GeoPandas

Easy, fast and scalable geospatial analysis in Python

Joris Van den Bossche, FOSDEM, February 4, 2018

https://github.com/jorisvandenbossche/talks/

@jorisvdbossche
About me

Joris Van den Bossche

- PhD bio-science engineer, air quality research
- pandas core dev, geopandas maintainer
- Currently working at the Université Paris-Saclay Center for Data Science (Inria)

https://github.com/jorisvandenbossche

@jorisvdbossche
Raster vs vector data
Raster vs vector data

-> in this talk: focus on vector data
Raster vs vector data

-> in this talk: focus on vector data

-> simple features (points, linestrings, polygons) with attributes
Open source geospatial software
GDAL / OGR

Geospatial Data Abstraction Library.

- The swiss army knife for geospatial.
- Read and write Raster (GDAL) and Vector (OGR) datasets
- More than 200 (mainly) geospatial formats and protocols.

*Slide from "GDAL 2.2 What's new?" by Even Rouault (CC BY-SA)*
GEOS

Geometry Engine Open Source

- C/C++ port of a subset of Java Topology Suite (JTS)
- Most widely used geospatial C++ geometry library
- Implements geometry objects (simple features), spatial predicate functions and spatial operations

Used under the hood by many applications (QGIS, PostGIS, MapServer, GRASS, GeoDjango, ...)

geos.osgeo.org
Python geospatial packages
Python geospatial packages

Interfaces to widely used libraries:

- Python bindings to GDAL/OGR (from osgeo import gdal, ogr)
- pyproj: python interface to PROJ.4.
- Pythonic binding to GDAL/OGR:
  - rasterio for GDAL
  - fiona for OGR
- shapely: python package based on GEOS.
Shapely

Python package for the manipulation and analysis of geometric objects

Pythonic interface to GEOS
Shapely

Python package for the manipulation and analysis of geometric objects

Pythonic interface to GEOS

```python
>>> from shapely.geometry import Point, LineString, Polygon

>>> point = Point(1, 1)
>>> line = LineString([(0, 0), (1, 2), (2, 2)])
>>> poly = line.buffer(1)

>>> poly.contains(point)
True
```
Shapely

Python package for the manipulation and analysis of geometric objects

Pythonic interface to GEOS

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True
```

Nice interface to GEOS, but: single objects, no attributes
One of the packages driving the growing popularity of Python for data science, machine learning and academic research:

- High-performance, easy-to-use data structures and tools
- Suited for tabular data (e.g. columnar data, spread-sheets, database tables)

```python
import pandas as pd
df = pd.read_csv("myfile.csv")
subset = df[df[\'value\'] > 0]
subset.groupby(\'key\').mean()
```
GeoPandas

Easy, fast and scalable geospatial analysis in Python
GeoPandas

Make working with geospatial data in python easier

- Started by Kelsey Jordahl in 2013
- Extends the pandas data analysis library to work with geographic objects and spatial operations
- Combines the power of whole ecosystem of (geo) tools (pandas, geos, shapely, gdal, fiona, pyproj, rtree, ...)

Documentation: http://geopandas.readthedocs.io/
Demo time!

See static version
Summary

- Read and write variety of formats (fiona, GDAL/OGR)
- Familiar manipulation of the attributes (pandas dataframe)
- Element-wise spatial predicates (intersects, within, ...) and operations (intersection, union, difference, ..) (shapely)
- Re-project your data (pyproj)
- Quickly visualize the geometries (matplotlib, descartes)
- More advanced spatial operations: spatial joins and overlays (rtree)
Summary

- Read and write variety of formats (fiona, GDAL/OGR)
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-> Interactive exploration and analysis of geospatial data
Ecosystem

**geoplot** (high-level geospatial visualization), **cartopy** (projection aware cartographic library)

**folium** (Leaflet.js maps)

**OSMnx** (python for street networks)

**PySAL** (Python Spatial Analysis Library)

**rasterio** (working with geospatial raster data)

...
GeoPandas

Easy, **fast** and scalable geospatial analysis in Python
However ...
However ... it can be slow

Timings for basic \texttt{within} and \texttt{distance} operation on 100,000 points:

\begin{verbatim}
  s.within(polygon)
  s.distance(polygon)
\end{verbatim}

\begin{figure}[h]
\centering
\begin{minipage}{0.45\textwidth}
\textbf{simple within}
\begin{tikzpicture}
\begin{axis}[
  title={simple within},
  ybar, ymajorgrids, 
  ylabel={Time (ms)},
  xlabel={geopandas},
  ymin=0, ymax=1000,
]
\addplot coordinates {
(1, 16)
(2, 27)
};
\end{axis}
\end{tikzpicture}
\end{minipage} \hfill
\begin{minipage}{0.45\textwidth}
\textbf{simple distance}
\begin{tikzpicture}
\begin{axis}[
  title={simple distance},
  ybar, ymajorgrids, 
  ylabel={Time (ms)},
  xlabel={geopandas},
  ymin=0, ymax=800,
]
\addplot coordinates {
(1, 16)
(2, 27)
};
\end{axis}
\end{tikzpicture}
\end{minipage}
\end{figure}
Comparison with PostGIS

-- What is the population and racial make-up of the neighborhoods of Manhattan?

```sql
SELECT
    neighborhoods.name AS neighborhood_name,
    SUM(census.popn_total) AS population,
    100.0 * SUM(census.popn_white) / NULLIF(SUM(census.popn_total),0) AS white_pct,
    100.0 * SUM(census.popn_black) / NULLIF(SUM(census.popn_total),0) AS black_pct
FROM nyc_neighborhoods AS neighborhoods
JOIN nyc_census_blocks AS census
ON ST_Intersects(neighborhoods.geom, census.geom)
GROUP BY neighborhoods.name
ORDER BY white_pct DESC;
```

```python
res = geopandas.sjoin(nyc_neighborhoods, nyc_census_blocks, op='intersects')
res = res.groupby('NAME')[['POPN_TOTAL', 'POPN_WHITE', 'POPN_BLACK']].sum()
res['POPN_BLACK'] = res['POPN_BLACK'] / res['POPN_TOTAL'] * 100
res['POPN_WHITE'] = res['POPN_WHITE'] / res['POPN_TOTAL'] * 100
res.sort_values('POPN_WHITE', ascending=False)
```

Disclaimer: dummy benchmark, and I am not a PostGIS expert!

Example from Boundless tutorial (CC BY SA)
Comparison with PostGIS

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Example from Boundless tutorial (CC BY SA)
Why is GeoPandas slower?

- GeoPandas stores custom Python objects in arrays
- For operations, it iterates through those objects
- Those Python objects each call the GEOS C operation
Why is GeoPandas slower?

- GeoPandas stores custom Python objects in arrays
- For operations, it iterates through those objects
- Those Python objects each call the GEOS C operation
Remove python overhead by only storing pointers to C GEOS objects and iterating in C

TL;DR: same API, but better performance and less memory use

Many thanks to Matthew Rocklin (Anaconda, Inc.) for his work!
New timings

**simple within**

**simple distance**

**distance**

**spatial join**
New timings

simple within

simple distance

distance

spatial join

<table>
<thead>
<tr>
<th></th>
<th>geopandas</th>
<th>geopandas +cython</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time</td>
<td></td>
<td></td>
</tr>
<tr>
<td>simple within</td>
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<tr>
<td>simple distance</td>
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<tr>
<td>distance</td>
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<tr>
<td>spatial join</td>
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</tbody>
</table>
Sounds interesting?

Blogpost of me and Matthew with more background:

- [https://jorisvandenbossche.github.io/blog/2017/09/19/geopandas-cython/](https://jorisvandenbossche.github.io/blog/2017/09/19/geopandas-cython/)

Try out development version (binary builds):

```bash
conda install --channel conda-forge/label/dev geopandas
```
GeoPandas

Easy, fast and **scalable** geospatial analysis in Python
A flexible library for parallelism
A flexible library for parallelism

- A parallel computing framework, written in pure Python
- Lets you work on larger-than-memory datasets
- That leverages the excellent Python ecosystem
- Using blocked algorithms and task scheduling

http://dask.pydata.org/
An experiment with taxi data

Ravi Shekhar published a blogpost Geospatial Operations at Scale with Dask and GeoPandas in which he counted the number of rides originating from each of the official taxi zones of New York City.

Matthew Rocklin re-ran the experiment with the in-development version: 3h -> 8min (see his blogpost)

dask-geopandas: experimental library with parallelized geospatial operations and joins
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dask-geopandas: experimental library with parallelized geospatial operations and joins

Demo time!
Thanks for listening!

Thanks to all contributors!

Those slides:

- [https://github.com/jorisvandenbossche/talks/](https://github.com/jorisvandenbossche/talks/)
- [jorisvandenbossche.github.io/talks/2018_FOSDEM_geopandas](http://jorisvandenbossche.github.io/talks/2018_FOSDEM_geopandas)

[http://geopandas.readthedocs.io](http://geopandas.readthedocs.io)
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