Geographic Information Systems: GeoPandas

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Introduction to Programming for Public Policy

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Geographic Information Systems: Maps

People love maps – emotional response to 'seeing yourself.'

- This is a huge field: there are entire classes at Harris and around the University for GIS, spatial statistics, etc.
- But huge bang for the buck at the entry level.
  - Easy to make compelling graphics.
  - Many datasets represent a spatial area or point at a specific time.
    $\Longrightarrow$ Great potential for joins!

What We'll Cover

1. Making simple maps with GeoPandas (`pandas+`).
   - Finding and importing shapefiles and geojson (like `read_csv()`).
   - Projections (briefly).
2. Attribute and spatial joins.
   - Geocoding APIs: geopy/nominatim, Census, etc.
   - Making a map with real data!
3. Making a simple web (!) map with GeoPandas

- Largely revisiting old material, with new functions.

Shapefiles

- Three forms of geographic objects: points (schools, crimes), lines (roads, rivers), and polygons (lots, census tracts, regions, lakes, etc.).
- Many, many sources for geographic data: **Chicago**, **US Census**, **USGS**, **Global Administrative Areas** (GADM), etc.
- Much of this is provided in 'ESRI Shapefiles' (Environmental Systems Research Institute, major GIS company) or in geojson. Modern databases (postgres) are helpful for assembling large datasets.
  - Shapefiles come zipped with a lot of other files. The shp file is the 'master' file, and references the others. That's what you import.
  - Let's browse: **census shapefiles**.
- Addresses may be geocoded and coordinates are also points!

Loading a Shapefile with GeoPandas

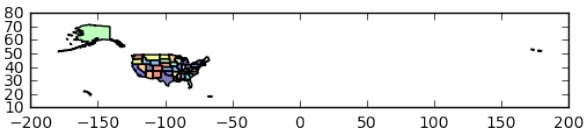
- **GeoPandas** simply adds a geometry series to a pandas DataFrame.
- It is tightly integrated with many other geographic programs, among them **fiona** for reading geojson/shapefiles and **shapely** for geometric operations (intersections, etc.).
- Really easy to import! Both shapefiles and geojson:

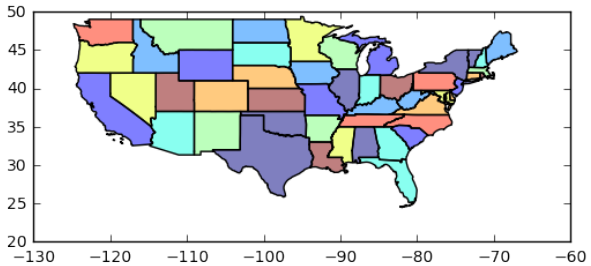
```
import geopandas as gpd
gdf = gpd.read_file("myfile.shp")
gdf.plot() # WOW!!!!
```

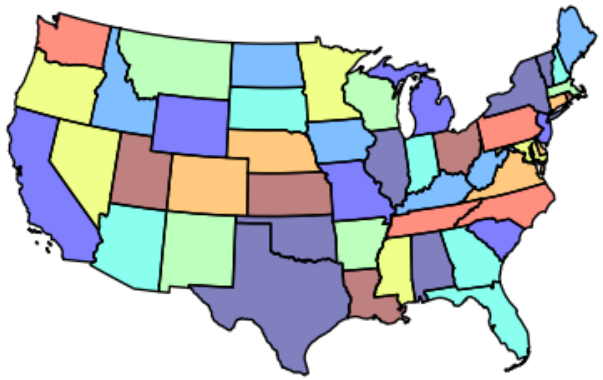
- All of the 'standard' dataframe operations (slicing, indexing, merging) are still available.

Making a Better Map

- Let's restrict ourselves to the contiguous 48 states.
- Make a mask to get rid of Alaska and Hawaii (STATEFP 2 and 15), and the territories (STATEFP ≥ 57).
  - Alternative: translate, rotate, and scale them with **shapely**.
- We also need a better better projection: `gpd.to_crs(epsg=2163)`.







Coordinate Reference Systems (CRS)

- To make maps, we need a description of the shape of Earth (an ellipsoid) and an origin/center. This is called a **datum**.
- We also need a **projection** from 3D to 2D.
- These are standardized in EPSG codes:

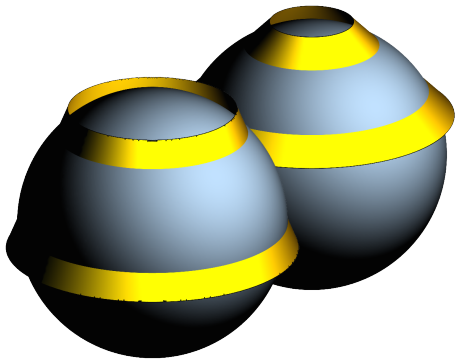
  4269 By default, GeoPandas uses a plate carée projection: a mapping of longitude and latitude lines to horizontal and vertical lines (gross).

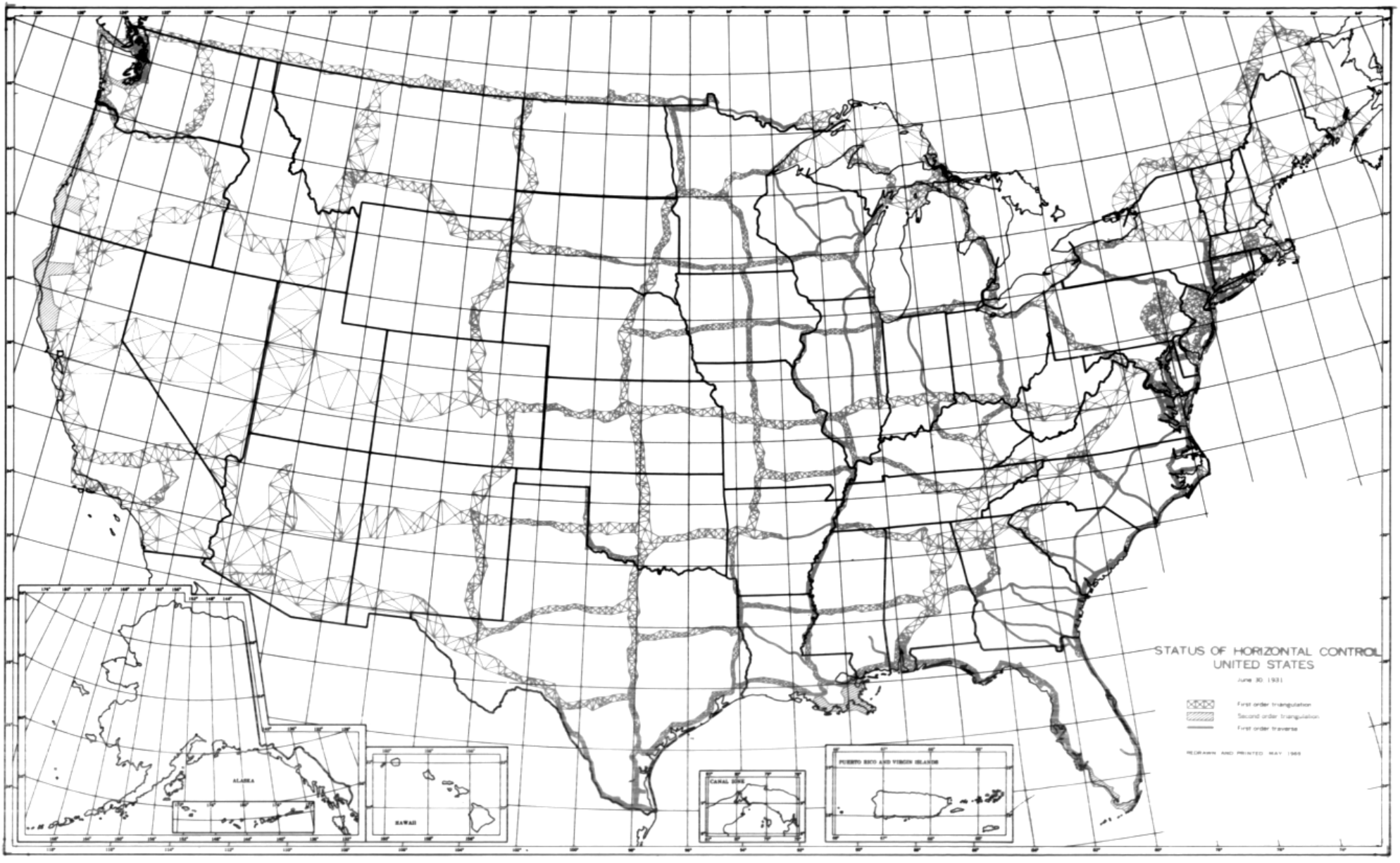
  3857 Most online maps use web Mercator, which is conformal (preserves shapes/angles) but much-maligned.

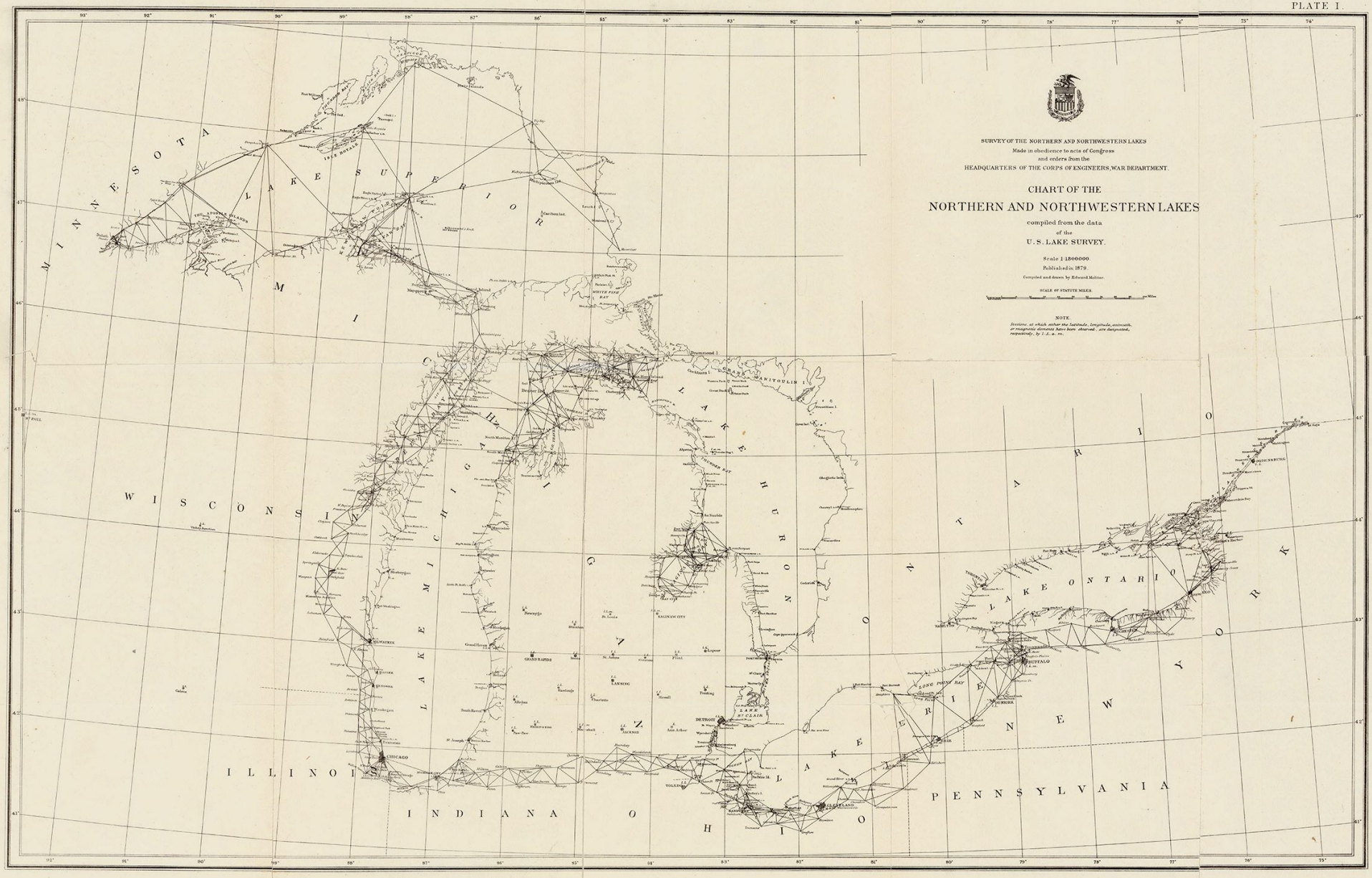
  2163 Albers Equal Area is a good conic projection for the US. ✓
- Inappropriate projections make maps look stupid.

Center of the World


∼ Goode Homolosine


Albers Equal Area!!


STATUS OF HORIZONTAL CONTROL
UNITED STATES
June 30, 1931
First order triangulation
Second order triangulation
First order traverse
REDRAWN AND PRINTED MAY 1966
ALASKA
HAWAII
CANAL ZONE
PUERTO RICO AND VIRGIN ISLANDS


SURVEY OF THE NORTHERN AND NORTHWESTERN LAKES
Made in obedience to acts of Congress
and orders from the
HEADQUARTERS OF THE CORPS OF ENGINEERS, WAR DEPARTMENT.
CHART OF THE
NORTHERN AND NORTHWESTERN LAKES
compiled from the data
of the
U. S. LAKE SURVEY.
Scale 1:1800000.
Published in 1879.
Compiled and drawn by Edward Molitor.
SCALE OF STATUTE MILES.
NOTE.
Stations at which either the latitude, longitude, azimuth, or magnetic elements have been observed, are designated, respectively, by l. d. a. m.
LAKE SUPERIOR
LAKE MICHIGAN
LAKE HURON
LAKE ONTARIO
LAKE ERIE
MINNESOTA
WISCONSIN
ILLINOIS
INDIANA
OHIO
PENNSYLVANIA
NEW YORK
ONTARIO
ISLE ROYALE
THE APOSTLE ISLANDS
GEORGIAN BAY
MANITOULIN I.
SAGINAW BAY
LONG POINT BAY
ST. PAUL
CHICAGO
MILWAUKEE
GRAND RAPIDS
DETROIT
LAKE ST. CLAIR
TOLEDO
CLEVELAND
BUFFALO
TORONTO
KINGSTON
OGDENSBURG

Joins

Several distinct goals:

1. Visualize a dataset as a map (join it to a shapefile).
2. Attribute join on two datasets with matching geometries.
   - Don't care about the geometry, just use it!
3. Datasets with different geometries (e.g., points and polygons).
   - Use a spatial join; may not care about map!

Attribute Join

- Attribute joins are the joins we've already been doing with pandas.
- Prepare them for the join by matching the indices (state codes).

Two examples:

1. Single mothers in the United States.
   - Join the state shapes to data from the (**census API**).
2. Voting returns in Pennsylvania from the election return **site**

Choropleth Maps: Shaded Areas

Easy to make basic, beautiful maps!

```
gdf.plot(column = "Percent Mothers Unmarried",
         scheme = "quantiles", k = 10,
         cmap = "rainbow", alpha = 0.4,
         edgecolor = "black", linewidth = 0.5,
         legend = True, figsize = (12, 8))
```

- The built-in method also allows for `equal_intervals` (linear, default), `quantiles`, and `fisher_jenks`.
  - Fisher Jenks defines categories by minimizing the in-group variance , and maximizing the between-group variance.
  - Most lay-people will only understand equal intervals!!
  - Without a scheme, geopandas will make a smooth, equal-interval coloring but a bad legend.
  - Can also use `vmin` and `vmax` for a smooth colormap.
- There are many, many **colormaps**.

Point to Polygon: Spatial Joins

- Spatial joins (`sjoin`) use properties of two geometries – instead of equality of attributes – to align rows.
  - One geometry `'contains'`, is `'within'`, or `'intersects'` another:

```
gpd.sjoin(pt_df, poly_df, how='left', op='within')
```

- For example: aggregate crimes (points) by community area (polygon).
- The geometry from the left DataFrame is preserved.

Building a GeoDataFrame from Scratch

- We also need to be able to create a GeoDataFrame from scratch.
- A GeoDataFrame, is just a DataFrame with a 'GeoSeries.'
- The GeoSeries is just a list of points, which we can construct as:

```
from shapely.geometry import Point
pt = Point(x, y)
```

- Create the GeoDataFrame by setting the geoemtry and CRS (4269):

```
gpd.GeoDataFrame(crime_df, crs = {'init':
'epsg:4269'}, geometry=geometry)
```

Example: associate murders to census tracts and community areas.

A Simple Web Map

ex/web_folium.py

- Folium creates a powerful javascript map on OpenStreetMap.
- Nice interface, easily embedded in other sites:
  - `<iframe src="map.html" width=800px height=500px></iframe>`

```
import folium

m = folium.Map([40, -98], tiles='cartodbpositron',
               zoom_start=4, max_zoom=14, min_zoom=4)

ft = "Percent Mothers Unmarried"
colormap = folium.LinearColormap(("orange", "white", "purple"),
                                 vmin = geo_merge[ft].min(),
                                 vmax = geo_merge[ft].max(),
                                 caption = ft)
colormap.add_to(m)

folium.GeoJson(geo_merge,
               style_function = lambda feature: {
                  'fillColor': colormap(feature['properties'][ft]),
                  "color" : "black", "weight" : 1, "fillOpacity" : 0.4
               }).add_to(m)

m.save("mothers.html")
```

Other Folium Features

- You can plot a collection of points with `GeoJson`, but you can get somewhat more control with

```
folium.Marker([41.7855052, -87.5971531],
              popup='Harris School').add_to(map)
```

- See also e.g., `CircleMarker`, `RegularPolygonMarker`, etc.
- Full documentation **here**.

- We'll come back to this after our last example.

Geocoding

- Often, we have latitudes and longitudes (ready to be wrapped as points), but addresses.
- Geocoding is the process of turning addresses into coordinates.
  - We have already done this with the google API.
- Many geocoding services (Census, Texas A&M) also provide census tracts, counties, etc. $\Longrightarrow$ Huge time saver!

Built-In Geocoding

- geopy plugs into the OpenStreetMap 'Nominatim' API, as well as google bing, yahoo, and openmapquest.
  - Some of the others require API keys for large numbers of requests.

```
from geopy.geocoders import Nominatim
Nominatim().geocode("1155 E. 60th St, Chicago 60637")
```

- GeoPandas provides tools to do many geocodes in one pass:

```
gpd.tools.geocode(["London", "Paris",
                   "New York", "Hong Kong"])
```

Census API (For Interest)

- The Census **geocoding API** matches tracts in **geography** endpoint
  - Also standard **location** mode.
- Capable of up to 1000 addresses at a time in batch mode:

```
curl -F addressFile=@short.csv\
     -F benchmark=Public_AR_Current\
     -F vintage=ACS2015_Current \
     https://geocoding.geo.census.gov/geocoder/geographies/addressbatch
```

Merges and Spatial Operations as Geocoding

Spatial operations (`intersects`, `within`, and `contains`) are effectively gecodes:

```
geo_df[geo_df.contains(pt)]["NAME"]
```

Second Folium Example

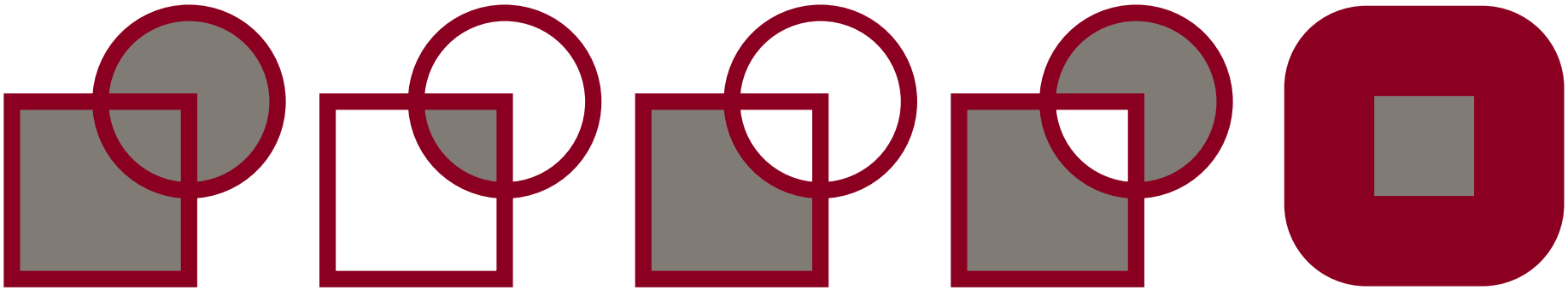
- Make a map of places represented in this class (points and countries).
- Curl these shapefiles for the world:

http://thematicmapping.org/downloads/TM_WORLD_BORDERS_SIMPL-0.3.zip

Spatial Operations: Beyond Joins and Aggregations

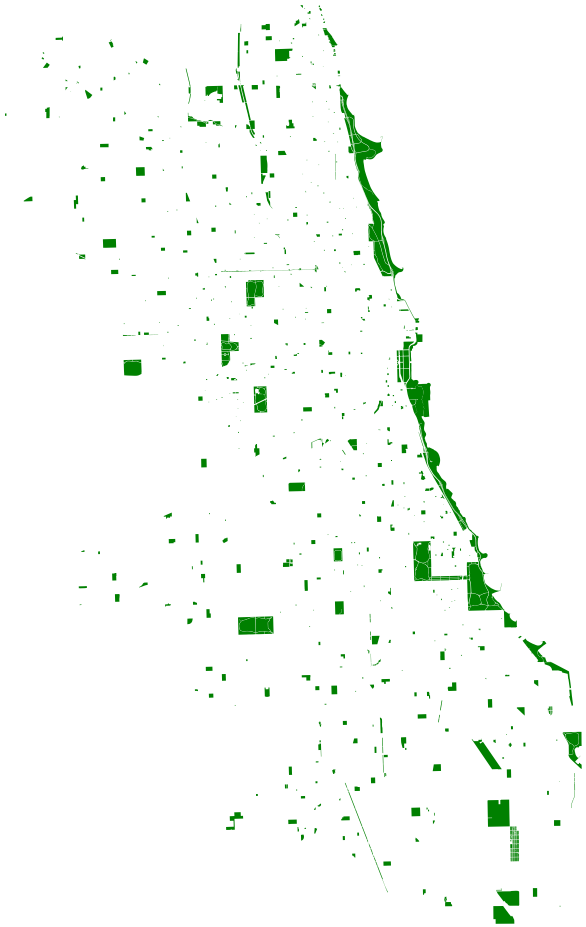
With spatial operations, we can create variables that express the distances to a point of service/care (trauma center), or the amount of a resource (e.g., park-land or grocery store square-footage) available within a radius.

- Non-trivial questions: how close do you have to you be to a park to enjoy it, or to a grocery store to use it?
- Geopandas provides these operations through **shapely**.
- To reduce an entire dataset to one shape: `gdf.unary_union`.

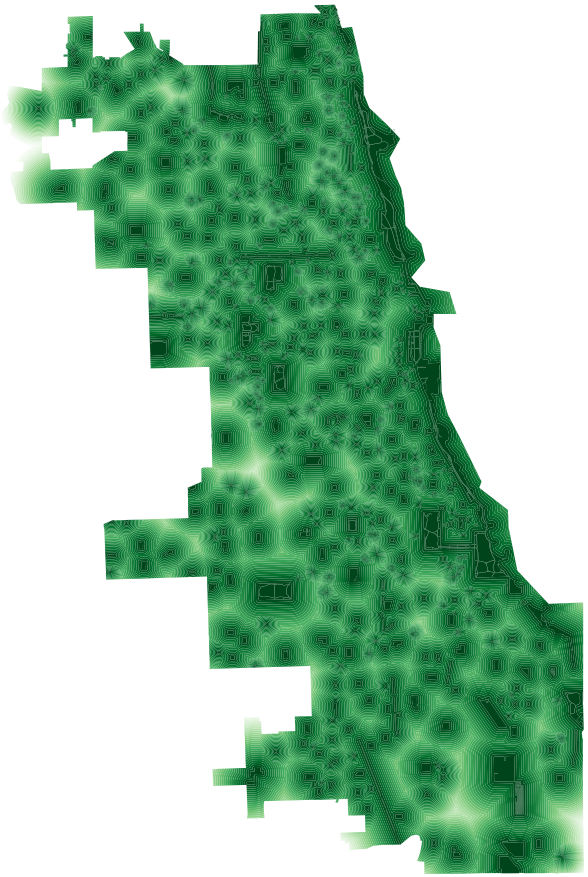


Access to Parks

City Parks



Distance to Area-Weighted Park



Quantiles of Area, < 250m from Census Tract