

Spatial II

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October 30, 2024

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Introduction to data structures in geopandas (6.2)

Geopandas roadmap

In practice, we won't be coding our geodata by hand... Instead we are going to use shapefiles!

```
import geopandas as gpd
```

Roadmap

- ▶ Vocabulary
- ▶ File formats
- ▶ Read in data
- ▶ Preview data

Define vocabulary

Vocabulary

- ▶ A `GeoDataFrame` is basically like a `pandas.DataFrame` that contains dedicated columns for storing geometries.
 - ▶ We will start with examples with a single column and later teach you how to use more than one column
- ▶ That column is called a `GeoSeries`. This can be any of data types (point, line, polygon) from the prior section. All of the methods you saw in the last section can also be used on a `GeoSeries`

File format I: Shapefile

- ▶ consists of at least three files `.shp` has feature geometrics, `.shx` has a positional index, `.dbf` has attribute information
- ▶ Usually also have `.prj` which describes the Coordinate Reference System (CRS)
- ▶ When you read in `map.shp` it automatically reads the rest of them as well to give you proper `GeoDataFrame` composed of geometry, attributes and projection.

Coordinate Reference Systems

- ▶ Coordinate Reference System (CRS) is a combination of:
 - ▶ “Datum”: origin of latitude and longitude
 - ▶ “Project”: representation of curved surface onto flat map
- ▶ Most common CRS: WGS84 (used for GPS)
- ▶ All coordinates are consistent *within* a CRS, but not always *across* CRS's
- ▶ Different CRS's suit different needs
 - ▶ optimized for local vs. global accuracy
 - ▶ different approaches to approx. shape of the earth
 - ▶ distance is measured in different units: degrees, miles, meters
- ▶ Each system is associated with a unique *EPSG code*.
Searchable on <https://epsg.io>
 - ▶ (Aside: EPSG stands for European Petroleum Survey Group)
 - ▶ These codes are used to convert one CRS into another

Reading a Shapefile .shp

```
#in same dir:  `.shx` and `.dbf`  
filepath = "data/shp/austin_pop_2019.shp"  
data = gpd.read_file(filepath)
```

File format II: GeoPackage

- ▶ single file .gpkg
- ▶ Supports both raster and vector data
- ▶ Efficiently decodable by software, particularly in mobile devices

GeoPackage is more modern, but you will encounter shapefiles everywhere you look so good to be familiar with it.

Reading a GeoPackage gpkg

```
filepath = "data/austin_pop_2019.gpkg"  
data = gpd.read_file(filepath)  
type(data)
```

```
geopandas.geodataframe.GeoDataFrame
```

Previewing a GeoDataFrame

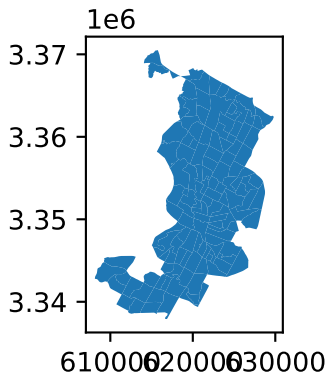
```
data.head()
```

	pop2019	tract	geometry
0	6070.0	002422	POLYGON ((615643.487 3338728.496, 615645.477 3...
1	2203.0	001751	POLYGON ((618576.586 3359381.053, 618614.330 3...
2	7419.0	002411	POLYGON ((619200.163 3341784.654, 619270.849 3...
3	4229.0	000401	POLYGON ((621623.757 3350508.165, 621656.294 3...
4	4589.0	002313	POLYGON ((621630.247 3345130.744, 621717.926 3...

Previewing a GeoSeries

```
data.plot()
```

<Axes: >



Discussion question: Why isn't it enough to just to head()?

Geopandas summary

- ▶ `GeoDataFrame` and `GeoSeries` are the counterparts of `pandas.DataFrame` and `pandas.Series`
- ▶ `.shp` and `.gpkg` are two ways of storing geo data
- ▶ Always plot your map before you do anything else

Geometries in geopandas (6.2)

geometries: roadmap

- ▶ methods applied to `GeoSeries`
- ▶ my first choropleth

GeoSeries

```
type(data["geometry"])
```

```
geopandas.geoseries.GeoSeries
```

head()

```
data["geometry"].head()
```

```
0    POLYGON ((615643.487 3338728.496, 615645.477 3...
1    POLYGON ((618576.586 3359381.053, 618614.330 3...
2    POLYGON ((619200.163 3341784.654, 619270.849 3...
3    POLYGON ((621623.757 3350508.165, 621656.294 3...
4    POLYGON ((621630.247 3345130.744, 621717.926 3...
Name: geometry, dtype: geometry
```

calculate area (in square meters)

```
data["geometry"].area
```

```
0      4.029772e+06
```

```
1      1.532030e+06
```

```
2      3.960344e+06
```

```
3      2.181762e+06
```

```
4      2.431208e+06
```

```
...
```

```
125    2.321182e+06
```

```
126    4.388407e+06
```

```
127    1.702764e+06
```

```
128    3.540893e+06
```

```
129    2.054702e+06
```

```
Length: 130, dtype: float64
```

add column to data frame

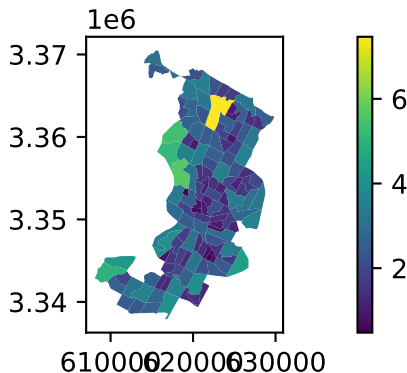
```
#data.area is just a shorthand for data.geometry.area  
data["area_km2"] = data.area / 1000000  
data[['tract', 'area_km2', 'geometry']].head()
```

	tract	area_km2	geometry
0	002422	4.029772	POLYGON ((615643.487 3338728.496, 615645.477 3...
1	001751	1.532030	POLYGON ((618576.586 3359381.053, 618614.330 3...
2	002411	3.960344	POLYGON ((619200.163 3341784.654, 619270.849 3...
3	000401	2.181762	POLYGON ((621623.757 3350508.165, 621656.294 3...
4	002313	2.431208	POLYGON ((621630.247 3345130.744, 621717.926 3...

my first choropleth

```
data.plot(column="area_km2", legend=True)
```

<Axes: >



Discussion question – why is this a nearly useless set of colors?

geometries: summary

- ▶ can do all the same operations on a `GeoSeries` that you would do on any other polygon, like `Area`
- ▶ `data.plot(column="var")` draws a choropleth map with shading corresponding to the highlighted variable

Common geometric operations (6.3)

common geometric operations: roadmap

- ▶ load and explore data
- ▶ methods
 - ▶ centroid
 - ▶ bounding box
 - ▶ buffer
 - ▶ dissolve
 - ▶ spatial join
- ▶ do-pair-share

Austin, continued

(The textbook uses a slightly different file here, unclear why to us.)

```
filepath = "data/austin_pop_density_2019.gpkg"  
data = gpd.read_file(filepath)
```

explore the data I

```
data.head()
```

	pop2019	tract	area_km2	pop_density_km2	geometry
0	6070.0	002422	4.029772	1506.288778	MULTIPOLYGON
1	2203.0	001751	1.532030	1437.961394	MULTIPOLYGON
2	7419.0	002411	3.960344	1873.322161	MULTIPOLYGON
3	4229.0	000401	2.181762	1938.341859	MULTIPOLYGON
4	4589.0	002313	2.431208	1887.538658	MULTIPOLYGON

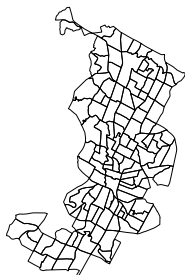
explore the data II

```
type(data["geometry"].values[0])
```

```
shapely.geometry.multipolygon.MultiPolygon
```

explore the data III

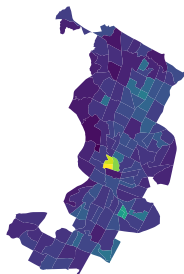
```
import matplotlib.pyplot as plt
data.plot(facecolor="none", linewidth=0.2)
plt.axis("off")
plt.show()
```



- ▶ Import `matplotlib.pyplot` to access additional plotting options (e.g., x and y labels, title)
- ▶ We turn the axis off because the WKT is not informative

explore the data IV

```
data.plot(column="pop_density_km2")  
plt.axis("off")  
plt.show()
```



- ▶ `facecolor` (or `fc` or `color`) defines a uniform color across all geometries
- ▶ whereas `columns` generates colors based on the underlying values

methods: centroid I

What it is: arithmetic mean position of all the points in a polygon

Sample use case: measuring distance between center of each multipolygon

```
data["geometry"].centroid.head()
```

```
0    POINT (616990.190 3339736.002)
1    POINT (619378.303 3359650.002)
2    POINT (620418.753 3342194.171)
3    POINT (622613.506 3351414.386)
4    POINT (622605.359 3343869.554)
dtype: geometry
```

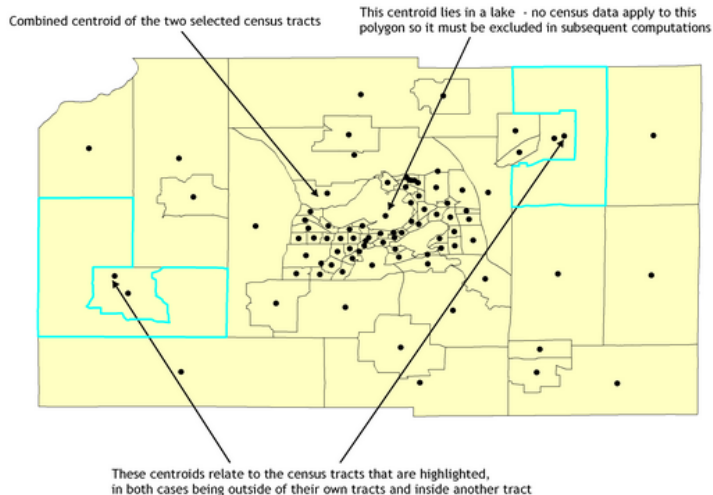
methods: centroid II

```
data.centroid.plot(markersize=1)  
plt.axis("off")  
plt.show()
```



centroid example outside polygon

Census tracts and centroids



Source:

https://spatialanalysisonline.com/HTML/centroids_and_centers.htm

aside: change active geometry

```
data["centroid"] = data.centroid
data.set_geometry("centroid")
data[['tract', 'centroid', 'geometry']].head()
```

	tract	centroid	geometry
0	002422	POINT (616990.190 3339736.002)	MULTIPOLYGON (((615643.488 333872
1	001751	POINT (619378.303 3359650.002)	MULTIPOLYGON (((618576.586 335938
2	002411	POINT (620418.753 3342194.171)	MULTIPOLYGON (((619200.163 334178
3	000401	POINT (622613.506 3351414.386)	MULTIPOLYGON (((621623.757 335050
4	002313	POINT (622605.359 3343869.554)	MULTIPOLYGON (((621630.247 334513

methods: bounding box definition

What it is: the tightest possible rectangle around a shape, capturing all of its points within this rectangle.

Sample use case: filtering a larger spatial dataset to subset of interest

methods: bounding box for each polygon I

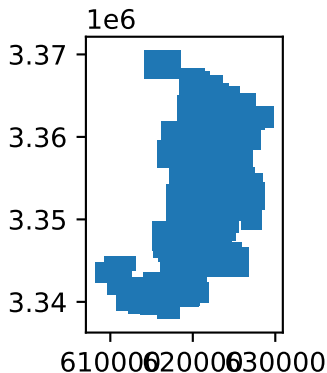
```
data.envelope.head()
```

```
0    POLYGON ((615643.488 3337909.895, 618358.033 3...
1    POLYGON ((618529.497 3358797.000, 620192.632 3...
2    POLYGON ((619198.456 3340875.421, 621733.880 3...
3    POLYGON ((621599.087 3350329.320, 623714.365 3...
4    POLYGON ((621630.247 3343015.679, 624133.189 3...
dtype: geometry
```

methods: bounding box for each polygon II

```
data.envelope.plot()
```

<Axes: >



methods: bounding box for whole data I

```
data.total_bounds
```

```
array([ 608125.39429998, 3337909.89499998,  629828.38850021,  
       3370513.68260002])
```

methods: bounding box for whole data II

Flashback to section 6.1

```
from shapely import Point, Polygon
point1 = Point(data.total_bounds[0], data.total_bounds[1])
point2 = Point(data.total_bounds[2], data.total_bounds[1])
point3 = Point(data.total_bounds[2], data.total_bounds[3])
point4 = Point(data.total_bounds[0], data.total_bounds[3])
poly = Polygon([point1, point2, point3, point4])
#poly
```

- *Note:* the order in which you put these points together matters, and you'll get all sorts of interesting shapes with different orders!

methods: buffer I

What it is: shape representing all points that are less than a certain distance from the original shape

Sample use cases:

- ▶ how many stores or parks near a neighborhood
- ▶ geometries that don't line up well (e.g. coasts)
- ▶ selecting nearby geometries

methods: buffer II

```
data.buffer(1000).plot(edgecolor="white") #1000 meters  
plt.axis("off")  
plt.show()
```



methods: dissolve |

What it is: combining geometries into coarser spatial units based on some attributes.

Sample use case: construct the geometries that you want to serve with public transit

```
# Create a new column and add a constant value  
data["dense"] = 0
```

```
# Filter rows with above average pop density and update the  
data.loc[data["pop_density_km2"] > data["pop_density_km2"].  
data.dense.value_counts()
```

```
dense
```

```
0      86
```

```
1      44
```

```
Name: count, dtype: int64
```

methods: dissolve II

```
dissolved = data[["pop2019", "area_km2", "dense", "geometry"]].dissolve(  
    by="dense", aggfunc="sum"  
)  
#aggregation step set index to "dense", reset to default  
dissolved = dissolved.reset_index()  
dissolved
```

	dense	geometry	pop2019	area_km
0	0	MULTIPOLYGON (((614108.230 3339640.551, 614288...	368992.0	231.131
1	1	MULTIPOLYGON (((612263.531 3338931.800, 612265...	242943.0	71.2345

- ▶ Aggregating alters the way the data is indexed and makes the grouping variable the index
- ▶ We need to reset it in order to plot, since some plotting libraries expect data to be indexed in a specific way

methods: dissolve III

```
dissolved.plot(column="dense")  
plt.axis("off")  
plt.show()
```



Discussion Question: What can we do to improve this map?

methods: spatial join

Spatial join: find the closest neighbor.

```
data_for_join = data[["tract", "geometry"]]
print("N tracts " + str(len(data_for_join)))
join_to_self = gpd.sjoin_nearest(
    data_for_join, #left df
    data_for_join, #right df
    how='inner',
    distance_col="distance"
)
```

N tracts 130

(Contrived) example: Join every Austin tract to its closest neighbor or neighbors. How many tracts should we expect to get?

methods: spatial join II

```
print("N tracts w closest neighbor " +  
      str(len(join_to_self)))  
join_to_self[['tract_left', 'tract_right', 'distance']].head()
```

N tracts w closest neighbor 848

	tract_left	tract_right	distance
0	002422	002423	0.0
0	002422	002422	0.0
0	002422	002424	0.0
0	002422	002402	0.0

common geometric operations: summary

- ▶ methods
 - ▶ centroid computes arithmetic mean of points in the polygon
 - ▶ bounding box expands polygon in a rectangle
 - ▶ buffer expands polygon in every direction
 - ▶ dissolve combines several polygons
 - ▶ spatial join finds nearest neighbor
- ▶ do-pair-share

do pair share

Goal: Create and plot a 500m buffer zone around the dense areas in Austin.

Steps

1. From the dissolved GeoDataFrame, get the polygon for the dense areas
2. Create a new geometry object called `geo`, which is the dense areas with a 500m buffer
3. `geo.plot()`

After you are done, here are some cosmetic suggestions:

- ▶ Start with a grey plot of all of the Austin boundaries: `austin = data.plot(color="grey")`
- ▶ Make your buffer transparent
- ▶ Putting it all together `geo.plot(ax = austin, alpha=0.5)`
 - ▶ This plots the `geo` object with 50% transparency, on top of axes based on the `austin` object