Spatial Visualization in R

To be able to run the code in this tutorial and complete your HW/lab assignments, you need to install and library the following packages:

- **tidyverse** & **ggplot2** (we've already used them, so you don't need to install them again - just library them)
- **ggmap**; **maps**; **mapproj**

To install packages in R, use the following syntax (which installs the **ggmap** package):

In [1]:
```
install.packages(c("ggmap","maps","mapproj"))
```

```
Updating HTML index of packages in '.Library'

Making 'packages.html' ...
 done
```

Once your packages have been installed, don't forget to **load them into your library**:

In [4]:
```
library(tidyverse)
library(ggmap)
library(ggplot2)
library(mapproj)
library(maps)
library(jsonlite)
```

If you receive an error message (**not simply a warning message**) at any point, email me with a screenshot.

I'll continue installing and librarying the required packages:

In [9]:
```
install.packages("maps")
install.packages("mapproj")
```

```
Updating HTML index of packages in '.Library'

Making 'packages.html' ...
 done
```

In [121…
```
library(tidyverse)
library(ggplot2)
library(ggmap)
library(maps)
library(mapproj)
```

Part 1: Plotting New York State Data (Lab)

The first step in creating a map in R is choosing the data used for the outline of your map. How about a map of New York State for starters?

In [5]:
```
ny_counties <- map_data("county","new york")
head(ny_counties)
```

A data.frame: 6 × 6

	long	lat	group	order	region	subregion
	<dbl>	<dbl>	<dbl>	<int>	<chr>	<chr>
1	-73.78550	42.46763	1	1	new york	albany
2	-74.25533	42.41034	1	2	new york	albany
3	-74.25533	42.41034	1	3	new york	albany
4	-74.27252	42.41607	1	4	new york	albany
5	-74.24960	42.46763	1	5	new york	albany
6	-74.22668	42.50774	1	6	new york	albany

What do you see in the **head()** data overview?

Answer: **ny_counties** contains several **long-lat coordinate pairs per county** in the state to help R visualize the **outline** of each county.

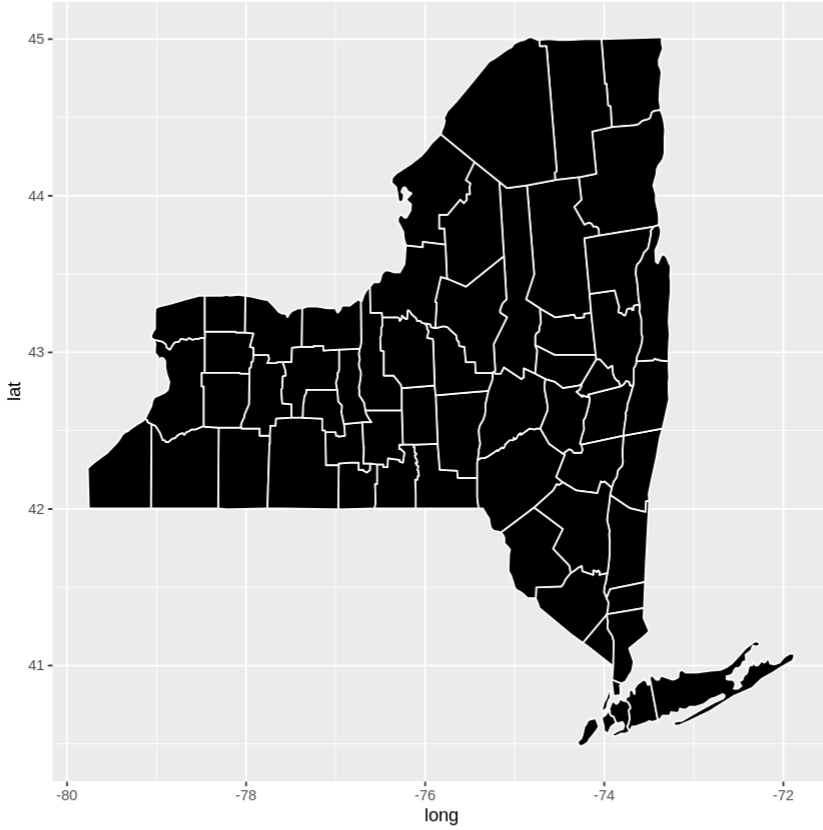
Remember that if we assign the map we're making to a **named object** (ex. **map1 <-...**), we need to specifically **call the name** of this object to see what we've created. We can actually **skip the assignment part** – the ***good thing*** about that is we see what we're plotting **directly**; the ***downside*** – we're not saving our work, i.e. we're not storing it into an object – **it only exists in the command line**:

In [5]:
```
ggplot(ny_counties) + aes(long,lat, group=group) + geom_polygon()
```

Remember the difference between a **point** and a **polygon** discussed in class videos and readings?

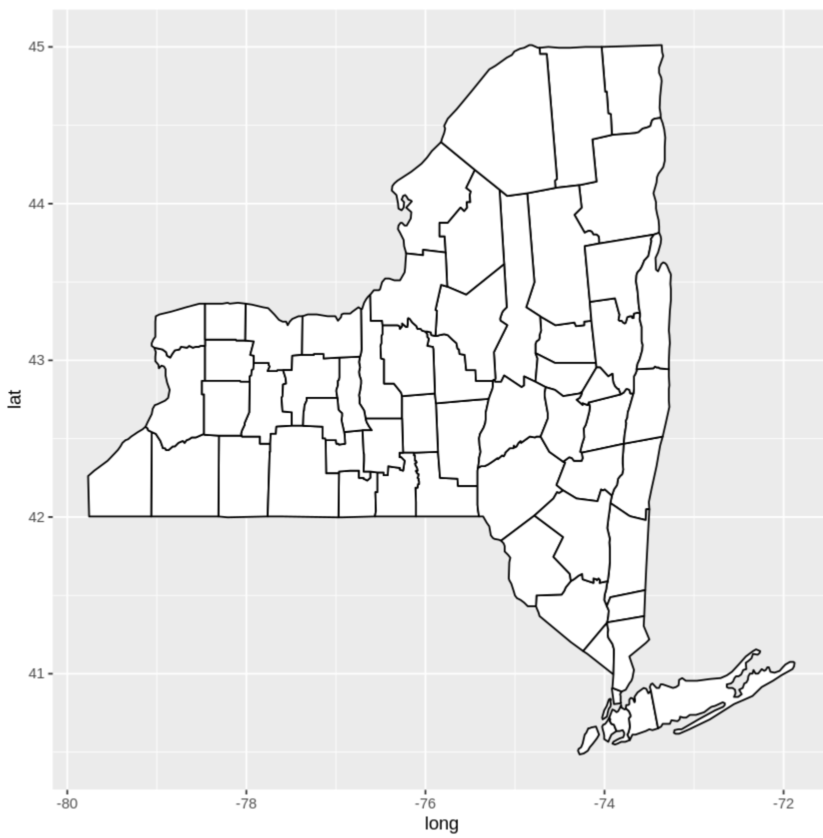
In this case, we’re interested in the latter instead of a single point – we want the **outline** of NYS counties. We can’t see them yet because we haven’t assigned colors to the fill and color arguments – what does each of them do? You’ll know the answer if you run this first:

In [6]:
```
ggplot(ny_counties) + aes(long,lat, group=group) + geom_polygon(fill="black",color="whi
```



... and then this:

In [7]:
```
ggplot(ny_counties) + aes(long,lat, group=group) + geom_polygon(fill="white",color="bla
```



Just staring at a blank map does not amount to much, however.

Let's give this map a **data layer** to make it more useful. Let's read the **nyData.csv** file into R:

In [9]:
```
nyData <- read_csv("https://ist387.s3.us-east-2.amazonaws.com/lab/nyData.csv")
head(nyData)
```

```
── Column specification ────────────────────────────────────────────────────────
cols(
  county = col_character(),
  pop2010 = col_number(),
  pop2000 = col_number(),
  sqMiles = col_number(),
  popDen = col_number()
)
```

A tibble: 6 × 5

county	pop2010	pop2000	sqMiles	popDen
<chr>	<dbl>	<dbl>	<dbl>	<dbl>
albany	304204	294565	522.80	581.87
allegany	48946	49927	1029.31	47.55
bronx	1385108	1332650	42.10	32900.43
broome	200600	200536	705.77	284.23
cattaraugus	80317	83955	1308.35	61.39
cayuga	80026	81963	691.58	115.71

Let us now **merge ny_counties** and **nyData** into a **common df**.

Wait a minute though – we know to use the **merge()** function, we need to identify a **"key" column** the two original datasets have in common. I don't see a column name they both share though!

No need to panic – **having no column names in common doesn't mean there are no common columns** – take a closer look at the **subregion** column in **ny_counties** and **county** in **nyData** – the headers may differ but they both **contain the same info** – **county names**. THIS is our key, we just need a couple extra arguments in the **merge()** function to deal with the difference in key column names:

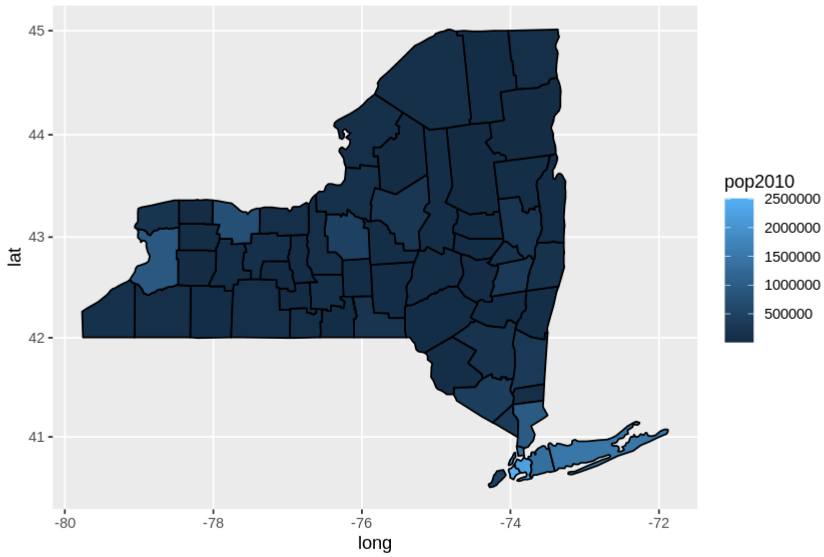
In [10]:
```
mergeNY <- merge(ny_counties,nyData, all.x=TRUE,by.x="subregion",by.y="county")
```

"**x**" stands for **df1** in the **join**, i.e. the first (left-most) df listed in the function (in our case that's **ny_counties**) and "**y**" – for **df2**, in our case – **nyData**.

We want to retain **all rows** of **ny_counties** (**all.x=TRUE**), and the **key column** is called **subregion** in **ny_counties** (**by.x='subregion'**) and **county** in **nyData** (**by.y='county'**).

What does this line of code do:

In [11]:
```
ggplot(mergeNY) + aes(long,lat, group=group) + geom_polygon(aes(fill=pop2010),color="bl
```

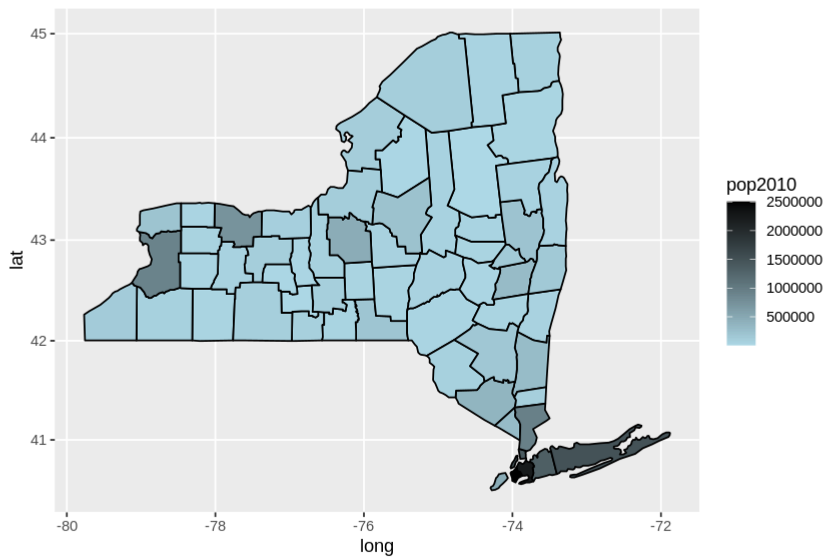


We just plotted a map of NYS counties shaded depending on their 2010 population.

We can see a slight problem though: Darker shades by default indicate lower values – typically, it's the other way around.

We can add an argument to deal with this – feel free to change the colors to any colors you want:

In [12]:
```
ggplot(mergeNY) + aes(long,lat, group=group) + geom_polygon(aes(fill=pop2010),color="bl
```



Here is the code as text

ggplot(mergeNY) + aes(long,lat, group=group) + geom_polygon(aes(fill=pop2010),color="black") + coord_map() + scale_fill_gradient(low='lightblue', high='black')

Part 2: Merging, Grouping and Plotting Data on Maps (HW)

To complete the homework, in addition to the packages above, you'll also need to library **jsonlite** because some of the datasets come in json format instead of .csv.

First, we'll read in df no. 1:

In [13]:

```
library(jsonlite)
url="https://ist387.s3.us-east-2.amazonaws.com/data/cities.json"
pop <- jsonlite::fromJSON(url)
head(pop)
```

A data.frame: 6 × 7

	city	growth_from_2000_to_2013	latitude	longitude	population	rank	state
	<chr>	<chr>	<dbl>	<dbl>	<chr>	<chr>	<chr>
1	New York	4.8%	40.71278	-74.00594	8405837	1	New York
2	Los Angeles	4.8%	34.05223	-118.24368	3884307	2	California
3	Chicago	-6.1%	41.87811	-87.62980	2718782	3	Illinois
4	Houston	11.0%	29.76043	-95.36980	2195914	4	Texas
5	Philadelphia	2.6%	39.95258	-75.16522	1553165	5	Pennsylvania

	city	growth_from_2000_to_2013	latitude	longitude	population	rank	state
	<chr>	<chr>	<dbl>	<dbl>	<chr>	<chr>	<chr>
6	Phoenix	14.0%	33.44838	-112.07404	1513367	6	Arizona

In [27]:

```
mean(as.numeric(pop$population)) # change to numeric to calculate
```

131132.443

In [29]:

```
pop$population <- as.numeric(pop$population) #another approach
mean(pop$population)
```

131132.443

In [ ]:

Let's inspect the **pop** df:

In [14]:

```
head(pop)
```

A data.frame: 6 × 7

	city	growth_from_2000_to_2013	latitude	longitude	population	rank	state
	<chr>	<chr>	<dbl>	<dbl>	<chr>	<chr>	<chr>
1	New York	4.8%	40.71278	-74.00594	8405837	1	New York
2	Los Angeles	4.8%	34.05223	-118.24368	3884307	2	California
3	Chicago	-6.1%	41.87811	-87.62980	2718782	3	Illinois
4	Houston	11.0%	29.76043	-95.36980	2195914	4	Texas
5	Philadelphia	2.6%	39.95258	-75.16522	1553165	5	Pennsylvania
6	Phoenix	14.0%	33.44838	-112.07404	1513367	6	Arizona

It appears that this is a population dataset. If we want to do calculations like calculating the mean, we can use vector math, right? Let's try it with **max()** on the **rank** variable:

In [31]:

```
max(pop$rank)
```

1000

Something isn't right - the **max()** function returns a text string when I can clearly see numbers in that column. Perhaps the values in the column aren't treated as numbers?

Sure enough, you can see right below the column heading that it's formatted as **"chr"** = text/character. Let's fix that and try again:

In [32]:

```
pop$rank <- as.numeric(pop$rank)
max(pop$rank)
```

1000

Let's see which city in the dataset is ranked the lowest, i.e. is the lowest in terms of population:

In [17]:
```
pop[which.max(pop$rank),]
```

A data.frame: 1 × 7

	city	growth_from_2000_to_2013	latitude	longitude	population	rank	state
	<chr>	<chr>	<dbl>	<dbl>	<chr>	<dbl>	<chr>
1000	Panama City	0.1%	30.15881	-85.66021	36877	1000	Florida

You need to do the same transformation for other variables that are treated as just text, if you want to use them in math operations. For example, the **population** column:

In [18]:
```
pop$population <- as.numeric(pop$population)
```

We can now proceed to the second step:

Merge the population data with the state name data

In [14]:
```
library(tidyverse)
abbr=read_csv("https://ist387.s3.us-east-2.amazonaws.com/data/states.csv")
```

```
── Column specification ────────────────────────────────────────
cols(
  State = col_character(),
  Abbreviation = col_character()
)
```

To successfully merge the dataframe **pop** with the **abbr** dataframe, we need to identify a **column they have in common** which will serve as the **"key"** to merge on.

One column both dataframes have is the **state** column. The only problem is the slight column name discrepancy – in **pop**, the column is called **"state"** and in **abbr** – **"State."** These names need to be reconciled for the **merge()** function to work. This is a way to **rename abbr's "State" to match the state column in pop** and merge the two dfs:

In [34]:
```
abbr$state <- abbr$State
dfNew <- merge(pop, abbr, by="state")
```

In [36]:
```
head(abbr)
```

A tibble: 6 × 3

State	Abbreviation	state
<chr>	<chr>	<chr>
Alabama	AL	Alabama

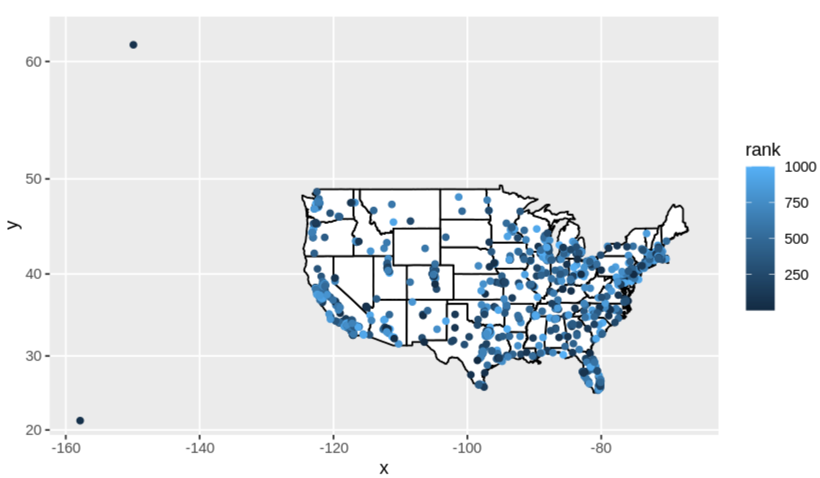
State	Abbreviation	state
<chr>	<chr>	<chr>
Alaska	AK	Alaska
Arizona	AZ	Arizona
Arkansas	AR	Arkansas
California	CA	California
Colorado	CO	Colorado

Next, we can plot **points** (on top of a map of the US) for each city (we'll need **ggplot2** and **ggmap** for that). Have the **color** represent the **rank**.

In [37]:

```
#install.packages('ggmap')
#install.packages('maps')
#install.packages('mapproj')
library(ggplot2)
library(ggmap)
library(maps)
library(mapproj)

us <- map_data("state")
dfNew$state_name <- tolower(dfNew$state)
map1 <- ggplot(dfNew, aes(map_id=state_name))
map1 <- map1 + geom_map(map=us, fill="white", color="black")
map1 <- map1 + expand_limits(x=us$long, y=us$lat)
map1 <- map1 + coord_map()
map1 <- map1 + geom_point(aes(x=longitude,y=latitude, color=rank))
map1
```



Step 3: Use aggregate() to make a dataframe of state-by-state population

Instead of having a bunch of points on a map, we can shade in polygons with the shape of each state. To do that though, we need to "fold up" our dfNew data which is currently at the city level to the state level. One way to do that is by using the aggregate() function which works the same way pivot tables in Excel do.

In [49]:

```
dfSimple = aggregate(dfNew$rank, by = list(dfNew$state), FUN = length)
dfSimple$name <- dfSimple$Group.1
dfSimple$Group.1 <- NULL
dfSimple$numRankedCities <- dfSimple$x
dfSimple$x <- NULL
```

After running the block of code above, we end up with a df with 51 observations (1 for each state and the District of Columbia), where the numRankedCities var represents the number of cities that made the list in each state. E.g., Alabama has 12 cities in the top 1,000, but Alaska only has 1.

Instead of "length," which essentially counts the number of ranked cities in a state, you can use a bunch of other math functions, such as "sum" which calculates the sum of values in a column for each state, etc.

In [50]:

```
dfSimple
```

A data.frame: 51 × 2

name	numRankedCities
<chr>	<int>
Alabama	12
Alaska	1
Arizona	25
Arkansas	10
California	212
Colorado	21
Connecticut	15
Delaware	2
District of Columbia	1
Florida	73
Georgia	18
Hawaii	1
Idaho	8
Illinois	52
Indiana	21

name	numRankedCities
<chr>	<int>
Iowa	13
Kansas	11
Kentucky	5
Louisiana	9
Maine	1
Maryland	7
Massachusetts	36
Michigan	31
Minnesota	24
Mississippi	6
Missouri	16
Montana	4
Nebraska	4
Nevada	6
New Hampshire	3
New Jersey	22
New Mexico	7
New York	17
North Carolina	22
North Dakota	4
Ohio	33
Oklahoma	11
Oregon	14
Pennsylvania	13
Rhode Island	6
South Carolina	12
South Dakota	2
Tennessee	17
Texas	83
Utah	19
Vermont	1
Virginia	17

name	numRankedCities
<chr>	<int>
Washington	28
West Virginia	2
Wisconsin	20
Wyoming	2

We can check out the state with the smallest amount of ranked cities by using subsetting:

In [51]:
```
dfSimple[which.min(dfSimple$numRankedCities),]
```

A data.frame: 1 × 2

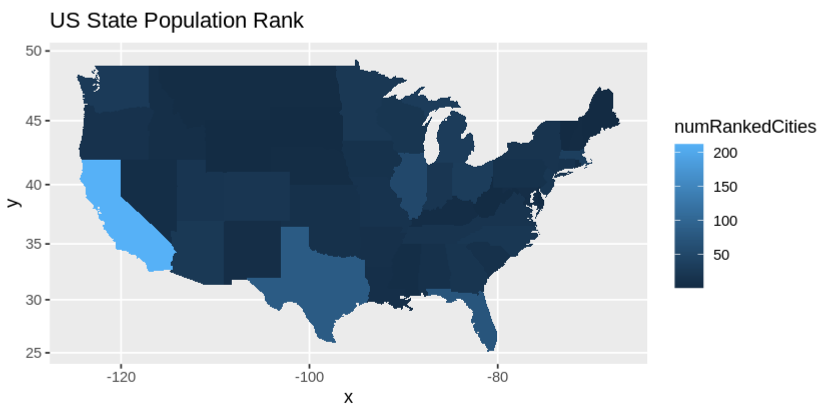
	name	numRankedCities
	<chr>	<int>
2	Alaska	1

We are almost ready to plot this new numRankedCities variable on a map of the US. The only thing we need to do though is remember to make sure the values in the state names column are all lowercase!

In [52]:
```
dfSimple$name <- tolower(dfSimple$name)
```

The following block of code creates a map of the US where states are shaded in depending on the number of ranked cities they have - we can see for instance, that there are more than 200 big cities in the state of Florida.

In [53]:
```
map2 <- ggplot(dfSimple, aes(map_id=name))
map2 <- map2 + geom_map(map=us, aes(fill=numRankedCities))
map2 <- map2 + expand_limits(x=us$long, y=us$lat)
map2 <- map2 + coord_map() + ggtitle("US State Population Rank")
map2
```


US State Population Rank
50
45
40
35
30
25
y
-120
-100
-80
x
numRankedCities
200
150
100
50

```
In [ ]:
```