

DeepFin Investor Virtual Tutorial

Spatial Data Science with CARTO

Introductions



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at CARTO**



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**Data Scientist
at CARTO**

CARTO

Pioneers in Location Intelligence

1,200

Customers

350K

Users

150+

Team members

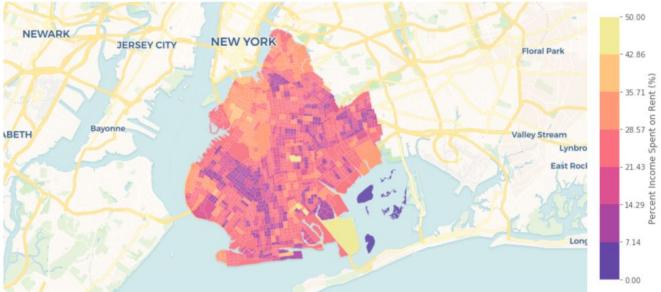
Accel

EARLYBIRD



A comprehensive platform for Spatial Analysis

```
In [18]: from cartoframes import Layer, styling
cc.map(layers=Layer('demographics_kmeans_out',
                    color='percent_income_spent_on_rent_2011_2015',
                    scheme='styling:sunset(7, "equal"),
                    legend:'Percent Income Spent on Rent (%)'));
```



Data Scientists

Integrate data, analysis and visualization into data science flows

Retail Location Insights

United States of America • Sales score ▾ All retail categories ▾ 2019 Aug ▾

LOCATIONS 294 Blocks AVG SCORE 703 / 1000

1 Order

131 Top Locations

Score	Location
1000	New York, New York
1000	New York, New York
997	New York, New York
997	New York, New York
997	New York, New York
996	New York, New York

Predicted Store Location

ALL SELECTED

Customers
3.3k Customers
2.6k Customers
2.3k Customers
2.2k Customers
224 Customers

SEARCH IN 6 CATEGORIES

Customer Online Purchase Amount \$142.43 (avg)

Customer Median Income 11K SELECTED

Income Range
6.1k
67k
130k
190k
250k

A network graph visualization showing predicted store locations as central nodes with radiating lines connecting them to various data points across a city map. The graph is dense with many connections, indicating complex spatial relationships between different locations.

Data Analysts

Tools to enable business users to analyze data and create lightweight dashboards without a single line of code.

Developers

Development of applications tailored to your needs.

CARTO is a B2B SaaS Platform

We offer our customers end-to-end solutions supported by:



Technology

Managed cloud or
on-premises
platform



Data

Open and
premium location
data streams



Services

Ongoing enablement
programs and custom
engagements

Why CARTO?

30%

30%

20%

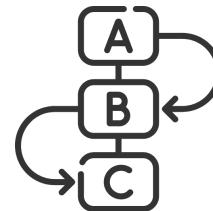
20%



Discovering data useful
for their analysis



Evaluating and
purchasing data



ETLing the data
into common
structures



Analyzing, doing
feature extraction and
modeling

	CARTO	ESRI	OPEN SOURCE
Data access	✓ Data Observatory	◆ Demographics, Landscape	◆ POI (OSM), Demographics
Viz	✓ CARTOframes	✓	◆ Geopandas, Folium
Geo-functions	✓ CARTOframes	✓	◆ Geopandas, Shapely, QGIS
LBS services	✓ CARTOframes	✓	◆ Openrouteservice
Geocoding Route engine Isochrones			
Easy to integrate with other DS tools	✓	◆	◆
Python SQL			

Market-leaders trust CARTO

What is Spatial Data Science?

09:10 a.m. - 09:40 a.m.

“Spatial data science treats location, distance, and spatial interaction as core aspects of the data”
(Luc Anselin)

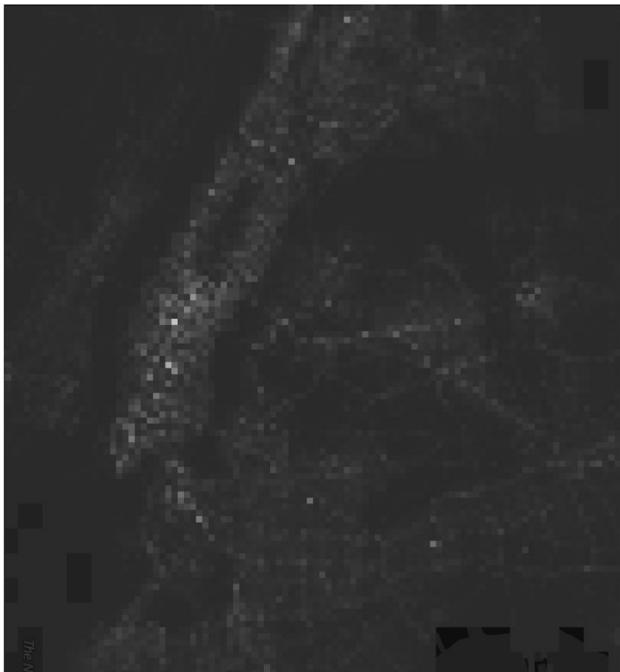


Spatial data comes in all forms and shapes

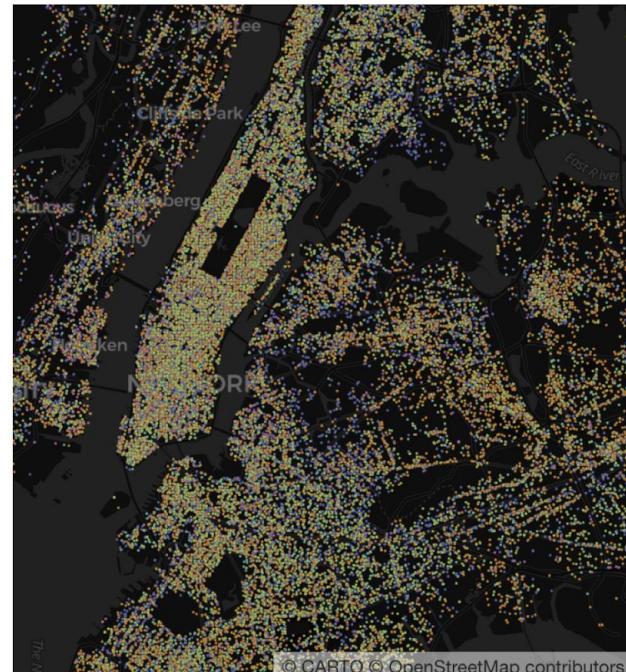
MEDIAN HOUSEHOLD INCOME



NUMBER OF VISITORS FROM GPS SOURCES



POI LOCATIONS BY CATEGORY



Spatial dependence

"Everything is related to everything else, but near things are more related than distant things." (Tobler, 1970)

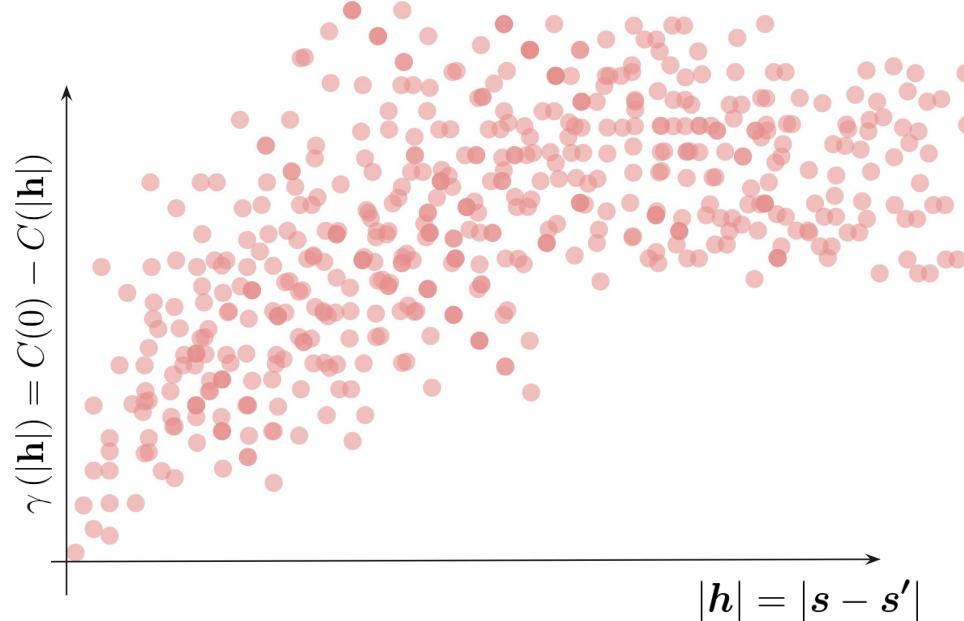
1. CONTINUOUS PROCESSES

A **Gaussian Processes (GP)** is parameterized by a mean function and covariance function

- as $|\mathbf{h}| = |s - s'| \uparrow$ then $C(\cdot) \downarrow$
- $C(\cdot)$ depends on some parameters

e.g.

$$C(|\mathbf{h}|) = \sigma^2 \exp\left(-\frac{1}{\rho} |\mathbf{h}|\right)$$



Spatial dependence

“Everything is related to everything else, but near things are more related than distant things.” (Tobler, 1970)

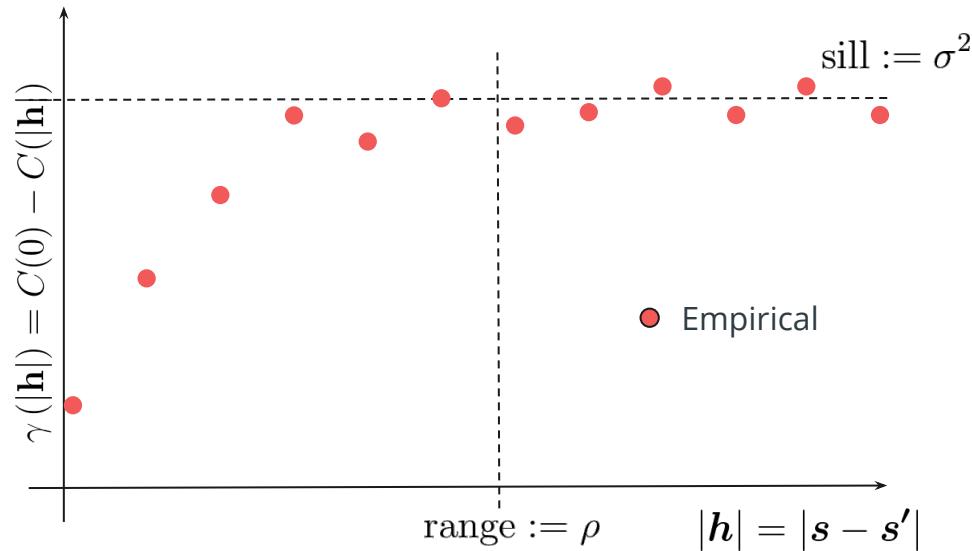
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Spatial dependence

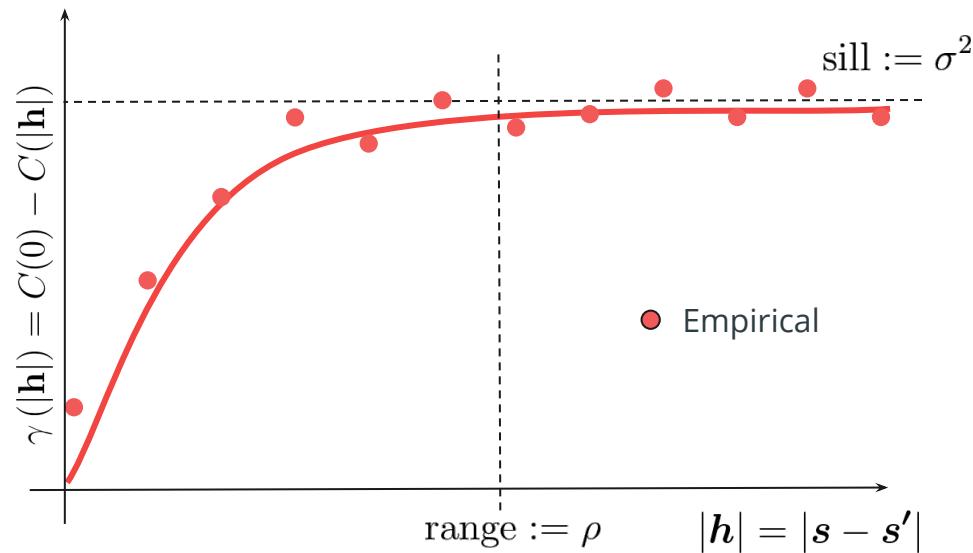
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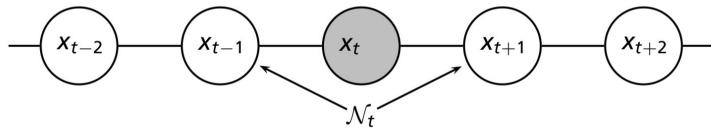
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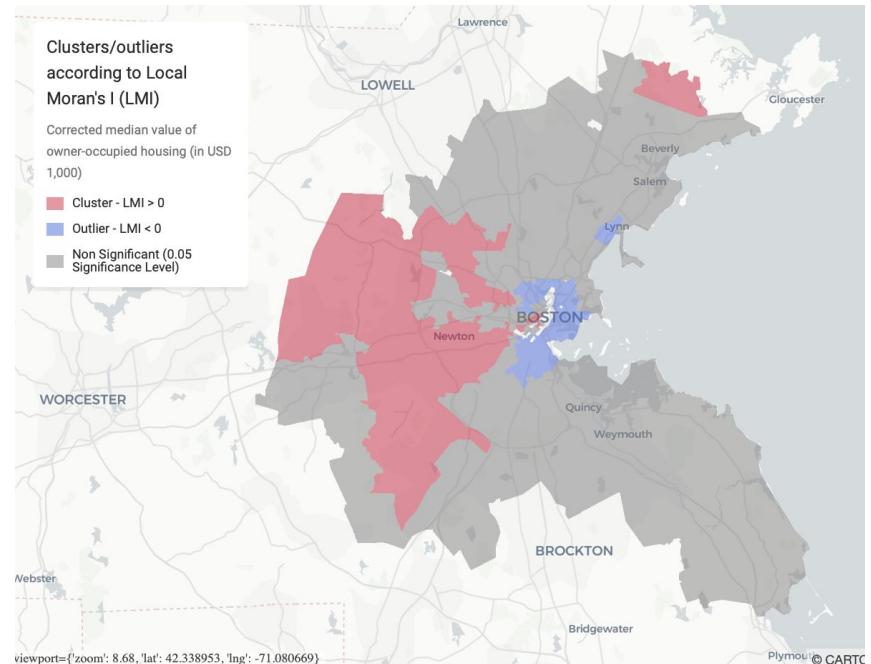
2. DISCRETE PROCESSES

- Neighborhood structures: **Gaussian Markov**

Random Fields (GMRF)



- **Autocorrelation statistics** (e.g. Moran's I)

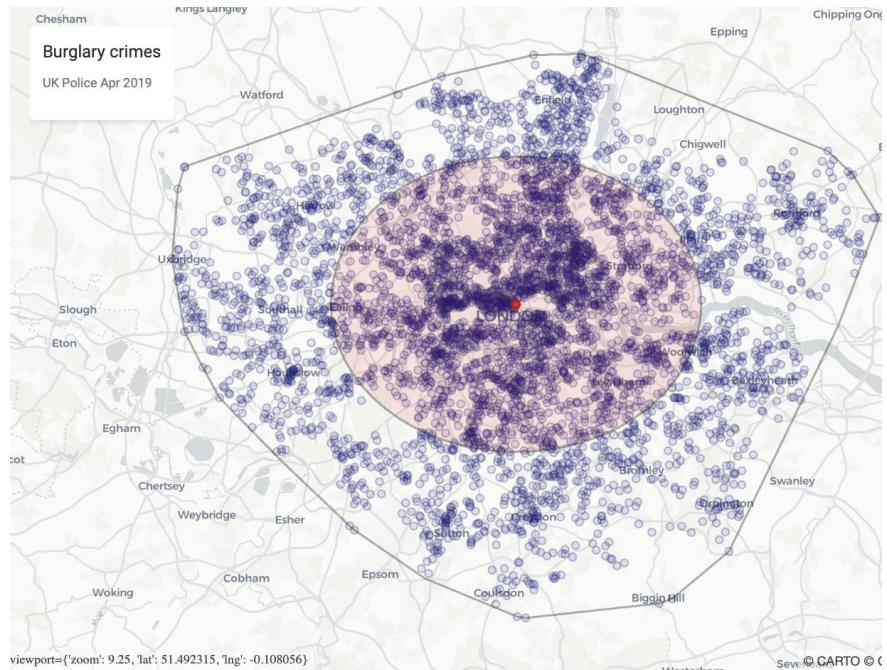


Spatial dependence

"Everything is related to everything else, but near things are more related than distant things." (Tobler, 1970)

3. POINT PATTERNS

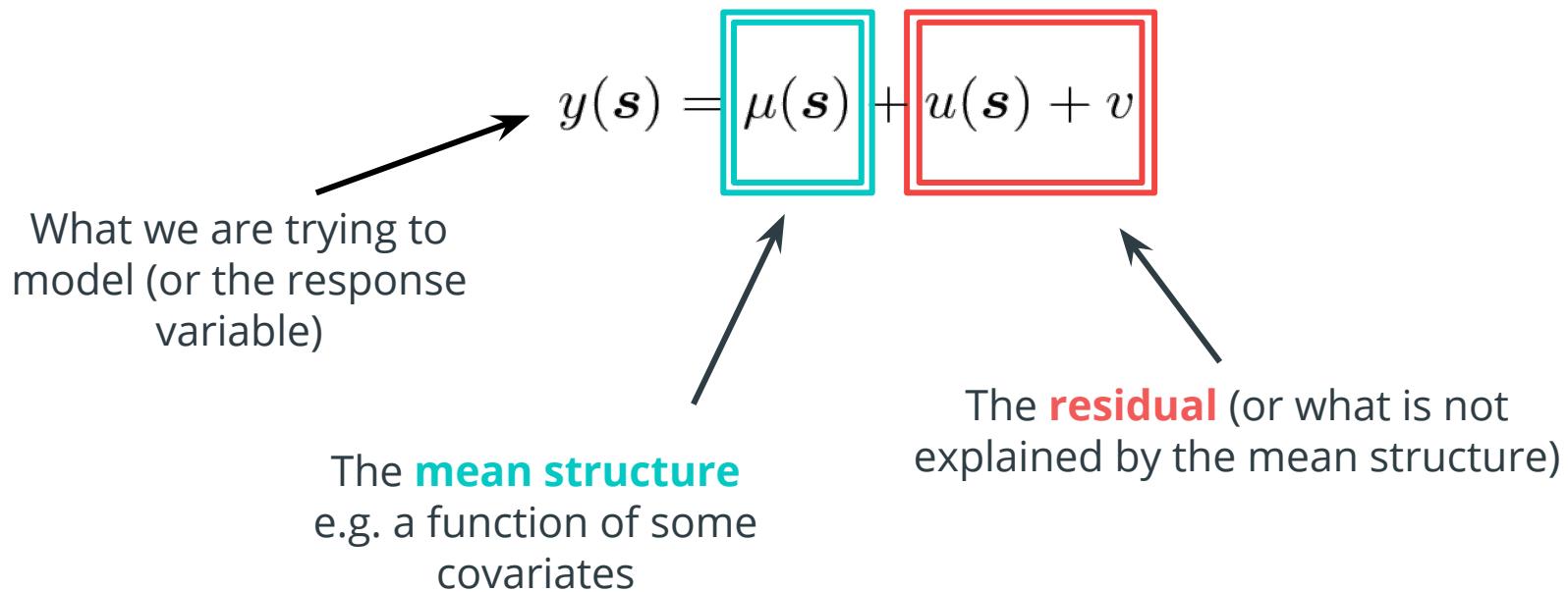
- Complete Spatial Randomness
- Summary statistics
- Nearest neighbor analysis (G-function, K-function, etc.)





Spatial Modeling: Leveraging Location in Prediction

Spatial modelling

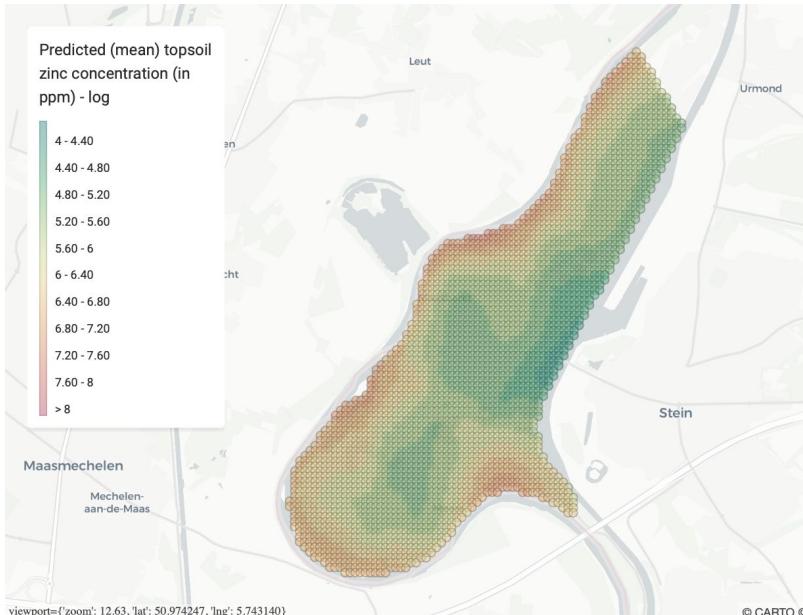


Spatial modelling

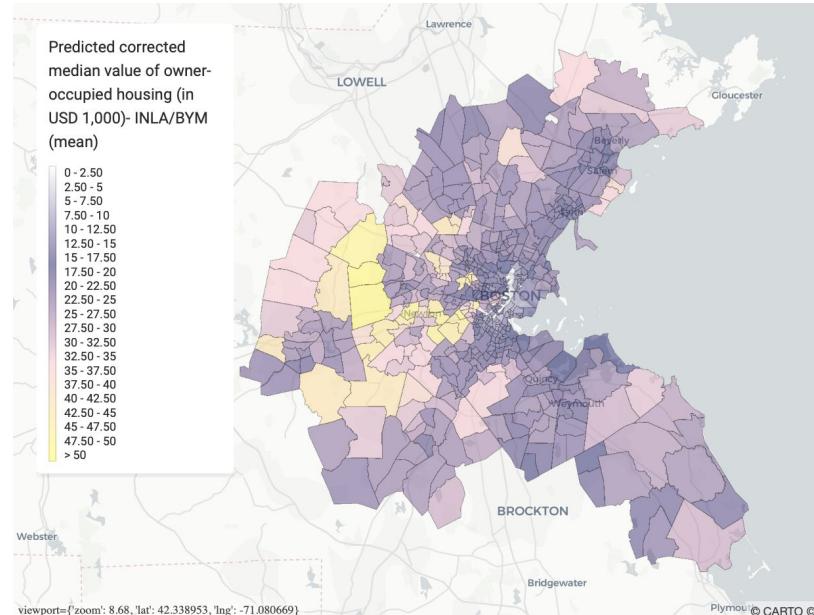
- Continuous Spatial Error Models (GP)
- Discrete Spatial Error Models (Gaussian Markov Random Fields, GMRF)
- . . .
- Spatially Varying Coefficient Models
- Spatio-temporal models
- Spatial confounding
- Validation tools

Spatial modelling

Continuous Spatial Error Models



Discrete Spatial Error Models



Spatial modelling

Continuous Spatial Error Models

Package	Language	Reference	Method
gstat	R	https://rdrr.io/cran/gstat	GP
PyKrig	Python	https://pypi.org/project/PyKrig	GP
mgcv	R	https://rdrr.io/cran/mgcv	GP with additive models
spBayes	R	https://rdrr.io/cran/spBayes	Bayesian GP (MCMC)
Stan	R/Python	http://mc-stan.org	Bayesian GP (MCMC)
PyMC3	Python	https://docs.pymc.io/	Bayesian GP (MCMC)
FKR	R	https://rdrr.io/cran/fkr	Fixed Rank Kriging
R-INLA	R	http://www.r-inla.org	Bayesian GP (INLA-SPDE)
spatstat	R	https://rdrr.io/cran/spatstat	Kernel smoothing

Discrete Spatial Error Models

Package	Language	Reference	Method
mgcv	R	https://rdrr.io/cran/mgcv	GMRF
spdep	R	https://rdrr.io/cran/spdep	GMRF
Stan	R/Python	http://mc-stan.org	Bayesian GMRF (MCMC)
PyMC3	Python	https://docs.pymc.io/	Bayesian GMRF (MCMC)
R-INLA	R	http://www.r-inla.org	Bayesian GMRF (INLA)



Spatial Clustering and Regionalization

Clustering VS Spatial Clustering

Clustering

Uses data attributes to create classes that, via those attributes, are different while staying alike within that category

- Longitude and latitude can be included as one of these attributes
- e.g. **K-means**

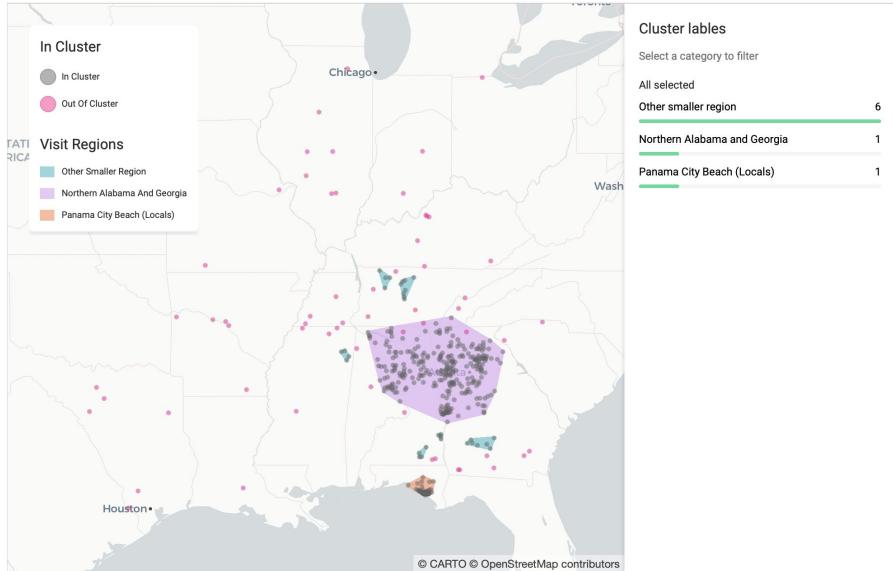
Spatial Clustering

Groups together points that are close to each other based on a distance measurement

- e.g. **DBSCAN, GENERALIZED DBSCAN**

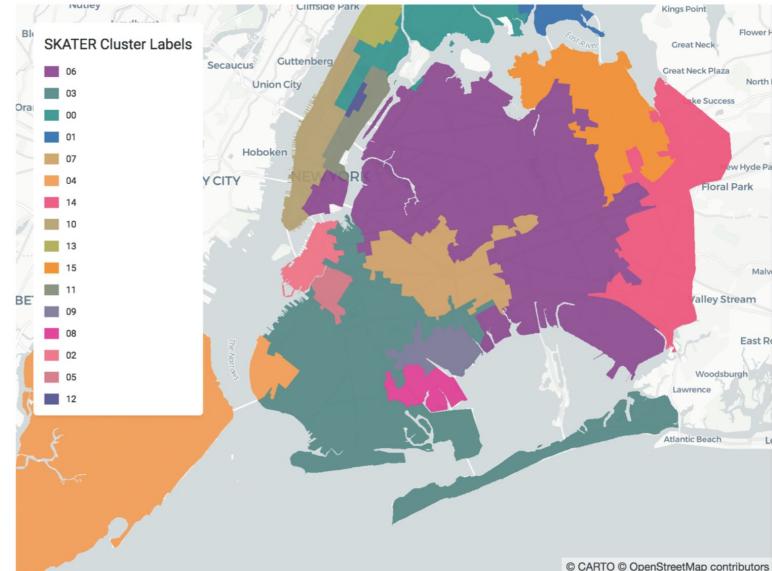
Clustering VS Regionalization

Clustering

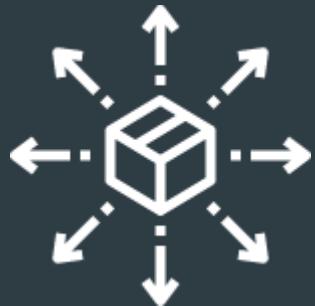


Using DBSCAN

Regionalization



Using SKATER



Logistics Optimization with Spatial Analysis

Optimization

A typical optimization model consists of the following components:

- **Decision Variables**
e.g. whether to open a distribution center (DC) at a specific location, whether a zip code is served by a DC, or which truck will serve one customer and when)
- **Objective Function**
e.g. costs, service level, etc.
- **Constraints**
e.g. physical constraints (a truck cannot transport more than its capacity), business constraints (every client should not be further than 20 miles away from the closest DC)

Exact VS approximate algorithms

Exact

Find the actual optimal solution

- e.g. Simplex Algorithm
- Google OR-Tools

Approximate

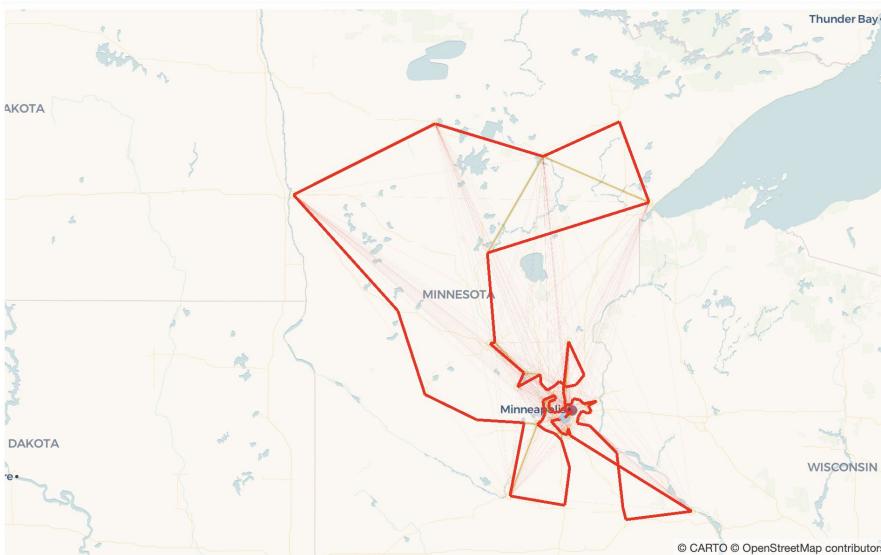
Close as possible to the optimum value in a reasonable amount of time

- e.g. Simulated Annealing, Tabu Search
- Google OR-Tools, Python packages (e.g. simanneal)

Solving the Traveling Salesman Problem

*Given a list of cities and the distances between each pair of cities,
what is the shortest possible route that visits each city and returns to the origin city?*

Christofides Algorithm

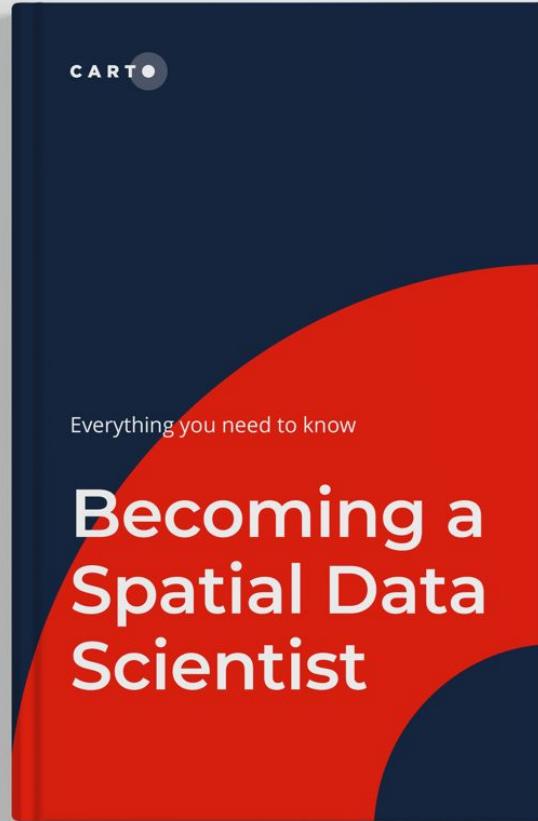


Ant Optimization



Ready to become a Spatial Expert?

<https://go.carto.com/ebooks/spatial-data-science>



Notebooks

Table of Contents

Chapter 1

- Visualizing spatial data with CARTOframes ([static preview](#)) - a notebook for easily visualizing your data on a map using CARTOframes.
- Computing measures of spatial dependence ([static preview](#)) - a notebook for exploring spatial dependence in your data and visualize the results using CARTOframes.
- Discrete spatial models ([static preview](#)) - a notebook with examples of spatial models for discrete processes and visualize the results using CARTOframes.
- Continuous spatial models ([static preview](#)) - a notebook with examples of spatial models for continuous processes and visualize the results using CARTOframes.



<https://github.com/CartoDB/data-science-book>

Chapter 2

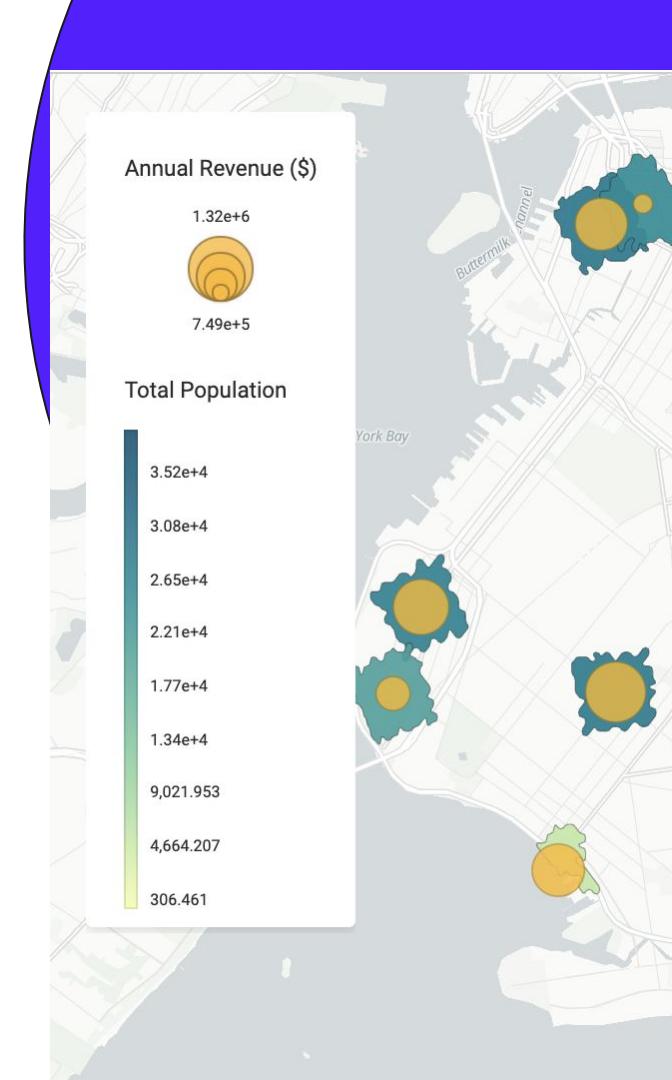
- Agglomerative Clustering ([static preview](#)) - a notebook demonstrating how to create spatially constrained clusters using agglomerative clustering
- DBSCAN ([static preview](#)) - a notebook demonstrating how to create clusters of points in geographic coordinates
- SKATER ([static preview](#)) - a notebook demonstrating how to create spatially constrained clusters that are homogeneous

Chapter 3

- Travelling Salesman Problem ([static preview](#)) - a notebook demonstrating how to solve travelling salesman problem.

Data Science Workflows using CARTO

09:40 a.m. - 10:00 a.m.



HOW IT WORKS

CARTO turns your Location Data Into Business Outcomes

Whether it's more efficient delivery routes, strategic store placements or targeted geomarketing campaigns - CARTO makes it simple in 5 key steps:



Data
Ingestion



Data
Enrichment



Analysis



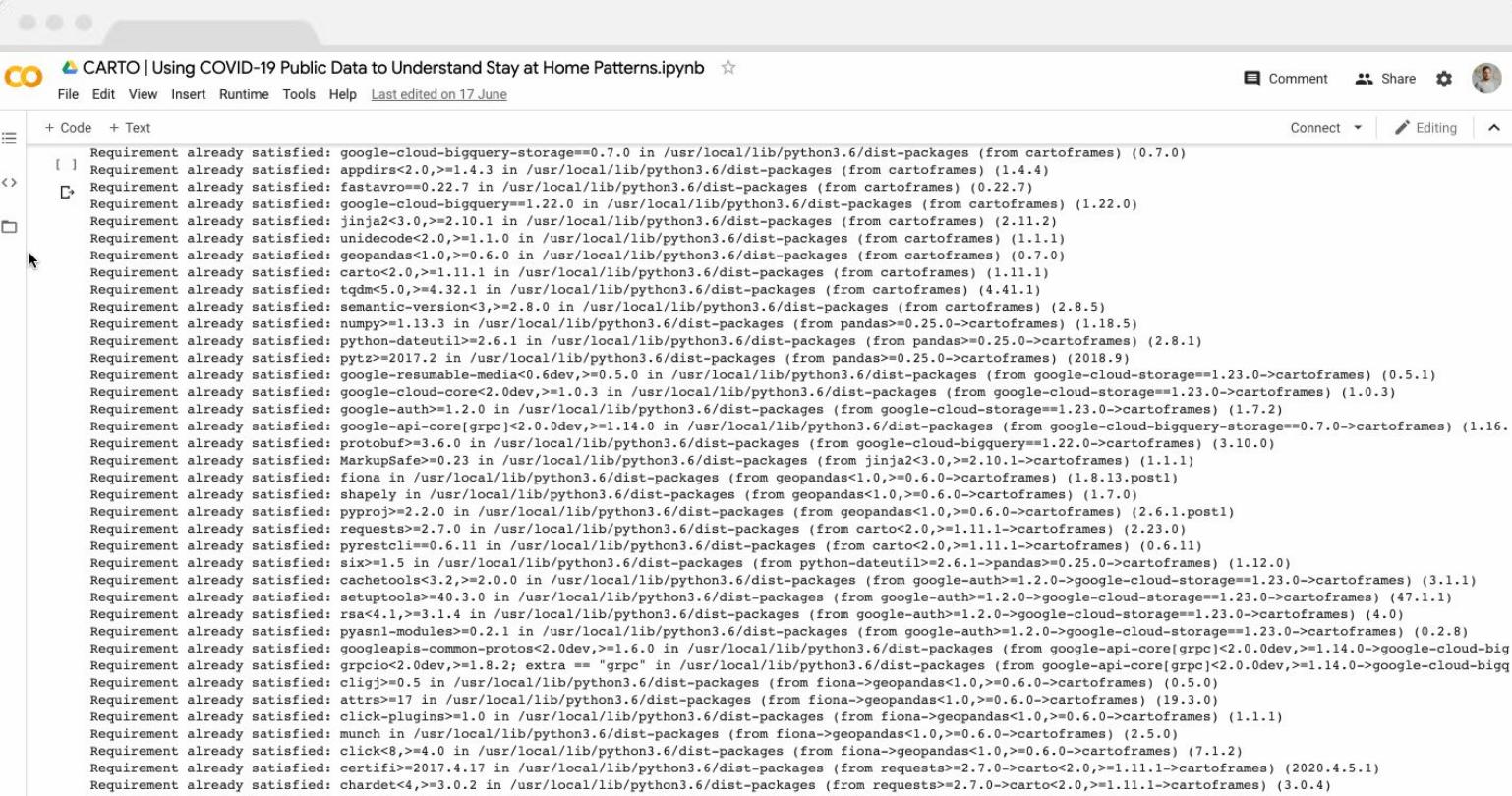
Solutions &
Visualization



Integrations

CARTOframes

A Python Library to Facilitate your Spatial Data Analysis Workflow



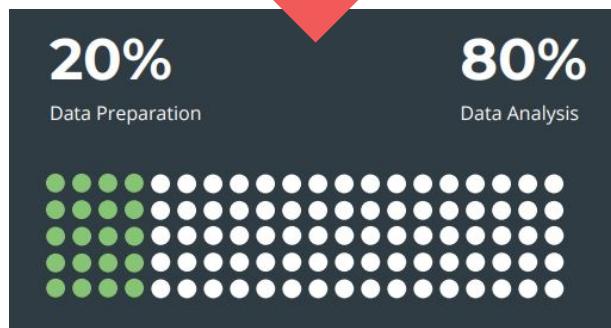
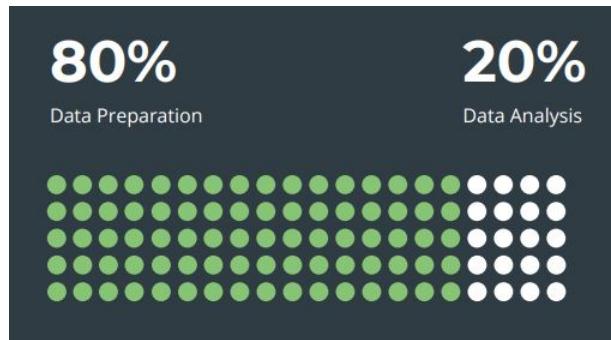
The screenshot shows a Jupyter Notebook interface with the following details:

- Title:** CARTO | Using COVID-19 Public Data to Understand Stay at Home Patterns.ipynb
- File Menu:** File, Edit, View, Insert, Runtime, Tools, Help
- Toolbar:** Last edited on 17 June, Comment, Share, Connect, Editing
- Code Area:** A large list of dependency requirements, starting with:
 - Requirement already satisfied: google-cloud-bigquery-storage==0.7.0 in /usr/local/lib/python3.6/dist-packages (from cartoframes) (0.7.0)
 - Requirement already satisfied: appdirs<2.0,>=1.4.3 in /usr/local/lib/python3.6/dist-packages (from cartoframes) (1.4.4)
 - Requirement already satisfied: fastavro==0.22.7 in /usr/local/lib/python3.6/dist-packages (from cartoframes) (0.22.7)
 - Requirement already satisfied: google-cloud-bigquery==1.22.0 in /usr/local/lib/python3.6/dist-packages (from cartoframes) (1.22.0)
 - Requirement already satisfied: jinja2<3.0,>=2.10.1 in /usr/local/lib/python3.6/dist-packages (from cartoframes) (2.11.2)
 - Requirement already satisfied: unidecode<2.0,>=1.1.0 in /usr/local/lib/python3.6/dist-packages (from cartoframes) (1.1.1)
 - Requirement already satisfied: geopandas<1.0,>=0.6.0 in /usr/local/lib/python3.6/dist-packages (from cartoframes) (0.7.0)
 - Requirement already satisfied: carto<2.0,>=1.11.1 in /usr/local/lib/python3.6/dist-packages (from cartoframes) (1.11.1)
 - Requirement already satisfied: tqdm<5.0,>=4.32.1 in /usr/local/lib/python3.6/dist-packages (from cartoframes) (4.41.1)
 - Requirement already satisfied: semantic-version<3,>=2.8.0 in /usr/local/lib/python3.6/dist-packages (from cartoframes) (2.8.5)
 - Requirement already satisfied: numpy>=1.13.3 in /usr/local/lib/python3.6/dist-packages (from pandas==0.25.0->cartoframes) (1.18.5)
 - Requirement already satisfied: python-dateutil>=2.6.1 in /usr/local/lib/python3.6/dist-packages (from pandas==0.25.0->cartoframes) (2.8.1)
 - Requirement already satisfied: pytz>=2017.2 in /usr/local/lib/python3.6/dist-packages (from pandas==0.25.0->cartoframes) (2018.9)
 - Requirement already satisfied: google-resumable-media<0.6dev,>=0.5.0 in /usr/local/lib/python3.6/dist-packages (from google-cloud-storage==1.23.0->cartoframes) (0.5.1)
 - Requirement already satisfied: google-cloud-core<2.0dev,>=1.0.3 in /usr/local/lib/python3.6/dist-packages (from google-cloud-storage==1.23.0->cartoframes) (1.0.3)
 - Requirement already satisfied: google-auth==1.2.0 in /usr/local/lib/python3.6/dist-packages (from google-cloud-storage==1.23.0->cartoframes) (1.7.2)
 - Requirement already satisfied: google-api-core[grpc]<2.0.0dev,>=1.14.0 in /usr/local/lib/python3.6/dist-packages (from google-cloud-bigquery-storage==0.7.0->cartoframes) (1.16.0)
 - Requirement already satisfied: protobuf>=3.6.0 in /usr/local/lib/python3.6/dist-packages (from google-cloud-bigquery==1.22.0->cartoframes) (3.10.0)
 - Requirement already satisfied: MarkupSafe<0.23 in /usr/local/lib/python3.6/dist-packages (from jinja2<3.0,>=2.10.1->cartoframes) (1.1.1)
 - Requirement already satisfied: Fiona in /usr/local/lib/python3.6/dist-packages (from geopandas<1.0,>=0.6.0->cartoframes) (1.8.13.post1)
 - Requirement already satisfied: shapely in /usr/local/lib/python3.6/dist-packages (from geopandas<1.0,>=0.6.0->cartoframes) (1.7.0)
 - Requirement already satisfied: pyproj>=2.2.0 in /usr/local/lib/python3.6/dist-packages (from geopandas<1.0,>=0.6.0->cartoframes) (2.6.1.post1)
 - Requirement already satisfied: requests>=2.7.0 in /usr/local/lib/python3.6/dist-packages (from carto<2.0,>=1.11.1->cartoframes) (2.23.0)
 - Requirement already satisfied: pyrestclient==0.6.11 in /usr/local/lib/python3.6/dist-packages (from carto<2.0,>=1.11.1->cartoframes) (0.6.11)
 - Requirement already satisfied: six>=1.5 in /usr/local/lib/python3.6/dist-packages (from python-dateutil>=2.6.1->pandas==0.25.0->cartoframes) (1.12.0)
 - Requirement already satisfied: cachetools<3.2,>=2.0.0 in /usr/local/lib/python3.6/dist-packages (from google-auth==1.2.0->google-cloud-storage==1.23.0->cartoframes) (3.1.1)
 - Requirement already satisfied: setuptools>=40.3.0 in /usr/local/lib/python3.6/dist-packages (from google-auth==1.2.0->google-cloud-storage==1.23.0->cartoframes) (47.1.1)
 - Requirement already satisfied: rsa<4.1,>=3.1.4 in /usr/local/lib/python3.6/dist-packages (from google-auth==1.2.0->google-cloud-storage==1.23.0->cartoframes) (4.0)
 - Requirement already satisfied: pyasn1-modules==0.2.1 in /usr/local/lib/python3.6/dist-packages (from google-auth==1.2.0->google-cloud-storage==1.23.0->cartoframes) (0.2.8)
 - Requirement already satisfied: googleapis-common-protos<2.0dev,>=1.6.0 in /usr/local/lib/python3.6/dist-packages (from google-api-core[grpc]<2.0.0dev,>=1.14.0->google-cloud-big
 - Requirement already satisfied: grpcio<2.0dev,>=1.8.2; extra == "grpc" in /usr/local/lib/python3.6/dist-packages (from google-api-core[grpc]<2.0.0dev,>=1.14.0->google-cloud-bigg
 - Requirement already satisfied: clickj>=0.5 in /usr/local/lib/python3.6/dist-packages (from fiona->geopandas<1.0,>=0.6.0->cartoframes) (0.5.0)
 - Requirement already satisfied: attrs>=17 in /usr/local/lib/python3.6/dist-packages (from fiona->geopandas<1.0,>=0.6.0->cartoframes) (19.3.0)
 - Requirement already satisfied: click-plugins>=1.0 in /usr/local/lib/python3.6/dist-packages (from fiona->geopandas<1.0,>=0.6.0->cartoframes) (1.1.1)
 - Requirement already satisfied: munch in /usr/local/lib/python3.6/dist-packages (from fiona->geopandas<1.0,>=0.6.0->cartoframes) (2.5.0)
 - Requirement already satisfied: click<8,>=4.0 in /usr/local/lib/python3.6/dist-packages (from fiona->geopandas<1.0,>=0.6.0->cartoframes) (7.1.2)
 - Requirement already satisfied: certifi>=2017.4.17 in /usr/local/lib/python3.6/dist-packages (from requests>=2.7.0->carto<2.0,>=1.11.1->cartoframes) (2020.4.5.1)
 - Requirement already satisfied: chardet<4,>=3.0.2 in /usr/local/lib/python3.6/dist-packages (from requests>=2.7.0->carto<2.0,>=1.11.1->cartoframes) (3.0.4)

Why CARTOframes?



Reduce context switching



Powering end-to-end data science workflows

Explore

Clean, geocode, and visualize your data straight out of Jupyter notebooks.

Enrich

Access a wide range of datasets - all on standardized spatial aggregations to reduce your time to insight.

Analyze

Get insights from your data using our API and your own libraries, functions, and workflows.

Share

Once your analysis is done, add widgets and share your results.

1. Explore

→ Manage your data

Load a CSV file

Load data from a CSV file

Load a JSON file

Load data from a JSON file

Load a GeoJSON file

Load data from a GeoJSON file

Load a shapefile

Load data from a shapefile

Load a CARTO table

Load data from a CARTO table

Load a CARTO SQL query

Load data from a CARTO table using a SQL Query

Upload to CARTO

Upload data to CARTO

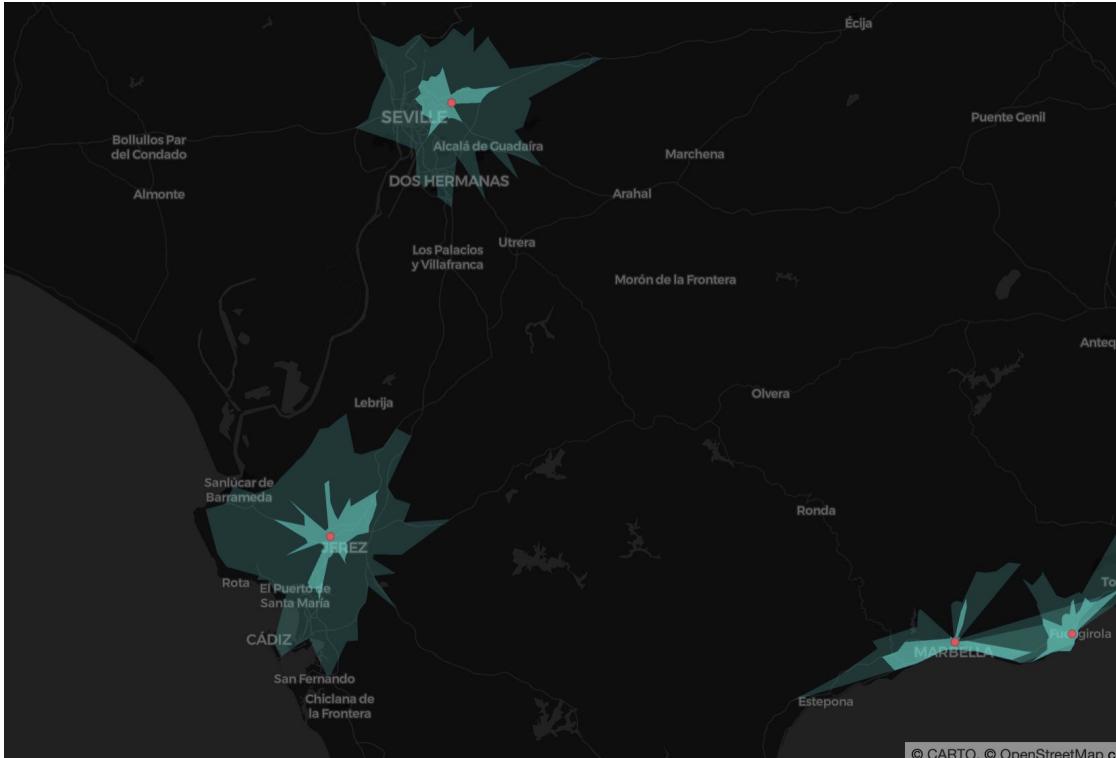
Change CARTO table privacy

Change the privacy of a CARTO table

1. Explore

→ Get your data ready

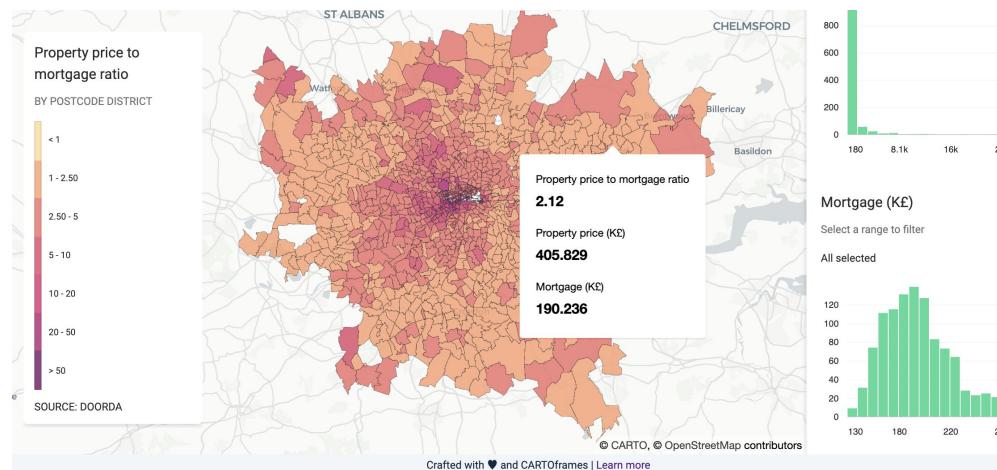
- Geocode large datasets in just one request
- Create isochrones for your points



1. Explore

→ Visualize

- Local data and hosted datasets
 - Maps with multiple layers
 - Styling for numerical and categorical variables
 - Custom basemaps
 - Legends, pop-ups, and widgets
 - Layouts



2. Enrich

→ CARTO Data Observatory

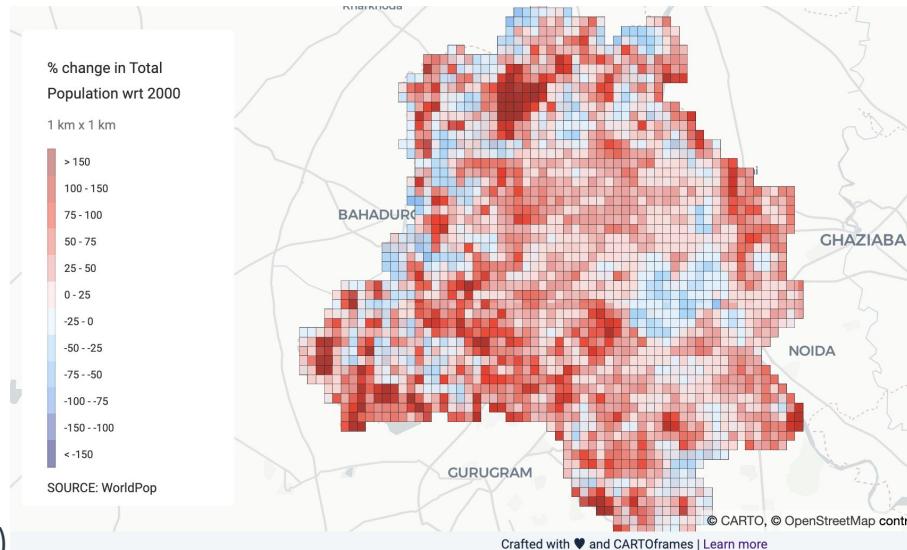
- Access to different location data streams on common geometries. Working with market-leaders, we bring together high-quality curated datasets to reduce the time to insight.
<https://carto.com/platform/spatial-data-catalog/>

 Financia l	 Housing
 Human Mobility	 POI's
 Road Traffic	 Environmental
 Demographics	 Global Boundaries
 GeoSocial	 COVID-19

2. Enrich

→ Discover and enrich your data

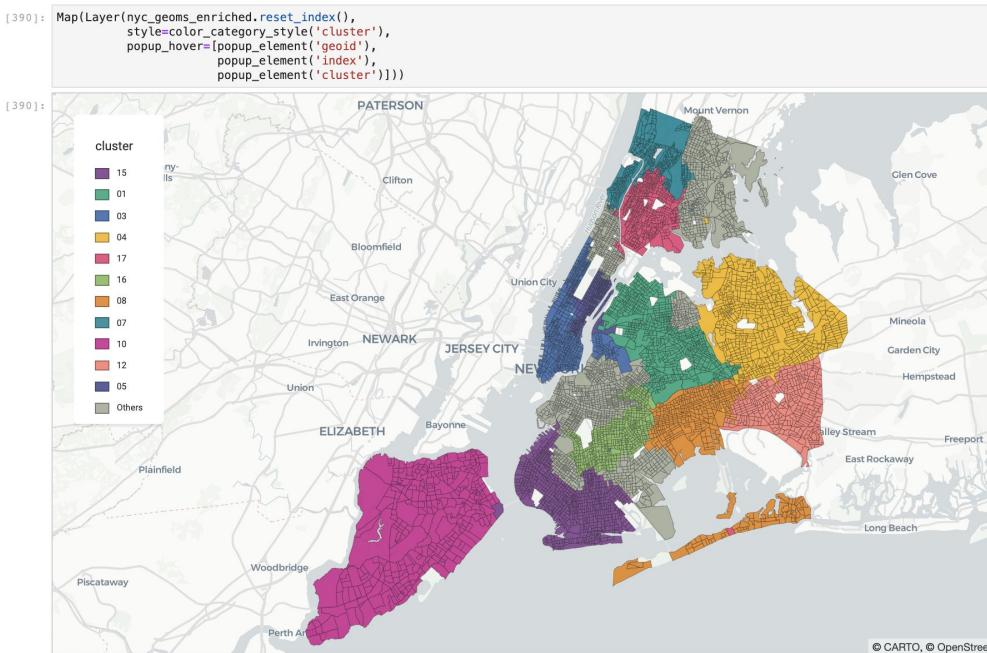
- Direct access to our Data Observatory
- Open and premium datasets
- Discover the data you need
 - By category
 - By country
 - By geography
 - By provider
- Check stats about available datasets
- Request a dataset
- Enrich your dataframe (points or polygons)



3. Analyze

We are working to help you *productize* your workflows and reduce your data preparation time, enabling you to focus on your analysis.

- Feature engineering (soon)
- Spatial Clustering (soon)
- Data partitioning for spatial data (soon)
- Spatial projection (soon)



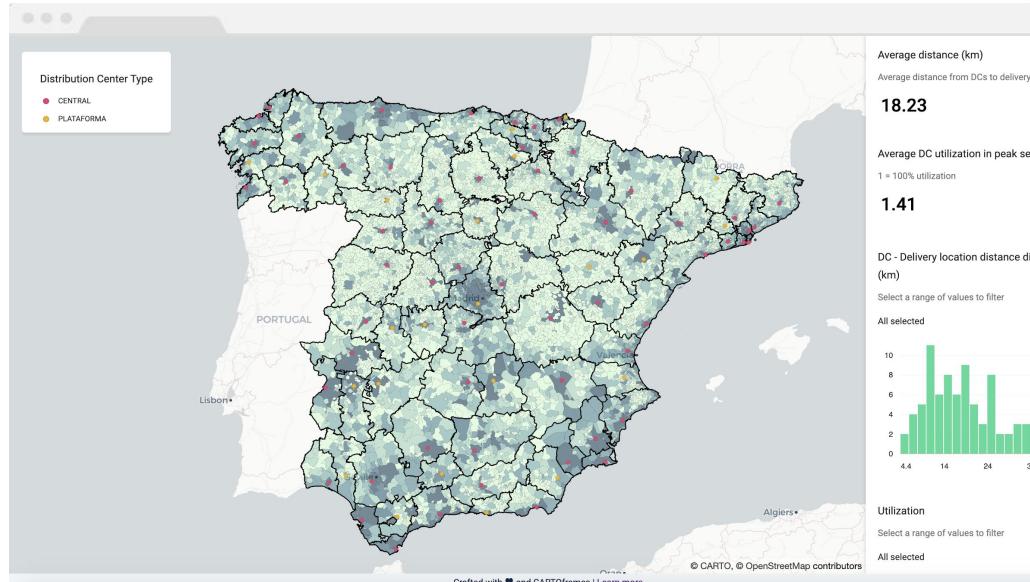
4. Share

→ Prepare your analysis output

- Make your analysis easy to consume by others in your organization by adding widgets: histogram, category, animation control, time series.

→ Publish

- Publish your map to CARTO and get the shareable link as response.



Break

10:00 a.m. - 10:10 a.m.

Hands-on with CARTO Practical Spatial Data Science in Python

10:10 a.m. - 11:30 a.m.

Using CARTO tech stack, in this session we will go through a step by step demo using Jupyter notebooks, from data exploration, to external data discovery and augmentation, to model formulation and results.

- ***Site selection:*** where should Starbucks open new coffee shops in Long Island, NY? In this demo we will go through a typical site selection use case, from modelling the revenues of the existing stores as a function of socioeconomic covariates, to predicting the potential revenues in new locations.
- ***Logistic spatial optimization:*** where should a parcel delivery company locate their distribution and fulfilment centers? What areas should they service? In this demo we will go through a supply chain network optimization use case, from analysing past data to identify spatio-temporal patterns to building an optimization model to analyze and quantify the impact of changes in the current network.

Q&A and discussion

11:30 a.m. - 11:45 a.m.

Online •

October 19th - 23rd 2020

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Spatial Data Science Conference

Thank you for listening! Any questions?

Request a demo at CARTO.com

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Miguel Álvarez

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JPM Big Data and AI Research

11:45 a.m. - 12:00 p.m.