Lecture 5:
Maps 1 of 2

March 3, 2019

Overview

Course Administration

Good, Bad and Ugly

What and Why of Maps

Representing Maps Digitally

Maps in R

Course Administration

1. Sign up for consultations!
    - sign up for slots April 8, 10 or 11
    - no class meeting April 15
2. Anything else?

Class 7, March 25: Good Bad and Ugly

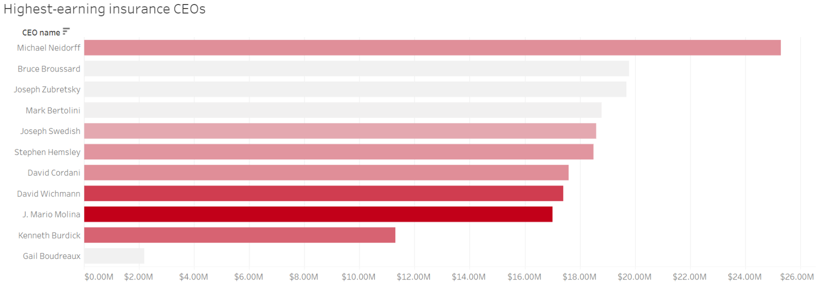
Strongly encourage you to send it ASAP so you don't forget. Maps are ok.

- EW
- MP

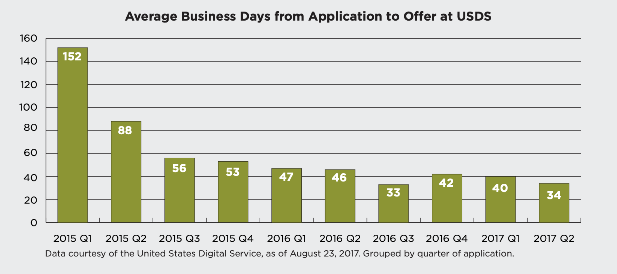
This Week's Good Bad and Ugly

- ER
- WD

Eli's Example



William’s Example



What and Why of Maps

Today

1. What is a map?
2. Why maps?
3. When do maps deceive?
4. Save for next time: Choropleth maps and dot density maps

1. What is a Map?

- "scale model of reality" (Monmonier)
- "almost always smaller" than reality

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- “scale model of reality” (Monmonier)
- “almost always smaller” than reality
- in distilling reality, there are three key choices
  1. scale
  2. projection
  3. symbolization

Projection

- We want to show both
  - equivalence: size proportional to physical size
  - conformality: shape proportional to true shape

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- When does this matter?

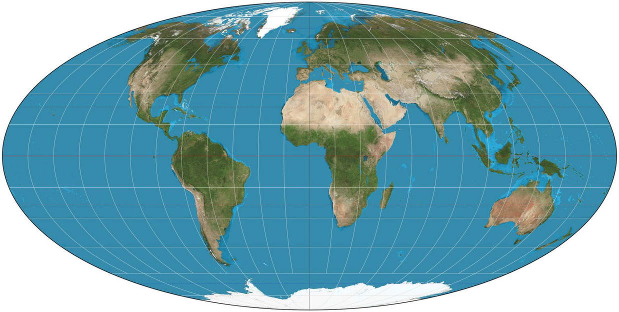
Projection

- We want to show both
  - equivalence: size proportional to physical size
  - conformality: shape proportional to true shape
- But you cannot do both!
- When does this matter?
  - This matters for maps of the world
  - It is practically irrelevant for a map of DC
  - For small areas, we care about precision of distance
  - Frequently use a UTM (Universal Transverse Meractor) projection: units in meters

Rules of Thumb for Projections for Small Areas

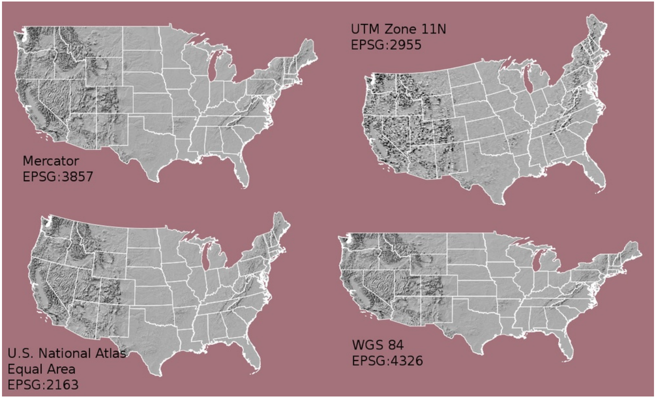
- Monmonier (p. 45) suggests for US either
  - Albers equal-area conic
  - Lambert conformal conic
- However, most maps you use should come with a projection defined

An Equal-Area Projection



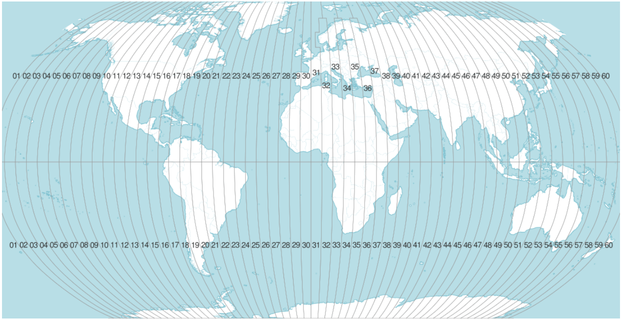
Thanks, Wikipedia.

The USA Four Ways



Thanks to Michael Corey.

UTM Zones



For small areas, use UTM projection if you need to calculate distances. Each number is a zone.
Thanks to Michael Corey.

2. Why Maps?

- Use a map when you want to show a **spatial** relationship
- Don't use a map if you want to compare geographic units

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When is Space Important?

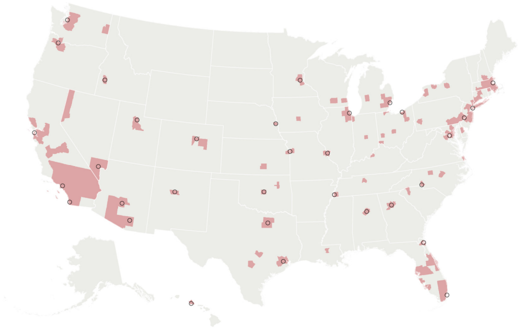
1. To show relationship between two geographic things. Examples?
    - metro stops relative to average home prices
    - population density relative to the equation
2. To show a geographic pattern in an outcome. Examples?
    - voting outcomes correlated over space
    - geographic features that change smoothly and sharply over space

Don't use a map if you can do something simpler!

3. Why Avoid Maps?

- They add complexity
- Geographic unit size infrequently related to importance
  - but remember that size indicates value
  - problematic!
- Examples?

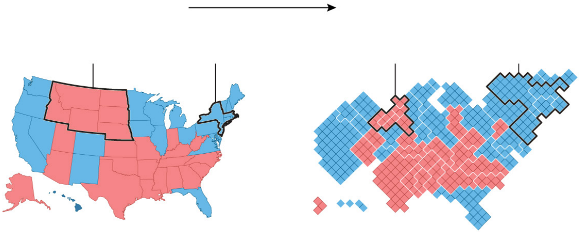
Red and Grey Areas Have About the Same Number of Votes Cast in 2012



With many thanks to the Washington Post

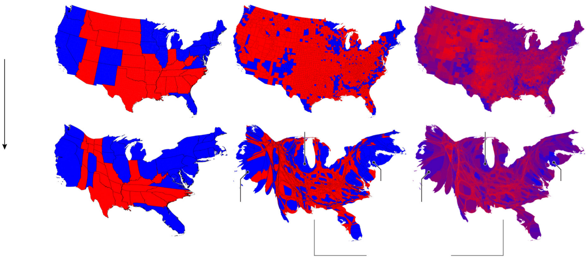
One Possible Solution

- A "cartogram" sizes locations by something: votes or people or electoral votes
- Five red midwestern states correspond to red block
- Mid-Atlantic corresponds to blue block

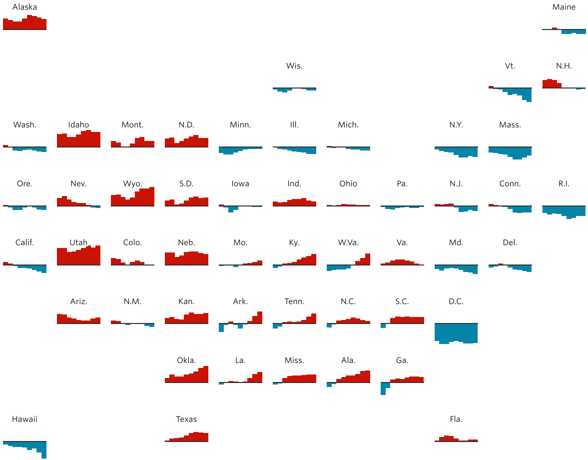


Another Possible Solution

- Thanks to U of Michigan physicist Newman
- Columns are state winner, county winner, county shaded by popular vote share
- Top is real map, bottom is cartogram
- Leftmost sized by electoral votes, others by votes cast



And a Quasi Map



Thanks to the Wall Street Journal, here.

How Do Computers Make Maps?

Maps Have

- Units defined by coordinates in space
- Data for each unit

Examples of a map unit of observation, please!

Digital Maps

- A map is a representation of space
- A digital map is a file that tells a computer how to do this
- There are many formats, but we'll focus on shapefiles
- Shapefiles are a ArcInfo format, but can be read in R

Three Major Types of Shapes for Maps

1. points
2. lines
3. polygons

Points in Space

- location 1: (x, y)
- location 2: (x, y)
- location 3: (x, y)

What would you represent with points?

Lines in Space

- location 1: $(x_1, y_1), (x_2, y_2)$
- location 2: $(x_1, y_1), (x_2, y_2)$
- location 3: $(x_1, y_1), (x_2, y_2)$

What would you represent with lines?

Polygons in Space

- location 1: $(x_1, y_1), (x_2, y_2), (x_3, y_3), (x_4, y_4), (x_1, y_1)$
- location 2: $(x_1, y_1), (x_2, y_2), (x_3, y_3), (x_4, y_4), (x_5, y_5), (x_1, y_1)$
- location 3: $(x_1, y_1), (x_2, y_2), (x_3, y_3), (x_1, y_1)$

Note that last point is the same as the first point.[1]
What would you represent with polygons?

[1] Polygons can have holes; we can talk about this.

But Where Do the Points Go?

- A map file needs some instructions on what the points mean
- We are not drawing on a globe, so we need some way of taking true coordinates and making them flat: projection
- Map makers define coordinate systems so that everyone agrees on what $(x_1, y_1), (x_2, y_2)$ means
- Coordinate systems have a defined unit of measurement: meters, feet, decimal degrees
- There are two major types of systems
  1. geographic/global/spherical system: in latitude/longitude
  2. projected coordinate system: in terms of meters/feet/miles

Implications for Mapping

- You can't put maps with two different coordinate systems on top of each other
- Easier to calculate distances and areas with projected coordinate systems
- You can go from one projection to another, but **use the right command**
- Digital maps usually come with a projection defined

R

Today

Z. `sf` package

A. Reading

B. Plotting

C. Spatially combining

Z. 'sf' Package

- a new package as of last year
- works with tidyverse and `ggplot`
- use all the other commands you've used to date
- still not fully released – help and community not as developed
- but faster and easier than previous
- ok for all map data except rasters

```
library(ggplot2)
library(sf)
```

A.1. Reading a Shapefile

- there are many types of digitial maps
- the most common is a “shapefile”
- a proprietary format from ESRI
- most downloads come in this format

A.2. What is a Shapefile?

- shapefiles have 4 to 7 parts
- all have the same name and these extensions
  - .shp
  - .shx
  - .dbf
  - .prj
  - .xml
  - .cpg
- the first 3 are mandatory
- it's odd if you don't have a projection, but you can still draw a map

A.3. Read the shapefile

The key command is `st_read("FILENAME.MAP_EXTENSION")`

```
shp.df <- st_read("c:/stuff/map.shp")
```

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This new file

- works like a dataframe
- plus it has spatial information

B.1 Plotting

Two main commands for plotting simple features in R

1. `plot()`
2. `ggplot()` using `geom_sf()`

Happily, `geom_sf()` works a lot like the other `geom_XXX()` commands you already know.

C. Spatially combining

Questions you can answer with `st_intersection()`

- Which states are cities in?
  - points and polygons: should return points
- What share of national park land area (polygons) is in cities (polygons)?
  - polygons and polygons: should return polygons
- How many miles of roads (lines) are in the 3 western coastal states (polygons)?
  - lines and polygons: should return lines, then sum to state level

C.0 Example: Which states are cities in?

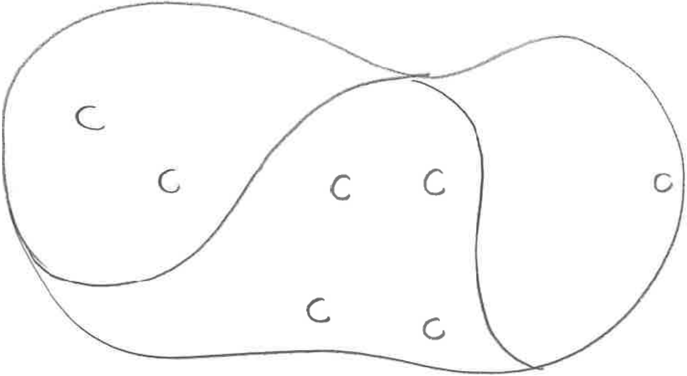


Figure 1:

C.0 Example: What share of national park land area is in cities?

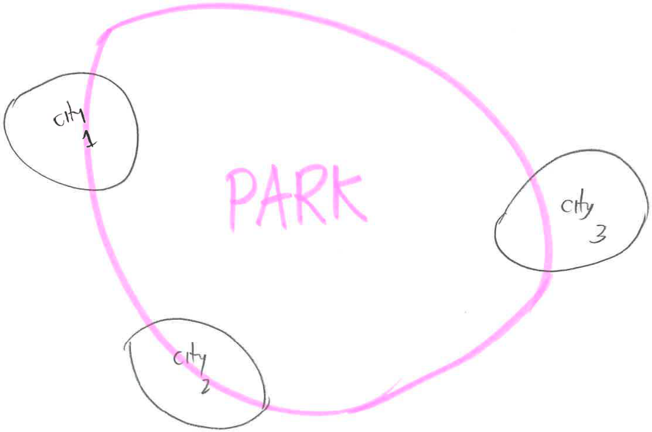


Figure 2:

C.0 Example: How many miles of roads in each state?

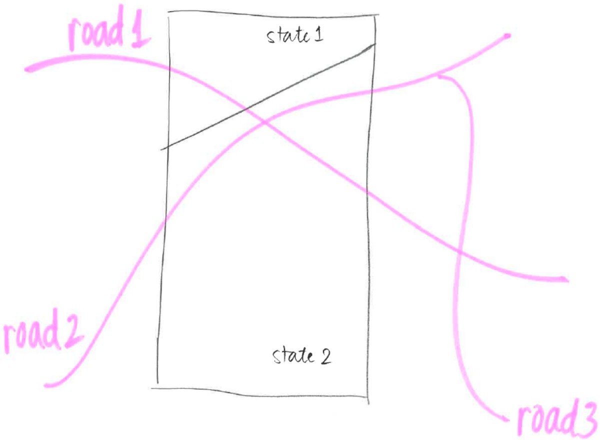


Figure 3:

C.1. How to do it

Use `st_intersection()`

commands

Don't confuse with `st_intersects()` which does the same thing but returns a matrix, not a simple feature.

C.2. Example

```
b0 = st_polygon(list(rbind(c(-1,-1),
                           c(1,-1),
                           c(1,1),
                           c(-1,1),
                           c(-1,-1))))
b1 = b0 + 2
b2 = b0 + c(-0.2, 2)
x = st_sfc(b0, b1, b2)
a0 = b0 * 0.8
a1 = a0 * 0.5 + c(2, 0.7)
a2 = a0 + 1
a3 = b0 * 0.5 + c(2, -0.5)
y = st_sfc(a0,a1,a2,a3)
```

Taken directly from `sf` vignette here.

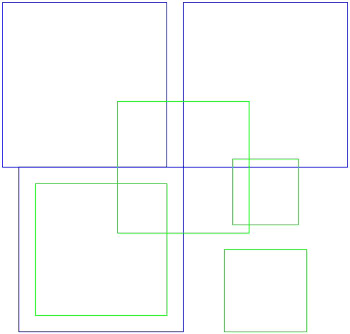
C.3. Simple Features

```
x
```

```
## Geometry set for 3 features
## geometry type:  POLYGON
## dimension:      XY
## bbox:           xmin: -1.2 ymin: -1 xmax: 3 ymax: 3
## epsg (SRID):    NA
## proj4string:    NA

## POLYGON ((-1 -1, 1 -1, 1 1, -1 1, -1 -1))

## POLYGON ((1 1, 3 1, 3 3, 1 3, 1 1))

## POLYGON ((-1.2 1, 0.8 1, 0.8 3, -1.2 3, -1.2 1))
```

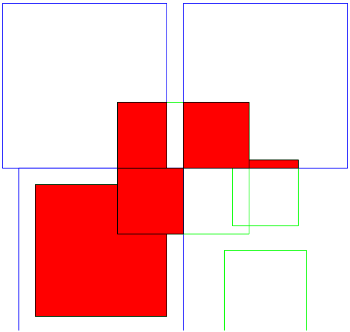
C.4. Plot it

```
plot(x, border = 'blue')
plot(y, border = 'green', add = TRUE)
```



C.5. Intersection

```
xy <- st_intersection(x,y)
plot(x, border = "blue")
plot(y, border = "green", add = TRUE)
plot(xy, add = TRUE, col = 'red')
```



C.6. How the New Simple Feature Looks

```
xy
```

```
## Geometry set for 5 features
## geometry type:  POLYGON
## dimension:      XY
## bbox:           xmin: -0.8 ymin: -0.8 xmax: 2.4 ymax: 1.
## epsg (SRID):    NA
## proj4string:    NA

## POLYGON ((-0.8 -0.8, -0.8 0.8, 0.8 0.8, 0.8 -0....

## POLYGON ((2.4 1, 1.6 1, 1.6 1.1, 2.4 1.1, 2.4 1))

## POLYGON ((0.2 1, 1 1, 1 0.2, 0.2 0.2, 0.2 1))

## POLYGON ((1.8 1, 1 1, 1 1.8, 1.8 1.8, 1.8 1))

## POLYGON ((0.8 1.8, 0.8 1, 0.2 1, 0.2 1.8, 0.8 1...
```

Next Lecture

- Next week: spring break
- Here for office hours if you want
- Next lecture is March 19: Functions and Storyboarding