Python Tutorial – Part 2: Objects and Classes

Mark A. Austin

University of Maryland

austin@umd.edu
ENCE 688R, Spring Semester 2023

February 27, 2023

Overview

1. Working with Objects and Classes
2. Data Hiding and Encapsulation
3. Relationships Among Classes
4. Inheritance Mechanisms
5. Composition of Object Models
6. Working with Groups of Objects
7. Spatial Data and Dataset Transformation (GeoPandas)
8. Case Study: GeoModeling the Worlds Megacities

Part 5

Spatial Data and Dataset Transformation

(GeoPandas)

GeoPandas

GeoPandas

GeoPandas is an open source project to make working with geospatial data in Python easier.

Approach:

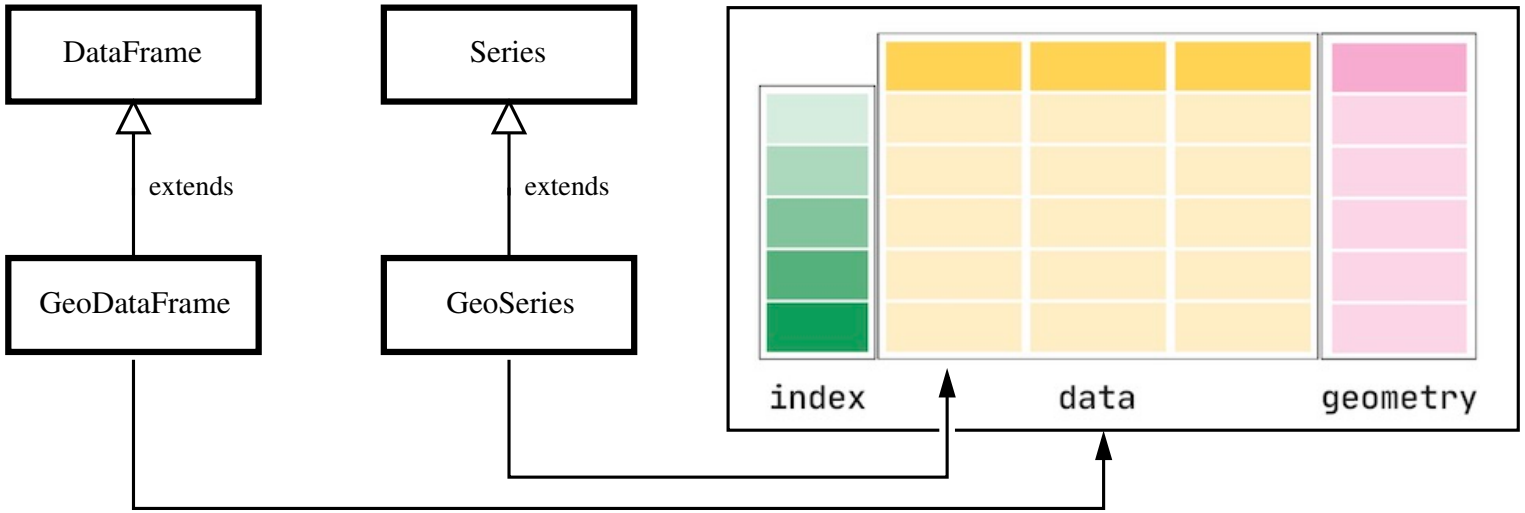
- Extend the datatypes used by Pandas to allow spatial operations on geometric types.
- Geometric operations are performed by shapely.
- Geopandas further depends on fiona for file access and matplotlib for plotting.

Installation

```
prompt >> pip3 install geopandas
```

Working with GeoPandas Dataframes

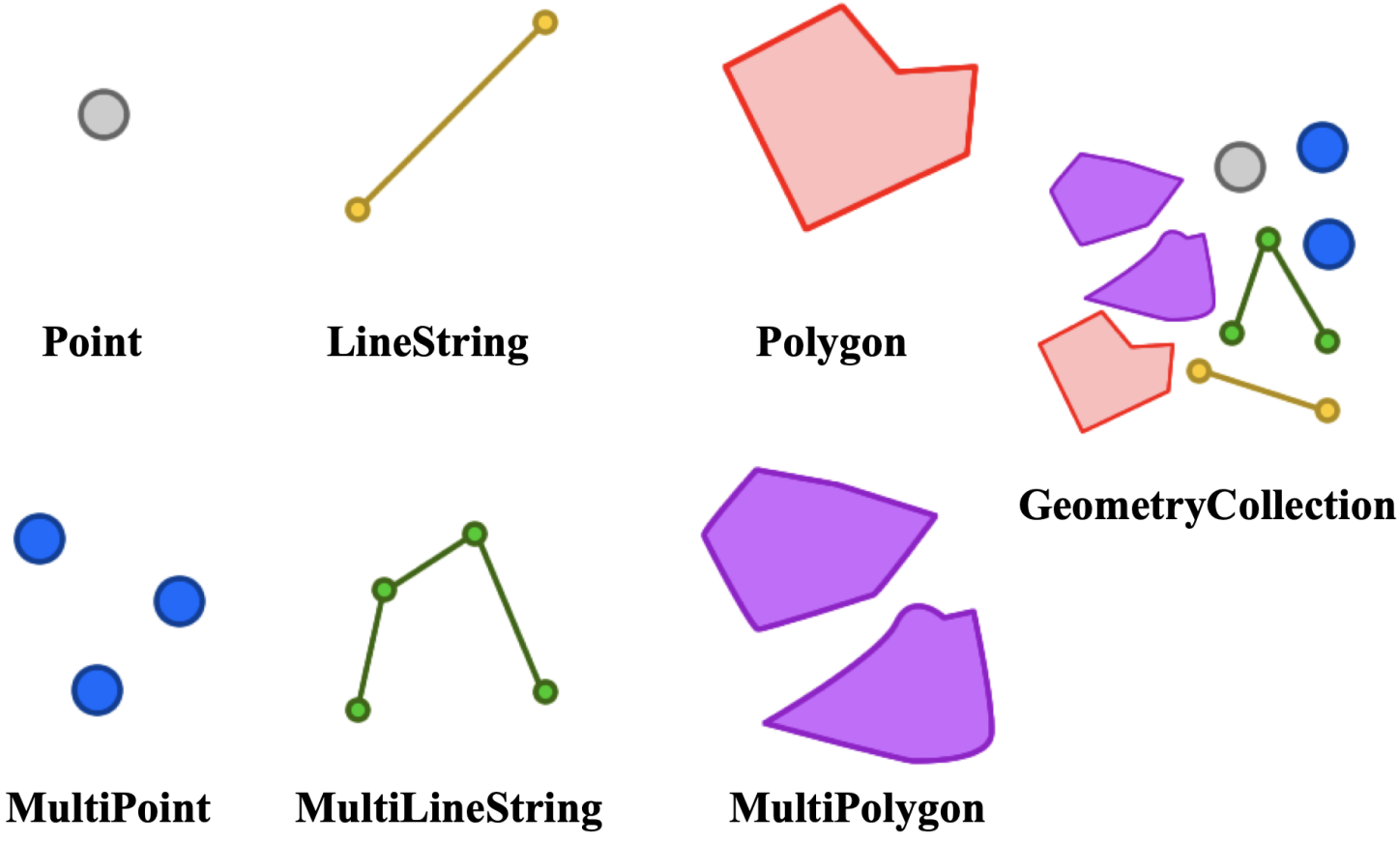
Core Modeling Concepts and Data Structure:



- GeoSeries handle geometries (points, polygons, etc).
- GeoDataFrames store geometry columns and perform spatial operations. They can be assembled from geopandas.GeoSeries.

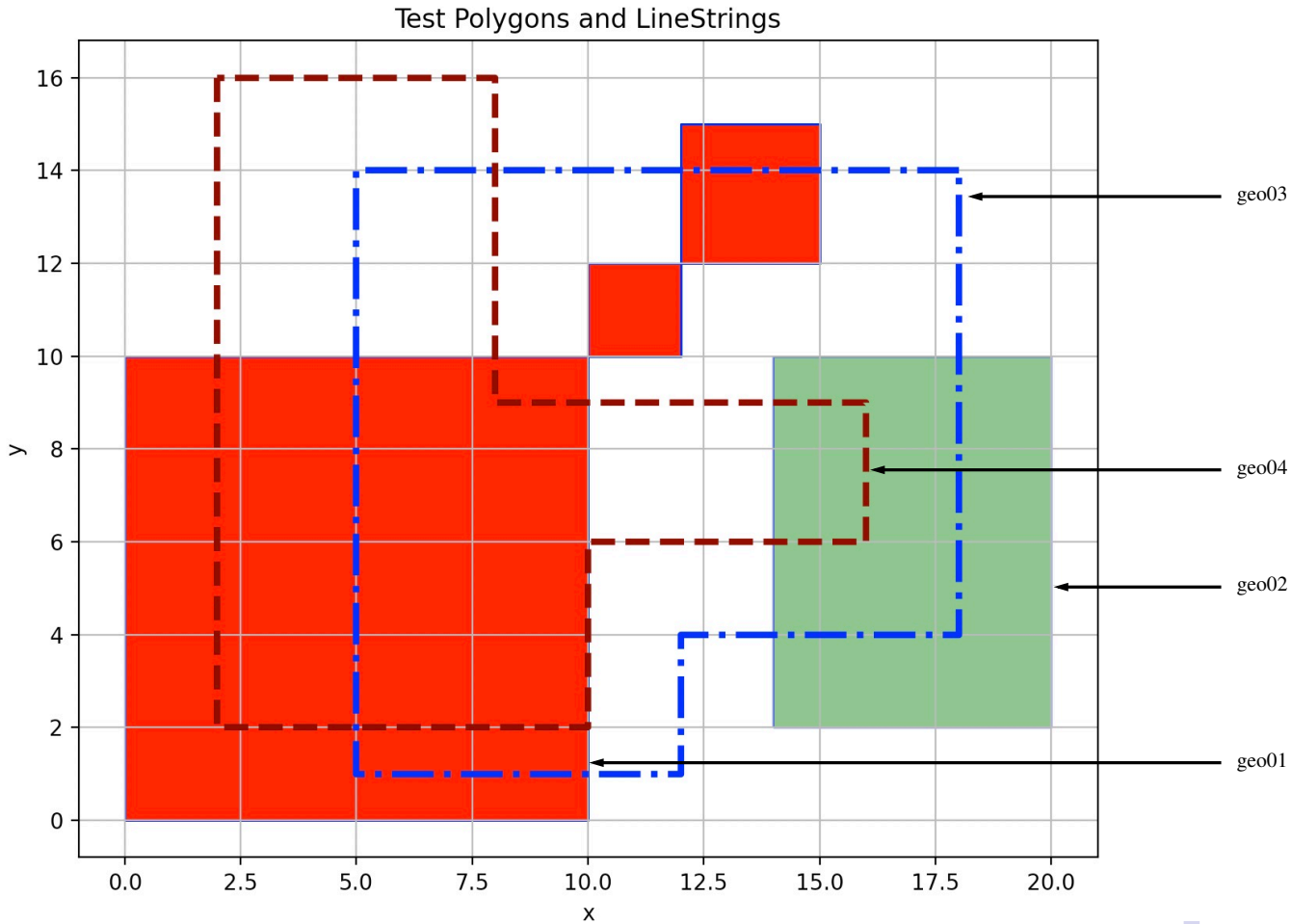
Working with GeoPandas Dataframes

Geometric Objects: points, multi-points, lines, multi-lines, polygons, multi-polygons.



Example 10: Manual Specification of Geometric Shapes

Example 10: Manual specification of polygon and linestring shapes ...



Example 10: Manual Specification of Geometric Shapes

Part I: Problem Setup

```
1   # ========================================================================
2   # TestGeoSeries01.py. Manual assembly of simple geometries.
3   #
4   # Written by: Mark Austin                                        February 2023
5   # ========================================================================
6
7   import geopandas
8   from geopandas import GeoSeries
9   from shapely.geometry import Polygon
10  from shapely.geometry import LineString
11
12  import matplotlib.pyplot as plt
13
14  # ==============================
15  # main method ...
16  # ==============================
17
18  def main():
19      print("--- Enter TestGeoSeries01.main()              ... ");
20      print("--- ======================================== ... ");
21
22      print("--- Part 01: Create individual polygons ... ");
23
24      polygon01 = Polygon([   (0,0),  (10,0), (10,10),  (0,10) ] )
25      polygon02 = Polygon([ (10,10), (12,10), (12,12), (10,12) ] )
26      polygon03 = Polygon([ (12,12), (15,12), (15,15), (12,15) ] )
```

Example 10: Manual Specification of Geometric Shapes

Part I: Problem Setup (Continued) ....

```
27      polygon04 = Polygon([ (14,2), (20,2), (20,10), (14,10) ] )
28
29      print("--- Part 02: Add polygons to GeoSeries ... ");
30
31      geo01 = GeoSeries( [ polygon01, polygon02, polygon03 ]);
32      geo02 = GeoSeries( [ polygon04 ]);
33
34      print("--- Part 03: Create simple linestring GeoSeries ... ");
35
36      line01 = LineString([ (18,14), (5,14), (5,1), (12,1), (12,4), (18,4), (18,14) ] )
37      geo03  = GeoSeries( [ line01 ]);
38      line02 = LineString([ (2,16), (2,2), (10,2), (10,6), (16,6), (16,9), (8,9), (8,16),
39      geo04  = GeoSeries( [ line02 ]);
40
41      print("--- Part 04: Print GeoSeries info and contents ... ");
42
43      print(geo01)
44      print(geo02)
45
46      print("--- Part 05: Area and boundary of geo01 ... ");
47
48      print(geo01.area)
49      print(geo01.boundary)
50
51      print("--- Part 06: Area and boundary of geo02 ... ");
52
53      print(geo02.area)
54      print(geo02.boundary)
```

Example 10: Manual Specification of Geometric Shapes

Part I: Problem Setup (Continued) ....

```
55
56      print("--- Part 07: Spatial relationship of geo01 through geo04 ... ");
57
58      print("--- Compute intersection of (lines) geo03 and geo04 ...")
59      geo02a = geo03.intersects(geo04)
60      print("---   geo03.intersects(geo04) --> {:s} ...".format( str( geo02a[0] ) ))
61      geo02b = geo03.intersection(geo04)
62      print("---   geo03.intersection(geo04) --> {:s} ...".format( str( geo02b[0] ) ))
63
64      print("--- Compute intersection of (region) geo01 and (lines) geo03 and geo04 ...")
65      geo02c = geo01.intersection(geo03)
66      print("---   geo01.intersection(geo03) --> {:s} ...".format( str( geo02c[0] ) ))
67      geo02d = geo01.intersection(geo04)
68      print("---   geo01.intersection(geo04) --> {:s} ...".format( str( geo02d[0] ) ))
69
70      print("--- Compute intersection of (region) geo02 and (lines) geo03 and geo04 ...")
71      geo02e = geo02.intersection(geo03)
72      print("---   geo02.intersection(geo03) --> {:s} ...".format( str( geo02e[0] ) ))
73      geo02f = geo02.intersection(geo04)
74      print("---   geo02.intersection(geo04) --> {:s} ...".format( str( geo02f[0] ) ))
75
76      print("--- Part 08: Plot polygons ... ");
77
78      ax = geo01.plot( color='blue', edgecolor='black')
79      ax.set_aspect('equal')
80      ax.set_title("Test Polygons and LineStrings")
```

Example 10: Manual Specification of Geometric Shapes

Part I: Problem Setup (Continued) ....

```
81
82      # Plot polygons ...
83
84      geo01.plot(ax=ax, edgecolor='blue', color='red',   alpha= 1.0 )
85      geo02.plot(ax=ax, edgecolor='blue', color='green', alpha= 0.5 )
86
87      # Plot linestring ...
88
89      geo03.plot(ax=ax, color='blue',   alpha= 1.0, linewidth=3.0, linestyle='dashdot' )
90      geo04.plot(ax=ax, color='maroon', alpha= 1.0, linewidth=3.0, linestyle='dashed' )
91
92      plt.xlabel('x')
93      plt.ylabel('y')
94      plt.grid(True)
95      plt.show()
96
97      print("--- ======================================== ... ");
98      print("--- Leave TestGeoSeries01.main()            ... ");
99
100 # ================================================
101 # call the main method ...
102 # ================================================
103
104 main()
```

Source Code: See: python-code.d/geopandas/

Example 10: Manual Specification of Geometric Shapes

Part II: Abbreviated Output:

```
--- Enter TestGeoSeries01.main()              ...
--- Part 01: Create individual polygons ...
--- Part 02: Add polygons to GeoSeries ...
--- Part 03: Create simple linestring GeoSeries ...

--- Part 04: Print GeoSeries info and contents ...

0    POLYGON ((0.00000 0.00000, 10.00000 0.00000, 1...
1    POLYGON ((10.00000 10.00000, 12.00000 10.00000...
2    POLYGON ((12.00000 12.00000, 15.00000 12.00000...
dtype: geometry
0    POLYGON ((14.00000 2.00000, 20.00000 2.00000, ...
dtype: geometry

--- Part 05: Area and boundary of geo01 ...

0    100.0
1      4.0
2      9.0
dtype: float64
0    LINESTRING (0.00000 0.00000, 10.00000 0.00000,...
1    LINESTRING (10.00000 10.00000, 12.00000 10.000...
2    LINESTRING (12.00000 12.00000, 15.00000 12.000...
dtype: geometry
```

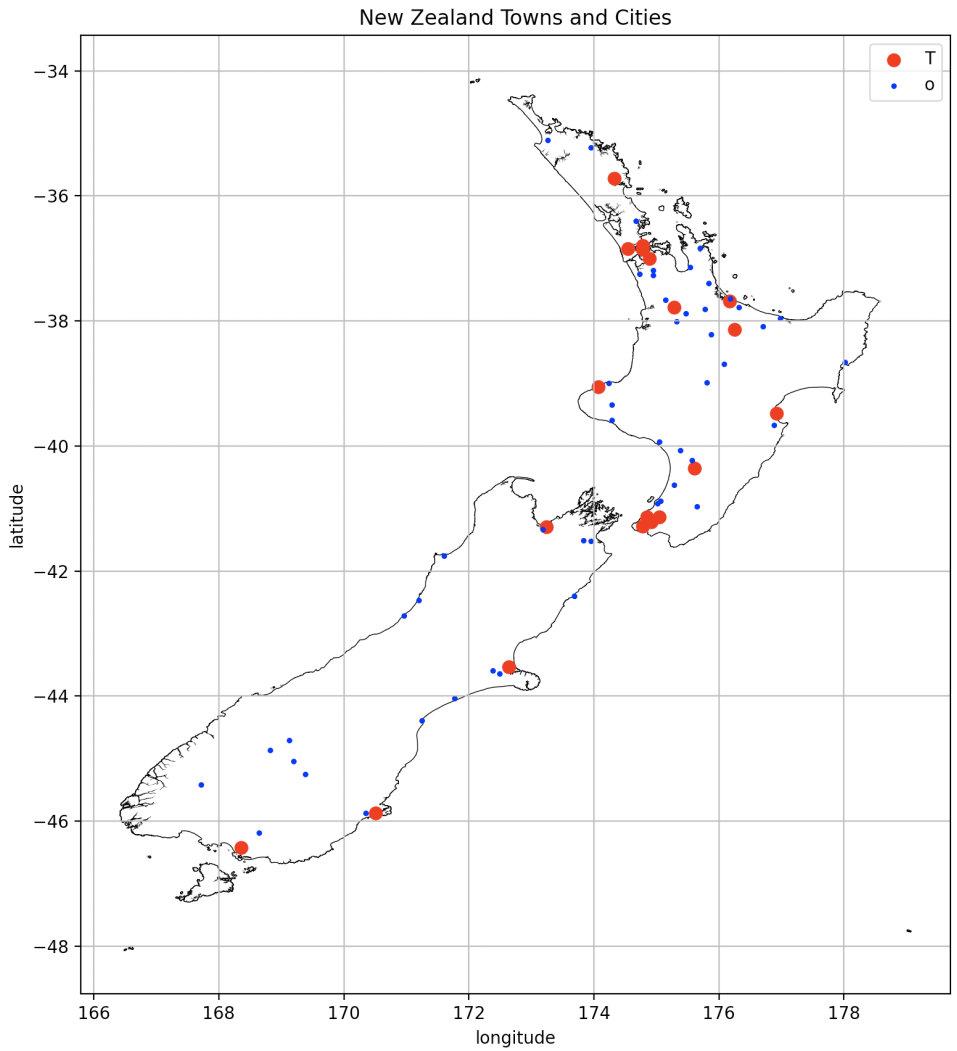
Example 10: Manual Specification of Geometric Shapes

Part II: Abbreviated Output:

```
--- Part 06: Area and boundary of geo02 ...

0    48.0
dtype: float64
0    LINESTRING (14.00000 2.00000, 20.00000 2.00000...
dtype: geometry

--- Part 07: Spatial relationship of geo01 through geo04 ...

--- Compute intersection of (lines) geo03 and geo04 ...

---   geo03.intersects(geo04) --> True ...
---   geo03.intersection(geo04) --> MULTIPOINT (5 2, 8 14) ...

--- Compute intersection of (region) geo01 and (lines) geo03 and geo04 ...

---   geo01.intersection(geo03) --> LINESTRING (5 10, 5 1, 10 1) ...
---   geo01.intersection(geo04) --> MULTILINESTRING ((10 2, 10 6), (2 10, 2 2, 10 2), (10 9, 8 9, 8 10))

--- Compute intersection of (region) geo02 and (lines) geo03 and geo04 ...

---   geo02.intersection(geo03) --> LINESTRING (14 4, 18 4, 18 10) ...
---   geo02.intersection(geo04) --> LINESTRING (14 6, 16 6, 16 9, 14 9) ...

--- Part 08: Plot polygons ...
--- Leave TestGeoSeries01.main()              ...
```

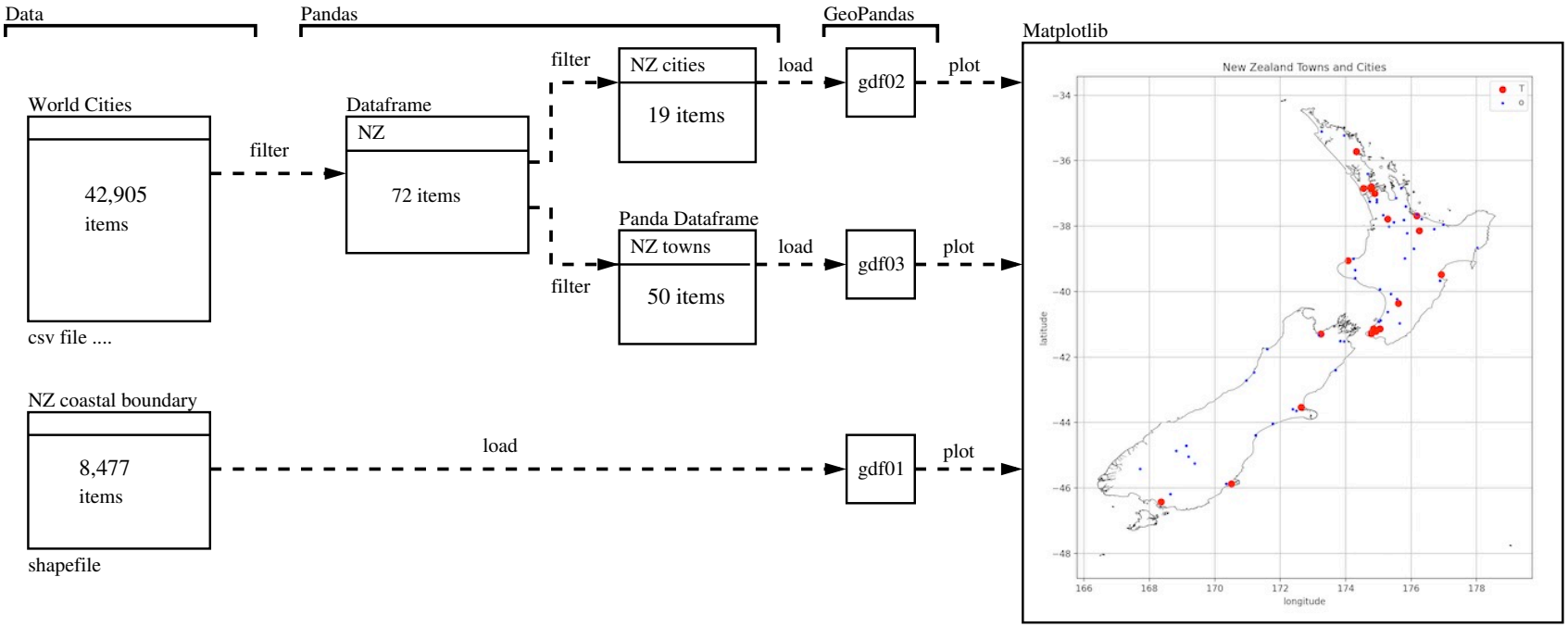
Example 11: Towns and Cities in New Zealand

Example 11: Towns and Cities in New Zealand.



Example 11: Towns and Cities in New Zealand

Part I: Data Processsing Pipeline:



Example 11: Towns and Cities in New Zealand

Part II: Program Source Code:

```
1  # ================================================================
2  # TestNewZealandDataModel.py. Assemble data model for towns and cities in
3  # New Zealand.
4  #
5  # Written by: Mark Austin                                  February 2023
6  # ================================================================
7
8  from pandas import DataFrame
9  from pandas import Series
10 from pandas import read_csv
11
12 import numpy as np
13 import pandas as pd
14 import geopandas
15
16 import matplotlib.pyplot as plt
17
18 # ==============================
19 # main method ...
20 # ==============================
21
22 def main():
23     print("--- Enter TestNewZealandDataModel.main()     ... ");
24     print("--- ======================================== ... ");
25
26     print("--- Part 01: Load world city dataset ... ");
```

Example 11: Towns and Cities in New Zealand

Part II: Program Source Code: (Continued) ...

```
27
28      df = pd.read_csv("../data/cities/world-cities.csv")
29
30      print("--- Part 02: Print dataframe info and contents ... ");
31
32      print(df)
33      print(df.info() )
34
35      print("--- Part 03: Filter dataframe to keep only cities from New Zealand ... ")
36
37      options = ['New Zealand']
38      dfNZ       = df [ df['country'].isin(options) ].copy()
39
40      print("--- Part 04: Filter data to find NZ cities and towns ... ")
41
42      dfNZcities = dfNZ [ (dfNZ['population'] > 40000) ].sort_values( by=['population'] )
43
44      dfNZtowns  = dfNZ [ (dfNZ['population'] > 1000) & (dfNZ['population'] < 40000) ]
45      dfNZtowns  = dfNZtowns.sort_values( by=['population'] )
46
47      print('--- New Zealand Cities:\n', dfNZcities )
48      print('--- New Zealand Towns:\n', dfNZtowns )
49
50      print("--- Part 05: Read NZ coastline shp file into geopandas ... ")
51
52      nzboundarydata = geopandas.read_file("../data/geography/nz/Coastline02.shp")
53      print(nzboundarydata)
```

Example 11: Towns and Cities in New Zealand

Part II: Program Source Code: (Continued) ...

```
55      print("--- Part 06: Define geopandas dataframes ... ")
56
57      gdf01 = geopandas.GeoDataFrame(nzboundarydata)
58      gdf02 = geopandas.GeoDataFrame( dfNZcities,
59                  geometry=geopandas.points_from_xy(dfNZcities.lng, dfNZcities.lat))
60      gdf03 = geopandas.GeoDataFrame(  dfNZtowns,
61                  geometry=geopandas.points_from_xy( dfNZtowns.lng, dfNZtowns.lat))
62
63      print(gdf01.head())
64
65      print("--- Part 07: Create boundary map for New Zealand ... ")
66
67      # We can now plot our ``GeoDataFrame``.
68
69      ax = gdf01.plot( color='white', edgecolor='black')
70      ax.set_aspect('equal')
71      ax.set_title("New Zealand Towns and Cities")
72
73      gdf01.plot(ax=ax, color='white')
74
75      gdf02.plot(ax=ax, color =  'red', markersize = 50, label= 'Cities')
76      gdf03.plot(ax=ax, color = 'blue', markersize =  5, label= 'Towns' )
77
78      plt.legend('Towns/Cities:')
79      plt.xlabel('longitude')
80      plt.ylabel('latitude')
```

Example 11: Towns and Cities in New Zealand

Part II: Program Source Code: (Continued) ...

```
81      plt.grid(True)
82      plt.show()
83
84      print("--- ======================================== ... ");
85      print("--- Leave TestNewZealandDataModel.main()     ... ");
86
87  # ================================================
88  # call the main method ...
89  # ================================================
90
91  main()
```

Source Code: See: python-code.d/geopandas/

Example 11: Towns and Cities in New Zealand

Part III: Abbreviated Output:

```
--- Enter TestNewZealandDataModel.main()     ...
--- ======================================== ...
--- Part 01: Load world city dataset ...
--- Part 02: Print dataframe info and contents ...
             city  city_ascii      lat  ... capital population         id
0           Tokyo       Tokyo  35.6839  ... primary 39105000.0 1392685764
1         Jakarta     Jakarta  -6.2146  ... primary 35362000.0 1360771077
...           ...         ...      ...  ...     ...        ...        ...
42903 Timmiarmiut Timmiarmiut  62.5333  ...     NaN       10.0 1304206491
42904     Nordvik     Nordvik  74.0165  ...     NaN        0.0 1643587468
[42905 rows x 11 columns]

<class 'pandas.core.frame.DataFrame'>
RangeIndex: 42905 entries, 0 to 42904
Data columns (total 11 columns):
 #   Column      Dtype             #   Column      Dtype
---  ------      -----            ---  ------      -----
 0   city        object            6   iso3        object
 1   city_ascii  object            7   admin_name  object
 2   lat         float64           8   capital     object
 3   lng         float64           9   population  float64
 4   country     object           10   id          int64
 5   iso2        object
dtypes: float64(3), int64(1), object(7)
memory usage: 3.6+ MB
```

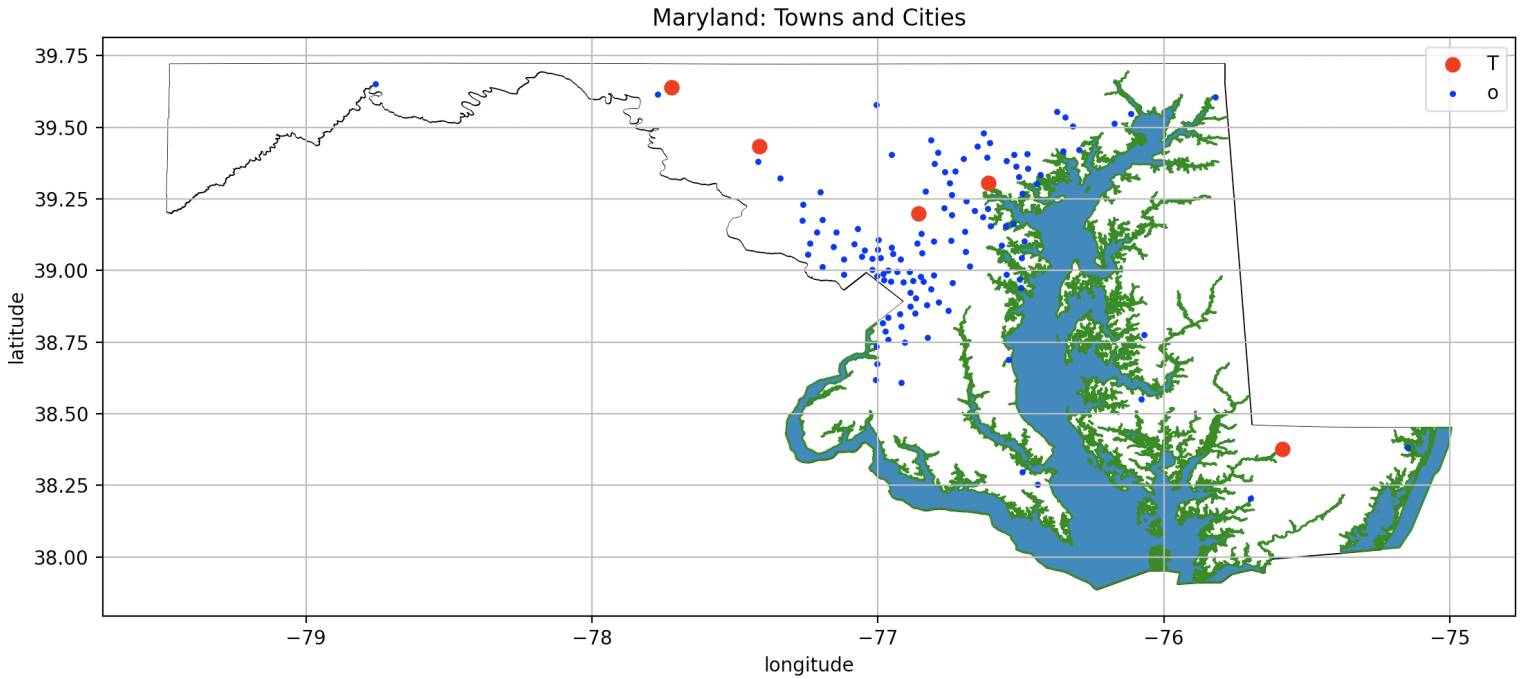
Example 11: Towns and Cities in New Zealand

Part III: Abbreviated Output (Continued) ...

```
--- Part 03: Filter dataframe to keep only cities from New Zealand ...
--- Part 04: Filter data to find NZ cities and towns ...

--- New Zealand Cities:
                  city        city_ascii  ...  population          id
14169        Upper Hutt        Upper Hutt  ...     41000.0  1554000042
6159       Invercargill      Invercargill  ...     47625.0  1554148942
.....
741          Wellington        Wellington  ...    418500.0  1554772152
516            Auckland          Auckland  ...   1346091.0  1554435911
[19 rows x 11 columns]

--- New Zealand Towns:
                  city       city_ascii  ...  population          id
42142         Kaikoura         Kaikoura  ...      2210.0  1554578431
.....
14309        Whanganui        Whanganui  ...     39400.0  1554827998
[50 rows x 11 columns]

--- Part 05: Read NZ coastline shp file into geopandas ...
0     POLYGON ((174.00369 -40.66489, 174.00372 -40.6...
.....
8476  POLYGON ((173.01384 -34.39348, 173.01395 -34.3...
[8477 rows x 1 columns]
--- Part 07: Create boundary map for New Zealand ...
--- ======================================== ...
--- Leave TestNewZealandDataModel.main()     ...
```

Example 12: Towns and Cities in Maryland

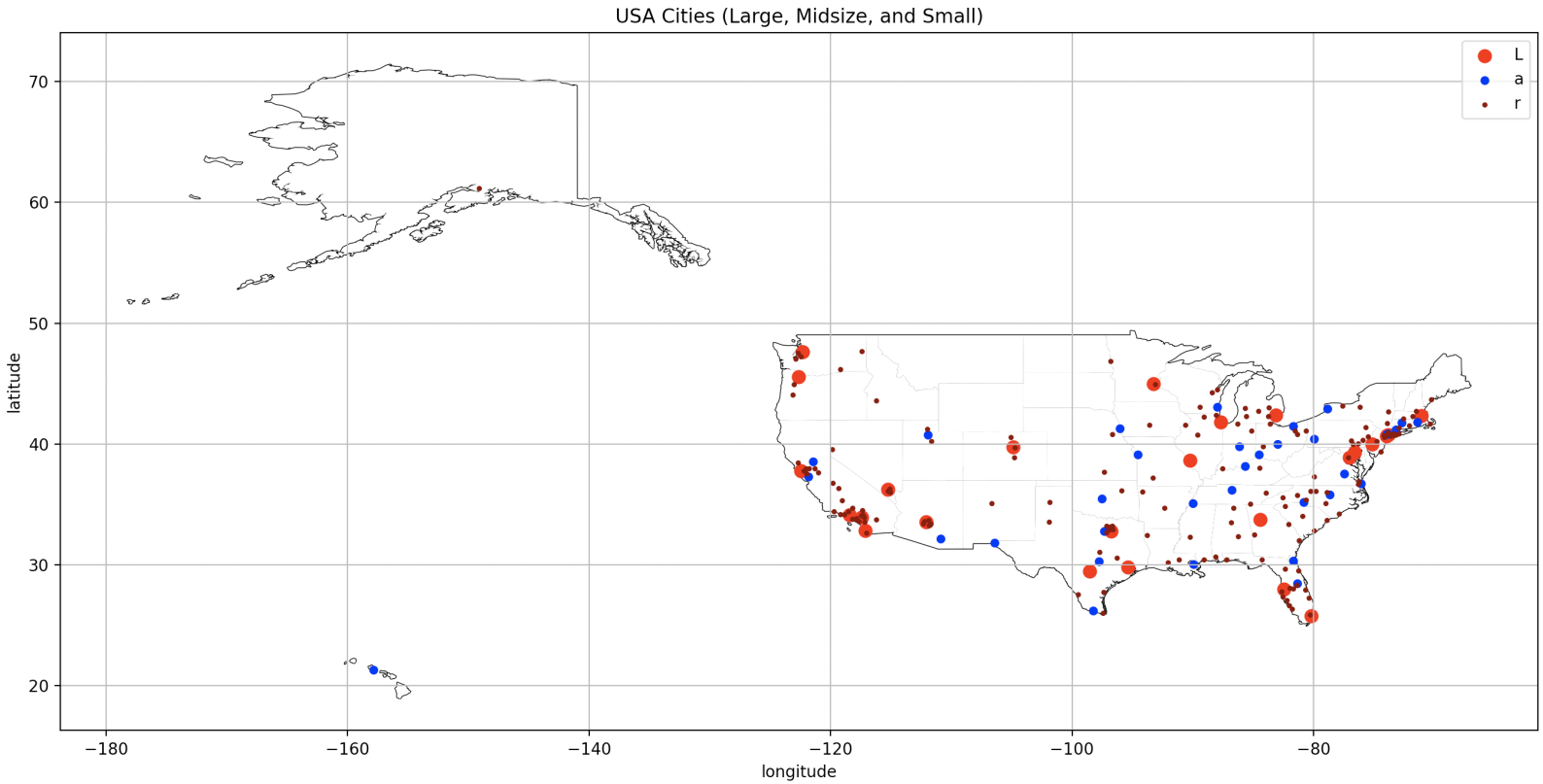
Example 12: Towns and Cities in Maryland.



Cities: Columbia (pop. 103991), Salisbury (pop. 106447), Frederick (pop. 156787), Hagerstown (pop. 184755), Baltimore (pop. 2106068).

Example 13: Large, Midsize, and Small US Cities

Example 13: Large, Midsize, and Small US Cities

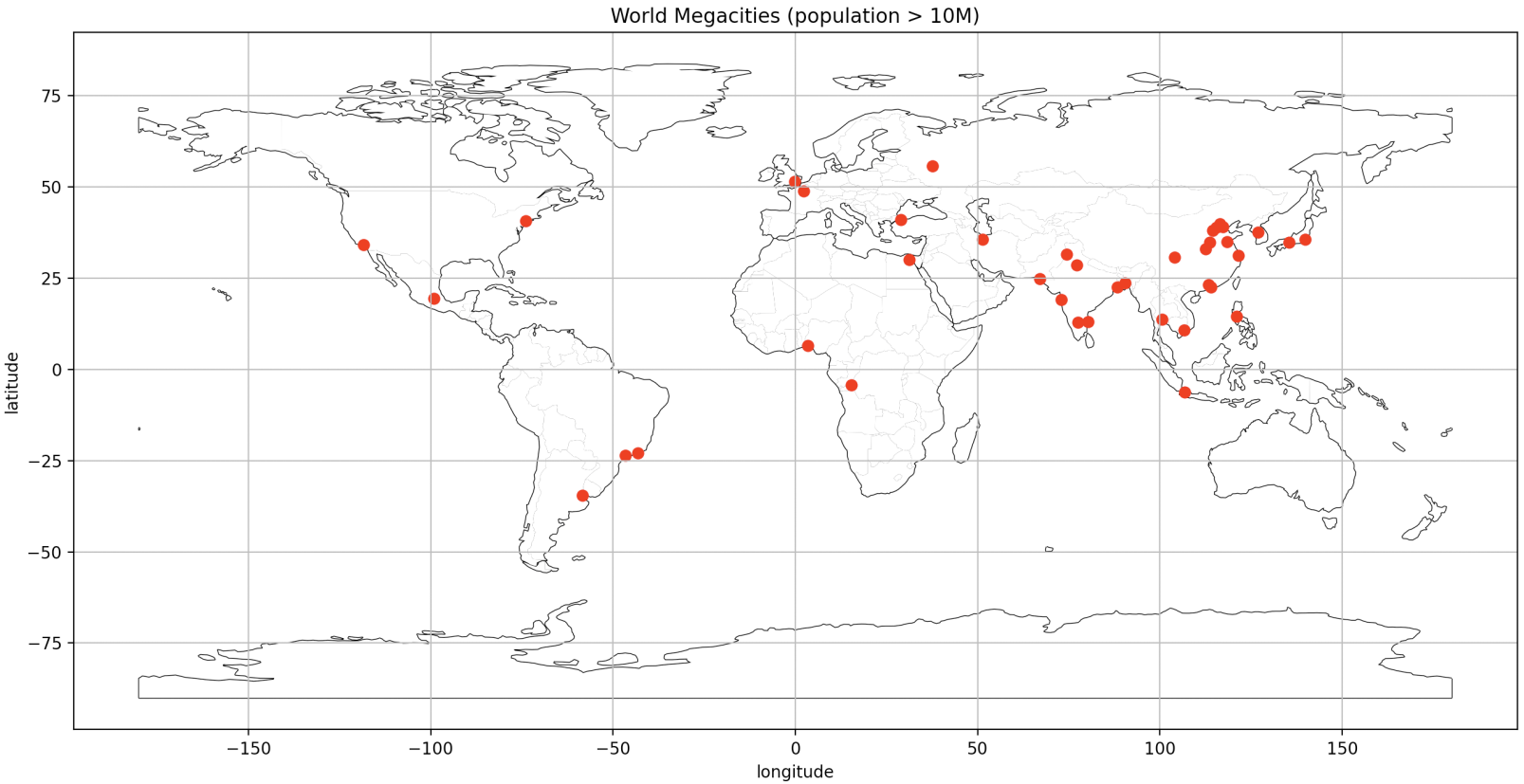


Cities: 26 large (pop. $>$ 2M), 34 midsize (800k $<$ pop. $<$ 2M), 172 small (200k $<$ pop. $<$ 800k).

Case Study

(GeoModeling the Worlds Megacities)

Case Study: GeoModeling the World's Megacities



Case Study: GeoModeling the World's Megacities

```
--- Part 02: Filter to keep only large cities (pop. > 10M) ...

              city        city_ascii  ...  population          id
0            Tokyo             Tokyo  ...  39105000.0  1392685764
1          Jakarta           Jakarta  ...  35362000.0  1360771077
2            Delhi             Delhi  ...  31870000.0  1356872604
3           Manila            Manila  ...  23971000.0  1608618140
4        São Paulo         Sao Paulo  ...  22495000.0  1076532519
5            Seoul             Seoul  ...  22394000.0  1410836482
6           Mumbai            Mumbai  ...  22186000.0  1356226629
7         Shanghai          Shanghai  ...  22118000.0  1156073548
8      Mexico City       Mexico City  ...  21505000.0  1484247881
9        Guangzhou         Guangzhou  ...  21489000.0  1156237133
10           Cairo             Cairo  ...  19787000.0  1818253931
11         Beijing           Beijing  ...  19437000.0  1156228865
12        New York          New York  ...  18713220.0  1840034016
13         Kolkāta           Kolkata  ...  18698000.0  1356060520
14          Moscow            Moscow  ...  17693000.0  1643318494
15          Bangkok           Bangkok  ...  17573000.0  1764068610

... details removed ...

33           London            London  ...  11120000.0  1826645935
34            Paris             Paris  ...  11027000.0  1250015082
35          Tianjin           Tianjin  ...  10932000.0  1156174046
36            Linyi             Linyi  ...  10820000.0  1156086320
37     Shijiazhuang      Shijiazhuang  ...  10784600.0  1156217541
38        Zhengzhou         Zhengzhou  ...  10136000.0  1156183137
39          Nanyang           Nanyang  ...  10013600.0  1156192287
```

Case Study: GeoModeling the World's Megacities

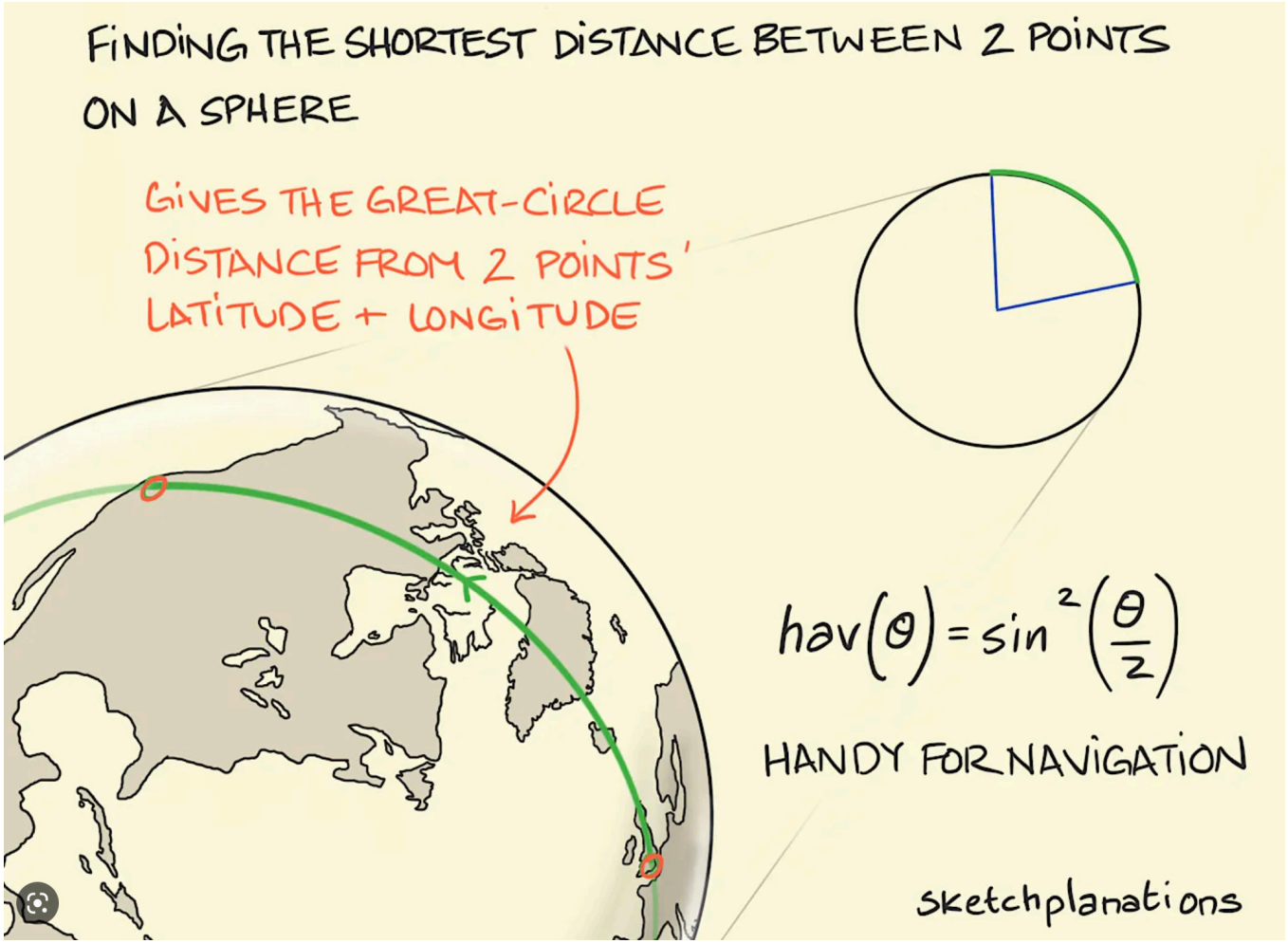
Simplified Spatial Data Model: name, latitude, longitude, population, capital?, state.

Case Study: GeoModeling the World's Cities

Collection of City Object Models

Case Study: GeoModeling the World's Cities

Haversine Formula



Case Study: GeoModeling the World's Cities

Haversine Formula: Python code ...

Case Study: Modeling the World's Cities

Compute Distance between Baltimore and NYC

References

- ....
- ....