9      4         23
## row.992     10     10      3         23
```

```
sub.outcomes.df = subsetDataFrame(outcomes.df, "roll.total", "==", 23);

sub.outcomes.df;
```

```
##    roll.total count  prob
```

```
## 21         23    36 0.036
```

(10 points) Questions from the Dice simulation

Roll 23

- How many ways can I roll a 23 when I throw the dice at the same time? What is the probability that I roll a 23 on a single throw?

Roll 12 or 22

- What is the probability that I roll a 12 or a 22 on a single throw?

```
## your code goes here ... if necessary

sub.outcomes.df = subsetDataFrame(outcomes.df, "roll.total", "==", 12);

sub.outcomes.df;
```

```
##    roll.total count  prob
## 10         12    55 0.055
```

```
sub.outcomes.df = subsetDataFrame(outcomes.df, "roll.total", "==", 22);

sub.outcomes.df;
```

```
##    roll.total count  prob
## 20         22    45 0.045
```

Roll 26 or 29

- What is the probability that I roll a 26 or a 29 on a single throw?

```
## your code goes here ... if necessary
sub.outcomes.df = subsetDataFrame(outcomes.df, "roll.total", "==", 26);

sub.outcomes.df;
```

```
##    roll.total count  prob
## 24         26    15 0.015
```

```
sub.outcomes.df = subsetDataFrame(outcomes.df, "roll.total", "==", 29);

sub.outcomes.df;
```

```
##    roll.total count  prob
## 27         29     3 0.003
```

Roll 3 once/twice in a row

- What is the probability that I roll a 3 on a single throw? What is the probability that I roll a 3 twice in a row? First throw = 3 **AND** second throw = 3?

```
## your code goes here ... if necessary
sub.myrolls = subsetDataFrame(myrolls, "roll.total", "==", 3);

sub.myrolls;
```

```
##     dice.1 dice.2 dice.3 roll.total
## row      1      1      1          3
```

```
sub.outcomes.df = subsetDataFrame(outcomes.df, "roll.total", "==", 3);

sub.outcomes.df;
```

```
##   roll.total count  prob
## 1          3     1 0.001
```

Roll 12 or lower

- What is the probability that I roll at most a 12 on a single throw? That is, a 12 or lower ...

```
## your code goes here ... if necessary
```

INITIAL EXPLORATION OF REAL DATA

We are going to use exploratory techniques to examine some Indeed.com data. If you recall, this `job` data examines how many jobs reference a certain keyword. Every Monday morning at 12:00:00AM EST (using a scheduler `crontab`), this data collection is performed. A few weeks ago, I added some new keys words. The data set we have consists of 5 weeks: `2020-38` to `2020-42`.

- For each "search phrase", I go to Indeed.com and download the first page of results.

- From this first page, I grab the "total count"
- An example is shown in a screenshot, taken this week.

Source: Data provenance history

Import "jobs" data

- Run code to import the data `jobs`.

```
jobs = utils::read.csv( paste0(path.mshaffer, "_data_/indeed-jobs.txt"), header=TRUE, quote="", sep="|")

colnames(jobs) = c("year.week", "search.query", "job.count");
jobs;
```

```
##     year.week               search.query job.count
## 1     2020-38                      Excel    375999
## 2     2020-38          Microsoft Office    223663
## 3     2020-38                        C++    158317
## 4     2020-38                         C#    158317
## 5     2020-38                   Database    124631
## 6     2020-38          Computer Science    107584
## 7     2020-38                Data entry     80465
## 8     2020-38                  modeling     78330
## 9     2020-38                      SQL+     63365
## 10    2020-38                       SQL     63365
## 11    2020-38                      .NET     62362
## 12    2020-38                    Python     56538
## 13    2020-38                    Google     50707
## 14    2020-38                      Java     49993
## 15    2020-38                Statistics     49383
## 16    2020-38                         R     46997
## 17    2020-38                     react     41603
## 18    2020-38             Data analysis     38384
```

```
## 19    2020-38                    HTML     38062
## 20    2020-38              Javascript     35938
## 21    2020-38                  Oracle     30143
## 22    2020-38                     SAP     29054
## 23    2020-38         Data management     25694
## 24    2020-38        machine learning     23197
## 25    2020-38                   scrum     21599
## 26    2020-38          Data analytics     21546
## 27    2020-38                     CSS     21303
## 28    2020-38                     API     20997
## 29    2020-38                     git     18270
## 30    2020-38                     Git     18270
## 31    2020-38         Object oriented     17548
## 32    2020-38                     PCA     17047
## 33    2020-38                      ai     16066
## 34    2020-38               Big data     15737
## 35    2020-38               debugging     15718
## 36    2020-38            Data science     15044
## 37    2020-38                 Android     13375
## 38    2020-38                 Tableau     13321
## 39    2020-38      agile development     13080
## 40    2020-38   Business intelligence     13032
## 41    2020-38               data sets     12875
## 42    2020-38              full stack     12799
## 43    2020-38                     PHP     12367
## 44    2020-38               PhotoShop     12275
## 45    2020-38                     iOS     11938
## 46    2020-38                 angular     11386
## 47    2020-38                   Mysql     10809
## 48    2020-38         design patterns     10689
## 49    2020-38                     SAS     10553
## 50    2020-38         Market Research     10489
## 51    2020-38               scrubbing     10141
## 52    2020-38    Database management     10097
## 53    2020-38 artificial intelligence      8968
## 54    2020-38               usability      8680
## 55    2020-38      Business analysis      8674
## 56    2020-38                datasets      8111
## 57    2020-38     Data Visualization      8001
## 58    2020-38       Business Analyst      7932
## 59    2020-38   relational databases      7895
## 60    2020-38                 Jquery      7745
## 61    2020-38             regression      7293
## 62    2020-38         version control      7259
## 63    2020-38        Google analytics      6544
## 64    2020-38            unit testing      6530
## 65    2020-38          Data warehouse      6320
## 66    2020-38                 Github      6121
## 67    2020-38    relational database      5931
## 68    2020-38             simulations      5749
## 69    2020-38            benchmarking      5566
## 70    2020-38                firmware      5558
## 71    2020-38                 Power BI      5266
## 72    2020-38              Postgresql      4824
```

```
## 73    2020-38               Data Analyst      4607
## 74    2020-38             Market Analysis     4253
## 75    2020-38               deep learning     4003
## 76    2020-38              Data scientist     3992
## 77    2020-38          Business analytics     3952
## 78    2020-38                   Bootstrap     3923
## 79    2020-38                 Windows 10      3858
## 80    2020-38                       Slack     3492
## 81    2020-38              Data Engineer      3308
## 82    2020-38                      arcgis     2846
## 83    2020-38               Visual Basic      2370
## 84    2020-38 natural language processing     2304
## 85    2020-38                  clustering     2237
## 86    2020-38           Data manipulation     2159
## 87    2020-38                        SPSS     2150
## 88    2020-38           Report generation     2025
## 89    2020-38                    Mac OS      1825
## 90    2020-38            Algorithm Design     1734
## 91    2020-38                         NLP     1692
## 92    2020-38                     merging     1632
## 93    2020-38        statistical modeling     1616
## 94    2020-38          Generating reports     1602
## 95    2020-38                   Wireshark     1547
## 96    2020-38                      Looker     1388
## 97    2020-38                multivariate     1342
## 98    2020-38              neural networks     1231
## 99    2020-38              Custom reports     1187
## 100   2020-38                       Stata     1186
## 101   2020-38          Marketing Research     1036
## 102   2020-38                    QlikView      895
## 103   2020-38            Data maintenance      860
## 104   2020-38                          D3      765
## 105   2020-38                Statistician      702
## 106   2020-38                        Curl      692
## 107   2020-38             C++ programming      688
## 108   2020-38               C programming      688
## 109   2020-38                    Spotfire      572
## 110   2020-38             Biostatistician      568
## 111   2020-38                         LSA      567
## 112   2020-38                    MariaDB       547
## 113   2020-38              decision trees      546
## 114   2020-38                   Qualtrics      491
## 115   2020-38         Git version control      490
## 116   2020-38                     Delphi      473
## 117   2020-38                       Domo      470
## 118   2020-38                       TSQL      447
## 119   2020-38           scenario analysis      438
## 120   2020-38                     SQLite      400
## 121   2020-38               neural network      399
## 122   2020-38          logistic regression      395
## 123   2020-38               Data wrangling      380
## 124   2020-38           Insights analytics      374
## 125   2020-38                     Debian      364
## 126   2020-38                Lab Notebook      364
```

```
## 127   2020-38        Sensitivity Analysis       362
## 128   2020-38                  Using R       335
## 129   2020-38        well-documented code       229
## 130   2020-38                     SVD       226
## 131   2020-38           Actuarial Analyst       208
## 132   2020-38              Power Analysis       200
## 133   2020-38               document code       197
## 134   2020-38                     SVM       196
## 135   2020-38                  k-means       157
## 136   2020-38                     LDA       135
## 137   2020-38                 R Studio       132
## 138   2020-38                   ggplot       130
## 139   2020-38                   plotly       128
## 140   2020-38                  SiSense       124
## 141   2020-38                  RStudio       117
## 142   2020-38             Web scraping       116
## 143   2020-38           Online analytics       115
## 144   2020-38           Insights Analyst       110
## 145   2020-38                 Highcharts        97
## 146   2020-38           Insights analysis        93
## 147   2020-38                    Birst        90
## 148   2020-38          Actuarial analysis        80
## 149   2020-38                      knn        47
## 150   2020-38                tidyverse        40
## 151   2020-38          spatial statistics        38
## 152   2020-38                 R packages        36
## 153   2020-38           Insurance Analyst        34
## 154   2020-38              C++ programmer        25
## 155   2020-38           Insurance analysis        25
## 156   2020-38                C programmer        25
## 157   2020-38                     Gauss        24
## 158   2020-38         Insurance analytics        23
## 159   2020-38                 GoodData        21
## 160   2020-38         Actuarial analytics        20
## 161   2020-38                 R Markdown        17
## 162   2020-38               Data scraping        16
## 163   2020-38     hierarchical clustering        13
## 164   2020-38                    kmeans        12
## 165   2020-38                Datawrapper         9
## 166   2020-38             Actuary Analyst         9
## 167   2020-38                FusionCharts         9
## 168   2020-38      Computational Engineer         8
## 169   2020-38              record linkage         7
## 170   2020-38             Insight Squared         5
## 171   2020-38                 R Developer         4
## 172   2020-38                   Dundas BI         3
## 173   2020-38           Actuary analytics         3
## 174   2020-38             Polling Analyst         2
## 175   2020-38                 Highcharter         1
## 176   2020-38            Polling analysis         1
## 177   2020-38           Polling analytics         1
## 178   2020-38                    Datapine         1
## 179   2020-38          Analytic Scripting         1
## 180   2020-38                   Zebra BI         0
```

```
## 181   2020-38            Actuary analysis        0
## 182   2020-39                       Excel   385706
## 183   2020-39           Microsoft Office   228397
## 184   2020-39                         C++   161156
## 185   2020-39                          C#   161156
## 186   2020-39                    Database   127108
## 187   2020-39           Computer Science   109819
## 188   2020-39                 Data entry    83373
## 189   2020-39                   modeling    79713
## 190   2020-39                       .NET    65649
## 191   2020-39                        SQL    64810
## 192   2020-39                       SQL+    64810
## 193   2020-39                     Python    57841
## 194   2020-39                     Google    51926
## 195   2020-39                       Java    51155
## 196   2020-39                 Statistics    50588
## 197   2020-39                          R    47809
## 198   2020-39                      react    42155
## 199   2020-39              Data analysis    39447
## 200   2020-39                       HTML    38810
## 201   2020-39                 Javascript    36633
## 202   2020-39                     Oracle    30729
## 203   2020-39                        SAP    29657
## 204   2020-39           Data management    26198
## 205   2020-39          machine learning    24005
## 206   2020-39            Data analytics    22342
## 207   2020-39                     scrum    22098
## 208   2020-39                       API    21830
## 209   2020-39                       CSS    21739
## 210   2020-39                       git    18617
## 211   2020-39                       Git    18617
## 212   2020-39          Object oriented    18023
## 213   2020-39                       PCA    17248
## 214   2020-39                        ai    16462
## 215   2020-39                  Big data    15997
## 216   2020-39                 debugging    15936
## 217   2020-39             Data science    15587
## 218   2020-39                  Tableau    13735
## 219   2020-39                  Android    13722
## 220   2020-39    Business intelligence    13524
## 221   2020-39                data sets    13445
## 222   2020-39        agile development    13240
## 223   2020-39               full stack    13164
## 224   2020-39                PhotoShop    12622
## 225   2020-39                      PHP    12610
## 226   2020-39                      iOS    12253
## 227   2020-39                  angular    11677
## 228   2020-39           design patterns    11132
## 229   2020-39                      SAS    11039
## 230   2020-39                    Mysql    10942
## 231   2020-39           Market Research    10748
## 232   2020-39                 scrubbing    10364
## 233   2020-39      Database management    10183
## 234   2020-39  artificial intelligence     9426
```

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## 235   2020-39           Business analysis      8873
## 236   2020-39                   usability      8847
## 237   2020-39                    datasets      8304
## 238   2020-39             Business Analyst      8153
## 239   2020-39          relational databases      8093
## 240   2020-39           Data Visualization      8012
## 241   2020-39                      Jquery      7878
## 242   2020-39              version control      7422
## 243   2020-39                   regression      7332
## 244   2020-39             Google analytics      6837
## 245   2020-39                 unit testing      6669
## 246   2020-39               Data warehouse      6505
## 247   2020-39                      Github      6363
## 248   2020-39           relational database      5997
## 249   2020-39                  simulations      5861
## 250   2020-39                     firmware      5673
## 251   2020-39                benchmarking      5671
## 252   2020-39                     Power BI      5456
## 253   2020-39                   Postgresql      4943
## 254   2020-39                Data Analyst      4688
## 255   2020-39              Market Analysis      4332
## 256   2020-39                deep learning      4171
## 257   2020-39           Business analytics      4104
## 258   2020-39               Data scientist      4040
## 259   2020-39                   Windows 10      4028
## 260   2020-39                    Bootstrap      3886
## 261   2020-39                        Slack      3600
## 262   2020-39                Data Engineer      3340
## 263   2020-39                       arcgis      2898
## 264   2020-39                 Visual Basic      2415
## 265   2020-39 natural language processing      2389
## 266   2020-39                   clustering      2282
## 267   2020-39           Data manipulation      2247
## 268   2020-39                        SPSS      2237
## 269   2020-39           Report generation      2102
## 270   2020-39                      Mac OS      1909
## 271   2020-39            Algorithm Design      1760
## 272   2020-39                         NLP      1715
## 273   2020-39         statistical modeling      1647
## 274   2020-39                   Wireshark      1619
## 275   2020-39                     merging      1602
## 276   2020-39           Generating reports      1588
## 277   2020-39                      Looker      1423
## 278   2020-39                 multivariate      1370
## 279   2020-39                       Stata      1271
## 280   2020-39              neural networks      1243
## 281   2020-39              Custom reports      1194
## 282   2020-39           Marketing Research      1120
## 283   2020-39                     QlikView       917
## 284   2020-39            Data maintenance       863
## 285   2020-39                          D3       771
## 286   2020-39                        Curl       753
## 287   2020-39                Statistician       736
## 288   2020-39                C programming       695
```

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## 289   2020-39            C++ programming       695
## 290   2020-39                   Spotfire       602
## 291   2020-39                        LSA       602
## 292   2020-39           Biostatistician       588
## 293   2020-39                   MariaDB       582
## 294   2020-39                  Qualtrics       568
## 295   2020-39             decision trees       551
## 296   2020-39                      Domo       496
## 297   2020-39       Git version control       491
## 298   2020-39                    Delphi       481
## 299   2020-39                      TSQL       457
## 300   2020-39          scenario analysis       441
## 301   2020-39                    SQLite       408
## 302   2020-39              Lab Notebook       400
## 303   2020-39             neural network       397
## 304   2020-39             Data wrangling       391
## 305   2020-39                    Debian       387
## 306   2020-39       logistic regression       384
## 307   2020-39        Insights analytics       359
## 308   2020-39      Sensitivity Analysis       357
## 309   2020-39                 Using R       341
## 310   2020-39                     SVD       230
## 311   2020-39      well-documented code       226
## 312   2020-39         Actuarial Analyst       216
## 313   2020-39                     SVM       212
## 314   2020-39            Power Analysis       206
## 315   2020-39             document code       203
## 316   2020-39          Insights Analyst       173
## 317   2020-39                  k-means       157
## 318   2020-39                     LDA       141
## 319   2020-39                  SiSense       141
## 320   2020-39                R Studio       137
## 321   2020-39          Online analytics       132
## 322   2020-39                   ggplot       127
## 323   2020-39                   plotly       124
## 324   2020-39                  RStudio       122
## 325   2020-39             Web scraping       117
## 326   2020-39               Highcharts       100
## 327   2020-39          Insights analysis       100
## 328   2020-39                    Birst        96
## 329   2020-39         Actuarial analysis        77
## 330   2020-39                      knn        46
## 331   2020-39              R packages        39
## 332   2020-39               tidyverse        38
## 333   2020-39         spatial statistics        37
## 334   2020-39          Insurance Analyst        33
## 335   2020-39       Insurance analytics        27
## 336   2020-39                 GoodData        26
## 337   2020-39        Insurance analysis        26
## 338   2020-39       Actuarial analytics        26
## 339   2020-39                    Gauss        23
## 340   2020-39            C++ programmer        22
## 341   2020-39              C programmer        22
## 342   2020-39                 R Markdown        20
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## 343   2020-39              Data scraping        20
## 344   2020-39    hierarchical clustering        14
## 345   2020-39                    kmeans        10
## 346   2020-39            record linkage        10
## 347   2020-39           Actuary Analyst        10
## 348   2020-39    Computational Engineer        10
## 349   2020-39               Datawrapper         9
## 350   2020-39              FusionCharts         8
## 351   2020-39              R Developer         5
## 352   2020-39          Insight Squared         5
## 353   2020-39         Actuary analytics         4
## 354   2020-39                 Dundas BI         3
## 355   2020-39          Polling Analyst         1
## 356   2020-39          Polling analysis         1
## 357   2020-39               Highcharter         1
## 358   2020-39         Polling analytics         1
## 359   2020-39        Analytic Scripting         1
## 360   2020-39                  Datapine         1
## 361   2020-39          Actuary analysis         0
## 362   2020-39                 Zebra BI         0
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## 364   2020-40          Microsoft Office    231979
## 365   2020-40                      C++    163044
## 366   2020-40                       C#    163044
## 367   2020-40                 Database    129835
## 368   2020-40          Computer Science    112070
## 369   2020-40                Data entry     84427
## 370   2020-40                  modeling     80792
## 371   2020-40                      .NET     67350
## 372   2020-40                       SQL     66175
## 373   2020-40                      SQL+     66175
## 374   2020-40                    Python     58898
## 375   2020-40                    Google     53052
## 376   2020-40                      Java     52113
## 377   2020-40                Statistics     51850
## 378   2020-40                         R     49571
## 379   2020-40                   react     42576
## 380   2020-40             Data analysis     40455
## 381   2020-40                      HTML     40160
## 382   2020-40                Javascript     37554
## 383   2020-40                    Oracle     31373
## 384   2020-40                       SAP     30335
## 385   2020-40           Data management     26442
## 386   2020-40          machine learning     24489
## 387   2020-40            Data analytics     23044
## 388   2020-40                     scrum     22891
## 389   2020-40                       API     22159
## 390   2020-40                       CSS     21960
## 391   2020-40                       git     19232
## 392   2020-40          Object oriented     18296
## 393   2020-40                       PCA     17219
## 394   2020-40                        ai     16825
## 395   2020-40                  Big data     16463
## 396   2020-40                 debugging     16386
```

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## 397   2020-40                Data science     15998
## 398   2020-40                     Android     14295
## 399   2020-40                     Tableau     13943
## 400   2020-40       Business intelligence     13865
## 401   2020-40                   data sets     13768
## 402   2020-40           agile development     13570
## 403   2020-40                  full stack     13471
## 404   2020-40                         PHP     12962
## 405   2020-40                   PhotoShop     12824
## 406   2020-40                         iOS     12575
## 407   2020-40                     angular     11847
## 408   2020-40              design patterns     11364
## 409   2020-40                       Mysql     11137
## 410   2020-40             Market Research     11120
## 411   2020-40                         SAS     11118
## 412   2020-40         Database management     10613
## 413   2020-40                   scrubbing     10526
## 414   2020-40     artificial intelligence      9882
## 415   2020-40                   usability      9044
## 416   2020-40           Business analysis      8998
## 417   2020-40                    datasets      8394
## 418   2020-40         relational databases      8291
## 419   2020-40            Business Analyst      8278
## 420   2020-40          Data Visualization      8269
## 421   2020-40                       Jquery      7986
## 422   2020-40              version control      7588
## 423   2020-40                   regression      7529
## 424   2020-40             Google analytics      7026
## 425   2020-40                 unit testing      6764
## 426   2020-40                       Github      6661
## 427   2020-40               Data warehouse      6539
## 428   2020-40          relational database      6152
## 429   2020-40                  simulations      6007
## 430   2020-40                benchmarking      5941
## 431   2020-40                    firmware      5796
## 432   2020-40                    Power BI      5626
## 433   2020-40                  Postgresql      5070
## 434   2020-40                Data Analyst      4786
## 435   2020-40           Business analytics      4285
## 436   2020-40                deep learning      4281
## 437   2020-40                  Windows 10      4269
## 438   2020-40              Market Analysis      4260
## 439   2020-40                Data scientist      4084
## 440   2020-40                     Bootstrap      3949
## 441   2020-40                         Slack      3733
## 442   2020-40                Data Engineer      3428
## 443   2020-40                       arcgis      2935
## 444   2020-40 natural language processing      2451
## 445   2020-40                 Visual Basic      2438
## 446   2020-40                   clustering      2374
## 447   2020-40                         SPSS      2372
## 448   2020-40            Data manipulation      2229
## 449   2020-40            Report generation      2193
## 450   2020-40                       Mac OS      1902
```

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## 451   2020-40           Algorithm Design      1804
## 452   2020-40                        NLP      1768
## 453   2020-40       statistical modeling      1678
## 454   2020-40                  Wireshark      1644
## 455   2020-40                    merging      1638
## 456   2020-40         Generating reports      1606
## 457   2020-40                     Looker      1444
## 458   2020-40               multivariate      1436
## 459   2020-40           neural networks       1348
## 460   2020-40                      Stata      1336
## 461   2020-40           Custom reports       1208
## 462   2020-40         Marketing Research      1124
## 463   2020-40                  QlikView       920
## 464   2020-40           Data maintenance       850
## 465   2020-40                      Curl       784
## 466   2020-40              Statistician       783
## 467   2020-40                        D3       779
## 468   2020-40            C programming        718
## 469   2020-40          C++ programming        718
## 470   2020-40                       LSA       618
## 471   2020-40           Biostatistician       616
## 472   2020-40                  Spotfire       602
## 473   2020-40            decision trees       564
## 474   2020-40                   MariaDB       560
## 475   2020-40                 Qualtrics       551
## 476   2020-40                      Domo       515
## 477   2020-40        Git version control       510
## 478   2020-40                    Delphi       499
## 479   2020-40                      TSQL       484
## 480   2020-40          scenario analysis       465
## 481   2020-40               Lab Notebook       418
## 482   2020-40           neural network        417
## 483   2020-40                    SQLite       416
## 484   2020-40        logistic regression       412
## 485   2020-40            Data wrangling       402
## 486   2020-40                    Debian       398
## 487   2020-40       Sensitivity Analysis       363
## 488   2020-40                  Using R        355
## 489   2020-40         Insights analytics       350
## 490   2020-40                       SVD       239
## 491   2020-40             document code       218
## 492   2020-40                       SVM       218
## 493   2020-40          Actuarial Analyst       213
## 494   2020-40             Power Analysis       208
## 495   2020-40       well-documented code       207
## 496   2020-40                  k-means        156
## 497   2020-40                  SiSense        152
## 498   2020-40                      LDA        148
## 499   2020-40           Online analytics       142
## 500   2020-40                     plotly      136
## 501   2020-40                   R Studio      135
## 502   2020-40                     ggplot      133
## 503   2020-40           Insights Analyst       132
## 504   2020-40                   RStudio       129
```

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## 505   2020-40              Web scraping       123
## 506   2020-40          Insights analysis       103
## 507   2020-40                 Highcharts        97
## 508   2020-40                      Birst        84
## 509   2020-40         Actuarial analysis        83
## 510   2020-40                        knn        49
## 511   2020-40                  tidyverse        40
## 512   2020-40          Insurance Analyst        39
## 513   2020-40                 R packages        36
## 514   2020-40         spatial statistics        28
## 515   2020-40                   GoodData        28
## 516   2020-40        Insurance analytics        27
## 517   2020-40         Insurance analysis        26
## 518   2020-40                      Gauss        26
## 519   2020-40        Actuarial analytics        26
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## 521   2020-40             C++ programmer        22
## 522   2020-40              Data scraping        19
## 523   2020-40                 R Markdown        18
## 524   2020-40    hierarchical clustering        15
## 525   2020-40             record linkage        11
## 526   2020-40                     kmeans         9
## 527   2020-40     Computational Engineer         8
## 528   2020-40                Datawrapper         8
## 529   2020-40               FusionCharts         8
## 530   2020-40             Actuary Analyst         7
## 531   2020-40                 R Developer         6
## 532   2020-40             Insight Squared         4
## 533   2020-40          Actuary analytics         4
## 534   2020-40                   Dundas BI         2
## 535   2020-40                 Highcharter         1
## 536   2020-40                    Datapine         1
## 537   2020-40          Polling analytics         1
## 538   2020-40         Analytic Scripting         1
## 539   2020-40            Polling Analyst         1
## 540   2020-40           Polling analysis         0
## 541   2020-40           Actuary analysis         0
## 542   2020-40                        Git         0
## 543   2020-40                  Zebra BI         0
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## 545   2020-41            Microsoft Office    232215
## 546   2020-41                        C++    164920
## 547   2020-41                         C#    164920
## 548   2020-41                   Database    130943
## 549   2020-41            Computer Science    113809
## 550   2020-41                  Data entry     85592
## 551   2020-41                    modeling     80138
## 552   2020-41                        .NET     67493
## 553   2020-41                         SQL     67313
## 554   2020-41                        SQL+     67313
## 555   2020-41                      Python     60241
## 556   2020-41                      Google     53377
## 557   2020-41                        Java     52872
## 558   2020-41                  Statistics     52159
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## 559   2020-41                         R     49991
## 560   2020-41                     react     41047
## 561   2020-41             Data analysis     40836
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## 563   2020-41                Javascript     38358
## 564   2020-41                    Oracle     31669
## 565   2020-41                       SAP     30495
## 566   2020-41           Data management     26861
## 567   2020-41          machine learning     24859
## 568   2020-41            Data analytics     23491
## 569   2020-41                     scrum     23250
## 570   2020-41                       API     22313
## 571   2020-41                       CSS     22042
## 572   2020-41                       git     19532
## 573   2020-41                       Git     19528
## 574   2020-41          Object oriented     18612
## 575   2020-41                        ai     17491
## 576   2020-41                       PCA     17092
## 577   2020-41                 debugging     16768
## 578   2020-41                  Big data     16619
## 579   2020-41             Data science     16247
## 580   2020-41                  Tableau     14430
## 581   2020-41                  Android     14225
## 582   2020-41     Business intelligence     14173
## 583   2020-41         agile development     13804
## 584   2020-41                 data sets     13773
## 585   2020-41                full stack     13675
## 586   2020-41                       PHP     13119
## 587   2020-41                 PhotoShop     12880
## 588   2020-41                       iOS     12686
## 589   2020-41                   angular     11954
## 590   2020-41           design patterns     11495
## 591   2020-41                       SAS     11379
## 592   2020-41           Market Research     11366
## 593   2020-41                     Mysql     11195
## 594   2020-41       Database management     10594
## 595   2020-41                 scrubbing     10486
## 596   2020-41   artificial intelligence     10154
## 597   2020-41                usability      9209
## 598   2020-41         Business analysis      9104
## 599   2020-41                  datasets      8553
## 600   2020-41       Data Visualization      8497
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## 602   2020-41      relational databases      8270
## 603   2020-41                   Jquery      8014
## 604   2020-41          version control      7648
## 605   2020-41               regression      7561
## 606   2020-41         Google analytics      7060
## 607   2020-41             unit testing      6825
## 608   2020-41           Data warehouse      6763
## 609   2020-41                   Github      6593
## 610   2020-41       relational database      6192
## 611   2020-41              benchmarking      6102
## 612   2020-41               simulations      6030
```

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## 613   2020-41                    firmware      5944
## 614   2020-41                    Power BI      5832
## 615   2020-41                  Postgresql      5139
## 616   2020-41                Data Analyst      4817
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## 618   2020-41           Business analytics      4322
## 619   2020-41                deep learning      4316
## 620   2020-41              Data scientist      4210
## 621   2020-41                  Windows 10      4173
## 622   2020-41                   Bootstrap      3950
## 623   2020-41                       Slack      3789
## 624   2020-41              Data Engineer      3504
## 625   2020-41                      arcgis      2910
## 626   2020-41 natural language processing      2502
## 627   2020-41                 Visual Basic      2482
## 628   2020-41                         SPSS      2326
## 629   2020-41                   clustering      2319
## 630   2020-41            Data manipulation      2283
## 631   2020-41            Report generation      2196
## 632   2020-41                          NLP      1872
## 633   2020-41                      Mac OS      1868
## 634   2020-41             Algorithm Design      1813
## 635   2020-41          statistical modeling      1719
## 636   2020-41                   Wireshark      1678
## 637   2020-41                     merging      1644
## 638   2020-41           Generating reports      1619
## 639   2020-41                 multivariate      1450
## 640   2020-41                       Looker      1432
## 641   2020-41                        Stata      1380
## 642   2020-41              neural networks      1355
## 643   2020-41              Custom reports      1255
## 644   2020-41           Marketing Research      1174
## 645   2020-41                     QlikView       944
## 646   2020-41            Data maintenance       856
## 647   2020-41                         Curl       792
## 648   2020-41                 Statistician       763
## 649   2020-41                           D3       758
## 650   2020-41               C programming       720
## 651   2020-41             C++ programming       720
## 652   2020-41                     Spotfire       674
## 653   2020-41              Biostatistician       619
## 654   2020-41               decision trees       597
## 655   2020-41                    Qualtrics       592
## 656   2020-41                          LSA       570
## 657   2020-41                      MariaDB       560
## 658   2020-41          Git version control       504
## 659   2020-41                        Domo       502
## 660   2020-41                        TSQL       494
## 661   2020-41                      Delphi       485
## 662   2020-41            scenario analysis       451
## 663   2020-41                 Lab Notebook       450
## 664   2020-41              Data wrangling       415
## 665   2020-41          logistic regression       404
## 666   2020-41               neural network       396
```

```
## 667   2020-41                   Debian       392
## 668   2020-41                   SQLite       387
## 669   2020-41       Sensitivity Analysis       373
## 670   2020-41         Insights analytics       364
## 671   2020-41                  Using R       351
## 672   2020-41                      SVD       243
## 673   2020-41                      SVM       236
## 674   2020-41          Actuarial Analyst       232
## 675   2020-41             Power Analysis       227
## 676   2020-41       well-documented code       224
## 677   2020-41              document code       218
## 678   2020-41                    k-means       154
## 679   2020-41                   SiSense       149
## 680   2020-41                      LDA       149
## 681   2020-41                    ggplot       143
## 682   2020-41                    plotly       136
## 683   2020-41                  R Studio       136
## 684   2020-41                   RStudio       136
## 685   2020-41               Web scraping       126
## 686   2020-41           Online analytics       124
## 687   2020-41           Insights Analyst       121
## 688   2020-41                 Highcharts        99
## 689   2020-41         Actuarial analysis        90
## 690   2020-41          Insights analysis        90
## 691   2020-41                      Birst        79
## 692   2020-41                        knn        49
## 693   2020-41                  tidyverse        39
## 694   2020-41          Insurance Analyst        34
## 695   2020-41                 R packages        33
## 696   2020-41                   GoodData        30
## 697   2020-41         spatial statistics        30
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## 699   2020-41        Actuarial analytics        29
## 700   2020-41              Data scraping        25
## 701   2020-41                      Gauss        24
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## 704   2020-41             C++ programmer        21
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## 706   2020-41                 R Markdown        17
## 707   2020-41     Computational Engineer        11
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## 709   2020-41                     kmeans         9
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## 711   2020-41                Datawrapper         8
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## 713   2020-41                R Developer         6
## 714   2020-41          Actuary analytics         4
## 715   2020-41           Insight Squared         4
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## 717   2020-41         Analytic Scripting         1
## 718   2020-41            Polling Analyst         0
## 719   2020-41                   Zebra BI         0
## 720   2020-41           Actuary analysis         0
```

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## 722   2020-41                Highcharter         0
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## 728   2020-42                        C++    169786
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## 732   2020-42                   modeling     80469
## 733   2020-42                       SQL+     68503
## 734   2020-42                        SQL     68503
## 735   2020-42                       .NET     68052
## 736   2020-42                     Python     61021
## 737   2020-42                     Google     54741
## 738   2020-42                 Statistics     53016
## 739   2020-42                       Java     52969
## 740   2020-42                          R     49861
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## 744   2020-42                 Javascript     38637
## 745   2020-42                        SAP     31450
## 746   2020-42                     Oracle     30632
## 747   2020-42           Data management     27239
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## 749   2020-42            Data analytics     24058
## 750   2020-42                      scrum     23424
## 751   2020-42                        API     23097
## 752   2020-42                        CSS     22530
## 753   2020-42                        Git     19945
## 754   2020-42                        git     19943
## 755   2020-42          Object oriented     18572
## 756   2020-42                         ai     17947
## 757   2020-42                        PCA     17351
## 758   2020-42             Data science     16665
## 759   2020-42                 Big data     16518
## 760   2020-42                debugging     16300
## 761   2020-42                  Tableau     14707
## 762   2020-42                  Android     14618
## 763   2020-42     Business intelligence     14337
## 764   2020-42                data sets     13919
## 765   2020-42         agile development     13896
## 766   2020-42                full stack     13683
## 767   2020-42                       PHP     13244
## 768   2020-42                PhotoShop     13081
## 769   2020-42                       iOS     12893
## 770   2020-42                   angular     12196
## 771   2020-42           Market Research     11698
## 772   2020-42                       SAS     11596
## 773   2020-42           design patterns     11457
## 774   2020-42                     Mysql     11425
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## 777   2020-42    artificial intelligence     10041
## 778   2020-42           Business analysis      9431
## 779   2020-42                   usability      9371
## 780   2020-42         Data Visualization      8666
## 781   2020-42                    datasets      8624
## 782   2020-42       relational databases      8610
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## 784   2020-42                     Jquery      8165
## 785   2020-42            version control      7727
## 786   2020-42                 regression      7658
## 787   2020-42           Google analytics      7197
## 788   2020-42               unit testing      7126
## 789   2020-42             Data warehouse      6970
## 790   2020-42                     Github      6735
## 791   2020-42               benchmarking      6262
## 792   2020-42                simulations      6156
## 793   2020-42                   firmware      6092
## 794   2020-42        relational database      6070
## 795   2020-42                   Power BI      5987
## 796   2020-42                  Postgresql      5342
## 797   2020-42               Data Analyst      4924
## 798   2020-42         Business analytics      4406
## 799   2020-42            Market Analysis      4399
## 800   2020-42                 Windows 10      4361
## 801   2020-42              deep learning      4316
## 802   2020-42             Data scientist      4274
## 803   2020-42                  Bootstrap      4076
## 804   2020-42                      Slack      3991
## 805   2020-42              Data Engineer      3451
## 806   2020-42                     arcgis      2886
## 807   2020-42               Visual Basic      2536
## 808   2020-42 natural language processing      2478
## 809   2020-42                       SPSS      2342
## 810   2020-42                 clustering      2289
## 811   2020-42          Data manipulation      2259
## 812   2020-42          Report generation      2232
## 813   2020-42                     Mac OS      1960
## 814   2020-42                        NLP      1816
## 815   2020-42           Algorithm Design      1791
## 816   2020-42       statistical modeling      1766
## 817   2020-42                 Wireshark      1723
## 818   2020-42                   merging      1711
## 819   2020-42         Generating reports      1500
## 820   2020-42               multivariate      1490
## 821   2020-42                     Looker      1464
## 822   2020-42                      Stata      1423
## 823   2020-42           neural networks      1363
## 824   2020-42            Custom reports      1279
## 825   2020-42         Marketing Research      1199
## 826   2020-42                   QlikView      1001
## 827   2020-42           Data maintenance       880
## 828   2020-42                       D3        794
```

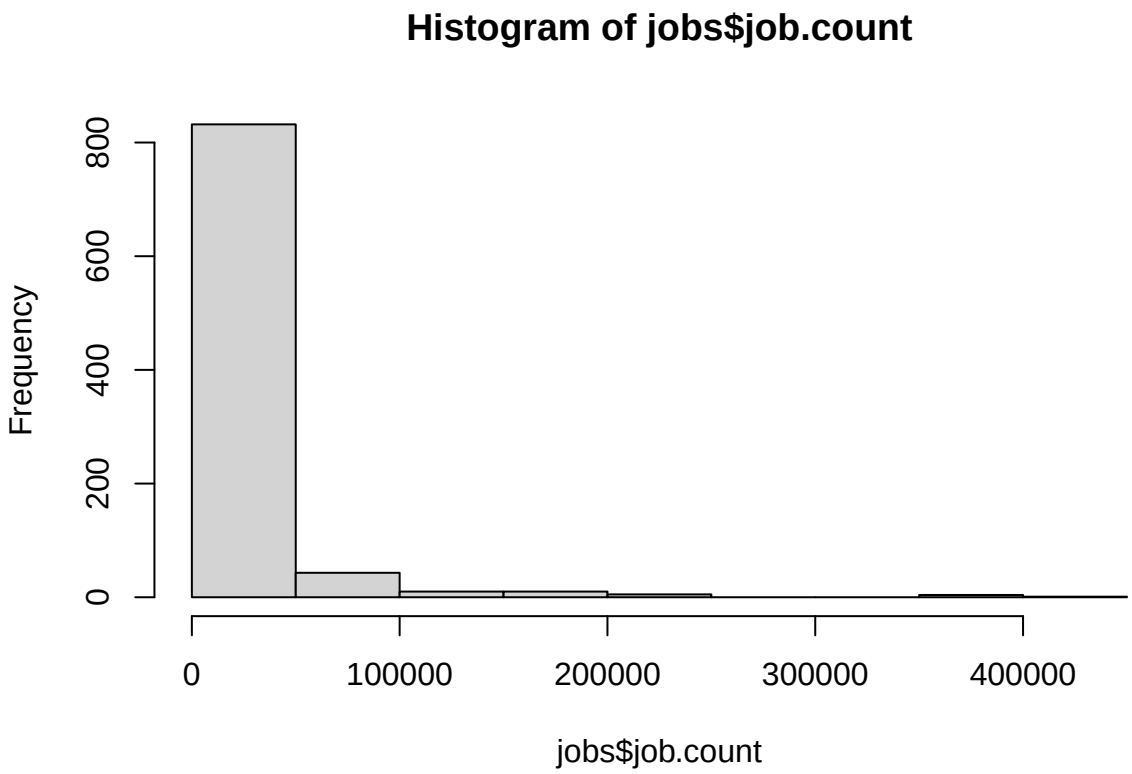
```
## 829   2020-42                    Curl       792
## 830   2020-42              Statistician       746
## 831   2020-42            C programming       734
## 832   2020-42          C++ programming       734
## 833   2020-42                 Spotfire       638
## 834   2020-42                Qualtrics       614
## 835   2020-42                  MariaDB       610
## 836   2020-42          Biostatistician       610
## 837   2020-42           decision trees       593
## 838   2020-42                      LSA       580
## 839   2020-42                    Domo        534
## 840   2020-42      Git version control       519
## 841   2020-42                   Delphi       495
## 842   2020-42        scenario analysis       480
## 843   2020-42                     TSQL       459
## 844   2020-42                   Debian       434
## 845   2020-42             Lab Notebook       433
## 846   2020-42           Data wrangling       421
## 847   2020-42      logistic regression       411
## 848   2020-42           neural network       397
## 849   2020-42       Insights analytics       392
## 850   2020-42                   SQLite       380
## 851   2020-42                 Using R        373
## 852   2020-42     Sensitivity Analysis       369
## 853   2020-42        Actuarial Analyst       259
## 854   2020-42                      SVD       246
## 855   2020-42           Power Analysis       235
## 856   2020-42     well-documented code       231
## 857   2020-42                      SVM       230
## 858   2020-42            document code       225
## 859   2020-42                      LDA       156
## 860   2020-42                R Studio        149
## 861   2020-42                 SiSense        148
## 862   2020-42                 RStudio        148
## 863   2020-42                  plotly        147
## 864   2020-42                  ggplot        147
## 865   2020-42                 k-means        144
## 866   2020-42             Web scraping       137
## 867   2020-42          Online analytics       127
## 868   2020-42          Insights Analyst       121
## 869   2020-42                Highcharts        94
## 870   2020-42         Insights analysis        93
## 871   2020-42       Actuarial analysis        88
## 872   2020-42                    Birst        86
## 873   2020-42                      knn        48
## 874   2020-42                tidyverse        45
## 875   2020-42               R packages        35
## 876   2020-42       spatial statistics        35
## 877   2020-42                 GoodData        34
## 878   2020-42       Insurance Analyst         34
## 879   2020-42      Actuarial analytics        27
## 880   2020-42      Insurance analytics        25
## 881   2020-42            Data scraping        25
## 882   2020-42             C programmer        22
```

```
## 883   2020-42                      Gauss        22
## 884   2020-42              C++ programmer        22
## 885   2020-42     hierarchical clustering        20
## 886   2020-42          Insurance analysis        20
## 887   2020-42                  R Markdown        19
## 888   2020-42              record linkage        11
## 889   2020-42                      kmeans        10
## 890   2020-42      Computational Engineer        10
## 891   2020-42                 Datawrapper         8
## 892   2020-42                FusionCharts         8
## 893   2020-42             Actuary Analyst         6
## 894   2020-42                 R Developer         5
## 895   2020-42             Insight Squared         4
## 896   2020-42           Actuary analytics         4
## 897   2020-42                   Dundas BI         3
## 898   2020-42             Polling Analyst         1
## 899   2020-42            Polling analysis         0
## 900   2020-42                    Datapine         0
## 901   2020-42          Analytic Scripting         0
## 902   2020-42            Actuary analysis         0
## 903   2020-42           Polling analytics         0
## 904   2020-42                    Zebra BI         0
## 905   2020-42                  Highcharter         0
```

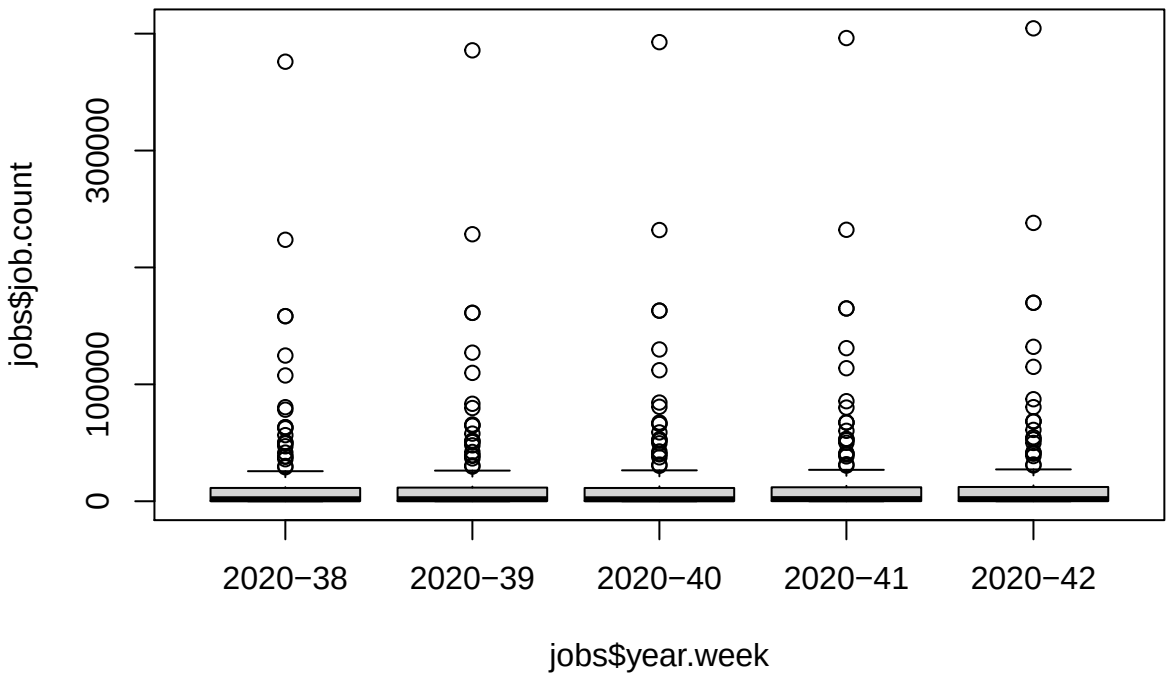
- Create a `hist` and `boxplot` and report `summary(jobs$job.count)`.

(5 points) Histogram and Box Plot

```
hist(jobs$job.count);
```




```
boxplot(jobs$job.count~jobs$year.week, data = jobs);
```




```
summary(jobs$job.count)
```

```
##    Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
##       0     149    1734   15170   11847  404527
```

[What does the histogram tell you about the data? What does the boxplot tell you about the data? What does `summary` tell you about the data?]

Answered this above.

```
deep.dive = c("Microsoft Office", "C++", "SQL", "Computer Science", "Python", "Java", "Statistics", "Da


or = "";
for(search in deep.dive)
  {
  or = paste0(or, " jobs$search.query == '",search,"' | ");
  }
or = substr(or,0, strlen(or) - 2);

## TODO ... update subsetDataFrame to allow "OR" logic, currently only does "AND" ...

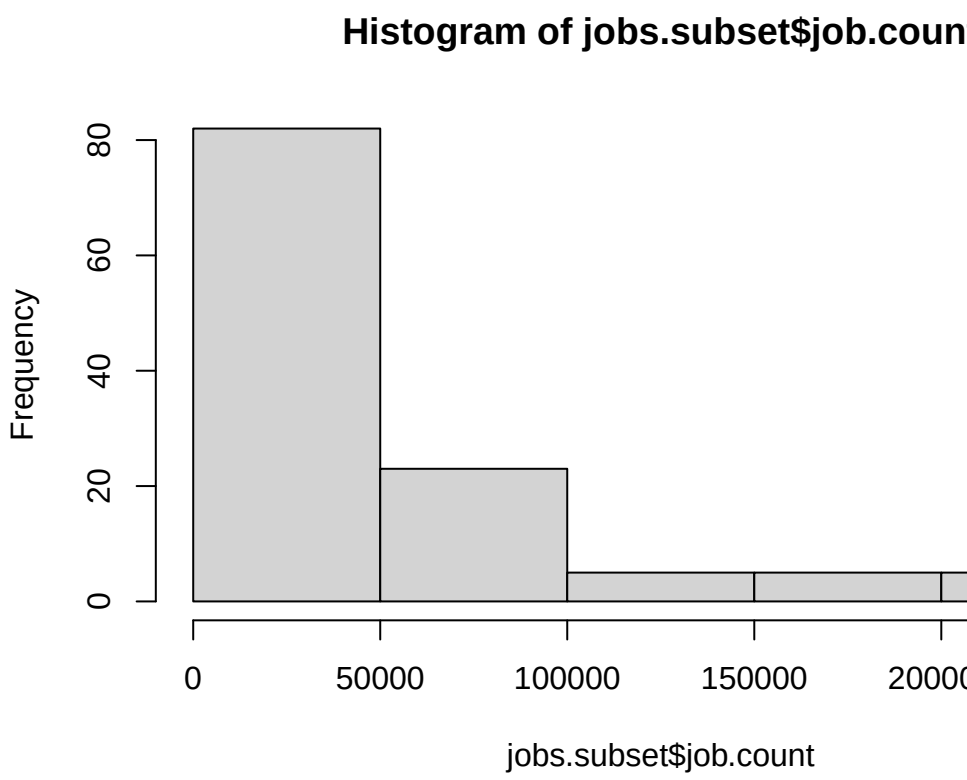
# jobs.subset = jobs[ or , ];  # doesn't work ...
jobs.subset = jobs[ jobs$search.query == 'Microsoft Office' |  jobs$search.query == 'C++' |  jobs$searc

# stem(jobs.subset$job.count);
```

```
# subsetDataFrame(jobs.subset, "job.count", "==", 0);
```

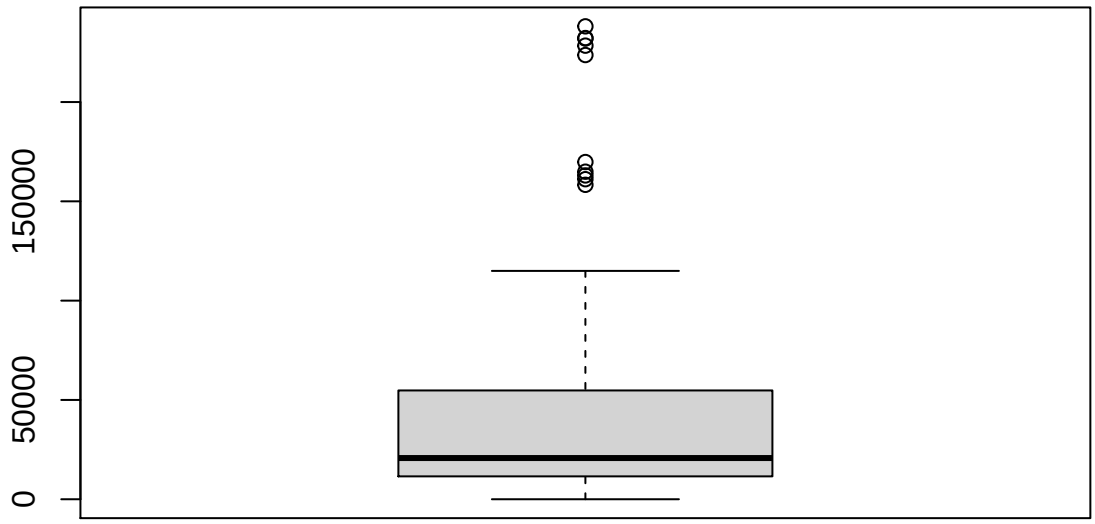
Subset some keywords relevant to this course

```
hist(jobs.subset$job.count);
```

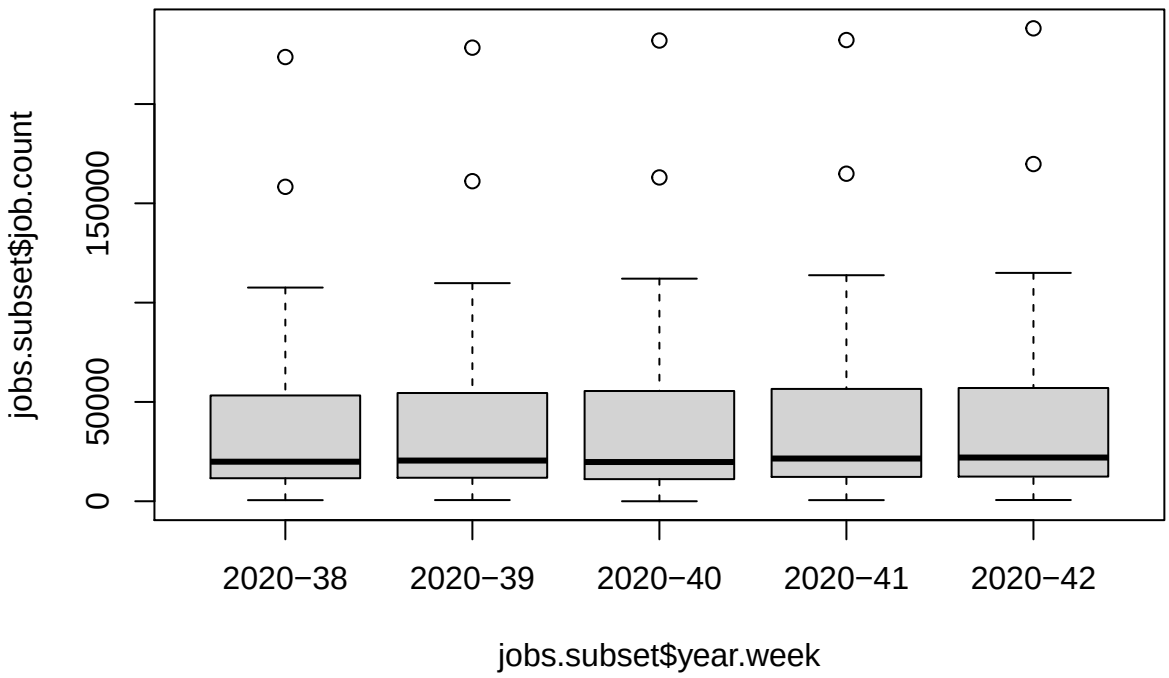


Histogram and Box Plot of Subset

```
boxplot(jobs.subset$job.count);
```




```
boxplot(jobs.subset$job.count~jobs.subset$year.week, data = jobs);
```



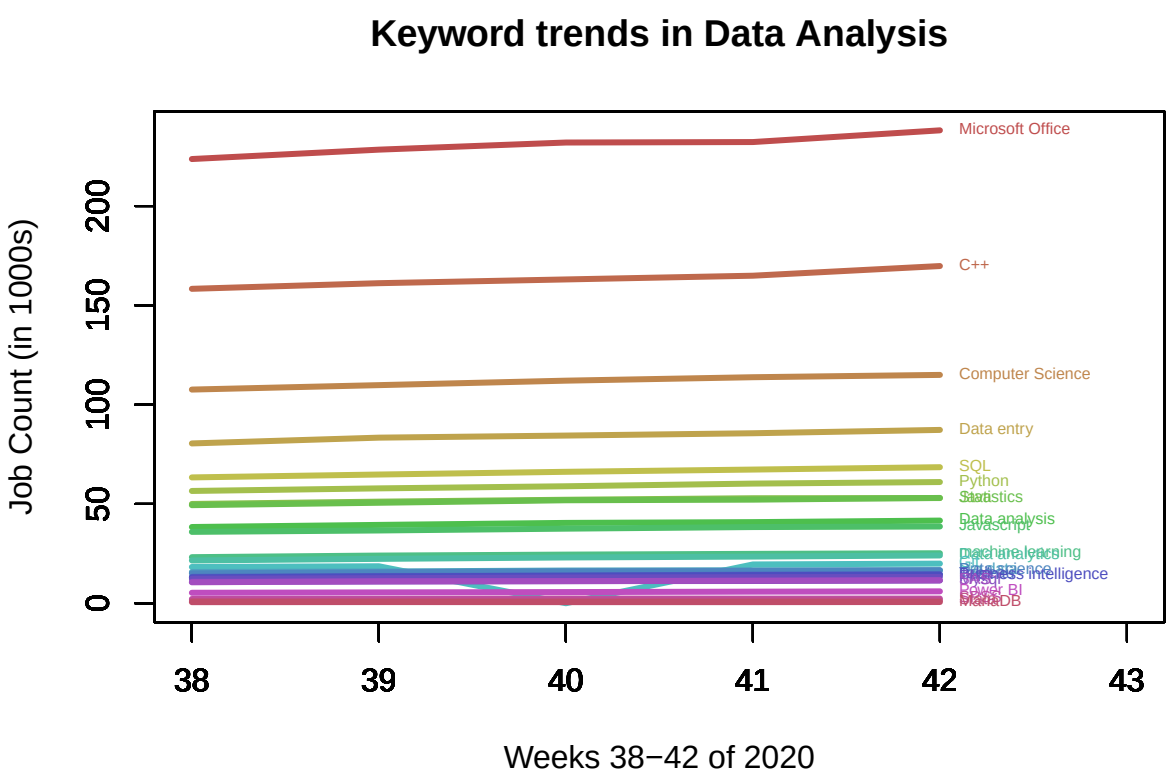
[What does the histogram tell you about the data? What does the boxplot tell you about the data?]

(10 points) Trends in Relevant Subset

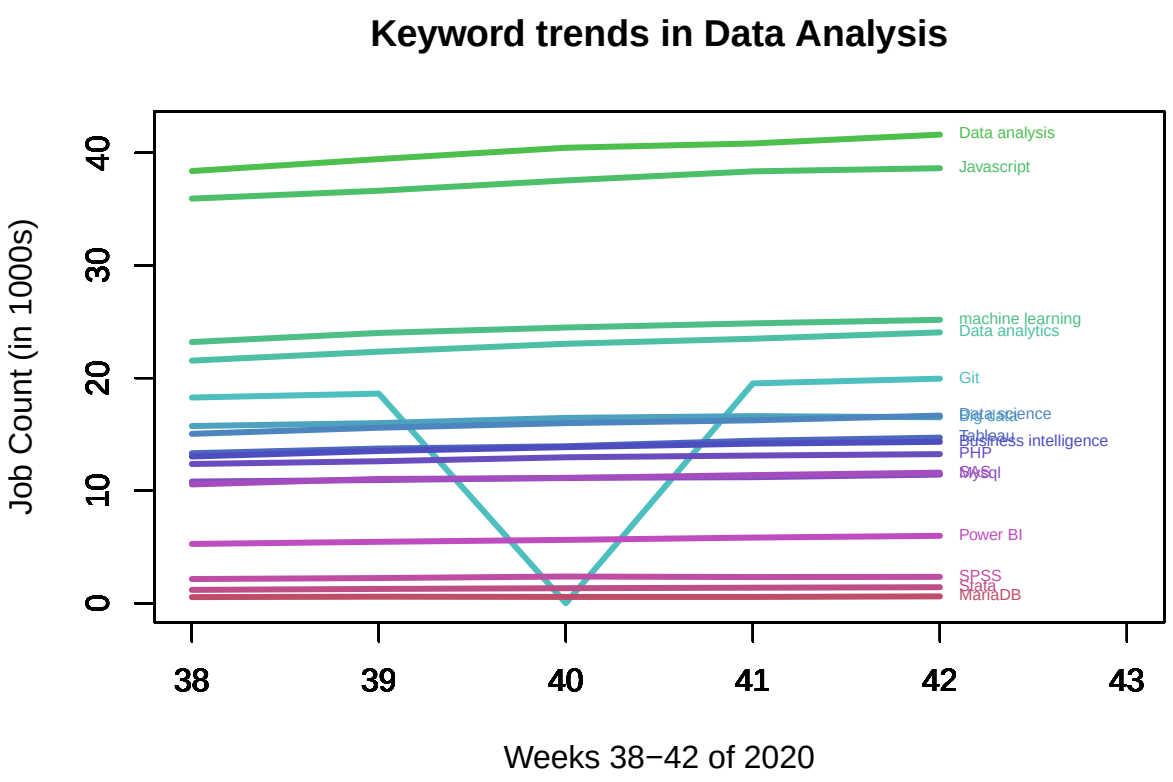
```
jobs.subset$year.week = as.numeric( gsub("-",".",jobs.subset$year.week, fixed=TRUE) );


jobs.subset = sortDataFrameByNumericColumns(jobs.subset, c("year.week","job.count"), c("ASC","DESC") );
# easier to manage as "how many thousand jobs"
jobs.subset$job.count.k = jobs.subset$job.count / 1000;

do.nothing = plotJobs(jobs.subset);
```




```
do.nothing = plotJobs(jobs.subset, myy.lim = c(0,42) );
```



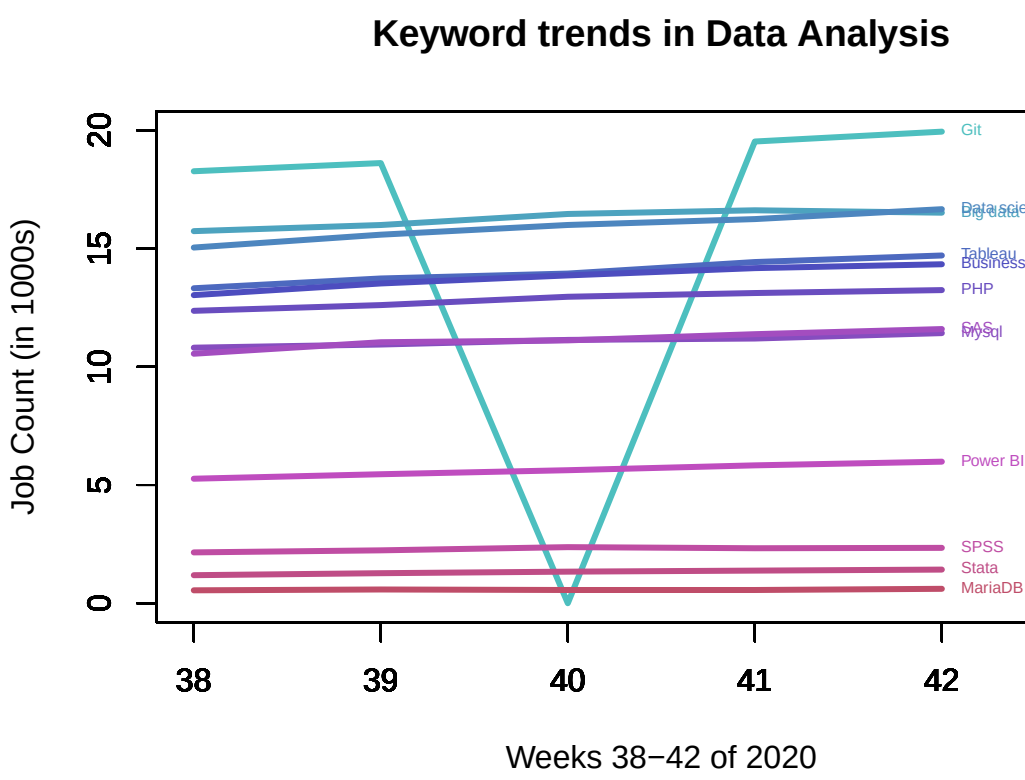
Initial Perspective [What is your initial "perspective" of this data, now that you see it? Why are the lines "parallel-ish"? What kind of a trend is that?

Now comment on the line of data for "Data analysis". How is it trending? How does it compare to other Search-Query Words?

What is your first perspective?

]

```
do.nothing = plotJobs(jobs.subset, myy.lim = c(0,20) );
```



Missing Data "Git" Week 40?

Git-40/Git-41 data history, notice the date-time and file sizes . . .

Source: Data provenance history

Source: Data provenance history

[Is this data missing or did it just drop to zero that week? How does this relate to the other data (remember the idea of "continuity" in mathematics)? What should you do about it?]

```
idxs.week.40 = which(jobs.subset$year.week == 2020.40);
idxs.Git     = which(jobs.subset$search.query == "Git");

# set notation
my.idx = intersect(idxs.Git,idxs.week.40);

jobs.subset[idxs.Git,];
```

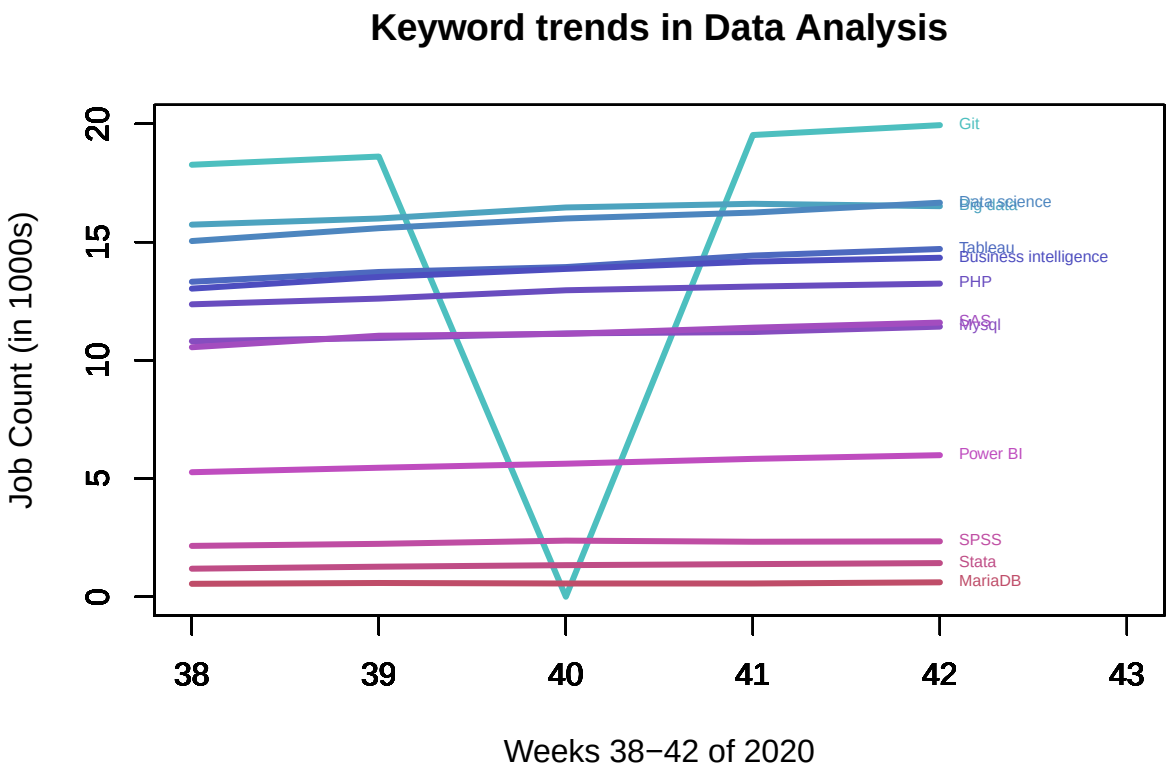
```
##     year.week search.query job.count job.count.k
## 30    2020.38          Git     18270      18.270
## 211   2020.39          Git     18617      18.617
## 542   2020.40          Git         0       0.000
## 573   2020.41          Git     19528      19.528
## 753   2020.42          Git     19945      19.945
```

```
jobs.subset[my.idx,];
```

```
##     year.week search.query job.count job.count.k
## 542    2020.4          Git         0           0
```

```
## change this if you feel appropriate?  To what number?
jobs.subset[my.idx,3] = 0;          # job.count
jobs.subset[my.idx,3] = 0/1000;     # job.count.k (in thousands) ...

do.nothing = plotJobs(jobs.subset, myy.lim = c(0,20) );
```

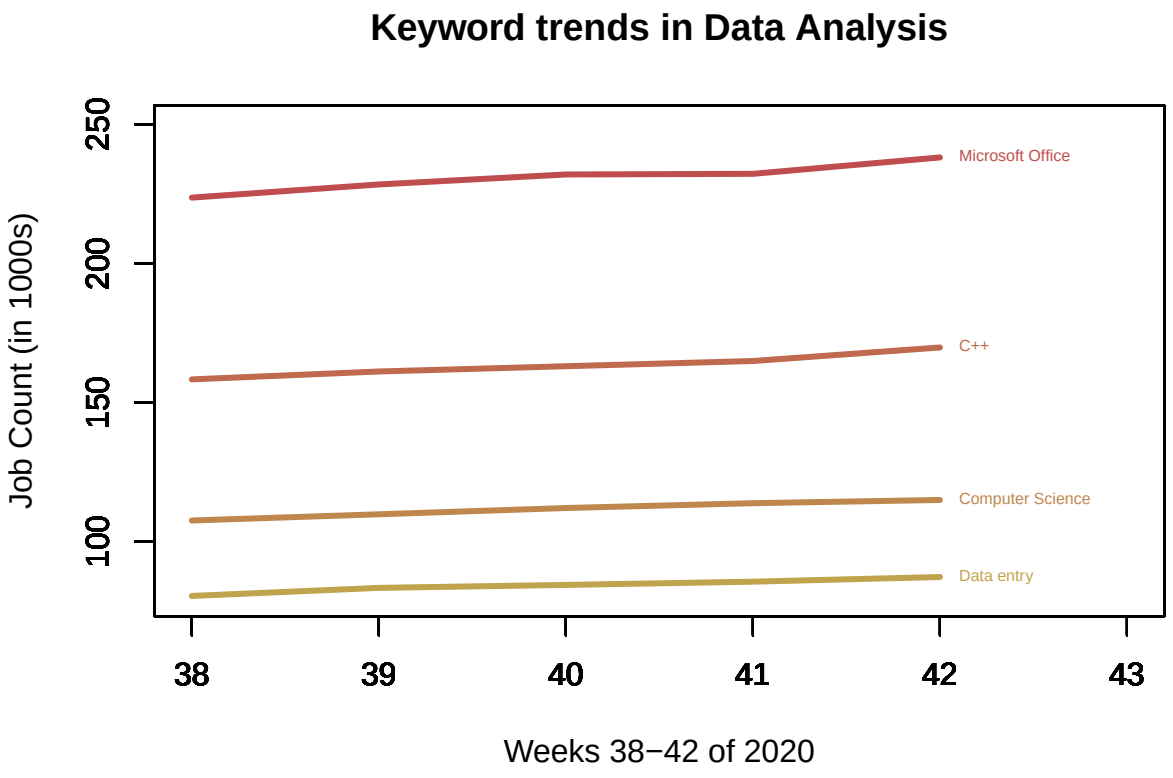


Is "Microsoft Office" bigger than "C++"? I use the term "bigger" or "better" intentionally. We are comparing two items, and these are generic ways of communicating such a comparison. In context of this data problem, a formalized form of the question would be something like: "Utilizing job count for a given search query, determine if the query 'Microsoft Office' has a larger job count than the query 'C++'?" This question will need to be formalized if we are trying to draw specific conclusions, but the initiation of analysis "which is bigger" allows us to understand what the data says or does not say, through exploration.

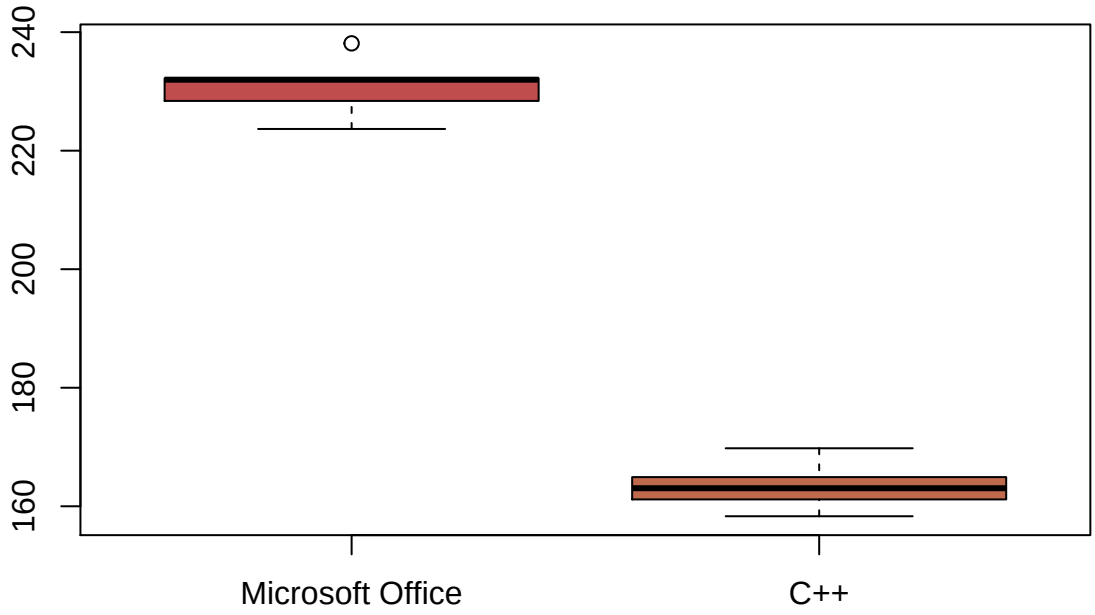
To answer the question:

Mathematically, if two lines are parallel, and one is above the other, can we use **distance** to draw a conclusion? Now, many times in statistics we deal with noise in the data, it is not "deterministic" but "stochastic" ... so we need to understand the variability. Based on the data we see, can we not use "parallel-line" logic to conclude that they are different? This is one dimension of EDA, use mathematics. ("mathematics")

```
do.nothing = plotJobs(jobs.subset, myy.lim = c(80,250) );
```




```
boxplotJobQueryComparison(jobs.subset, "Microsoft Office", "C++");
```



Tukey invented the boxplot as a nice EDA representation of the data. What logical inference can we make about the distances between the boxplots and the fact that no data is overlapping. This is another dimension of EDA, use "distance" and the boxplot "IQR" to compare two elements. What conclusion would we make? ("boxplot")

[Can we conclude the data are different based on "mathematics" or "boxplot"?

I conclude that the data is different based on the boxplots.

Would a formal "inferential statistical test" tell us something different than logical inference?

I don't think with this data that inferential statistical tests would tell us anything different than logical inference.

How do you think "formal tests" were derived if not from "mathematics" and "boxplot" (EDA)?]

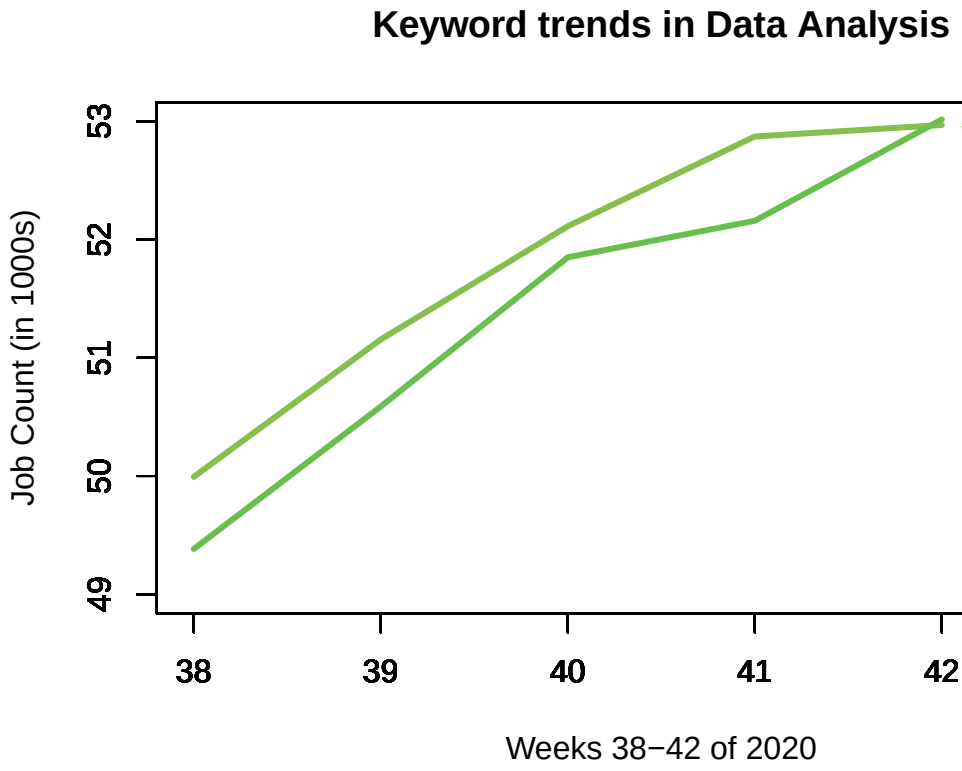
```
# courage in trusting your intuition may require a fall-back ... for those that need it ...

t.test.jobs(jobs.subset, "Microsoft Office", "C++");
```

```
##
##  Welch Two Sample t-test
##
## data:  x and y
## t = 22.016, df = 7.6613, p-value = 0.00000003332
## alternative hypothesis: true difference in means is not equal to 0
## 95 percent confidence interval:
##  60.31098 74.54582
## sample estimates:
## mean of x mean of y
```

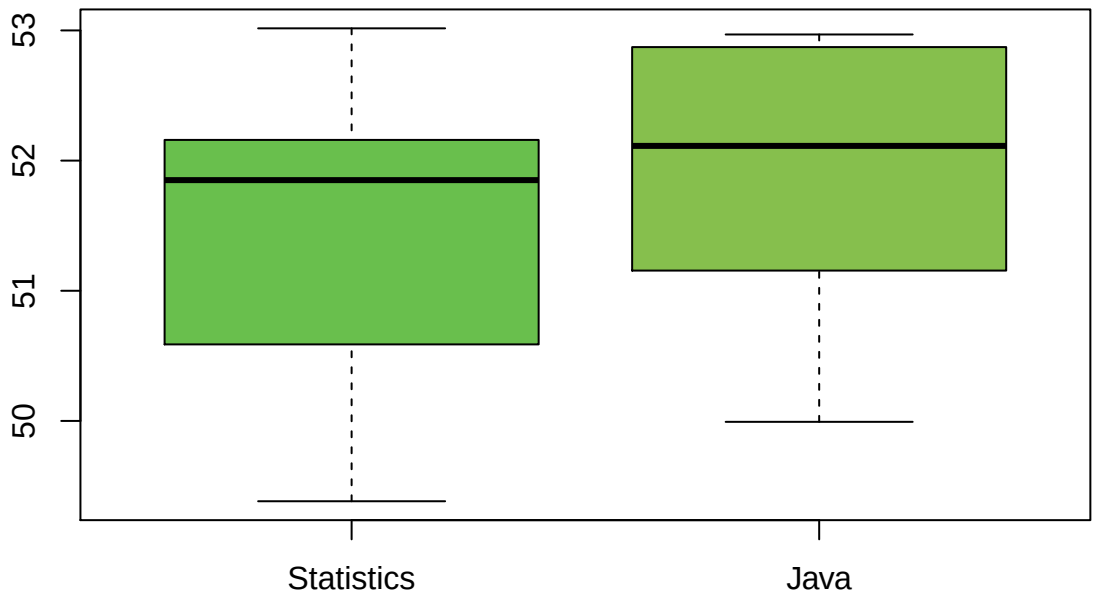
```
##  230.8730  163.4446
```

```
do.nothing = plotJobs(jobs.subset, myy.lim = c(49,53) );
```



Is "Statistics" bigger than "Java"?

```
do.nothing = boxplotJobQueryComparison(jobs.subset, "Statistics", "Java");
```



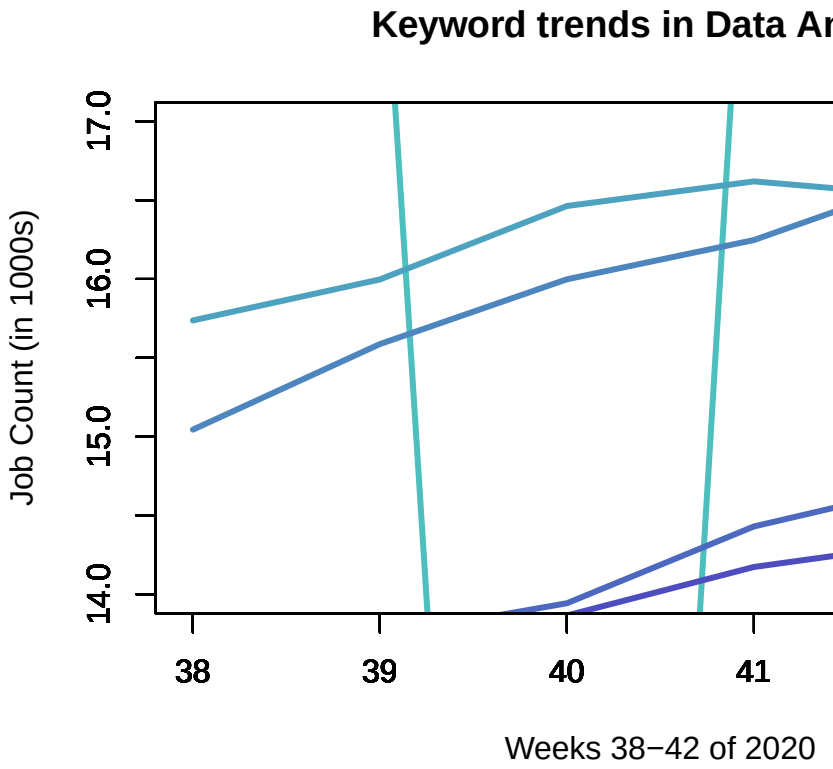

```
t.test.jobs(jobs.subset,"Statistics", "Java");
```

```
##
##  Welch Two Sample t-test
##
## data:  x and y
## t = -0.49621, df = 7.8738, p-value = 0.6333
## alternative hypothesis: true difference in means is not equal to 0
## 95 percent confidence interval:
##  -2.384104  1.541704
## sample estimates:
## mean of x mean of y
##   51.3992   51.8204
```

For this data, I can descriptively report that the third-quartile `Q3` of "Statistics" is about equal to the `median` of "Java". The inter-quartile range (`IQR`) of each overlap. The minimum value of "Java" is larger than the minimum value of "Statistics". The maximum value of "Java" is slightly smaller than the maximum value of "Statistics".

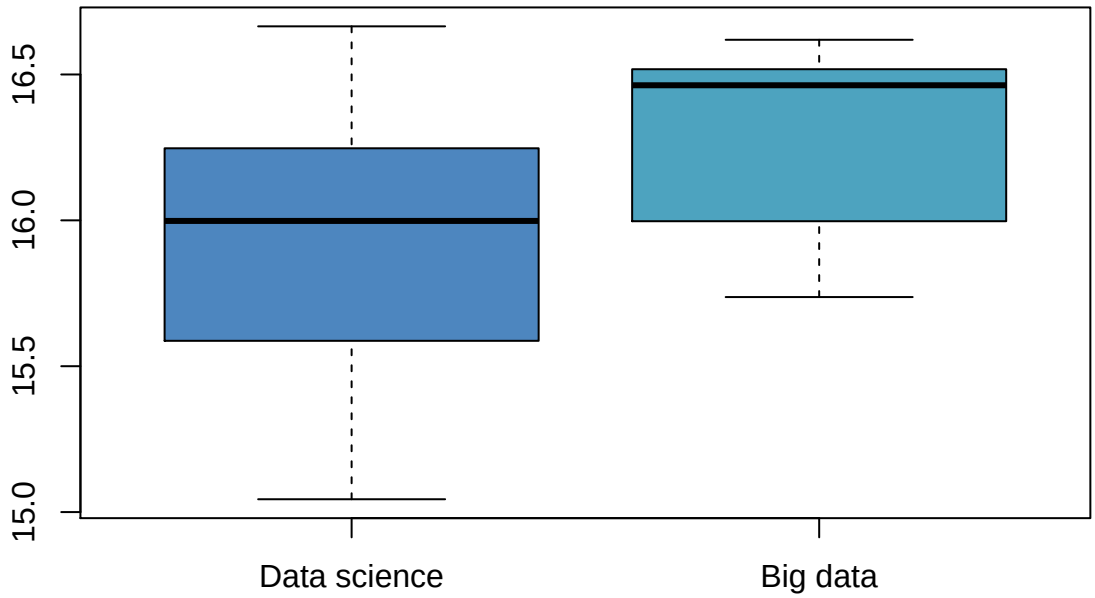
[Use "mathematics" and "boxplot" and "ttest" to answer the question: Is "Statistics" bigger than "Java"?]

```
do.nothing = plotJobs(jobs.subset, myy.lim = c(14,17) );
```



What about "Data science" and "Big data"?

```
boxplotJobQueryComparison(jobs.subset, "Data science", "Big data");
```




```
t.test.jobs(jobs.subset,"Data science", "Big data");
```

```
##
##  Welch Two Sample t-test
##
## data:  x and y
## t = -1.1002, df = 6.6285, p-value = 0.3096
## alternative hypothesis: true difference in means is not equal to 0
## 95 percent confidence interval:
##  -1.1381677  0.4209677
## sample estimates:
## mean of x mean of y
##   15.9082   16.2668
```

[Use "mathematics" and "boxplot" and "ttest" to make a conclusion.

Next, think carefully about the nature of the data. Is the "collection-approach" flawed to make a conclusion comparing job-counts of these specific keywords? How likely is it that a single-job posting may have both keywords?

This is an example where "data-integrity" knowledge would surpass the other three logical conclusions.

This intuition requires an understanding of what mathematicians call "set theory". If I am doing an independent search on keywords, is it possible that one job would show up in multiple searches. That is, being counted twice or more.

Intuition and logic would also allow us to conclude that our other comparisons are "very likely okay". Why?

What would be an improved approach to collecting the data that would allow me to more accurately compare

these two keywords?

This is representative of why exploratory data analysis is essential. It provides us insight into the domain and highlights the need for better data, if we can find it.

]

Conclusions on logical inference

Distance is a fundamental unit of comparison. We can use our "mathematical" understanding of distance. We can use an "EDA" understanding of the data (e.g., the boxplot). We need to understand the data sourcing and how that will relate to the logical conclusions we are trying to draw.

When we transition to "confirmatory inferential statistics", we cannot leave our understanding of "maths" and "EDA" behind. They are the foundation from which "inferential statistics" is built. They are "logical inference".

COMPUTING DISTANCES

If you recall, we had a notebook on collecting data from Wikipedia. We documented the "data-provenance" protocols to make this happen. We have documented and can replicate our data-collection strategies.

(10 points) Data Provenance defined

Imagine you are preparing for a job interview. Write a 90-second blurb describing "what is data provenance" and "why it matters". I would suggest the STAR(S) approach mentioned in one of the notebooks. Reference the "Wikipedia" project as an example of how one can implement the features.

[What is data provenance?

Probably about 200-250 words (with the 90 second limit)]

Geospatial distances

"Geo-spatial" studies are becoming much more common in the "data analytics" community, so let's use basic "latitude/longitude" data to formally talk about "distance."

So we will look at the 50 state capitals of America (USA). Before that, let's examine some basic principles of distances using my hometown.

(5 points) Distance from one input to multiple outputs

My Hometown "Columbia Falls, Montana" `cfalls`

- Find all ZIP codes within 22 miles of Columbia Falls, MT `cfalls` (use lat/long provide from the Wikipedia lookup)... build the bounding "box" and perform the post-hoc "radial distance" computations (as we did in the homework).

```
# copy/paste __student_access__/_SECRET_/_SECRET_database_.txt into console...  or this won't work

cfalls.latitude = 48.37028;
cfalls.longitude = -114.18889;
my.radius = 22; my.units = "mi"; #miles

# THIS is where these exam functions live ...
# source_url( paste0(path.github,"misc/functions-midterm-F2000.R") );  # should be 2020 ... oh well

cfalls.info = getNeighborsFromLatLong(22, 48.37028, -114.18889, "mi");
```

```
## [1] "The QUERY returned ...  13  ... NEIGHBORS"
```

```
cfalls.info$neighbors;
```

```
##    zipcode latitude longitude           city state_long state
## 1    59901 48.21124 -114.2939      KALISPELL    MONTANA    MT
## 2    59903 48.19303 -114.3579      KALISPELL    MONTANA    MT
## 3    59904 48.19452 -114.3123      KALISPELL    MONTANA    MT
## 4    59912 48.36531 -114.1927 COLUMBIA FALLS    MONTANA    MT
## 5    59913 48.43674 -114.0507          CORAM    MONTANA    MT
## 6    59916 48.61750 -113.9095          ESSEX    MONTANA    MT
## 7    59919 48.38969 -114.0630   HUNGRY HORSE    MONTANA    MT
## 8    59920 48.06516 -114.5023           KILA    MONTANA    MT
## 9    59921 48.62189 -113.8739 LAKE MC DONALD    MONTANA    MT
## 10   59926 48.39134 -114.0393    MARTIN CITY    MONTANA    MT
## 11   59932 48.07931 -114.2389         SOMERS    MONTANA    MT
## 12   59936 48.49720 -113.9892   WEST GLACIER    MONTANA    MT
## 13   59937 48.40834 -114.3522      WHITEFISH    MONTANA    MT
```

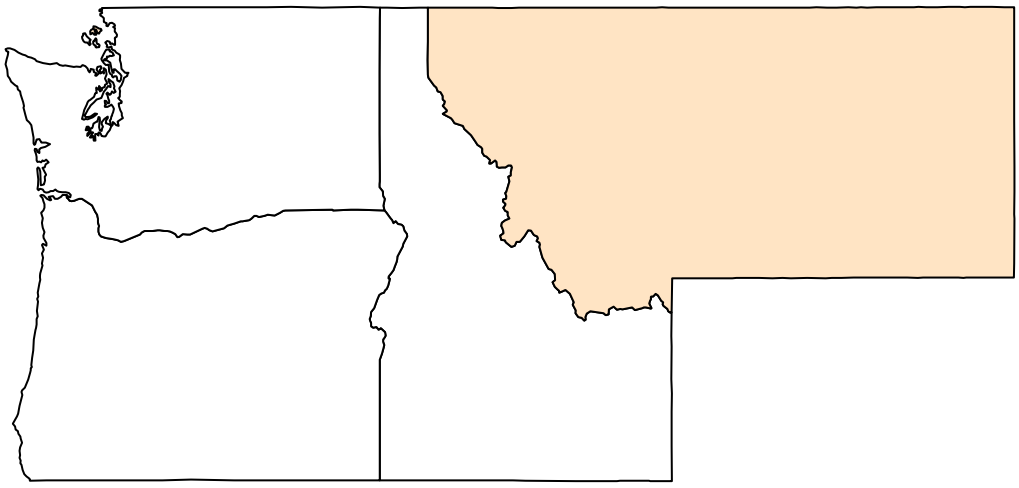
```
############## plotting ##############
brown = "#ffe4c4";
green = "#014421";

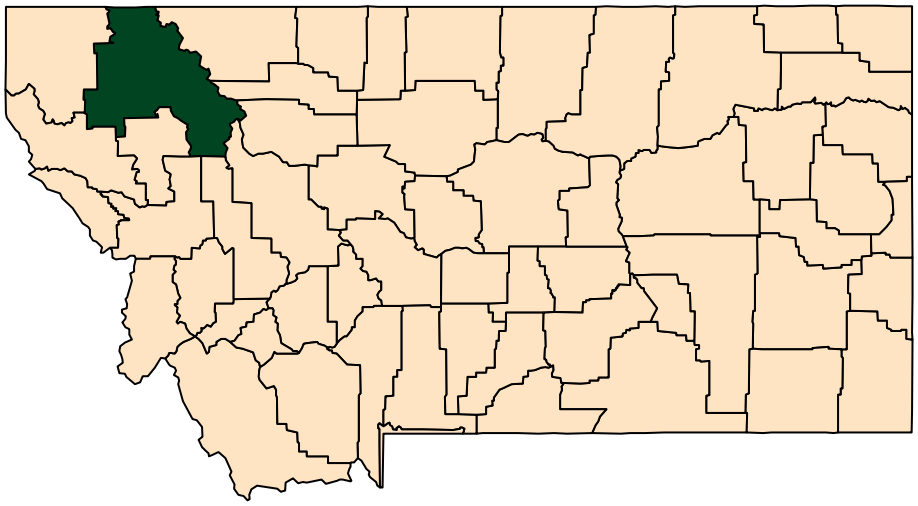
my.state = "montana";
my.state.color = "#ffe4c4";

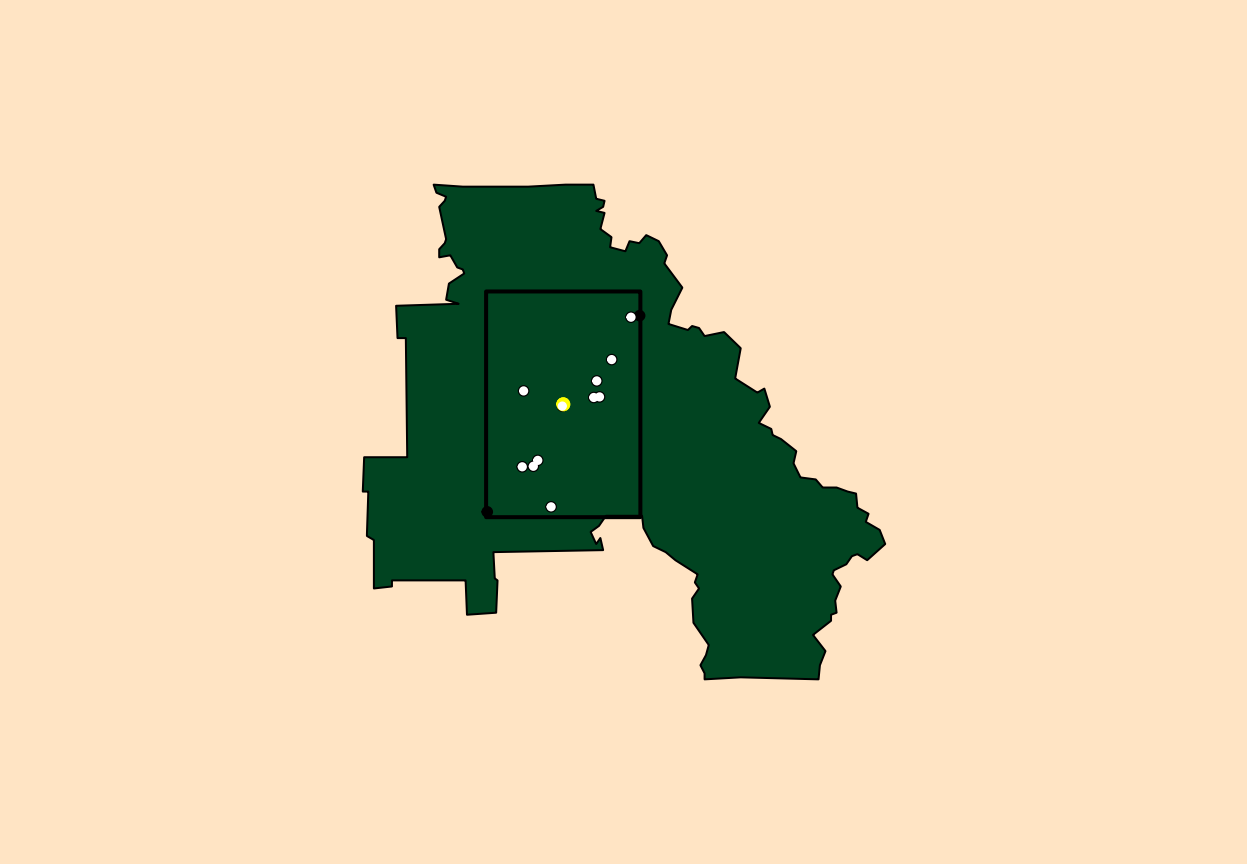
my.county = "flathead";
my.county.color = "#014421";

my.nearby.states = c("idaho", "washington", "oregon");


plotNeighbors(cfalls.info,
                    state          = my.state,
                    state.color    = my.state.color,
                    state.border   = 0.05,
                    county         = my.county,
                    county.border   = 0.05,  # if you don't see the box, increase this to like 0.75
                    county.color   = my.county.color,
                    nearby.states  = my.nearby.states);
```







[- why is the box not a square, but a rectangle? ... see `factor.lat` and `factor.long` in function `buildBoundingBoxFromRadiusAndGivenLatitudeLongitude` - critique the visualization ... what do you like? what would make it better?]

Your Hometown of something like it Instead of `cfalls.info`, you do `hometown.info`

- a location in the continental US of your choosing (not in Montana, Alaska, or Hawaii). [Graphing will not work for Alaska/Hawaii, Alaska has "boroughs" not counties.]
- find the latitude/longitude of the location you have selected (how and where to look that up?)
- Initially start with a radius of `13 miles`
- When you run the code, note how many total "neighbors"; if it is less than 20; increase the "miles" so at least 20 results are returned.
- In the end, you should select a location and radius that works for you. And its visualization also works.
- Be certain to review and update the parameters before calling these functions.

hometown.latitude = 00.00000; hometown.longitude = -000.00000; my.radius = 13; my.units = "mi"; #miles hometown.info = getNeighborsFromLatLong(????); plotNeighbors(hometown.info, ????); # you are going to have to change some of these parameters ...

```
hometown.latitude = 48.0518;
hometown.longitude = -122.1771;
my.radius = 20; my.units = "mi"; #miles
hometown.info = getNeighborsFromLatLong(20, 48.0518, -122.1771, "mi");
```

```
## [1] "The QUERY returned ...  35  ... NEIGHBORS"
```

```
hometown.info$neighbors;
```

```
##    zipcode latitude longitude             city state_long state
```

```
## 1    98012 47.84130 -122.2058           BOTHELL WASHINGTON    WA
## 2    98020 47.80094 -122.3743           EDMONDS WASHINGTON    WA
## 3    98021 47.79165 -122.2174           BOTHELL WASHINGTON    WA
## 4    98026 47.84077 -122.3367           EDMONDS WASHINGTON    WA
## 5    98036 47.80278 -122.2849          LYNNWOOD WASHINGTON    WA
## 6    98037 47.85110 -122.2815          LYNNWOOD WASHINGTON    WA
## 7    98043 47.79179 -122.3041 MOUNTLAKE TERRACE WASHINGTON    WA
## 8    98046 47.83017 -122.3040          LYNNWOOD WASHINGTON    WA
## 9    98082 47.85524 -122.2210        MILL CREEK WASHINGTON    WA
## 10   98087 47.87263 -122.2709          LYNNWOOD WASHINGTON    WA
## 11   98155 47.76313 -122.2902           SEATTLE WASHINGTON    WA
## 12   98160 47.77113 -122.3824           SEATTLE WASHINGTON    WA
## 13   98201 47.98859 -122.2018           EVERETT WASHINGTON    WA
## 14   98203 47.94596 -122.2299           EVERETT WASHINGTON    WA
## 15   98204 47.89843 -122.2548           EVERETT WASHINGTON    WA
## 16   98205 47.99055 -122.1141           EVERETT WASHINGTON    WA
## 17   98206 47.92563 -122.2264           EVERETT WASHINGTON    WA
## 18   98207 47.95998 -122.1968           EVERETT WASHINGTON    WA
## 19   98208 47.89491 -122.1934           EVERETT WASHINGTON    WA
## 20   98213 47.94082 -122.2347           EVERETT WASHINGTON    WA
## 21   98223 48.18180 -121.9796         ARLINGTON WASHINGTON    WA
## 22   98236 47.95950 -122.4021           CLINTON WASHINGTON    WA
## 23   98238 48.33875 -122.3438            CONWAY WASHINGTON    WA
## 24   98258 48.02742 -122.0624      LAKE STEVENS WASHINGTON    WA
## 25   98259 48.16499 -122.2992    NORTH LAKEWOOD WASHINGTON    WA
## 26   98260 48.03366 -122.4502           LANGLEY WASHINGTON    WA
## 27   98270 48.06088 -122.1539        MARYSVILLE WASHINGTON    WA
## 28   98271 48.09840 -122.2373        MARYSVILLE WASHINGTON    WA
## 29   98272 47.85709 -121.9377            MONROE WASHINGTON    WA
## 30   98275 47.90714 -122.3091          MUKILTEO WASHINGTON    WA
## 31   98287 48.19051 -122.2503           SILVANA WASHINGTON    WA
## 32   98290 47.93953 -122.0167         SNOHOMISH WASHINGTON    WA
## 33   98291 47.92897 -122.0999         SNOHOMISH WASHINGTON    WA
## 34   98292 48.17928 -122.3714          STANWOOD WASHINGTON    WA
## 35   98296 47.82290 -122.1182         SNOHOMISH WASHINGTON    WA
```

```
############### plotting ###############
brown = "#ffe4c4";
green = "#014421";

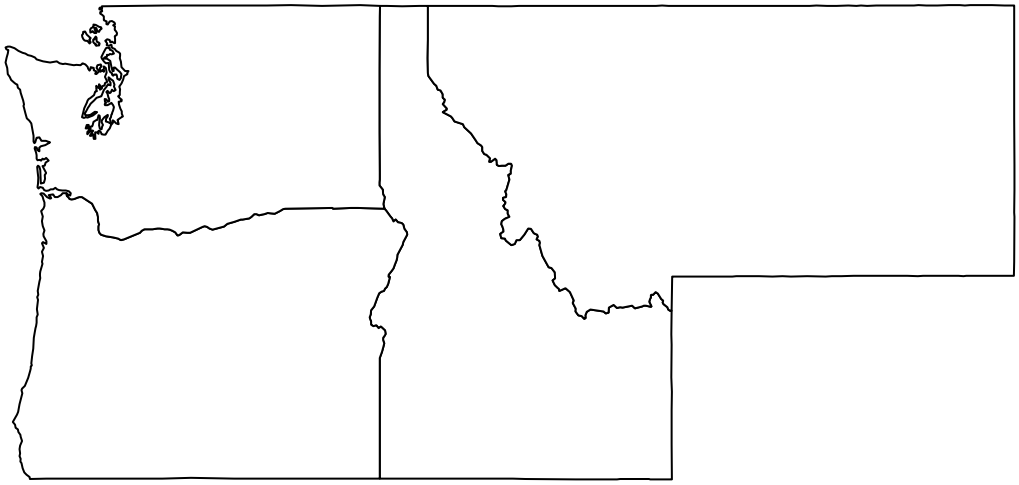
my.state = "washington";
my.state.color = "#ffe4c4";

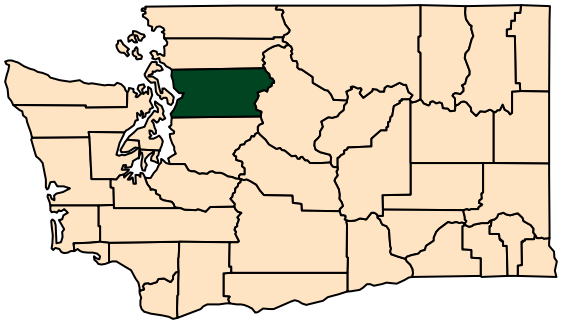
my.county = "snohomish";
my.county.color = "#014421";

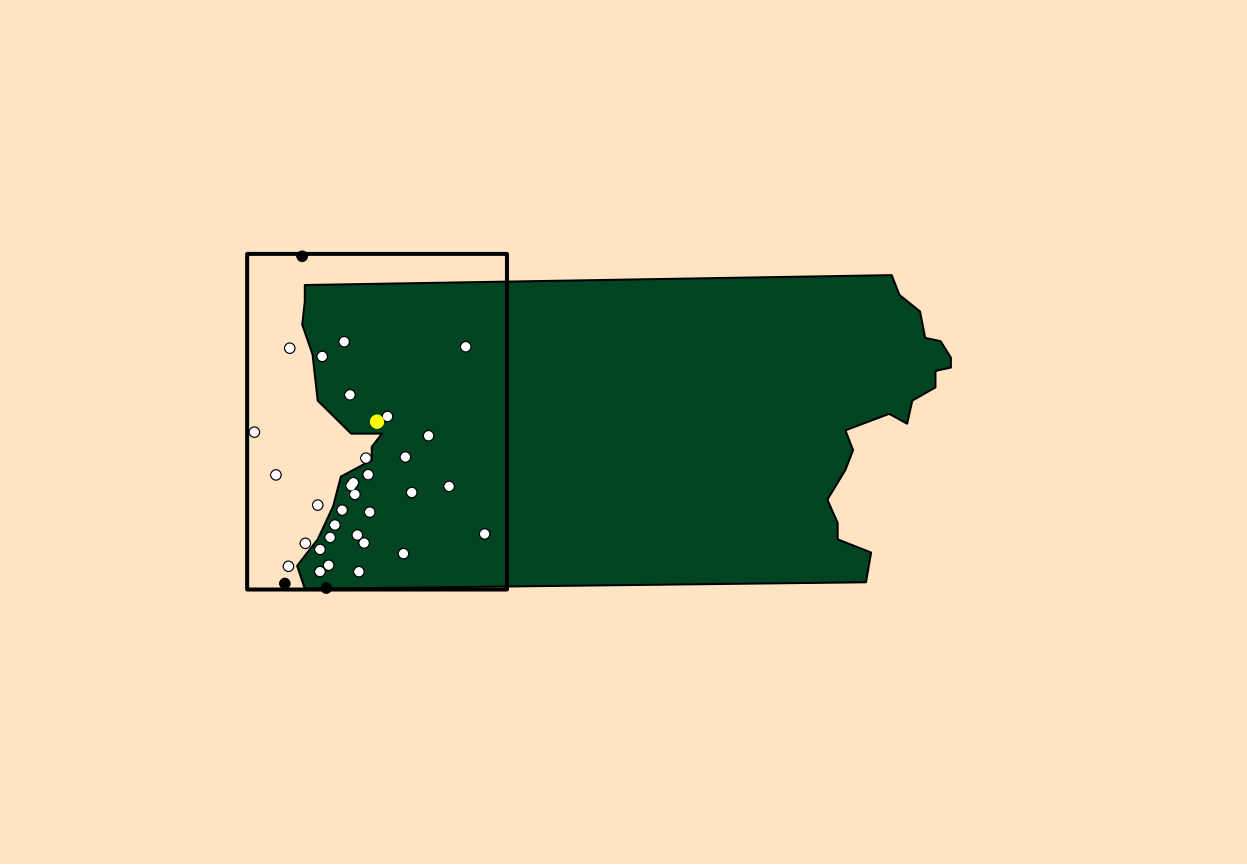
my.nearby.states = c("idaho", "montana", "oregon");

#why wont my box show up?
plotNeighbors(hometown.info,
                    state          = my.state,
                    state.color    = my.state.color,
                    state.border   = 0.05,
                    county         = my.county,
```

```
                    county.border   = 0.25,  # if you don't see the box, increase this to like 0.75
                    county.color    = my.county.color,
                    nearby.states   = my.nearby.states);
```







U.S. State Capitals (cities)

From Wikipedia, we grabbed one page that listed the 50 U.S. cities that are designated the capitals of each individual state in America (United States of America).

Using the power of a `for-loop` we make our functions work for us. We now have the data ready to go.

```
capitals = utils::read.csv( paste0(path.mshaffer, "_data_/state-capitals/final/state-capitals.txt"), hea

colnames(capitals) = c("state", "capital", "latitude", "longitude", "capital.since", "area.sq.miles", "p

# hack-add from https://en.wikipedia.org/wiki/ISO_3166-2:US
# TODO, grab this table "appropriately" as a new function
# Is there a dictionary for shortened city names?
# the long-field names is also an issue that needs to be improved upon in the next iteration.

capitals$st = c("AL","AK","AZ","AR","CA","CO","CT","DE","FL","GA","HI","ID","IL","IN","IA","KS","KY","LA

myLabels = paste0(capitals$capital, ", ", capitals$st);

capitals;
```

```
##             state        capital latitude  longitude capital.since
## 1         Alabama     Montgomery 32.36167  -86.27917          1846
## 2          Alaska         Juneau 58.30000 -134.41600          1906
## 3         Arizona        Phoenix 33.45000 -112.06700          1912
## 4        Arkansas    Little Rock 34.73611  -92.33111          1821
```

```
## 5      California     Sacramento 38.58167 -121.49444          1854
## 6        Colorado         Denver 39.73917 -104.99028          1867
## 7     Connecticut       Hartford 41.76250  -72.67417          1875
## 8        Delaware          Dover 39.15806  -75.52444          1777
## 9         Florida    Tallahassee 30.45500  -84.25333          1824
## 10        Georgia        Atlanta 33.75500  -84.39000          1868
## 11         Hawaii       Honolulu 21.30694 -157.85833          1845
## 12          Idaho          Boise 43.61583 -116.20167          1865
## 13       Illinois    Springfield 39.79944  -89.65500          1837
## 14        Indiana   Indianapolis 39.76861  -86.15806          1825
## 15           Iowa     Des Moines 41.59083  -93.62083          1857
## 16         Kansas         Topeka 39.05583  -95.68944          1856
## 17       Kentucky      Frankfort 38.20000  -84.86700          1792
## 18      Louisiana    Baton Rouge 30.44750  -91.17861          1880
## 19          Maine        Augusta 44.31056  -69.77944          1832
## 20       Maryland      Annapolis 38.97306  -76.50111          1694
## 21  Massachusetts         Boston 42.35806  -71.06361          1630
## 22       Michigan        Lansing 42.73361  -84.54667          1847
## 23      Minnesota     Saint Paul 44.94417  -93.09361          1849
## 24    Mississippi        Jackson 32.29889  -90.18472          1821
## 25       Missouri Jefferson City 38.57667  -92.17361          1826
## 26        Montana         Helena 46.59111 -112.02028          1875
## 27       Nebraska        Lincoln 40.80889  -96.67889          1867
## 28         Nevada    Carson City 39.16444 -119.76694          1861
## 29  New Hampshire        Concord 43.20667  -71.53806          1808
## 30     New Jersey        Trenton 40.22384  -74.76362          1784
## 31     New Mexico       Santa Fe 35.66722 -105.96444          1610
## 32       New York         Albany 42.65250  -73.75722          1797
## 33 North Carolina        Raleigh 35.76700  -78.63300          1792
## 34   North Dakota       Bismarck 46.80833 -100.78361          1883
## 35           Ohio       Columbus 39.96222  -83.00056          1816
## 36       Oklahoma  Oklahoma City 35.46861  -97.52139          1910
## 37         Oregon          Salem 44.93917 -123.03944          1855
## 38   Pennsylvania     Harrisburg 40.26972  -76.87556          1812
## 39   Rhode Island     Providence 41.82361  -71.42222          1900
## 40 South Carolina       Columbia 34.00056  -81.03472          1786
## 41   South Dakota         Pierre 44.37250 -100.32000          1889
## 42      Tennessee      Nashville 36.16667  -86.78333          1826
## 43          Texas         Austin 30.26722  -97.74306          1839
## 44           Utah Salt Lake City 40.76083 -111.89111          1858
## 45        Vermont     Montpelier 44.25944  -72.57583          1805
## 46       Virginia       Richmond 37.53300  -77.46700          1780
## 47     Washington        Olympia 47.03778 -122.90083          1853
## 48  West Virginia     Charleston 38.34722  -81.63333          1885
## 49      Wisconsin        Madison 43.07472  -89.38417          1838
## 50        Wyoming       Cheyenne 41.14000 -104.82028          1869
##    area.sq.miles population.2019.est population.2019.est.MSA
## 1         159.80              198525                  373290
## 2        2716.70               32113                   32113
## 3         517.60             1680992                 4948203
## 4         116.20              197312                  742384
## 5          97.90              513624                 2363730
## 6         153.30              727211                 2967239
## 7          17.30              122105                 1204877
```

```
## 8          22.40              38079                180786
## 9          95.70             194500                387227
## 10        133.50             506811               6020364
## 11         68.40             345064                974563
## 12         63.80             228959                749202
## 13         54.00             114230                206868
## 14        361.50             876384               2074537
## 15         75.80             214237                699292
## 16         56.00             125310                231969
## 17         14.70              27679                 73663
## 18         76.80             220236                854884
## 19         55.40              18681                122302
## 20          6.73              39174               2800053
## 21         89.60             692600               4873019
## 22         35.00             118210                550391
## 23         52.80             308096               3654908
## 24        104.90             160628                594806
## 25         27.30              42838                151235
## 26         14.00              32315                 77414
## 27         74.60             289102                336374
## 28        143.40              55916                 55916
## 29         64.30              43627                151391
## 30          7.66              83203                367430
## 31         37.30              84683                150358
## 32         21.40              96460                880381
## 33        114.60             474069               1390785
## 34         26.90              73529                128949
## 35        210.30             898553               2122271
## 36        620.30             655057               1408950
## 37         45.70             174365                433903
## 38          8.11              49528                577941
## 39         18.50             179883               1624578
## 40        125.20             131674                838433
## 41         13.00              13646                 20672
## 42        525.90             670820               1934317
## 43        305.10             978908               2227083
## 44        109.10             200567               1232696
## 45         10.20               7855                    NA
## 46         60.10             230436               1291900
## 47         16.70              46478                290536
## 48         31.60              46536                257074
## 49         68.70             259680                664865
## 50         21.10              64235                 99500
##    population.2019.est.CSA city.rank.in.state
## 1                   461516                  2
## 2                       NA                  3
## 3                  5002221                  1
## 4                   908941                  1
## 5                  2639124                  6
## 6                  3617927                  1
## 7                  1470083                  3
## 8                  7209620                  2
## 9                       NA                  7
## 10                 6853392                  1
```

```
## 11              NA            1
## 12          831235            1
## 13          306399            6
## 14         2457286            1
## 15          877991            1
## 16              NA            4
## 17          745033           15
## 18              NA            2
## 19              NA            8
## 20         9814928            7
## 21         8287710            1
## 22              NA            5
## 23         4027861            2
## 24          674340            1
## 25              NA           15
## 26              NA            6
## 27          357887            2
## 28          637973            6
## 29         8287710            3
## 30        22589036           10
## 31         1158464            4
## 32         1167594            6
## 33         2079687            2
## 34              NA            2
## 35         2525639            1
## 36         1481542            1
## 37         3259710            3
## 38         1271801            9
## 39         8287710            1
## 40          963048            2
## 41              NA            8
## 42         2062547            1
## 43              NA            4
## 44         2641048            1
## 45              NA            6
## 46              NA            4
## 47         4903675           24
## 48          776694            1
## 49          892661            2
## 50              NA            1
##                                                     url st
## 1       https://en.wikipedia.org/wiki/Montgomery,_Alabama AL
## 2            https://en.wikipedia.org/wiki/Juneau,_Alaska AK
## 3          https://en.wikipedia.org/wiki/Phoenix,_Arizona AZ
## 4      https://en.wikipedia.org/wiki/Little_Rock,_Arkansas AR
## 5     https://en.wikipedia.org/wiki/Sacramento,_California CA
## 6                   https://en.wikipedia.org/wiki/Denver CO
## 7      https://en.wikipedia.org/wiki/Hartford,_Connecticut CT
## 8           https://en.wikipedia.org/wiki/Dover,_Delaware DE
## 9       https://en.wikipedia.org/wiki/Tallahassee,_Florida FL
## 10                 https://en.wikipedia.org/wiki/Atlanta GA
## 11                https://en.wikipedia.org/wiki/Honolulu HI
## 12            https://en.wikipedia.org/wiki/Boise,_Idaho ID
## 13     https://en.wikipedia.org/wiki/Springfield,_Illinois IL
```

```
## 14              https://en.wikipedia.org/wiki/Indianapolis IN
## 15          https://en.wikipedia.org/wiki/Des_Moines,_Iowa IA
## 16            https://en.wikipedia.org/wiki/Topeka,_Kansas KS
## 17       https://en.wikipedia.org/wiki/Frankfort,_Kentucky KY
## 18    https://en.wikipedia.org/wiki/Baton_Rouge,_Louisiana LA
## 19            https://en.wikipedia.org/wiki/Augusta,_Maine ME
## 20       https://en.wikipedia.org/wiki/Annapolis,_Maryland MD
## 21                    https://en.wikipedia.org/wiki/Boston MA
## 22         https://en.wikipedia.org/wiki/Lansing,_Michigan MI
## 23     https://en.wikipedia.org/wiki/Saint_Paul,_Minnesota MN
## 24      https://en.wikipedia.org/wiki/Jackson,_Mississippi MS
## 25  https://en.wikipedia.org/wiki/Jefferson_City,_Missouri MO
## 26           https://en.wikipedia.org/wiki/Helena,_Montana MT
## 27         https://en.wikipedia.org/wiki/Lincoln,_Nebraska NE
## 28       https://en.wikipedia.org/wiki/Carson_City,_Nevada NV
## 29    https://en.wikipedia.org/wiki/Concord,_New_Hampshire NH
## 30       https://en.wikipedia.org/wiki/Trenton,_New_Jersey NJ
## 31      https://en.wikipedia.org/wiki/Santa_Fe,_New_Mexico NM
## 32          https://en.wikipedia.org/wiki/Albany,_New_York NY
## 33   https://en.wikipedia.org/wiki/Raleigh,_North_Carolina NC
## 34    https://en.wikipedia.org/wiki/Bismarck,_North_Dakota ND
## 35            https://en.wikipedia.org/wiki/Columbus,_Ohio OH
## 36             https://en.wikipedia.org/wiki/Oklahoma_City OK
## 37             https://en.wikipedia.org/wiki/Salem,_Oregon OR
## 38  https://en.wikipedia.org/wiki/Harrisburg,_Pennsylvania PA
## 39  https://en.wikipedia.org/wiki/Providence,_Rhode_Island RI
## 40  https://en.wikipedia.org/wiki/Columbia,_South_Carolina SC
## 41      https://en.wikipedia.org/wiki/Pierre,_South_Dakota SD
## 42      https://en.wikipedia.org/wiki/Nashville,_Tennessee TN
## 43             https://en.wikipedia.org/wiki/Austin,_Texas TX
## 44           https://en.wikipedia.org/wiki/Salt_Lake_City UT
## 45       https://en.wikipedia.org/wiki/Montpelier,_Vermont VT
## 46        https://en.wikipedia.org/wiki/Richmond,_Virginia VA
## 47       https://en.wikipedia.org/wiki/Olympia,_Washington WA
## 48 https://en.wikipedia.org/wiki/Charleston,_West_Virginia WV
## 49        https://en.wikipedia.org/wiki/Madison,_Wisconsin WI
## 50         https://en.wikipedia.org/wiki/Cheyenne,_Wyoming WY
```

Initial Plotting

- Plot the data on usmap (ggplot2)

```
latlong = removeAllColumnsBut(capitals,c( "state", "st", "capital", "latitude", "longitude", "populatio

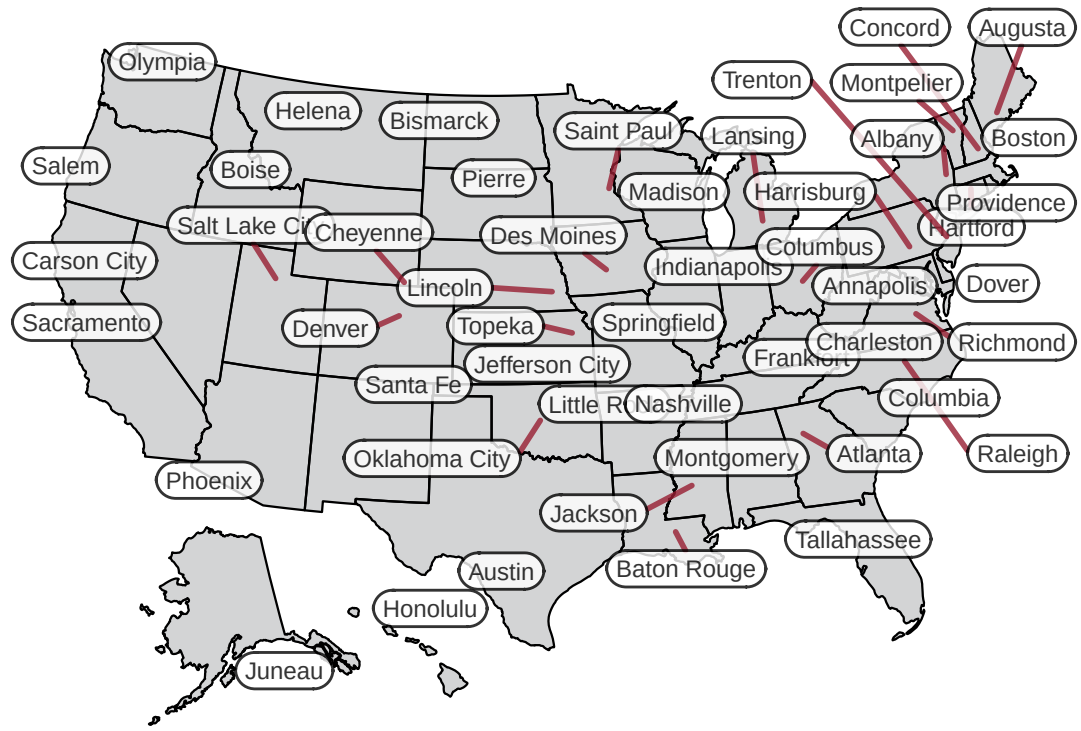
# first two elements have to be this
latlong = moveColumnsInDataFrame(latlong, c("longitude","latitude"), "before", "state");

# for transform to work
library(usmap);
latlong.transform = usmap_transform(latlong);
library(ggplot2);

### plot_usmap ...

plot_usmap(fill = "#53565A", alpha = 0.25) +
```

```
  ggrepel::geom_label_repel(data = latlong.transform,
            aes(x = longitude.1, y = latitude.1, label = capital),
            size = 3, alpha = 0.8,
            label.r = unit(0.5, "lines"), label.size = 0.5,
            segment.color = "#981E32", segment.size = 1,
            seed = 1002) +
  scale_size_continuous(range = c(1, 16),
                        label = scales::comma) +
  labs(title = "U.S. State Capitals",
       subtitle = "Source: Wikipedia (October 2020)") +
  theme(legend.position = "right")
```

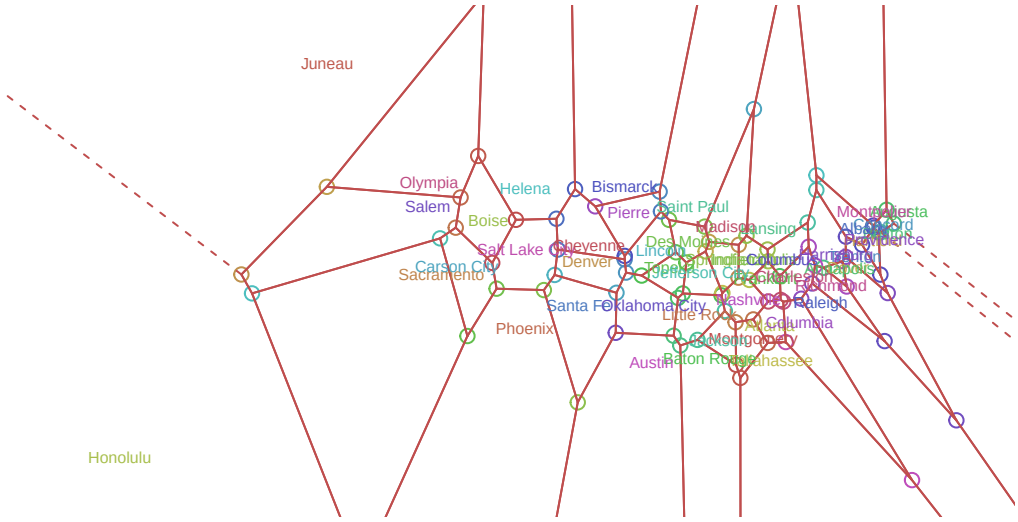


- Plot the data using maths `voronoi` (tripack)

```
colors = rainbow(50, s = 0.6, v = 0.75);

## initial visualization ...
library(tripack);
# plot( voronoi.mosaic(latlong[,4:3], duplicate="remove"), col=colors, xlab="");
plot( voronoi.mosaic(x = latlong$longitude, y = latlong$latitude), col=colors, xlab="");
text(x = latlong$longitude, y = latlong$latitude, labels = latlong$capital, col=colors, cex=0.5);
```

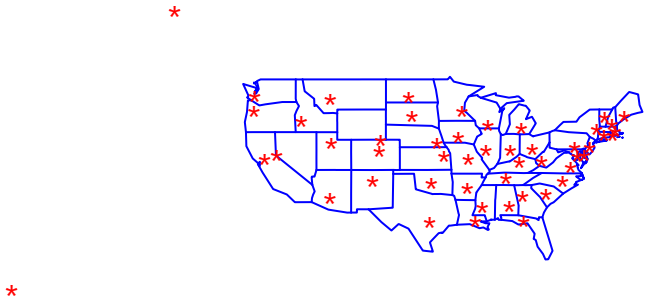
Voronoi mosaic



voronoi.mosaic(x = latlong$longitude, y = latlong$latitude)

- Plot the data on `map` (base)

```
### how is any of the other visualizations really any better than a simple map ... with actual location
library(maps);
map('state', plot = TRUE, fill = FALSE,
    col = "blue", myborder = 0.5
    );
points(x = latlong$longitude, y = latlong$latitude,
                  col = "red", pch = "*", cex = 1);
```



(5 points) Comparing "Visualization Options" Above, the data was displayed using three different visualization packages.

The first `plot_usmap` uses the 'ggplot2 methodology which is tied to the "tidyverse" landscape of the `R` community.

The second `voronoi.mosaic` uses the graph-theory topology known as Voroni partitioning https://en.wikipedia.org/wiki/Voronoi_diagram with the "base" plot function to visualize the topology.

The last one `map` is from the "base" environment.

[Visually, which is the most appealing to you? Why?

Functionally, which presents the data most effectively? Why?

When we create visualizations, it is essential to portray the data accurately. For example, there are times when putting Alaska/Hawaii next to California might be appropriate, and other times it might not be.

What is a one key factor that would determine this appropriateness?

]

(5 points) Building the distance matrix The dataframe we are using has been named `latlong` to represent the latitudes and longitudes of the 50 U.S. cities in America.

```
# manual conversion
# how many miles is 1 degree of latitude
latitude.factor = 69;  # rough mile estimate  # 68.703 ?
latlong$x.lat = latlong$latitude * latitude.factor;
```

```
longitude.factor = 54.6;  # rough mile estimate
latlong$y.long = latlong$longitude * longitude.factor;

latlong = moveColumnsInDataFrame(latlong, c("y.long","x.lat"), "before", "longitude");
```

Let's start with geo-spatial distances. I will do `distMeeus` and you will do `distHaversine`

Meeus These distance formulas can utilize the true geo-spatial coordinates. The distance table is getting large, so there is a helper function to lookup a certain value.

```
library(geosphere);
library(measurements);


dist.meeus = conv_unit(  distm( latlong[,3:4],
                  fun=distMeeus),  "m", "mi");  # default meters to miles

dist.meeus.m = as.matrix( dist.meeus );
  rownames(dist.meeus.m) =
  colnames(dist.meeus.m) = myLabels;

dist.meeus.df = as.data.frame( round( dist.meeus.m, digits=1) );

dist.meeus.df;  ## too big
```

```
##                    Montgomery, AL Juneau, AK Phoenix, AZ Little Rock, AR
## Montgomery, AL                0.0     2855.6      1497.1           385.6
## Juneau, AK                 2855.6        0.0      2005.8          2516.3
## Phoenix, AZ                1497.1     2005.8         0.0          1133.4
## Little Rock, AR             385.6     2516.3      1133.4             0.0
## Sacramento, CA             2018.8     1480.3       635.1          1634.7
## Denver, CO                 1161.4     1825.6       585.2           777.6
## Hartford, CT                990.5     2855.1      2215.2          1170.3
## Dover, DE                   763.8     2881.2      2062.7           977.2
## Tallahassee, FL             177.7     3032.3      1642.0           555.6
## Atlanta, GA                 145.7     2845.3      1591.5           459.4
## Honolulu, HI               4408.0     2809.0      2910.9          4040.4
## Boise, ID                  1795.1     1280.7       735.9          1413.7
## Springfield, IL             546.4     2338.4      1316.1           379.0
## Indianapolis, IN            510.7     2464.8      1498.7           485.8
## Des Moines, IA              754.3     2106.8      1154.9           478.0
## Topeka, KS                  701.4     2167.1       991.0           351.1
## Frankfort, KY               410.3     2591.8      1556.0           479.2
## Baton Rouge, LA             318.1     2796.7      1242.3           303.1
## Augusta, ME                1213.3     2836.7      2370.3          1367.5
## Annapolis, MD               713.6     2855.0      2010.2           923.1
## Boston, MA                 1081.8     2884.4      2299.3          1261.7
## Lansing, MI                 721.6     2375.7      1621.6           693.0
## Saint Paul, MN              942.1     1961.5      1285.2           705.4
## Jackson, MS                 228.5     2725.0      1272.6           208.7
## Jefferson City, MO          542.0     2313.6      1166.3           265.0
## Helena, MT                 1677.8     1234.8       906.7          1312.5
## Lincoln, NE                 819.6     2040.7       987.5           481.6
## Carson City, NV            1927.5     1474.7       582.6          1542.6
```

```
## Concord, NH               1097.1     2826.1      2277.8          1258.1
## Trenton, NJ                839.5     2855.3      2103.4          1034.8
## Santa Fe, NM              1150.5     2031.7       380.0           773.5
## Albany, NY                 986.3     2772.4      2162.9          1139.4
## Raleigh, NC                497.2     2943.7      1903.0           777.2
## Bismarck, ND              1257.7     1600.9      1095.9           942.4
## Columbus, OH               555.1     2568.8      1666.8           626.9
## Oklahoma City, OK          680.1     2303.0       841.2           298.3
## Salem, OR                 2146.1     1042.2       985.5          1764.9
## Harrisburg, PA             755.8     2776.0      1991.9           929.3
## Providence, RI            1045.8     2897.5      2279.9          1233.3
## Columbia, SC               324.2     2951.4      1780.7           647.3
## Pierre, SD                1122.7     1733.9       982.0           789.0
## Nashville, TN              263.8     2630.7      1445.5           328.1
## Austin, TX                 692.9     2596.4       869.6           441.1
## Salt Lake City, UT        1530.8     1564.2       504.3          1145.8
## Montpelier, VT            1105.1     2738.3      2231.8          1238.6
## Richmond, VA               613.7     2893.7      1959.9           852.4
## Olympia, WA               2171.6      914.1      1096.3          1795.8
## Charleston, WV             488.8     2700.6      1732.1           644.7
## Madison, WI                758.0     2184.2      1394.4           596.6
## Cheyenne, WY              1190.0     1753.3       663.3           811.4
##                    Sacramento, CA Denver, CO Hartford, CT Dover, DE
## Montgomery, AL             2018.8     1161.4       990.5     763.8
## Juneau, AK                 1480.3     1825.6      2855.1    2881.2
## Phoenix, AZ                 635.1      585.2      2215.2    2062.7
## Little Rock, AR            1634.7      777.6      1170.3     977.2
## Sacramento, CA                0.0      888.7      2558.5    2452.1
## Denver, CO                 888.7        0.0      1691.6    1569.4
## Hartford, CT               2558.5     1691.6         0.0     234.2
## Dover, DE                  2452.1     1569.4       234.2       0.0
## Tallahassee, FL            2181.2     1333.2      1011.7     777.8
## Atlanta, GA                2086.5     1211.9       845.0     618.1
## Honolulu, HI               2461.8     3343.9      5018.8    4912.6
## Boise, ID                   443.7      638.1      2194.7    2114.9
## Springfield, IL            1702.3      815.5       899.4     756.0
## Indianapolis, IN           1886.8     1001.0       719.9     569.8
## Des Moines, IA             1485.1      610.4      1081.2     967.7
## Topeka, KS                 1388.2      499.8      1224.4    1081.6
## Frankfort, KY              1975.1     1086.5       691.5     509.2
## Baton Rouge, LA            1808.7     1009.1      1291.6    1071.2
## Augusta, ME                2669.3     1824.8       228.9     463.1
## Annapolis, MD              2404.2     1520.3       278.9      54.1
## Boston, MA                 2631.2     1769.7        92.5     321.7
## Lansing, MI                1946.8     1082.0       612.0     532.2
## Saint Paul, MN             1522.9      706.2      1048.8     985.4
## Jackson, MS                1809.3      973.2      1163.9     948.4
## Jefferson City, MO         1580.7      692.4      1052.8     897.5
## Helena, MT                  733.2      591.0      1962.3    1903.8
## Lincoln, NE                1327.0      445.2      1247.2    1125.8
## Carson City, NV             101.5      790.4      2457.2    2351.7
## Concord, NH                2596.2     1740.9       115.3     348.1
## Trenton, NJ                2474.4     1596.8       152.3      84.0
## Santa Fe, NM                879.6      285.9      1835.3    1683.7
```

```
## Albany, NY                2492.3     1631.0        82.8     258.3
## Raleigh, NC               2351.8     1463.5       523.7     289.6
## Bismarck, ND              1192.5      531.9      1428.7    1377.1
## Columbus, OH              2050.2     1166.5       554.7     402.9
## Oklahoma City, OK         1338.8      504.4      1407.2    1234.8
## Salem, OR                  445.9      988.8      2505.8    2441.0
## Harrisburg, PA            2364.7     1485.9       242.5     105.2
## Providence, RI            2620.9     1755.3        64.8     283.7
## Columbia, SC              2262.0     1380.1       703.1     469.2
## Pierre, SD                1165.3      399.8      1404.0    1325.0
## Nashville, TN             1906.3     1022.4       850.8     650.3
## Austin, TX                1467.2      770.9      1603.7    1400.2
## Salt Lake City, UT         533.3      371.5      2025.4    1920.1
## Montpelier, VT            2533.0     1686.2       172.4     383.6
## Richmond, VA              2378.8     1490.9       387.8     153.9
## Olympia, WA                588.0     1029.5      2469.5    2418.7
## Charleston, WV            2144.4     1256.6       529.9     334.6
## Madison, WI               1700.6      841.4       857.9     771.0
## Cheyenne, WY               902.5       97.1      1659.8    1549.8
##                    Tallahassee, FL Atlanta, GA Honolulu, HI Boise, ID
## Montgomery, AL               177.7       145.7       4408.0    1795.1
## Juneau, AK                  3032.3      2845.3       2809.0    1280.7
## Phoenix, AZ                 1642.0      1591.5       2910.9     735.9
## Little Rock, AR              555.6       459.4       4040.4    1413.7
## Sacramento, CA              2181.2      2086.5       2461.8     443.7
## Denver, CO                  1333.2      1211.9       3343.9     638.1
## Hartford, CT                1011.7       845.0       5018.8    2194.7
## Dover, DE                    777.8       618.1       4912.6    2114.9
## Tallahassee, FL                0.0       227.5       4549.8    1968.8
## Atlanta, GA                  227.5         0.0       4499.8    1835.5
## Honolulu, HI                4549.8      4499.8          0.0    2835.4
## Boise, ID                   1968.8      1835.5       2835.4       0.0
## Springfield, IL              712.8       508.7       4159.3    1391.7
## Indianapolis, IN             651.0       426.1       4344.9    1567.8
## Des Moines, IA               928.6       739.4       3946.6    1156.3
## Topeka, KS                   878.9       727.3       3838.8    1109.0
## Frankfort, KY                535.0       307.6       4426.8    1671.8
## Baton Rouge, LA              413.2       458.6       4142.8    1644.5
## Augusta, ME                 1240.0      1068.5       5118.9    2284.0
## Annapolis, MD                733.8       567.9       4864.0    2070.8
## Boston, MA                  1099.1       936.2       5089.5    2260.7
## Lansing, MI                  846.8       619.3       4407.8    1590.8
## Saint Paul, MN              1108.9       900.5       3975.7    1146.0
## Jackson, MS                  372.8       351.0       4182.9    1611.2
## Jefferson City, MO           718.8       547.3       4029.5    1296.5
## Helena, MT                  1855.1      1696.3       3095.1     289.8
## Lincoln, NE                  997.3       832.4       3786.8    1017.8
## Carson City, NV             2091.5      1992.4       2562.8     358.7
## Concord, NH                 1124.2       952.1       5052.0    2220.3
## Trenton, NJ                  859.6       693.9       4936.2    2126.5
## Santa Fe, NM                1306.9      1232.6       3268.4     772.7
## Albany, NY                  1022.0       842.1       4951.0    2123.3
## Raleigh, NC                  490.0       355.6       4795.1    2055.2
## Bismarck, ND                1433.3      1244.7       3617.5     782.7
```

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## Columbus, OH                659.2       434.9       4510.0    1721.6
## Oklahoma City, OK           843.7       757.0       3743.7    1141.4
## Salem, OR                  2319.9      2184.7       2560.8     351.2
## Harrisburg, PA              793.9       611.5       4826.3    2020.4
## Providence, RI             1060.3       900.2       5080.7    2254.7
## Columbia, SC                308.5       193.6       4686.2    1993.1
## Pierre, SD                 1299.9      1123.5       3617.8     792.1
## Nashville, TN               419.9       214.7       4340.3    1635.7
## Austin, TX                  805.4       819.2       3755.2    1369.4
## Salt Lake City, UT         1701.0      1583.4       2995.0     296.2
## Montpelier, VT             1146.1       962.0       4984.9    2150.9
## Richmond, VA                623.9       468.4       4833.2    2061.3
## Olympia, WA                2347.5      2200.4       2636.9     402.7
## Charleston, WV              564.1       352.2       4599.2    1830.1
## Madison, WI                 915.1       697.3       4161.3    1345.8
## Cheyenne, WY               1364.7      1229.4       3364.0     606.4
##                    Springfield, IL Indianapolis, IN Des Moines, IA Topeka, KS
## Montgomery, AL               546.4             510.7          754.3      701.4
## Juneau, AK                  2338.4            2464.8         2106.8     2167.1
## Phoenix, AZ                 1316.1            1498.7         1154.9      991.0
## Little Rock, AR              379.0             485.8          478.0      351.1
## Sacramento, CA              1702.3            1886.8         1485.1     1388.2
## Denver, CO                   815.5            1001.0          610.4      499.8
## Hartford, CT                 899.4             719.9         1081.2     1224.4
## Dover, DE                    756.0             569.8          967.7     1081.6
## Tallahassee, FL              712.8             651.0          928.6      878.9
## Atlanta, GA                  508.7             426.1          739.4      727.3
## Honolulu, HI                4159.3            4344.9         3946.6     3838.8
## Boise, ID                   1391.7            1567.8         1156.3     1109.0
## Springfield, IL                0.0             186.1          242.2      326.8
## Indianapolis, IN             186.1               0.0          411.5      512.2
## Des Moines, IA               242.2             411.5            0.0      206.2
## Topeka, KS                   326.8             512.2          206.2        0.0
## Frankfort, KY                280.3             128.6          520.4      588.2
## Baton Rouge, LA              650.4             702.4          780.3      646.3
## Augusta, ME                 1065.6             897.2         1219.0     1382.2
## Annapolis, MD                705.8             519.7          920.9     1030.7
## Boston, MA                   984.6             807.2         1159.5     1308.2
## Lansing, MI                  334.2             221.1          472.3      635.6
## Saint Paul, MN               396.2             503.3          233.0      427.7
## Jackson, MS                  518.0             562.1          668.2      559.1
## Jefferson City, MO           159.4             333.2          221.6      192.6
## Helena, MT                  1217.7            1381.2          975.7      976.4
## Lincoln, NE                  377.4             560.2          168.3      131.9
## Carson City, NV             1602.8            1787.0         1384.4     1290.2
## Concord, NH                  966.7             793.7         1131.9     1287.4
## Trenton, NJ                  789.6             605.0          989.7     1116.5
## Santa Fe, NM                 936.1            1118.8          781.8      611.5
## Albany, NY                   850.0             675.4         1020.9     1172.1
## Raleigh, NC                  663.7             495.6          902.8      963.7
## Bismarck, ND                 739.6             881.1          505.9      593.9
## Columbus, OH                 353.8             168.4          567.9      680.4
## Oklahoma City, OK            524.4             689.6          472.1      267.2
## Salem, OR                   1732.2            1904.5         1493.6     1457.6
```

```
## Harrisburg, PA              677.9           493.4          879.7     1004.8
## Providence, RI              964.2           784.6         1144.9     1289.1
## Columbia, SC                622.2           488.4          863.6      885.5
## Pierre, SD                  631.9           793.2          389.9      438.0
## Nashville, TN               295.5           250.8          524.9      527.4
## Austin, TX                  800.5           926.1          814.0      617.0
## Salt Lake City, UT         1173.8          1357.0          952.5      867.6
## Montpelier, VT              929.1           763.5         1080.3     1244.2
## Richmond, VA                676.8           494.5          905.3      994.4
## Olympia, WA                1731.3          1897.1         1489.9     1474.3
## Charleston, WV              442.6           262.3          673.9      760.6
## Madison, WI                 226.5           283.0          239.9      430.3
## Cheyenne, WY                803.4           986.3          582.7      504.4
##                    Frankfort, KY Baton Rouge, LA Augusta, ME Annapolis, MD
## Montgomery, AL             410.3          318.1      1213.3         713.6
## Juneau, AK                2591.8         2796.7      2836.7        2855.0
## Phoenix, AZ               1556.0         1242.3      2370.3        2010.2
## Little Rock, AR            479.2          303.1      1367.5         923.1
## Sacramento, CA            1975.1         1808.7      2669.3        2404.2
## Denver, CO                1086.5         1009.1      1824.8        1520.3
## Hartford, CT               691.5         1291.6       228.9         278.9
## Dover, DE                  509.2         1071.2       463.1          54.1
## Tallahassee, FL            535.0          413.2      1240.0         733.8
## Atlanta, GA                307.6          458.6      1068.5         567.9
## Honolulu, HI              4426.8         4142.8      5118.9        4864.0
## Boise, ID                 1671.8         1644.5      2284.0        2070.8
## Springfield, IL            280.3          650.4      1065.6         705.8
## Indianapolis, IN           128.6          702.4       897.2         519.7
## Des Moines, IA             520.4          780.3      1219.0         920.9
## Topeka, KS                 588.2          646.3      1382.2        1030.7
## Frankfort, KY                0.0          644.4       889.8         455.9
## Baton Rouge, LA            644.4            0.0      1508.7        1019.3
## Augusta, ME                889.8         1508.7         0.0         506.4
## Annapolis, MD              455.9         1019.3       506.4           0.0
## Boston, MA                 782.7         1383.8       149.5         368.9
## Lansing, MI                313.3          923.2       748.7         494.7
## Saint Paul, MN             630.5         1005.2      1146.5         946.5
## Jackson, MS                505.7          140.4      1377.8         895.6
## Jefferson City, MO         397.4          563.2      1223.7         845.7
## Helena, MT                1495.5         1576.5      2034.6        1863.4
## Lincoln, NE                655.8          778.1      1387.2        1077.4
## Carson City, NV           1876.4         1724.1      2567.9        2304.0
## Concord, NH                779.3         1393.6       116.4         390.3
## Trenton, NJ                559.5         1143.2       380.4         126.7
## Santa Fe, NM              1178.3          929.1      1992.5        1631.4
## Albany, NY                 660.7         1278.9       230.4         291.8
## Raleigh, NC                383.4          813.8       752.6         250.3
## Bismarck, ND              1003.8         1240.2      1504.1        1338.8
## Columbus, OH               157.6          801.9       741.4         354.1
## Oklahoma City, OK          725.6          505.3      1585.8        1181.3
## Salem, OR                 2012.5         1993.0      2578.2        2398.9
## Harrisburg, PA             451.7         1051.6       458.0          91.7
## Providence, RI             754.8         1349.6       190.7         332.3
## Columbia, SC               360.2          642.2       931.6         425.6
```

```
## Pierre, SD                908.1          1082.3      1504.5        1282.3
## Nashville, TN             175.6           468.9      1057.0         596.3
## Austin, TX                916.3           392.3      1806.0        1346.5
## Salt Lake City, UT       1449.7          1360.6      2139.8        1872.8
## Montpelier, VT            763.5          1392.4       138.7         417.5
## Richmond, VA              407.1           924.9       616.4         112.4
## Olympia, WA              2010.2          2038.6      2529.0        2378.9
## Charleston, WV            176.1           769.8       740.2         280.9
## Madison, WI               411.6           876.3       983.4         729.3
## Cheyenne, WY             1080.5          1060.8      1782.9        1502.2
##                    Boston, MA Lansing, MI Saint Paul, MN Jackson, MS
## Montgomery, AL         1081.8      721.6          942.1       228.5
## Juneau, AK             2884.4     2375.7         1961.5      2725.0
## Phoenix, AZ            2299.3     1621.6         1285.2      1272.6
## Little Rock, AR        1261.7      693.0          705.4       208.7
## Sacramento, CA         2631.2     1946.8         1522.9      1809.3
## Denver, CO             1769.7     1082.0          706.2       973.2
## Hartford, CT             92.5      612.0         1048.8      1163.9
## Dover, DE               321.7      532.2          985.4       948.4
## Tallahassee, FL        1099.1      846.8         1108.9       372.8
## Atlanta, GA             936.2      619.3          900.5       351.0
## Honolulu, HI           5089.5     4407.8         3975.7      4182.9
## Boise, ID              2260.7     1590.8         1146.0      1611.2
## Springfield, IL         984.6      334.2          396.2       518.0
## Indianapolis, IN        807.2      221.1          503.3       562.1
## Des Moines, IA         1159.5      472.3          233.0       668.2
## Topeka, KS             1308.2      635.6          427.7       559.1
## Frankfort, KY           782.7      313.3          630.5       505.7
## Baton Rouge, LA        1383.8      923.2         1005.2       140.4
## Augusta, ME             149.5      748.7         1146.5      1377.8
## Annapolis, MD           368.9      494.7          946.5       895.6
## Boston, MA                0.0      687.9         1115.1      1256.3
## Lansing, MI             687.9        0.0          453.3       783.0
## Saint Paul, MN         1115.1      453.3            0.0       886.2
## Jackson, MS            1256.3      783.0          886.2         0.0
## Jefferson City, MO     1139.4      492.5          442.0       447.1
## Helena, MT             2022.6     1372.5          919.6      1519.2
## Lincoln, NE            1326.5      640.1          338.5       688.6
## Carson City, NV        2529.8     1845.5         1421.5      1720.4
## Concord, NH              63.4      659.6         1076.4      1263.4
## Trenton, NJ             242.4      536.1          987.5      1017.6
## Santa Fe, NM           1919.6     1244.2          931.6       934.1
## Albany, NY              139.1      549.0          977.4      1147.5
## Raleigh, NC             609.8      575.5          989.1       704.1
## Bismarck, ND           1489.0      844.9          392.5      1147.5
## Columbus, OH            643.5      207.5          619.3       663.3
## Oklahoma City, OK      1495.8      857.2          694.2       474.8
## Salem, OR              2566.7     1911.6         1460.2      1962.0
## Harrisburg, PA          334.9      432.6          885.7       922.4
## Providence, RI           41.2      674.9         1108.7      1223.3
## Columbia, SC            790.7      631.7          990.6       543.0
## Pierre, SD             1472.2      798.7          358.2       996.6
## Nashville, TN           943.0      468.5          690.2       330.1
## Austin, TX             1695.8     1127.9         1043.4       468.5
```

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## Salt Lake City, UT     2098.7      1413.6          994.8      1336.5
## Montpelier, VT          151.8       610.2         1010.6      1258.9
## Richmond, VA            475.6       518.6          958.8       806.3
## Olympia, WA            2526.2      1886.7         1433.5      1997.7
## Charleston, WV          622.2       339.2          746.6       637.7
## Madison, WI             932.0       246.6          225.4       744.5
## Cheyenne, WY           1735.2      1048.0          648.4      1013.4
##                   Jefferson City, MO Helena, MT Lincoln, NE Carson City, NV
## Montgomery, AL                 542.0     1677.8       819.6          1927.5
## Juneau, AK                    2313.6     1234.8      2040.7          1474.7
## Phoenix, AZ                   1166.3      906.7       987.5           582.6
## Little Rock, AR                265.0     1312.5       481.6          1542.6
## Sacramento, CA                1580.7      733.2      1327.0           101.5
## Denver, CO                     692.4      591.0       445.2           790.4
## Hartford, CT                  1052.8     1962.3      1247.2          2457.2
## Dover, DE                      897.5     1903.8      1125.8          2351.7
## Tallahassee, FL                718.8     1855.1       997.3          2091.5
## Atlanta, GA                    547.3     1696.3       832.4          1992.4
## Honolulu, HI                  4029.5     3095.1      3786.8          2562.8
## Boise, ID                     1296.5      289.8      1017.8           358.7
## Springfield, IL                159.4     1217.7       377.4          1602.8
## Indianapolis, IN               333.2     1381.2       560.2          1787.0
## Des Moines, IA                 221.6      975.7       168.3          1384.4
## Topeka, KS                     192.6      976.4       131.9          1290.2
## Frankfort, KY                  397.4     1495.5       655.8          1876.4
## Baton Rouge, LA                563.2     1576.5       778.1          1724.1
## Augusta, ME                   1223.7     2034.6      1387.2          2567.9
## Annapolis, MD                  845.7     1863.4      1077.4          2304.0
## Boston, MA                    1139.4     2022.6      1326.5          2529.8
## Lansing, MI                    492.5     1372.5       640.1          1845.5
## Saint Paul, MN                 442.0      919.6       338.5          1421.5
## Jackson, MS                    447.1     1519.2       688.6          1720.4
## Jefferson City, MO               0.0     1149.0       285.2          1482.8
## Helena, MT                    1149.0        0.0       863.9           645.4
## Lincoln, NE                    285.2      863.9         0.0          1227.0
## Carson City, NV               1482.8      645.4      1227.0             0.0
## Concord, NH                   1123.5     1978.5      1299.7          2494.8
## Trenton, NJ                    937.2     1907.0      1151.7          2373.6
## Santa Fe, NM                   786.7      816.7       616.6           795.7
## Albany, NY                    1006.1     1887.5      1188.1          2390.9
## Raleigh, NC                    771.1     1876.3      1038.5          2253.9
## Bismarck, ND                   716.7      533.8       462.1          1093.2
## Columbus, OH                   500.8     1523.6       723.3          1950.0
## Oklahoma City, OK              365.1     1075.1       371.2          1248.1
## Salem, OR                     1643.3      544.2      1362.0           432.6
## Harrisburg, PA                 825.7     1805.1      1040.9          2263.9
## Providence, RI                1117.6     2020.0      1311.2          2519.5
## Columbia, SC                   696.6     1836.5       978.3          2166.4
## Pierre, SD                     581.5      588.1       308.1          1064.0
## Nashville, TN                  340.0     1486.7       624.2          1810.0
## Austin, TX                     654.8     1361.9       729.2          1390.5
## Salt Lake City, UT            1059.7      402.6       796.9           432.2
## Montpelier, VT                1087.6     1904.8      1248.5          2431.6
## Richmond, VA                   804.4     1866.2      1053.8          2279.4
```

```
## Olympia, WA                  1654.4      516.5      1369.8           566.0
## Charleston, WV                571.5     1641.4       819.9          2045.1
## Madison, WI                   343.0     1134.2       406.9          1599.3
## Cheyenne, WY                  694.6      520.1       426.2           801.9
##                    Concord, NH Trenton, NJ Santa Fe, NM Albany, NY Raleigh, NC
## Montgomery, AL          1097.1       839.5       1150.5      986.3       497.2
## Juneau, AK              2826.1      2855.3       2031.7     2772.4      2943.7
## Phoenix, AZ             2277.8      2103.4        380.0     2162.9      1903.0
## Little Rock, AR         1258.1      1034.8        773.5     1139.4       777.2
## Sacramento, CA          2596.2      2474.4        879.6     2492.3      2351.8
## Denver, CO              1740.9      1596.8        285.9     1631.0      1463.5
## Hartford, CT             115.3       152.3       1835.3       82.8       523.7
## Dover, DE                348.1        84.0       1683.7      258.3       289.6
## Tallahassee, FL         1124.2       859.6       1306.9     1022.0       490.0
## Atlanta, GA              952.1       693.9       1232.6      842.1       355.6
## Honolulu, HI            5052.0      4936.2       3268.4     4951.0      4795.1
## Boise, ID               2220.3      2126.5        772.7     2123.3      2055.2
## Springfield, IL          966.7       789.6        936.1      850.0       663.7
## Indianapolis, IN         793.7       605.0       1118.8      675.4       495.6
## Des Moines, IA          1131.9       989.7        781.8     1020.9       902.8
## Topeka, KS              1287.4      1116.5        611.5     1172.1       963.7
## Frankfort, KY            779.3       559.5       1178.3      660.7       383.4
## Baton Rouge, LA         1393.6      1143.2        929.1     1278.9       813.8
## Augusta, ME              116.4       380.4       1992.5      230.4       752.6
## Annapolis, MD            390.3       126.7       1631.4      291.8       250.3
## Boston, MA                63.4       242.4       1919.6      139.1       609.8
## Lansing, MI              659.6       536.1       1244.2      549.0       575.5
## Saint Paul, MN          1076.4       987.5        931.6      977.4       989.1
## Jackson, MS             1263.4      1017.6        934.1     1147.5       704.1
## Jefferson City, MO      1123.5       937.2        786.7     1006.1       771.1
## Helena, MT              1978.5      1907.0        816.7     1887.5      1876.3
## Lincoln, NE             1299.7      1151.7        616.6     1188.1      1038.5
## Carson City, NV         2494.8      2373.6        795.7     2390.9      2253.9
## Concord, NH                0.0       264.9       1898.8      118.9       637.6
## Trenton, NJ              264.9         0.0       1723.6      175.6       372.9
## Santa Fe, NM            1898.8      1723.6          0.0     1783.6      1531.7
## Albany, NY               118.9       175.6       1783.6        0.0       542.1
## Raleigh, NC              637.6       372.9       1531.7      542.1         0.0
## Bismarck, ND            1445.4      1376.4        814.4     1353.7      1374.4
## Columbus, OH             634.1       436.7       1287.0      515.2       375.0
## Oklahoma City, OK       1483.3      1283.1        475.6     1365.0      1061.9
## Salem, OR               2522.7      2447.3       1102.1     2431.4      2395.7
## Harrisburg, PA           342.2       111.7       1612.0      230.7       325.0
## Providence, RI            95.6       206.6       1900.1      132.7       570.6
## Columbia, SC             815.8       551.1       1417.8      715.2       182.9
## Pierre, SD              1434.3      1334.6        670.7     1334.0      1288.3
## Nashville, TN            944.5       710.8       1074.6      826.9       457.5
## Austin, TX              1695.2      1463.5        605.0     1576.8      1170.1
## Salt Lake City, UT      2064.6      1941.4        476.7     1959.7      1829.7
## Montpelier, VT            89.3       300.3       1854.2      125.8       667.8
## Richmond, VA             500.9       236.0       1583.5      404.1       137.9
## Olympia, WA             2479.6      2419.7       1174.9     2393.0      2391.8
## Charleston, WV           626.1       390.2       1354.2      509.9       243.2
## Madison, WI              900.5       780.8       1021.6      792.9       763.8
```

```
## Cheyenne, WY            1703.4      1572.3        382.6     1596.1      1461.8
##                    Bismarck, ND Columbus, OH Oklahoma City, OK Salem, OR
## Montgomery, AL           1257.7        555.1             680.1    2146.1
## Juneau, AK               1600.9       2568.8            2303.0    1042.2
## Phoenix, AZ              1095.9       1666.8             841.2     985.5
## Little Rock, AR           942.4        626.9             298.3    1764.9
## Sacramento, CA           1192.5       2050.2            1338.8     445.9
## Denver, CO                531.9       1166.5             504.4     988.8
## Hartford, CT             1428.7        554.7            1407.2    2505.8
## Dover, DE                1377.1        402.9            1234.8    2441.0
## Tallahassee, FL          1433.3        659.2             843.7    2319.9
## Atlanta, GA              1244.7        434.9             757.0    2184.7
## Honolulu, HI             3617.5       4510.0            3743.7    2560.8
## Boise, ID                 782.7       1721.6            1141.4     351.2
## Springfield, IL           739.6        353.8             524.4    1732.2
## Indianapolis, IN          881.1        168.4             689.6    1904.5
## Des Moines, IA            505.9        567.9             472.1    1493.6
## Topeka, KS                593.9        680.4             267.2    1457.6
## Frankfort, KY            1003.8        157.6             725.6    2012.5
## Baton Rouge, LA          1240.2        801.9             505.3    1993.0
## Augusta, ME              1504.1        741.4            1585.8    2578.2
## Annapolis, MD            1338.8        354.1            1181.3    2398.9
## Boston, MA               1489.0        643.5            1495.8    2566.7
## Lansing, MI               844.9        207.5             857.2    1911.6
## Saint Paul, MN            392.5        619.3             694.2    1460.2
## Jackson, MS              1147.5        663.3             474.8    1962.0
## Jefferson City, MO        716.7        500.8             365.1    1643.3
## Helena, MT                533.8       1523.6            1075.1     544.2
## Lincoln, NE               462.1        723.3             371.2    1362.0
## Carson City, NV          1093.2       1950.0            1248.1     432.6
## Concord, NH              1445.4        634.1            1483.3    2522.7
## Trenton, NJ              1376.4        436.7            1283.1    2447.3
## Santa Fe, NM              814.4       1287.0             475.6    1102.1
## Albany, NY               1353.7        515.2            1365.0    2431.4
## Raleigh, NC              1374.4        375.0            1061.9    2395.7
## Bismarck, ND                0.0       1009.2             800.6    1077.7
## Columbus, OH             1009.2          0.0             852.5    2053.9
## Oklahoma City, OK         800.6        852.5               0.0    1491.2
## Salem, OR                1077.7       2053.9            1491.2       0.0
## Harrisburg, PA           1276.6        325.1            1173.2    2343.8
## Providence, RI           1486.3        619.2            1471.7    2563.8
## Columbia, SC             1359.1        425.2             942.5    2339.6
## Pierre, SD                169.7        937.8             631.9    1116.8
## Nashville, TN            1030.0        333.2             604.6    1983.1
## Austin, TX               1152.6       1067.1             358.7    1705.6
## Salt Lake City, UT        693.9       1518.9             862.5     634.7
## Montpelier, VT           1372.8        611.7            1450.7    2448.9
## Richmond, VA             1350.2        342.6            1123.3    2395.5
## Olympia, WA              1043.4       2040.1            1533.7     145.1
## Charleston, WV           1133.7        133.4             900.7    2166.6
## Madison, WI               614.9        394.5             681.7    1670.0
## Cheyenne, WY              439.9       1148.3             556.7     956.7
##                    Harrisburg, PA Providence, RI Columbia, SC Pierre, SD
## Montgomery, AL              755.8         1045.8        324.2     1122.7
```

```
## Juneau, AK                2776.0         2897.5       2951.4     1733.9
## Phoenix, AZ               1991.9         2279.9       1780.7      982.0
## Little Rock, AR            929.3         1233.3        647.3      789.0
## Sacramento, CA            2364.7         2620.9       2262.0     1165.3
## Denver, CO                1485.9         1755.3       1380.1      399.8
## Hartford, CT               242.5           64.8        703.1     1404.0
## Dover, DE                  105.2          283.7        469.2     1325.0
## Tallahassee, FL            793.9         1060.3        308.5     1299.9
## Atlanta, GA                611.5          900.2        193.6     1123.5
## Honolulu, HI              4826.3         5080.7       4686.2     3617.8
## Boise, ID                 2020.4         2254.7       1993.1      792.1
## Springfield, IL            677.9          964.2        622.2      631.9
## Indianapolis, IN           493.4          784.6        488.4      793.2
## Des Moines, IA             879.7         1144.9        863.6      389.9
## Topeka, KS                1004.8         1289.1        885.5      438.0
## Frankfort, KY              451.7          754.8        360.2      908.1
## Baton Rouge, LA           1051.6         1349.6        642.2     1082.3
## Augusta, ME                458.0          190.7        931.6     1504.5
## Annapolis, MD               91.7          332.3        425.6     1282.3
## Boston, MA                 334.9           41.2        790.7     1472.2
## Lansing, MI                432.6          674.9        631.7      798.7
## Saint Paul, MN             885.7         1108.7        990.6      358.2
## Jackson, MS                922.4         1223.3        543.0      996.6
## Jefferson City, MO         825.7         1117.6        696.6      581.5
## Helena, MT                1805.1         2020.0       1836.5      588.1
## Lincoln, NE               1040.9         1311.2        978.3      308.1
## Carson City, NV           2263.9         2519.5       2166.4     1064.0
## Concord, NH                342.2           95.6        815.8     1434.3
## Trenton, NJ                111.7          206.6        551.1     1334.6
## Santa Fe, NM              1612.0         1900.1       1417.8      670.7
## Albany, NY                 230.7          132.7        715.2     1334.0
## Raleigh, NC                325.0          570.6        182.9     1288.3
## Bismarck, ND              1276.6         1486.3       1359.1      169.7
## Columbus, OH               325.1          619.2        425.2      937.8
## Oklahoma City, OK         1173.2         1471.7        942.5      631.9
## Salem, OR                 2343.8         2563.8       2339.6     1116.8
## Harrisburg, PA               0.0          304.3        489.4     1229.2
## Providence, RI             304.3            0.0        752.0     1464.7
## Columbia, SC               489.4          752.0          0.0     1253.4
## Pierre, SD                1229.2         1464.7       1253.4        0.0
## Nashville, TN              608.4          912.6        358.3      910.3
## Austin, TX                1361.4         1665.6       1011.5      982.9
## Salt Lake City, UT        1831.9         2087.9       1750.9      640.1
## Montpelier, VT             352.6          178.0        840.0     1368.7
## Richmond, VA               191.5          437.3        315.4     1280.0
## Olympia, WA               2319.1         2525.7       2347.0     1104.0
## Charleston, WV             287.4          591.4        301.6     1053.7
## Madison, WI                674.8          920.4        771.4      554.4
## Cheyenne, WY              1462.3         1722.9       1389.9      319.6
##                    Nashville, TN Austin, TX Salt Lake City, UT Montpelier, VT
## Montgomery, AL             263.8      692.9             1530.8         1105.1
## Juneau, AK                2630.7     2596.4             1564.2         2738.3
## Phoenix, AZ               1445.5      869.6              504.3         2231.8
## Little Rock, AR            328.1      441.1             1145.8         1238.6
```

```
## Sacramento, CA            1906.3     1467.2             533.3         2533.0
## Denver, CO                1022.4      770.9             371.5         1686.2
## Hartford, CT               850.8     1603.7            2025.4          172.4
## Dover, DE                  650.3     1400.2            1920.1          383.6
## Tallahassee, FL            419.9      805.4            1701.0         1146.1
## Atlanta, GA                214.7      819.2            1583.4          962.0
## Honolulu, HI              4340.3     3755.2            2995.0         4984.9
## Boise, ID                 1635.7     1369.4             296.2         2150.9
## Springfield, IL            295.5      800.5            1173.8          929.1
## Indianapolis, IN           250.8      926.1            1357.0          763.5
## Des Moines, IA             524.9      814.0             952.5         1080.3
## Topeka, KS                 527.4      617.0             867.6         1244.2
## Frankfort, KY              175.6      916.3            1449.7          763.5
## Baton Rouge, LA            468.9      392.3            1360.6         1392.4
## Augusta, ME               1057.0     1806.0            2139.8          138.7
## Annapolis, MD              596.3     1346.5            1872.8          417.5
## Boston, MA                 943.0     1695.8            2098.7          151.8
## Lansing, MI                468.5     1127.9            1413.6          610.2
## Saint Paul, MN             690.2     1043.4             994.8         1010.6
## Jackson, MS                330.1      468.5            1336.5         1258.9
## Jefferson City, MO         340.0      654.8            1059.7         1087.6
## Helena, MT                1486.7     1361.9             402.6         1904.8
## Lincoln, NE                624.2      729.2             796.9         1248.5
## Carson City, NV           1810.0     1390.5             432.2         2431.6
## Concord, NH                944.5     1695.2            2064.6           89.3
## Trenton, NJ                710.8     1463.5            1941.4          300.3
## Santa Fe, NM              1074.6      605.0             476.7         1854.2
## Albany, NY                 826.9     1576.8            1959.7          125.8
## Raleigh, NC                457.5     1170.1            1829.7          667.8
## Bismarck, ND              1030.0     1152.6             693.9         1372.8
## Columbus, OH               333.2     1067.1            1518.9          611.7
## Oklahoma City, OK          604.6      358.7             862.5         1450.7
## Salem, OR                 1983.1     1705.6             634.7         2448.9
## Harrisburg, PA             608.4     1361.4            1831.9          352.6
## Providence, RI             912.6     1665.6            2087.9          178.0
## Columbia, SC               358.3     1011.5            1750.9          840.0
## Pierre, SD                 910.3      982.9             640.1         1368.7
## Nashville, TN                0.0      753.1            1392.8          934.0
## Austin, TX                 753.1        0.0            1074.1         1678.6
## Salt Lake City, UT        1392.8     1074.1               0.0         2002.8
## Montpelier, VT             934.0     1678.6            2002.8            0.0
## Richmond, VA               524.6     1264.9            1850.5          529.9
## Olympia, WA               1993.9     1771.8             698.8         2402.9
## Charleston, WV             321.2     1074.3            1616.4          622.7
## Madison, WI                496.3      996.5            1167.5          844.8
## Cheyenne, WY              1031.8      848.0             370.8         1645.0
##                    Richmond, VA Olympia, WA Charleston, WV Madison, WI
## Montgomery, AL            613.7      2171.6          488.8       758.0
## Juneau, AK               2893.7       914.1         2700.6      2184.2
## Phoenix, AZ              1959.9      1096.3         1732.1      1394.4
## Little Rock, AR           852.4      1795.8          644.7       596.6
## Sacramento, CA           2378.8       588.0         2144.4      1700.6
## Denver, CO               1490.9      1029.5         1256.6       841.4
## Hartford, CT              387.8      2469.5          529.9       857.9
```

```
## Dover, DE                153.9      2418.7         334.6       771.0
## Tallahassee, FL          623.9      2347.5         564.1       915.1
## Atlanta, GA              468.4      2200.4         352.2       697.3
## Honolulu, HI            4833.2      2636.9        4599.2      4161.3
## Boise, ID               2061.3       402.7        1830.1      1345.8
## Springfield, IL          676.8      1731.3         442.6       226.5
## Indianapolis, IN         494.5      1897.1         262.3       283.0
## Des Moines, IA           905.3      1489.9         673.9       239.9
## Topeka, KS               994.4      1474.3         760.6       430.3
## Frankfort, KY            407.1      2010.2         176.1       411.6
## Baton Rouge, LA          924.9      2038.6         769.8       876.3
## Augusta, ME              616.4      2529.0         740.2       983.4
## Annapolis, MD            112.4      2378.9         280.9       729.3
## Boston, MA               475.6      2526.2         622.2       932.0
## Lansing, MI              518.6      1886.7         339.2       246.6
## Saint Paul, MN           958.8      1433.5         746.6       225.4
## Jackson, MS              806.3      1997.7         637.7       744.5
## Jefferson City, MO       804.4      1654.4         571.5       343.0
## Helena, MT              1866.2       516.5        1641.4      1134.2
## Lincoln, NE             1053.8      1369.8         819.9       406.9
## Carson City, NV         2279.4       566.0        2045.1      1599.3
## Concord, NH              500.9      2479.6         626.1       900.5
## Trenton, NJ              236.0      2419.7         390.2       780.8
## Santa Fe, NM            1583.5      1174.9        1354.2      1021.6
## Albany, NY               404.1      2393.0         509.9       792.9
## Raleigh, NC              137.9      2391.8         243.2       763.8
## Bismarck, ND            1350.2      1043.4        1133.7       614.9
## Columbus, OH             342.6      2040.1         133.4       394.5
## Oklahoma City, OK       1123.3      1533.7         900.7       681.7
## Salem, OR               2395.5       145.1        2166.6      1670.0
## Harrisburg, PA           191.5      2319.1         287.4       674.8
## Providence, RI           437.3      2525.7         591.4       920.4
## Columbia, SC             315.4      2347.0         301.6       771.4
## Pierre, SD              1280.0      1104.0        1053.7       554.4
## Nashville, TN            524.6      1993.9         321.2       496.3
## Austin, TX              1264.9      1771.8        1074.3       996.5
## Salt Lake City, UT      1850.5       698.8        1616.4      1167.5
## Montpelier, VT           529.9      2402.9         622.7       844.8
## Richmond, VA               0.0      2382.7         234.4       735.5
## Olympia, WA             2382.7         0.0        2157.7      1650.1
## Charleston, WV           234.4      2157.7           0.0       521.2
## Madison, WI              735.5      1650.1         521.2         0.0
## Cheyenne, WY            1480.0       984.6        1246.1       803.3
##                  Cheyenne, WY
## Montgomery, AL          1190.0
## Juneau, AK              1753.3
## Phoenix, AZ              663.3
## Little Rock, AR          811.4
## Sacramento, CA           902.5
## Denver, CO                97.1
## Hartford, CT            1659.8
## Dover, DE               1549.8
## Tallahassee, FL         1364.7
## Atlanta, GA             1229.4
```

```
## Honolulu, HI            3364.0
## Boise, ID                606.4
## Springfield, IL          803.4
## Indianapolis, IN         986.3
## Des Moines, IA           582.7
## Topeka, KS               504.4
## Frankfort, KY           1080.5
## Baton Rouge, LA         1060.8
## Augusta, ME             1782.9
## Annapolis, MD           1502.2
## Boston, MA              1735.2
## Lansing, MI             1048.0
## Saint Paul, MN           648.4
## Jackson, MS             1013.4
## Jefferson City, MO       694.6
## Helena, MT               520.1
## Lincoln, NE              426.2
## Carson City, NV          801.9
## Concord, NH             1703.4
## Trenton, NJ             1572.3
## Santa Fe, NM             382.6
## Albany, NY              1596.1
## Raleigh, NC             1461.8
## Bismarck, ND             439.9
## Columbus, OH            1148.3
## Oklahoma City, OK        556.7
## Salem, OR                956.7
## Harrisburg, PA          1462.3
## Providence, RI          1722.9
## Columbia, SC            1389.9
## Pierre, SD               319.6
## Nashville, TN           1031.8
## Austin, TX               848.0
## Salt Lake City, UT       370.8
## Montpelier, VT          1645.0
## Richmond, VA            1480.0
## Olympia, WA              984.6
## Charleston, WV          1246.1
## Madison, WI              803.3
## Cheyenne, WY               0.0
```

```
lookupPairwiseValue(dist.meeus.df, "Juneau, AK", "Montgomery, AL");
```

```
## [1] 2855.6
```

```
dist.haversine = conv_unit(  distm( latlong[,3:4],
                  fun=distHaversine),  "m", "mi");  # default meters to miles

dist.haversine.h = as.matrix( dist.haversine );
  rownames(dist.haversine.h) =
  colnames(dist.haversine.h) = myLabels;

dist.haversine.df = as.data.frame( round( dist.haversine.h, digits=1) );
```

```
dist.haversine.df;
```

Haversine

```
##                    Montgomery, AL Juneau, AK Phoenix, AZ Little Rock, AR
## Montgomery, AL                0.0     2854.6      1495.6           385.5
## Juneau, AK                 2854.6        0.0      2007.1          2515.3
## Phoenix, AZ                1495.6     2007.1         0.0          1132.2
## Little Rock, AR             385.5     2515.3      1132.2             0.0
## Sacramento, CA             2016.9     1481.3       635.2          1632.9
## Denver, CO                 1161.1     1824.8       585.9           777.3
## Hartford, CT                991.1     2850.8      2213.1          1169.6
## Dover, DE                   764.2     2877.7      2060.6           976.4
## Tallahassee, FL             178.0     3031.6      1640.6           555.8
## Atlanta, GA                 145.9     2843.8      1589.8           459.0
## Honolulu, HI               4405.8     2814.2      2910.1          4038.5
## Boise, ID                  1794.3     1280.3       737.6          1412.9
## Springfield, IL             547.9     2336.0      1315.1           379.9
## Indianapolis, IN            512.4     2462.1      1497.4           486.3
## Des Moines, IA              755.7     2104.5      1154.6           479.3
## Topeka, KS                  702.0     2165.4       990.5           351.8
## Frankfort, KY               411.6     2589.3      1554.5           479.1
## Baton Rouge, LA             318.1     2796.7      1241.3           304.1
## Augusta, ME                1214.1     2831.8      2368.1          1367.0
## Annapolis, MD               714.1     2851.6      2008.2           922.4
## Boston, MA                 1082.4     2879.9      2297.1          1261.0
## Lansing, MI                 723.7     2372.4      1620.6           693.9
## Saint Paul, MN              944.1     1958.6      1285.4           707.2
## Jackson, MS                 228.3     2724.4      1271.4           209.1
## Jefferson City, MO          542.9     2311.7      1165.4           265.8
## Helena, MT                 1677.8     1233.5       909.0          1312.6
## Lincoln, NE                 820.4     2038.8       987.4           482.5
## Carson City, NV            1925.8     1475.4       583.1          1541.0
## Concord, NH                1097.9     2821.5      2275.7          1257.6
## Trenton, NJ                 840.1     2851.5      2101.3          1034.1
## Santa Fe, NM               1149.5     2031.9       379.9           772.6
## Albany, NY                  987.2     2768.1      2161.0          1139.0
## Raleigh, NC                 497.2     2941.1      1901.0           776.4
## Bismarck, ND               1259.1     1598.6      1097.4           943.8
## Columbus, OH                556.6     2565.8      1665.4           627.1
## Oklahoma City, OK           679.7     2302.4       840.4           298.0
## Salem, OR                  2144.8     1042.1       986.7          1763.6
## Harrisburg, PA              756.7     2772.4      1990.0           928.8
## Providence, RI             1046.3     2893.2      2277.7          1232.5
## Columbia, SC                324.0     2949.4      1778.8           646.6
## Pierre, SD                 1123.8     1731.8       983.1           790.2
## Nashville, TN               264.8     2628.8      1444.1           327.8
## Austin, TX                  692.4     2597.2       869.0           441.7
## Salt Lake City, UT         1529.9     1563.9       505.8          1145.0
## Montpelier, VT             1106.2     2733.7      2229.9          1238.4
## Richmond, VA                614.0     2890.6      1957.9           851.6
## Olympia, WA                2170.6      913.8      1097.9          1794.8
## Charleston, WV              489.8     2697.8      1730.4           644.3
## Madison, WI                 760.1     2181.3      1393.9           598.1
```

```
## Cheyenne, WY              1189.9     1752.1       664.2           811.4
##                    Sacramento, CA Denver, CO Hartford, CT Dover, DE
## Montgomery, AL            2016.9     1161.1        991.1     764.2
## Juneau, AK                1481.3     1824.8       2850.8    2877.7
## Phoenix, AZ                635.2      585.9       2213.1    2060.6
## Little Rock, AR           1632.9      777.3       1169.6     976.4
## Sacramento, CA               0.0      887.5       2555.0    2448.9
## Denver, CO                 887.5        0.0       1689.2    1567.3
## Hartford, CT              2555.0     1689.2          0.0     234.4
## Dover, DE                 2448.9     1567.3        234.4       0.0
## Tallahassee, FL           2179.5     1333.1       1013.1     779.0
## Atlanta, GA               2084.3     1211.1        845.5     618.3
## Honolulu, HI              2462.7     3343.5       5016.3    4910.1
## Boise, ID                  444.1      637.6       2191.3    2112.0
## Springfield, IL           1700.0      814.3        898.2     754.9
## Indianapolis, IN          1884.3      999.6        718.9     569.1
## Des Moines, IA            1483.1      609.6       1079.6     966.5
## Topeka, KS                1386.4      499.2       1222.8    1080.1
## Frankfort, KY             1972.6     1085.1        690.9     508.6
## Baton Rouge, LA           1807.5     1009.9       1292.2    1071.5
## Augusta, ME               2665.6     1822.2        229.1     463.4
## Annapolis, MD             2401.1     1518.2        279.1      54.0
## Boston, MA                2627.6     1767.2         92.4     321.8
## Lansing, MI               1944.2     1080.6        611.1     531.9
## Saint Paul, MN            1521.1      705.8       1047.3     984.5
## Jackson, MS               1807.7      973.2       1164.1     948.4
## Jefferson City, MO        1578.7      691.5       1051.5     896.3
## Helena, MT                 733.6      591.4       1959.3    1901.4
## Lincoln, NE               1325.2      444.6       1245.4    1124.2
## Carson City, NV            101.4      789.3       2453.8    2348.6
## Concord, NH               2592.7     1738.5        115.5     348.5
## Trenton, NJ               2471.1     1594.6        152.4      84.1
## Santa Fe, NM               878.7      286.7       1833.3    1681.7
## Albany, NY                2488.9     1628.7         82.9     258.8
## Raleigh, NC               2349.0     1461.9        524.4     290.0
## Bismarck, ND              1191.7      532.7       1426.6    1375.7
## Columbus, OH              2047.4     1164.9        554.0     402.4
## Oklahoma City, OK         1337.4      504.5       1405.9    1233.5
## Salem, OR                  446.9      987.8       2501.9    2437.5
## Harrisburg, PA            2361.5     1483.8        242.3     105.3
## Providence, RI            2617.3     1752.9         64.7     283.8
## Columbia, SC              2259.6     1379.0        704.0     469.8
## Pierre, SD                1164.1      400.2       1401.9    1323.4
## Nashville, TN             1904.0     1021.3        850.4     649.8
## Austin, TX                1466.6      772.6       1603.6    1400.0
## Salt Lake City, UT         532.7      371.0       2022.5    1917.5
## Montpelier, VT            2529.5     1683.9        172.8     384.2
## Richmond, VA              2375.8     1489.0        388.1     154.1
## Olympia, WA                589.2     1028.7       2465.7    2415.4
## Charleston, WV            2141.6     1254.9        529.5     334.2
## Madison, WI               1698.4      840.5        856.7     770.2
## Cheyenne, WY               901.4       97.3       1657.4    1547.7
##                    Tallahassee, FL Atlanta, GA Honolulu, HI Boise, ID
## Montgomery, AL              178.0       145.9       4405.8    1794.3
```

```
## Juneau, AK                 3031.6      2843.8       2814.2    1280.3
## Phoenix, AZ                1640.6      1589.8       2910.1     737.6
## Little Rock, AR             555.8       459.0       4038.5    1412.9
## Sacramento, CA             2179.5      2084.3       2462.7     444.1
## Denver, CO                 1333.1      1211.1       3343.5     637.6
## Hartford, CT               1013.1       845.5       5016.3    2191.3
## Dover, DE                   779.0       618.3       4910.1    2112.0
## Tallahassee, FL               0.0       228.4       4547.4    1968.2
## Atlanta, GA                 228.4         0.0       4497.5    1834.2
## Honolulu, HI               4547.4      4497.5          0.0    2836.7
## Boise, ID                  1968.2      1834.2       2836.7       0.0
## Springfield, IL             714.6       509.6       4157.7    1389.8
## Indianapolis, IN            653.1       427.3       4343.1    1565.6
## Des Moines, IA              930.3       740.2       3945.5    1154.6
## Topeka, KS                  879.7       727.3       3837.5    1107.8
## Frankfort, KY               536.9       308.6       4424.7    1669.8
## Baton Rouge, LA             412.9       458.7       4140.7    1644.7
## Augusta, ME                1241.6      1069.0       5116.4    2280.3
## Annapolis, MD               735.2       568.2       4861.5    2068.0
## Boston, MA                 1100.5       936.6       5086.9    2257.2
## Lansing, MI                 849.5       621.1       4406.1    1588.3
## Saint Paul, MN             1111.2       901.9       3974.9    1144.1
## Jackson, MS                 372.7       350.8       4180.8    1610.7
## Jefferson City, MO          720.0       547.5       4028.0    1295.0
## Helena, MT                 1855.5      1695.7       3096.4     289.8
## Lincoln, NE                 998.4       832.6       3785.8    1016.4
## Carson City, NV            2090.0      1990.3       2563.6     359.1
## Concord, NH                1125.8       952.8       5049.5    2216.8
## Trenton, NJ                 861.0       694.3       4933.7    2123.4
## Santa Fe, NM               1306.1      1231.4       3267.5     773.2
## Albany, NY                 1023.8       842.9       4948.6    2119.9
## Raleigh, NC                 490.8       355.4       4792.6    2052.9
## Bismarck, ND               1435.0      1245.5       3617.7     781.6
## Columbus, OH                661.4       436.2       4507.9    1719.2
## Oklahoma City, OK           843.5       756.3       3742.2    1141.0
## Salem, OR                  2318.8      2182.9       2563.1     350.7
## Harrisburg, PA              795.6       612.2       4823.9    2017.5
## Providence, RI             1061.6       900.5       5078.1    2251.3
## Columbia, SC                309.2       193.4       4683.7    1991.3
## Pierre, SD                 1301.3      1123.9       3617.5     790.8
## Nashville, TN               421.2       215.0       4338.3    1634.1
## Austin, TX                  804.8       818.8       3753.4    1370.4
## Salt Lake City, UT         1700.4      1582.1       2995.3     296.2
## Montpelier, VT             1148.0       962.9       4982.6    2147.4
## Richmond, VA                625.0       468.5       4830.7    2058.7
## Olympia, WA                2346.7      2198.8       2639.6     402.5
## Charleston, WV              565.9       353.0       4597.0    1827.7
## Madison, WI                 917.6       698.8       4160.0    1343.6
## Cheyenne, WY               1364.9      1228.8       3363.7     605.7
##                   Springfield, IL Indianapolis, IN Des Moines, IA Topeka, KS
## Montgomery, AL              547.9           512.4          755.7      702.0
## Juneau, AK                 2336.0          2462.1         2104.5     2165.4
## Phoenix, AZ                1315.1          1497.4         1154.6      990.5
## Little Rock, AR             379.9           486.3          479.3      351.8
```

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## Sacramento, CA             1700.0          1884.3         1483.1     1386.4
## Denver, CO                  814.3           999.6          609.6      499.2
## Hartford, CT                898.2           718.9         1079.6     1222.8
## Dover, DE                   754.9           569.1          966.5     1080.1
## Tallahassee, FL             714.6           653.1          930.3      879.7
## Atlanta, GA                 509.6           427.3          740.2      727.3
## Honolulu, HI               4157.7          4343.1         3945.5     3837.5
## Boise, ID                  1389.8          1565.6         1154.6     1107.8
## Springfield, IL               0.0           185.9          242.1      326.4
## Indianapolis, IN            185.9             0.0          411.1      511.5
## Des Moines, IA              242.1           411.1            0.0      206.5
## Topeka, KS                  326.4           511.5          206.5        0.0
## Frankfort, KY               280.1           128.8          520.1      587.5
## Baton Rouge, LA             652.6           704.2          782.7      648.0
## Augusta, ME                1064.3           896.2         1217.2     1380.5
## Annapolis, MD               704.9           519.1          919.7     1029.4
## Boston, MA                  983.3           806.2         1157.8     1306.5
## Lansing, MI                 334.2           221.5          471.7      635.1
## Saint Paul, MN              396.8           503.5          233.5      428.5
## Jackson, MS                 519.7           563.5          670.1      560.2
## Jefferson City, MO          159.3           332.9          222.1      192.3
## Helena, MT                 1216.4          1379.7          974.5      975.9
## Lincoln, NE                 376.9           559.4          168.1      132.1
## Carson City, NV            1600.6          1784.6         1382.6     1288.5
## Concord, NH                 965.5           792.8         1130.2     1285.8
## Trenton, NJ                 788.5           604.2          988.3     1115.0
## Santa Fe, NM                935.3          1117.7          781.6      611.1
## Albany, NY                  848.9           674.7         1019.4     1170.6
## Raleigh, NC                 663.3           495.6          902.3      962.7
## Bismarck, ND                739.6           880.6          506.0      594.8
## Columbus, OH                353.3           168.2          567.2      679.5
## Oklahoma City, OK           524.5           689.3          473.0      267.8
## Salem, OR                  1729.9          1901.9         1491.4     1455.8
## Harrisburg, PA              677.0           492.7          878.5     1003.4
## Providence, RI              962.9           783.6         1143.2     1287.4
## Columbia, SC                622.6           489.2          863.9      885.1
## Pierre, SD                  631.6           792.5          389.6      438.5
## Nashville, TN               296.0           251.5          525.3      527.0
## Austin, TX                  802.0           927.2          816.3      619.0
## Salt Lake City, UT         1172.1          1355.1          951.2      866.4
## Montpelier, VT              928.1           762.8         1078.7     1242.8
## Richmond, VA                676.1           494.1          904.4      993.2
## Olympia, WA                1729.1          1894.6         1487.7     1472.8
## Charleston, WV              442.2           262.1          673.2      759.6
## Madison, WI                 227.0           283.3          239.7      430.4
## Cheyenne, WY                802.4           984.9          581.8      503.9
##                    Frankfort, KY Baton Rouge, LA Augusta, ME Annapolis, MD
## Montgomery, AL             411.6           318.1       1214.1         714.1
## Juneau, AK                2589.3          2796.7       2831.8        2851.6
## Phoenix, AZ               1554.5          1241.3       2368.1        2008.2
## Little Rock, AR            479.1           304.1       1367.0         922.4
## Sacramento, CA            1972.6          1807.5       2665.6        2401.1
## Denver, CO                1085.1          1009.9       1822.2        1518.2
## Hartford, CT               690.9          1292.2        229.1         279.1
```

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## Dover, DE                508.6          1071.5       463.4          54.0
## Tallahassee, FL          536.9           412.9      1241.6         735.2
## Atlanta, GA              308.6           458.7      1069.0         568.2
## Honolulu, HI            4424.7          4140.7      5116.4        4861.5
## Boise, ID               1669.8          1644.7      2280.3        2068.0
## Springfield, IL          280.1           652.6      1064.3         704.9
## Indianapolis, IN         128.8           704.2       896.2         519.1
## Des Moines, IA           520.1           782.7      1217.2         919.7
## Topeka, KS               587.5           648.0      1380.5        1029.4
## Frankfort, KY              0.0           645.8       889.2         455.3
## Baton Rouge, LA          645.8             0.0      1509.4        1019.8
## Augusta, ME              889.2          1509.4         0.0         506.6
## Annapolis, MD            455.3          1019.8       506.6           0.0
## Boston, MA               782.0          1384.3       149.7         368.9
## Lansing, MI              314.0           925.4       747.6         494.5
## Saint Paul, MN           630.9          1008.1      1144.6         945.8
## Jackson, MS              506.6           140.9      1378.1         895.7
## Jefferson City, MO       396.9           565.1      1222.4         844.6
## Helena, MT              1494.1          1577.7      2031.2        1861.0
## Lincoln, NE              655.1           780.1      1385.3        1076.0
## Carson City, NV         1874.0          1723.2      2564.3        2300.9
## Concord, NH              778.8          1394.3       116.4         390.6
## Trenton, NJ              558.9          1143.7       380.6         126.7
## Santa Fe, NM            1176.9           928.8      1990.4        1629.6
## Albany, NY               660.4          1279.8       230.2         292.2
## Raleigh, NC              383.3           813.8       753.4         250.8
## Bismarck, ND            1003.5          1242.8      1501.6        1337.6
## Columbus, OH             157.8           803.4       740.7         353.7
## Oklahoma City, OK        724.9           505.9      1584.6        1180.1
## Salem, OR               2009.9          1992.7      2573.9        2395.6
## Harrisburg, PA           451.3          1052.4       457.9          91.9
## Providence, RI           754.1          1350.0       191.0         332.3
## Columbia, SC             360.8           642.1       932.5         426.3
## Pierre, SD               907.5          1084.6      1502.0        1280.8
## Nashville, TN            175.9           470.0      1056.7         595.8
## Austin, TX               916.8           392.0      1806.0        1346.3
## Salt Lake City, UT      1447.8          1360.7      2136.7        1870.2
## Montpelier, VT           763.3          1393.4       138.5         418.1
## Richmond, VA             406.6           925.1       616.9         112.6
## Olympia, WA             2007.8          2038.6      2524.7        2375.6
## Charleston, WV           175.9           770.7       740.0         280.5
## Madison, WI              412.1           879.0       981.9         728.7
## Cheyenne, WY            1079.1          1061.8      1780.3        1500.2
##                  Boston, MA Lansing, MI Saint Paul, MN Jackson, MS
## Montgomery, AL       1082.4      723.7         944.1       228.3
## Juneau, AK           2879.9     2372.4        1958.6      2724.4
## Phoenix, AZ          2297.1     1620.6        1285.4      1271.4
## Little Rock, AR      1261.0      693.9         707.2       209.1
## Sacramento, CA       2627.6     1944.2        1521.1      1807.7
## Denver, CO           1767.2     1080.6         705.8       973.2
## Hartford, CT           92.4      611.1        1047.3      1164.1
## Dover, DE             321.8      531.9         984.5       948.4
## Tallahassee, FL      1100.5      849.5        1111.2       372.7
## Atlanta, GA           936.6      621.1         901.9       350.8
```

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## Honolulu, HI          5086.9      4406.1         3974.9      4180.8
## Boise, ID             2257.2      1588.3         1144.1      1610.7
## Springfield, IL        983.3       334.2          396.8       519.7
## Indianapolis, IN       806.2       221.5          503.5       563.5
## Des Moines, IA        1157.8       471.7          233.5       670.1
## Topeka, KS            1306.5       635.1          428.5       560.2
## Frankfort, KY          782.0       314.0          630.9       506.6
## Baton Rouge, LA       1384.3       925.4         1008.1       140.9
## Augusta, ME            149.7       747.6         1144.6      1378.1
## Annapolis, MD          368.9       494.5          945.8       895.7
## Boston, MA               0.0       686.9         1113.4      1256.4
## Lansing, MI            686.9         0.0          452.7       784.8
## Saint Paul, MN        1113.4       452.7            0.0       888.5
## Jackson, MS           1256.4       784.8          888.5         0.0
## Jefferson City, MO    1138.0       492.5          443.0       448.4
## Helena, MT            2019.4      1370.4          918.1      1519.7
## Lincoln, NE           1324.6       639.3          338.8       689.9
## Carson City, NV       2526.3      1843.0         1419.8      1719.0
## Concord, NH             63.4       658.6         1074.7      1263.7
## Trenton, NJ            242.4       535.5          986.4      1017.6
## Santa Fe, NM          1917.5      1243.3          932.1       933.4
## Albany, NY             138.9       548.2          975.9      1148.0
## Raleigh, NC            610.3       576.3          989.3       703.7
## Bismarck, ND          1486.8       843.8          391.9      1149.4
## Columbus, OH           642.7       207.8          619.0       664.4
## Oklahoma City, OK     1494.4       857.2          695.6       474.7
## Salem, OR             2562.7      1908.5         1457.7      1961.0
## Harrisburg, PA         334.6       432.2          884.8       922.8
## Providence, RI          41.3       673.9         1107.1      1223.3
## Columbia, SC           791.4       633.2          991.5       542.6
## Pierre, SD            1469.9       797.5          357.6       998.2
## Nashville, TN          942.5       469.6          691.3       330.7
## Austin, TX            1695.6      1129.4         1046.2       468.3
## Salt Lake City, UT    2095.7      1411.5          993.5      1336.0
## Montpelier, VT         152.0       609.3         1008.9      1259.5
## Richmond, VA           475.9       518.9          958.4       806.1
## Olympia, WA           2522.2      1883.8         1431.0      1997.0
## Charleston, WV         621.8       339.8          746.5       638.2
## Madison, WI            930.5       246.2          225.3       746.6
## Cheyenne, WY          1732.6      1046.4          647.8      1013.8
##                  Jefferson City, MO Helena, MT Lincoln, NE Carson City, NV
## Montgomery, AL                542.9     1677.8       820.4          1925.8
## Juneau, AK                   2311.7     1233.5      2038.8          1475.4
## Phoenix, AZ                  1165.4      909.0       987.4           583.1
## Little Rock, AR               265.8     1312.6       482.5          1541.0
## Sacramento, CA               1578.7      733.6      1325.2           101.4
## Denver, CO                    691.5      591.4       444.6           789.3
## Hartford, CT                 1051.5     1959.3      1245.4          2453.8
## Dover, DE                     896.3     1901.4      1124.2          2348.6
## Tallahassee, FL               720.0     1855.5       998.4          2090.0
## Atlanta, GA                   547.5     1695.7       832.6          1990.3
## Honolulu, HI                 4028.0     3096.4      3785.8          2563.6
## Boise, ID                    1295.0      289.8      1016.4           359.1
## Springfield, IL               159.3     1216.4       376.9          1600.6
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## Indianapolis, IN                332.9     1379.7       559.4          1784.6
## Des Moines, IA                  222.1      974.5       168.1          1382.6
## Topeka, KS                      192.3      975.9       132.1          1288.5
## Frankfort, KY                   396.9     1494.1       655.1          1874.0
## Baton Rouge, LA                 565.1     1577.7       780.1          1723.2
## Augusta, ME                    1222.4     2031.2      1385.3          2564.3
## Annapolis, MD                   844.6     1861.0      1076.0          2300.9
## Boston, MA                     1138.0     2019.4      1324.6          2526.3
## Lansing, MI                     492.5     1370.4       639.3          1843.0
## Saint Paul, MN                  443.0      918.1       338.8          1419.8
## Jackson, MS                     448.4     1519.7       689.9          1719.0
## Jefferson City, MO                0.0     1148.2       285.1          1480.8
## Helena, MT                     1148.2        0.0       863.1           645.9
## Lincoln, NE                     285.1      863.1         0.0          1225.3
## Carson City, NV                1480.8      645.9      1225.3             0.0
## Concord, NH                    1122.2     1975.3      1297.8          2491.3
## Trenton, NJ                     936.0     1904.4      1150.1          2370.3
## Santa Fe, NM                    785.9      818.2       616.7           795.0
## Albany, NY                     1004.9     1884.5      1186.4          2387.6
## Raleigh, NC                     770.4     1874.7      1037.6          2251.2
## Bismarck, ND                    717.3      532.8       462.6          1092.4
## Columbus, OH                    500.2     1521.7       722.3          1947.4
## Oklahoma City, OK               365.2     1075.7       372.2          1246.8
## Salem, OR                      1641.3      543.4      1360.1           433.3
## Harrisburg, PA                  824.7     1802.6      1039.5          2260.9
## Providence, RI                 1116.2     2016.9      1309.3          2516.0
## Columbia, SC                    696.4     1835.5       978.1          2164.1
## Pierre, SD                      581.7      587.2       308.4          1062.9
## Nashville, TN                   339.9     1485.8       624.0          1807.9
## Austin, TX                      656.4     1364.0       731.6          1390.2
## Salt Lake City, UT             1058.4      403.3       795.7           431.7
## Montpelier, VT                 1086.6     1901.6      1246.8          2428.2
## Richmond, VA                    803.4     1864.2      1052.6          2276.5
## Olympia, WA                    1652.6      515.6      1368.1           567.0
## Charleston, WV                  570.8     1639.7       818.9          2042.4
## Madison, WI                     343.6     1132.5       406.5          1597.1
## Cheyenne, WY                    693.8      520.2       425.6           800.9
##                    Concord, NH Trenton, NJ Santa Fe, NM Albany, NY Raleigh, NC
## Montgomery, AL          1097.9      840.1      1149.5      987.2       497.2
## Juneau, AK              2821.5     2851.5      2031.9     2768.1      2941.1
## Phoenix, AZ             2275.7     2101.3       379.9     2161.0      1901.0
## Little Rock, AR         1257.6     1034.1       772.6     1139.0       776.4
## Sacramento, CA          2592.7     2471.1       878.7     2488.9      2349.0
## Denver, CO              1738.5     1594.6       286.7     1628.7      1461.9
## Hartford, CT             115.5      152.4      1833.3       82.9       524.4
## Dover, DE                348.5       84.1      1681.7      258.8       290.0
## Tallahassee, FL         1125.8      861.0      1306.1     1023.8       490.8
## Atlanta, GA              952.8      694.3      1231.4      842.9       355.4
## Honolulu, HI            5049.5     4933.7      3267.5     4948.6      4792.6
## Boise, ID               2216.8     2123.4       773.2     2119.9      2052.9
## Springfield, IL          965.5      788.5       935.3      848.9       663.3
## Indianapolis, IN         792.8      604.2      1117.7      674.7       495.6
## Des Moines, IA          1130.2      988.3       781.6     1019.4       902.3
## Topeka, KS              1285.8     1115.0       611.1     1170.6       962.7
```

```
## Frankfort, KY            778.8       558.9      1176.9      660.4       383.3
## Baton Rouge, LA         1394.3      1143.7       928.8     1279.8       813.8
## Augusta, ME              116.4       380.6      1990.4      230.2       753.4
## Annapolis, MD            390.6       126.7      1629.6      292.2       250.8
## Boston, MA                63.4       242.4      1917.5      138.9       610.3
## Lansing, MI              658.6       535.5      1243.3      548.2       576.3
## Saint Paul, MN          1074.7       986.4       932.1      975.9       989.3
## Jackson, MS             1263.7      1017.6       933.4     1148.0       703.7
## Jefferson City, MO      1122.2       936.0       785.9     1004.9       770.4
## Helena, MT              1975.3      1904.4       818.2     1884.5      1874.7
## Lincoln, NE             1297.8      1150.1       616.7     1186.4      1037.6
## Carson City, NV         2491.3      2370.3       795.0     2387.6      2251.2
## Concord, NH                0.0       265.1      1896.8      118.7       638.4
## Trenton, NJ              265.1         0.0      1721.7      175.9       373.4
## Santa Fe, NM            1896.8      1721.7         0.0     1781.7      1529.9
## Albany, NY               118.7       175.9      1781.7        0.0       543.0
## Raleigh, NC              638.4       373.4      1529.9      543.0         0.0
## Bismarck, ND            1443.1      1374.8       815.9     1351.7      1374.0
## Columbus, OH             633.4       436.1      1285.6      514.7       375.5
## Oklahoma City, OK       1482.0      1281.9       475.1     1363.9      1060.7
## Salem, OR               2518.6      2443.7      1102.1     2427.5      2393.0
## Harrisburg, PA           342.2       111.5      1610.3      230.8       325.8
## Providence, RI            95.8       206.5      1898.0      132.6       571.1
## Columbia, SC             816.8       551.9      1416.3      716.4       183.0
## Pierre, SD              1432.0      1332.8       671.9     1331.9      1287.6
## Nashville, TN            944.2       710.3      1073.3      826.7       457.0
## Austin, TX              1695.2      1463.3       605.5     1577.0      1169.5
## Salt Lake City, UT      2061.6      1938.7       477.1     1956.9      1827.6
## Montpelier, VT            89.4       300.8      1852.4      126.0       668.9
## Richmond, VA             501.4       236.3      1581.7      404.8       138.2
## Olympia, WA             2475.5      2416.2      1175.2     2389.2      2389.3
## Charleston, WV           625.9       389.9      1352.7      509.8       243.5
## Madison, WI              899.1       779.9      1021.3      791.7       764.1
## Cheyenne, WY            1700.9      1570.1       383.6     1593.8      1460.3
##                   Bismarck, ND Columbus, OH Oklahoma City, OK Salem, OR
## Montgomery, AL          1259.1       556.6             679.7    2144.8
## Juneau, AK              1598.6      2565.8            2302.4    1042.1
## Phoenix, AZ             1097.4      1665.4             840.4     986.7
## Little Rock, AR          943.8       627.1             298.0    1763.6
## Sacramento, CA          1191.7      2047.4            1337.4     446.9
## Denver, CO               532.7      1164.9             504.5     987.8
## Hartford, CT            1426.6       554.0            1405.9    2501.9
## Dover, DE               1375.7       402.4            1233.5    2437.5
## Tallahassee, FL         1435.0       661.4             843.5    2318.8
## Atlanta, GA             1245.5       436.2             756.3    2182.9
## Honolulu, HI            3617.7      4507.9            3742.2    2563.1
## Boise, ID                781.6      1719.2            1141.0     350.7
## Springfield, IL          739.6       353.3             524.5    1729.9
## Indianapolis, IN         880.6       168.2             689.3    1901.9
## Des Moines, IA           506.0       567.2             473.0    1491.4
## Topeka, KS               594.8       679.5             267.8    1455.8
## Frankfort, KY           1003.5       157.8             724.9    2009.9
## Baton Rouge, LA         1242.8       803.4             505.9    1992.7
## Augusta, ME             1501.6       740.7            1584.6    2573.9
```

```
## Annapolis, MD           1337.6       353.7           1180.1    2395.6
## Boston, MA              1486.8       642.7           1494.4    2562.7
## Lansing, MI              843.8       207.8            857.2    1908.5
## Saint Paul, MN           391.9       619.0            695.6    1457.7
## Jackson, MS             1149.4       664.4            474.7    1961.0
## Jefferson City, MO       717.3       500.2            365.2    1641.3
## Helena, MT               532.8      1521.7           1075.7     543.4
## Lincoln, NE              462.6       722.3            372.2    1360.1
## Carson City, NV         1092.4      1947.4           1246.8     433.3
## Concord, NH             1443.1       633.4           1482.0    2518.6
## Trenton, NJ             1374.8       436.1           1281.9    2443.7
## Santa Fe, NM             815.9      1285.6            475.1    1102.1
## Albany, NY              1351.7       514.7           1363.9    2427.5
## Raleigh, NC             1374.0       375.5           1060.7    2393.0
## Bismarck, ND               0.0      1008.4            802.4    1075.9
## Columbus, OH            1008.4         0.0            851.9    2050.9
## Oklahoma City, OK        802.4       851.9              0.0    1490.3
## Salem, OR               1075.9      2050.9           1490.3       0.0
## Harrisburg, PA          1275.1       324.6           1172.1    2340.3
## Providence, RI          1484.1       618.4           1470.3    2559.8
## Columbia, SC            1359.4       426.4            941.6    2337.4
## Pierre, SD               170.0       936.7            633.4    1114.9
## Nashville, TN           1030.5       333.6            603.9    1981.0
## Austin, TX              1155.7      1067.8            360.0    1706.1
## Salt Lake City, UT       693.6      1516.8            862.0     634.2
## Montpelier, VT          1370.6       611.3           1449.7    2444.8
## Richmond, VA            1349.3       342.5           1122.0    2392.4
## Olympia, WA             1041.5      2037.3           1533.0     145.3
## Charleston, WV          1133.0       133.6            899.8    2163.8
## Madison, WI              614.2       394.4            682.4    1667.3
## Cheyenne, WY             440.4      1146.7            557.1     955.5
##                    Harrisburg, PA Providence, RI Columbia, SC Pierre, SD
## Montgomery, AL              756.7        1046.3        324.0     1123.8
## Juneau, AK                 2772.4        2893.2       2949.4     1731.8
## Phoenix, AZ                1990.0        2277.7       1778.8      983.1
## Little Rock, AR             928.8        1232.5        646.6      790.2
## Sacramento, CA             2361.5        2617.3       2259.6     1164.1
## Denver, CO                 1483.8        1752.9       1379.0      400.2
## Hartford, CT                242.3          64.7        704.0     1401.9
## Dover, DE                   105.3         283.8        469.8     1323.4
## Tallahassee, FL             795.6        1061.6        309.2     1301.3
## Atlanta, GA                 612.2         900.5        193.4     1123.9
## Honolulu, HI               4823.9        5078.1       4683.7     3617.5
## Boise, ID                  2017.5        2251.3       1991.3      790.8
## Springfield, IL             677.0         962.9        622.6      631.6
## Indianapolis, IN            492.7         783.6        489.2      792.5
## Des Moines, IA              878.5        1143.2        863.9      389.6
## Topeka, KS                 1003.4        1287.4        885.1      438.5
## Frankfort, KY               451.3         754.1        360.8      907.5
## Baton Rouge, LA            1052.4        1350.0        642.1     1084.6
## Augusta, ME                 457.9         191.0        932.5     1502.0
## Annapolis, MD                91.9         332.3        426.3     1280.8
## Boston, MA                  334.6          41.3        791.4     1469.9
## Lansing, MI                 432.2         673.9        633.2      797.5
```

```
## Saint Paul, MN              884.8         1107.1        991.5      357.6
## Jackson, MS                 922.8         1223.3        542.6      998.2
## Jefferson City, MO          824.7         1116.2        696.4      581.7
## Helena, MT                 1802.6         2016.9       1835.5      587.2
## Lincoln, NE                1039.5         1309.3        978.1      308.4
## Carson City, NV            2260.9         2516.0       2164.1     1062.9
## Concord, NH                 342.2           95.8        816.8     1432.0
## Trenton, NJ                 111.5          206.5        551.9     1332.8
## Santa Fe, NM               1610.3         1898.0       1416.3      671.9
## Albany, NY                  230.8          132.6        716.4     1331.9
## Raleigh, NC                 325.8          571.1        183.0     1287.6
## Bismarck, ND               1275.1         1484.1       1359.4      170.0
## Columbus, OH                324.6          618.4        426.4      936.7
## Oklahoma City, OK          1172.1         1470.3        941.6      633.4
## Salem, OR                  2340.3         2559.8       2337.4     1114.9
## Harrisburg, PA                0.0          304.0        490.4     1227.6
## Providence, RI              304.0            0.0        752.7     1462.5
## Columbia, SC                490.4          752.7          0.0     1253.4
## Pierre, SD                 1227.6         1462.5       1253.4        0.0
## Nashville, TN               608.1          912.0        358.1      910.4
## Austin, TX                 1361.4         1665.4       1010.9      985.8
## Salt Lake City, UT         1829.3         2084.9       1749.3      639.5
## Montpelier, VT              352.9          178.3        841.3     1366.5
## Richmond, VA                192.0          437.6        315.9     1278.8
## Olympia, WA                2315.8         2521.8       2345.1     1102.3
## Charleston, WV              287.2          591.0        302.5     1052.8
## Madison, WI                 674.0          919.1        772.4      553.6
## Cheyenne, WY               1460.3         1720.4       1388.9      319.6
##                    Nashville, TN Austin, TX Salt Lake City, UT Montpelier, VT
## Montgomery, AL             264.8      692.4             1529.9         1106.2
## Juneau, AK                2628.8     2597.2             1563.9         2733.7
## Phoenix, AZ               1444.1      869.0              505.8         2229.9
## Little Rock, AR            327.8      441.7             1145.0         1238.4
## Sacramento, CA            1904.0     1466.6              532.7         2529.5
## Denver, CO                1021.3      772.6              371.0         1683.9
## Hartford, CT               850.4     1603.6             2022.5          172.8
## Dover, DE                  649.8     1400.0             1917.5          384.2
## Tallahassee, FL            421.2      804.8             1700.4         1148.0
## Atlanta, GA                215.0      818.8             1582.1          962.9
## Honolulu, HI              4338.3     3753.4             2995.3         4982.6
## Boise, ID                 1634.1     1370.4              296.2         2147.4
## Springfield, IL            296.0      802.0             1172.1          928.1
## Indianapolis, IN           251.5      927.2             1355.1          762.8
## Des Moines, IA             525.3      816.3              951.2         1078.7
## Topeka, KS                 527.0      619.0              866.4         1242.8
## Frankfort, KY              175.9      916.8             1447.8          763.3
## Baton Rouge, LA            470.0      392.0             1360.7         1393.4
## Augusta, ME               1056.7     1806.0             2136.7          138.5
## Annapolis, MD              595.8     1346.3             1870.2          418.1
## Boston, MA                 942.5     1695.6             2095.7          152.0
## Lansing, MI                469.6     1129.4             1411.5          609.3
## Saint Paul, MN             691.3     1046.2              993.5         1008.9
## Jackson, MS                330.7      468.3             1336.0         1259.5
## Jefferson City, MO         339.9      656.4             1058.4         1086.6
```

```
## Helena, MT               1485.8     1364.0              403.3         1901.6
## Lincoln, NE               624.0      731.6              795.7         1246.8
## Carson City, NV          1807.9     1390.2              431.7         2428.2
## Concord, NH               944.2     1695.2             2061.6           89.4
## Trenton, NJ               710.3     1463.3             1938.7          300.8
## Santa Fe, NM             1073.3      605.5              477.1         1852.4
## Albany, NY                826.7     1577.0             1956.9          126.0
## Raleigh, NC               457.0     1169.5             1827.6          668.9
## Bismarck, ND             1030.5     1155.7              693.6         1370.6
## Columbus, OH              333.6     1067.8             1516.8          611.3
## Oklahoma City, OK         603.9      360.0              862.0         1449.7
## Salem, OR                1981.0     1706.1              634.2         2444.8
## Harrisburg, PA            608.1     1361.4             1829.3          352.9
## Providence, RI            912.0     1665.4             2084.9          178.3
## Columbia, SC              358.1     1010.9             1749.3          841.3
## Pierre, SD                910.4      985.8              639.5         1366.5
## Nashville, TN               0.0      753.4             1391.3          934.0
## Austin, TX                753.4        0.0             1075.1         1678.9
## Salt Lake City, UT       1391.3     1075.1                0.0         1999.9
## Montpelier, VT            934.0     1678.9             1999.9            0.0
## Richmond, VA              524.0     1264.5             1848.2          530.7
## Olympia, WA              1992.1     1772.6              698.6         2398.8
## Charleston, WV            321.1     1074.5             1614.3          622.8
## Madison, WI               497.5      998.7             1165.9          843.5
## Cheyenne, WY             1030.9      849.9              370.2         1642.5
##                  Richmond, VA Olympia, WA Charleston, WV Madison, WI
## Montgomery, AL          614.0     2170.6          489.8       760.1
## Juneau, AK             2890.6      913.8         2697.8      2181.3
## Phoenix, AZ            1957.9     1097.9         1730.4      1393.9
## Little Rock, AR         851.6     1794.8          644.3       598.1
## Sacramento, CA         2375.8      589.2         2141.6      1698.4
## Denver, CO             1489.0     1028.7         1254.9       840.5
## Hartford, CT            388.1     2465.7          529.5       856.7
## Dover, DE               154.1     2415.4          334.2       770.2
## Tallahassee, FL         625.0     2346.7          565.9       917.6
## Atlanta, GA             468.5     2198.8          353.0       698.8
## Honolulu, HI           4830.7     2639.6         4597.0      4160.0
## Boise, ID              2058.7      402.5         1827.7      1343.6
## Springfield, IL         676.1     1729.1          442.2       227.0
## Indianapolis, IN        494.1     1894.6          262.1       283.3
## Des Moines, IA          904.4     1487.7          673.2       239.7
## Topeka, KS              993.2     1472.8          759.6       430.4
## Frankfort, KY           406.6     2007.8          175.9       412.1
## Baton Rouge, LA         925.1     2038.6          770.7       879.0
## Augusta, ME             616.9     2524.7          740.0       981.9
## Annapolis, MD           112.6     2375.6          280.5       728.7
## Boston, MA              475.9     2522.2          621.8       930.5
## Lansing, MI             518.9     1883.8          339.8       246.2
## Saint Paul, MN          958.4     1431.0          746.5       225.3
## Jackson, MS             806.1     1997.0          638.2       746.6
## Jefferson City, MO      803.4     1652.6          570.8       343.6
## Helena, MT             1864.2      515.6         1639.7      1132.5
## Lincoln, NE            1052.6     1368.1          818.9       406.5
## Carson City, NV        2276.5      567.0         2042.4      1597.1
```

```
## Concord, NH              501.4      2475.5         625.9       899.1
## Trenton, NJ              236.3      2416.2         389.9       779.9
## Santa Fe, NM            1581.7      1175.2        1352.7      1021.3
## Albany, NY               404.8      2389.2         509.8       791.7
## Raleigh, NC              138.2      2389.3         243.5       764.1
## Bismarck, ND            1349.3      1041.5        1133.0       614.2
## Columbus, OH             342.5      2037.3         133.6       394.4
## Oklahoma City, OK       1122.0      1533.0         899.8       682.4
## Salem, OR               2392.4       145.3        2163.8      1667.3
## Harrisburg, PA           192.0      2315.8         287.2       674.0
## Providence, RI           437.6      2521.8         591.0       919.1
## Columbia, SC             315.9      2345.1         302.5       772.4
## Pierre, SD              1278.8      1102.3        1052.8       553.6
## Nashville, TN            524.0      1992.1         321.1       497.5
## Austin, TX              1264.5      1772.6        1074.5       998.7
## Salt Lake City, UT      1848.2       698.6        1614.3      1165.9
## Montpelier, VT           530.7      2398.8         622.8       843.5
## Richmond, VA               0.0      2379.7         234.1       735.2
## Olympia, WA             2379.7         0.0        2155.0      1647.5
## Charleston, WV           234.1      2155.0           0.0       521.2
## Madison, WI              735.2      1647.5         521.2         0.0
## Cheyenne, WY            1478.2       983.6        1244.5       802.2
##                    Cheyenne, WY
## Montgomery, AL          1189.9
## Juneau, AK              1752.1
## Phoenix, AZ              664.2
## Little Rock, AR          811.4
## Sacramento, CA           901.4
## Denver, CO                97.3
## Hartford, CT            1657.4
## Dover, DE               1547.7
## Tallahassee, FL         1364.9
## Atlanta, GA             1228.8
## Honolulu, HI            3363.7
## Boise, ID                605.7
## Springfield, IL          802.4
## Indianapolis, IN         984.9
## Des Moines, IA           581.8
## Topeka, KS               503.9
## Frankfort, KY           1079.1
## Baton Rouge, LA         1061.8
## Augusta, ME             1780.3
## Annapolis, MD           1500.2
## Boston, MA              1732.6
## Lansing, MI             1046.4
## Saint Paul, MN           647.8
## Jackson, MS             1013.8
## Jefferson City, MO       693.8
## Helena, MT               520.2
## Lincoln, NE              425.6
## Carson City, NV          800.9
## Concord, NH             1700.9
## Trenton, NJ             1570.1
## Santa Fe, NM             383.6
```

```
## Albany, NY               1593.8
## Raleigh, NC              1460.3
## Bismarck, ND              440.4
## Columbus, OH             1146.7
## Oklahoma City, OK         557.1
## Salem, OR                 955.5
## Harrisburg, PA           1460.3
## Providence, RI           1720.4
## Columbia, SC             1388.9
## Pierre, SD                319.6
## Nashville, TN            1030.9
## Austin, TX                849.9
## Salt Lake City, UT        370.2
## Montpelier, VT           1642.5
## Richmond, VA             1478.2
## Olympia, WA               983.6
## Charleston, WV           1244.5
## Madison, WI               802.2
## Cheyenne, WY                0.0
```

```
lookupPairwiseValue(dist.haversine.df, "Juneau, AK", "Montgomery, AL");
```

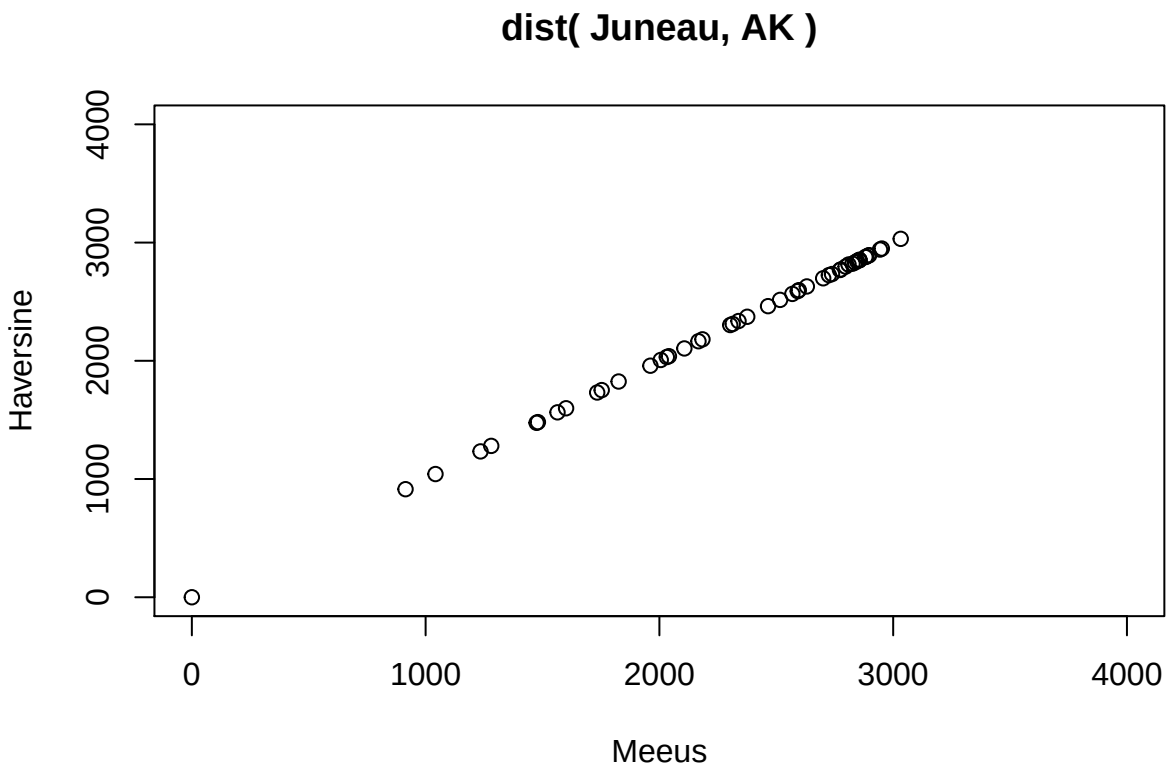
```
## [1] 2854.6
```

You can compare the two with the code below (currently in comments).

```
#View(dist.meeus.df)
x = dist.meeus.df[,2]; # Juneau ... pick one location
y = dist.haversine.df[,2];

my.lim = c(0, 4000 );

plot(x, y,
           xlab="Meeus",
           ylab="Haversine",
           main="dist( Juneau, AK )",
           xlim=my.lim,
           ylim=my.lim);
```




```
plotXYwithBoxPlots(x, y,
           xlab="Meeus",
           ylab="Haversine",
           main="dist( Juneau, AK )",
           xlim=my.lim,
           ylim=my.lim);
```

[Examining the data above, is there much difference between these two calculations?

What is the conceptual difference between these two calculations? Try `?distMeeus` or `?distHaversine`

Are the results similar?

Is there a more accurate distance algorithm for geo-spatial calculations? If so, what is it?

]

Let's now do `manhattan` and `euclidean` which are more common in the "statistical clustering" domain. I will do `euclidean`.

```
dist.manhattan = dist( latlong[,1:2],
                       method="manhattan", diag=TRUE, upper=TRUE);
dist.manhattan.m = as.matrix( dist.manhattan );
  rownames(dist.manhattan.m) =
  colnames(dist.manhattan.m) = myLabels;

dist.manhattan.df = as.data.frame( round( dist.manhattan.m, digits=1) );
```

```
dist.manhattan.df;  ## too big
```

Manhattan

```
##                    Montgomery, AL Juneau, AK Phoenix, AZ Little Rock, AR
## Montgomery, AL                0.0     4418.0      1483.1           494.3
## Juneau, AK                 4418.0        0.0      2934.9          3923.7
## Phoenix, AZ                1483.1     2934.9         0.0          1166.3
## Little Rock, AR             494.3     3923.7      1166.3             0.0
## Sacramento, CA             2351.9     2066.1       868.8          1857.7
## Denver, CO                 1530.7     2887.3       820.3          1036.4
## Hartford, CT               1391.5     4512.2      2724.4          1558.1
## Dover, DE                  1056.2     4536.3      2389.1          1222.8
## Tallahassee, FL             242.2     4660.2      1725.3           736.4
## Atlanta, GA                 199.3     4425.0      1532.2           501.3
## Honolulu, HI               4671.0     3832.5      3338.1          4504.4
## Boise, ID                  2410.3     2007.7       927.2          1916.0
## Springfield, IL             697.5     3720.5      1661.8           495.5
## Indianapolis, IN            517.7     3913.5      1850.6           684.3
## Des Moines, IA             1037.7     3380.3      1568.9           543.4
## Topeka, KS                  975.7     3442.3      1281.0           481.4
## Frankfort, KY               479.9     4092.3      1812.9           646.5
## Baton Rouge, LA             399.6     4282.6      1347.7           358.8
## Augusta, ME                1725.4     4494.4      3058.3          1892.0
## Annapolis, MD               990.1     4495.7      2323.0          1156.7
## Boston, MA                 1520.5     4559.0      2853.4          1687.1
## Lansing, MI                 810.3     3796.9      2143.2           976.9
## Saint Paul, MN             1240.3     3177.8      1829.0           746.0
## Jackson, MS                 217.6     4209.1      1274.2           285.4
## Jefferson City, MO          750.7     3667.3      1439.9           273.6
## Helena, MT                 2387.3     2030.7       909.3          1893.0
## Lincoln, NE                1150.7     3267.3      1348.0           656.4
## Carson City, NV            2297.8     2120.2       814.7          1803.6
## Concord, NH                1553.2     4474.6      2886.1          1719.8
## Trenton, NJ                1171.2     4504.3      2504.2          1337.8
## Santa Fe, NM               1302.9     3115.1       486.2           808.6
## Albany, NY                 1393.8     4391.6      2726.7          1560.4
## Raleigh, NC                 652.4     4600.5      1985.4           819.0
## Bismarck, ND               1788.8     2629.3      1537.8          1294.5
## Columbus, OH                703.5     4072.6      2036.4           870.0
## Oklahoma City, OK           828.2     3589.8       933.5           333.9
## Salem, OR                  2875.0     1543.1      1391.8          2380.7
## Harrisburg, PA             1059.1     4385.8      2392.0          1225.7
## Providence, RI             1464.1     4576.3      2797.0          1630.7
## Columbia, SC                399.4     4591.3      1732.4           667.5
## Pierre, SD                 1595.4     2822.6      1395.0          1101.1
## Nashville, TN               290.1     4127.9      1567.9           401.6
## Austin, TX                  770.4     3936.6      1001.7           603.8
## Salt Lake City, UT         1978.0     2440.1       514.1          1483.7
## Montpelier, VT             1569.1     4345.3      2902.1          1735.7
## Richmond, VA                838.0     4542.3      2170.9          1004.6
## Olympia, WA                3012.2     1405.8      1529.1          2517.9
## Charleston, WV              666.7     4258.7      1999.6           833.3
## Madison, WI                 908.7     3509.3      1902.6           736.3
```

```
## Cheyenne, WY              1618.0     2800.0       926.3          1123.8
##                    Sacramento, CA Denver, CO Hartford, CT Dover, DE
## Montgomery, AL            2351.9     1530.7       1391.5    1056.2
## Juneau, AK                2066.1     2887.3       4512.2    4536.3
## Phoenix, AZ                868.8      820.3       2724.4    2389.1
## Little Rock, AR           1857.7     1036.4       1558.1    1222.8
## Sacramento, CA               0.0      981.0       2885.1    2549.7
## Denver, CO                 981.0        0.0       1904.1    1648.9
## Hartford, CT              2885.1     1904.1          0.0     335.3
## Dover, DE                 2549.7     1648.9        335.3       0.0
## Tallahassee, FL           2594.1     1772.8       1412.4    1077.1
## Atlanta, GA               2358.9     1537.7       1192.2     856.9
## Honolulu, HI              3177.4     4158.4       6062.5    5727.2
## Boise, ID                  636.3      879.6       2504.5    2528.6
## Springfield, IL           1822.5      841.5       1062.6     815.8
## Indianapolis, IN          2011.3     1030.3        873.8     622.7
## Des Moines, IA            1729.5      748.5       1155.5    1155.9
## Topeka, KS                1441.7      555.0       1443.4    1108.1
## Frankfort, KY             2026.2     1204.9        911.5     576.2
## Baton Rouge, LA           2216.5     1395.2       1791.1    1455.7
## Augusta, ME               3218.9     2237.9        333.9     669.2
## Annapolis, MD             2483.6     1608.4        401.4      66.1
## Boston, MA                3014.1     2033.1        129.0     464.4
## Lansing, MI               2303.8     1322.8        715.2     739.3
## Saint Paul, MN            1989.7     1008.7       1334.4    1358.5
## Jackson, MS               2143.0     1321.8       1609.1    1273.7
## Jefferson City, MO        1601.3      780.0       1284.5     949.2
## Helena, MT                1069.9      856.6       2481.5    2505.6
## Lincoln, NE               1508.6      527.6       1376.5    1268.9
## Carson City, NV            134.5      846.5       2750.5    2416.1
## Concord, NH               3046.7     2065.7        161.7     497.0
## Trenton, NJ               2664.8     1683.8        220.3     115.1
## Santa Fe, NM              1049.0      334.2       2238.2    1902.9
## Albany, NY                2887.3     1906.3        120.5     337.6
## Raleigh, NC               2534.4     1713.2        739.0     403.7
## Bismarck, ND              1698.5      717.5       1882.9    1907.0
## Columbus, OH              2197.0     1216.0        688.0     463.7
## Oklahoma City, OK         1523.7      702.5       1790.9    1455.6
## Salem, OR                  523.0     1344.3       2969.1    2993.2
## Harrisburg, PA            2552.7     1571.7        332.4     150.5
## Providence, RI            2957.6     1976.6         72.6     407.9
## Columbia, SC              2525.2     1703.9        992.1     656.7
## Pierre, SD                1555.7      574.7       1689.6    1713.6
## Nashville, TN             2061.9     1240.6       1156.5     821.1
## Austin, TX                1870.5     1049.3       2161.9    1826.6
## Salt Lake City, UT         674.7      447.3       2210.4    2096.2
## Montpelier, VT            3062.7     2081.7        177.7     513.0
## Richmond, VA              2476.3     1655.0        553.5     218.2
## Olympia, WA                660.3     1481.5       3106.4    3130.5
## Charleston, WV            2192.6     1371.3        724.8     389.5
## Madison, WI               2063.2     1082.2       1002.9    1027.0
## Cheyenne, WY              1086.9      105.9       1798.1    1736.3
##                    Tallahassee, FL Atlanta, GA Honolulu, HI Boise, ID
## Montgomery, AL              242.2       199.3       4671.0    2410.3
```

```
## Juneau, AK                 4660.2      4425.0       3832.5    2007.7
## Phoenix, AZ                1725.3      1532.2       3338.1     927.2
## Little Rock, AR             736.4       501.3       4504.4    1916.0
## Sacramento, CA             2594.1      2358.9       3177.4     636.3
## Denver, CO                 1772.8      1537.7       4158.4     879.6
## Hartford, CT               1412.4      1192.2       6062.5    2504.5
## Dover, DE                  1077.1       856.9       5727.2    2528.6
## Tallahassee, FL               0.0       235.2       4650.0    2652.5
## Atlanta, GA                 235.2         0.0       4870.3    2417.3
## Honolulu, HI               4650.0      4870.3          0.0    3813.8
## Boise, ID                  2652.5      2417.3       3813.8       0.0
## Springfield, IL             939.7       704.5       4999.9    1712.8
## Indianapolis, IN            746.6       511.5       5188.7    1905.8
## Des Moines, IA             1279.8      1044.7       4907.0    1372.6
## Topeka, KS                 1217.9       982.7       4619.1    1434.6
## Frankfort, KY               567.9       332.7       5150.9    2084.6
## Baton Rouge, LA             378.6       598.9       4271.4    2274.9
## Augusta, ME                1746.3      1526.1       6396.4    2582.6
## Annapolis, MD              1011.0       790.8       5661.1    2488.0
## Boston, MA                 1541.5      1321.2       6191.5    2551.3
## Lansing, MI                 863.2       628.1       5481.3    1789.2
## Saint Paul, MN             1482.4      1247.3       5167.1    1353.4
## Jackson, MS                 451.1       416.9       4453.4    2201.4
## Jefferson City, MO          992.8       757.7       4778.0    1659.6
## Helena, MT                 2629.5      2394.3       4247.4     433.6
## Lincoln, NE                1392.9      1157.7       4686.0    1259.6
## Carson City, NV            2540.0      2304.8       3312.0     501.8
## Concord, NH                1574.1      1353.9       6224.2    2466.9
## Trenton, NJ                1192.2       972.0       5842.2    2496.6
## Santa Fe, NM               1545.1      1309.9       3824.3    1107.4
## Albany, NY                 1414.7      1194.5       6064.8    2383.9
## Raleigh, NC                 673.4       453.2       5323.4    2592.8
## Bismarck, ND               2030.9      1795.8       4875.9    1062.1
## Columbus, OH                724.4       504.2       5374.4    2064.9
## Oklahoma City, OK          1070.4       835.2       4271.6    1582.1
## Salem, OR                  3117.1      2882.0       3531.7     464.7
## Harrisburg, PA             1080.0       859.8       5730.1    2378.1
## Providence, RI             1485.0      1264.8       6135.1    2568.6
## Columbia, SC                420.4       200.1       5070.4    2583.6
## Pierre, SD                 1837.5      1602.4       4733.1     919.3
## Nashville, TN               532.2       297.1       4906.0    2120.2
## Austin, TX                  749.5       969.7       3900.6    1928.9
## Salt Lake City, UT         2220.1      1985.0       3852.1     432.4
## Montpelier, VT             1590.1      1369.9       6240.1    2426.4
## Richmond, VA                858.9       638.7       5509.0    2534.6
## Olympia, WA                3254.4      3019.2       3684.1     601.9
## Charleston, WV              687.6       467.4       5337.7    2251.0
## Madison, WI                1150.9       915.7       5240.7    1501.6
## Cheyenne, WY               1860.2      1625.1       4264.4     792.3
##                  Springfield, IL Indianapolis, IN Des Moines, IA Topeka, KS
## Montgomery, AL             697.5           517.7         1037.7      975.7
## Juneau, AK                3720.5          3913.5         3380.3     3442.3
## Phoenix, AZ               1661.8          1850.6         1568.9     1281.0
## Little Rock, AR            495.5           684.3          543.4      481.4
```

```
## Sacramento, CA             1822.5          2011.3         1729.5     1441.7
## Denver, CO                  841.5          1030.3          748.5      555.0
## Hartford, CT               1062.6           873.8         1155.5     1443.4
## Dover, DE                   815.8           622.7         1155.9     1108.1
## Tallahassee, FL             939.7           746.6         1279.8     1217.9
## Atlanta, GA                 704.5           511.5         1044.7      982.7
## Honolulu, HI               4999.9          5188.7         4907.0     4619.1
## Boise, ID                  1712.8          1905.8         1372.6     1434.6
## Springfield, IL               0.0           193.1          340.1      380.8
## Indianapolis, IN            193.1             0.0          533.2      569.6
## Des Moines, IA              340.1           533.2            0.0      287.9
## Topeka, KS                  380.8           569.6          287.9        0.0
## Frankfort, KY               371.8           178.7          711.9      650.0
## Baton Rouge, LA             728.5           917.3          902.2      840.3
## Augusta, ME                1396.5          1207.7         1489.4     1777.3
## Annapolis, MD               775.2           582.2         1115.4     1053.4
## Boston, MA                 1191.6          1002.8         1284.6     1572.4
## Lansing, MI                 481.4           292.6          574.3      862.2
## Saint Paul, MN              542.7           735.8          260.2      548.0
## Jackson, MS                 546.5           735.3          828.8      766.8
## Jefferson City, MO          221.9           410.7          287.0      225.0
## Helena, MT                 1689.8          1882.8         1349.6     1411.6
## Lincoln, NE                 453.2           646.2          220.9      175.0
## Carson City, NV            1687.9          1876.7         1595.0     1322.1
## Concord, NH                1224.3          1035.5         1317.2     1605.1
## Trenton, NJ                 842.4           653.5         1123.9     1223.1
## Santa Fe, NM               1175.6          1364.4         1082.7      794.8
## Albany, NY                 1064.9           876.1         1157.8     1445.7
## Raleigh, NC                 880.0           687.0         1220.2     1158.2
## Bismarck, ND               1091.2          1284.3          751.1      813.1
## Columbus, OH                374.6           185.8          692.2      755.4
## Oklahoma City, OK           728.3           917.1          635.4      347.5
## Salem, OR                  2177.4          2370.5         1837.3     1899.3
## Harrisburg, PA              730.2           541.4         1005.4     1111.0
## Providence, RI             1135.2           946.4         1228.1     1516.0
## Columbia, SC                870.8           677.7         1210.9     1149.0
## Pierre, SD                  897.9          1090.9          557.7      619.7
## Nashville, TN               407.5           282.7          747.6      685.6
## Austin, TX                 1099.3          1288.1         1006.4      718.5
## Salt Lake City, UT         1280.4          1473.5         1054.8     1002.3
## Montpelier, VT             1240.3          1051.5         1333.2     1621.1
## Richmond, VA                821.8           628.8         1162.0     1100.0
## Olympia, WA                2314.7          2507.7         1974.5     2036.5
## Charleston, WV              538.2           345.1          878.3      816.4
## Madison, WI                 240.8           404.3          333.7      621.6
## Cheyenne, WY                920.5          1113.6          642.6      642.4
##                    Frankfort, KY Baton Rouge, LA Augusta, ME Annapolis, MD
## Montgomery, AL             479.9           399.6       1725.4         990.1
## Juneau, AK                4092.3          4282.6       4494.4        4495.7
## Phoenix, AZ               1812.9          1347.7       3058.3        2323.0
## Little Rock, AR            646.5           358.8       1892.0        1156.7
## Sacramento, CA            2026.2          2216.5       3218.9        2483.6
## Denver, CO                1204.9          1395.2       2237.9        1608.4
## Hartford, CT               911.5          1791.1        333.9         401.4
```

```
## Dover, DE                576.2          1455.7       669.2          66.1
## Tallahassee, FL          567.9           378.6      1746.3        1011.0
## Atlanta, GA              332.7           598.9      1526.1         790.8
## Honolulu, HI            5150.9          4271.4      6396.4        5661.1
## Boise, ID               2084.6          2274.9      2582.6        2488.0
## Springfield, IL          371.8           728.5      1396.5         775.2
## Indianapolis, IN         178.7           917.3      1207.7         582.2
## Des Moines, IA           711.9           902.2      1489.4        1115.4
## Topeka, KS               650.0           840.3      1777.3        1053.4
## Frankfort, KY              0.0           879.5      1245.4         510.1
## Baton Rouge, LA          879.5             0.0      2124.9        1389.7
## Augusta, ME             1245.4          2124.9         0.0         735.3
## Annapolis, MD            510.1          1389.7       735.3           0.0
## Boston, MA              1040.6          1920.1       204.8         530.5
## Lansing, MI              330.3          1209.8       915.1         698.8
## Saint Paul, MN           914.5          1104.8      1316.7        1318.0
## Jackson, MS              697.5           182.0      1942.9        1207.6
## Jefferson City, MO       424.9           615.2      1618.4         883.1
## Helena, MT              2061.6          2251.9      2463.7        2465.0
## Lincoln, NE              824.9          1015.3      1710.3        1228.4
## Carson City, NV         1972.1          2162.4      3084.4        2375.5
## Concord, NH             1073.2          1952.8       172.2         563.1
## Trenton, NJ              691.3          1570.8       554.1         181.2
## Santa Fe, NM            1326.7          1167.5      2572.1        1836.8
## Albany, NY               913.8          1793.4       331.6         403.7
## Raleigh, NC              508.3          1052.0      1072.9         337.6
## Bismarck, ND            1463.0          1653.3      1865.2        1866.5
## Columbus, OH             223.5          1103.0      1021.9         423.1
## Oklahoma City, OK        879.4           692.8      2124.8        1389.5
## Salem, OR               2549.2          2739.5      2951.4        2952.7
## Harrisburg, PA           579.1          1458.7       666.3         109.9
## Providence, RI           984.1          1863.7       261.3         474.0
## Columbia, SC             499.0           799.0      1325.9         590.6
## Pierre, SD              1269.6          1459.9      1671.8        1673.1
## Nashville, TN            244.9           634.6      1490.3         755.1
## Austin, TX              1250.4           370.9      2495.8        1760.5
## Salt Lake City, UT      1652.2          1842.5      2544.2        2055.7
## Montpelier, VT          1089.2          1968.7       156.2         579.1
## Richmond, VA             450.1          1237.6       887.4         152.1
## Olympia, WA             2686.5          2876.8      3088.6        3089.9
## Charleston, WV           186.7          1066.3      1058.7         323.4
## Madison, WI              583.0           969.3      1155.7         986.4
## Cheyenne, WY            1292.3          1482.6      2132.0        1695.7
##                  Boston, MA Lansing, MI Saint Paul, MN Jackson, MS
## Montgomery, AL       1520.5       810.3         1240.3       217.6
## Juneau, AK           4559.0      3796.9         3177.8      4209.1
## Phoenix, AZ          2853.4      2143.2         1829.0      1274.2
## Little Rock, AR      1687.1       976.9          746.0       285.4
## Sacramento, CA       3014.1      2303.8         1989.7      2143.0
## Denver, CO           2033.1      1322.8         1008.7      1321.8
## Hartford, CT          129.0       715.2         1334.4      1609.1
## Dover, DE             464.4       739.3         1358.5      1273.7
## Tallahassee, FL      1541.5       863.2         1482.4       451.1
## Atlanta, GA          1321.2       628.1         1247.3       416.9
```

```
## Honolulu, HI          6191.5      5481.3         5167.1      4453.4
## Boise, ID             2551.3      1789.2         1353.4      2201.4
## Springfield, IL       1191.6       481.4          542.7       546.5
## Indianapolis, IN      1002.8       292.6          735.8       735.3
## Des Moines, IA        1284.6       574.3          260.2       828.8
## Topeka, KS            1572.4       862.2          548.0       766.8
## Frankfort, KY         1040.6       330.3          914.5       697.5
## Baton Rouge, LA       1920.1      1209.8         1104.8       182.0
## Augusta, ME            204.8       915.1         1316.7      1942.9
## Annapolis, MD          530.5       698.8         1318.0      1207.6
## Boston, MA               0.0       762.1         1381.3      1738.1
## Lansing, MI            762.1         0.0          619.2      1027.8
## Saint Paul, MN        1381.3       619.2            0.0      1031.3
## Jackson, MS           1738.1      1027.8         1031.3         0.0
## Jefferson City, MO    1413.5       703.3          489.6       541.8
## Helena, MT            2528.3      1766.2         1147.0      2178.4
## Lincoln, NE           1505.5       795.2          481.1       941.8
## Carson City, NV       2879.6      2169.3         1855.2      2088.9
## Concord, NH             84.5       742.9         1296.8      1770.7
## Trenton, NJ            349.3       707.3         1326.5      1388.8
## Santa Fe, NM          2367.3      1657.0         1342.9      1094.0
## Albany, NY             167.4       594.7         1213.9      1611.3
## Raleigh, NC            868.1       803.6         1422.8       870.0
## Bismarck, ND          1929.8      1167.7          548.5      1579.9
## Columbus, OH           817.1       275.6          894.8       921.0
## Oklahoma City, OK     1920.0      1209.7          895.6       619.3
## Salem, OR             3016.0      2253.9         1635.4      2666.0
## Harrisburg, PA         461.4       588.9         1208.0      1276.7
## Providence, RI          56.5       779.4         1398.6      1681.6
## Columbia, SC          1121.1       794.3         1413.5       617.0
## Pierre, SD            1736.4       974.3          434.0      1386.5
## Nashville, TN         1285.5       575.2          950.2       452.6
## Austin, TX            2291.0      1580.7         1266.6       552.9
## Salt Lake City, UT    2339.4      1629.1         1315.0      1769.0
## Montpelier, VT         213.8       758.9         1167.5      1786.7
## Richmond, VA           682.6       745.4         1364.6      1055.5
## Olympia, WA           3153.2      2391.1         1771.9      2803.3
## Charleston, WV         853.9       461.7         1080.9       884.2
## Madison, WI           1049.8       287.7          331.5       787.2
## Cheyenne, WY          1927.2      1216.9          902.8      1409.1
##                  Jefferson City, MO Helena, MT Lincoln, NE Carson City, NV
## Montgomery, AL                750.7     2387.3      1150.7          2297.8
## Juneau, AK                   3667.3     2030.7      3267.3          2120.2
## Phoenix, AZ                  1439.9      909.3      1348.0           814.7
## Little Rock, AR               273.6     1893.0       656.4          1803.6
## Sacramento, CA               1601.3     1069.9      1508.6           134.5
## Denver, CO                    780.0      856.6       527.6           846.5
## Hartford, CT                 1284.5     2481.5      1376.5          2750.5
## Dover, DE                     949.2     2505.6      1268.9          2416.1
## Tallahassee, FL               992.8     2629.5      1392.9          2540.0
## Atlanta, GA                   757.7     2394.3      1157.7          2304.8
## Honolulu, HI                 4778.0     4247.4      4686.0          3312.0
## Boise, ID                    1659.6      433.6      1259.6           501.8
## Springfield, IL               221.9     1689.8       453.2          1687.9
```

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## Indianapolis, IN               410.7     1882.8       646.2          1876.7
## Des Moines, IA                 287.0     1349.6       220.9          1595.0
## Topeka, KS                     225.0     1411.6       175.0          1322.1
## Frankfort, KY                  424.9     2061.6       824.9          1972.1
## Baton Rouge, LA                615.2     2251.9      1015.3          2162.4
## Augusta, ME                   1618.4     2463.7      1710.3          3084.4
## Annapolis, MD                  883.1     2465.0      1228.4          2375.5
## Boston, MA                    1413.5     2528.3      1505.5          2879.6
## Lansing, MI                    703.3     1766.2       795.2          2169.3
## Saint Paul, MN                 489.6     1147.0       481.1          1855.2
## Jackson, MS                    541.8     2178.4       941.8          2088.9
## Jefferson City, MO               0.0     1636.6       400.0          1547.2
## Helena, MT                    1636.6        0.0      1236.6           935.4
## Lincoln, NE                    400.0     1236.6         0.0          1374.1
## Carson City, NV               1547.2      935.4      1374.1             0.0
## Concord, NH                   1446.2     2443.9      1538.1          2912.2
## Trenton, NJ                   1064.2     2473.6      1236.9          2530.3
## Santa Fe, NM                   953.7     1084.4       861.8           994.9
## Albany, NY                    1286.8     2360.9      1378.7          2752.8
## Raleigh, NC                    933.2     2569.8      1333.2          2480.3
## Bismarck, ND                  1038.1      628.5       638.1          1563.9
## Columbus, OH                   596.5     2041.9       805.3          2062.5
## Oklahoma City, OK              506.4     1559.1       414.5          1469.6
## Salem, OR                     2124.3      715.6      1724.3           577.1
## Harrisburg, PA                 952.1     2355.1      1118.5          2418.1
## Providence, RI                1357.1     2545.6      1449.0          2823.1
## Columbia, SC                   923.9     2560.6      1323.9          2471.1
## Pierre, SD                     844.7      791.9       444.7          1421.2
## Nashville, TN                  460.6     2097.2       860.6          2007.8
## Austin, TX                     877.4     1905.9       785.5          1816.4
## Salt Lake City, UT            1227.3      409.3       833.9           540.2
## Montpelier, VT                1462.1     2314.6      1554.1          2928.2
## Richmond, VA                   875.0     2511.6      1275.0          2422.1
## Olympia, WA                   2261.5      624.9      1861.5           714.4
## Charleston, WV                 591.3     2228.0       991.3          2138.5
## Madison, WI                    462.7     1478.6       554.6          1928.7
## Cheyenne, WY                   867.4      769.2       467.4           952.4
##                    Concord, NH Trenton, NJ Santa Fe, NM Albany, NY Raleigh, NC
## Montgomery, AL          1553.2      1171.2       1302.9     1393.8       652.4
## Juneau, AK              4474.6      4504.3       3115.1     4391.6      4600.5
## Phoenix, AZ             2886.1      2504.2        486.2     2726.7      1985.4
## Little Rock, AR         1719.8      1337.8        808.6     1560.4       819.0
## Sacramento, CA          3046.7      2664.8       1049.0     2887.3      2534.4
## Denver, CO              2065.7      1683.8        334.2     1906.3      1713.2
## Hartford, CT             161.7       220.3       2238.2      120.5       739.0
## Dover, DE                497.0       115.1       1902.9      337.6       403.7
## Tallahassee, FL         1574.1      1192.2       1545.1     1414.7       673.4
## Atlanta, GA             1353.9       972.0       1309.9     1194.5       453.2
## Honolulu, HI            6224.2      5842.2       3824.3     6064.8      5323.4
## Boise, ID               2466.9      2496.6       1107.4     2383.9      2592.8
## Springfield, IL         1224.3       842.4       1175.6     1064.9       880.0
## Indianapolis, IN        1035.5       653.5       1364.4      876.1       687.0
## Des Moines, IA          1317.2      1123.9       1082.7     1157.8      1220.2
## Topeka, KS              1605.1      1223.1        794.8     1445.7      1158.2
```

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## Frankfort, KY          1073.2      691.3      1326.7      913.8       508.3
## Baton Rouge, LA        1952.8     1570.8      1167.5     1793.4      1052.0
## Augusta, ME             172.2      554.1      2572.1      331.6      1072.9
## Annapolis, MD           563.1      181.2      1836.8      403.7       337.6
## Boston, MA               84.5      349.3      2367.3      167.4       868.1
## Lansing, MI             742.9      707.3      1657.0      594.7       803.6
## Saint Paul, MN         1296.8     1326.5      1342.9     1213.9      1422.8
## Jackson, MS            1770.7     1388.8      1094.0     1611.3       870.0
## Jefferson City, MO     1446.2     1064.2       953.7     1286.8       933.2
## Helena, MT             2443.9     2473.6      1084.4     2360.9      2569.8
## Lincoln, NE            1538.1     1236.9       861.8     1378.7      1333.2
## Carson City, NV        2912.2     2530.3       994.9     2752.8      2480.3
## Concord, NH               0.0      381.9      2399.9      159.4       900.7
## Trenton, NJ             381.9        0.0      2018.0      222.5       518.8
## Santa Fe, NM           2399.9     2018.0         0.0     2240.5      1499.2
## Albany, NY              159.4      222.5      2240.5        0.0       741.3
## Raleigh, NC             900.7      518.8      1499.2      741.3         0.0
## Bismarck, ND           1845.3     1875.0      1051.6     1762.4      1971.3
## Columbus, OH            849.7      467.8      1550.2      690.3       527.9
## Oklahoma City, OK      1952.6     1570.7       474.7     1793.2      1051.9
## Salem, OR              2931.5     2961.2      1572.1     2848.6      3057.5
## Harrisburg, PA          494.1      118.5      1905.8      334.7       406.6
## Providence, RI          101.8      292.8      2310.8      184.7       811.6
## Columbia, SC           1153.7      771.8      1476.2      994.3       253.0
## Pierre, SD             1651.9     1681.6       908.9     1569.0      1777.9
## Nashville, TN          1318.2      936.2      1081.8     1158.7       472.6
## Austin, TX             2323.6     1941.7       821.5     2164.2      1422.9
## Salt Lake City, UT     2372.0     2064.2       675.1     2212.6      2160.5
## Montpelier, VT          129.3      397.9      2415.9      175.4       916.7
## Richmond, VA            715.2      333.3      1684.7      555.8       185.5
## Olympia, WA            3068.8     3098.5      1709.3     2985.8      3194.7
## Charleston, WV          886.5      504.6      1513.4      727.1       341.9
## Madison, WI             983.5      995.0      1416.4      882.4      1091.2
## Cheyenne, WY           1959.8     1704.3       440.1     1800.4      1800.6
##                   Bismarck, ND Columbus, OH Oklahoma City, OK Salem, OR
## Montgomery, AL          1788.8       703.5            828.2    2875.0
## Juneau, AK              2629.3      4072.6           3589.8    1543.1
## Phoenix, AZ             1537.8      2036.4            933.5    1391.8
## Little Rock, AR         1294.5       870.0            333.9    2380.7
## Sacramento, CA          1698.5      2197.0           1523.7     523.0
## Denver, CO               717.5      1216.0            702.5    1344.3
## Hartford, CT            1882.9       688.0           1790.9    2969.1
## Dover, DE               1907.0       463.7           1455.6    2993.2
## Tallahassee, FL         2030.9       724.4           1070.4    3117.1
## Atlanta, GA             1795.8       504.2            835.2    2882.0
## Honolulu, HI            4875.9      5374.4           4271.6    3531.7
## Boise, ID               1062.1      2064.9           1582.1     464.7
## Springfield, IL         1091.2       374.6            728.3    2177.4
## Indianapolis, IN        1284.3       185.8            917.1    2370.5
## Des Moines, IA           751.1       692.2            635.4    1837.3
## Topeka, KS               813.1       755.4            347.5    1899.3
## Frankfort, KY           1463.0       223.5            879.4    2549.2
## Baton Rouge, LA         1653.3      1103.0            692.8    2739.5
## Augusta, ME             1865.2      1021.9           2124.8    2951.4
```

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## Annapolis, MD            1866.5        423.1            1389.5    2952.7
## Boston, MA               1929.8        817.1            1920.0    3016.0
## Lansing, MI              1167.7        275.6            1209.7    2253.9
## Saint Paul, MN            548.5        894.8             895.6    1635.4
## Jackson, MS              1579.9        921.0             619.3    2666.0
## Jefferson City, MO       1038.1        596.5             506.4    2124.3
## Helena, MT                628.5       2041.9            1559.1     715.6
## Lincoln, NE               638.1        805.3             414.5    1724.3
## Carson City, NV          1563.9       2062.5            1469.6     577.1
## Concord, NH              1845.3        849.7            1952.6    2931.5
## Trenton, NJ              1875.0        467.8            1570.7    2961.2
## Santa Fe, NM             1051.6       1550.2             474.7    1572.1
## Albany, NY               1762.4        690.3            1793.2    2848.6
## Raleigh, NC              1971.3        527.9            1051.9    3057.5
## Bismarck, ND                0.0       1443.3             960.6    1344.1
## Columbus, OH             1443.3          0.0            1102.9    2529.5
## Oklahoma City, OK         960.6       1102.9               0.0    2046.8
## Salem, OR                1344.1       2529.5            2046.8       0.0
## Harrisburg, PA           1756.5        355.6            1458.5    2842.7
## Providence, RI           1947.1        760.6            1863.5    3033.3
## Columbia, SC             1962.0        518.7            1001.5    3048.2
## Pierre, SD                193.4       1250.0             767.2    1279.6
## Nashville, TN            1498.7        468.4             634.5    2584.9
## Austin, TX               1307.4       1473.9             371.0    2393.5
## Salt Lake City, UT       1023.7       1632.5            1149.7     897.0
## Montpelier, VT           1716.0        865.7            1968.6    2802.2
## Richmond, VA             1913.1        469.7            1237.4    2999.3
## Olympia, WA              1223.4       2666.8            2184.0     152.4
## Charleston, WV           1629.4        186.1            1066.1    2715.6
## Madison, WI               880.0        563.3             969.1    1966.2
## Cheyenne, WY              611.5       1272.6             789.8    1256.9
##                    Harrisburg, PA Providence, RI Columbia, SC Pierre, SD
## Montgomery, AL             1059.1        1464.1         399.4     1595.4
## Juneau, AK                 4385.8        4576.3        4591.3     2822.6
## Phoenix, AZ                2392.0        2797.0        1732.4     1395.0
## Little Rock, AR            1225.7        1630.7         667.5     1101.1
## Sacramento, CA             2552.7        2957.6        2525.2     1555.7
## Denver, CO                 1571.7        1976.6        1703.9      574.7
## Hartford, CT                332.4          72.6         992.1     1689.6
## Dover, DE                   150.5         407.9         656.7     1713.6
## Tallahassee, FL            1080.0        1485.0         420.4     1837.5
## Atlanta, GA                 859.8        1264.8         200.1     1602.4
## Honolulu, HI               5730.1        6135.1        5070.4     4733.1
## Boise, ID                  2378.1        2568.6        2583.6      919.3
## Springfield, IL             730.2        1135.2         870.8      897.9
## Indianapolis, IN            541.4         946.4         677.7     1090.9
## Des Moines, IA             1005.4        1228.1        1210.9      557.7
## Topeka, KS                 1111.0        1516.0        1149.0      619.7
## Frankfort, KY               579.1         984.1         499.0     1269.6
## Baton Rouge, LA            1458.7        1863.7         799.0     1459.9
## Augusta, ME                 666.3         261.3        1325.9     1671.8
## Annapolis, MD               109.9         474.0         590.6     1673.1
## Boston, MA                  461.4          56.5        1121.1     1736.4
## Lansing, MI                 588.9         779.4         794.3      974.3
```

```
## Saint Paul, MN            1208.0        1398.6       1413.5      434.0
## Jackson, MS               1276.7        1681.6        617.0     1386.5
## Jefferson City, MO         952.1        1357.1        923.9      844.7
## Helena, MT                2355.1        2545.6       2560.6      791.9
## Lincoln, NE               1118.5        1449.0       1323.9      444.7
## Carson City, NV           2418.1        2823.1       2471.1     1421.2
## Concord, NH                494.1         101.8       1153.7     1651.9
## Trenton, NJ                118.5         292.8        771.8     1681.6
## Santa Fe, NM              1905.8        2310.8       1476.2      908.9
## Albany, NY                 334.7         184.7        994.3     1569.0
## Raleigh, NC                406.6         811.6        253.0     1777.9
## Bismarck, ND              1756.5        1947.1       1962.0      193.4
## Columbus, OH               355.6         760.6        518.7     1250.0
## Oklahoma City, OK         1458.5        1863.5       1001.5      767.2
## Salem, OR                 2842.7        3033.3       3048.2     1279.6
## Harrisburg, PA               0.0         405.0        659.7     1563.2
## Providence, RI             405.0           0.0       1064.6     1753.7
## Columbia, SC               659.7        1064.6          0.0     1768.6
## Pierre, SD                1563.2        1753.7       1768.6        0.0
## Nashville, TN              824.1        1229.0        463.3     1305.3
## Austin, TX                1829.5        2234.5       1169.9     1114.0
## Salt Lake City, UT        1945.7        2282.9       2151.2      881.0
## Montpelier, VT             510.1         231.1       1169.7     1522.6
## Richmond, VA               221.1         626.1        438.5     1719.7
## Olympia, WA               2980.0        3170.5       3185.5     1416.8
## Charleston, WV             392.4         797.4        332.6     1436.0
## Madison, WI                876.5        1067.0       1082.0      686.6
## Cheyenne, WY              1585.8        1870.7       1791.3      468.8
##                    Nashville, TN Austin, TX Salt Lake City, UT Montpelier, VT
## Montgomery, AL             290.1      770.4             1978.0         1569.1
## Juneau, AK                4127.9     3936.6             2440.1         4345.3
## Phoenix, AZ               1567.9     1001.7              514.1         2902.1
## Little Rock, AR            401.6      603.8             1483.7         1735.7
## Sacramento, CA            2061.9     1870.5              674.7         3062.7
## Denver, CO                1240.6     1049.3              447.3         2081.7
## Hartford, CT              1156.5     2161.9             2210.4          177.7
## Dover, DE                  821.1     1826.6             2096.2          513.0
## Tallahassee, FL            532.2      749.5             2220.1         1590.1
## Atlanta, GA                297.1      969.7             1985.0         1369.9
## Honolulu, HI              4906.0     3900.6             3852.1         6240.1
## Boise, ID                 2120.2     1928.9              432.4         2426.4
## Springfield, IL            407.5     1099.3             1280.4         1240.3
## Indianapolis, IN           282.7     1288.1             1473.5         1051.5
## Des Moines, IA             747.6     1006.4             1054.8         1333.2
## Topeka, KS                 685.6      718.5             1002.3         1621.1
## Frankfort, KY              244.9     1250.4             1652.2         1089.2
## Baton Rouge, LA            634.6      370.9             1842.5         1968.7
## Augusta, ME               1490.3     2495.8             2544.2          156.2
## Annapolis, MD              755.1     1760.5             2055.7          579.1
## Boston, MA                1285.5     2291.0             2339.4          213.8
## Lansing, MI                575.2     1580.7             1629.1          758.9
## Saint Paul, MN             950.2     1266.6             1315.0         1167.5
## Jackson, MS                452.6      552.9             1769.0         1786.7
## Jefferson City, MO         460.6      877.4             1227.3         1462.1
```

```
## Helena, MT                2097.2     1905.9              409.3         2314.6
## Lincoln, NE                860.6      785.5              833.9         1554.1
## Carson City, NV           2007.8     1816.4              540.2         2928.2
## Concord, NH               1318.2     2323.6             2372.0          129.3
## Trenton, NJ                936.2     1941.7             2064.2          397.9
## Santa Fe, NM              1081.8      821.5              675.1         2415.9
## Albany, NY                1158.7     2164.2             2212.6          175.4
## Raleigh, NC                472.6     1422.9             2160.5          916.7
## Bismarck, ND              1498.7     1307.4             1023.7         1716.0
## Columbus, OH               468.4     1473.9             1632.5          865.7
## Oklahoma City, OK          634.5      371.0             1149.7         1968.6
## Salem, OR                 2584.9     2393.5              897.0         2802.2
## Harrisburg, PA             824.1     1829.5             1945.7          510.1
## Providence, RI            1229.0     2234.5             2282.9          231.1
## Columbia, SC               463.3     1169.9             2151.2         1169.7
## Pierre, SD                1305.3     1114.0              881.0         1522.6
## Nashville, TN                0.0     1005.5             1687.9         1334.1
## Austin, TX                1005.5        0.0             1496.5         2339.6
## Salt Lake City, UT        1687.9     1496.5                0.0         2388.0
## Montpelier, VT            1334.1     2339.6             2388.0            0.0
## Richmond, VA               602.9     1608.4             2102.3          731.2
## Olympia, WA               2722.1     2530.8             1034.2         2939.5
## Charleston, WV             431.6     1437.1             1818.6          902.5
## Madison, WI                618.7     1340.1             1388.5          999.5
## Cheyenne, WY              1328.0     1136.6              412.2         1975.8
##                  Richmond, VA Olympia, WA Charleston, WV Madison, WI
## Montgomery, AL            838.0     3012.2          666.7       908.7
## Juneau, AK               4542.3     1405.8         4258.7      3509.3
## Phoenix, AZ              2170.9     1529.1         1999.6      1902.6
## Little Rock, AR          1004.6     2517.9          833.3       736.3
## Sacramento, CA           2476.3      660.3         2192.6      2063.2
## Denver, CO               1655.0     1481.5         1371.3      1082.2
## Hartford, CT              553.5     3106.4          724.8      1002.9
## Dover, DE                 218.2     3130.5          389.5      1027.0
## Tallahassee, FL           858.9     3254.4          687.6      1150.9
## Atlanta, GA               638.7     3019.2          467.4       915.7
## Honolulu, HI             5509.0     3684.1         5337.7      5240.7
## Boise, ID                2534.6      601.9         2251.0      1501.6
## Springfield, IL           821.8     2314.7          538.2       240.8
## Indianapolis, IN          628.8     2507.7          345.1       404.3
## Des Moines, IA           1162.0     1974.5          878.3       333.7
## Topeka, KS               1100.0     2036.5          816.4       621.6
## Frankfort, KY             450.1     2686.5          186.7       583.0
## Baton Rouge, LA          1237.6     2876.8         1066.3       969.3
## Augusta, ME               887.4     3088.6         1058.7      1155.7
## Annapolis, MD             152.1     3089.9          323.4       986.4
## Boston, MA                682.6     3153.2          853.9      1049.8
## Lansing, MI               745.4     2391.1          461.7       287.7
## Saint Paul, MN           1364.6     1771.9         1080.9       331.5
## Jackson, MS              1055.5     2803.3          884.2       787.2
## Jefferson City, MO        875.0     2261.5          591.3       462.7
## Helena, MT               2511.6      624.9         2228.0      1478.6
## Lincoln, NE              1275.0     1861.5          991.3       554.6
## Carson City, NV          2422.1      714.4         2138.5      1928.7
```

```
## Concord, NH              715.2      3068.8          886.5       983.5
## Trenton, NJ              333.3      3098.5          504.6       995.0
## Santa Fe, NM            1684.7      1709.3         1513.4      1416.4
## Albany, NY               555.8      2985.8          727.1       882.4
## Raleigh, NC              185.5      3194.7          341.9      1091.2
## Bismarck, ND            1913.1      1223.4         1629.4       880.0
## Columbus, OH             469.7      2666.8          186.1       563.3
## Oklahoma City, OK       1237.4      2184.0         1066.1       969.1
## Salem, OR               2999.3       152.4         2715.6      1966.2
## Harrisburg, PA           221.1      2980.0          392.4       876.5
## Providence, RI           626.1      3170.5          797.4      1067.0
## Columbia, SC             438.5      3185.5          332.6      1082.0
## Pierre, SD              1719.7      1416.8         1436.0       686.6
## Nashville, TN            602.9      2722.1          431.6       618.7
## Austin, TX              1608.4      2530.8         1437.1      1340.1
## Salt Lake City, UT      2102.3      1034.2         1818.6      1388.5
## Montpelier, VT           731.2      2939.5          902.5       999.5
## Richmond, VA               0.0      3136.5          283.7      1033.1
## Olympia, WA             3136.5         0.0         2852.9      2103.5
## Charleston, WV           283.7      2852.9            0.0       749.4
## Madison, WI             1033.1      2103.5          749.4         0.0
## Cheyenne, WY            1742.4      1394.1         1458.7       976.3
##                    Cheyenne, WY
## Montgomery, AL          1618.0
## Juneau, AK              2800.0
## Phoenix, AZ              926.3
## Little Rock, AR         1123.8
## Sacramento, CA          1086.9
## Denver, CO               105.9
## Hartford, CT            1798.1
## Dover, DE               1736.3
## Tallahassee, FL         1860.2
## Atlanta, GA             1625.1
## Honolulu, HI            4264.4
## Boise, ID                792.3
## Springfield, IL          920.5
## Indianapolis, IN        1113.6
## Des Moines, IA           642.6
## Topeka, KS               642.4
## Frankfort, KY           1292.3
## Baton Rouge, LA         1482.6
## Augusta, ME             2132.0
## Annapolis, MD           1695.7
## Boston, MA              1927.2
## Lansing, MI             1216.9
## Saint Paul, MN           902.8
## Jackson, MS             1409.1
## Jefferson City, MO       867.4
## Helena, MT               769.2
## Lincoln, NE              467.4
## Carson City, NV          952.4
## Concord, NH             1959.8
## Trenton, NJ             1704.3
## Santa Fe, NM             440.1
```

```
## Albany, NY               1800.4
## Raleigh, NC              1800.6
## Bismarck, ND              611.5
## Columbus, OH             1272.6
## Oklahoma City, OK         789.8
## Salem, OR                1256.9
## Harrisburg, PA           1585.8
## Providence, RI           1870.7
## Columbia, SC             1791.3
## Pierre, SD                468.8
## Nashville, TN            1328.0
## Austin, TX               1136.6
## Salt Lake City, UT        412.2
## Montpelier, VT           1975.8
## Richmond, VA             1742.4
## Olympia, WA              1394.1
## Charleston, WV           1458.7
## Madison, WI               976.3
## Cheyenne, WY                0.0
```

```
lookupPairwiseValue(dist.manhattan.df, "Juneau, AK", "Montgomery, AL");
```

```
## [1] 4418
```

Euclidean We have converted the true latitude/longitude to a miles-type format, so the resulting table will report miles.

```
dist.euclidean = dist( latlong[,1:2],
                       method="euclidean", diag=TRUE, upper=TRUE);
dist.euclidean.m = as.matrix( dist.euclidean );
  rownames(dist.euclidean.m) =
  colnames(dist.euclidean.m) = myLabels;

dist.euclidean.df = as.data.frame( round( dist.euclidean.m, digits=1) );

dist.euclidean.df;  ## too big
```

```
##                    Montgomery, AL Juneau, AK Phoenix, AZ Little Rock, AR
## Montgomery, AL                0.0     3179.8      1410.0           368.8
## Juneau, AK                 3179.8        0.0      2104.5          2814.9
## Phoenix, AZ                1410.0     2104.5         0.0          1081.2
## Little Rock, AR             368.8     2814.9      1081.2             0.0
## Sacramento, CA             1970.1     1532.6       624.8          1614.3
## Denver, CO                 1141.4     2054.6       581.0           772.6
## Hartford, CT                986.2     3559.0      2226.0          1177.7
## Dover, DE                   751.5     3476.2      2033.7           967.0
## Tallahassee, FL             171.9     3345.6      1532.6           530.8
## Atlanta, GA                 141.0     3213.9      1511.3           438.8
## Honolulu, HI               3982.0     2855.5      2636.9          3695.8
## Boise, ID                  1808.9     1419.7       736.9          1440.2
## Springfield, IL             545.3     2757.3      1299.8           378.7
## Indianapolis, IN            511.1     2928.8      1480.3           483.9
## Des Moines, IA              752.5     2508.1      1153.2           478.2
## Topeka, KS                  690.9     2496.8       974.3           349.9
## Frankfort, KY               410.2     3040.2      1520.9           472.5
```

```
## Baton Rouge, LA             298.3     3044.1      1159.2          302.5
## Augusta, ME                1221.2     3658.8      2427.5         1397.4
## Annapolis, MD               702.2     3431.8      1978.9          912.4
## Boston, MA                 1079.8     3629.7      2321.6         1274.7
## Lansing, MI                 721.9     2927.1      1633.5          696.5
## Saint Paul, MN              944.6     2437.2      1304.7          705.6
## Jackson, MS                 213.3     3008.5      1197.4          205.0
## Jefferson City, MO          536.2     2678.0      1142.3          265.1
## Helena, MT                 1714.4     1465.6       906.7         1350.9
## Lincoln, NE                 813.7     2387.9       981.7          481.6
## Carson City, NV            1887.7     1543.7       576.4         1528.8
## Concord, NH                1099.0     3587.6      2313.0         1276.9
## Trenton, NJ                 830.4     3487.7      2089.7         1031.2
## Santa Fe, NM               1098.7     2202.7       366.6          747.1
## Albany, NY                  985.7     3483.5      2186.0         1151.9
## Raleigh, NC                 479.1     3419.6      1832.5          751.3
## Bismarck, ND               1273.1     2000.2      1108.7          952.3
## Columbus, OH                554.1     3079.3      1649.4          624.2
## Oklahoma City, OK           650.2     2557.3       806.3          287.9
## Salem, OR                  2186.7     1111.6       993.7         1818.5
## Harrisburg, PA              749.2     3379.1      1978.2          926.2
## Providence, RI             1041.3     3622.5      2293.2         1242.0
## Columbia, SC                307.9     3362.5      1694.8          618.9
## Pierre, SD                 1129.0     2095.0       989.6          795.2
## Nashville, TN               264.0     3016.0      1393.2          318.6
## Austin, TX                  642.4     2784.0       812.3          427.1
## Salt Lake City, UT         1513.7     1725.4       504.5         1146.0
## Montpelier, VT             1110.7     3512.7      2281.6         1263.0
## Richmond, VA                599.0     3423.7      1910.1          834.2
## Olympia, WA                2241.3      999.6      1108.6         1872.5
## Charleston, WV              484.7     3193.9      1695.7          635.0
## Madison, WI                 758.4     2673.8      1405.3          597.4
## Cheyenne, WY               1179.7     2003.3       661.9          812.6
##                    Sacramento, CA Denver, CO Hartford, CT Dover, DE
## Montgomery, AL             1970.1     1141.4       986.2     751.5
## Juneau, AK                 1532.6     2054.6      3559.0    3476.2
## Phoenix, AZ                 624.8      581.0      2226.0    2033.7
## Little Rock, AR            1614.3      772.6      1177.7     967.0
## Sacramento, CA                0.0      904.7      2674.6    2510.3
## Denver, CO                  904.7        0.0      1770.0    1609.3
## Hartford, CT               2674.6     1770.0         0.0     237.7
## Dover, DE                  2510.3     1609.3       237.7       0.0
## Tallahassee, FL            2109.3     1300.9      1004.2     766.7
## Atlanta, GA                2053.1     1198.2       845.3     611.0
## Honolulu, HI               2315.8     3154.4      4860.5    4661.1
## Boise, ID                   451.9      668.0      2380.0    2242.2
## Springfield, IL            1740.5      837.3       937.0     772.8
## Indianapolis, IN           1931.1     1028.2       749.0     582.1
## Des Moines, IA             1536.0      633.8      1143.7    1002.2
## Topeka, KS                 1409.3      510.0      1270.4    1101.0
## Frankfort, KY              2000.0     1103.9       709.7     514.4
## Baton Rouge, LA            1747.8      989.8      1276.8    1044.9
## Augusta, ME                2851.2     1948.2       236.4     474.1
## Annapolis, MD              2456.8     1556.4       284.1      54.8
```

```
## Boston, MA                2765.8     1861.2        97.1     328.7
## Lansing, MI               2037.6     1135.2       651.7     550.9
## Saint Paul, MN            1611.6      742.2      1136.3    1039.0
## Jackson, MS               1763.6      957.6      1157.8     929.9
## Jefferson City, MO        1600.9      704.4      1087.1     909.9
## Helena, MT                 757.0      609.0      2174.0    2057.6
## Lincoln, NE               1363.6      459.8      1312.3    1160.6
## Carson City, NV            102.5      807.8      2577.5    2415.6
## Concord, NH               2746.2     1842.1       117.4     354.1
## Trenton, NJ               2554.0     1650.7       155.8      84.5
## Santa Fe, NM               871.5      286.0      1865.7    1679.4
## Albany, NY                2621.5     1717.1        85.3     259.7
## Raleigh, NC               2348.3     1465.0       526.3     289.1
## Bismarck, ND              1265.3      539.1      1573.8    1476.7
## Columbus, OH              2103.9     1200.7       577.3     412.0
## Oklahoma City, OK         1326.4      503.1      1424.5    1227.7
## Salem, OR                  446.7     1048.8      2758.7    2624.8
## Harrisburg, PA            2439.0     1535.5       251.5     106.4
## Providence, RI            2743.1     1838.5        68.5     289.8
## Columbia, SC              2231.6     1366.6       703.7     466.0
## Pierre, SD                1223.2      408.9      1520.2    1400.8
## Nashville, TN             1902.5     1024.2       861.7     648.5
## Austin, TX                1418.1      764.0      1582.0    1359.4
## Salt Lake City, UT         545.5      383.3      2142.4    1988.7
## Montpelier, VT            2699.5     1797.1       172.4     387.1
## Richmond, VA              2405.0     1510.5       392.0     154.3
## Olympia, WA                588.5     1100.0      2766.4    2643.3
## Charleston, WV            2176.5     1278.9       543.0     338.2
## Madison, WI               1780.4      882.6       916.8     803.5
## Cheyenne, WY               927.4       97.1      1755.7    1605.4
##                    Tallahassee, FL Atlanta, GA Honolulu, HI Boise, ID
## Montgomery, AL              171.9       141.0      3982.0    1808.9
## Juneau, AK                 3345.6      3213.9      2855.5    1419.7
## Phoenix, AZ                1532.6      1511.3      2636.9     736.9
## Little Rock, AR             530.8       438.8      3695.8    1440.2
## Sacramento, CA             2109.3      2053.1      2315.8     451.9
## Denver, CO                 1300.9      1198.2      3154.4     668.0
## Hartford, CT               1004.2       845.3      4860.5    2380.0
## Dover, DE                   766.7       611.0      4661.1    2242.2
## Tallahassee, FL               0.0       227.8      4068.1    1966.6
## Atlanta, GA                 227.8         0.0      4102.3    1865.4
## Honolulu, HI               4068.1      4102.3         0.0    2746.4
## Boise, ID                  1966.6      1865.4      2746.4       0.0
## Springfield, IL             709.0       506.5      3936.4    1473.2
## Indianapolis, IN            651.0       426.0      4116.9    1661.7
## Des Moines, IA              923.0       739.2      3776.3    1240.8
## Topeka, KS                  861.4       717.2      3608.6    1163.3
## Frankfort, KY               535.5       307.8      4152.3    1751.2
## Baton Rouge, LA             378.1       435.3      3694.9    1640.8
## Augusta, ME                1240.4      1080.2      5064.3    2535.1
## Annapolis, MD               724.3       561.4      4606.3    2191.2
## Boston, MA                 1092.3       939.0      4956.6    2466.1
## Lansing, MI                 847.4       619.6      4267.1    1729.4
## Saint Paul, MN             1110.2       906.6      3894.2    1265.0
```

```
## Jackson, MS                347.9       332.0       3772.0    1621.0
## Jefferson City, MO         707.9       539.7       3779.2    1357.2
## Helena, MT                1881.0      1749.4       3050.8     307.0
## Lincoln, NE                985.2       828.9       3601.2    1083.4
## Carson City, NV           2030.0      1967.3       2417.4     363.6
## Concord, NH               1120.8       958.0       4949.4    2438.8
## Trenton, NJ                850.2       689.6       4721.0    2274.6
## Santa Fe, NM              1238.8      1185.3       3001.7     783.1
## Albany, NY                1018.2       845.0       4822.3    2318.4
## Raleigh, NC                478.0       343.6       4439.3    2121.5
## Bismarck, ND              1444.9      1269.8       3578.7     870.2
## Columbus, OH               659.6       435.0       4285.1    1830.2
## Oklahoma City, OK          802.8       726.7       3436.3    1164.6
## Salem, OR                 2341.7      2246.9       2504.6     384.3
## Harrisburg, PA             788.0       608.6       4611.2    2159.6
## Providence, RI            1051.7       900.7       4927.2    2448.1
## Columbia, SC               301.2       184.0       4285.0    2031.5
## Pierre, SD                1300.7      1137.2       3521.7     868.7
## Nashville, TN              417.6       211.6       4013.9    1686.5
## Austin, TX                 736.7       767.8       3340.0    1365.3
## Salt Lake City, UT        1668.2      1577.5       2846.2     306.9
## Montpelier, VT            1146.2       970.3       4918.4    2382.4
## Richmond, VA               613.0       459.2       4529.9    2156.2
## Olympia, WA               2400.4      2293.8       2606.8     435.4
## Charleston, WV             563.0       350.8       4324.8    1922.1
## Madison, WI                914.7       698.5       4029.1    1464.7
## Cheyenne, WY              1343.3      1226.4       3202.9     644.5
##                  Springfield, IL Indianapolis, IN Des Moines, IA Topeka, KS
## Montgomery, AL             545.3           511.1          752.5      690.9
## Juneau, AK                2757.3          2928.8         2508.1     2496.8
## Phoenix, AZ               1299.8          1480.3         1153.2      974.3
## Little Rock, AR            378.7           483.9          478.2      349.9
## Sacramento, CA            1740.5          1931.1         1536.0     1409.3
## Denver, CO                 837.3          1028.2          633.8      510.0
## Hartford, CT               937.0           749.0         1143.7     1270.4
## Dover, DE                  772.8           582.1         1002.2     1101.0
## Tallahassee, FL            709.0           651.0          923.0      861.4
## Atlanta, GA                506.5           426.0          739.2      717.2
## Honolulu, HI              3936.4          4116.9         3776.3     3608.6
## Boise, ID                 1473.2          1661.7         1240.8     1163.3
## Springfield, IL              0.0           190.9          249.3      333.5
## Indianapolis, IN           190.9             0.0          426.4      522.7
## Des Moines, IA             249.3           426.4            0.0      208.2
## Topeka, KS                 333.5           522.7          208.2        0.0
## Frankfort, KY              283.8           129.2          532.2      593.8
## Baton Rouge, LA            650.6           699.1          780.4      643.0
## Augusta, ME               1129.0           947.6         1315.2     1460.4
## Annapolis, MD              720.5           530.1          952.0     1047.7
## Boston, MA                1030.3           843.3         1232.8     1363.7
## Lansing, MI                344.6           222.7          501.7      659.2
## Saint Paul, MN             401.6           520.5          233.2      430.3
## Jackson, MS                518.3           560.3          668.0      554.7
## Jefferson City, MO         161.3           338.6          222.5      194.8
## Helena, MT                1308.0          1488.5         1062.2     1032.2
```

```
## Lincoln, NE                389.8           578.9          175.5      132.5
## Carson City, NV           1644.7          1835.5         1437.4     1314.7
## Concord, NH               1016.7           832.8         1210.9     1349.4
## Trenton, NJ                813.6           622.9         1033.9     1145.4
## Santa Fe, NM               935.0          1117.8          788.2      607.8
## Albany, NY                 890.1           705.7         1087.0     1222.9
## Raleigh, NC                663.0           495.0          911.7      958.5
## Bismarck, ND               776.6           934.7          531.6      602.9
## Columbus, OH               363.5           172.9          590.7      695.6
## Oklahoma City, OK          523.2           687.7          473.1      267.0
## Salem, OR                 1857.0          2045.1         1622.8     1547.5
## Harrisburg, PA             698.5           508.0          918.8     1030.6
## Providence, RI            1005.3           817.0         1212.2     1338.7
## Columbia, SC               617.8           486.5          864.0      872.9
## Pierre, SD                 662.3           836.0          413.1      445.5
## Nashville, TN              295.7           250.9          528.6      525.6
## Austin, TX                 792.2           911.0          813.1      616.7
## Salt Lake City, UT        1215.9          1406.7          999.2      892.4
## Montpelier, VT             982.0           803.7         1163.7     1312.1
## Richmond, VA               683.6           499.0          925.4     1000.5
## Olympia, WA               1882.7          2067.9         1642.3     1584.5
## Charleston, WV             449.3           265.8          691.7      769.0
## Madison, WI                226.5           288.2          253.0      442.1
## Cheyenne, WY               833.2          1023.3          612.3      518.9
##                    Frankfort, KY Baton Rouge, LA Augusta, ME Annapolis, MD
## Montgomery, AL             410.2          298.3       1221.2         702.2
## Juneau, AK                3040.2         3044.1       3658.8        3431.8
## Phoenix, AZ               1520.9         1159.2       2427.5        1978.9
## Little Rock, AR            472.5          302.5       1397.4         912.4
## Sacramento, CA            2000.0         1747.8       2851.2        2456.8
## Denver, CO                1103.9          989.8       1948.2        1556.4
## Hartford, CT               709.7         1276.8        236.4         284.1
## Dover, DE                  514.4         1044.9        474.1          54.8
## Tallahassee, FL            535.5          378.1       1240.4         724.3
## Atlanta, GA                307.8          435.3       1080.2         561.4
## Honolulu, HI              4152.3         3694.9       5064.3        4606.3
## Boise, ID                 1751.2         1640.8       2535.1        2191.2
## Springfield, IL            283.8          650.6       1129.0         720.5
## Indianapolis, IN           129.2          699.1        947.6         530.1
## Des Moines, IA             532.2          780.4       1315.2         952.0
## Topeka, KS                 593.8          643.0       1460.4        1047.7
## Frankfort, KY                0.0          636.3        925.4         459.9
## Baton Rouge, LA            636.3            0.0       1510.0         994.1
## Augusta, ME                925.4         1510.0          0.0         519.9
## Annapolis, MD              459.9          994.1        519.9           0.0
## Boston, MA                 806.4         1371.7        151.9         377.7
## Lansing, MI                313.3          921.8        813.6         510.2
## Saint Paul, MN             646.8         1005.7       1273.7         995.2
## Jackson, MS                500.1          138.8       1388.6         877.7
## Jefferson City, MO         399.8          563.5       1285.1         856.2
## Helena, MT                1591.6         1592.4       2311.7        2009.3
## Lincoln, NE                669.6          775.4       1488.5        1109.0
## Carson City, NV           1906.7         1672.8       2752.3        2362.4
## Concord, NH                805.6         1387.5        122.6         398.5
```

```
## Trenton, NJ               569.0          1121.7       391.9         128.2
## Santa Fe, NM             1165.1           884.0      2063.8        1624.8
## Albany, NY                680.0          1270.4       245.5         294.8
## Raleigh, NC               379.5           777.1       762.4         250.0
## Bismarck, ND             1052.6          1244.8      1701.6        1431.8
## Columbus, OH              158.7           794.0       781.7         361.4
## Oklahoma City, OK         716.2           489.9      1633.0        1172.9
## Salem, OR                2135.5          2006.5      2908.3        2574.1
## Harrisburg, PA            459.1          1034.0       477.3          91.8
## Providence, RI            775.5          1334.1       193.6         340.0
## Columbia, SC              357.4           605.7       940.1         423.1
## Pierre, SD                945.1          1082.7      1667.5        1352.8
## Nashville, TN             175.0           461.9      1085.2         593.9
## Austin, TX                891.0           358.6      1808.3        1306.1
## Salt Lake City, UT       1486.1          1336.2      2312.3        1936.2
## Montpelier, VT            790.7          1392.8       152.7         423.1
## Richmond, VA              406.7           894.2       628.4         112.5
## Olympia, WA              2164.3          2076.1      2906.5        2593.8
## Charleston, WV            176.9           754.1       766.9         283.5
## Madison, WI               417.1           876.8      1073.8         758.2
## Cheyenne, WY             1108.2          1048.4      1925.7        1553.4
##                   Boston, MA Lansing, MI Saint Paul, MN Jackson, MS
## Montgomery, AL        1079.8      721.9         944.6       213.3
## Juneau, AK            3629.7     2927.1        2437.2      3008.5
## Phoenix, AZ           2321.6     1633.5        1304.7      1197.4
## Little Rock, AR       1274.7      696.5         705.6       205.0
## Sacramento, CA        2765.8     2037.6        1611.6      1763.6
## Denver, CO            1861.2     1135.2         742.2       957.6
## Hartford, CT            97.1      651.7        1136.3      1157.8
## Dover, DE              328.7      550.9        1039.0       929.9
## Tallahassee, FL       1092.3      847.4        1110.2       347.9
## Atlanta, GA            939.0      619.6         906.6       332.0
## Honolulu, HI          4956.6     4267.1        3894.2      3772.0
## Boise, ID             2466.1     1729.4        1265.0      1621.0
## Springfield, IL       1030.3      344.6         401.6       518.3
## Indianapolis, IN       843.3      222.7         520.5       560.3
## Des Moines, IA        1232.8      501.7         233.2       668.0
## Topeka, KS            1363.7      659.2         430.3       554.7
## Frankfort, KY          806.4      313.3         646.8       500.1
## Baton Rouge, LA       1371.7      921.8        1005.7       138.8
## Augusta, ME            151.9      813.6        1273.7      1388.6
## Annapolis, MD          377.7      510.2         995.2       877.7
## Boston, MA               0.0      736.6        1216.0      1253.7
## Lansing, MI            736.6        0.0         491.0       783.0
## Saint Paul, MN        1216.0      491.0           0.0       886.9
## Jackson, MS           1253.7      783.0         886.9         0.0
## Jefferson City, MO    1181.8      505.7         442.2       446.6
## Helena, MT            2255.2     1523.5        1039.6      1547.2
## Lincoln, NE           1402.7      675.6         346.0       685.9
## Carson City, NV       2668.3     1938.7        1510.0      1683.2
## Concord, NH             64.0      711.0        1183.0      1266.1
## Trenton, NJ            250.0      561.5        1052.5      1004.0
## Santa Fe, NM          1960.7     1267.0         950.6       892.4
## Albany, NY             148.5      589.1        1067.5      1146.7
```

```
## Raleigh, NC             614.5       579.1         1012.1       674.6
## Bismarck, ND           1651.5       930.1          439.1      1156.4
## Columbus, OH            672.4       209.0          649.5       658.4
## Oklahoma City, OK      1520.8       867.8          697.1       456.4
## Salem, OR              2843.5      2107.2         1635.0      1994.7
## Harrisburg, PA          348.5       452.0          942.4       911.3
## Providence, RI           41.8       719.3         1202.7      1217.1
## Columbia, SC            793.1       632.4         1001.8       513.2
## Pierre, SD             1603.4       868.6          396.5      1000.1
## Nashville, TN           958.7       469.3          696.8       325.1
## Austin, TX             1678.7      1122.1         1044.0       435.8
## Salt Lake City, UT     2231.9      1499.2         1066.2      1321.2
## Montpelier, VT          155.0       662.0         1121.3      1267.1
## Richmond, VA            482.8       527.4          994.7       782.7
## Olympia, WA            2848.7      2115.1         1633.9      2055.5
## Charleston, WV          640.0       341.9          773.8       626.2
## Madison, WI            1001.5       265.2          240.1       744.8
## Cheyenne, WY           1845.0      1112.4          692.0      1005.3
##                  Jefferson City, MO Helena, MT Lincoln, NE Carson City, NV
## Montgomery, AL                536.2     1714.4       813.7          1887.7
## Juneau, AK                   2678.0     1465.6      2387.9          1543.7
## Phoenix, AZ                  1142.3      906.7       981.7           576.4
## Little Rock, AR               265.1     1350.9       481.6          1528.8
## Sacramento, CA               1600.9      757.0      1363.6           102.5
## Denver, CO                    704.4      609.0       459.8           807.8
## Hartford, CT                 1087.1     2174.0      1312.3          2577.5
## Dover, DE                     909.9     2057.6      1160.6          2415.6
## Tallahassee, FL               707.9     1881.0       985.2          2030.0
## Atlanta, GA                   539.7     1749.4       828.9          1967.3
## Honolulu, HI                 3779.2     3050.8      3601.2          2417.4
## Boise, ID                    1357.2      307.0      1083.4           363.6
## Springfield, IL               161.3     1308.0       389.8          1644.7
## Indianapolis, IN              338.6     1488.5       578.9          1835.5
## Des Moines, IA                222.5     1062.2       175.5          1437.4
## Topeka, KS                    194.8     1032.2       132.5          1314.7
## Frankfort, KY                 399.8     1591.6       669.6          1906.7
## Baton Rouge, LA               563.5     1592.4       775.4          1672.8
## Augusta, ME                  1285.1     2311.7      1488.5          2752.3
## Annapolis, MD                 856.2     2009.3      1109.0          2362.4
## Boston, MA                   1181.8     2255.2      1402.7          2668.3
## Lansing, MI                   505.7     1523.5       675.6          1938.7
## Saint Paul, MN                442.2     1039.6       346.0          1510.0
## Jackson, MS                   446.6     1547.2       685.9          1683.2
## Jefferson City, MO              0.0     1216.6       290.2          1507.1
## Helena, MT                   1216.6        0.0       927.8           664.5
## Lincoln, NE                   290.2      927.8         0.0          1265.7
## Carson City, NV              1507.1      664.5      1265.7             0.0
## Concord, NH                  1171.1     2222.6      1382.6          2648.0
## Trenton, NJ                   957.4     2081.1      1197.3          2458.3
## Santa Fe, NM                  779.3      823.1       618.8           791.3
## Albany, NY                   1044.1     2106.8      1258.0          2523.6
## Raleigh, NC                   764.3     1970.0      1044.9          2258.1
## Bismarck, ND                  737.3      613.7       470.7          1163.0
## Columbus, OH                  509.9     1649.2       749.1          2008.2
```

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## Oklahoma City, OK              362.3     1102.6       371.3          1241.1
## Salem, OR                     1741.5      612.3      1467.2           436.7
## Harrisburg, PA                 843.4     1967.8      1081.9          2343.1
## Providence, RI                1155.0     2240.9      1380.8          2646.0
## Columbia, SC                   685.3     1901.8       974.8          2144.6
## Pierre, SD                     598.1      656.9       316.2          1121.0
## Nashville, TN                  338.0     1554.4       628.1          1812.7
## Austin, TX                     649.0     1369.8       729.7          1350.1
## Salt Lake City, UT            1087.1      402.4       830.6           443.9
## Montpelier, VT                1139.6     2159.7      1337.4          2600.5
## Richmond, VA                   806.2     1987.4      1073.0          2312.3
## Olympia, WA                   1776.4      594.9      1494.8           569.6
## Charleston, WV                 575.7     1753.9       838.9          2082.9
## Madison, WI                    345.7     1259.5       427.9          1680.7
## Cheyenne, WY                   712.8      544.1       445.1           827.4
##                    Concord, NH Trenton, NJ Santa Fe, NM Albany, NY Raleigh, NC
## Montgomery, AL          1099.0       830.4       1098.7      985.7       479.1
## Juneau, AK              3587.6      3487.7       2202.7     3483.5      3419.6
## Phoenix, AZ             2313.0      2089.7        366.6     2186.0      1832.5
## Little Rock, AR         1276.9      1031.2        747.1     1151.9       751.3
## Sacramento, CA          2746.2      2554.0        871.5     2621.5      2348.3
## Denver, CO              1842.1      1650.7        286.0     1717.1      1465.0
## Hartford, CT             117.4       155.8       1865.7       85.3       526.3
## Dover, DE                354.1        84.5       1679.4      259.7       289.1
## Tallahassee, FL         1120.8       850.2       1238.8     1018.2       478.0
## Atlanta, GA              958.0       689.6       1185.3      845.0       343.6
## Honolulu, HI            4949.4      4721.0       3001.7     4822.3      4439.3
## Boise, ID               2438.8      2274.6        783.1     2318.4      2121.5
## Springfield, IL         1016.7       813.6        935.0      890.1       663.0
## Indianapolis, IN         832.8       622.9       1117.8      705.7       495.0
## Des Moines, IA          1210.9      1033.9        788.2     1087.0       911.7
## Topeka, KS              1349.4      1145.4        607.8     1222.9       958.5
## Frankfort, KY            805.6       569.0       1165.1      680.0       379.5
## Baton Rouge, LA         1387.5      1121.7        884.0     1270.4       777.1
## Augusta, ME              122.6       391.9       2063.8      245.5       762.4
## Annapolis, MD            398.5       128.2       1624.8      294.8       250.0
## Boston, MA                64.0       250.0       1960.7      148.5       614.5
## Lansing, MI              711.0       561.5       1267.0      589.1       579.1
## Saint Paul, MN          1183.0      1052.5        950.6     1067.5      1012.1
## Jackson, MS             1266.1      1004.0        892.4     1146.7       674.6
## Jefferson City, MO      1171.1       957.4        779.3     1044.1       764.3
## Helena, MT              2222.6      2081.1        823.1     2106.8      1970.0
## Lincoln, NE             1382.6      1197.3        618.8     1258.0      1044.9
## Carson City, NV         2648.0      2458.3        791.3     2523.6      2258.1
## Concord, NH                0.0       270.9       1950.3      127.1       643.1
## Trenton, NJ              270.9         0.0       1732.3      176.4       373.1
## Santa Fe, NM            1950.3      1732.3          0.0     1823.4      1492.3
## Albany, NY               127.1       176.4       1823.4        0.0       544.6
## Raleigh, NC              643.1       373.1       1492.3      544.6         0.0
## Bismarck, ND            1616.0      1491.6        819.1     1503.2      1429.4
## Columbus, OH             664.7       450.1       1288.4      537.7       375.0
## Oklahoma City, OK       1515.8      1285.2        461.2     1389.0      1031.5
## Salem, OR               2814.5      2655.9       1130.7     2695.4      2505.8
## Harrisburg, PA           355.0       115.4       1619.7      236.7       325.2
```

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## Providence, RI            95.6       213.2       1933.3      139.7       574.2
## Columbia, SC             820.0       549.2       1366.0      717.1       179.0
## Pierre, SD              1573.6      1424.4        675.1     1455.2      1324.6
## Nashville, TN            963.8       713.5       1047.9      840.3       445.9
## Austin, TX              1686.5      1430.5        583.4     1563.8      1110.3
## Salt Lake City, UT      2209.7      2027.5        477.7     2086.2      1848.3
## Montpelier, VT            92.1       303.0       1917.0      128.3       672.9
## Richmond, VA             508.0       237.2       1561.3      407.2       137.5
## Olympia, WA             2816.8      2670.0       1212.7     2700.2      2539.1
## Charleston, WV           645.2       396.8       1341.3      522.7       241.9
## Madison, WI              974.4       822.2       1039.6      853.7       773.8
## Cheyenne, WY            1822.8      1642.3        382.8     1699.3      1477.1
##                    Bismarck, ND Columbus, OH Oklahoma City, OK Salem, OR
## Montgomery, AL           1273.1       554.1             650.2    2186.7
## Juneau, AK               2000.2      3079.3            2557.3    1111.6
## Phoenix, AZ              1108.7      1649.4             806.3     993.7
## Little Rock, AR           952.3       624.2             287.9    1818.5
## Sacramento, CA           1265.3      2103.9            1326.4     446.7
## Denver, CO                539.1      1200.7             503.1    1048.8
## Hartford, CT             1573.8       577.3            1424.5    2758.7
## Dover, DE                1476.7       412.0            1227.7    2624.8
## Tallahassee, FL          1444.9       659.6             802.8    2341.7
## Atlanta, GA              1269.8       435.0             726.7    2246.9
## Honolulu, HI             3578.7      4285.1            3436.3    2504.6
## Boise, ID                 870.2      1830.2            1164.6     384.3
## Springfield, IL           776.6       363.5             523.2    1857.0
## Indianapolis, IN          934.7       172.9             687.7    2045.1
## Des Moines, IA            531.6       590.7             473.1    1622.8
## Topeka, KS                602.9       695.6             267.0    1547.5
## Frankfort, KY            1052.6       158.7             716.2    2135.5
## Baton Rouge, LA          1244.8       794.0             489.9    2006.5
## Augusta, ME              1701.6       781.7            1633.0    2908.3
## Annapolis, MD            1431.8       361.4            1172.9    2574.1
## Boston, MA               1651.5       672.4            1520.8    2843.5
## Lansing, MI               930.1       209.0             867.8    2107.2
## Saint Paul, MN            439.1       649.5             697.1    1635.0
## Jackson, MS              1156.4       658.4             456.4    1994.7
## Jefferson City, MO        737.3       509.9             362.3    1741.5
## Helena, MT                613.7      1649.2            1102.6     612.3
## Lincoln, NE               470.7       749.1             371.3    1467.2
## Carson City, NV          1163.0      2008.2            1241.1     436.7
## Concord, NH              1616.0       664.7            1515.8    2814.5
## Trenton, NJ              1491.6       450.1            1285.2    2655.9
## Santa Fe, NM              819.1      1288.4             461.2    1130.7
## Albany, NY               1503.2       537.7            1389.0    2695.4
## Raleigh, NC              1429.4       375.0            1031.5    2505.8
## Bismarck, ND                0.0      1079.8             802.5    1222.0
## Columbus, OH             1079.8         0.0             851.3    2212.9
## Oklahoma City, OK         802.5       851.3               0.0    1538.9
## Salem, OR                1222.0      2212.9            1538.9       0.0
## Harrisburg, PA           1381.1       335.1            1174.9    2541.1
## Providence, RI           1639.6       645.1            1491.0    2826.5
## Columbia, SC             1394.2       425.1             905.9    2414.5
## Pierre, SD                170.0       993.4             633.1    1241.1
```

```
## Nashville, TN           1059.9       333.5            588.3    2070.1
## Austin, TX              1153.3      1046.6            359.1    1712.5
## Salt Lake City, UT       736.2      1578.4            865.4     673.5
## Montpelier, VT          1550.2       641.8           1491.0    2755.7
## Richmond, VA            1424.9       345.5           1104.2    2540.2
## Olympia, WA             1207.7      2232.6           1599.2     145.0
## Charleston, WV          1197.6       134.1            889.9    2306.1
## Madison, WI              673.6       409.4            687.6    1842.1
## Cheyenne, WY             448.9      1194.1            558.5    1028.7
##                   Harrisburg, PA Providence, RI Columbia, SC Pierre, SD
## Montgomery, AL             749.2        1041.3        307.9     1129.0
## Juneau, AK                3379.1        3622.5       3362.5     2095.0
## Phoenix, AZ               1978.2        2293.2       1694.8      989.6
## Little Rock, AR            926.2        1242.0        618.9      795.2
## Sacramento, CA            2439.0        2743.1       2231.6     1223.2
## Denver, CO                1535.5        1838.5       1366.6      408.9
## Hartford, CT               251.5          68.5        703.7     1520.2
## Dover, DE                  106.4         289.8        466.0     1400.8
## Tallahassee, FL            788.0        1051.7        301.2     1300.7
## Atlanta, GA                608.6         900.7        184.0     1137.2
## Honolulu, HI              4611.2        4927.2       4285.0     3521.7
## Boise, ID                 2159.6        2448.1       2031.5      868.7
## Springfield, IL            698.5        1005.3        617.8      662.3
## Indianapolis, IN           508.0         817.0        486.5      836.0
## Des Moines, IA             918.8        1212.2        864.0      413.1
## Topeka, KS                1030.6        1338.7        872.9      445.5
## Frankfort, KY              459.1         775.5        357.4      945.1
## Baton Rouge, LA           1034.0        1334.1        605.7     1082.7
## Augusta, ME                477.3         193.6        940.1     1667.5
## Annapolis, MD               91.8         340.0        423.1     1352.8
## Boston, MA                 348.5          41.8        793.1     1603.4
## Lansing, MI                452.0         719.3        632.4      868.6
## Saint Paul, MN             942.4        1202.7       1001.8      396.5
## Jackson, MS                911.3        1217.1        513.2     1000.1
## Jefferson City, MO         843.4        1155.0        685.3      598.1
## Helena, MT                1967.8        2240.9       1901.8      656.9
## Lincoln, NE               1081.9        1380.8        974.8      316.2
## Carson City, NV           2343.1        2646.0       2144.6     1121.0
## Concord, NH                355.0          95.6        820.0     1573.6
## Trenton, NJ                115.4         213.2        549.2     1424.4
## Santa Fe, NM              1619.7        1933.3       1366.0      675.1
## Albany, NY                 236.7         139.7        717.1     1455.2
## Raleigh, NC                325.2         574.2        179.0     1324.6
## Bismarck, ND              1381.1        1639.6       1394.2      170.0
## Columbus, OH               335.1         645.1        425.1      993.4
## Oklahoma City, OK         1174.9        1491.0        905.9      633.1
## Salem, OR                 2541.1        2826.5       2414.5     1241.1
## Harrisburg, PA               0.0         316.5        488.6     1311.0
## Providence, RI             316.5           0.0        752.9     1587.6
## Columbia, SC               488.6         752.9          0.0     1273.2
## Pierre, SD                1311.0        1587.6       1273.2        0.0
## Nashville, TN              610.6         925.1        347.6      931.1
## Austin, TX                1332.1        1643.5        947.9      983.4
## Salt Lake City, UT        1912.1        2210.8       1748.1      679.2
```

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## Montpelier, VT              361.8          179.5        845.2     1514.9
## Richmond, VA                191.6          443.4        312.0     1334.0
## Olympia, WA                2556.0         2833.7       2456.5     1246.6
## Charleston, WV              291.7          606.9        301.7     1101.7
## Madison, WI                 709.9          984.5        774.5      603.8
## Cheyenne, WY               1527.0         1824.1       1389.0      331.8
##                    Nashville, TN Austin, TX Salt Lake City, UT Montpelier, VT
## Montgomery, AL             264.0      642.4             1513.7         1110.7
## Juneau, AK                3016.0     2784.0             1725.4         3512.7
## Phoenix, AZ               1393.2      812.3              504.5         2281.6
## Little Rock, AR            318.6      427.1             1146.0         1263.0
## Sacramento, CA            1902.5     1418.1              545.5         2699.5
## Denver, CO                1024.2      764.0              383.3         1797.1
## Hartford, CT               861.7     1582.0             2142.4          172.4
## Dover, DE                  648.5     1359.4             1988.7          387.1
## Tallahassee, FL            417.6      736.7             1668.2         1146.2
## Atlanta, GA                211.6      767.8             1577.5          970.3
## Honolulu, HI              4013.9     3340.0             2846.2         4918.4
## Boise, ID                 1686.5     1365.3              306.9         2382.4
## Springfield, IL            295.7      792.2             1215.9          982.0
## Indianapolis, IN           250.9      911.0             1406.7          803.7
## Des Moines, IA             528.6      813.1              999.2         1163.7
## Topeka, KS                 525.6      616.7              892.4         1312.1
## Frankfort, KY              175.0      891.0             1486.1          790.7
## Baton Rouge, LA            461.9      358.6             1336.2         1392.8
## Augusta, ME               1085.2     1808.3             2312.3          152.7
## Annapolis, MD              593.9     1306.1             1936.2          423.1
## Boston, MA                 958.7     1678.7             2231.9          155.0
## Lansing, MI                469.3     1122.1             1499.2          662.0
## Saint Paul, MN             696.8     1044.0             1066.2         1121.3
## Jackson, MS                325.1      435.8             1321.2         1267.1
## Jefferson City, MO         338.0      649.0             1087.1         1139.6
## Helena, MT                1554.4     1369.8              402.4         2159.7
## Lincoln, NE                628.1      729.7              830.6         1337.4
## Carson City, NV           1812.7     1350.1              443.9         2600.5
## Concord, NH                963.8     1686.5             2209.7           92.1
## Trenton, NJ                713.5     1430.5             2027.5          303.0
## Santa Fe, NM              1047.9      583.4              477.7         1917.0
## Albany, NY                 840.3     1563.8             2086.2          128.3
## Raleigh, NC                445.9     1110.3             1848.3          672.9
## Bismarck, ND              1059.9     1153.3              736.2         1550.2
## Columbus, OH               333.5     1046.6             1578.4          641.8
## Oklahoma City, OK          588.3      359.1              865.4         1491.0
## Salem, OR                 2070.1     1712.5              673.5         2755.7
## Harrisburg, PA             610.6     1332.1             1912.1          361.8
## Providence, RI             925.1     1643.5             2210.8          179.5
## Columbia, SC               347.6      947.9             1748.1          845.2
## Pierre, SD                 931.1      983.4              679.2         1514.9
## Nashville, TN                0.0      723.7             1407.1          955.8
## Austin, TX                 723.7        0.0             1058.8         1679.4
## Salt Lake City, UT        1407.1     1058.8                0.0         2160.1
## Montpelier, VT             955.8     1679.4             2160.1            0.0
## Richmond, VA               517.3     1215.3             1892.7          535.5
## Olympia, WA               2109.9     1796.1              740.9         2754.4
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```
## Charleston, WV             318.9     1041.4             1660.4          641.1
## Madison, WI                497.4      994.6             1239.2          921.4
## Cheyenne, WY              1042.9      843.9              387.0         1773.7
##                    Richmond, VA Olympia, WA Charleston, WV Madison, WI
## Montgomery, AL            599.0     2241.3           484.7       758.4
## Juneau, AK               3423.7      999.6          3193.9      2673.8
## Phoenix, AZ              1910.1     1108.6          1695.7      1405.3
## Little Rock, AR           834.2     1872.5           635.0       597.4
## Sacramento, CA           2405.0      588.5          2176.5      1780.4
## Denver, CO               1510.5     1100.0          1278.9       882.6
## Hartford, CT              392.0     2766.4           543.0       916.8
## Dover, DE                 154.3     2643.3           338.2       803.5
## Tallahassee, FL           613.0     2400.4           563.0       914.7
## Atlanta, GA               459.2     2293.8           350.8       698.5
## Honolulu, HI             4529.9     2606.8          4324.8      4029.1
## Boise, ID                2156.2      435.4          1922.1      1464.7
## Springfield, IL           683.6     1882.7           449.3       226.5
## Indianapolis, IN          499.0     2067.9           265.8       288.2
## Des Moines, IA            925.4     1642.3           691.7       253.0
## Topeka, KS               1000.5     1584.5           769.0       442.1
## Frankfort, KY             406.7     2164.3           176.9       417.1
## Baton Rouge, LA           894.2     2076.1           754.1       876.8
## Augusta, ME               628.4     2906.5           766.9      1073.8
## Annapolis, MD             112.5     2593.8           283.5       758.2
## Boston, MA                482.8     2848.7           640.0      1001.5
## Lansing, MI               527.4     2115.1           341.9       265.2
## Saint Paul, MN            994.7     1633.9           773.8       240.1
## Jackson, MS               782.7     2055.5           626.2       744.8
## Jefferson City, MO        806.2     1776.4           575.7       345.7
## Helena, MT               1987.4      594.9          1753.9      1259.5
## Lincoln, NE              1073.0     1494.8           838.9       427.9
## Carson City, NV          2312.3      569.6          2082.9      1680.7
## Concord, NH               508.0     2816.8           645.2       974.4
## Trenton, NJ               237.2     2670.0           396.8       822.2
## Santa Fe, NM             1561.3     1212.7          1341.3      1039.6
## Albany, NY                407.2     2700.2           522.7       853.7
## Raleigh, NC               137.5     2539.1           241.9       773.8
## Bismarck, ND             1424.9     1207.7          1197.6       673.6
## Columbus, OH              345.5     2232.6           134.1       409.4
## Oklahoma City, OK        1104.2     1599.2           889.9       687.6
## Salem, OR                2540.2      145.0          2306.1      1842.1
## Harrisburg, PA            191.6     2556.0           291.7       709.9
## Providence, RI            443.4     2833.7           606.9       984.5
## Columbia, SC              312.0     2456.5           301.7       774.5
## Pierre, SD               1334.0     1246.6          1101.7       603.8
## Nashville, TN             517.3     2109.9           318.9       497.4
## Austin, TX               1215.3     1796.1          1041.4       994.6
## Salt Lake City, UT       1892.7      740.9          1660.4      1239.2
## Montpelier, VT            535.5     2754.4           641.1       921.4
## Richmond, VA                0.0     2565.9           234.3       754.7
## Olympia, WA              2565.9        0.0          2331.6      1850.3
## Charleston, WV            234.3     2331.6             0.0       534.3
## Madison, WI               754.7     1850.3           534.3         0.0
## Cheyenne, WY             1514.1     1067.8          1280.6       853.3
```

```
##                    Cheyenne, WY
## Montgomery, AL           1179.7
## Juneau, AK               2003.3
## Phoenix, AZ               661.9
## Little Rock, AR           812.6
## Sacramento, CA            927.4
## Denver, CO                 97.1
## Hartford, CT             1755.7
## Dover, DE                1605.4
## Tallahassee, FL          1343.3
## Atlanta, GA              1226.4
## Honolulu, HI             3202.9
## Boise, ID                 644.5
## Springfield, IL           833.2
## Indianapolis, IN         1023.3
## Des Moines, IA            612.3
## Topeka, KS                518.9
## Frankfort, KY            1108.2
## Baton Rouge, LA          1048.4
## Augusta, ME              1925.7
## Annapolis, MD            1553.4
## Boston, MA               1845.0
## Lansing, MI              1112.4
## Saint Paul, MN            692.0
## Jackson, MS              1005.3
## Jefferson City, MO        712.8
## Helena, MT                544.1
## Lincoln, NE               445.1
## Carson City, NV           827.4
## Concord, NH              1822.8
## Trenton, NJ              1642.3
## Santa Fe, NM              382.8
## Albany, NY               1699.3
## Raleigh, NC              1477.1
## Bismarck, ND              448.9
## Columbus, OH             1194.1
## Oklahoma City, OK         558.5
## Salem, OR                1028.7
## Harrisburg, PA           1527.0
## Providence, RI           1824.1
## Columbia, SC             1389.0
## Pierre, SD                331.8
## Nashville, TN            1042.9
## Austin, TX                843.9
## Salt Lake City, UT        387.0
## Montpelier, VT           1773.7
## Richmond, VA             1514.1
## Olympia, WA              1067.8
## Charleston, WV           1280.6
## Madison, WI               853.3
## Cheyenne, WY                0.0
```

```
lookupPairwiseValue(dist.euclidean.df, "Juneau, AK", "Montgomery, AL");
```

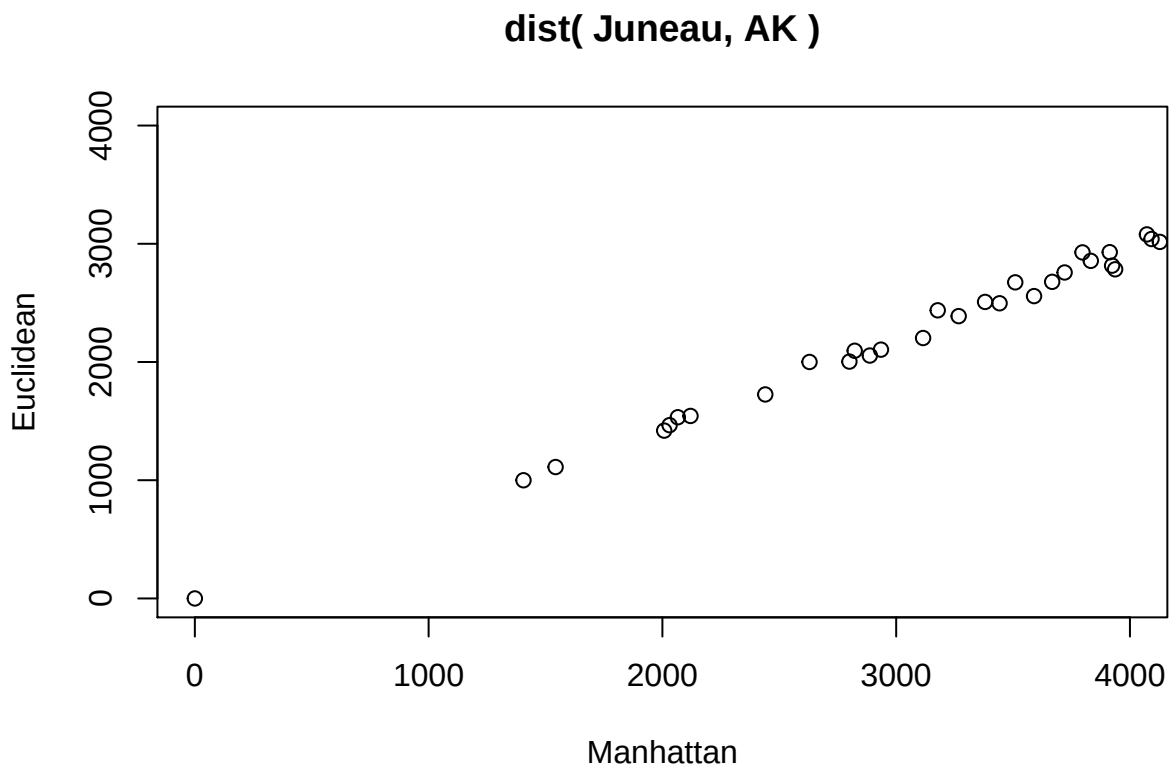
```
## [1] 3179.8
```

You can compare the two with the code below (currently in comments).

```
x = dist.manhattan.df[,2]; # Juneau ... pick one location
y = dist.euclidean.df[,2];

my.lim = c(0, 4000 );

plot(x, y,
           xlab="Manhattan",
           ylab="Euclidean",
           main="dist( Juneau, AK )",
           xlim=my.lim,
           ylim=my.lim);
```




```
plotXYwithBoxPlots(x, y,
           xlab="Manhattan",
           ylab="Euclidean",
           main="dist( Juneau, AK )",
           xlim=my.lim,
           ylim=my.lim);
```

[What is the difference between these two calculations?

Are the results similar?

]

HIERARCHICAL clustering as a function of distance

Aggregating or agglomerating data is typically called "clustering" and is generally considered to be a "unsupervised learning" method.

Introduction

We use `hclust` to perform Hierarchical Clustering. The word "hierarchical" is used because the nature of the data is organized like a family genealogy. The bottom of the tree represents the descendants that eventually "link" to a common ancestor.

If you type `?hclust` you can review the parameter options which we explored in a notebook. `hclust` is primarily a function of `dist()` [distance], and we have just computed some distances, so we could try and apply `hclust` to our data to see if our state capitals will cluster into meaningful regions.

There are several agglomeration methods ("linkage") one could choose from. Each method takes the `dist` https://en.wikipedia.org/wiki/Hierarchical_clustering#Metric and performs some pairwise distance algorithm called a linkage criteria https://en.wikipedia.org/wiki/Hierarchical_clustering#Linkage_criteria.

I generally use either the "complete" linkage method or the "ward.D2" linkage method. You can read help `?hclust` to better appreciate why: "A number of different clustering methods are provided. Ward's minimum variance method aims at finding compact, spherical clusters. The complete linkage method finds similar clusters."

If you are trying to link binary data (zeroes and ones) or genomic data (where the distances were computed using a genetic-distance algorithm), you may want to try the UPGMA approach: "average" or "centroid".

Analogy of Family

Since I am from a large family, I will make a family tree analogy. For me, I am the 5th of 11 siblings (5 brothers, 5 sisters). If I wanted to cluster the siblings in a pair-wise fashion, how would I begin?

First, I would ask, which other sibling is most like me? Since this is a pair-wise approach, and there are 11 siblings, maybe at the initial stage, I will not be paired with another sibling.

In fact, at least one will not be paired because the total number is 11. And maybe more than one will not be paired in the initial stage. Remember "similarity" is being defined based on some distance-linkage method. And to use this approach, "similarity" needs to numerical data.

At each stage, pair-wise joining occurs until there is nothing left to join. The tree contains all of the elements. Every element (branch) eventually joins the main branch (trunk) of the tree.

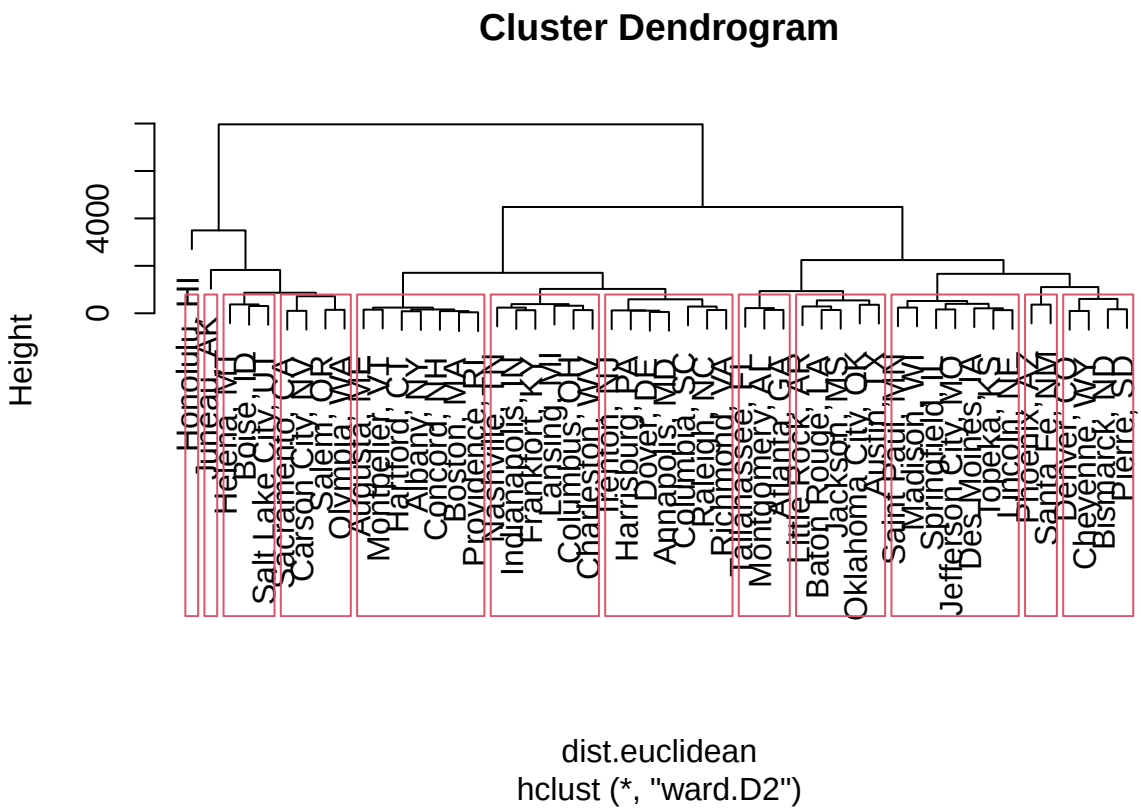
Clustering U.S. capital cities based on latitude, longitude

We already have some data for the U.S. capitals and have computed a Euclidean distance using a capital-city's longitude and latitude. Let's choose to cut the result into `12` agglomerations. Why 12? It was a choice based on my life experience and intuition. As I reflected on why, I did some external searching that validates a choice in that range https://en.wikipedia.org/wiki/List_of_regions_of_the_United_States. You certainly could run this analysis with another choice It is exploratory, and your intuition matters.

Geographically, I am saying the capital-city does represent the state. An ideal representation may be in the center (centroid) of the state. Remember this when we see the linkages with "New York", the city is Albany, not Manhattan.

```
## ward.D2
hclust.ward2.dist.euclidean = hclust(dist.euclidean, method="ward.D2");

plot( hclust.ward2.dist.euclidean,
      labels= myLabels );
rect.hclust( hclust.ward2.dist.euclidean, k=12 );
```




```
## complete
#
#hclust.complete.dist.euclidean = hclust(dist.euclidean, method="complete");
#
#plot( hclust.ward2.dist.euclidean,
#     labels= myLabels );
#rect.hclust( hclust.ward2.dist.euclidean, k=12 );
```

Understanding the `cutree`

In the above example, the tree was cut into 12 groups based on the "distance" formula used and based on the "agglomeration" linkage technique invoice. I likely should have used a "geo-spatial" distance, but we will see that mere "euclidean" distance seems to perform okay.

A fancy word for this statistical tree is a "dendrogram". I call each element of the tree a branch. The smallest branches (twigs) are the fundamental elements, in this case the cities. Over time, they merge with other small branches, and so on.

The relative height when this smallest branch merges with another branch demonstrates when the branch has found a similar pair-wise match (with another smallest branch or a merging branch). I call "Honolulu Hawaii" an isolate because the vertical height when it merges with another branch is the highest of all of the smallest branches (e.g., cities). "Juneau Alaska" is another isolate, but it does merge before "Hawaii".

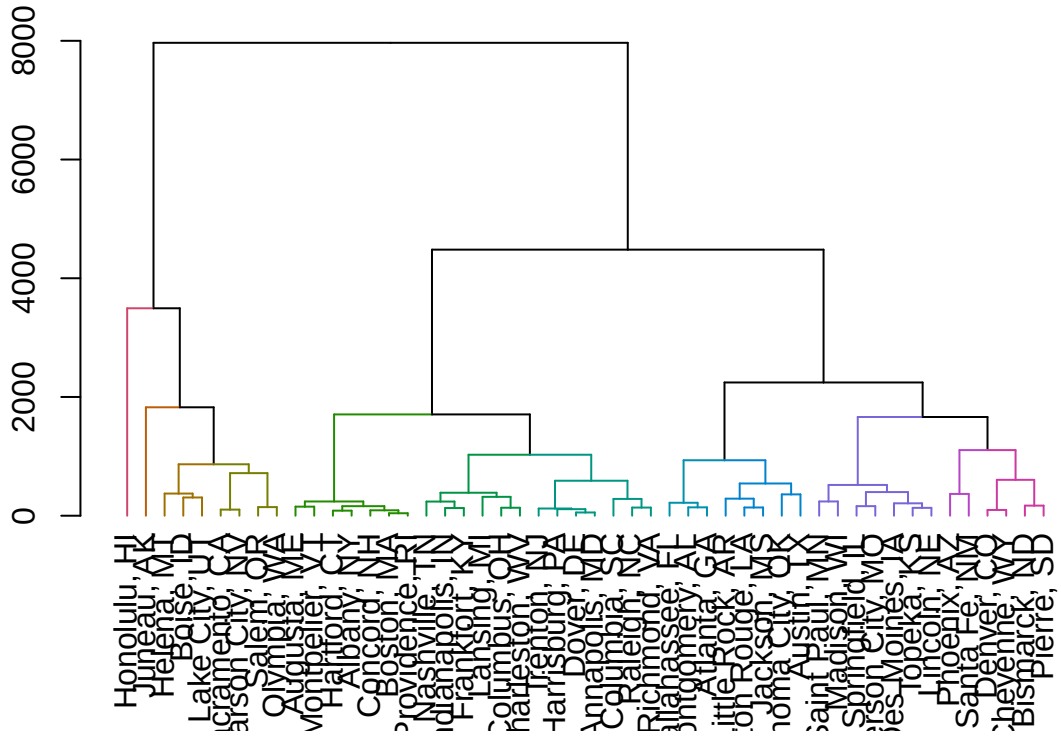
It would be nice if we could decompose this information and look at one `cutree` at a time. And color-code the distinctions. Using the function `plot.hclust.sub` we can do this.

```
source_url( paste0(path.github,"humanVerseWSU/R/functions-EDA.R") );  # EDA functions ...
```

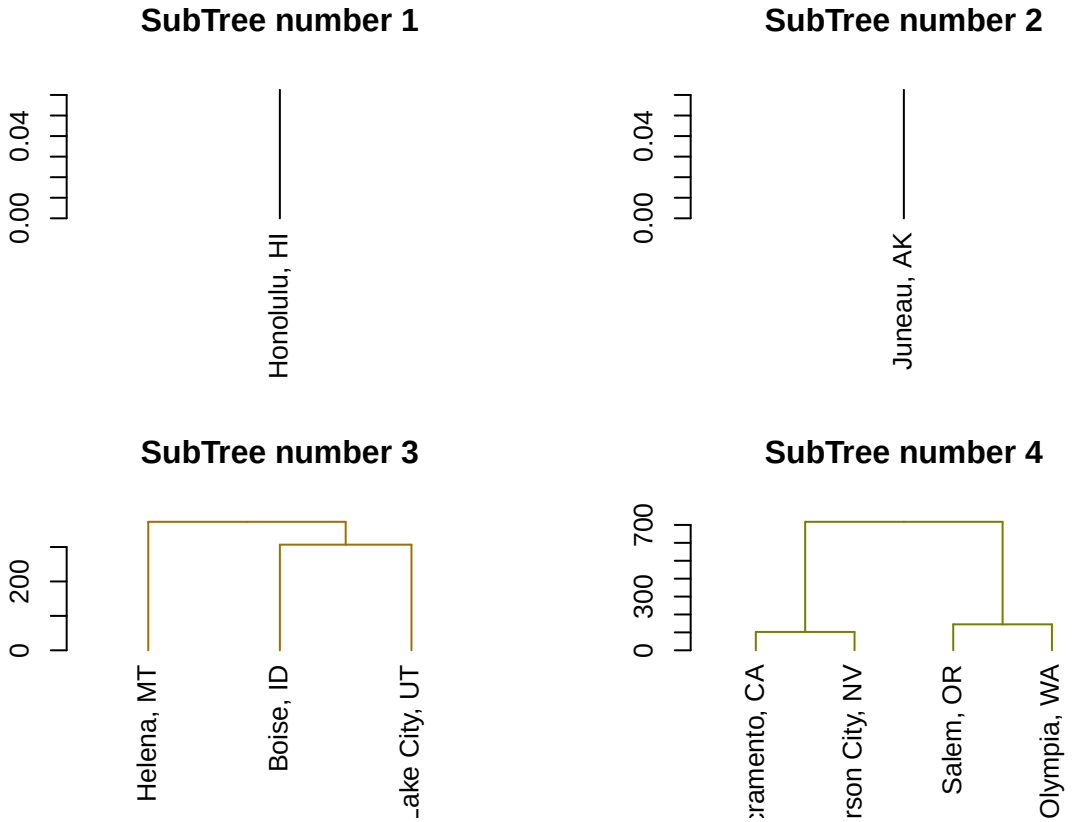
```
## SHA-1 hash of file is dd72e464241952b23d5b08d2213099eccf7a86f6
```

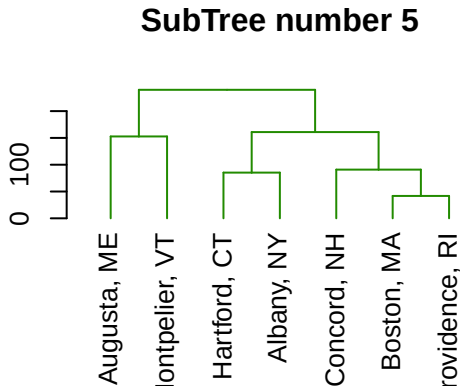
```
hclust.ward2.dist.euclidean$labels = myLabels;
plot.hclust.sub(hclust.ward2.dist.euclidean, k=12);
```

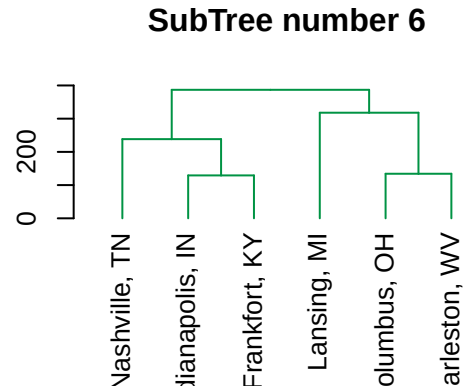
```
## Registered S3 method overwritten by 'dendextend':
##   method       from
##   text.pvclust pvclust
```

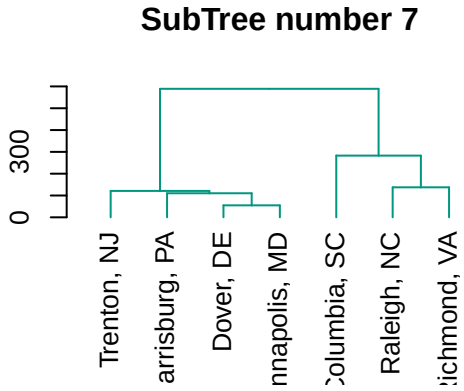


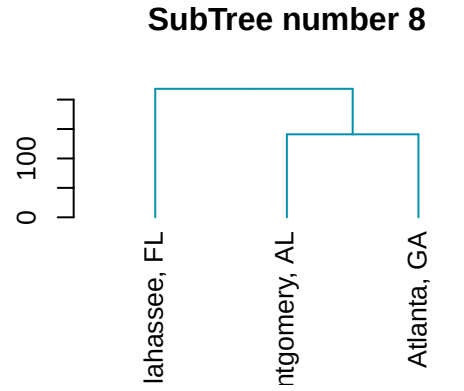

```
## [1] "Pruning 1 of 12"
## [1] "Pruning 2 of 12"
## [1] "Pruning 3 of 12"
## [1] "Pruning 4 of 12"
## [1] "Pruning 5 of 12"
## [1] "Pruning 6 of 12"
## [1] "Pruning 7 of 12"
## [1] "Pruning 8 of 12"
## [1] "Pruning 9 of 12"
## [1] "Pruning 10 of 12"
## [1] "Pruning 11 of 12"
## [1] "Pruning 12 of 12"
```

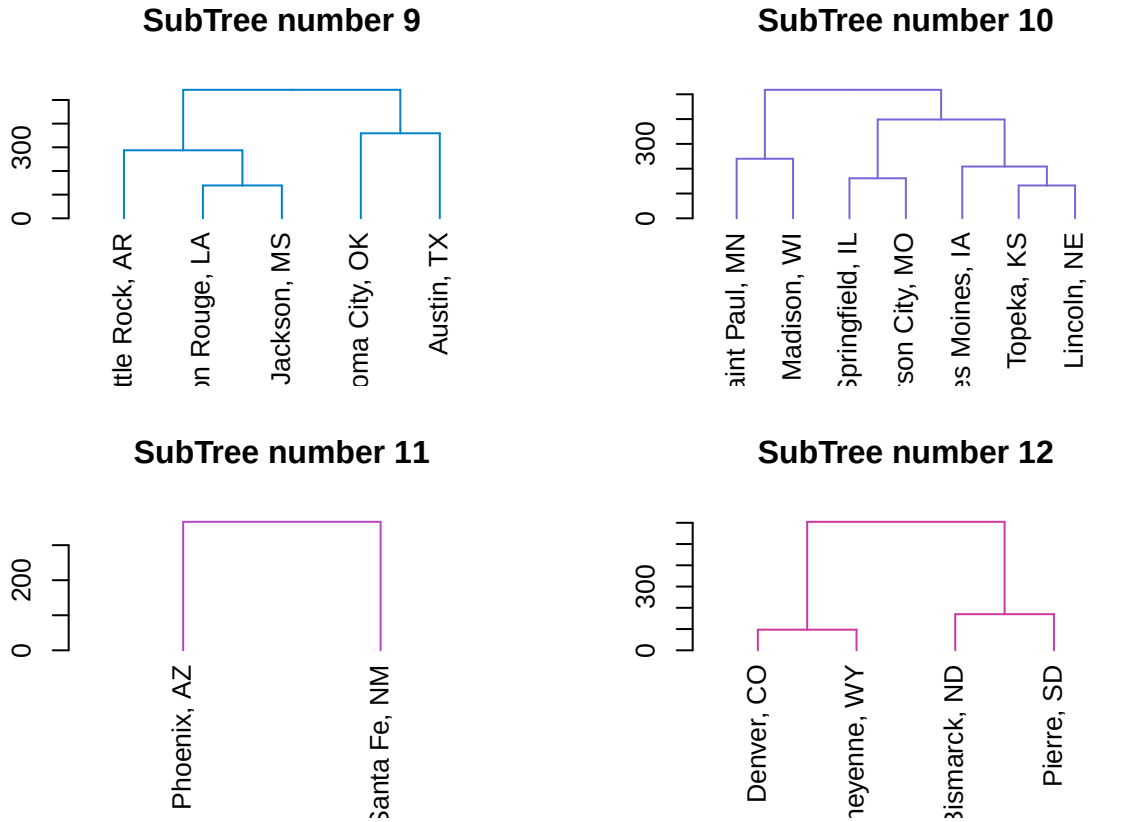

SubTree number 1
0.00
0.04
Honolulu, HI
SubTree number 2
0.00
0.04
Juneau, AK
SubTree number 3
0
200
Helena, MT
Boise, ID
ake City, UT
SubTree number 4
0
300
700
ramento, CA
rson City, NV
Salem, OR
Olympia, WA


SubTree number 5
0
100
Augusta, ME
ontpelier, VT
Hartford, CT
Albany, NY
Concord, NH
Boston, MA
rovidence, RI


SubTree number 6
0
200
Vashville, TN
dianapolis, IN
Frankfort, KY
Lansing, MI
olumbus, OH
arleston, WV


SubTree number 7
0
300
Trenton, NJ
arrisburg, PA
Dover, DE
nnapolis, MD
Columbia, SC
Raleigh, NC
ichmond, VA


SubTree number 8
0
100
lahassee, FL
ntgomery, AL
Atlanta, GA




```
#plot.hclust.sub(hclust.complete.dist.euclidean, k=12);
```

(10 points) Review one clustering tree (dendrogram)

Choose either `hclust.ward2.dist.euclidean` or `hclust.complete.dist.euclidean` and review how the U.S. state capitals are clustered. [I commented out one form, so you will have to re-run if you want to select that one.]

Comment on the "face validity" of this approach based on your understanding about how the U.S. regions are defined? Are the North/South Dakotas together? What about the North/South Carolinas? What about the Pacific Northwest? While living in Kentucky, some people called the area "Kentuckiana" meaning Kentucky/Indiana. Does that show up? Also note anything that seems peculiar.

Additional remarks about `hclust`

I find `hclust` to be a nice initial perusal of the data.

If you want to understand the stability of a particular `hclust` to use it for something other than an "initial perusal of the data," I would recommend `pvclust` which I introduced in the weekly notebooks. It is often used in peer-reviewed research, as it provides a `p-value` of sorts regarding the **stability** of the `hclust` structure.

GENERIC clustering

Aggregating or agglomerating data is typically called "clustering". In exploration, we can create some generic clustering techniques. Below we will create two adhoc clustering rules.

Arbitrary Aggregation

Recall the "movie dataset" with "Will Smith" and "Denzel Washington". We have a collection of movies, and how much money each movie made at the box office. We could organize those movies by some arbitrary rules. For example:

- Cluster 1: NA. We have missing data regarding the money. So let's put all movies that are NA into that cluster.
- Cluster 2: Under a million dollars
- Cluster 3: 1-4.99... million dollars (greater than or equal to one, but less than 5)
- Cluster 4: 5-49.99...
- Cluster 5: 50+

```
library(plyr)
library(dplyr)
library(devtools);
source_url( paste0(path.mshaffer, "will") );
```

(5 points) Movie Aggregation [Arbitrary] for Will and Denzel

```
## SHA-1 hash of file is 3c1c97d961577e9b47a12faa20dca74bfe755c87
```

```
source_url( paste0(path.mshaffer, "denzel") );
```

```
## SHA-1 hash of file is 6692d8c5629db1ae023691bb55de2664a48cdde0
```

```
movies.50 = rbind(will$movies.50, denzel$movies.50);
#View(denzel$movies.50)
unique(movies.50$ttid); # are they in any shared movies ???
```

```
##   [1] "tt0480249" "tt1386697" "tt0116629" "tt0119654" "tt0343818" "tt0454921"
##   [7] "tt0448157" "tt0120912" "tt1409024" "tt0386588" "tt0814314" "tt0112442"
##  [13] "tt0172156" "tt0120660" "tt6139732" "tt0145660" "tt2381941" "tt1815862"
##  [19] "tt1596350" "tt1229340" "tt5519340" "tt0307453" "tt1155076" "tt0120891"
##  [25] "tt0120783" "tt1502397" "tt0248667" "tt4682786" "tt3322364" "tt1025100"
##  [31] "tt0114558" "tt0300051" "tt0284490" "tt0146984" "tt1837709" "tt0338466"
##  [37] "tt0947802" "tt1823664" "tt0268397" "tt1082886" "tt5814534" "tt3721964"
##  [43] "tt0416212" "tt0108149" "tt0328099" "tt0167427" "tt0466839" "tt0107478"
##  [49] "tt7255568" "tt0466856" "tt0765429" "tt0139654" "tt0454848" "tt0455944"
##  [55] "tt0328107" "tt1907668" "tt0453467" "tt1037705" "tt0107818" "tt1599348"
##  [61] "tt0210945" "tt1272878" "tt1111422" "tt0477080" "tt2404435" "tt0145681"
##  [67] "tt3766354" "tt0251160" "tt0097441" "tt0368008" "tt0112740" "tt2671706"
##  [73] "tt0174856" "tt0104797" "tt0107798" "tt0119099" "tt0133952" "tt0313443"
##  [79] "tt0427309" "tt0115956" "tt0107616" "tt0124718" "tt0168786" "tt6000478"
##  [85] "tt0114857" "tt0112857" "tt0102789" "tt0092804" "tt0100168" "tt0117372"
##  [91] "tt0088146" "tt0097880" "tt0102456" "tt0099750" "tt0091786" "tt0082138"
##  [97] "tt0097373" "tt4283892" "tt1698652" "tt0118783"
```

```
loadInflationData();
#View(denzel$movies.50)

movies.50 = standardizeDollarsInDataFrame(movies.50,
                2000,
                "millions",
                "year",
                "millionsAdj2000");
```

```
movies.50$cluster.arbitrary = NA;

## you do something here ..

# (1) populate cluster.arbitrary
# (2) summarize how many movies live in each (table count)

movies.50$cluster.arbitrary[is.na(movies.50$millionsAdj2000)] = 1

movies.50$cluster.arbitrary[movies.50$millionsAdj2000 < 1] = 2

movies.50$cluster.arbitrary[movies.50$millionsAdj2000 < 5 & movies.50$millionsAdj2000 >= 1] = 3

movies.50$cluster.arbitrary[movies.50$millionsAdj2000 >= 5 & movies.50$millionsAdj2000 < 50] = 4

movies.50$cluster.arbitrary[movies.50$millionsAdj2000 >= 50 & movies.50$millionsAdj2000 >= 50] = 5

View(movies.50)

count(movies.50, "cluster.arbitrary")
```

```
##   cluster.arbitrary freq
## 1                 1    5
## 2                 2    4
## 3                 3    2
## 4                 4   38
## 5                 5   51
```

Aggregating using Quantiles

John Tukey emphasized that ordering the data and then splitting it based on the ordering was a fundamental premise of exploratory data analysis.

Tukey's Summary Data John Tukey proposed five elements as primary data for analysis.

- the minimum `min`
- the maximum `max`

Sorting the data makes it easiest to find these data, and will be useful to find the other three exploratory summary features.

This is what I would call "slice and dice". The data is cut in half, and the value of that middle "cutting point" is the `Q2` which we call the `median`.

Next, the lower half could also be cut in half, and the value of that middle "cutting" point is `Q1`.

Then, the upper half could also be cut in half, and the value of that middle "cutting" point is `Q3`.

A common metric derived from this "median-split" procedure is called the interquartile range `IQR` which is defined as the distance between `Q3` and `Q1`. It literally represents the middle 50% of the data; 50% of the elements of the dataset are between `Q3` and `Q1`.

```
x = 1:99;
length(x);
```

Quartile Example

```
## [1] 99
```

```
median(x);
```

```
## [1] 50
```

```
x[50];
```

```
## [1] 50
```

```
median(x[1:49]);
```

```
## [1] 25
```

```
x[25];
```

```
## [1] 25
```

```
median(x[51:99]);
```

```
## [1] 75
```

```
x[75];
```

```
## [1] 75
```

```
# probability-approach ...
# algorithm: the default type=7
stats::quantile(x, prob = c(0.25, 0.5, 0.75), type=1);
```

```
## 25% 50% 75%
##  25  50  75
```

Algorithms address various issues associated with dividing numbers and whether or not to include the dividing number in the subset division, but the principle holds.

We can generalize this idea by not always cutting the data in half (median-split as `n=2`, median-median-split as `n=4`). Instead, we could cut by tens (we call them deciles). Or we could cut by hundreds (we call them centiles). The function `quantile` performs this operation, and if you dig into the `doStatsSummary` function used in this course, you can see its application.

```
movies.50$cluster.deciles = NA;
str(movies.50);
```

(5 points) Movie Aggregation [Decile] for Will and Denzel

```
## 'data.frame':    100 obs. of  14 variables:
##  $ rank             : num  1 2 3 4 5 6 7 8 9 10 ...
##  $ title            : chr  "I Am Legend" "Suicide Squad" "Independence Day" "Men in Black" ...
##  $ ttid             : chr  "tt0480249" "tt1386697" "tt0116629" "tt0119654" ...
##  $ year             : num  2007 2016 1996 1997 2004 ...
##  $ rated            : chr  "PG-13" "PG-13" "PG-13" "PG-13" ...
##  $ minutes          : num  101 123 145 98 115 117 92 88 106 118 ...
##  $ genre            : chr  "Action, Adventure, Drama" "Action, Adventure, Fantasy" "Action, Adventure
##  $ ratings          : num  7.2 6 7 7.3 7.1 8 6.4 6.2 6.8 6.6 ...
##  $ metacritic       : num  65 40 59 71 59 64 49 49 58 58 ...
##  $ votes            : num  675193 588111 520657 507618 491489 ...
##  $ millions         : num  256 325 306 251 145 ...
##  $ millionsAdj2000  : num  213 233 336 269 132 ...
##  $ cluster.arbitrary: num  5 5 5 5 5 5 5 5 5 5 ...
```

```
##  $ cluster.deciles  : logi  NA NA NA NA NA NA ...
```

```
# 1 number of NA's
sum(is.na(movies.50$cluster.deciles))
```

```
## [1] 100
```

```
#View(movies.50)

## you do something here ...

#stats::quantile(x, prob=seq(0.1,0.9,by=0.1), type=1 );

# (1) how many NA's are there ... keep them NA's
# (2) for the rest of the data, break it up into deciles
# (3) $cluster.deciles for a given movie should be NA, 1, 2, 3, ... 10
# (4) summarize how many movies live in each (table count)
```

CENTROID clustering (k-means) as a function of distance

Introduction

Rather than clustering on distance-linkage in a pair-wise fashion, we can cluster based on randomly selecting just `k` points in our data and begin identifying their nearest neighbors using some distance approach.

For example, if `k=3`, we would randomly select three of our data points. We would then compute the distances from all of the remaining points to these `3` anchor points. The points that are closest to a given anchor will be assigned to that anchor. At the end of the stage, we now have new data, so a new centroid is determined. At this point, the centroid https://en.wikipedia.org/wiki/Centroid is likely not one of our data points, but a location within the given centroid cluster. In the "naive" approach, you merely take an average (mean) of all the members of your cluster. More advanced approaches (the default "Hartigan-Wong" of `kmeans`) utilize deviations from the average, called a sum-of-squares approach. This is why in our `kmeans-notebook` we analyzed the `wss` to ascertain how many clusters `k` should we use.

Regardless, after the new centroids (centers) for the clusters are determined, the process iterates. All distances are computed from all points to the new centroids; points are assigned to a given centroid cluster (in this example: 1, 2, 3); a new centroid center is computed, and we repeat the process until a stopping rule is reached: maybe we have exhausted the number of iterations allowed (`iter.max` parameter of `kmeans`)? Or maybe we are not changing membership of any of the data points? Or maybe we have met some objective (like `wss`)?

It is possible to get a `kmeans` result by merely starting with `3 different` random points. In general, `kmeans` is fast (and our computers are so much faster than the computers of 1990: the first computer I built in 1995 had 32MB of RAM, a Pentium processor https://en.wikipedia.org/wiki/Pentium#Pentium and a 900MB Cheetah hard-drive).

Anyway, we can utilize the parameter `nstart` to try many different starting values, and let the program identify the best, most consistent solution.

My recommendations

I would recommend the default algorithm `Hartigan-Wong` with `iter.max=100` and `nstart=100`. You can test the timings from the default values: `iter.max=10` and `nstart=1`. Since the data is likely multidimensional `stars` are the best way to summary the results and membership of `kmeans`. Please see the "kmeans-notebook" for examples.

WIKIPEDIA CLIMATE DATA

For the 50 U.S. cities, we harvested climate data. In the "Wikipedia" notebook, details of that data provenance were outlined. If we want to compare the cities using the climate data, we have to build a matching dataframe, which means we have to select features that exist in each city's climate data set.

There are four temperature features that are always present:

- Record high F (C) ... we will call it "high.max"
- Average high F (C) ... we will call it "high.avg"
- Average low F (C) ... we will call it "low.avg"
- Record low F (C) ... we will call it "low.max" [probably not the best name choice, but it is parallel in form to the first element]

Additionally, for precipitation we have:

- Average precipitation inches (mm) ... we will call it "rain"
- Average snowfall inches (cm) ... we will call it "snow"

For each of these features we have 12 months of data. This is a nice dataset. Let's see what we can do with it.

Basic Background Research We should begin by doing a bit of peripheral research on the topic, to gain "domain knowledge" so we know what to do with the data. A few elements that would benefit.

https://www.forbes.com/sites/brianbrettschneider/2018/07/08/when-does-the-hottest-day-of-the-year-usually-occur/#78141f47548c

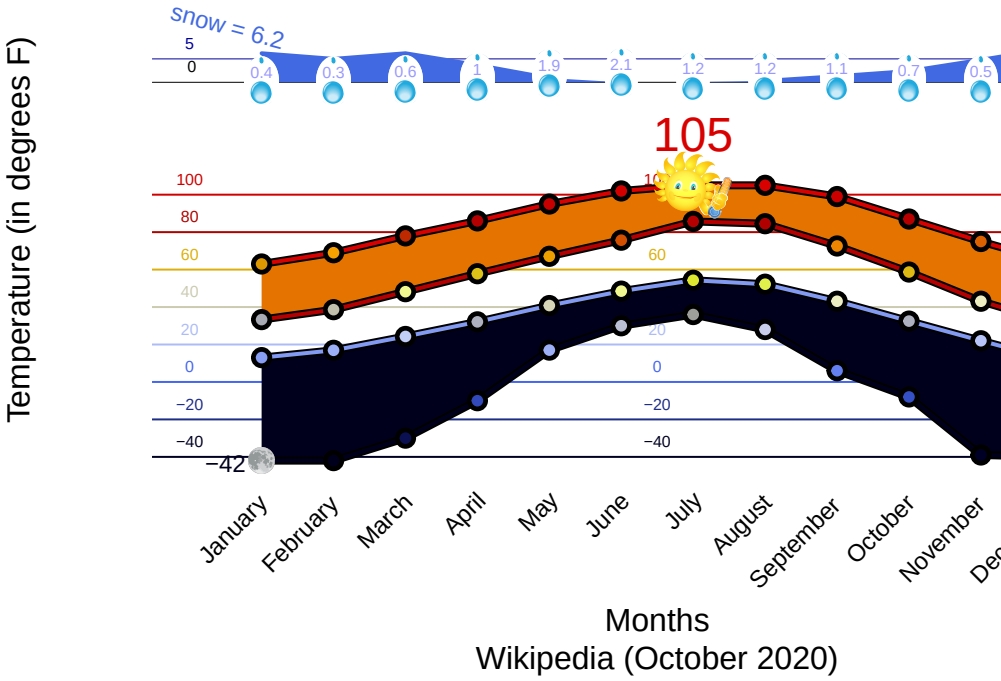
Source: https://bit.ly/359HAnY

https://www.climate.gov/news-features/featured-images/whats-coldest-day-year

One Graph When graphing data to visualize, it is essential that you keep the scales uniform so quick-visual comparisons are accurate. I gave you a task to practice the idea of creation that "one informative" research graphic. And I now present my version for you to use and critique based on your efforts. I am a `plot` guy, so some of you may have a different '`ggplot2` type solution. Ultimately, the intent of this graphic is to best summarize the data in a meaninful way for exploratory analysis.

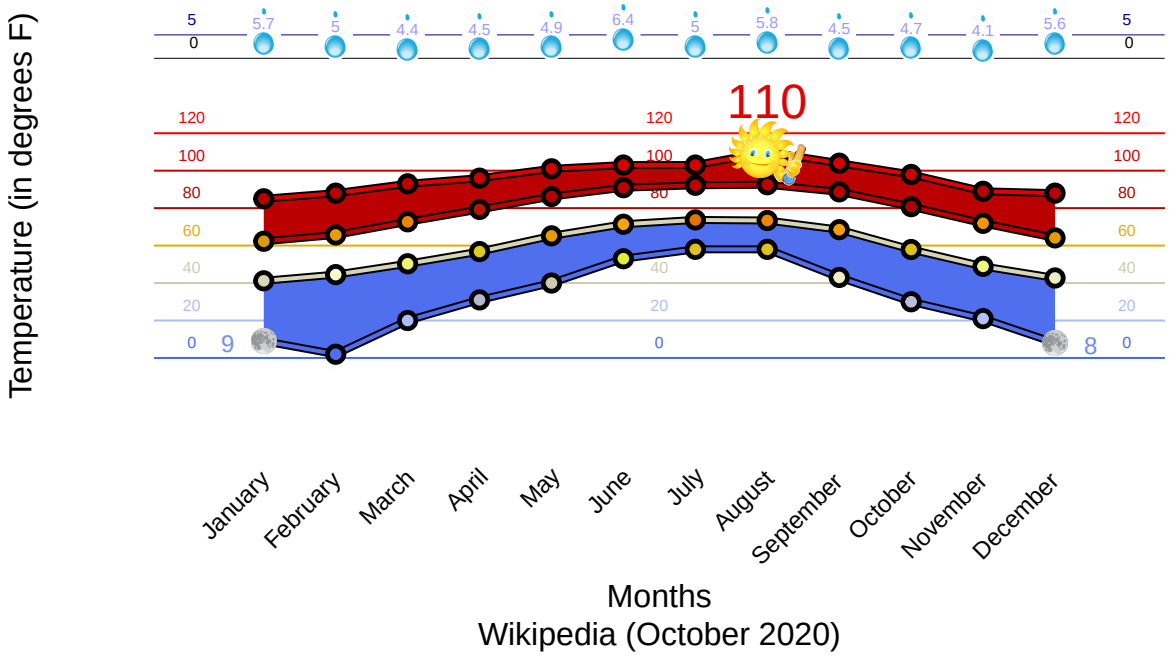
```
climate = utils::read.csv( paste0(path.mshaffer, "_data_/state-capitals/final/state-capitals-climatedata

plotTemperatureFromWikipediaData(climate, city.key="capital", city.val="Helena");
```



(5 points) One Research Graph

```
plotTemperatureFromWikipediaData(climate, city.key="capital", city.val="Baton Rouge");
```



[What do you like about this graphic?

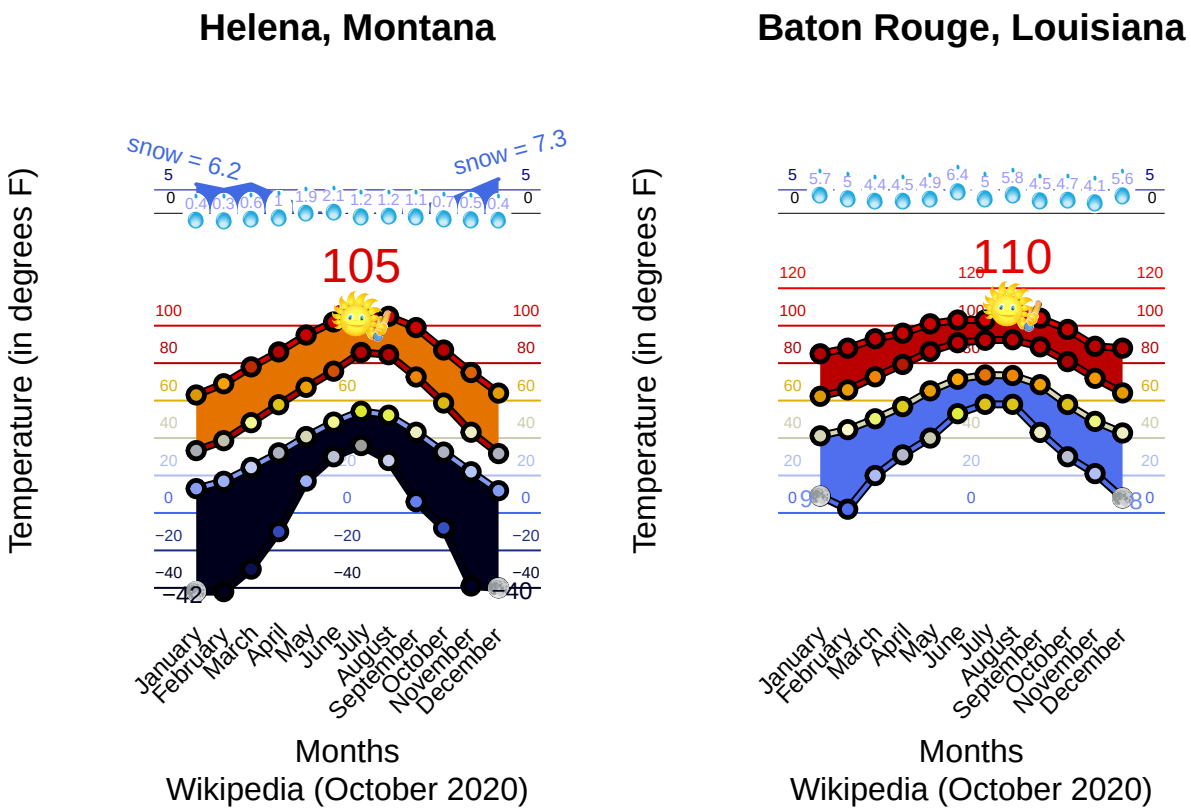
What do you dislike?

Is it aesthetically pleasing? Is it functional?

]

We can achieve a side-by-side comparison using the function described below. The first city will be graphed on the left, the second city on the right.

```
compareTwoCitiesClimates(climate, city.key="capital", city.1="Helena", city.2="Baton Rouge");
```



[What do you like about this graphic?

What do you dislike?

Are the y-axis the same scale? Are the visible gridlines for each the same?

What is the difference between rain and snow on the graphic? Was that a good approach? How would you have done it?

]

(5 points) One Publication Graph We are in exploration, so the "one" research graphic may be very different than the "one" formal graphic designed for a client. Typically, the final graphic needs to meet certain criteria:

- Very pleasing aesthetically
- Interactive if possible
- Live data feeds if possible
- Served in a secure, safe, private location (if required by the client)

To demonstrate the differences, I created a mockup of our 50 U.S. cities and put it into a nice finalized product form called "highcharts".

http://md5.mshaffer.com/WSU_STATS419/_EXAMPLES_/fiddle_usmap/

It pulls data in real time (using AJAX) to grab the weather at the latitudes/longitudes we defined in our Wikipedia notebook.

- You can use your mouse to draw a box to zoom in.

- The third-wheel on the mouse also helps you zoom in/out.
- Hold down CNTRL with your left hand and use your mouse key to drag the map. It seems to only "pan" in the x-direction at the moment.

- The data in the popup displayed can be customized. I report the temperature in Celsius/Fahrenheit and also display the population data we gathered from Wikipedia.

Once you have a template built, it is rather easy to modify it. Here I changed the background map, and all of the data/features stay the same:

http://md5.mshaffer.com/WSU_STATS419/_EXAMPLES_/fiddle_usmap/world.html

Which Features to Include in the Analysis

- months, you can pick all of them `1:12` or maybe just one month per season (April, July, October, January)
- X, depending on what you chose for months, you can now select what climate columns you want to use
  - Some of Temperature Data
  - All of Temperature Data
  - Precipitation Data
  - Everything (All of Temperature Data, Precipitation Data)

If we want to cluster cities, which decisions seem best? Why? As you can see from the code below, you just comment out two options, and can quickly rerun the analysis.

- WHICH MONTHS
- WHICH COLUMNS

```
climate = utils::read.csv( paste0(path.mshaffer, "_data_/state-capitals/final/state-capitals-climatedata

##################### WHICH MONTHS ####################
#########################################################
#months = 1:12; # all the data
months = c(1,4,7,10); # one month of each of the four seasons
#########################################################


month.abb;  # ?month.abb
```

WHICH MONTHS & WHICH COLUMNS

```
##  [1] "Jan" "Feb" "Mar" "Apr" "May" "Jun" "Jul" "Aug" "Sep" "Oct" "Nov" "Dec"
```

```
month.name;
```

```
##  [1] "January"   "February"  "March"     "April"     "May"       "June"
##  [7] "July"      "August"    "September" "October"   "November"  "December"
```

```
month.name[months];  # these are the names of the months you are selecting ...
```

```
## [1] "January" "April"   "July"    "October"
```

```
# this function would allow us to use different months as criteria and different climate-data keys.  It

climate.df = buildClimateDataFrame(climate, months, keys=c("Record high F (C)", "Average high F (C)", "

climate.df;
```

```
##               state        capital st             labels highmax.Jan
## 1           Alabama     Montgomery AL     Montgomery, AL          83
## 23           Alaska         Juneau AK         Juneau, AK          60
## 39          Arizona        Phoenix AZ        Phoenix, AZ          88
## 59         Arkansas    Little Rock AR    Little Rock, AR          83
## 79       California     Sacramento CA     Sacramento, CA          79
## 94         Colorado         Denver CO         Denver, CO          76
## 117     Connecticut       Hartford CT       Hartford, CT          72
## 141        Delaware          Dover DE          Dover, DE          77
## 162         Florida    Tallahassee FL    Tallahassee, FL          83
## 182         Georgia        Atlanta GA        Atlanta, GA          79
## 205          Hawaii       Honolulu HI       Honolulu, HI          88
## 225           Idaho          Boise ID          Boise, ID          63
## 248        Illinois    Springfield IL    Springfield, IL          73
## 265         Indiana   Indianapolis IN   Indianapolis, IN          71
## 289            Iowa     Des Moines IA     Des Moines, IA          67
## 311          Kansas         Topeka KS         Topeka, KS          78
## 334        Kentucky      Frankfort KY      Frankfort, KY          80
## 350       Louisiana    Baton Rouge LA    Baton Rouge, LA          85
## 365           Maine        Augusta ME        Augusta, ME          61
## 381        Maryland      Annapolis MD      Annapolis, MD          77
## 399   Massachusetts          Boston MA         Boston, MA          74
## 423        Michigan         Lansing MI        Lansing, MI          66
## 446       Minnesota     Saint Paul MN     Saint Paul, MN          57
## 458     Mississippi         Jackson MS        Jackson, MS          85
## 476        Missouri Jefferson City MO Jefferson City, MO          79
## 490         Montana          Helena MT         Helena, MT          63
## 509        Nebraska         Lincoln NE        Lincoln, NE          73
## 532          Nevada    Carson City NV    Carson City, NV          72
## 552   New Hampshire         Concord NH        Concord, NH          72
## 574      New Jersey         Trenton NJ        Trenton, NJ          73
## 597      New Mexico       Santa Fe NM       Santa Fe, NM          65
## 617        New York          Albany NY         Albany, NY          71
## 641  North Carolina         Raleigh NC        Raleigh, NC          80
## 665    North Dakota       Bismarck ND       Bismarck, ND          63
## 688            Ohio       Columbus OH       Columbus, OH          74
## 712        Oklahoma  Oklahoma City OK  Oklahoma City, OK          83
## 734          Oregon           Salem OR          Salem, OR          68
## 754    Pennsylvania     Harrisburg PA     Harrisburg, PA          73
## 776    Rhode Island     Providence RI     Providence, RI          70
## 800  South Carolina       Columbia SC       Columbia, SC          84
## 823    South Dakota         Pierre SD         Pierre, SD          68
## 837       Tennessee      Nashville TN      Nashville, TN          78
## 861           Texas         Austin TX         Austin, TX          90
## 885            Utah Salt Lake City UT Salt Lake City, UT          63
## 908         Vermont     Montpelier VT     Montpelier, VT          66
## 925        Virginia       Richmond VA       Richmond, VA          81
## 949      Washington        Olympia WA        Olympia, WA          64
## 968   West Virginia     Charleston WV     Charleston, WV          81
## 986       Wisconsin        Madison WI        Madison, WI          58
## 1007        Wyoming       Cheyenne WY       Cheyenne, WY          70
##      highmax.Apr highmax.Jul highmax.Oct highavg.Jan highavg.Apr highavg.Jul
## 1             94         107         102        57.4        76.6        92.1
## 23            72          89          68        34.6        49.1        63.4
```

```
## 39           105         121         107        67.2        85.2       106.1
## 59            95         112          98        50.5        73.1        92.5
## 79            98         114         102        54.4        72.7        93.3
## 94            90         105          90        44.0        61.5        89.4
## 117           96         103          91        34.5        60.5        84.5
## 141           97         104          95        43.4        65.7        87.0
## 162           95         104          95        63.5        79.9        92.1
## 182           93         105          98        52.3        72.5        89.1
## 205           91          94          94        80.1        82.7        87.9
## 225           92         111          94        37.8        62.3        91.2
## 248           90         112          93        34.8        64.6        86.2
## 265           90         106          92        35.6        63.4        85.0
## 289           93         110          95        31.0        62.3        85.7
## 311           97         114          97        39.9        66.7        89.5
## 334           95         111          98        41.5        66.5        87.3
## 350           96         103          98        62.3        79.3        92.2
## 365           90          99          85        27.6        53.1        79.2
## 381           95         105          92        42.7        63.9        85.8
## 399           94         104          90        35.8        55.6        81.4
## 423           88         103          90        30.1        57.8        82.4
## 446           93         105          88        26.0        58.0        85.0
## 458           94         107          98        56.1        75.9        91.6
## 476           96         112          96        39.9        66.7        88.3
## 490           86         105          87        33.3        57.8        85.7
## 509           97         115          98        35.4        64.3        89.0
## 532           88         107          93        45.2        62.7        89.6
## 552           95         102          92        30.8        57.4        82.3
## 574           93         106          94        39.0        61.4        85.3
## 597           84         101          87        43.5        64.7        85.9
## 617           93         104          91        30.6        58.3        82.3
## 641           95         105         100        50.9        72.4        90.2
## 665           93         114          95        23.4        57.0        84.7
## 688           90         106          94        36.5        63.5        84.9
## 712          100         110          97        49.7        72.3        93.9
## 734           93         108          93        47.7        61.1        82.0
## 754           93         107          97        37.0        62.4        85.5
## 776           98         102          88        37.4        58.6        82.8
## 800           96         107         101        56.0        76.3        92.7
## 823           98         117          98        30.0        59.7        88.8
## 837           91         107          99        46.9        70.5        89.3
## 861           99         109         100        61.5        79.8        95.6
## 885           89         107          89        37.4        61.6        92.6
## 908           90          97          84        26.4        53.3        78.5
## 925           96         105          99        47.4        70.3        89.7
## 949           88         104          90        45.9        58.9        76.8
## 968           96         108          96        42.5        67.7        85.2
## 986           94         107          90        26.4        57.3        81.6
## 1007          84         100          85        39.5        54.9        83.4
##      highavg.Oct lowavg.Jan lowavg.Apr lowavg.Jul lowavg.Oct lowmin.Jan
## 1           78.3       35.7       51.6       71.5       53.5          0
## 23          48.4       26.2       35.3       51.4       39.0        -20
## 39          88.5       45.6       60.2       83.5       64.8         16
## 59          74.8       31.2       51.0       73.2       52.6         -8
## 79          77.9       40.7       49.0       60.9       52.8         19
```

```
## 94          65.3       17.4       33.3       58.9       36.6        -29
## 117         63.1       17.7       38.4       62.7       41.1        -26
## 141         68.8       27.1       44.3       68.4       48.7         -7
## 162         81.4       39.0       52.3       72.0       57.3          6
## 182         72.7       34.3       51.5       71.3       54.0         -8
## 205         86.7       66.3       69.4       74.5       73.4         52
## 225         64.8       24.7       39.3       60.4       40.9        -28
## 248         66.4       18.7       42.4       65.4       43.8        -22
## 265         65.3       20.5       42.7       65.8       44.7        -27
## 289         63.1       14.3       41.1       66.8       43.0        -30
## 311         68.4       19.6       43.5       68.4       44.7        -23
## 334         69.5       21.9       40.5       63.8       43.0        -27
## 350         80.8       41.2       56.8       73.7       57.9          9
## 365         57.2       11.0       34.6       59.9       39.6        -33
## 381         66.3       29.1       45.8       71.2       50.5         -8
## 399         61.4       22.2       40.6       65.4       46.5        -13
## 423         59.9       16.8       37.0       60.6       40.7        -29
## 446         59.0        7.0       38.0       64.0       41.0        -29
## 458         77.2       35.3       52.2       71.6       53.1         -5
## 476         68.5       20.9       43.8       68.1       44.9        -23
## 490         58.7       13.0       32.1       54.3       32.5        -42
## 509         65.8       13.8       38.8       66.1       40.6        -33
## 532         67.9       21.7       33.9       52.2       34.6        -27
## 552         60.5       10.4       32.7       57.7       35.8        -35
## 574         65.0       23.2       41.0       66.0       44.2        -13
## 597         66.5       17.5       32.3       54.4       35.5        -14
## 617         59.8       14.5       37.3       61.4       39.6        -28
## 641         72.6       31.0       48.0       69.9       49.8         -9
## 665         57.5        2.2       30.7       57.4       32.2        -45
## 688         65.1       22.6       42.6       65.5       45.0        -22
## 712         73.4       28.8       49.7       72.2       51.6        -11
## 734         64.1       34.7       39.6       53.1       42.3        -10
## 754         64.1       22.8       41.9       66.3       44.6        -22
## 776         63.3       21.0       39.6       64.2       43.9        -13
## 800         76.1       33.7       50.4       71.6       52.1         -1
## 823         61.0        9.8       34.2       61.9       36.4        -33
## 837         71.7       28.4       47.5       69.5       48.9        -17
## 861         81.8       41.5       58.6       74.4       60.6         -2
## 885         64.7       21.6       39.5       64.7       41.3        -22
## 908         56.0        7.0       31.5       55.7       35.3        -34
## 925         71.0       28.3       46.1       68.9       48.3        -12
## 949         60.2       33.7       37.7       50.8       40.5         -8
## 968         67.7       26.3       44.5       65.7       45.4        -16
## 986         58.9       11.1       35.8       61.0       38.8        -37
## 1007        58.8       18.0       30.8       55.5       33.9        -38
##      lowmin.Apr lowmin.Jul lowmin.Oct rain.Jan rain.Apr rain.Jul rain.Oct
## 1            28         59         26     4.65     4.02     5.24     2.92
## 23           12         39         13     7.98     4.64     5.44    13.23
## 39           35         63         34     0.91     0.28     1.05     0.58
## 59           28         54         27     3.55     5.14     3.27     4.91
## 79           34         47         34     3.63     1.36     0.02     1.06
## 94           -2         42         -2     0.41     1.71     2.16     1.02
## 117           9         44         17     3.23     3.72     4.18     4.37
## 141          14         45         25     3.41     3.88     4.09     3.42
```

```
## 162          29         57         29     4.34     3.06     7.17     3.23
## 182          25         53         28     4.20     3.36     5.27     3.41
## 205          56         63         61     0.00     0.00     0.00     0.00
## 225          11         35         11     1.24     1.23     0.33     0.75
## 248          16         48         13     1.82     3.51     3.94     3.15
## 265          18         46         20     2.66     3.81     4.55     3.12
## 289           9         47          7     1.00     3.86     4.47     2.64
## 311          10         43         16     0.86     3.53     3.82     3.03
## 334          16         48         20     3.70     3.74     4.14     2.53
## 350          31         58         30     5.72     4.46     4.96     4.70
## 365           9         43         21     2.61     3.78     3.41     4.36
## 381          13         50         26     3.32     3.66     4.56     3.89
## 399          11         50         25     3.36     3.74     3.43     3.94
## 423          -6         31         10     1.65     3.03     2.84     2.53
## 446           3         45         15     0.79     2.87     4.41     2.91
## 458          27         51         26     4.97     4.96     4.81     3.92
## 476          13         42         14     1.93     4.16     4.31     3.35
## 490         -10         36         -8     0.36     0.98     1.19     0.68
## 509           3         45          3     0.64     2.71     3.40     1.97
## 532           3         33          6     1.59     0.43     0.19     0.77
## 552           4         35         10     2.70     3.41     3.74     4.04
## 574          11         48         22     3.16     3.54     4.95     4.18
## 597          10         37          5     0.60     0.77     2.33     1.33
## 617           9         40         16     2.59     3.17     4.12     3.68
## 641          23         48         19     3.50     2.92     4.73     3.25
## 665         -12         32        -10     0.43     1.26     2.89     1.25
## 688          14         43         17     2.73     3.40     4.79     2.61
## 712          20         53         16     1.39     3.07     2.93     3.71
## 734          23         35         19     5.96     2.81     0.46     3.03
## 754          11         49         23     2.88     3.10     4.61     3.27
## 776          11         48         20     3.86     4.36     3.29     3.93
## 800          26         54         23     3.58     2.62     5.46     3.17
## 823           1         42          4     0.42     1.81     2.61     1.65
## 837          23         51         26     3.75     4.00     3.64     3.04
## 861          30         57         30     2.22     2.09     1.88     3.88
## 885          14         40         14     1.25     1.99     0.61     1.52
## 908           2         35         14     2.45     2.66     4.08     3.44
## 925          19         51         21     3.04     3.27     4.51     2.98
## 949          23         35         14     7.84     3.54     0.63     4.60
## 968          18         46         17     3.00     3.24     4.94     2.67
## 986           0         36         12     1.23     3.40     4.18     2.40
## 1007         -8         33         -5     0.33     1.78     2.19     0.93
##      snow.Jan snow.Apr snow.Jul snow.Oct
## 1         0.0      0.0        0      0.0
## 23       24.2      0.9        0      0.6
## 39        0.0      0.0        0      0.0
## 59        1.6      0.0        0      0.0
## 79        0.0      0.0        0      0.0
## 94        7.0      6.8        0      4.0
## 117      12.3      1.4        0      0.0
## 141       4.6      0.0        0      0.0
## 162       0.0      0.0        0      0.0
## 182       1.3      0.0        0      0.0
## 205       0.0      0.0        0      0.0
```

```
## 225       5.1      0.3        0      0.1
## 248       6.4      0.3        0      0.0
## 265       8.6      0.2        0      0.4
## 289       8.5      1.8        0      0.4
## 311       4.9      0.3        0      0.3
## 334       3.4      0.0        0      0.0
## 350       0.0      0.0        0      0.0
## 365      20.0      4.7        0      0.3
## 381       4.4      0.0        0      0.0
## 399      12.9      1.9        0      0.0
## 423      13.8      1.9        0      0.4
## 446       0.0      0.0        0      0.0
## 458       0.0      0.0        0      0.0
## 476       4.8      0.1        0      0.0
## 490       6.2      3.7        0      2.4
## 509       5.4      1.4        0      0.7
## 532       3.4      0.2        0      0.0
## 552      18.1      2.8        0      0.0
## 574       6.0      0.0        0      0.0
## 597       4.0      0.4        0      1.0
## 617      17.9      2.3        0      0.3
## 641       2.9      0.1        0      0.0
## 665       8.9      4.2        0      2.2
## 688       9.2      1.1        0      0.2
## 712       2.8      0.0        0      0.0
## 734       0.6      0.0        0      0.0
## 754       8.8      0.4        0      0.0
## 776       9.0      0.6        0      0.0
## 800       0.8      0.0        0      0.0
## 823       5.4      3.5        0      0.9
## 837       2.6      0.0        0      0.0
## 861       0.4      0.0        0      0.0
## 885      12.5      4.0        0      1.4
## 908      22.6      4.9        0      0.0
## 925       3.9      0.1        0      0.0
## 949       1.9      0.0        0      0.0
## 968      11.3      1.4        0      0.1
## 986      12.9      2.6        0      0.5
## 1007      5.9     10.2        0      5.0
```

```
names(climate.df); # this helps you see the indexes ...
```

```
##  [1] "state"       "capital"     "st"          "labels"      "highmax.Jan"
##  [6] "highmax.Apr" "highmax.Jul" "highmax.Oct" "highavg.Jan" "highavg.Apr"
## [11] "highavg.Jul" "highavg.Oct" "lowavg.Jan"  "lowavg.Apr"  "lowavg.Jul"
## [16] "lowavg.Oct"  "lowmin.Jan"  "lowmin.Apr"  "lowmin.Jul"  "lowmin.Oct"
## [21] "rain.Jan"    "rain.Apr"    "rain.Jul"    "rain.Oct"    "snow.Jan"
## [26] "snow.Apr"    "snow.Jul"    "snow.Oct"
```

```
#View(climate.df)
###################### WHICH COLUMNS ######################
###########################################################
#X = climate.df[,5:52];  # temperature
#X = climate.df[,5:76];  # was 76 everything (includes rain)
#X = climate.df[,5:20];  # temperature, 1 month per season
```

```
X = climate.df[,5:28];  # everything (includes rain), 1 month per season
#########################################################


  rownames(X) = climate.df$labels;
Xs = scale(X);
```

To scale or not to scale, that is the question

```
X = climate.df[,5:28];  # everything ... you have to change months above to get this dataframe to be th
  rownames(X) = climate.df$labels;
Xs = scale(X);
```

So let's do some analysis with all of the data available to us. Most of the data is in Temperature, with ranges from -42 degrees Fahrenheit (Helena, Montana) to 122 (Phoenix, Arizona).

The precipitation data (rain and snow) is measured in inches. So should we scale the data. The answer in PCA and orthogonal projections is absolutely YES, but for `hclust` and `kmeans` is that always the case?

You can make a choice below, and observe how it influences your answers.

```
whichX = X;
#whichX = Xs;
```

WHICH X

Perform k-means on All Climate Features

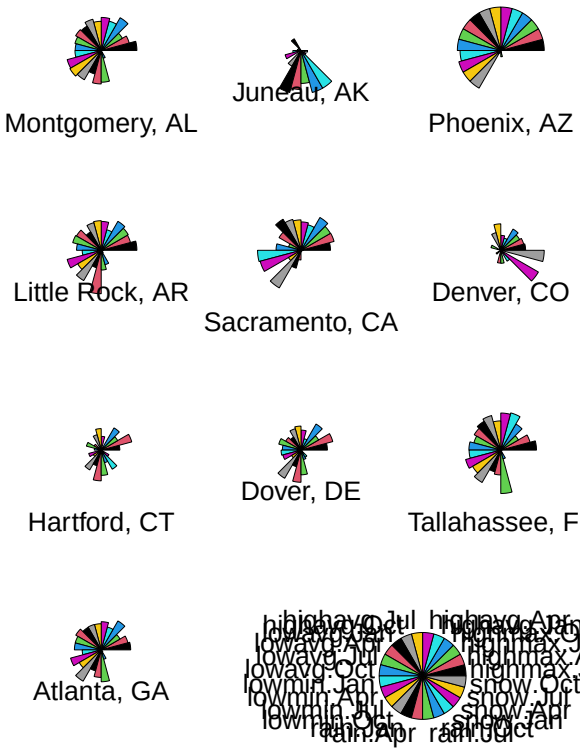
With the selected features let's perform k-means. Let's select k=12. I will select all of the features, but you can change that if you wish.

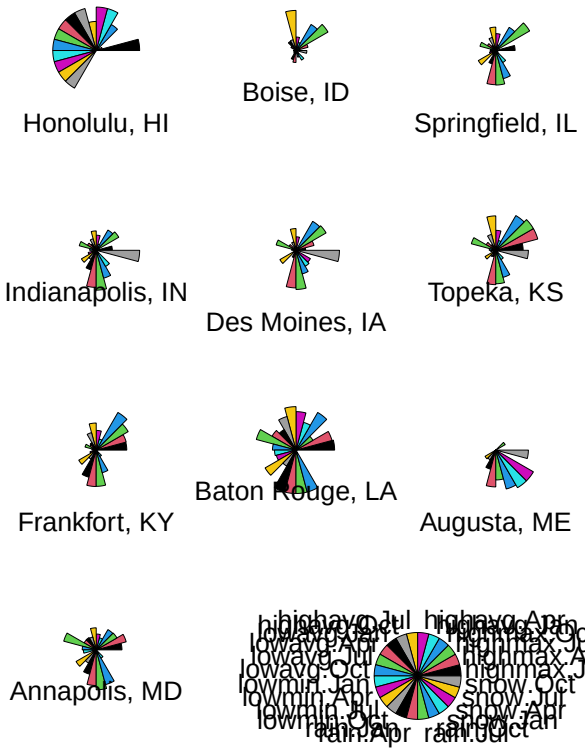
```
colors = rainbow(50, s = 0.6, v = 0.75); # 50 colors for 50 states

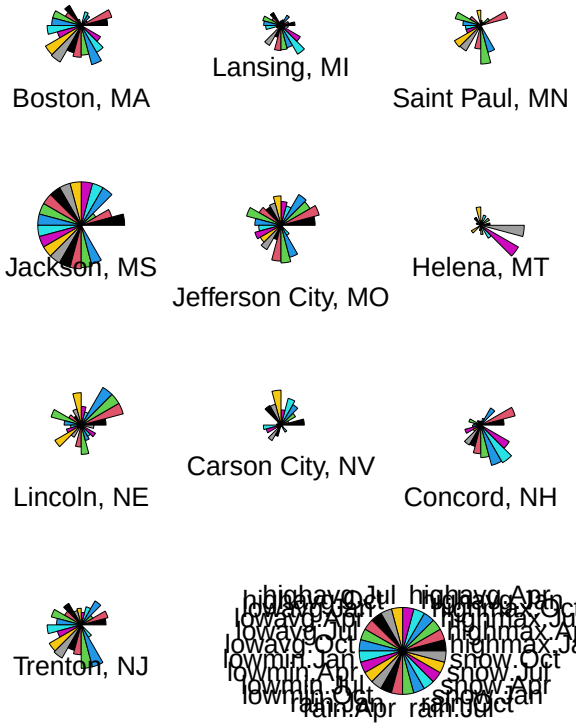
# descriptive star plot to start
stars(whichX, len = 0.5, key.loc=c(12,2), draw.segments = TRUE);
```

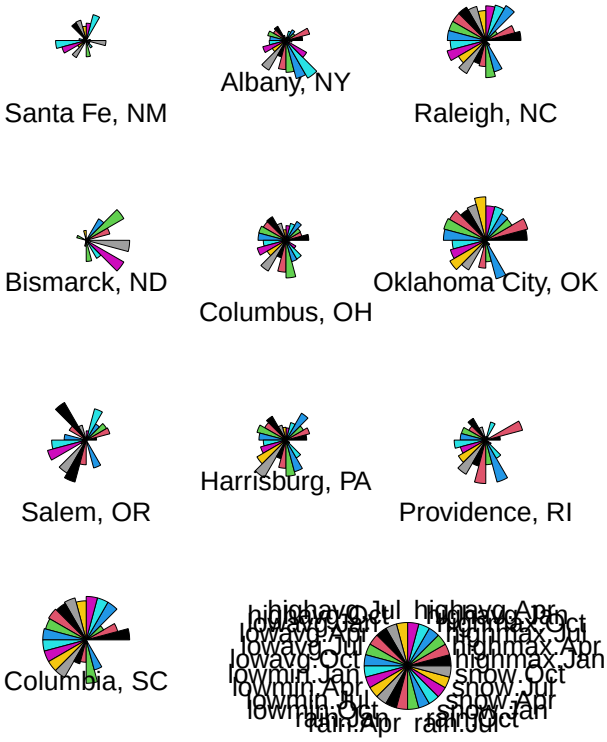
Descriptives of Sample

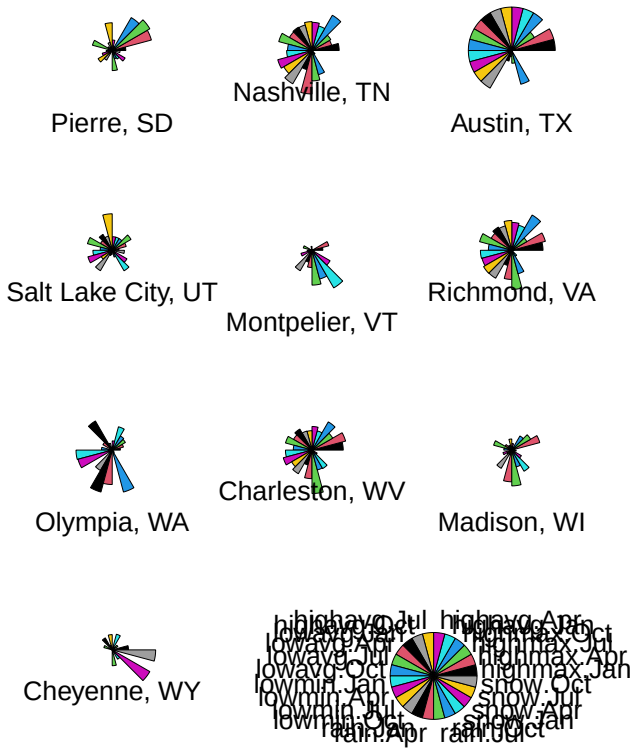
```
## too busy, let's group them
x.start = 1;
x.end = 10;
for(i in 1:5)
  {
  stars( whichX[x.start:x.end,] ,
          len = 0.5, key.loc=c(6,2), draw.segments = TRUE);
  x.start = 1 + x.end;
  x.end = 10 + x.end;
  }
```


Montgomery, AL
Juneau, AK
Phoenix, AZ
Little Rock, AR
Sacramento, CA
Denver, CO
Hartford, CT
Dover, DE
Tallahassee, FL
Atlanta, GA


Honolulu, HI
Boise, ID
Springfield, IL
Indianapolis, IN
Des Moines, IA
Topeka, KS
Frankfort, KY
Baton Rouge, LA
Augusta, ME
Annapolis, MD


Boston, MA
Lansing, MI
Saint Paul, MN
Jackson, MS
Jefferson City, MO
Helena, MT
Lincoln, NE
Carson City, NV
Concord, NH
Trenton, NJ


Santa Fe, NM
Albany, NY
Raleigh, NC
Bismarck, ND
Columbus, OH
Oklahoma City, OK
Salem, OR
Harrisburg, PA
Providence, RI
Columbia, SC



Above, you are just analyzing the general shapes. Which ones are "fuller" circles? Why?

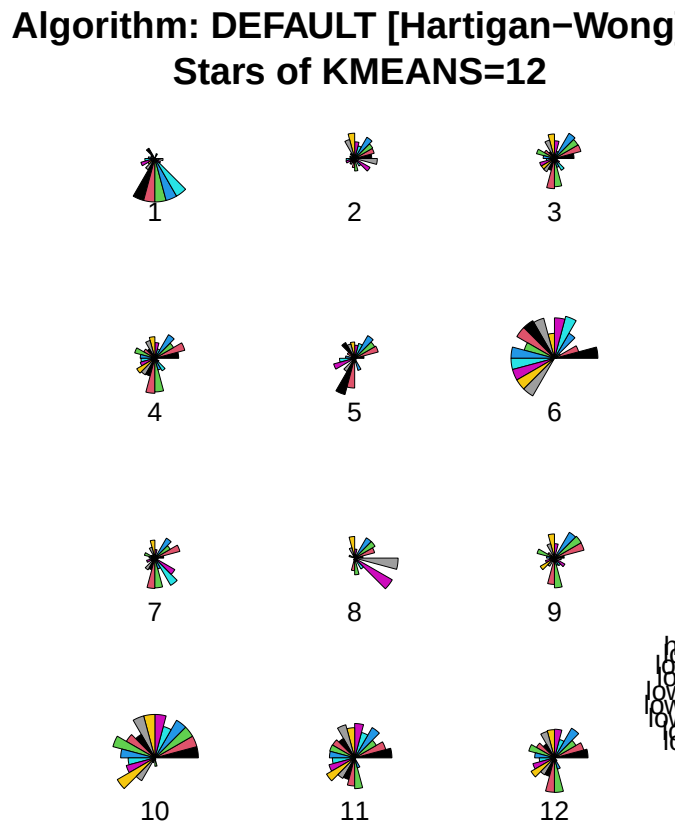
Circles representing Arizona and Hawaii are both "fuller" because they're representing hotter temperatures throughout the year. The bigger the slice the higher the correlation for that month.

Which ones are not very "full circles"? Why?

Circles representing Montana and Maine show not very "full circles" because they're implying throughout the year the temperatures not extremely hot (probably cold), and shows rain/snow there spiking in the later months Oct-Dec. Another conclusion I would draw from this is ones with less full circles that dont have spikes in temperature, they have more consistent cold weather.

```
k = 12;
iterations = 100;
number.starts = 100;

whichX.kmeans = kmeans(whichX, 12,
                    iter.max=iterations,
                    nstart = number.starts);  # default algorithm
stars(whichX.kmeans$centers, len = 0.5, key.loc = c(10, 3),
        main = "Algorithm: DEFAULT [Hartigan-Wong] \n Stars of KMEANS=12", draw.segments = TRUE);
```



Computation of Clusters/Centroids

```
membership = matrix( whichX.kmeans$cluster, ncol=1);
membership = membership[order(membership),];
membership = as.data.frame(membership);
        rownames(membership) = climate.df$labels;
        colnames(membership) = c("Cluster");

membership;
```

Cluster Membership and Centroid Attributes

```
##                    Cluster
## Montgomery, AL           1
## Juneau, AK               2
## Phoenix, AZ              2
## Little Rock, AR          2
## Sacramento, CA           3
## Denver, CO               3
## Hartford, CT             3
## Dover, DE                3
## Tallahassee, FL          3
## Atlanta, GA              3
## Honolulu, HI             3
## Boise, ID                3
## Springfield, IL          3
## Indianapolis, IN         3
```

```
## Des Moines, IA           4
## Topeka, KS               4
## Frankfort, KY            4
## Baton Rouge, LA          4
## Augusta, ME              4
## Annapolis, MD            4
## Boston, MA               5
## Lansing, MI              5
## Saint Paul, MN           6
## Jackson, MS              7
## Jefferson City, MO       7
## Helena, MT               7
## Lincoln, NE              7
## Carson City, NV          7
## Concord, NH              7
## Trenton, NJ              8
## Santa Fe, NM             8
## Albany, NY               8
## Raleigh, NC              9
## Bismarck, ND             9
## Columbus, OH             9
## Oklahoma City, OK        9
## Salem, OR               10
## Harrisburg, PA          11
## Providence, RI          11
## Columbia, SC            11
## Pierre, SD              11
## Nashville, TN           11
## Austin, TX              12
## Salt Lake City, UT      12
## Montpelier, VT          12
## Richmond, VA            12
## Olympia, WA             12
## Charleston, WV          12
## Madison, WI             12
## Cheyenne, WY            12
```

```
print( table(membership) ) ;
```

```
## membership
##  1  2  3  4  5  6  7  8  9 10 11 12
##  1  3 10  6  2  1  6  3  4  1  5  8
```

```
# I believe in an older version of R these were called $centroids
attributes = as.data.frame( whichX.kmeans$centers );
    rownames(attributes) = paste0("Cluster.",1:12);
  attributes;
```

```
##            highmax.Jan highmax.Apr highmax.Jul highmax.Oct highavg.Jan
## Cluster.1     60.00000    72.00000     89.0000    68.00000    34.60000
## Cluster.2     71.00000    87.33333    104.3333    90.00000    44.23333
## Cluster.3     72.60000    92.80000    108.9000    94.10000    37.49000
## Cluster.4     75.33333    95.50000    104.8333    92.50000    40.13333
## Cluster.5     66.00000    90.50000    106.0000    91.50000    46.80000
## Cluster.6     88.00000    91.00000     94.0000    94.00000    80.10000
```

```
## Cluster.7     65.66667    91.66667    102.0000    88.66667    28.65000
## Cluster.8     65.33333    87.66667    106.3333    89.00000    32.06667
## Cluster.9     66.25000    95.25000    111.7500    94.75000    30.60000
## Cluster.10    88.00000   105.00000    121.0000   107.00000    67.20000
## Cluster.11    84.00000    96.40000    107.4000    99.40000    59.82000
## Cluster.12    81.62500    95.00000    107.2500    98.75000    51.22500
##            highavg.Apr highavg.Jul highavg.Oct lowavg.Jan lowavg.Apr lowavg.Jul
## Cluster.1     49.10000    63.40000    48.40000   26.20000   35.30000   51.40000
## Cluster.2     62.96667    88.30000    66.56667   18.86667   33.16667   55.16667
## Cluster.3     63.82000    87.50000    65.99000   21.10000   41.46000   65.11000
## Cluster.4     62.15000    84.58333    65.41667   24.81667   42.63333   66.81667
## Cluster.5     60.00000    79.40000    62.15000   34.20000   38.65000   51.95000
## Cluster.6     82.70000    87.90000    86.70000   66.30000   69.40000   74.50000
## Cluster.7     56.20000    81.05000    58.71667   11.80000   34.81667   59.38333
## Cluster.8     56.56667    84.60000    58.33333   11.06667   31.20000   55.73333
## Cluster.9     61.07500    87.12500    62.22500   11.22500   38.02500   64.70000
## Cluster.10    85.20000   106.10000    88.50000   45.60000   60.20000   83.50000
## Cluster.11    77.66000    93.06000    80.04000   39.62000   53.66000   70.50000
## Cluster.12    72.91250    91.12500    73.68750   31.37500   49.55000   71.02500
##            lowavg.Oct lowmin.Jan lowmin.Apr lowmin.Jul lowmin.Oct  rain.Jan
## Cluster.1    39.00000  -20.00000  12.000000   39.00000  13.000000 7.9800000
## Cluster.2    35.56667  -23.33333   3.666667   37.33333   3.000000 0.8666667
## Cluster.3    43.40000  -24.20000  13.200000   43.80000  16.500000 2.2300000
## Cluster.4    46.53333  -11.66667  13.000000   47.83333  22.500000 3.3516667
## Cluster.5    41.40000   -9.00000  23.000000   35.00000  16.500000 6.9000000
## Cluster.6    73.40000   52.00000  56.000000   63.00000  61.000000 0.0000000
## Cluster.7    38.30000  -32.66667   3.000000   36.66667  13.833333 2.2050000
## Cluster.8    32.86667  -41.66667 -10.000000   33.66667  -7.666667 0.3733333
## Cluster.9    40.25000  -31.25000   4.000000   44.75000   7.250000 0.7125000
## Cluster.10   64.80000   16.00000  35.000000   63.00000  34.000000 0.9100000
## Cluster.11   56.42000    6.40000  30.400000   55.60000  29.800000 4.1120000
## Cluster.12   51.30000   -8.87500  23.875000   51.87500  23.250000 3.4975000
##            rain.Apr rain.Jul   rain.Oct  snow.Jan snow.Apr snow.Jul   snow.Oct
## Cluster.1  4.640000 5.440000 13.2300000 24.200000 0.900000        0 0.60000000
## Cluster.2  0.970000 1.560000  1.0400000  4.800000 2.466667        0 1.66666667
## Cluster.3  3.219000 3.528000  2.7700000  7.600000 0.810000        0 0.24000000
## Cluster.4  3.736667 4.210000  3.6716667  8.033333 0.650000        0 0.01666667
## Cluster.5  3.175000 0.545000  3.8150000  1.250000 0.000000        0 0.00000000
## Cluster.6  0.000000 0.000000  0.0000000  0.000000 0.000000        0 0.00000000
## Cluster.7  3.241667 3.728333  3.4083333 17.550000 3.200000        0 0.25000000
## Cluster.8  1.340000 2.090000  0.9533333  7.000000 6.033333        0 3.20000000
## Cluster.9  2.812500 3.722500  2.2925000  4.825000 1.675000        0 0.50000000
## Cluster.10 0.280000 1.050000  0.5800000  0.000000 0.000000        0 0.00000000
## Cluster.11 2.998000 3.854000  3.1580000  0.080000 0.000000        0 0.00000000
## Cluster.12 3.667500 4.327500  3.5487500  1.987500 0.025000        0 0.00000000
```

(10 points) Summarize Findings

- Identify which states share a common cluster.
- For a given cluster, what are its primary characteristics

[Summarize your k-means findings for 12 clusters.]

(15 points) Correlation

Correlation, like distance, is an important feature of multivariate analysis. So let's review some basic correlation related to our climate data. For simplicity, let's consider "Record High Temperature" and "Record Low Temperature" and see how they correlate with other factors we have gathered from Wikipedia.

Recall, in this table, "Jan-Dec" are different months of the same temperature variable.

```
library(Hmisc); # p-values for correlation

high = subsetDataFrame(climate, c("key", "units"), "==", c("Record high F (C)",1));
high = merge(high, capitals, by=c("capital","state"));

high.X = high[,c(5:18,21)]; # numeric data
high.cor = round( cor(high.X), digits=2);
# high.cor.p = rcorr(as.matrix(high.X), type="pearson");  # p-values for statistical significance ... #

# examine July (idx = 7)

as.data.frame( high.cor ) ; # so it will render nicely in RStudio
```

```
##                       Jan   Feb   Mar   Apr   May   Jun   Jul   Aug   Sep   Oct
## Jan                  1.00  0.92  0.76  0.57  0.43  0.39  0.25  0.41  0.62  0.71
## Feb                  0.92  1.00  0.80  0.63  0.62  0.53  0.45  0.59  0.74  0.79
## Mar                  0.76  0.80  1.00  0.87  0.73  0.56  0.53  0.67  0.76  0.82
## Apr                  0.57  0.63  0.87  1.00  0.82  0.68  0.65  0.75  0.79  0.81
## May                  0.43  0.62  0.73  0.82  1.00  0.83  0.85  0.85  0.86  0.81
## Jun                  0.39  0.53  0.56  0.68  0.83  1.00  0.90  0.86  0.87  0.78
## Jul                  0.25  0.45  0.53  0.65  0.85  0.90  1.00  0.91  0.86  0.73
## Aug                  0.41  0.59  0.67  0.75  0.85  0.86  0.91  1.00  0.90  0.78
## Sep                  0.62  0.74  0.76  0.79  0.86  0.87  0.86  0.90  1.00  0.88
## Oct                  0.71  0.79  0.82  0.81  0.81  0.78  0.73  0.78  0.88  1.00
## Nov                  0.89  0.89  0.89  0.76  0.65  0.56  0.46  0.57  0.74  0.86
## Dec                  0.94  0.89  0.81  0.65  0.46  0.41  0.27  0.46  0.65  0.72
## latitude            -0.83 -0.80 -0.68 -0.49 -0.40 -0.30 -0.15 -0.29 -0.46 -0.67
## longitude            0.07  0.01  0.39  0.34  0.08  0.01  0.02  0.04  0.07  0.14
## population.2019.est  0.40  0.42  0.36  0.35  0.38  0.48  0.31  0.31  0.44  0.39
##                       Nov   Dec latitude longitude population.2019.est
## Jan                  0.89  0.94    -0.83      0.07                0.40
## Feb                  0.89  0.89    -0.80      0.01                0.42
## Mar                  0.89  0.81    -0.68      0.39                0.36
## Apr                  0.76  0.65    -0.49      0.34                0.35
## May                  0.65  0.46    -0.40      0.08                0.38
## Jun                  0.56  0.41    -0.30      0.01                0.48
## Jul                  0.46  0.27    -0.15      0.02                0.31
## Aug                  0.57  0.46    -0.29      0.04                0.31
## Sep                  0.74  0.65    -0.46      0.07                0.44
## Oct                  0.86  0.72    -0.67      0.14                0.39
## Nov                  1.00  0.91    -0.82      0.17                0.40
## Dec                  0.91  1.00    -0.85      0.12                0.42
## latitude            -0.82 -0.85     1.00      0.01               -0.34
## longitude            0.17  0.12     0.01      1.00               -0.10
## population.2019.est  0.40  0.42    -0.34     -0.10                1.00
```

```
high.cor.july = high.cor[,7];
high.cor.july;
```

```
##                 Jan                 Feb                 Mar                 Apr
##                0.25                0.45                0.53                0.65
##                 May                 Jun                 Jul                 Aug
##                0.85                0.90                1.00                0.91
##                 Sep                 Oct                 Nov                 Dec
##                0.86                0.73                0.46                0.27
##            latitude           longitude population.2019.est
##               -0.15                0.02                0.31
```

```
#View(high.cor.july)
```

Describe the correlation of July in "Record high F (C)" to the other numeric factors printed above.

x is correlated with y (0.00). This correlation is positive/negative which means ... This correlation is strong/weak because ... overall, this suggests ...

- July perfectly correlates with July (1.00). This correlation is positive and very strong. This is because they are the same data.
- With the months, you can note each, or plot a trend showing them, and discussing them briefly as a trend.
- latitude is a measure of north/south, so be certain to apply the correlation value with some meaning. be certain you know which direction is positive or negative to correctly interpret the sign of the correlation.
- longitude is a measure of east/west, so be certain ...
- population is the size of the city
- intuitively, which months do you think correlate most with latitude for this data? which correlate the least? is the correlation always the same sign (positive/negative), or does it change?

[You can use the dataframe output to do this analysis, or create your own subset]

```
library(Hmisc); # p-values for correlation

low = subsetDataFrame(climate, c("key", "units"), "==", c("Record low F (C)",1));
low = merge(low, capitals, by=c("capital","state"));

low.X = low[,c(5:18,21)]; # numeric data
low.cor = round( cor(low.X), digits=2);
# low.cor.p = rcorr(as.matrix(low.X), type="pearson");  # p-values for statistical significance ... # s

# examine Jan (idx = 1)

as.data.frame( low.cor ) ; # so it will render nicely in RStudio
```

```
##                      Jan   Feb   Mar   Apr   May   Jun   Jul   Aug   Sep   Oct
## Jan                 1.00  0.95  0.93  0.92  0.89  0.80  0.74  0.77  0.90  0.87
## Feb                 0.95  1.00  0.94  0.92  0.86  0.75  0.70  0.72  0.88  0.86
## Mar                 0.93  0.94  1.00  0.92  0.85  0.73  0.71  0.72  0.85  0.85
## Apr                 0.92  0.92  0.92  1.00  0.91  0.82  0.78  0.81  0.93  0.89
## May                 0.89  0.86  0.85  0.91  1.00  0.93  0.88  0.88  0.95  0.93
## Jun                 0.80  0.75  0.73  0.82  0.93  1.00  0.92  0.91  0.88  0.82
## Jul                 0.74  0.70  0.71  0.78  0.88  0.92  1.00  0.96  0.87  0.77
## Aug                 0.77  0.72  0.72  0.81  0.88  0.91  0.96  1.00  0.87  0.77
## Sep                 0.90  0.88  0.85  0.93  0.95  0.88  0.87  0.87  1.00  0.94
## Oct                 0.87  0.86  0.85  0.89  0.93  0.82  0.77  0.77  0.94  1.00
## Nov                 0.91  0.92  0.90  0.89  0.89  0.81  0.75  0.75  0.92  0.93
```

```
## Dec                   0.97  0.95  0.93  0.92  0.91  0.82  0.78  0.79  0.91  0.90
## latitude             -0.72 -0.64 -0.69 -0.71 -0.72 -0.75 -0.75 -0.80 -0.72 -0.66
## longitude            -0.33 -0.36 -0.31 -0.25 -0.12 -0.05  0.09  0.02 -0.09 -0.04
## population.2019.est   0.34  0.37  0.32  0.37  0.35  0.39  0.46  0.46  0.40  0.32
##                        Nov   Dec latitude longitude population.2019.est
## Jan                   0.91  0.97    -0.72     -0.33                0.34
## Feb                   0.92  0.95    -0.64     -0.36                0.37
## Mar                   0.90  0.93    -0.69     -0.31                0.32
## Apr                   0.89  0.92    -0.71     -0.25                0.37
## May                   0.89  0.91    -0.72     -0.12                0.35
## Jun                   0.81  0.82    -0.75     -0.05                0.39
## Jul                   0.75  0.78    -0.75      0.09                0.46
## Aug                   0.75  0.79    -0.80      0.02                0.46
## Sep                   0.92  0.91    -0.72     -0.09                0.40
## Oct                   0.93  0.90    -0.66     -0.04                0.32
## Nov                   1.00  0.94    -0.70     -0.12                0.28
## Dec                   0.94  1.00    -0.71     -0.24                0.33
## latitude             -0.70 -0.71     1.00      0.01               -0.34
## longitude            -0.12 -0.24     0.01      1.00               -0.10
## population.2019.est   0.28  0.33    -0.34     -0.10                1.00
```

```
low.cor.january = low.cor[,1];
low.cor.january;
```

```
##                 Jan                 Feb                 Mar                 Apr
##                1.00                0.95                0.93                0.92
##                 May                 Jun                 Jul                 Aug
##                0.89                0.80                0.74                0.77
##                 Sep                 Oct                 Nov                 Dec
##                0.90                0.87                0.91                0.97
##            latitude           longitude population.2019.est
##               -0.72               -0.33                0.34
```

Describe the correlation of January in "Record low F (C)" to the other numeric factors printed above.

Similar to "high" writeup, but for the "low" data.

"So What" is DATA ANALYSIS?

In the social sciences (e.g., Karl Weick), the concept of "sense making" refers to "the process by which people give meaning to their collective experiences". I have used this framework in my high-technology innovation research (See Figure 1 of http://www.mshaffer.com/arizona/pdf/LoneGenius.pdf, my rubric concept comes from learning-theory growth models: Nascent, Adolescent, Mature.)

This final topic is reflective: we are thinking about how we think.

Statistics

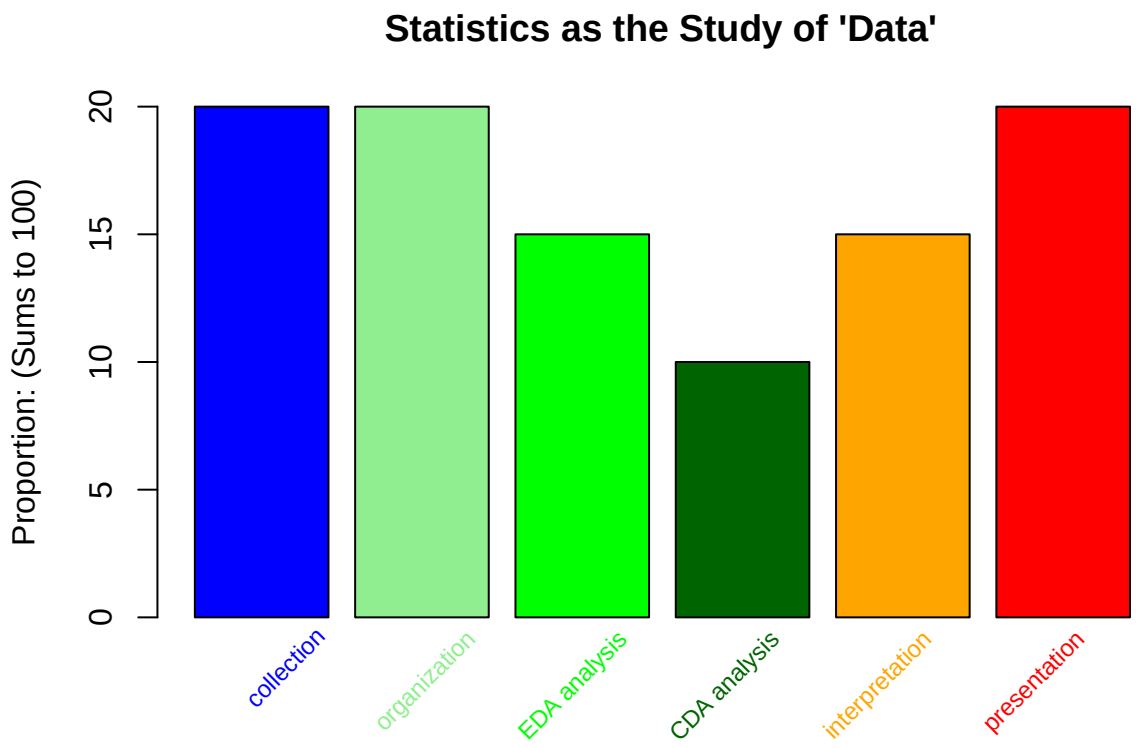
The syllabus defined statistics as "the discipline that concerns the collection, organization, analysis, interpretation and presentation of data." (See https://en.wikipedia.org/wiki/Statistics)

There are 5 elements mentioned: collection, organization, analysis, interpretation, and presentation of "data". Are those equally weighted? That is, should we devote 20% of our time to each of those? Now, consider the "analysis" stage. I have suggested there are two camps: exploratory and confirmatory data analysis. Are those equally weighted? That is, should we devote 50% of our time to each of those? Now, in an "equally-likely" scenario, we would have.

```
x = c(20,20,15,10,15,20);
x.labels = c("collection", "organization", "EDA analysis", "CDA analysis", "interpretation", "presentati
x.colors = c("blue", "lightgreen", "green", "darkgreen", "orange", "red");

barplot(x,
        col = x.colors,
        ylim = c(0, 20),
        ylab = "Proportion: (Sums to 100)",
        main="Statistics as the Study of 'Data'");


text(1.14* (1:6), par("usr")[3], col = x.colors, labels = x.labels, srt = 45, adj = c(1.1,1.1), xpd = T
```



Data Analytics

Source: https://data-analytics.wsu.edu/197-2/ (Accessed October 2010)

"Data analytics is the application of powerful new methods—drawn from computer science, mathematics and statistics, and domain sciences—to collect, curate, analyze, discover and communicate knowledge from 'big data'." https://data-analytics.wsu.edu/ (Accessed October 2010)

Importance of 'Data' I love data.

I also love math/physics. I also love exploratory data analysis. I also love computational statistics or statistical computing https://en.wikipedia.org/wiki/Computational_statistics. I also love thinking about developing the one graphic to summarize data most effectively.

Apprenticeship as Learning a Trade The idea of sharing in the learning process is an important aspect of the apprenticeship model. You are learning a trade (data analytics). I have experience in this trade. My job as the instructor is to provide you with a variety of "situated-learning" experiences To help you understand the nature of the trade. This exam is an example of such an experience.

Tools of the Trade Below are the core requirements for the data analytics program:

- Calculus and linear algebra (10 credits)
- Computer science fundamentals (11 credits)
- Machine learning and data management (9 credits)
- Statistics (15 credits)
- Data analytics introduction, ethics & project-focused * capstone experience (9 credits)

These are not the tools of the trade, but hopefully, they introduce you to key tools of the trade. What exactly are tools of the trade? [You will have an opportunity to write a response below.]

Dimensional Reduction, an Axiomatic View This video was recently shared with me that highlights some distinctions among persons practicing various forms of data analysis https://www.youtube.com/watch?v=uHGlCi9jOWY. As an orthogonal projection, I would create two axes. On the horizontal axis (x-axis), I would place "theory of data" to the left and "application of data" toward the right. On the vertical axis (y-axis), I would place "care for data integrity" at the top and "less care for data integrity" at the bottom.

Skills of the Trade As someone that is coming from industry, having hired young people like you out of Computer Science, Electrical-Computer Engineering, I have opinions related to skills of the trade.

- Can you acquire an appreciation for "data intimacy"?
- Can you track and document how data is curated?
- Can you track and document the analyses you perform? Can you recreate them? Do you have basic version-control protocols in place?
- Can you view data from multiple perspectives and synthesize those perspectives to identify the central them of the data? Can you be objective? Can you try and identify objective metrics to enlighten your understanding about the essence of data?
- Can you experiment with different visualizations in search of an optimal "one graphic" result? Do you have practice using various visualization tools? Can you comprehend which visualization tool is appropriate for messaging (communicating results) to a particular audience?
- Can you communicate and defend your findings to a particular audience? Are your communications professional? Is the final work product both simple and comprehensive: simple in its summary findings and comprehensive in its ability to be replicated and audited as necessary.

(20 points) YOUR OPINION OF DATA ANALYTICS

[This is worth 20 points.

Specifically, address:

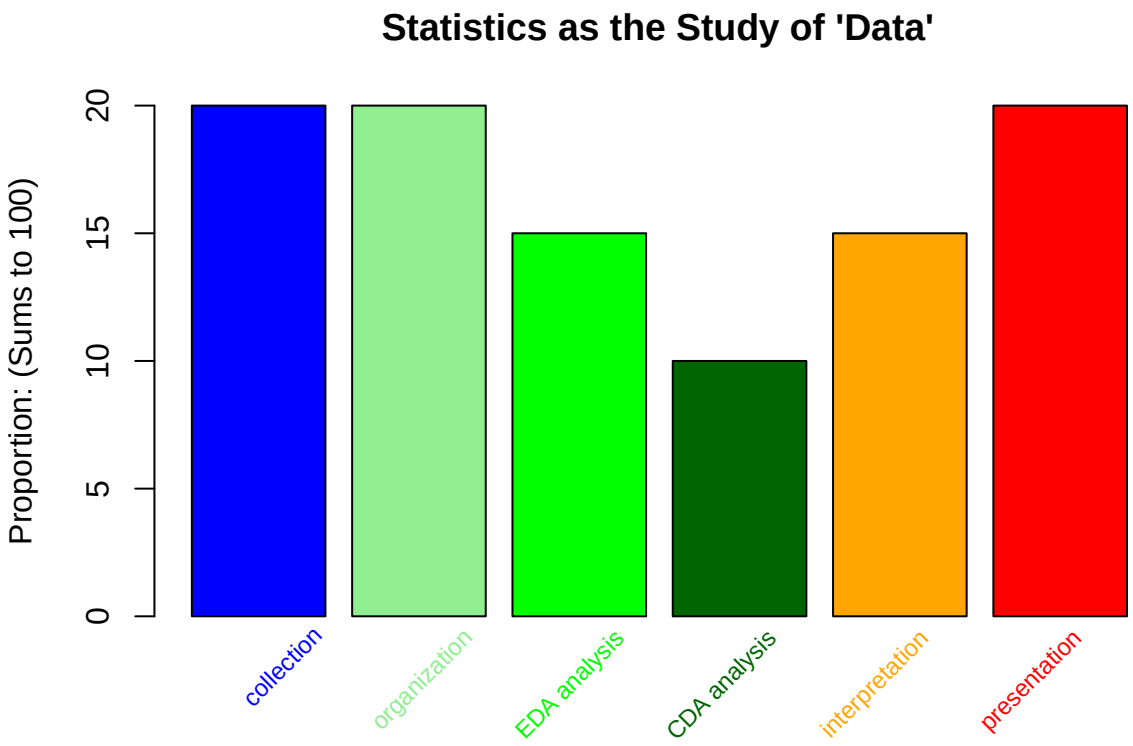
(1) what proportion of "statistics" should be divided among: collection, organization, analysis, interpretation, and presentation of "data" ... providing a `barplot` of your opinion within your response would seem appropriate

```
x = c(20,20,15,10,15,20);  ## change these values and discuss ...
x.labels = c("collection", "organization", "EDA analysis", "CDA analysis", "interpretation", "presentati
x.colors = c("blue", "lightgreen", "green", "darkgreen", "orange", "red");

barplot(x,
        col = x.colors,
        ylim = c(0, max(x)),
        ylab = "Proportion: (Sums to 100)",
```

```
        main="Statistics as the Study of 'Data'");

text(1.14* (1:6), par("usr")[3], col = x.colors, labels = x.labels, srt = 45, adj = c(1.1,1.1), xpd = T
```



(2) what tools of the trade should you be acquiring from the core courses? how are you doing in that acquisition process (e.g., tool X is . . . and right now I feel like my understanding/proficiency of tool X . . .) . . .

(3) utilize the provided `plot` script to place the coure-course categories on the proposed x-y graph related to analytics practice (Applied vs Theoretical) and care of data integrity (Great Care vs Little Care) . . . Also place your personal assessment on the plot script provided

(4) evaluate your skill-level on the six "skills of the trade": Emerging (Nascent), Developing (Adolescent), Mastering (Mature). explain your evaluation and include other important skills you believe are relevant that are not included

(5) Any other comments you would like to share.

]

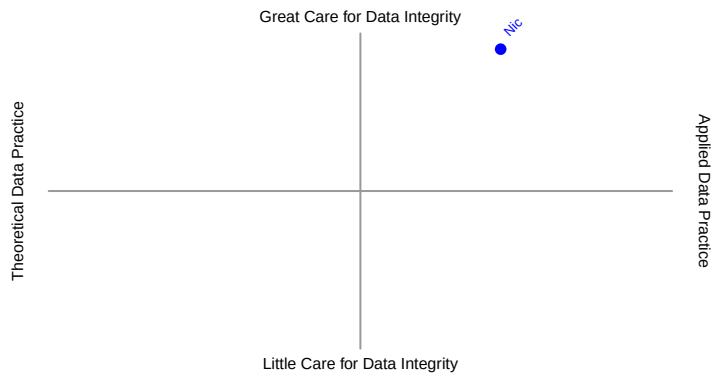
```
# x is -1 for perfectly theoretical
# x is 1 for perfectly applied

# y is -1 for no care whatsoever for data integrity
# y is 1 is perfect care for data integrity

############################ basic plot setup #####
```

```
plot(0,0, col="white",
  ylim=c(-1.5,1.5), xlim=c(-1.5,1.5),
  xlab = "",
  ylab = "",
  xaxt = 'n', bty = 'n', yaxt = 'n',
  main = "Axiomatic Perspective on Practice/Care",
  );
segments(-1,0,1,0, col="#999999");
segments(0,-1,0,1, col="#999999");
text(-1.1,0, "Theoretical Data Practice", cex=0.5, srt = 90);
text(1.1,0, "Applied Data Practice", cex=0.5, srt = -90);
text(0,1.1, "Great Care for Data Integrity", cex=0.5, srt = 0);
text(0,-1.1, "Little Care for Data Integrity", cex=0.5, srt = 0);
############################ basic plot setup #####


############################ you can add elements here #####
## this point represents the professor's self-perception
points(0.45, 0.90, pch=20, col="blue");
text(0.50, 0.90, "Nic", col="blue", cex=0.45, srt = 45, pos=3);
```




```
##############  TODO ###### ... maybe change color for each data point

# https://brand.wsu.edu/visual/colors/
# crimson = #981e32
# you need to change the x,y from 0,0 ...
```

```
# you can change col ... cex (font size), srt (angle), and pos = 1,2,3,4
#
# points(0, 0, pch=20, col="#981e32");
# text(0, 0, "Student (self)", col="#981e32", cex=0.75, srt = 45, pos=3);
#
# ## evaluate the Course Categories of Tools of the Trade
# ## give them a score
#
# points(0, 0, pch=20, col="#981e32");
# text(0, 0, "Math(s)", col="#981e32", cex=0.5, srt = 45, pos=3);
#
#
# points(0, 0, pch=20, col="#981e32");
# text(0, 0, "Computer Science", col="#981e32", cex=0.5, srt = 45, pos=3);
#
# points(0, 0, pch=20, col="#981e32");
# text(0, 0, "Machine learning", col="#981e32", cex=0.5, srt = 45, pos=3);
#
# points(0, 0, pch=20, col="#981e32");
# text(0, 0, "Statistics", col="#981e32", cex=0.5, srt = 45, pos=3);
#
# points(0, 0, pch=20, col="#981e32");
# text(0, 0, "Data analytics", col="#981e32", cex=0.5, srt = 45, pos=3);
#
# # You have a track (e.g., Business)
# points(0, 0, pch=20, col="#981e32");
# text(0, 0, "Core discipline", col="#981e32", cex=0.5, srt = 45, pos=3);
```