GIS/Spatial analytics : quel potentiel pour les données géographiques

Vandy Berten – Smals Research

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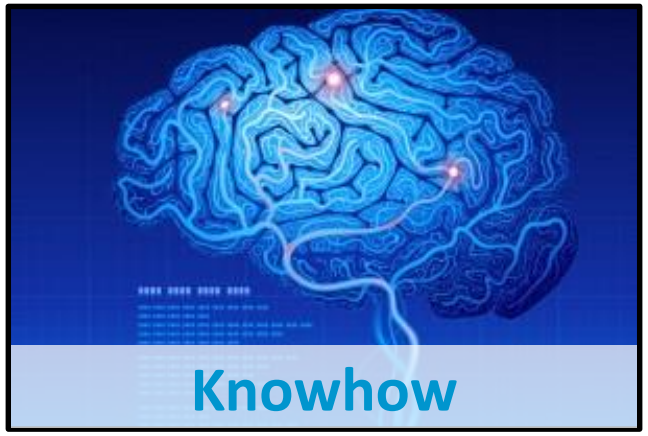

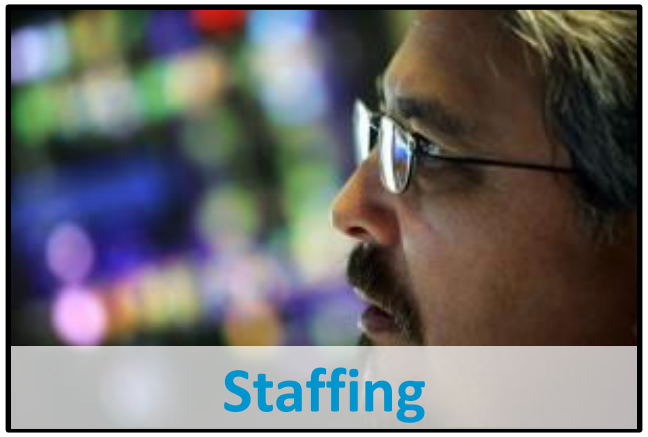

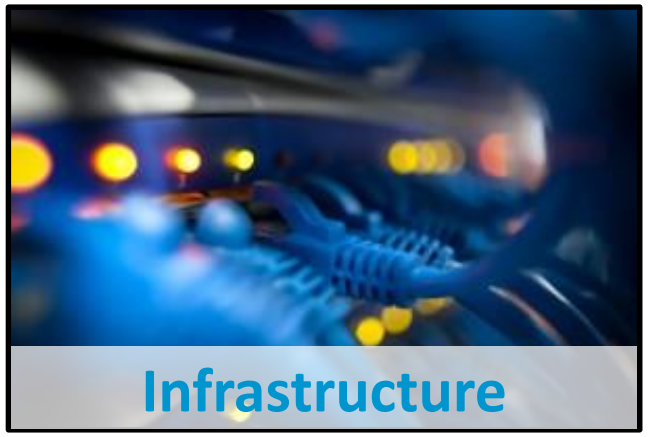

g-cloud

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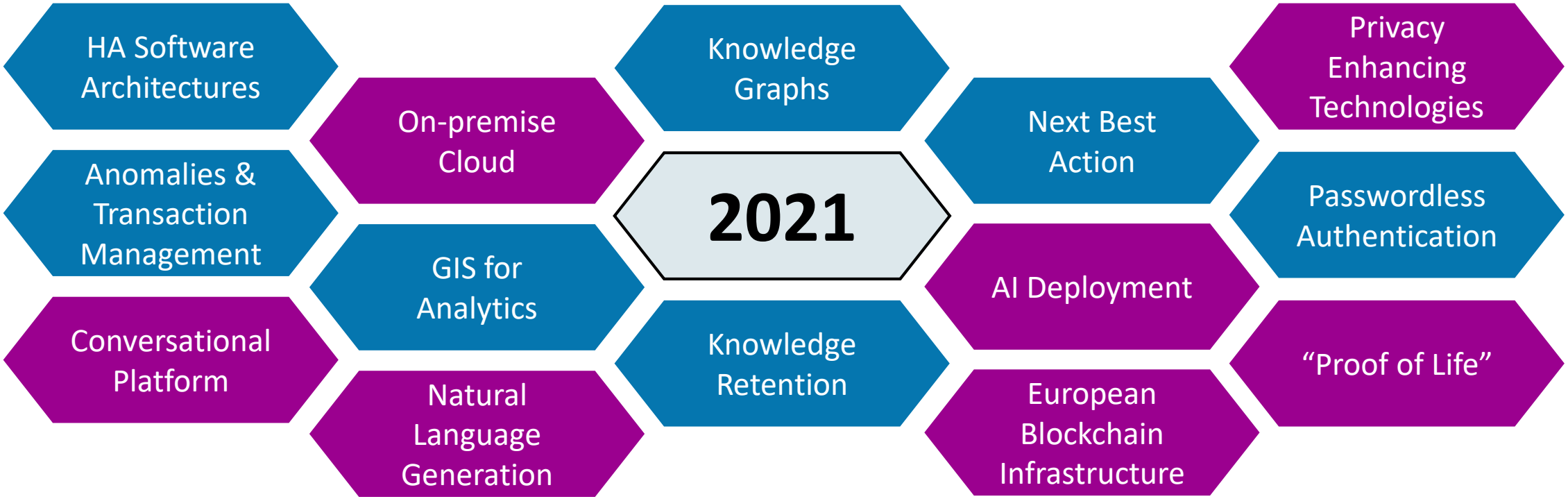
Innovation with new technologies

Consultancy & expertise

Internal & external knowledge transfer

Support for going live



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Contenu

- Définition
- Géocodage
- Sources de données
- Visualisation
- Jointure spatiale
- Autocorrélation spatiale
- Atteignabilité
- Anomalies CAW

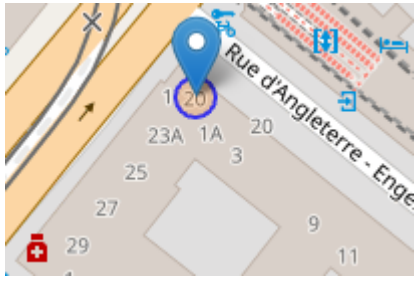
Contexte

- On s’intéresse à l’aspect collecte de données/analytique, pas/peu aux aspects visualisation
- Pas à des modèles épidémiologiques
- Pas à de la cartographie (nature de sols, réseau routier, hydrologie…)

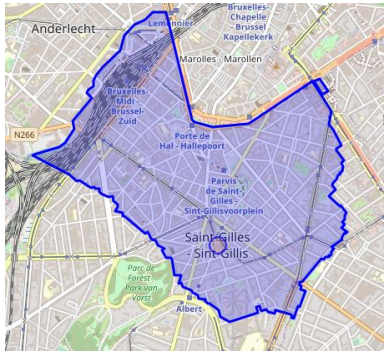
Donnée géographique

- Donnée géographique : donnée que l'on peut placer sur une carte, directement ou indirectement
- Directement :
  - 50.8361263, 4.3382716 (WGS 84 – EPSG:4326)
  - 50°50'10.1"N, 4°20'17.8"E
  - 147859.164113, 169482.701283 (Lambert 1972 – EPSG:31370)
- Indirectement :
  - Avenue Fonsny 20, 1060 Saint-Gilles
  - 1060
  - Saint-Gilles
  - Smals, Saint-Gilles
- Objet spatial/géographique :
  - Point (localisation précise)
  - Ligne (segment de route)
  - Rectangle ("bounding box")
  - Polygone

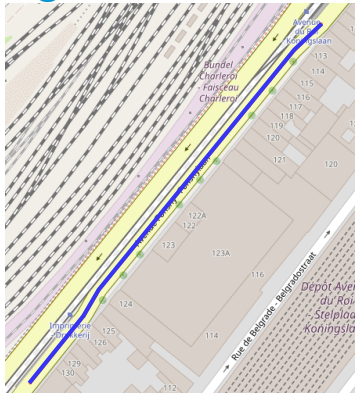
Point



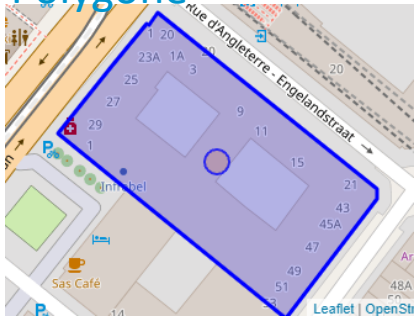
Polygône



Ligne



Polygône



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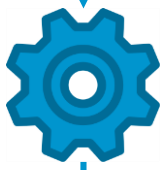
Géocodage

Geocoding: concept

Pour être exploitable géographiquement, un adresse doit être “géocodée”

“Av. Fonsny 20, 1060 Bruxelles”



```
{“street”  : “Avenue Fonsny”,
 “housenbr”: “20”,
 “zipcode” : “1060”,
 “city”    : “Saint-Gilles”,
 “country” : “Belgique”,
 “location”:[50.8358,4.3361]}
```

Address validation:

- Data quality:
  - Standardization
  - Deduplication
  - Matching
- Auto-completion (type-ahead)
- …

Geocoding:

- Visualization
- Controls
- Spatial (GIS) analytics
- …

Or polygon (point sequence)

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Geocoding: tools

- Cloud commercial providers:
  - Here we go
  - Bing maps
  - Google maps
  - TomTom
- Sometimes free in specific conditions

- Mainly one open-source/open-data solution: OpenStreetMap/Nominatim
- Variant (with ElasticSearch): Photon
- On-premise possible (1 Docker cmd line) for a specific region

OpenStreetMap

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Geocoding: pros/cons

	Cloud solutions	On-premise solutions
Pros	• Easy to implement • No infrastructure cost • High quality	• Confidentiality • OK for large volumes • OSM: no data/soft costs
Cons	• GDPR • Confidentiality • Requires internet access • Cost for large volumes (time, €)	• World coverage unaffordable • Quality? • Infra costs

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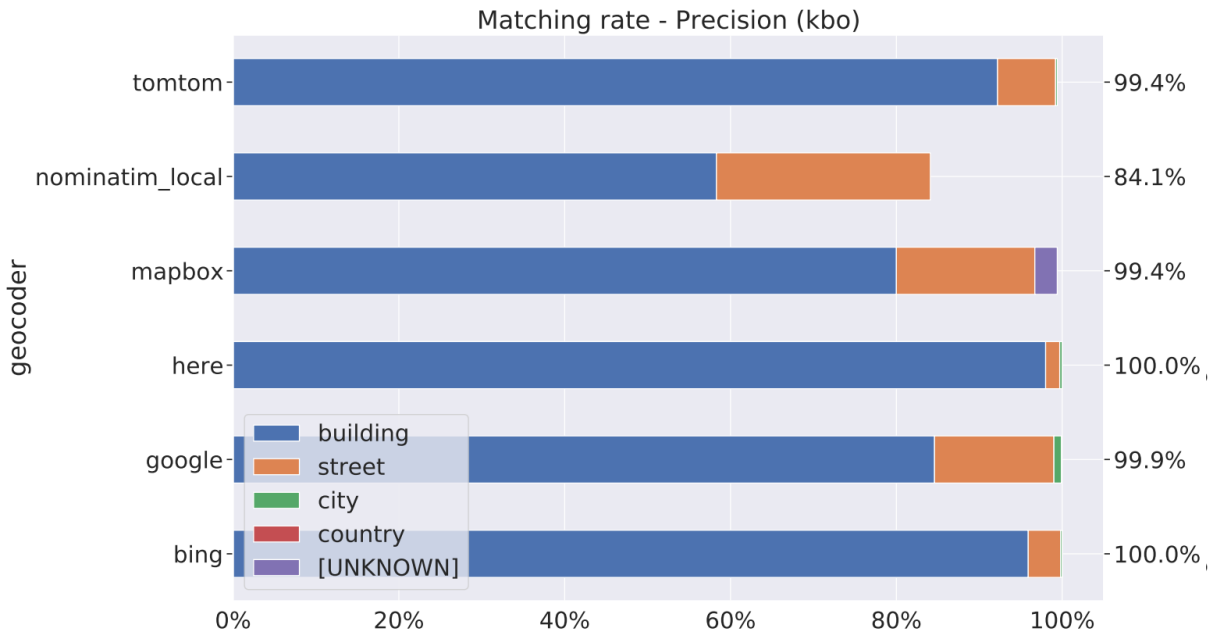
Geocoding: quality

Dataset : 1,000 (belgian) addresses from KBO OpenData



- Matching rate: proportion of addresses with a match
- Precision:
  - Building: localizes the building
  - City: localizes the city center
- Main weaknesses of Nominatim/OSM:
  - Not very robust
  - Often street level
    → not a problem in most of our applications
  - Weak output coherence (~10 fields for « street »)
- But: on-premise!

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Nominatim: weak robustness (input)

- In general, does not support “small typos”
- Robustness for house numbers:
  - Avenue Fonsny 20, 1060 Bruxelles → OK
  - Avenue Fonsny 20 bte 2, 1060 Bruxelles → No result
  - Avenue Fonsny 20/2, 1060 Bruxelles → Street level (skip 20/2)
- Robnustness with names:
  - Avenue Fonsny 20, 1060 Bruxell**e** → No result
  - Avenue Fons**ni** 20, 1060 Bruxelles → No result
  - Aven**u** Fonsny 20, 1060 Bruxelles → No result
- With an unknow house number:
  - Rue des Guildes, 22, 1000 Bruxelles → Street level (skip 22)
  - Rue Gray 96, 1040 Etterbeek → No result
  - … but : Rue Gray, 1040 Etterbeek → Street level
- Real life example : « Avenue Fonsny, en face du 20 », « … (entrée rue X) », « Gallerie Y »

Nominatim: weak coherence (output)

- In general : https://nominatim.openstreetmap.org/search.php?q=**Avenue+Fonsny+20,+1060+Bruxelles**&format=jsonv2&addressdetails=1

➔

```
{ place_id: 48588284,
lat: "50.8358216", lon: "4.3386884", (…)
address: {
   house_number: "20",
   road: "Avenue Fonsny",
   town: "Saint-Gilles", (…) }
```

- But “street” in sometimes in another field : “road”, “pedestrian”, ”footway”, “cycleway”, “path”, “address27”, “construction”, “hamlet”, “park”
- “ city” is sometimes in “town”, “village”, “city_district”, “county”, “city”.

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Nominatim: observations

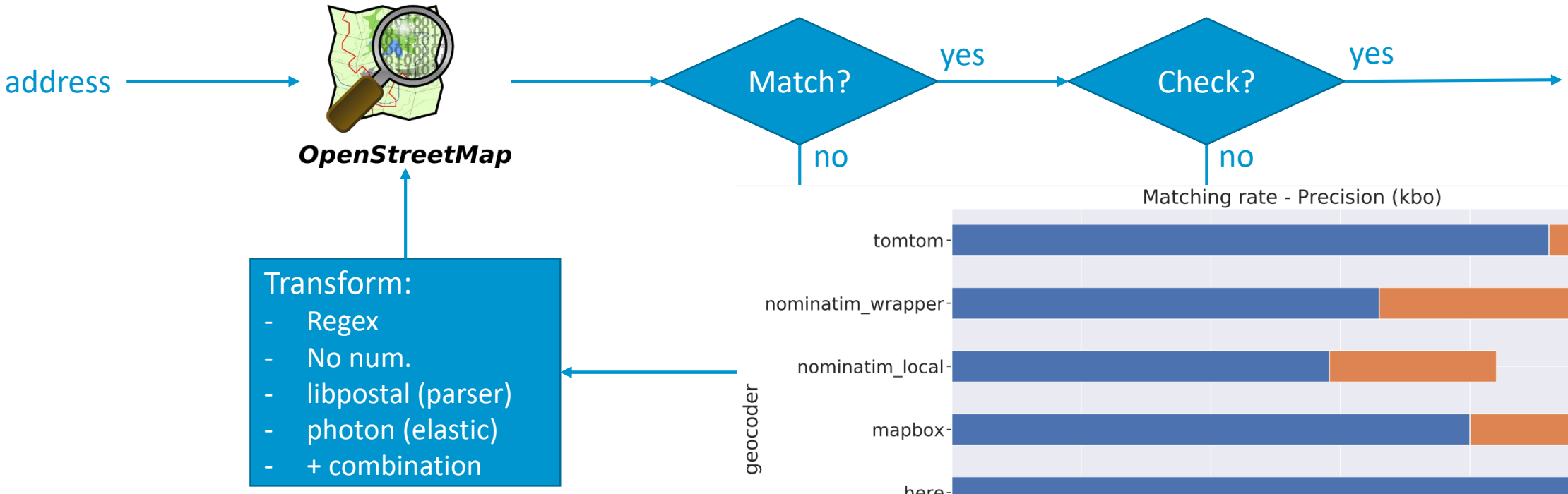
- Often, simple change allows matching :
  - Av. Fonsny → Avenue Fonsny
  - Avenue Fonsny 20 bte 2 → Avenue Fonsny 20
  - Rue Gray 96 → Rue Gray
  - Rue de Namur, Spy (Jemeppe-s-s) → Rue de Namur, Spy
  - Specific to dataset: “Fonsny (Avenue)”, “A.FONSNY” → Avenue Fonsny
- Simple tools allow to “clean” addresses:
  - Regex
  - Libpostal (address parser) : “Smals, Avenue Fonsny 20 bte 5, 1060 Saint-Gilles” →

```
[('smals', 'house'),
 ('avenue fonsny', 'road'),
 ('20', 'house_number'),
 ('bte 5', 'unit'),
 ('1060', 'postcode'),
 ('saint-gilles', 'city')]
```

  - Photon = Nominatim+ElasticSearch

NominatimWrapper

- To address the robustness problem, we build a (REST API) « wrapper » around Nominatim
- Main idea: if Nominatim does not recognize an address, « clean it » beforehand



Transformers performances (KBO – 3M addresses)

Method	Sent	Match	Match rate (%)	Glob MR	Cum MR
orig	3.062.332	2.551.079	83,31	83,31	83,31
regex[init]	348.011	319.321	91,76	10,43	93,73
nonum	184.503	36.653	19,87	1,20	94,93
libpostal+regex[lpost]	69.780	16.881	24,19	0,55	95,48
libpostal+regex[lpost]+nonum	129.906	895	0,69	0,03	95,51
libpostal+regex[lpost]+photon	91.867	86.853	94,54	2,84	98,35
libpostal+regex[lpost]+photon+nonum	5.400	2.450	45,37	0,08	98,43
photon	8.591	6.038	70,28	0,20	98,62
photon+nonum	2.949	454	15,40	0,01	98,64
nostreet	41.708	40.875	98,00	1,33	99,97

NominatimWrapper: API

- URL: https://github.com/SmalsResearch/NominatimWrapper
- Input:
  - 3 input modes:
    - Non structured: "Av. Fonsny 20, 1060 Bruxelles"
    - Structured: {'street': 'Av. Fonsny 20', 'housenbr': '', 'zipcode': '1060', 'city': 'Bruxelles'}
    - Batch: [{'street': 'Av. Fonsny 20', 'housenbr': '', 'zipcode': '1060', 'city': '…'},
      {'street': 'Quai de Willebroeck', 'housenbr': '38','zipcode': '1000', 'city': '…'}]
  - Options:
    - output mode=geo|short|long
    - check_result=yes|no: checks that the output is not "too far away" from the input
    - with_rejected=yes|no: provides also the rejected results
- Output:
  - Structured address(es): {'street': 'Avenue Fonsny', 'housenbr': '20',
    'zipcode': '1060', 'city': 'Saint-Gilles'}
  - Location: {'lat': '50.8358216', 'lon': '4.3386884'}
  - Level of precision: {'place_rank': 30} (30:building, 26:street, …)
  - Method (transformation): {'method': 'libpostal;regex'}
  - Misc. extra indicators

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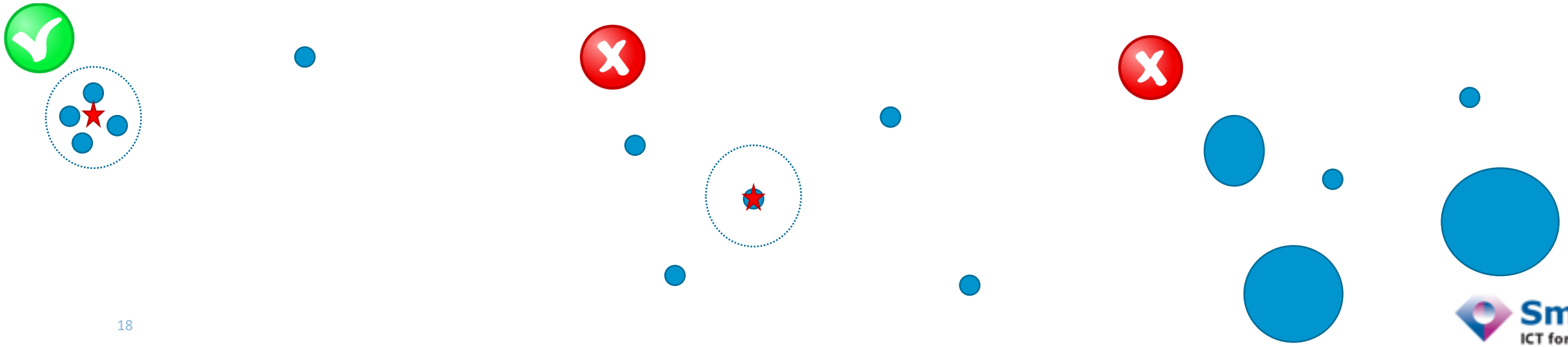
Performances

- Giving an answer does not make this answer to be correct!
- If we don’t have a reference address list with known location, evaluating performance is complex
- Methodology:
  - Collect a (not too clean) address dataset → 1000 addresses from KBO OpenData
  - Send this dataset to several coders → 7: here, bing, mapbox, nominatim (local, BEL), tomtom, google, NW)
  - Use median point for each address as reference, with some conditions :
    - Enough (precise) matches → 950 with ≥ 3 /6 “building” matches
    - Enough answers close to median → 942 with ≥ 2/7 within 100 m
  - Compute misc. stats about « distance to median »



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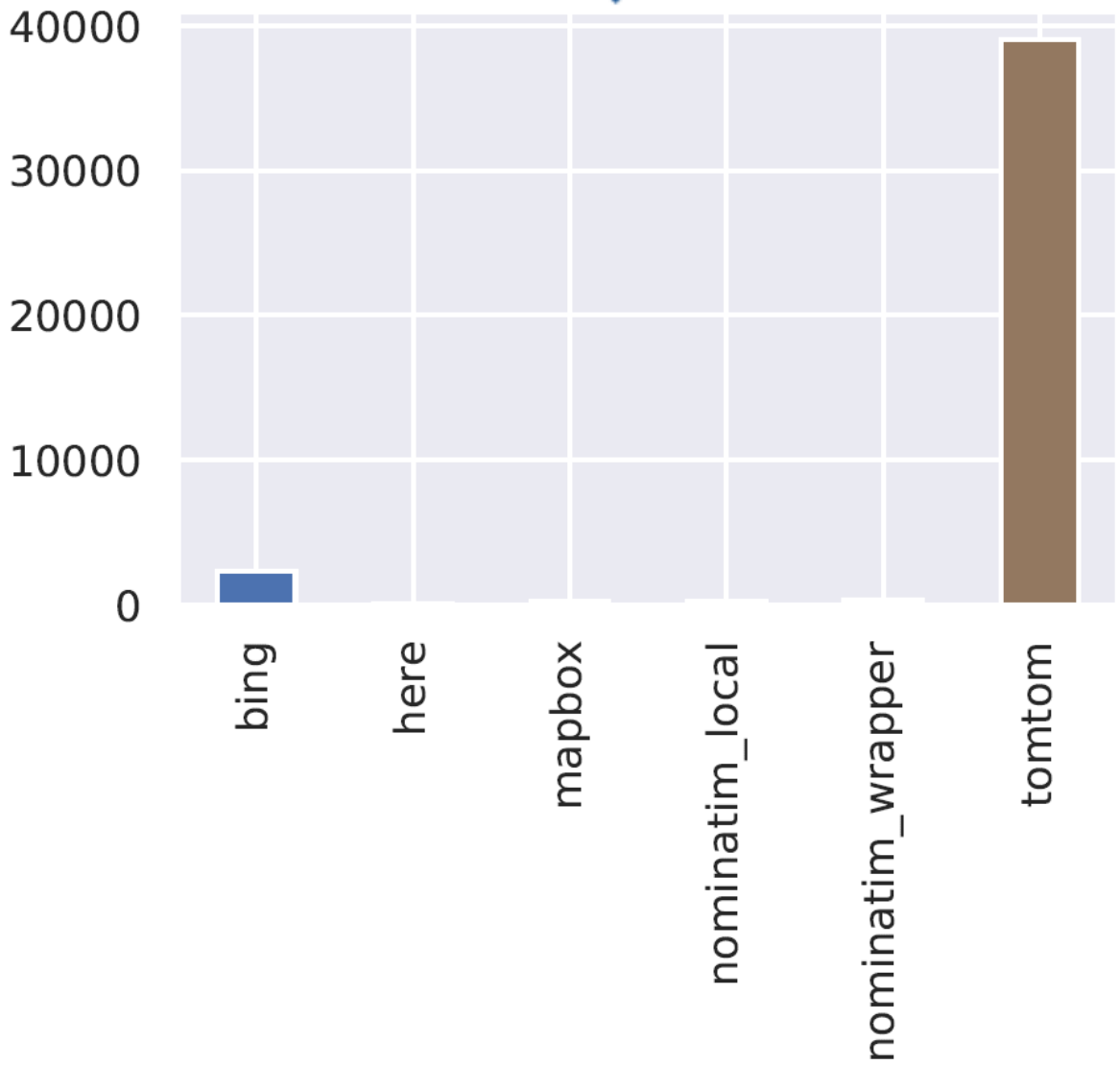
Avg distance to median



Dataset : 1000 addresses from KBO (in Belgium) – a few months ago

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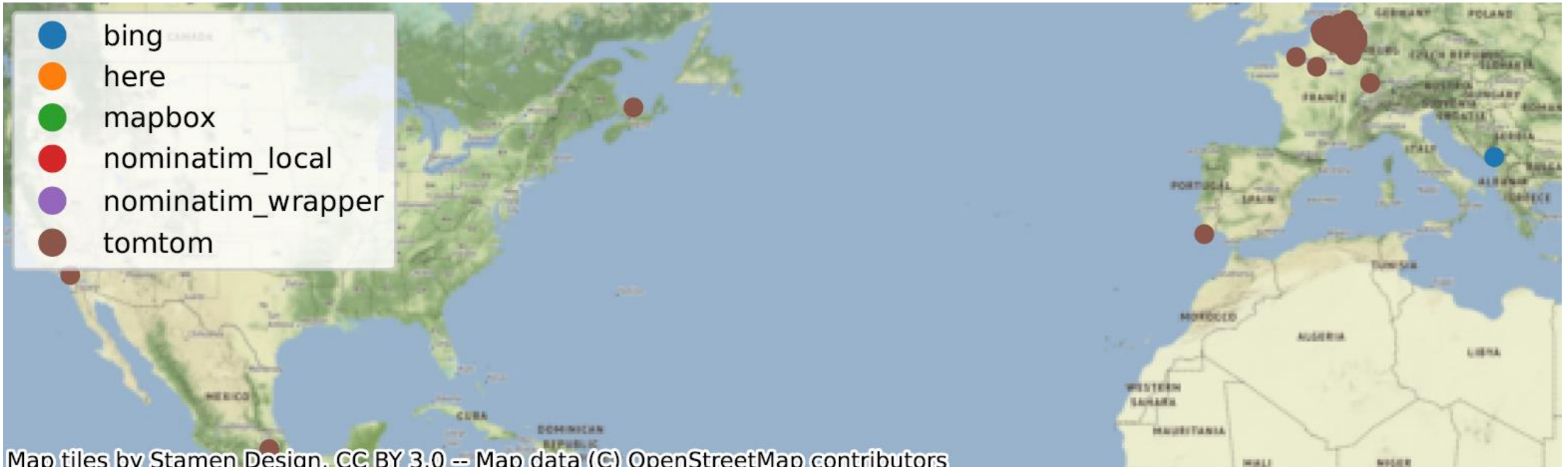
Global view



A few months ago

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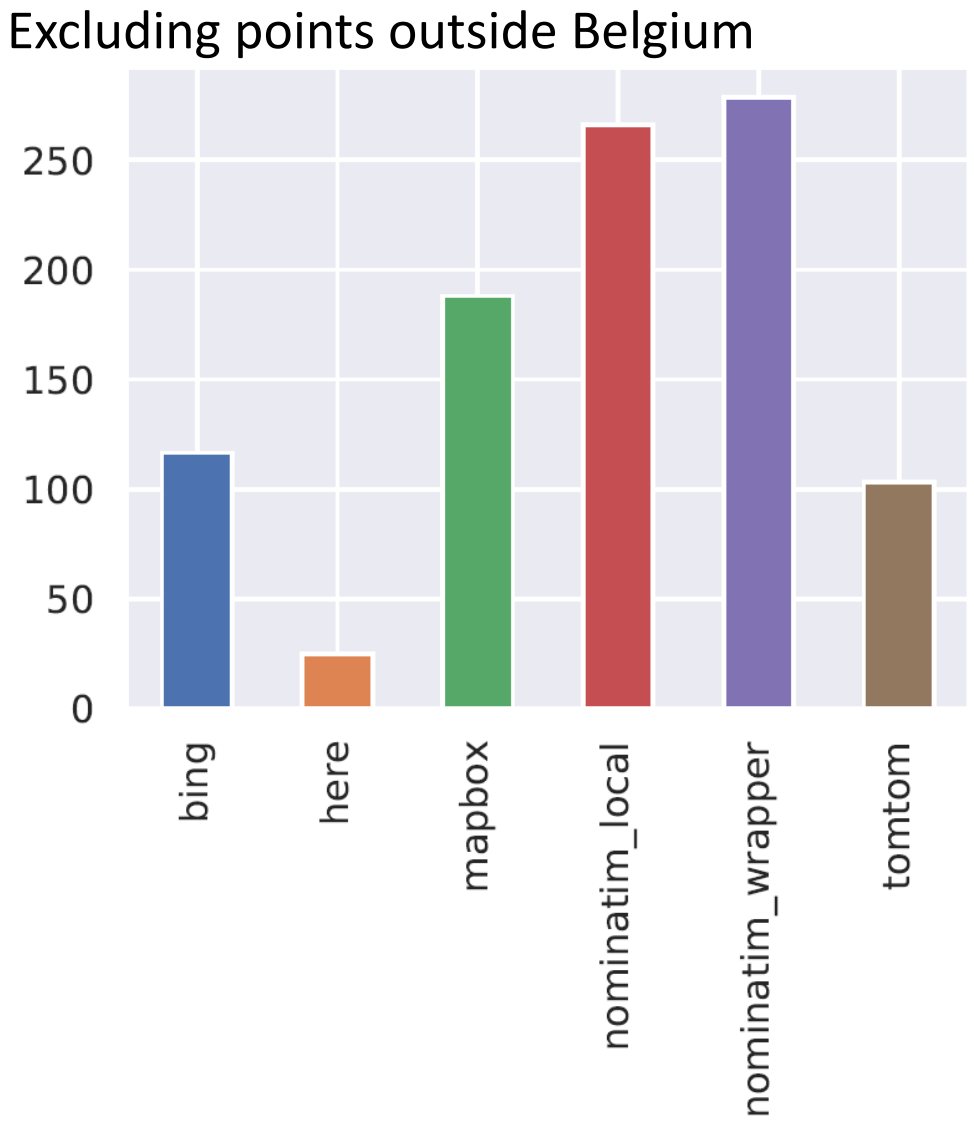
Reliable distance to median



Remind: OSM localizes building only in ~ 65% - only Belgium dataset

A few months ago

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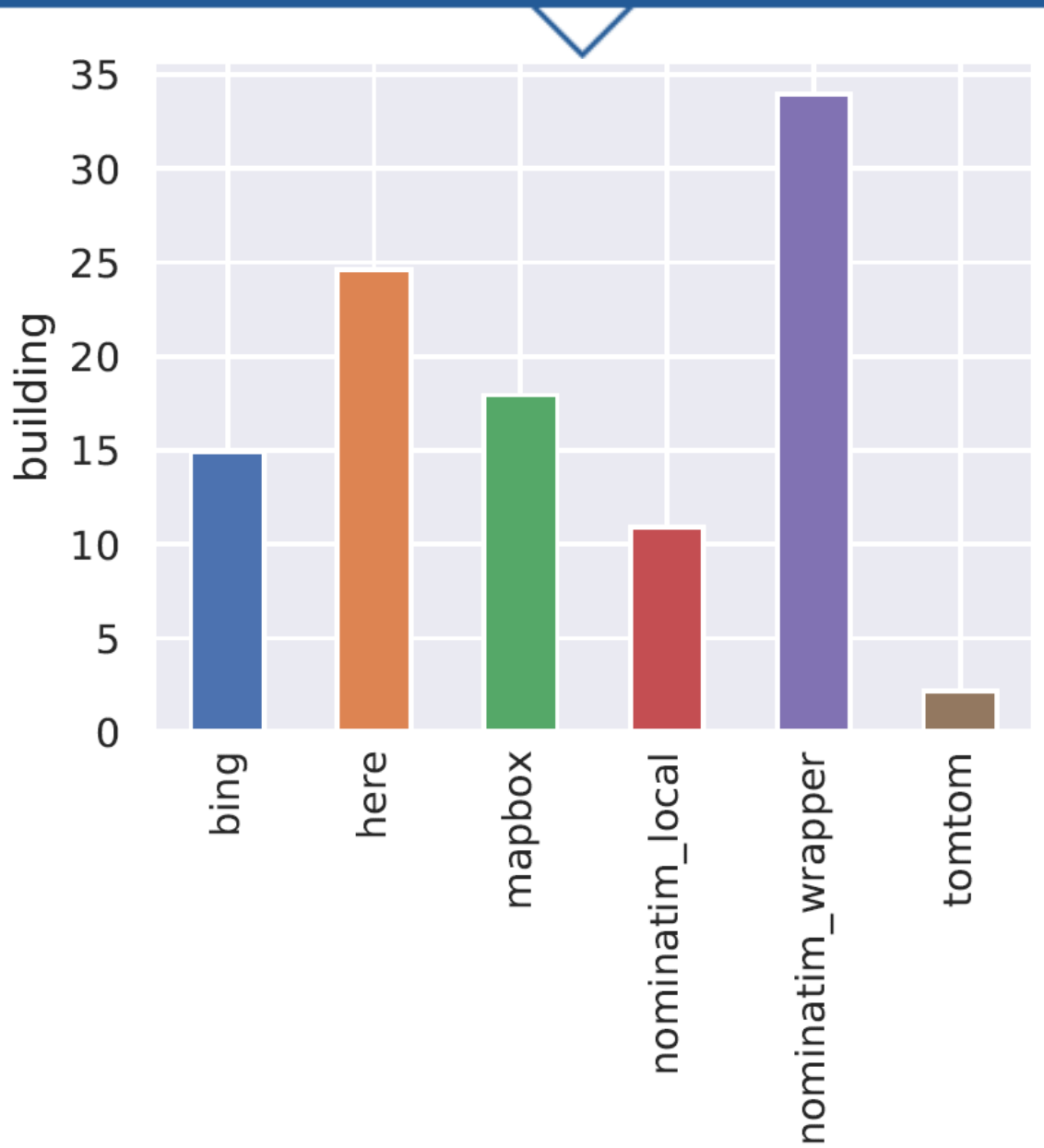
Reliable distance, if “building”



A few months ago

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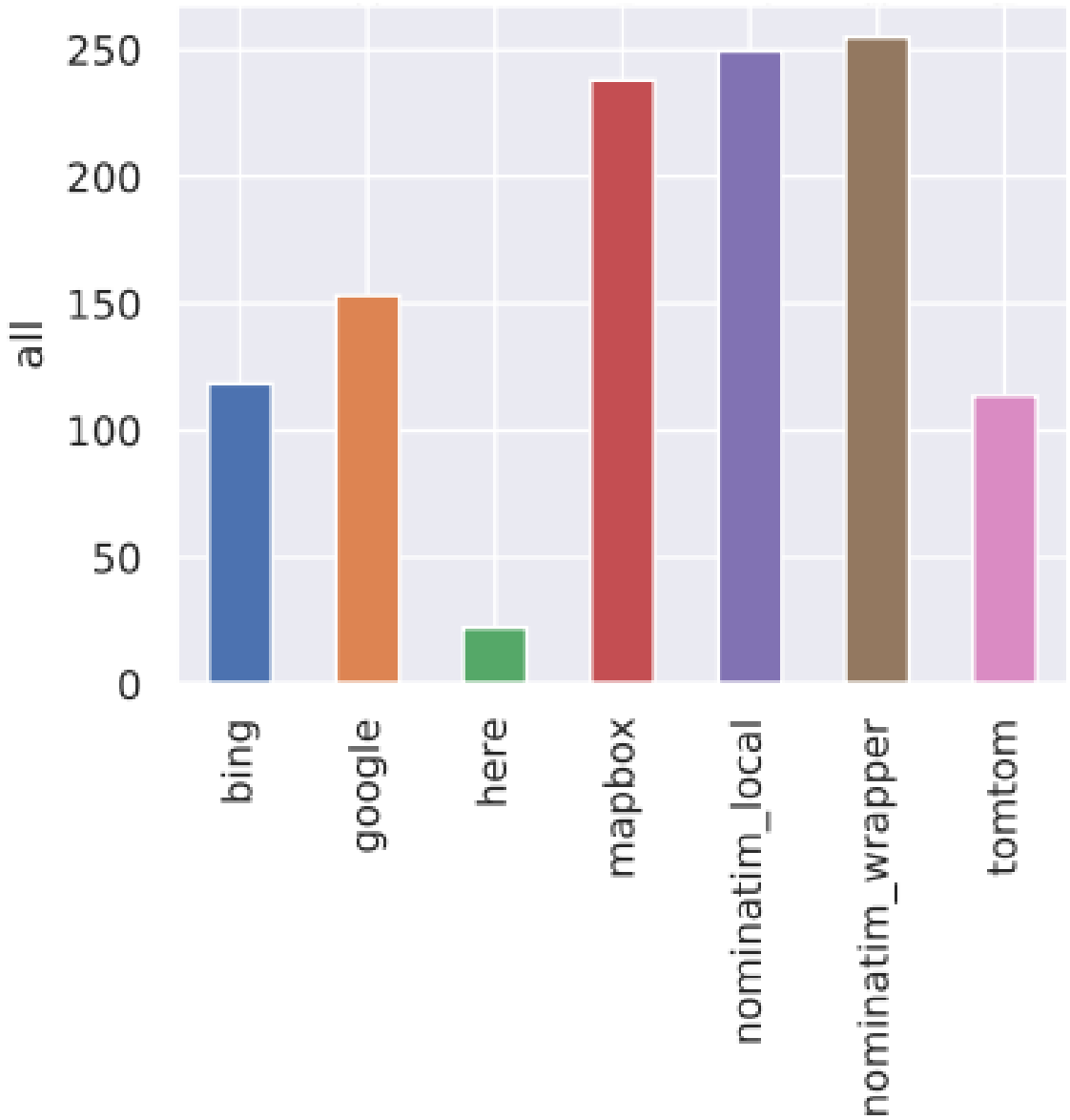
Avg distance to median - Rerun last week



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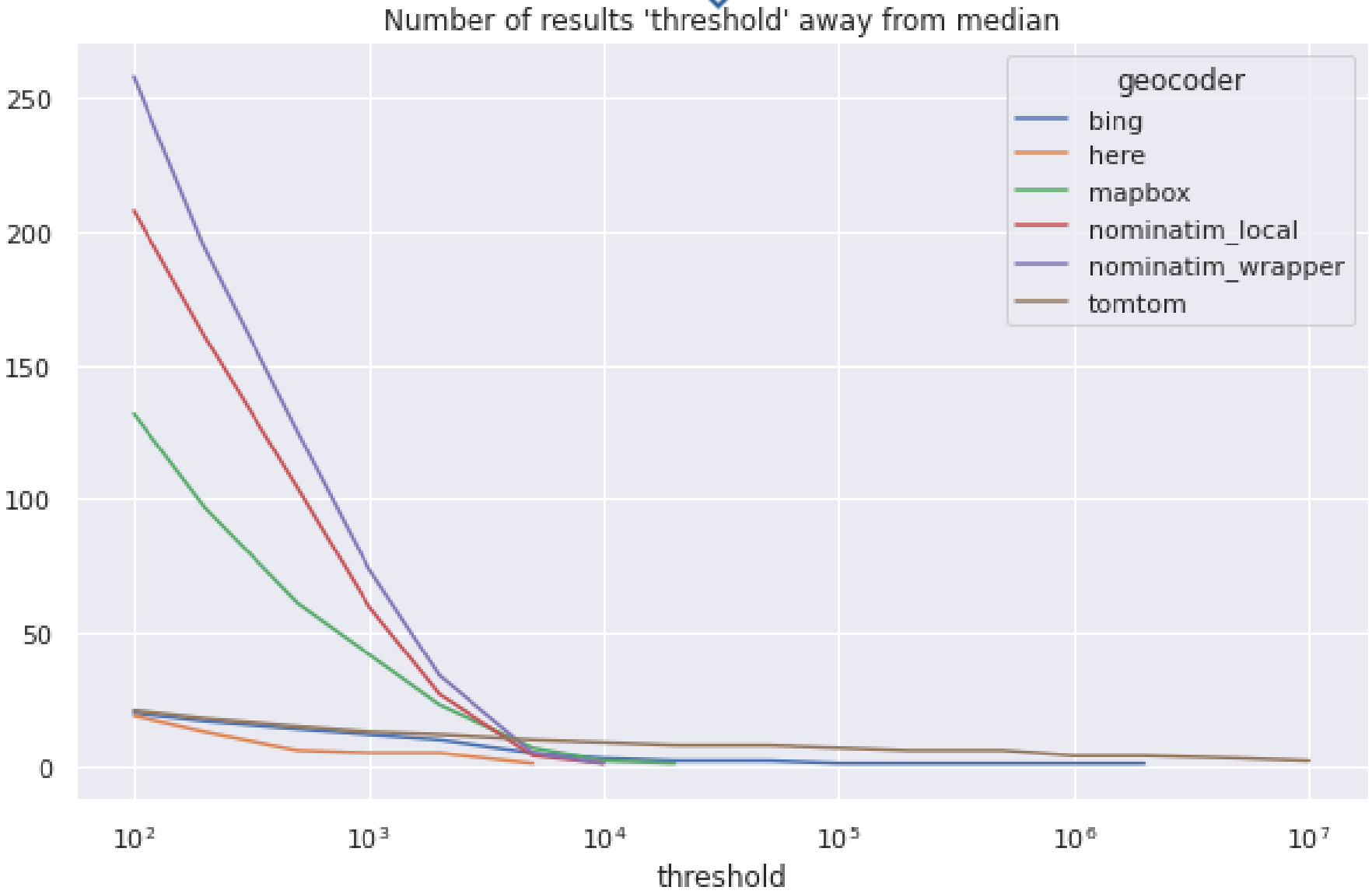
Distance distribution



A few months ago

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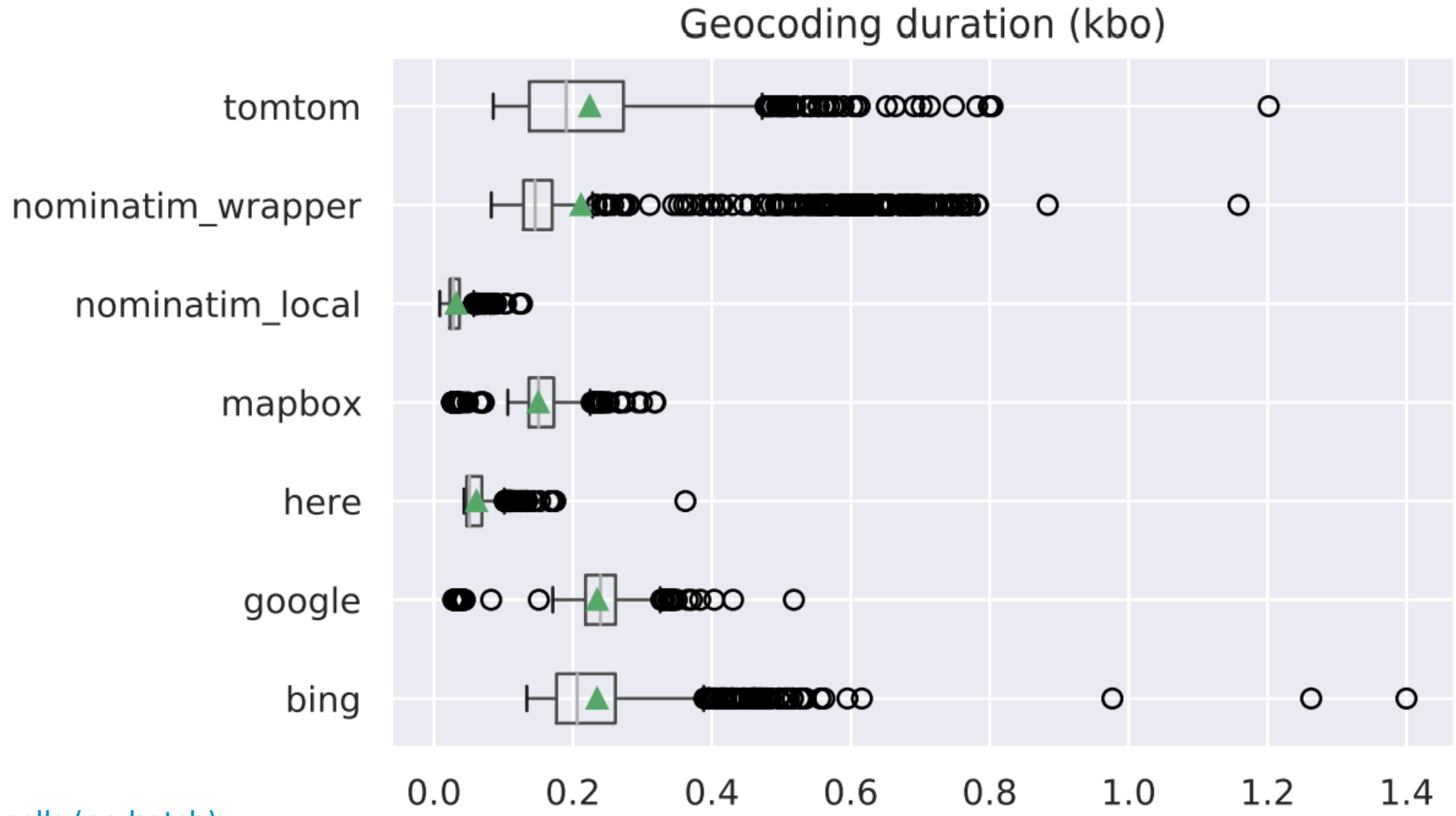
Geocoding speed



Sequential calls (no batch)

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Data sources

Sources

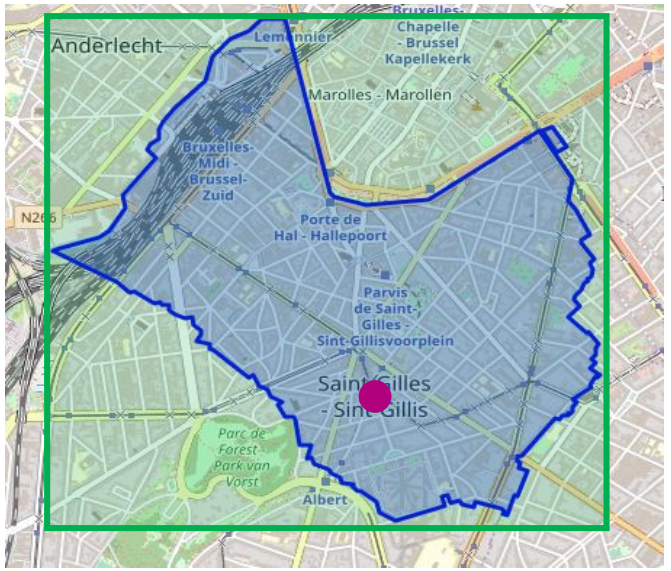
- Principalement deux façons d'obtenir des données géographiques :
  - En enrichissant les données "internes" (adresses, …), via des APIs
  - En utilisant des données authentiques/Open Sources (frontières et hiérarchies d'entités…)
- Les APIs permettent (souvent gratuitement) de collecter une multitude d'information:
  - Géocodage
  - Collecte de POI
  - Courbes isochrones
  - Itinéraires

API – Nominatim (OpenStreetMap)

https://nominatim.openstreetmap.org/search.php?q=**1060+saint-gilles**&format=jsonv2&addressdetails=1&polygon_geojson=1

[{**place_id**: 281729964,
boundingbox:
["50.8200036", "50.8401825", "4.3264847", "4.3588636"],
lat: "50.8249958", **lon**: "4.3454841",
display_name: "Saint-Gilles, Brussels-Capital, 1060, Belgium",
place_rank: 14,
address:
{**town**: "Saint-Gilles",
county: "Brussels-Capital",
region: "Brussels-Capital",
postcode: "1060",
country: "Belgium",
country_code: "be"
}, (...)

geojson:
{**type**: "MultiPolygon",
coordinates:
[[[[4.3264847, 50.8308493], [4.3302516, 50.829586], [4.3310
50.8291262], [4.3312378, 50.8292228],(...)],



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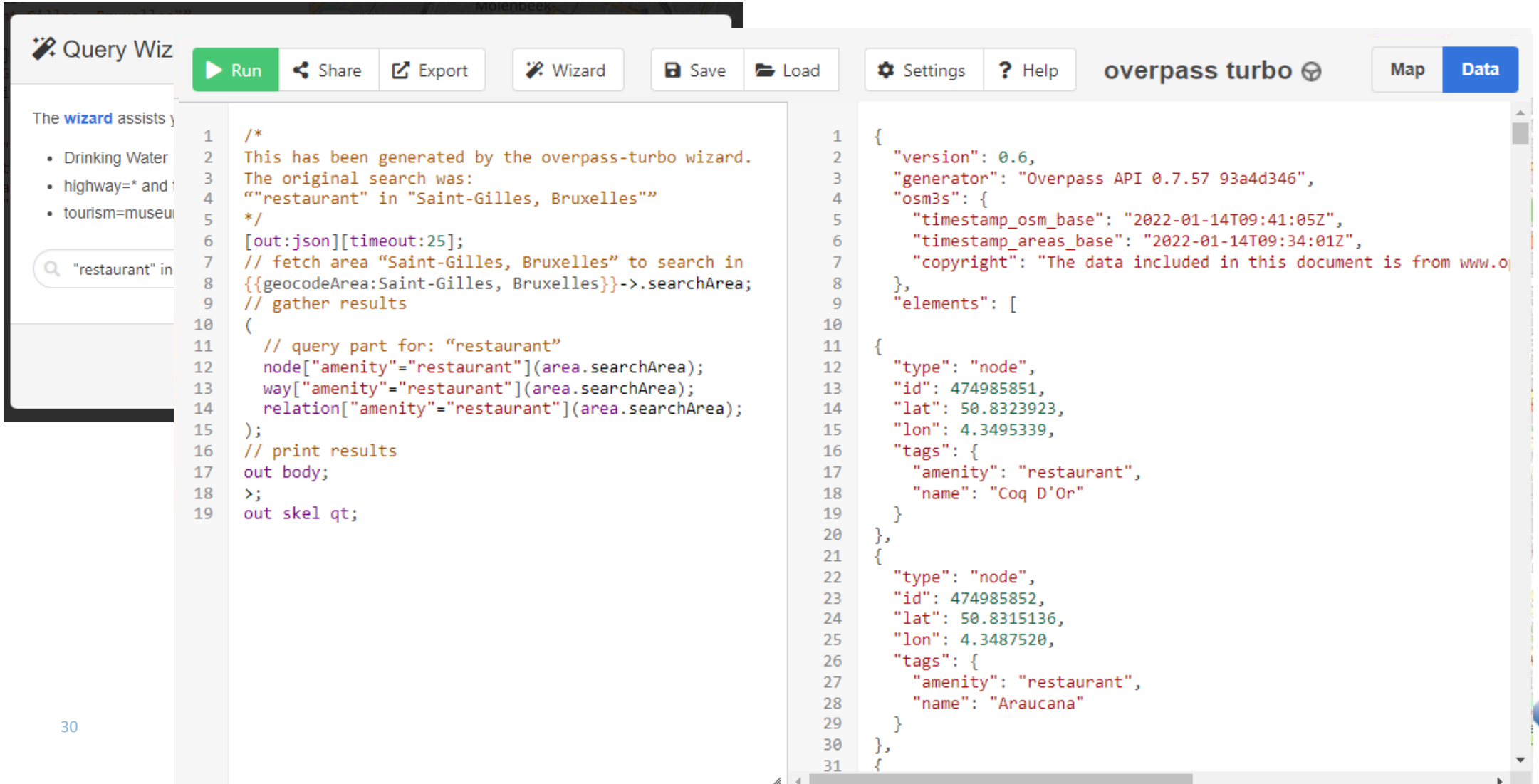
API – Nominatim (OpenStreetMap)

- Base: https://nominatim.openstreetmap.org/(...)
- Adresse exacte :
  (...)search?q=**Avenue+Fonsny+20,+1060+saint-gilles**&format=jsonv2&addressdetails=1
- POI (restaurant, Saint-Gilles):
  (...)search?q=**restaurant,+1060+saint-gilles,+Bruxelles**&format=jsonv2&addressdetails=1
- POI (restaurant, par “bounding box”):
  (...)search?q=**restaurant&viewbox=4.35886,50.84018,4.32648,50.82&bounded=1**&format=jsonv2
- Reverse:
  (...)**reverse?lat=50.83582&lon=4.33868**&format=jsonv2

API : Overpass (OpenStreetMap)

- http://overpass-turbo.eu/



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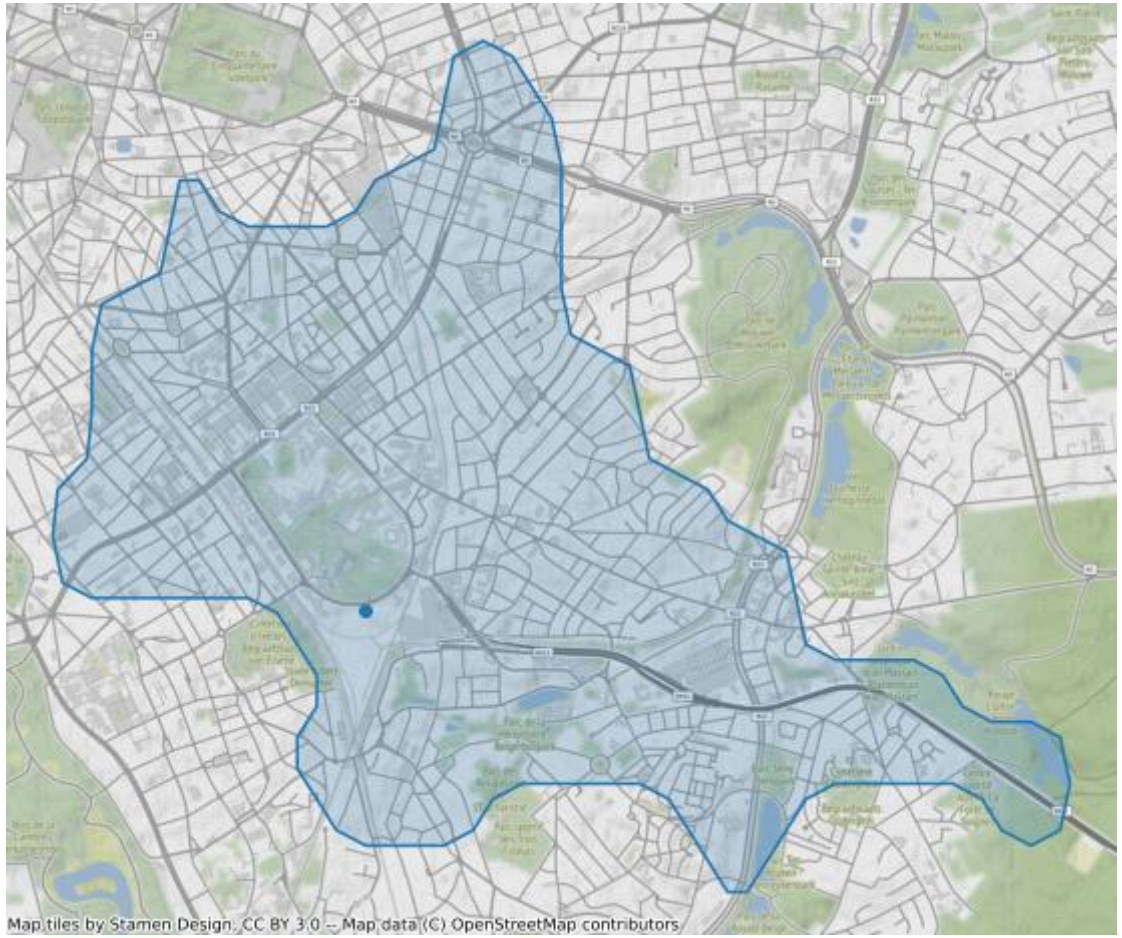
API : Here (routing)

- Routing:
  - https://router.hereapi.com/v8/routes?transportMode=car&**origin=50.83582,4.33868&destination=50.8249958,4.3454841**&return=summary&apiKey=X(...)zE&departureTime=any
  - **(…) travelSummary**:
    {**duration**: 294,
    length: 1636,
    baseDuration: 294},
- "Full routing": out of scope
- Matrix routing : tous les trajets possibles entre une liste de points
- Public transport routing: https://transit.hereapi.com/v8/routes?origin=50.83582,4.33868&destination=50.8249958,4.3454841&apiKey=X(...)zE

API : Here (isochrone)

- Isoline : ensemble des points accessibles à partir de/vers un point, en un temps (isochrone) ou une distance définie (voiture, camion, piéton)
- Résultat : polygône
- Exemple : zone accessible en 5 minutes à partir de l'hôpital Delta (Auderghem, Bruxelles)



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Sources officielles

- Contours des codes postaux (BPost):
  - https://www.geo.be/catalog/details/9738c7c0-5255-11ea-8895-34e12d0f0423?l=fr
  - https://bgu.bpost.be/assets/9738c7c0-5255-11ea-8895-34e12d0f0423_x-shapefile_3812.zip
- Contours des secteurs statistiques (StatBel):
  - https://statbel.fgov.be/fr/open-data/secteurs-statistiques-2020
  - https://statbel.fgov.be/sites/default/files/files/opendata/Statistische%20sectoren/sh_statbel_statistical_sectors_31370_20200101.shp.zip
- Localisation de chaque adresse (BestAddress) : https://opendata.bosa.be/index.fr.html
- Quartiers Bruxellois : https://monitoringdesquartiers.brussels/
- Structures des codes postaux/localité/communes/province (BPost): https://www.bpost2.be/zipcodes/files/zipcodes_alpha_fr_new.xls

BestAddress: open data

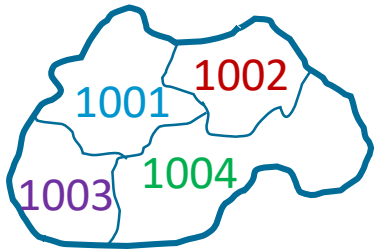
- BestAddress permet de télécharger toutes les addresses belges : https://opendata.bosa.be/
- Un fichier CSV par région :

	C	D	E	G	H	J	L	O	P	Q	R	U
1	EPSG:4326	EPSG:4326	address_i	house_nu	municipal	municipal	postcode	street_id	streetnam	streetname_fr	streetname_nl	
2	50.88995	4.31196	212450	6	21010	Jette	1090	2559		Place Jean-Louis Th	Jean-Louis Thysplaats	
3	50.82095	4.28556	200187	20	21001	Anderlech	1070	3959		Square Marie Curie	Marie Curiesquare	
4	50.79599	4.41243	25899	25	21017	Watermae	1170	4637		Avenue Delleur	Delleurlaan	
5	50.85773	4.30862	19920	31	21012	Molenbee	1080	3811		Rue Joseph Diongre	Joseph Diongrestraat	

- Difficulté : mapping “adresse en input” vs “adress BestAddress”
- À venir: REST API de géocodage (avril 2022?)

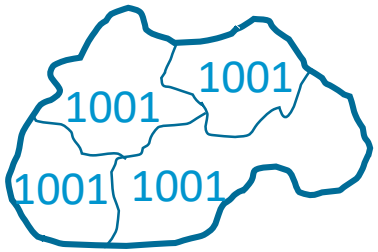
Belgium division schemes – Postal scheme

- Postal schemes (BPost): main commune – localities



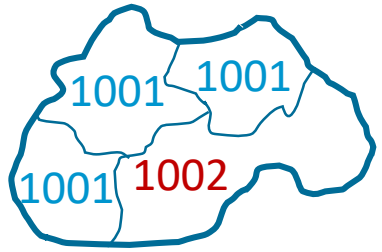
Main commune : Bruxelles(-Ville)

Zipcode	Locality
1000	Bruxelles
1020	Laeken
1120	Neder-Over-Hembeek
1130	Haren



Main commune : Jemeppe-Sur-Sambre

Zipcode	Locality
5190	Jemeppe-sur-Sambre
5190	Spy
5190	Onoz
5190	Balâtre
5190	…



Main commune : Assesse

Zipcode	Locality
5330	Assesse
5330	Maillen
5330	Sart-Bernard
5332	Crupet
5333	…

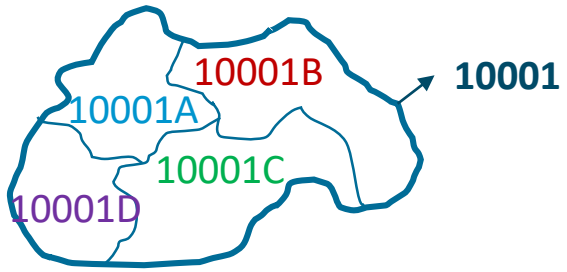
- No (numerical) ID for a commune (only « commune name ») → 581 values
- Locality ID : Zipcode + locality name
- Lots of « special codes » (1110 NATO, 1044 RTBF, …)

https://www.bpost.be/fr/codes-postaux

Smals ICT for society

Belgium division schemes – statistical scheme

- Statistical scheme (Statbel):
  - Main commune (NIS5) → 581 values
  - Sections (NIS6)

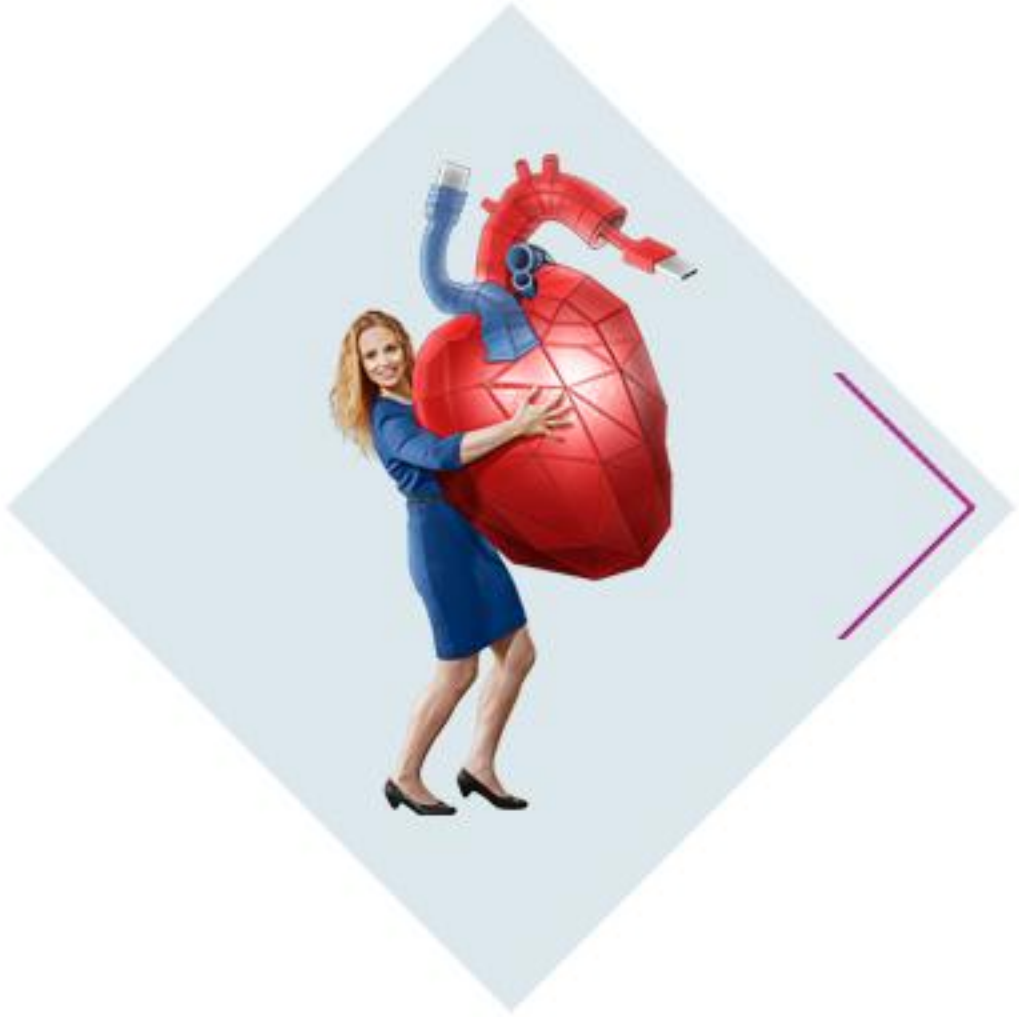


- No mapping Zipcode-NIS5 (or NIS6)
- No special code

Main commune : Bruxelles(-Ville)

NIS5		NIS6
21004	BRUXELLES PENTAGONE	21004A
21004	BRUXELLES-RUE DE LA LOI	21004B
21004	BRUXELLES-LOUISE	21004C
21004	BRUXELLES-CHAUSSEE D'ANVERS	21004D
21004	BRUXELLES-LAEKEN	21004E
21004	BRUXELLES-NEDER-OVERHEEMBEEK	21004F
21004	BRUXELLES-HAREN	21004G

https://statbel.fgov.be/fr/propos-de-statbel/methodologie/classifications/geographie



Visualisation

Visualisation

- Question : y a-t-il une composante/dépendance géographique dans un indicateur ?
- Premier réflex avant d'analyser des données : les visualiser
- Exemple : revenu moyen déclaré par commune :

INS	MEAN_INCOME
11001	21 966.0
11002	18 417.0
11004	20 091.0
…	…

INS	GEOM
11001	polygon(pt_1, pt_2,…)
11002	polygon(…)
11004	polygon(…)
…	…

INS	GEOM	MEAN_INCOME
11001	polygon(pt_1, pt_2,…)	21 966.0
11002	polygon(…)	18 417.0
11004	polygon(…)	20 091.0
…	…	…

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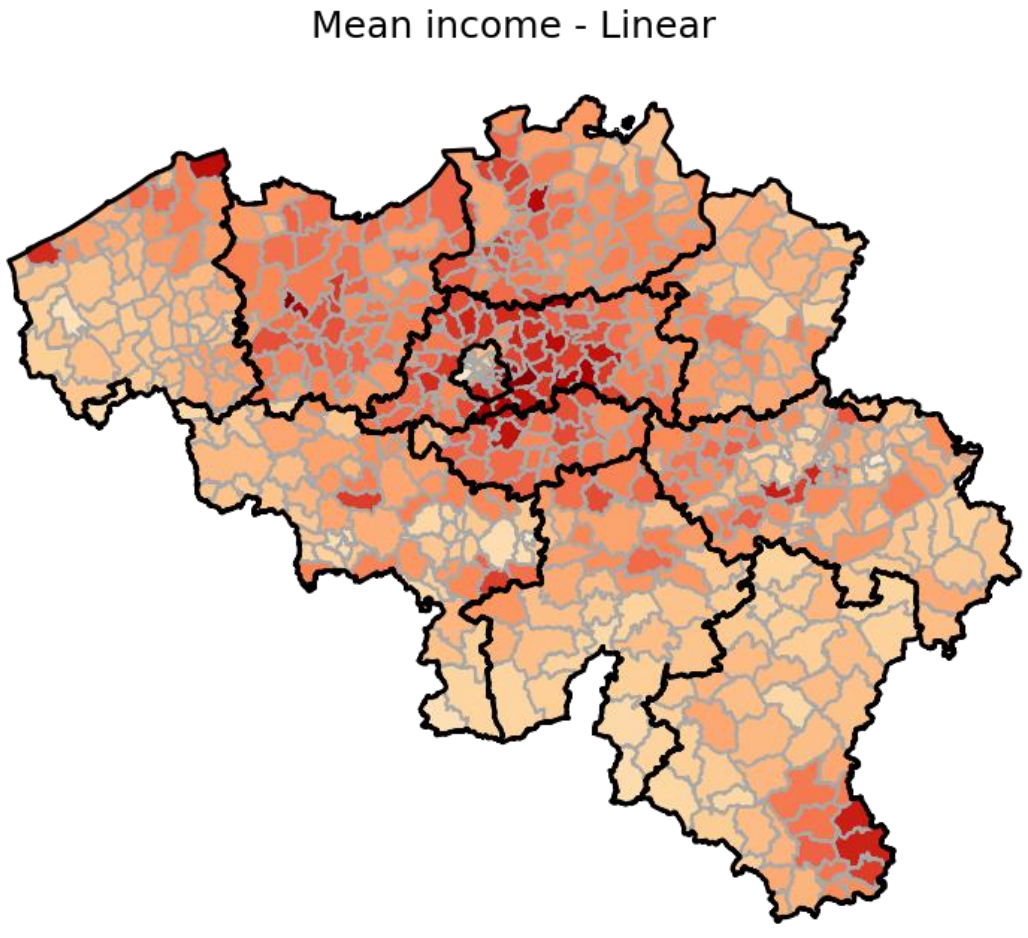
Colorisation linéaire



- Colorisation linéaire entre min et max
- Si quelques outiers très éloignés du reste, peu de distinction
- Petites communes (ex: Bxl) difficile à voir

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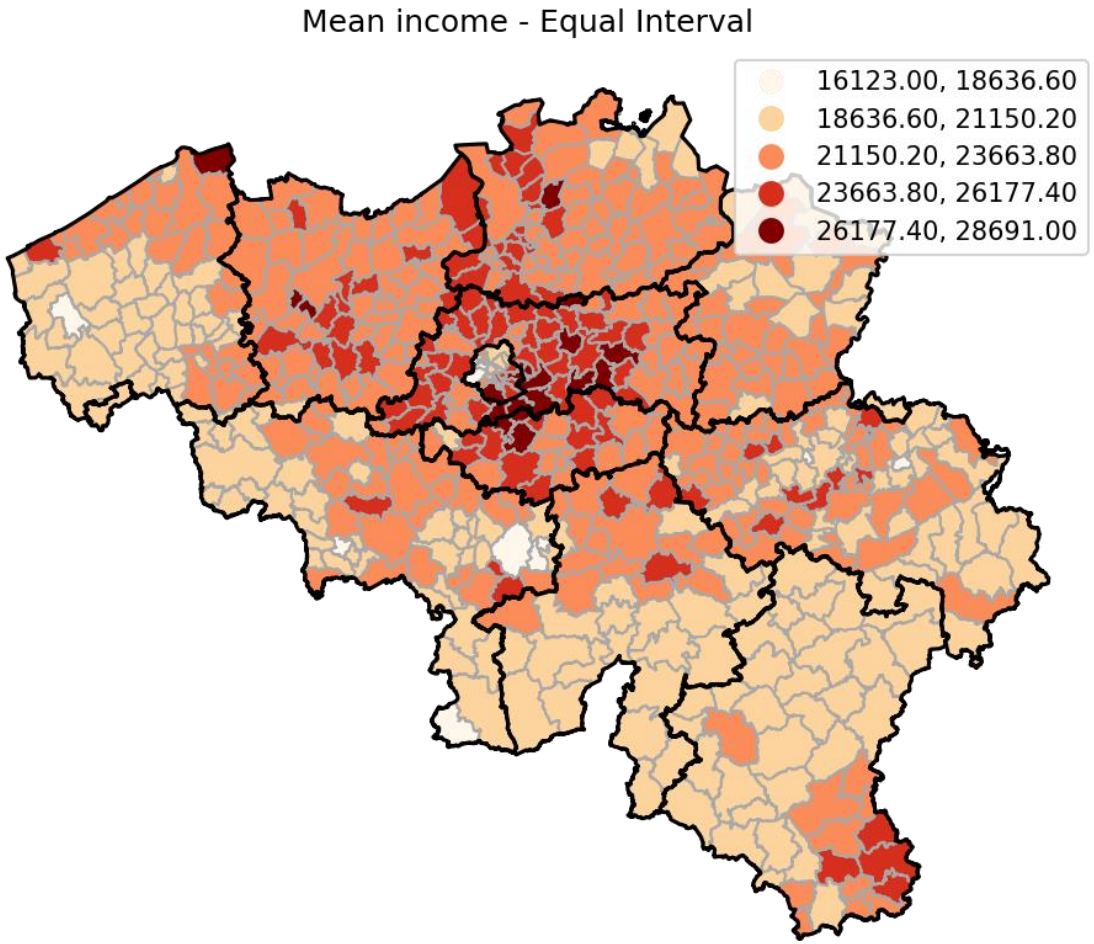
ICT for society

Equal intervals



- On découpe l'intervalle [min, max] en K (ici: 5) classes de taille égale
- Rend les couleurs plus distinctes, mais on perd en précision
- Pas de garantie que toutes les classes soient utilisées

From	To	Width	Count
16123,0	18636,6	2513,6	**11**
18636,6	21150,2	2513,6	**190**
21150,2	23663,8	2513,6	**256**
23663,8	26177,4	2513,6	**103**
26177,4	28691,0	2513,6	**21**

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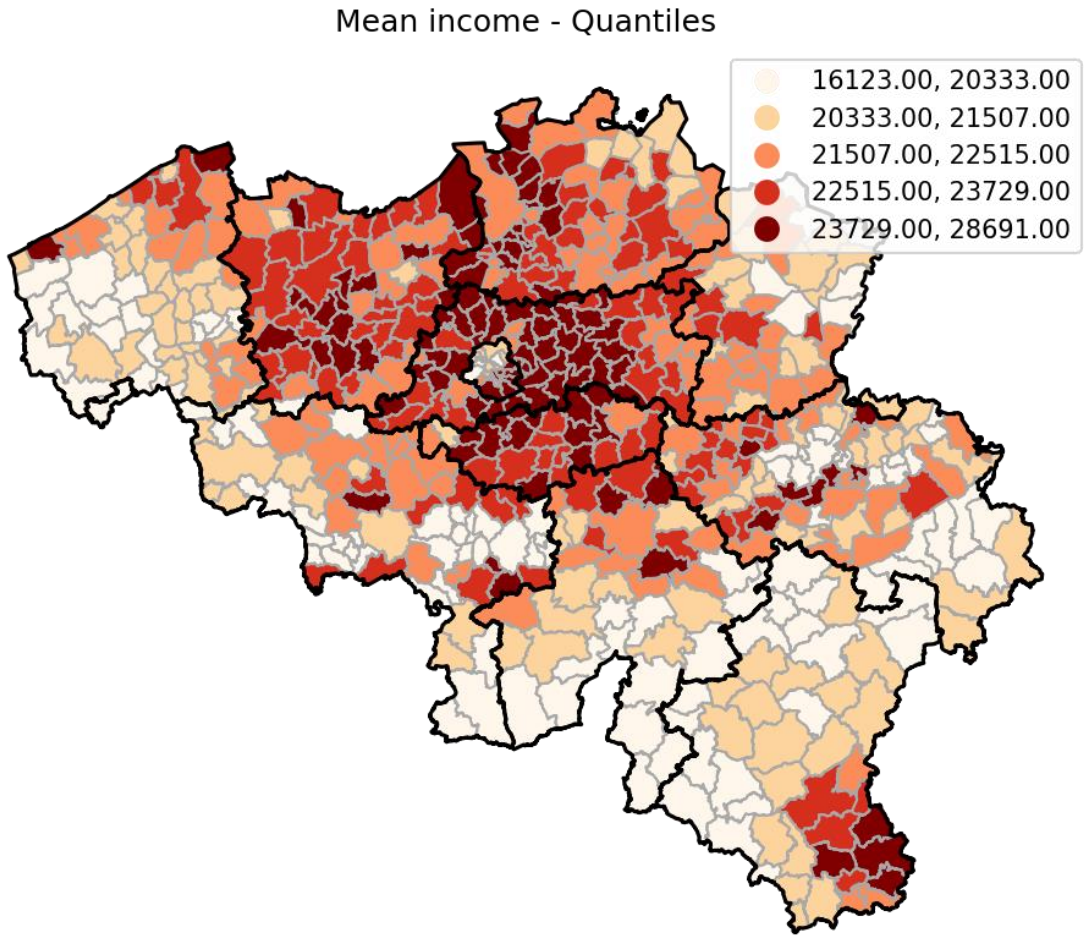
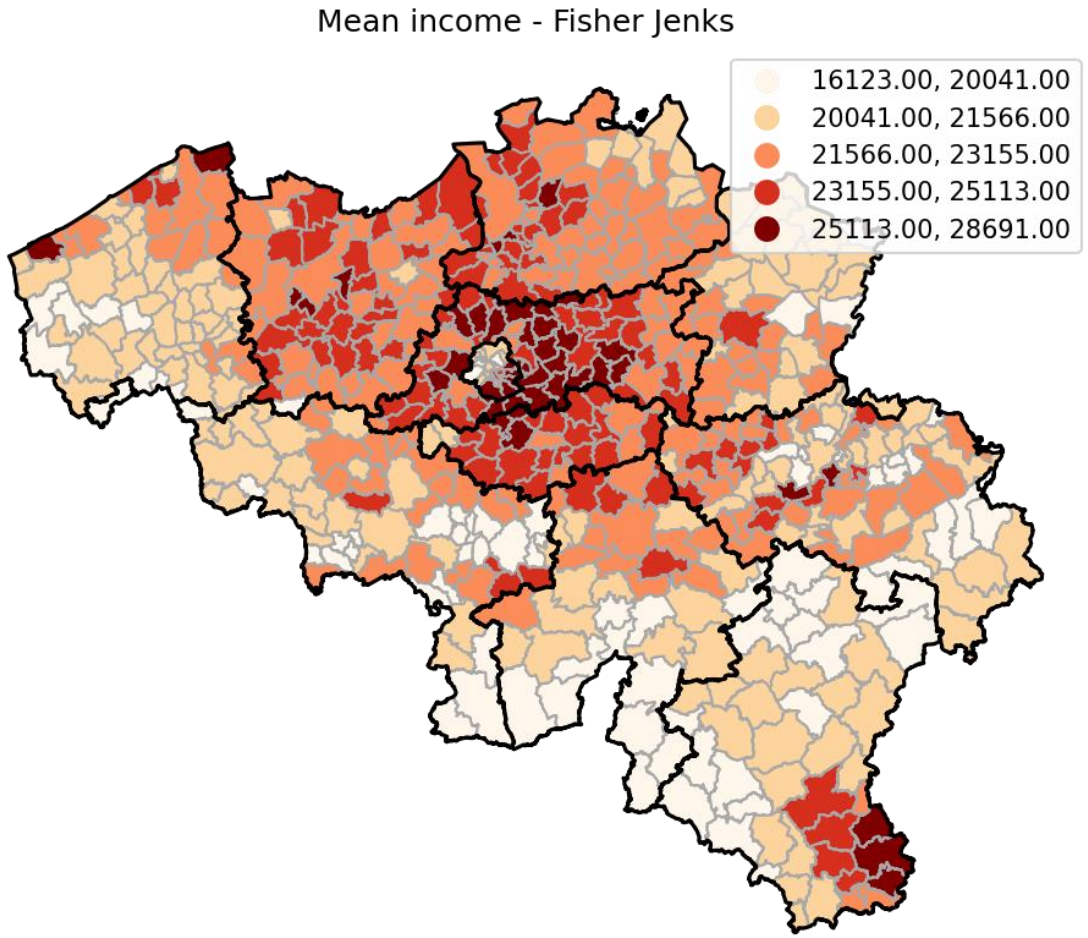
Quantiles



- On découpe les données en K (ici: 5) classes de taille égale (si possible)

From	To	Width	Count
16123	20333	**4210**	117
20333	21507	**1174**	116
21507	22515	**1008**	116
22515	23729	**1214**	116
23729	28691	**4962**	116

Fisher-Jenks



- On découpe les données en K (ici: 5) classes les plus « uniformes possibles »
- Minimise la variance au sein de chaque classe, la maximise entre les classes
- Version à 1 dimension de « K-means »

From	To	Width	Count
16123	20041	3918	82
20041	21566	1525	163
21566	23155	1589	168
23155	25113	1958	122
25113	28691	3578	46

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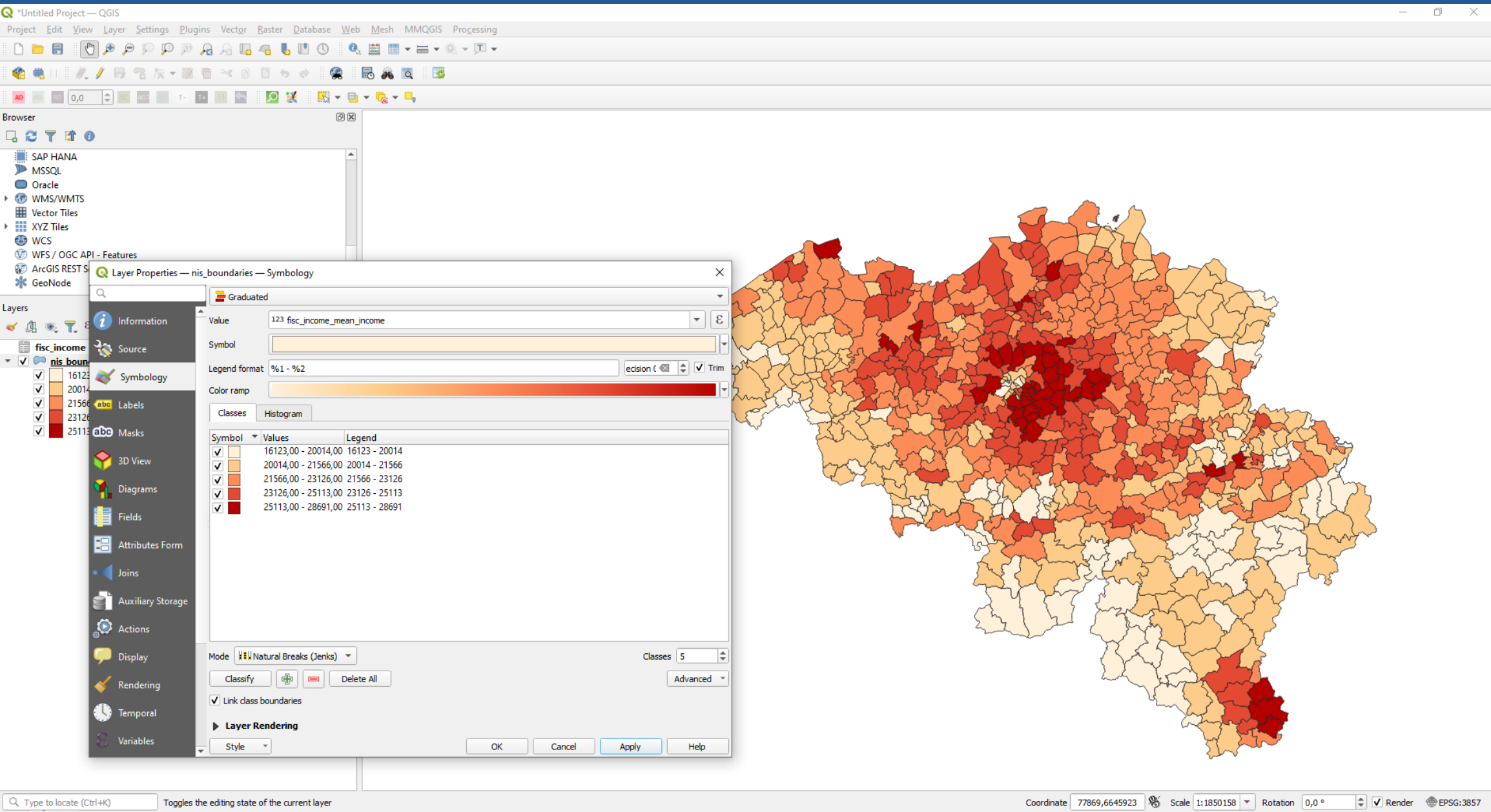
QGIS



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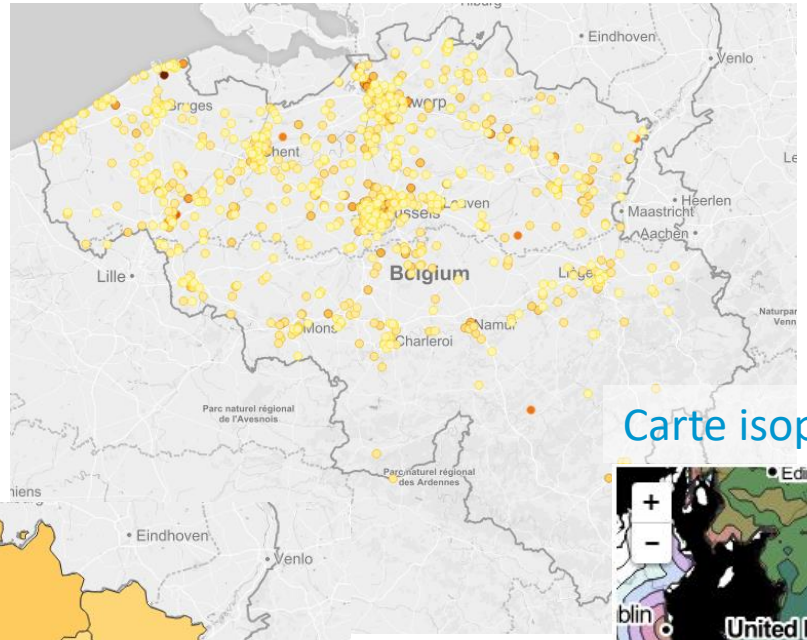
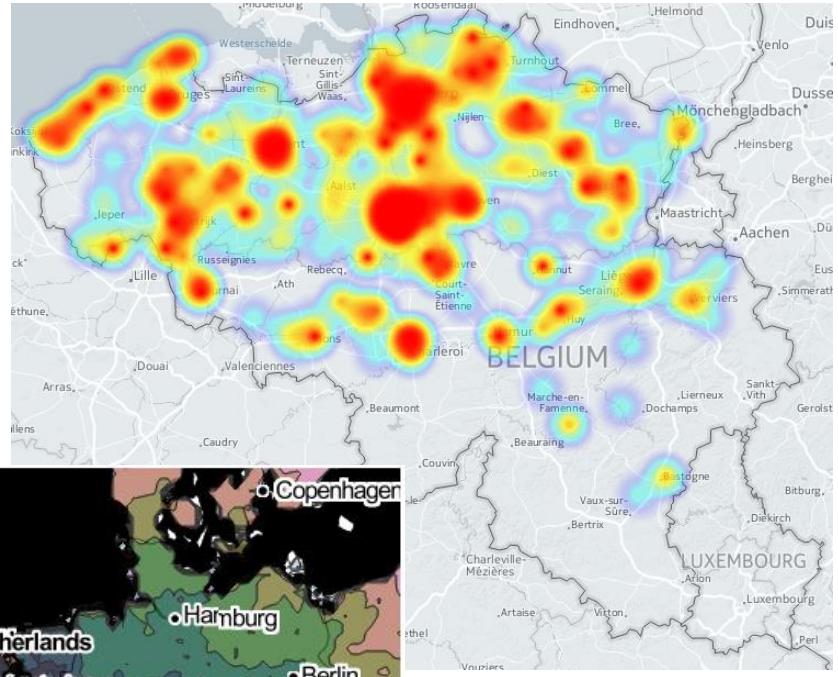
Autres visualisations

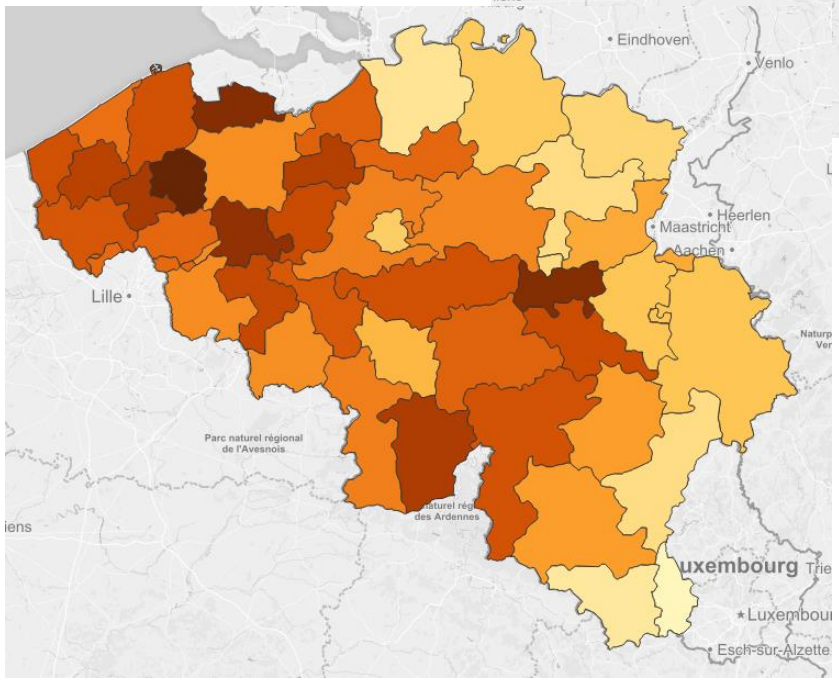
Carte par point



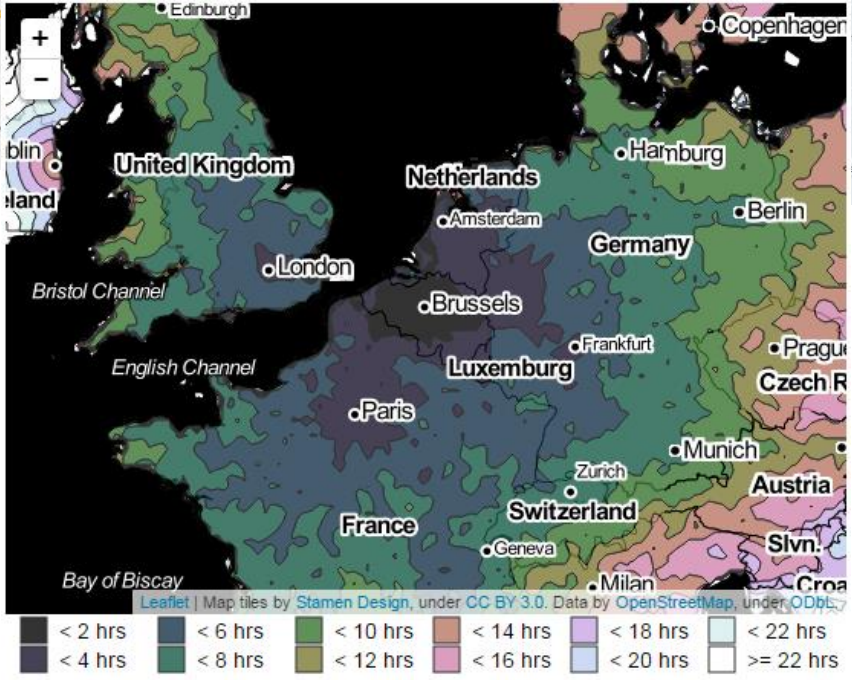
Heatmap (carte de chaleur)



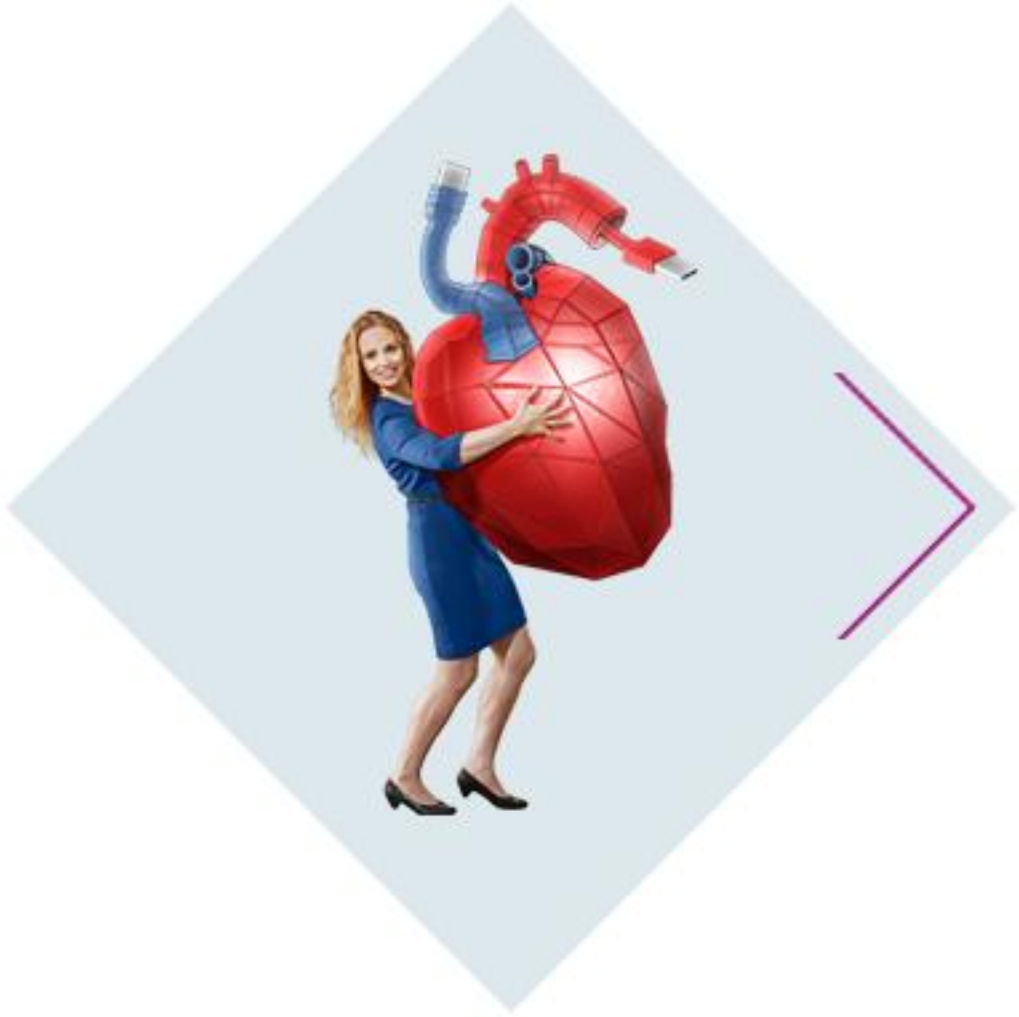
Carte choroplèthe



Carte isoplèthe



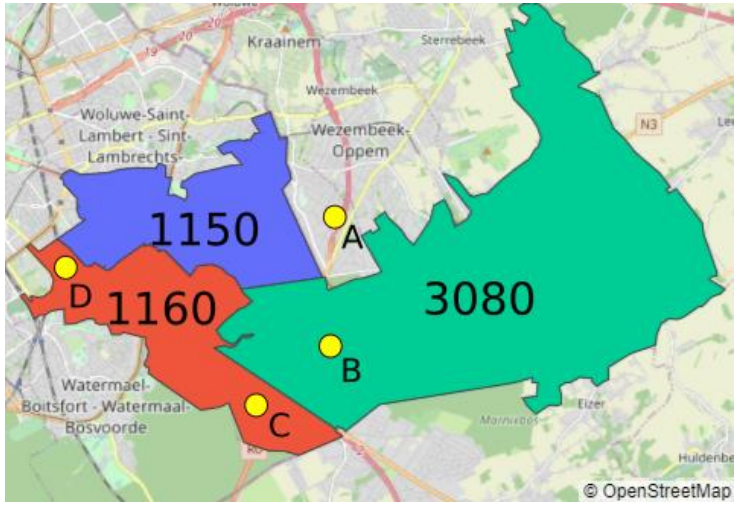
Smals
ICT for society



Jointure spatiale et bases de données géographiques

Jointure spatiale

- Jointure “classique”



observations

ID	ZIPCODE
A	
B	3080
C	1160
D	1160
…	…

zipcodes

ZIPCODE	PROVINCE
1150	Bruxelles-Capitale
1160	Bruxelles-Capitale
3080	Brabant Flamand
…	…

```
SELECT o.ID, o.zipcode, z.province
FROM observations o
LEFT JOIN zipcodes z
ON o.zipcode = z.zipcode
```

ID	ZIPCODE	PROVINCE
A		
B	3080	Brabant Flamand
C	1160	Bruxelles-Capitale
D	1160	Bruxelles-Capitale
…		

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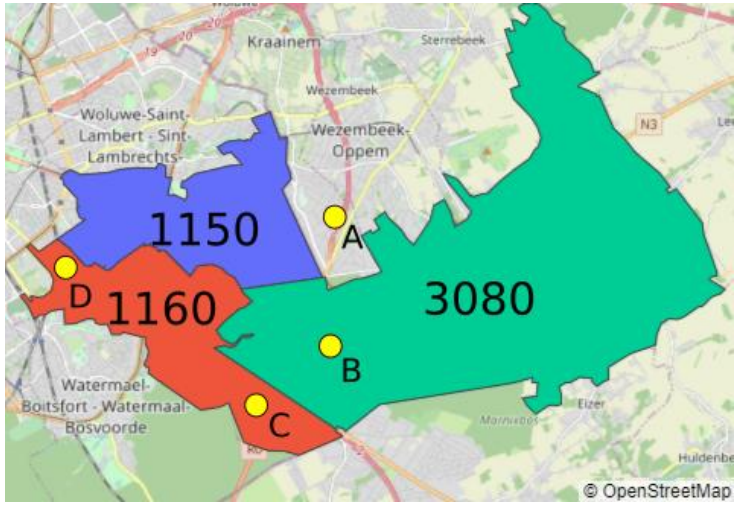
Jointure spatiale

- Jointure “spatiale”



observations

ID	GEOM
A	point(x_a, y_a)
B	point(x_b, y_b)
C	point(x_c, y_c)
D	point(x_d, y_d)
…	…

provinces

PROVINCE	GEOM
Bruxelles-Capitale	polygon(pt_1, pt_2,…)
Brabant Flamand	polygon(…)
Braband Wallon	polygon(…)
…	…

```
SELECT o.ID, p.province
FROM observations o
LEFT JOIN provinces p
ON ST_Contains (p.geom, o.geom)
```

ID	PROVINCE
A	Brabant Flamand
B	Brabant Flamand
C	Bruxelles-Capitale
D	Bruxelles-Capitale
…	

Query “PostGIS” (extension de PostGreSQL)

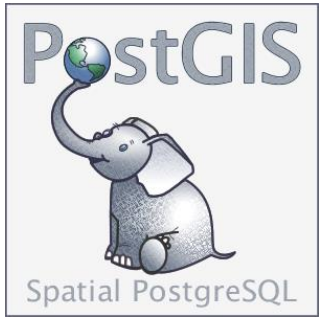
Smals ICT for society

PostGIS

- PostGIS (https://postgis.net/) is an extension of PostGreSQL

- Add new (spatial) data types :
  - POINT (+MULTIPOINT)
  - LINESTRING (+MULTILINESTRING)
  - POLYGON (+MULTIPOLYGON)
  - GEOMETRYCOLLECTION

- Add set of new (spatial) operations "ST_" (spatial type):
  - Comparison: ST_Contains, ST_Within, ST_Intersects
  - Aggregation: ST_Union
  - Combinations: ST_Intersection, ST_Difference
  - Measurement: ST_Distance, ST_Area
  - Projection handling: ST_Transform



- POINT = x, y (, z) + CRS
  - EPSG:4326 / WGS 84 (polar)
    - 4.3383, 50.8357 (longitude, latitude)
  - EPSG:3857 / WGS 84 pseudo-Mercator (metric)
    - 482 944.1, 6 592 292.4 (easting, northing)
  - EPSG:31370 / Belgian Lambert 72:
    - 147 859.2, 169 482.7 (easting, northing)

- (Minimal) Installation:
  - Install PostGreSQL
  - Install PostGIS binary (or build sources)
  - `CREATE EXTENSION postgis;`

Smals ICT for society

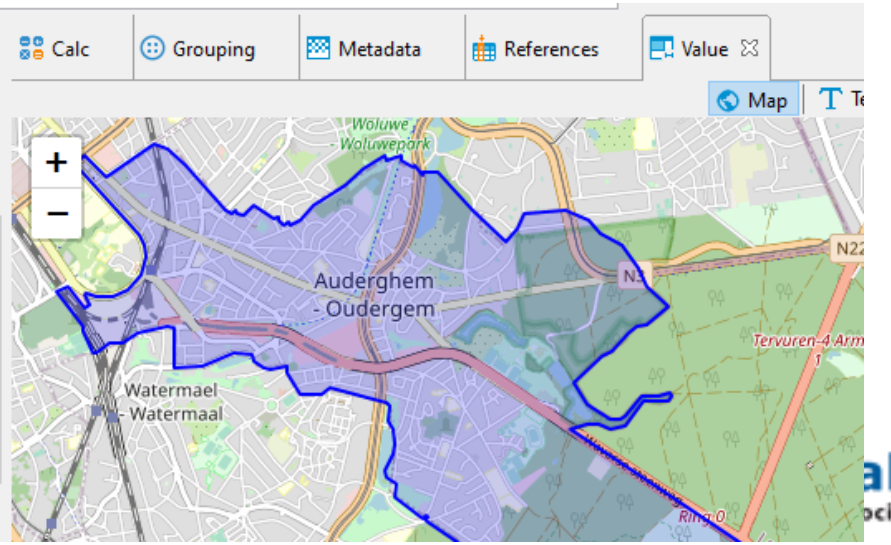
Data sources

- We will load 4 OpenData sources:

Subject	Source	Shapes	Format	URL
Zipcode list (mapping zipcode-main commune)	BPost	Non geo	Excel	https://www.bpost2.be/(...)/zipcodes_alpha_fr_new.xls
Zipcode boundaries	BPost	Polygons	Shapefile	https://bgu.bpost.be/(...)_x-shapefile_3812.zip
Zipcode centers	Agence du Numérique	Points	GeoJSON	https://www.odwb.be/(...)/code-postaux-belge/exports/geojson
NIS code boundaries (statistical code level)	Statbel	Polygons	Shapefile	https://statbel.fgov.be/(...)/sh_statbel_statistical_sectors_31370_20200101.shp.zip

- In DBeaver:

	zipcode	is_special	geometry
8	1083	[ ]	POLYGON Z((4.3141200710327965 50.879913314876895 0, 4.314364646248509 50.879910343655084 0, 4.3147113301714 41 50.879
9	1090	[ ]	POLYGON Z((4.327598207423981 50.893364785417354 0, 4.32626134037569 50.891408698066954 0, 4.32632830591178 50.8913892
0	1099	[v]	POLYGON Z((4.413543363024862 50.911582341339376 0, 4.413093431163375 50.91108304503646 0, 4.413061327321158 50.911042
1	1105	[v]	POLYGON Z((4.3531983480800145 50.85014122453475 0, 4.353247117590716 50.84997084005416 0, 4.353175537163507 50.849816
2	1110	[v]	POLYGON Z((4.42819723854411 50.882026337836 0, 4.429700045875309 50.8782804223708 0, 4.429484134859504 50.8777816956 0
3	1120	[ ]	MULTIPOLYGON Z(((4.406288376086285 50.913103136943214 0, 4.405861863346267 50.91250310244647 0, 4.405579633475274 50
4	1130	[ ]	POLYGON Z((4.421194590355868 50.90319073244135 0, 4.421300360278826 50.90318924713572 0, 4.42175262727196 50.90322401
5	1140	[ ]	POLYGON Z((4.402965863242295 50.885036114397074 0, 4.403236808800037 50.88495647629276 0, 4.403266394272282 50.884996
6	1150	[ ]	POLYGON Z((4.46453289128135 50.84543458084347 0, 4.464620997901788 50.845280038669415 0, 4.464660977110739 50.8452099
7	1160	[ ]	POLYGON Z((4.407530006463037 50.825526663960815 0, 4.408787206768317 50.82468003618179 0, 4.409639560497666 50.824134
8	1170	[ ]	POLYGON Z((4.406281879386394 50.81487173035492 0, 4.4063036984364095 50.81465642072515 0, 4.406273655148961 50.814529
9	1180	[ ]	POLYGON Z((4.367312449506682 50.816632364494566 0, 4.367301468664922 50.81657067518872 0, 4.367292880103075 50.816522
0	1190	[ ]	POLYGON Z((4.332631838354738 50.82868882934866 0, 4.33278910519502 50.82863412946709 0, 4.332855508690386 50.828611 03
1	1200	[ ]	POLYGON Z((4.436304387773484 50.8588848028416 0, 4.437371685036211 50.85850521008912 0, 4.437392187931652 50.858528 03
2	1210	[ ]	POLYGON Z((4.367165693806663 50.85791404502723 0, 4.367886918603596 50.8577594939246 0, 4.368046460119377 50.857725 30



Simple distance

```
SELECT
        a.locality,
        b.locality,
        ST_Distance(a.geometry, b.geometry),
        ST_DistanceSphere(a.geometry, b.geometry)
FROM
        gistest.zipcodes_centers a,
        gistest.zipcodes_centers b
WHERE a.zipcode='1160' AND b.zipcode='5190'
```

Geometric Euclidian distance (ok only for metric CRS)

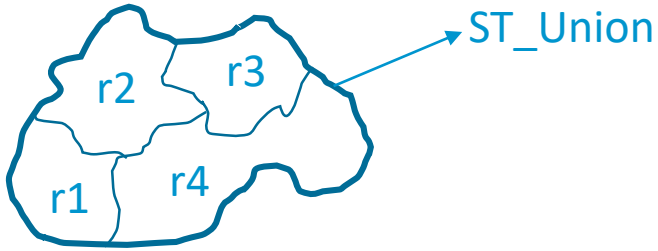
Geographical distance (in meters)

$$\sqrt{(4.433 - 4.995)^2 + (50.815 - 50.828)^2}$$

	locality	locality	st_distance	st_distancesphere
1	Auderghem	Moustier-Sur-Sambre	0.4378300821	43,089.00047741
2	Auderghem	Saint-Martin	0.3807369552	38,121.84729085
3	Auderghem	Balâtre	0.3778559061	38,134.34560066
4	Auderghem	Onoz	0.4006119939	39,630.80735948
5	Auderghem	Jemeppe-Sur-Sambre	0.4164304942	42,209.58949063
6	Auderghem	Ham-Sur-Sambre	0.4421927051	44,618.0699368
7	Auderghem	Mornimont	0.4508334992	44,379.13904389
8	Auderghem	Spy	0.4295900467	41,768.06793197

Aggregation

```
SELECT
        c_provi, t_provi_fr, t_regio_fr,
        ST_Union(geometry) as geometry
FROM gistest.statistical_sectors
GROUP BY c_provi, t_provi_fr, t_regio_fr
```



statistical_sectors 1

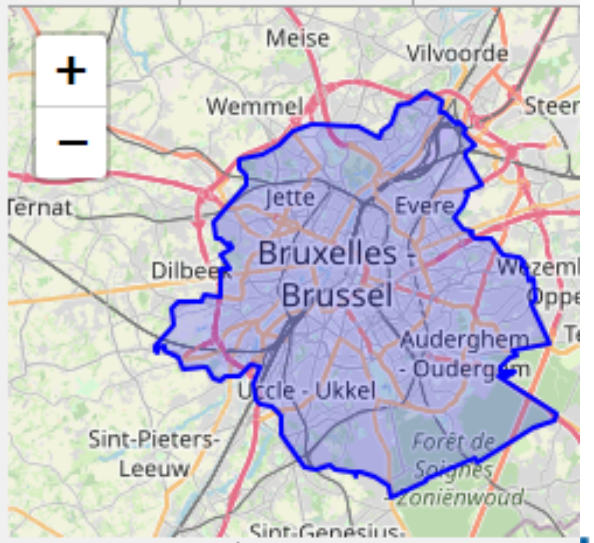
SELECT c_provi, t_provi_fr, t_regio_fr, ST_Union(geometry) as geome

Enter a SQL expression to filter results (use Ctrl+Space)

Grid | Text | Spatial | Record

	c_provi	t_provi_fr	t_regio_fr	geometry
1	40000	Province de Flandre orientale	Région flamande	POLYGON Z((3.8913699566800735 50.743034458685
2	80000	Province du Luxembourg	Région wallonne	POLYGON Z((5.619343985306024 49.5246340405451
3	10000	Province d'Anvers	Région flamande	MULTIPOLYGON Z(((4.356497945561555 51.0167519
4	70000	Province du Limbourg	Région flamande	MULTIPOLYGON Z(((5.152636643029442 50.6965789
5	60000	Province de Liège	Région wallonne	POLYGON Z((6.141075404446796 50.1658812945573
6	50000	Province du Hainaut	Région wallonne	MULTIPOLYGON Z(((4.25039772880804 49.96223026
7	20002	Province du Brabant wallon	Région wallonne	POLYGON Z((4.554173509041858 50.5361666493454
8	30000	Province de Flandre occidentale	Région flamande	POLYGON Z((3.191547205152201 50.7559780002177
9	90000	Province de Namur	Région wallonne	POLYGON Z((4.870313712271117 49.7924532777839
10	20001	Province du Brabant flamand	Région flamande	POLYGON Z((4.261234445222165 50.7000576337673
11	-	[NULL]	Région de Bruxelles-Capitale	POLYGON Z((4.4040908520136535 50.769799396396

Calc | Grouping | Metadata



ICT for society

Aggregation – commune boundaries

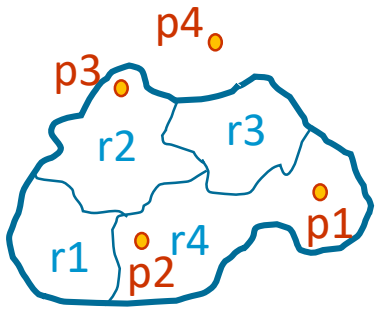
```
-- Create a table with NIS boundaries
CREATE TABLE gistest.nis_boundaries AS -- or: CREATE VIEW
    SELECT cnis5_2020, -- Code NIS5
           t_mun_fr,   -- Commune name
           ST_Union(geometry) AS geometry
    FROM gistest.statistical_sectors
    GROUP BY cnis5_2020, t_mun_fr


-- Create a table with postal boundaries
CREATE TABLE gistest.zip_commune_boundaries AS  -- or: CREATE VIEW
    SELECT main_commune,
           ST_Union(geometry) AS geometry
    FROM gistest.zipcodes zp
      JOIN gistest.zipcodes_boundaries zp_bnd
      ON zp.zipcode = zp_bnd.zipcode
    WHERE NOT zp.is_special
    GROUP BY main_commune
```

Spatial Join

table_polygons

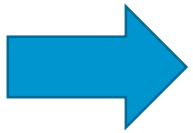
ID	geom
r1	POLYGON(…)
r2	POLYGON(…)
r3	POLYGON(…)
r4	POLYGON(…)



table_points

ID	geom
p1	POINT(…)
p2	POINT(…)
p3	POINT(…)
p4	POINT(…)

```
SELECT plg.ID, pnt.ID
FROM table_polygons plg
FULL JOIN table_points pnt
  ON ST_Contains(plg.geom, pnt.geom)
```



plg.ID	pnt.ID
r1	NULL
r2	p3
r3	NULL
r4	p1
r4	p2
NULL	p4

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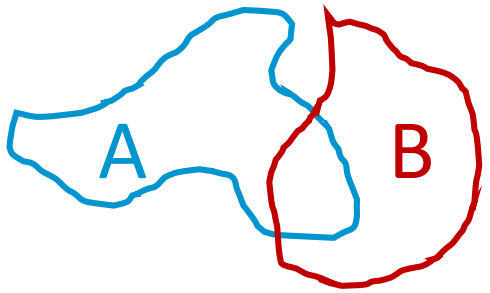
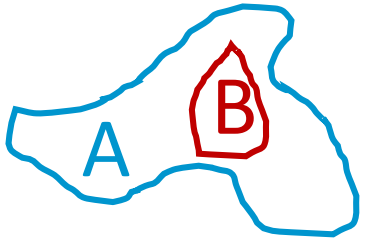
Spatial operations



ST_Intersects(A, B)

ST_Touches(A, B)



ST_Contains(A, B)
= ST_Within(B, A)

ST_Equals
ST_Overlaps
ST_Covers
ST_Disjoint
…

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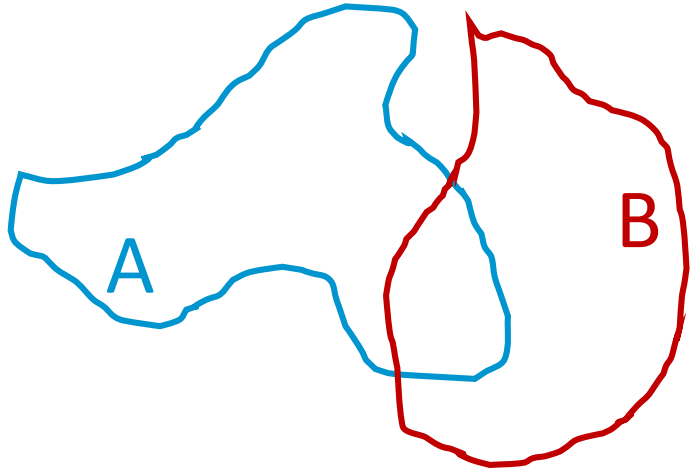
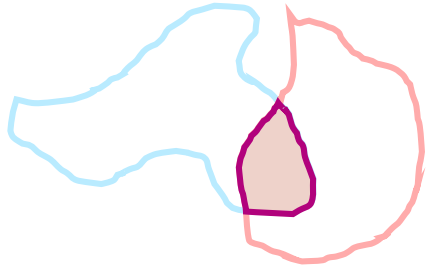
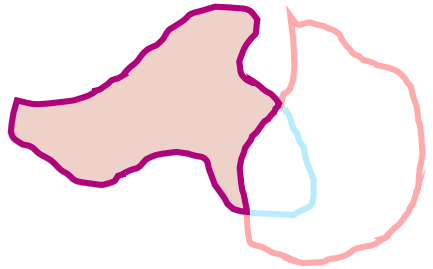
Spatial operations



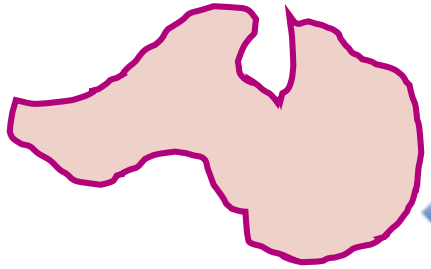
ST_Intersection(A, B):



ST_Difference (A, B):



ST_Union (A, B):



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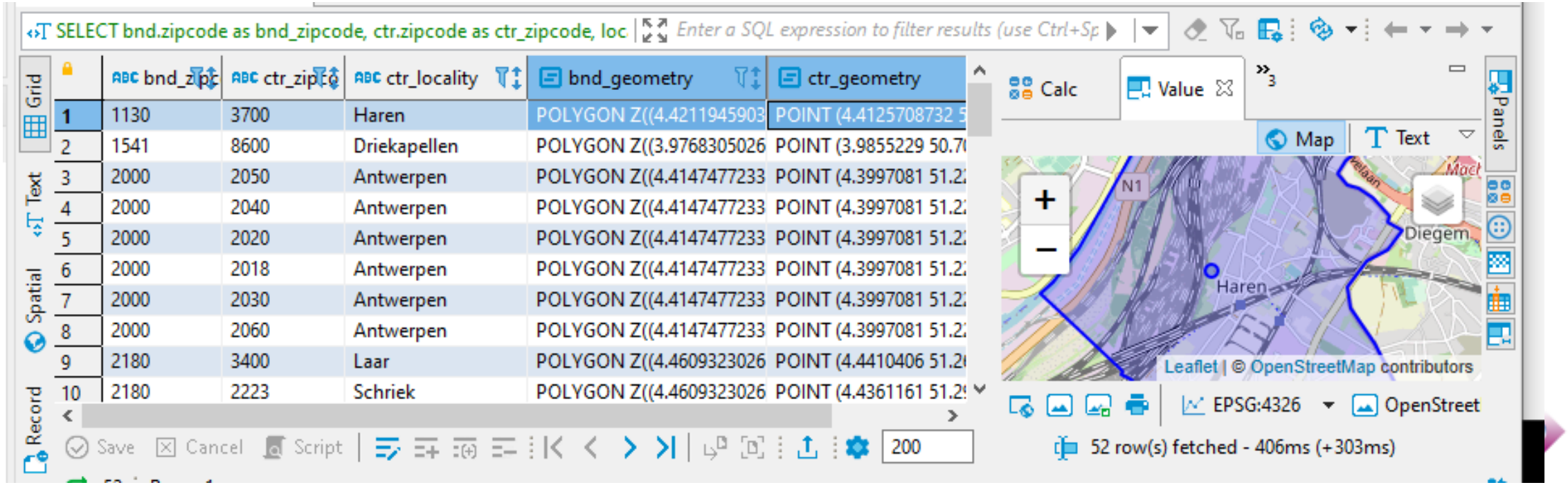
Spatial join: Mismatch zip centers – zip boundaries

```
SELECT
       bnd.zipcode  as bnd_zipcode, ctr.zipcode  as ctr_zipcode,
       locality     as ctr_locality,
       bnd.geometry as bnd_geometry, ctr.geometry as ctr_geometry
FROM gistest.zipcodes_boundaries bnd
       JOIN gistest.zipcodes_centers ctr
       ON ST_Contains(bnd.geometry, ctr.geometry)
WHERE bnd.zipcode != ctr.zipcode
```



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Spatial join – Internal mismatch @ BPost

```
SELECT zp1.zipcode, zp2.zipcode,
       zp1.geometry, zp2.geometry,
       ST_intersection(zp1.geometry, zp2.geometry),
       st_area(ST_intersection(zp1.geometry, zp2.geometry))/ST_Area(zp1.geometry)
              AS common_ratio
FROM gistest.zipcodes_boundaries zp1
JOIN gistest.zipcodes_boundaries zp2
ON ST_intersects(zp1.geometry, zp2.geometry)
       AND zp1.zipcode < zp2.zipcode
       AND ST_Area(ST_Intersection(zp1.geometry, zp2.geometry))/ST_Area(zp1.geometry) >0.01
ORDER BY common_ratio
```


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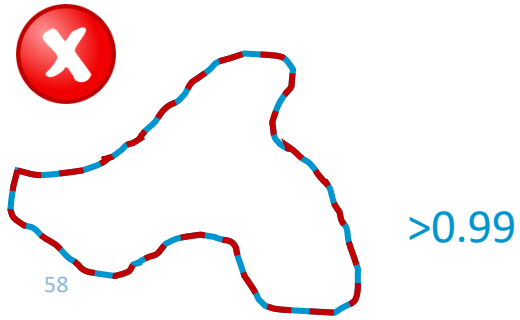
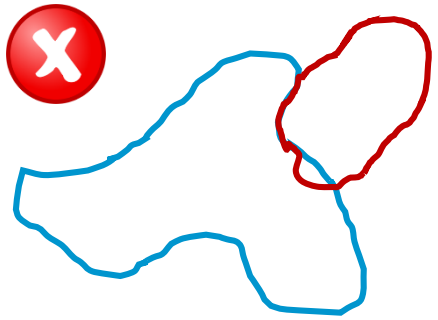
Spatial join: Mismatch NIS – Zip boundaries

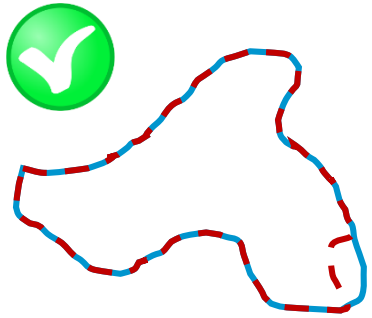
```
SELECT cnis5_2020, t_mun_fr, main_commune,
    nis_bnd.geometry as nis_geom,
    zip_bnd.geometry as zip_geom,
    ST_Difference(nis_bnd.geometry, zip_bnd.geometry) as only_nis_geom,
    ST_Difference(zip_bnd.geometry, nis_bnd.geometry) as only_zip_geom,
    ST_Intersection(nis_bnd.geometry, zip_bnd.geometry) as common_geom,
    ST_Area(ST_Intersection(nis_bnd.geometry, zip_bnd.geometry)) /
      ST_Area(nis_bnd.geometry) as overlap_ratio
FROM gistest.nis_boundaries nis_bnd
JOIN gistest.zip_commune_boundaries_filled zip_bnd
ON   ST_Intersects(nis_bnd.geometry, zip_bnd.geometry)
WHERE ST_Area(ST_Intersection(nis_bnd.geometry, zip_bnd.geometry)) /
       ST_Area(nis_bnd.geometry) between 0.5 and 0.99
```



>0.99



<0.5



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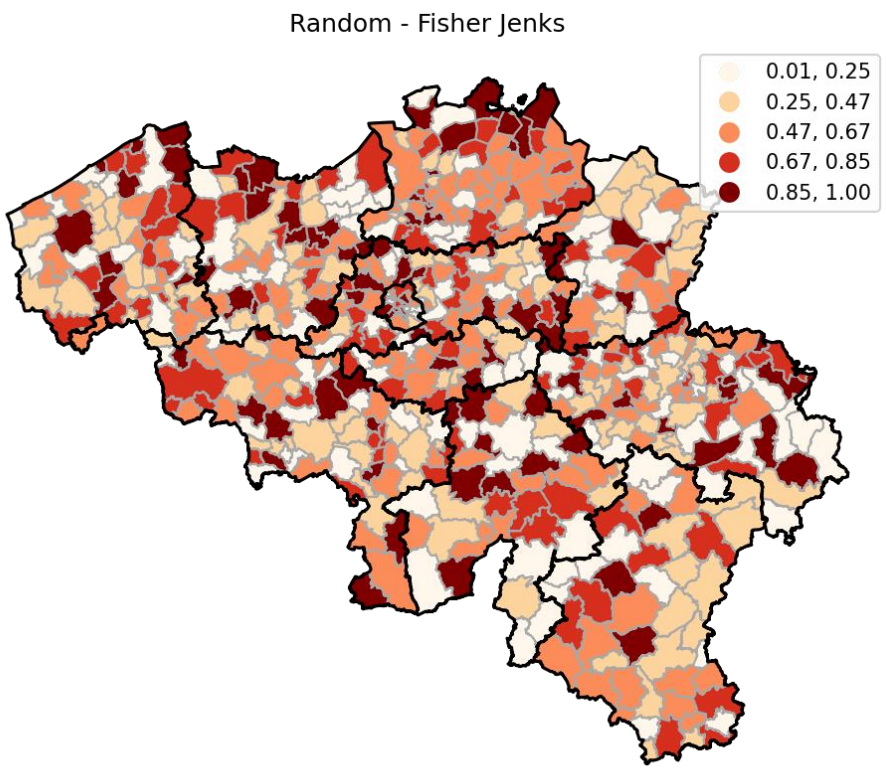
Applications

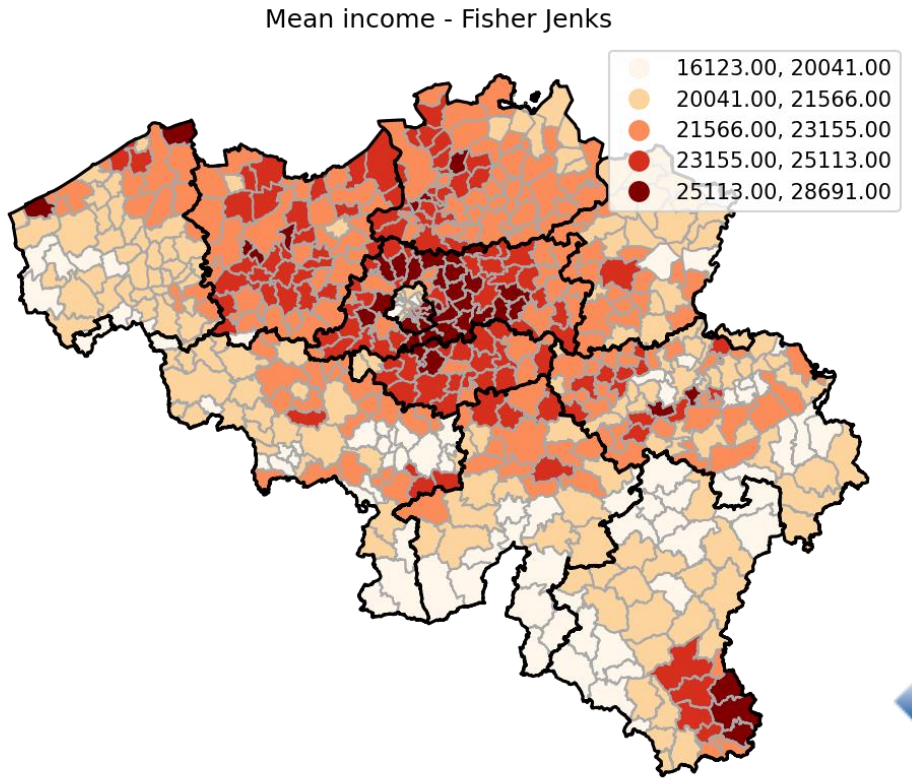
- Détection d'anomalies:
  - Centre de code postal pas situé dans le bon polygone (52 cas pour l'Agence du Numérique)
  - Superposition de polygones :
    - Intrasource: territoires attribués à deux codes postaux (Bpost: ~15 CP spéciaux pas correctement "extraits")
    - Intersource: territoires partagés entre une commune "postale" et une commune "statistique" (~25 incohérences)
- Attribuer un code postal, une commune, province, arrondissement… à chaque point d'une liste
- Combinaison avec une courbe isochrone: communes accessibles en X minutes à partir d'un point (cf plus loin)

Autocorrélation spatiale

Autocorrélation spatiale

- La valeur d'une observation d'une variable A est-elle liée aux observations voisines (géographiquement) ? Un indicateur a-t-il une composante géographique ?
- A-t-on plus de chance d'observer un salaire élevé près d'une commune avec un salaire élevé ?
- Le salaire moyen a-t-il un plus grande dépendance géographique que le niveau d'éducation ?
- Visuellement assez clair, mais comment le formaliser/quantifier ?





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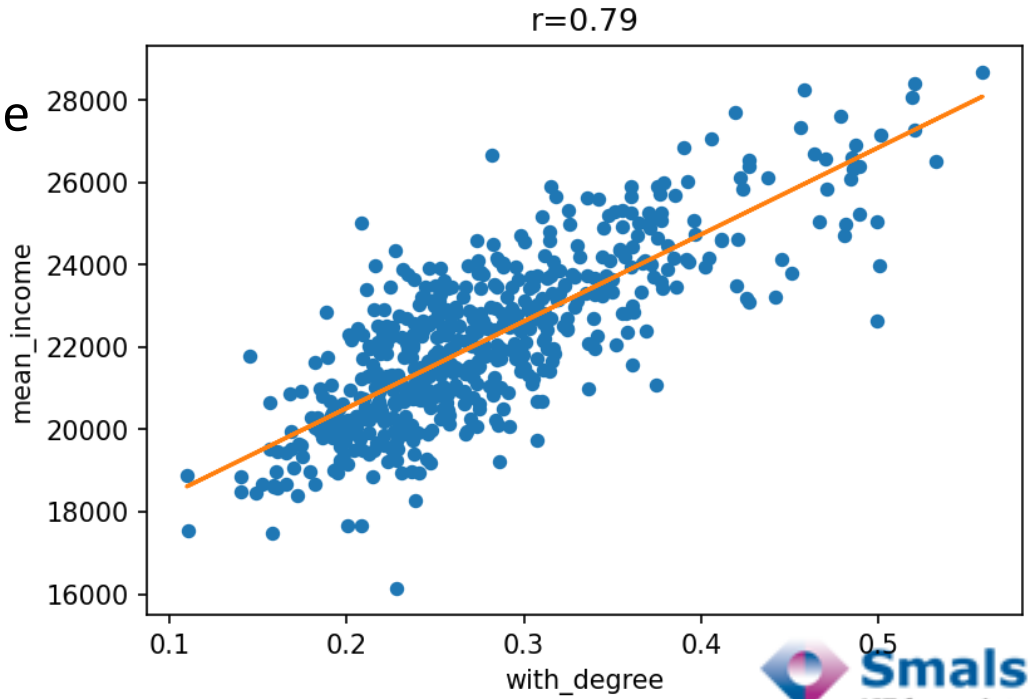
Corrélation

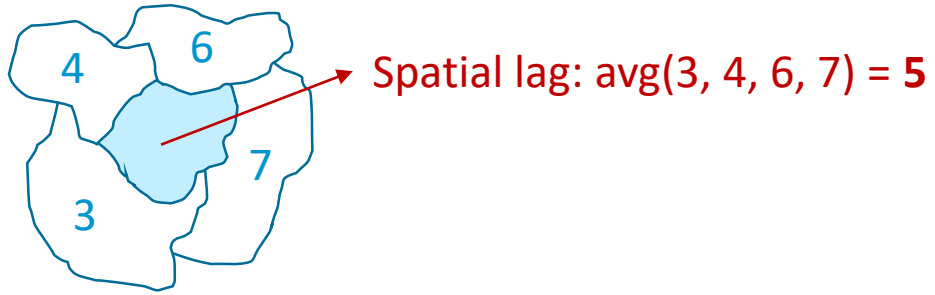
- Corrélation (classique) : caractérise le niveau de liaison entre deux « variables » (ou plus)
- Exemple: revenu moyen vs proportion avec un diplôme de l'ens. sup. (« degree »), par commune
- Corrélation n'implique pas causalité !
  - Bon revenu → accès à un enseignement de qualité ?
  - Bon diplôme → accès à des jobs bien rémunérés ?
  - Niveau/classe social(e) → accès à un enseignement de qualité ET à des jobs bien rémunérés ?
  - Dépendance cyclique ?
- Corrélation entre A et B si connaitre une valeur de A donne une indication de la valeur de B
- Causalité de A vers B si modifier A aura un impact sur B
- Coefficient de corrélation (Pearson's r) : 1 si corrélation parfaite, 0 si aucune corrélation, -1 si corrélation inverse

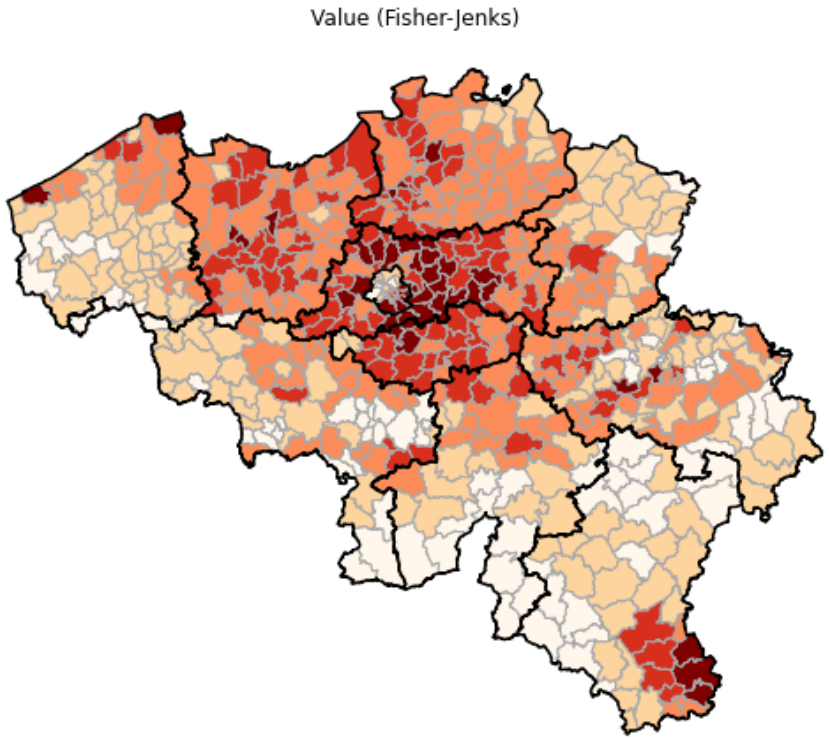


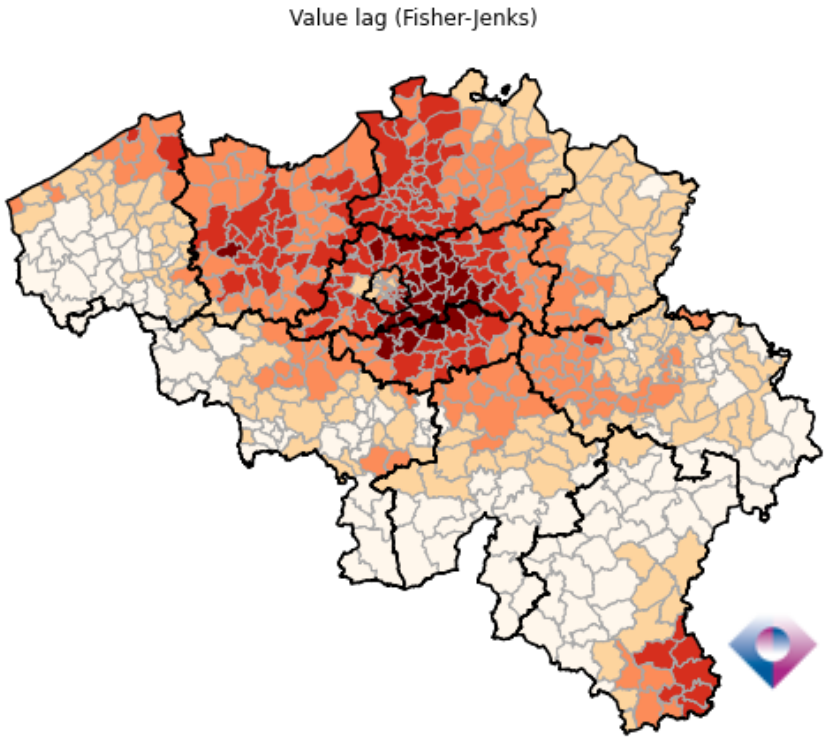
Sources: https://www.census2011.be/, https://statbel.fgov.be/

Autocorrélation locale : spatial lag

- Spatial lag (« décalage spatial ») : valeur moyenne des zones voisines de chaque zone
- Sans tenir compte de « soi-même »
- Permet de « lisser les valeurs »
- Nécessite un calcul de voisinage : quelle sont les voisins de chaque zone ? (Queen neighborhood)







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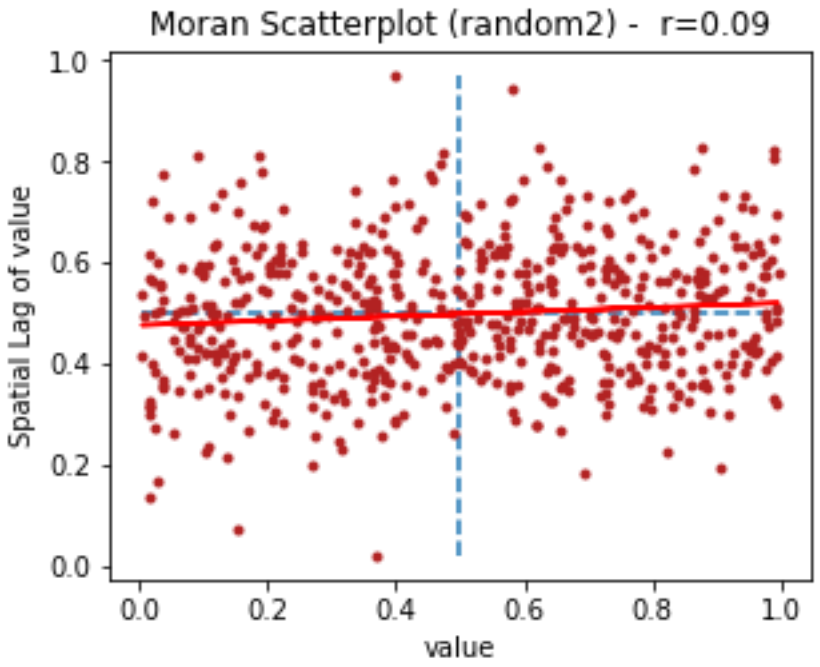
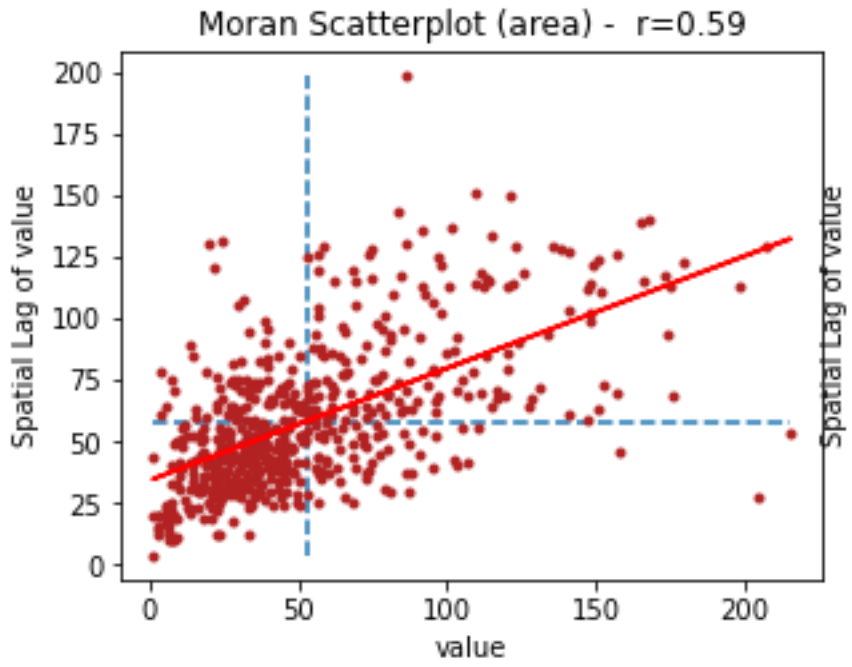
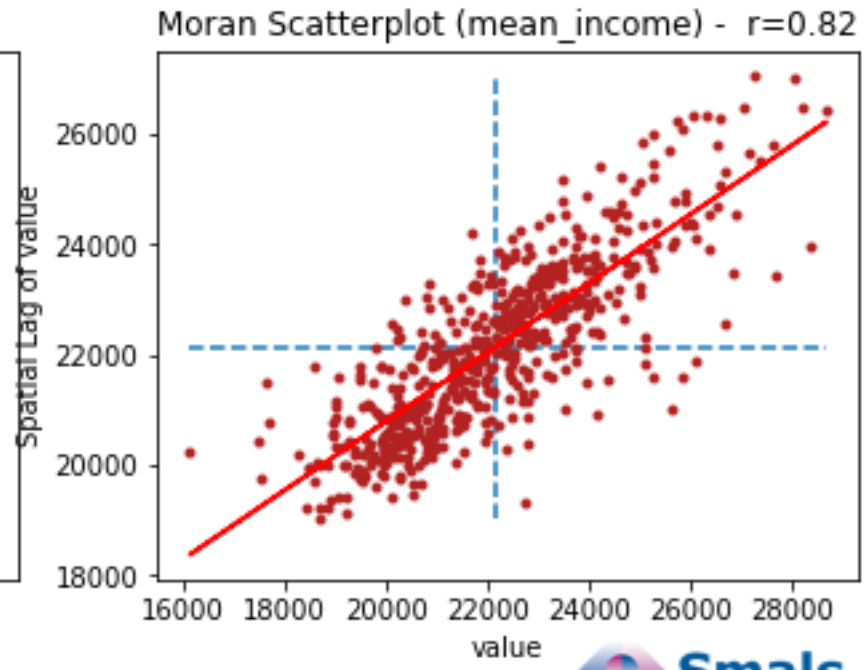
Autocorrélation locale : Moran scatterplot

- Indicateur de dépendance spatiale : corrélation entre la valeur et son « spatial lag »
- Aucune pour « random », très nette pour « mean income »→ indique une forte dépendance spatiale (valeur d'une zone corrélée à la valeur de ses voisines)







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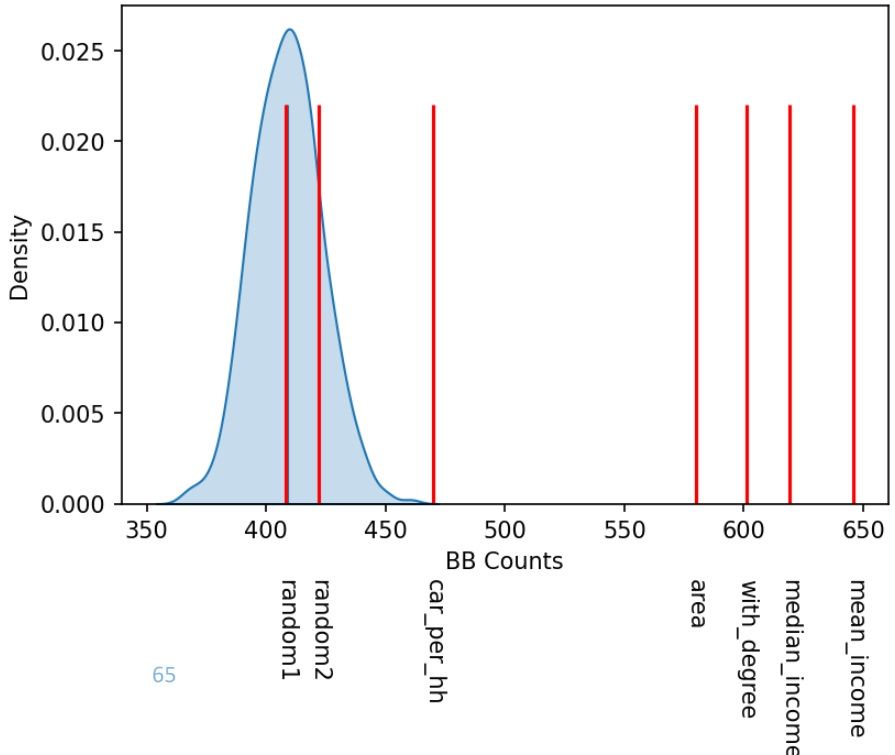
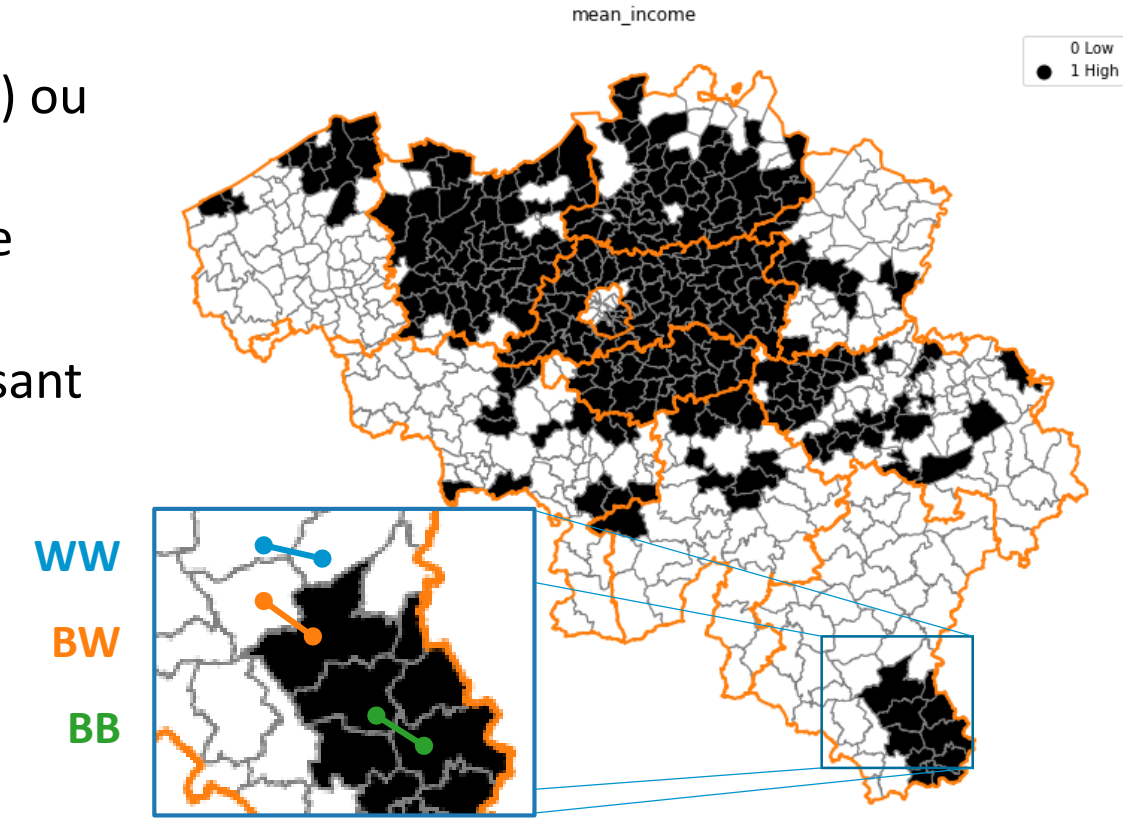
Autocorrélation globale : version binaire

- On convertit chaque valeur en 0 (≤ médiane, « White ») ou 1 (> médiane, « Black»)
- On regarde le nombre de « jonction Black-Black » (zone « Black » touchant une autre zone « Black »)
- On compare avec le nombre qu'on aurait eu en choisissant la couleur au hasard (pour la même géographie)





- Cloche: distribution d'un grand nombre de tirages aléatoires
- Plus on s'en éloigne, plus faible est la probabilité que la métrique soit aléatoire … donc plus grande est qu'elle soit « spatialement dépendante »
- Il existe une généralisation « continue » (Moran's I)

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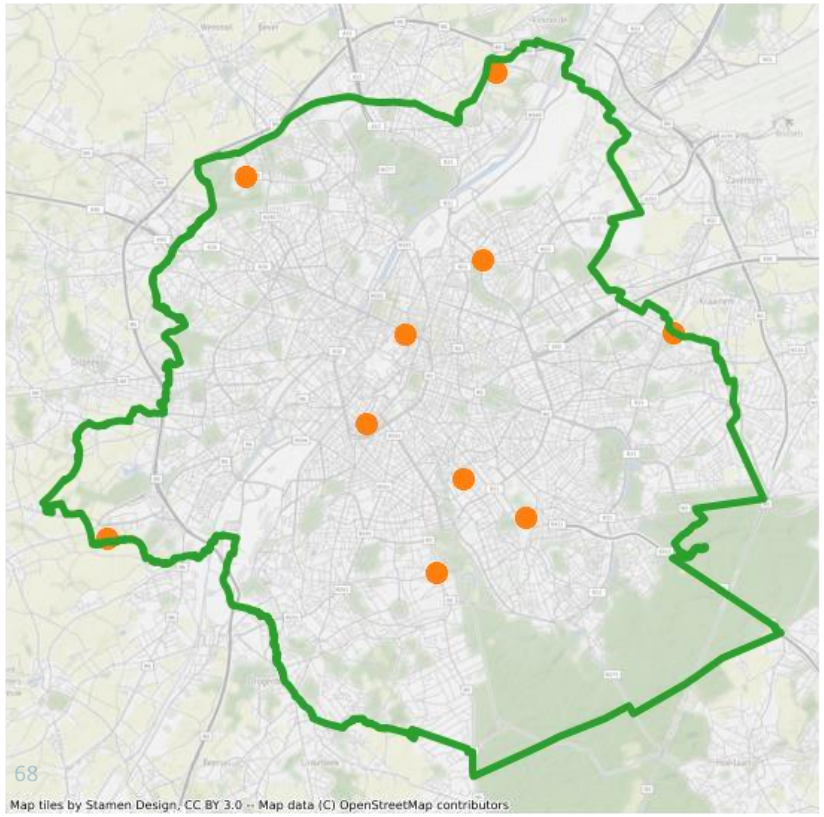
Autocorrélation spatiale : conclusion

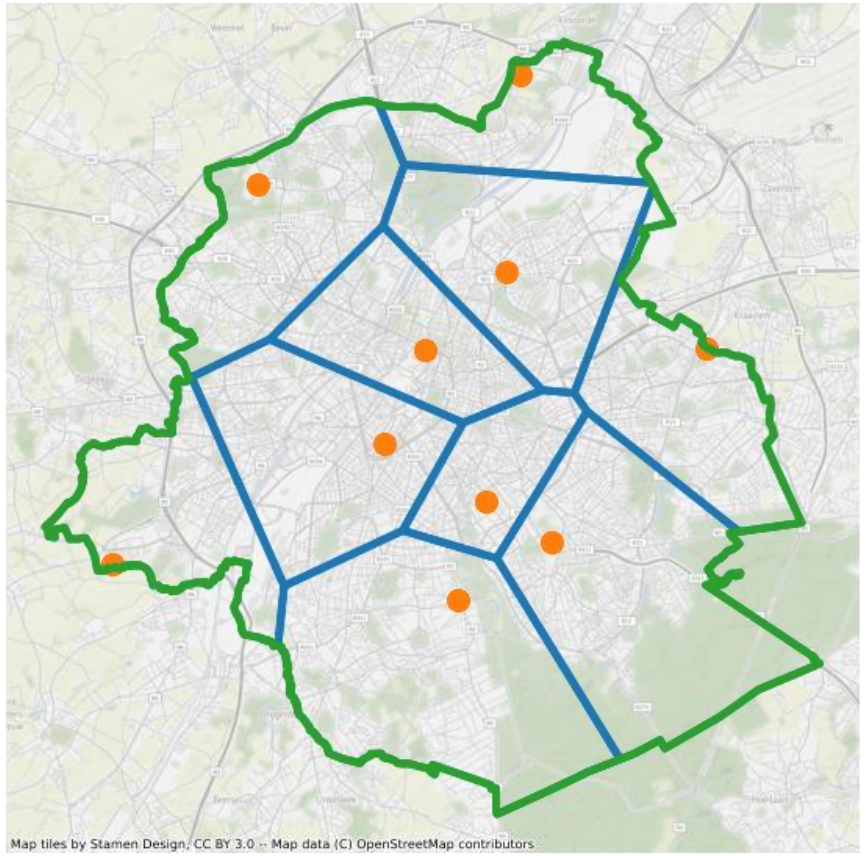
- L'autocorrélation permet quantifier/objectiver la dimension géographique d'une métrique
- Permet aussi d'identifier des anomalies (« hot spots », « donnuts »)
- Ne permet pas de déduire de causalité, mais est une première étape
- Métriques attribuées à des secteurs. Il existe aussi des méthodes pour des points. Exemple : corrélation entre le chiffre d'affaire/nombre de travailleurs/… d'un restaurant et celui des restaurant voisins ?

Diagramme de Voronoi

Diagramme de Voronoï

- Diagramme de Voronoï: À partir d'un ensemble de points (germe) dans un territoire (polygone), découpe le territoire en fonction du point le plus proche (zone d'influence)
- Détermine, pour chaque endroit du territoire, qui sera « le plus rapide à intervenir » (à vol d'oiseau), ou quelle est le « l'antenne la plus proche »
- Exemple : Polygone = Brucap, points = départs SMUR





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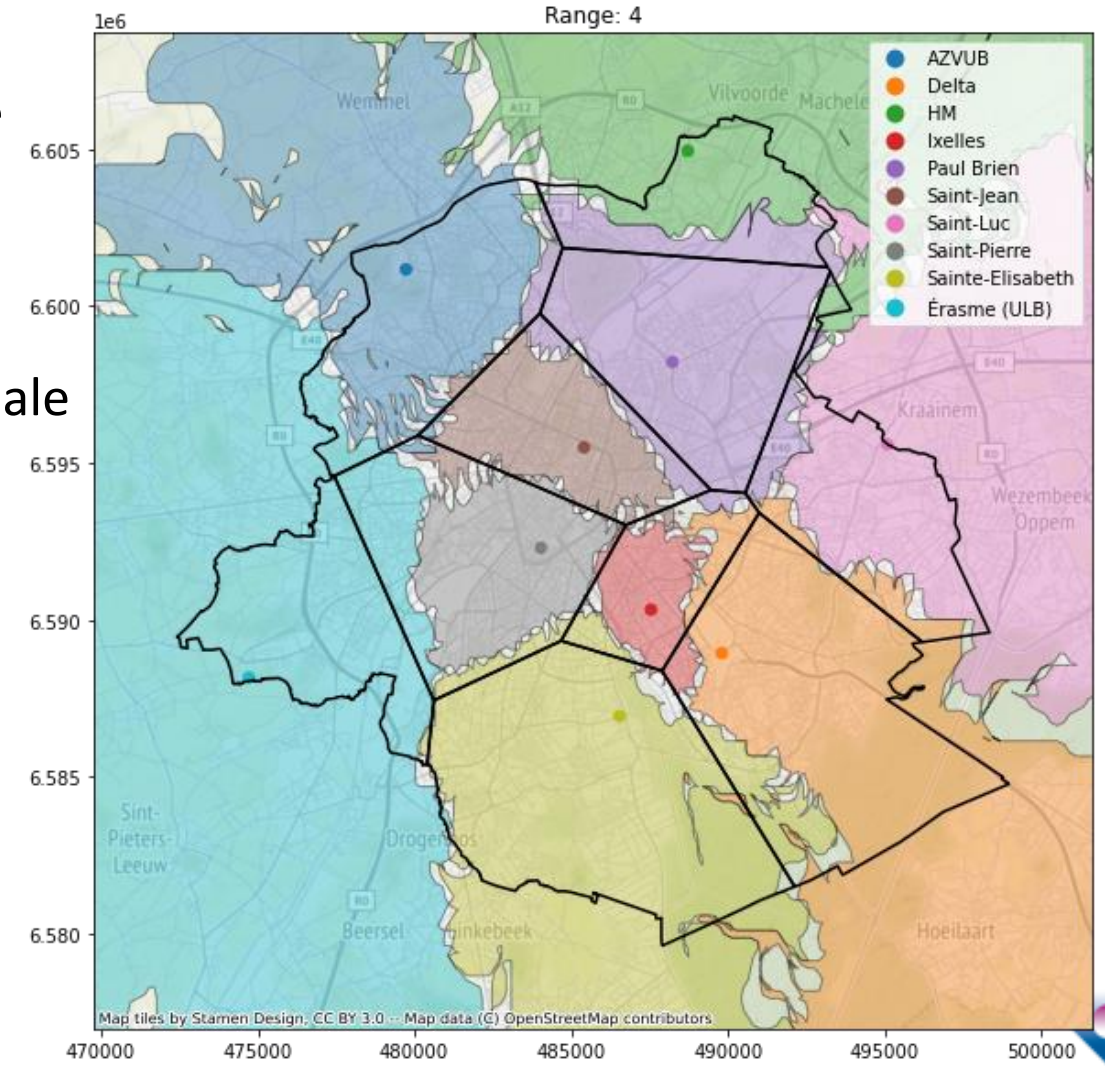
Avec isolines

- S’il est nécessaire de tenir compte des temps de parcours, il est possible de combiner une série d’isolines
- Exemple, en extrayant les isolines de chaque départ, pour chaque pas de 30 secondes :
- Peu de différence par rapport à Voronoi (pour cet exemple)
- Peut être comparé à une attribution territoriale existante: à quel point est-elle efficace?



Multipoint reachability

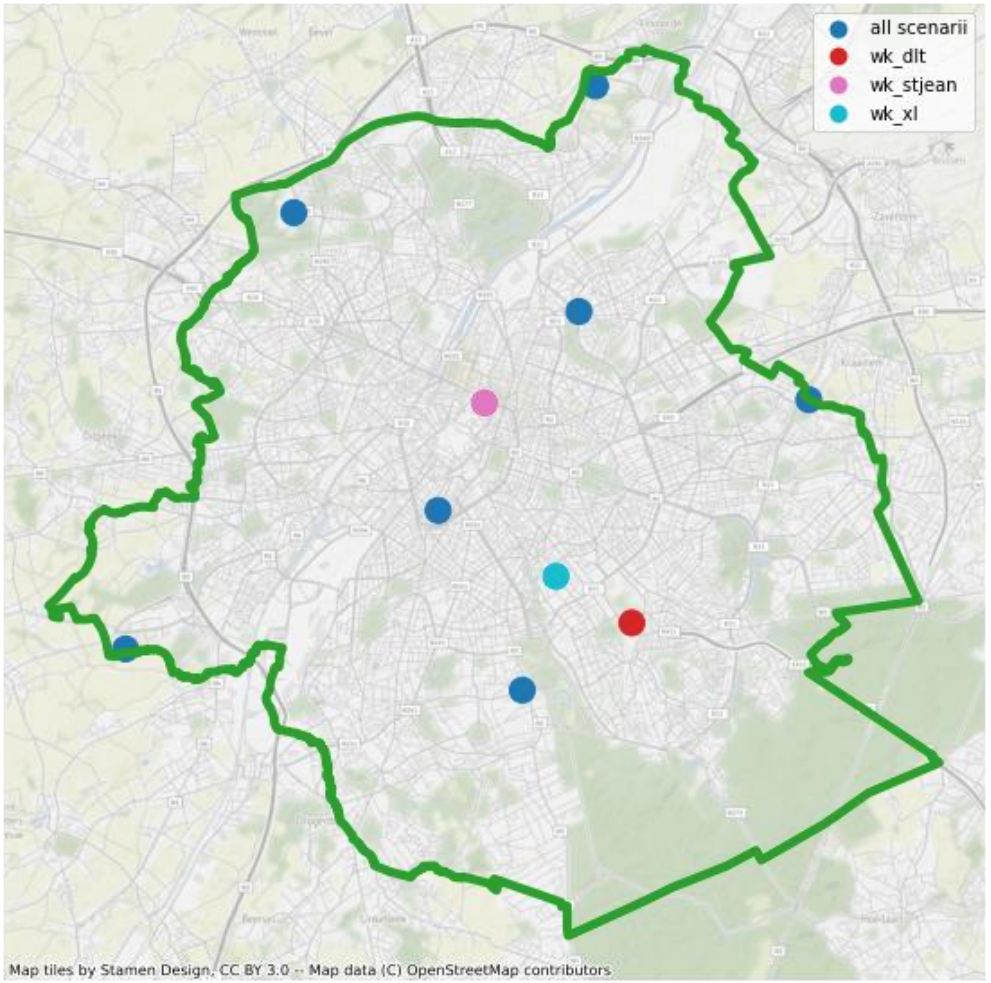
Multipoint reachability

- Question centrale : quel territoire ou quelle population est atteignable à partir d'un ensemble de points (hôpitaux, antenne locale d'une administration, domicile des agents de terrain…)
- En supposant un déplacement en voiture (possibles extensions : à pieds, en transport en commun…)
- On combine des « courbes isochrones »
- On va comparer plusieurs scénarios (ouverture/fermeture ou non d'un ou plusieurs départs)
- Usecase : SMUR (MUG) à Bruxelles : 10 départs, dont 3 en alternance un semaine/3
- « Disclaimer »: déplacement à allure « normale » et analyse simplifiée !
- Plus de détails :
  - https://www.smalsresearch.be/peut-on-toujours-atteindre-une-maternite-en-30-minutes/
  - https://www.smalsresearch.be/peut-on-toujours-atteindre-une-maternite-en-30-minutes-partie-2/

Départs

		wk_dlt	wk_stjean	wk_xl
Saint-Luc	Av. Hippocrate	x	x	x
Saint-Pierre	Rue haute	x	x	x
…	…			
Delta	Bvd du triomphe	x		
Saint-Jean	Rue du marais		x	
Ixelles	Rue Paquot			x

Géocodage



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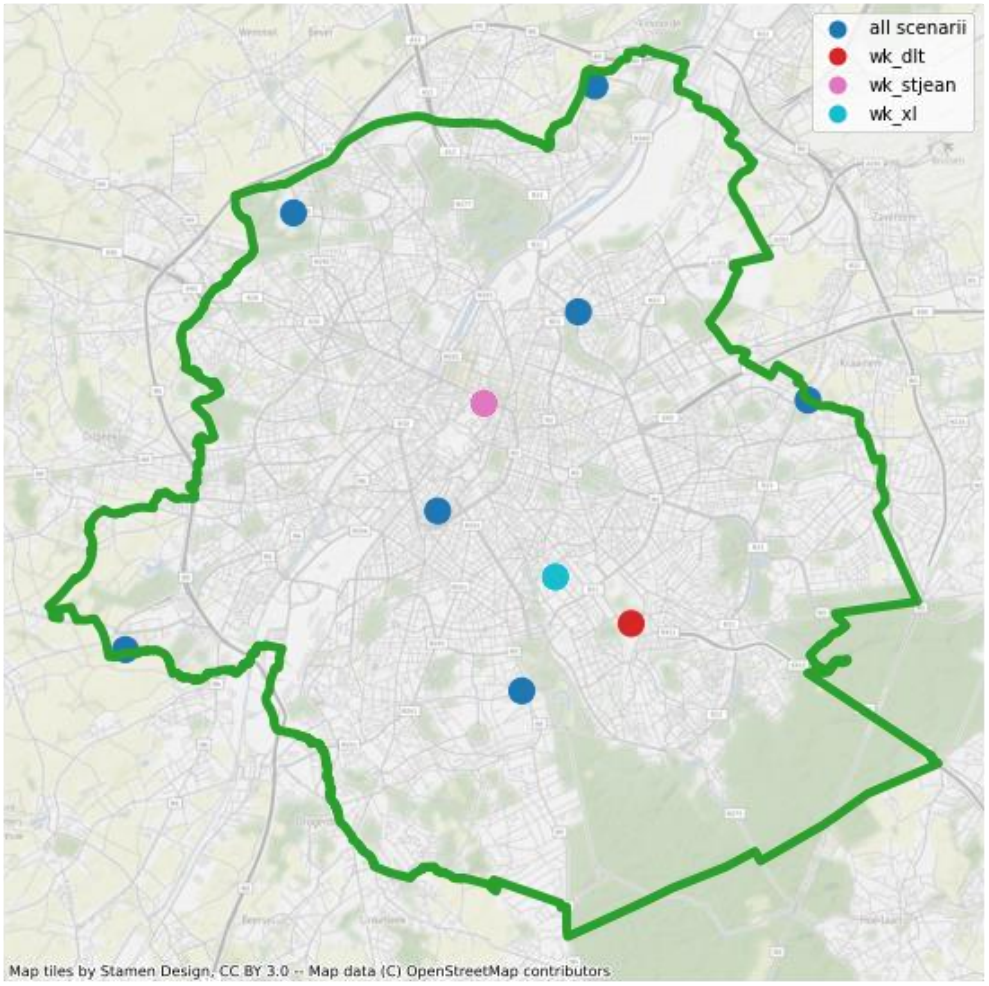
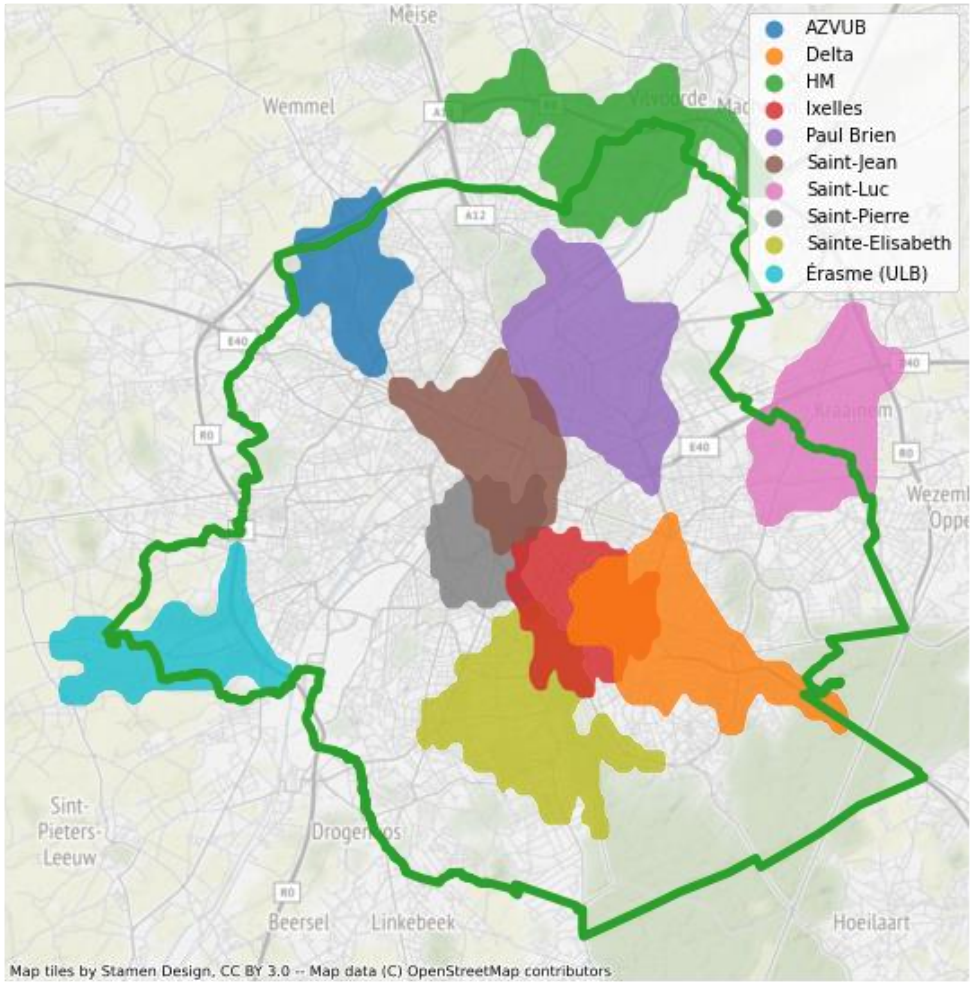
Courbes isochrones



Isoline (5 min)



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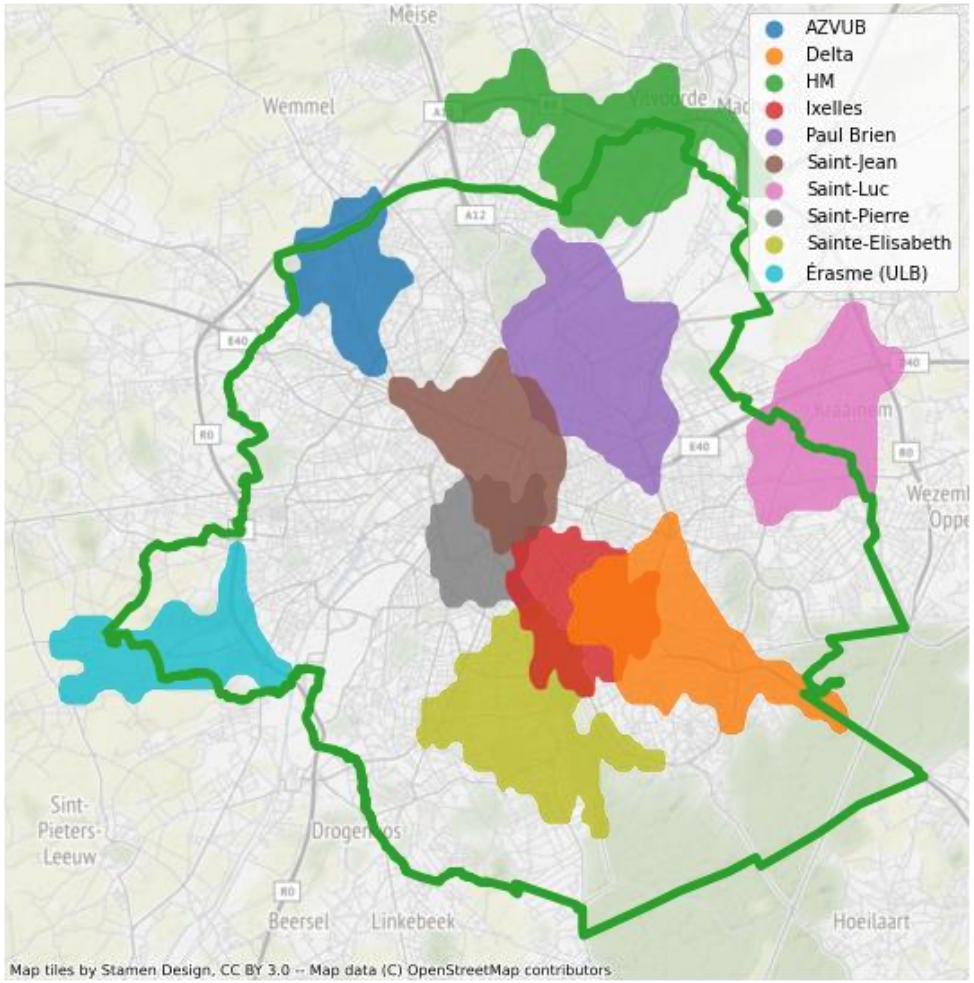
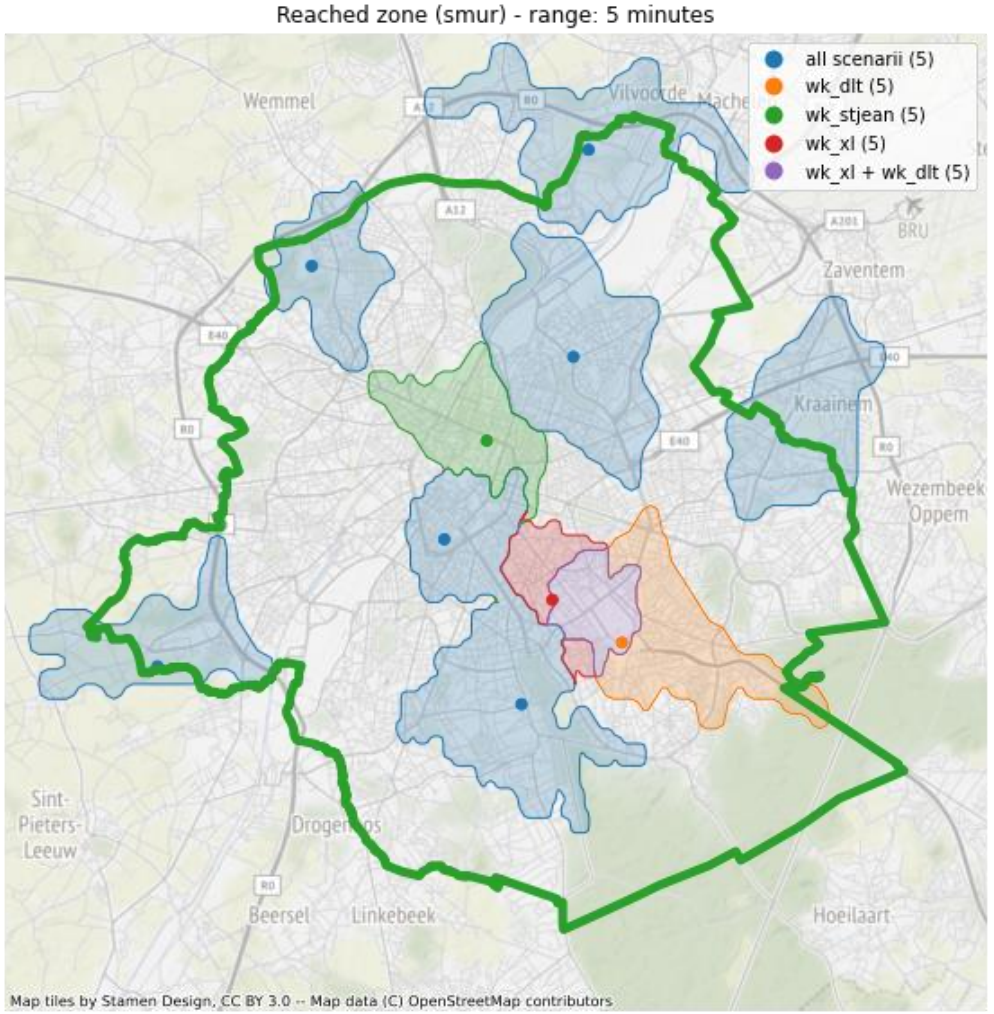
Pour un délai donné …



Spatial ops



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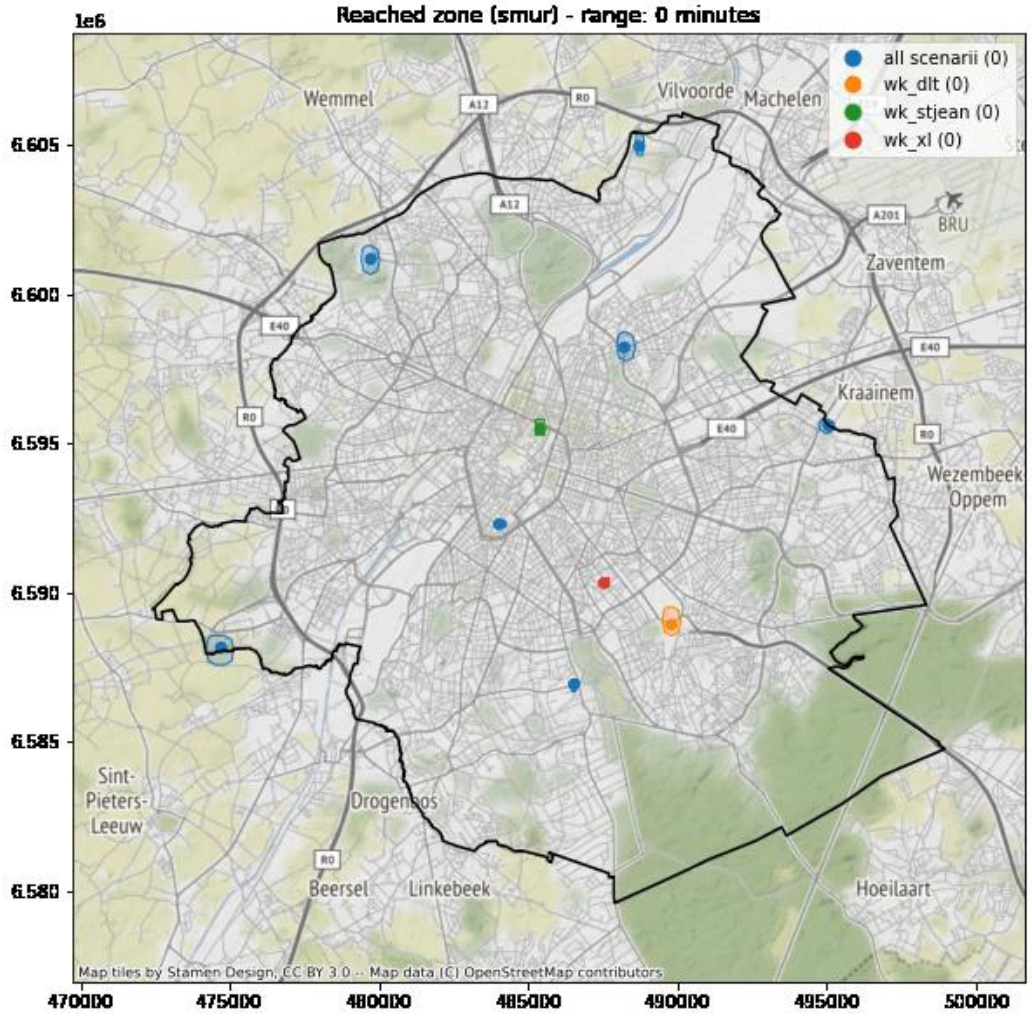
Temps variable



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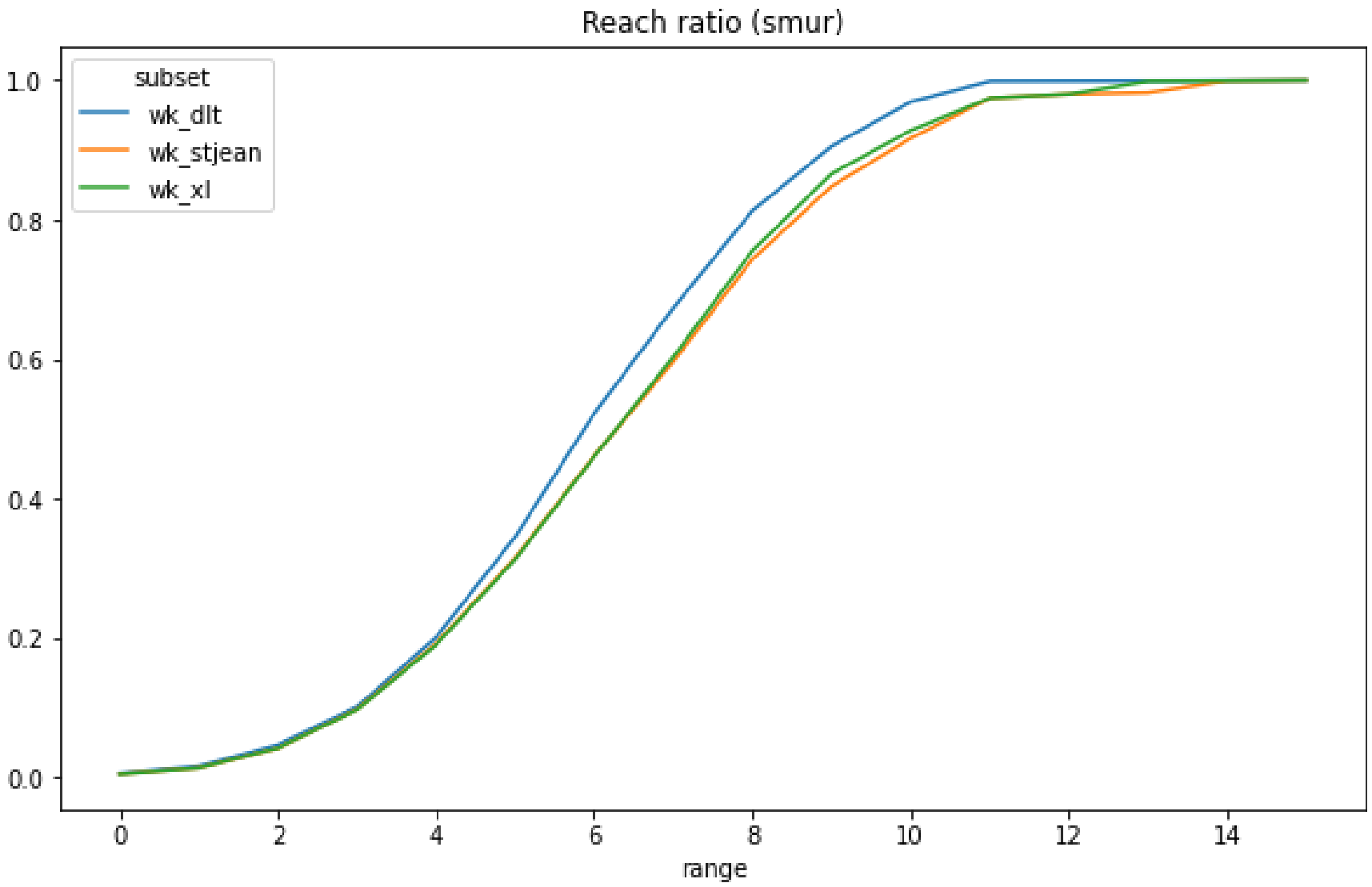
Vue globale : reached ratio



Version interactive : https://smalsresearch.be/rawfiles/reach_ratio_smur.html

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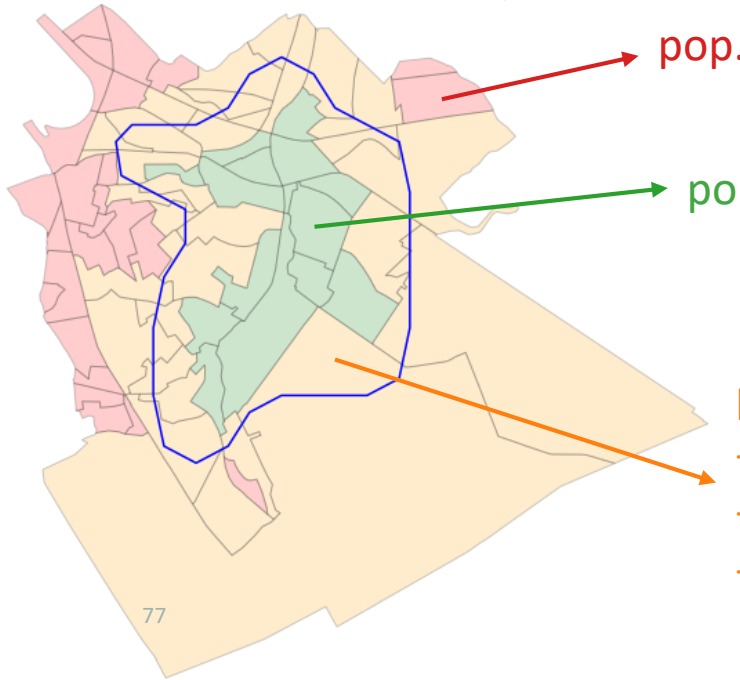
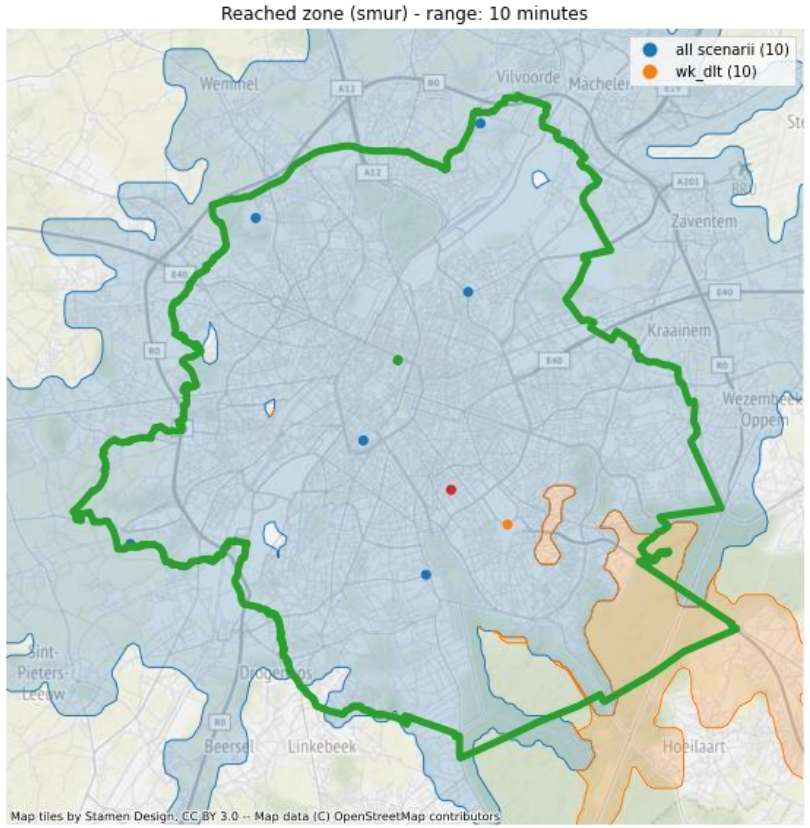
Couverture populationnelle

- Couverture territorial <> couverture populationnelle !
- Plus-value de la semaine “Delta”: couverture de …
  la forêt de Soignes !
- Connaissant la population par secteur statistique (Statbel), on peut approximer la population couverte par jointure spatiale
- “Approximer” car on ne connait pas la répartition au sein des secteurs statistiques





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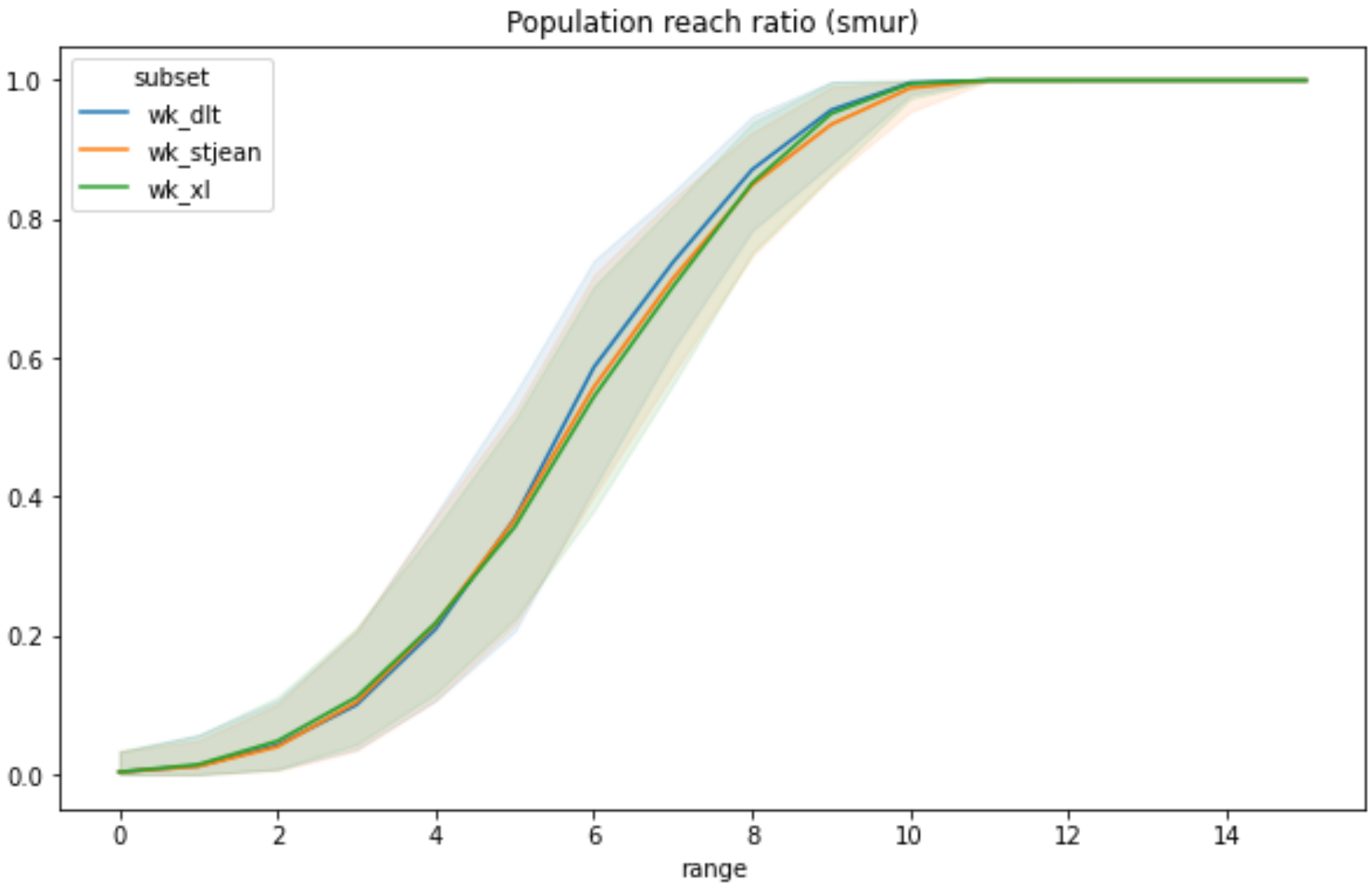
Population reach ratio



Version interactive : https://smalsresearch.be/rawfiles/pop_reach_mean_ratio_smur.html

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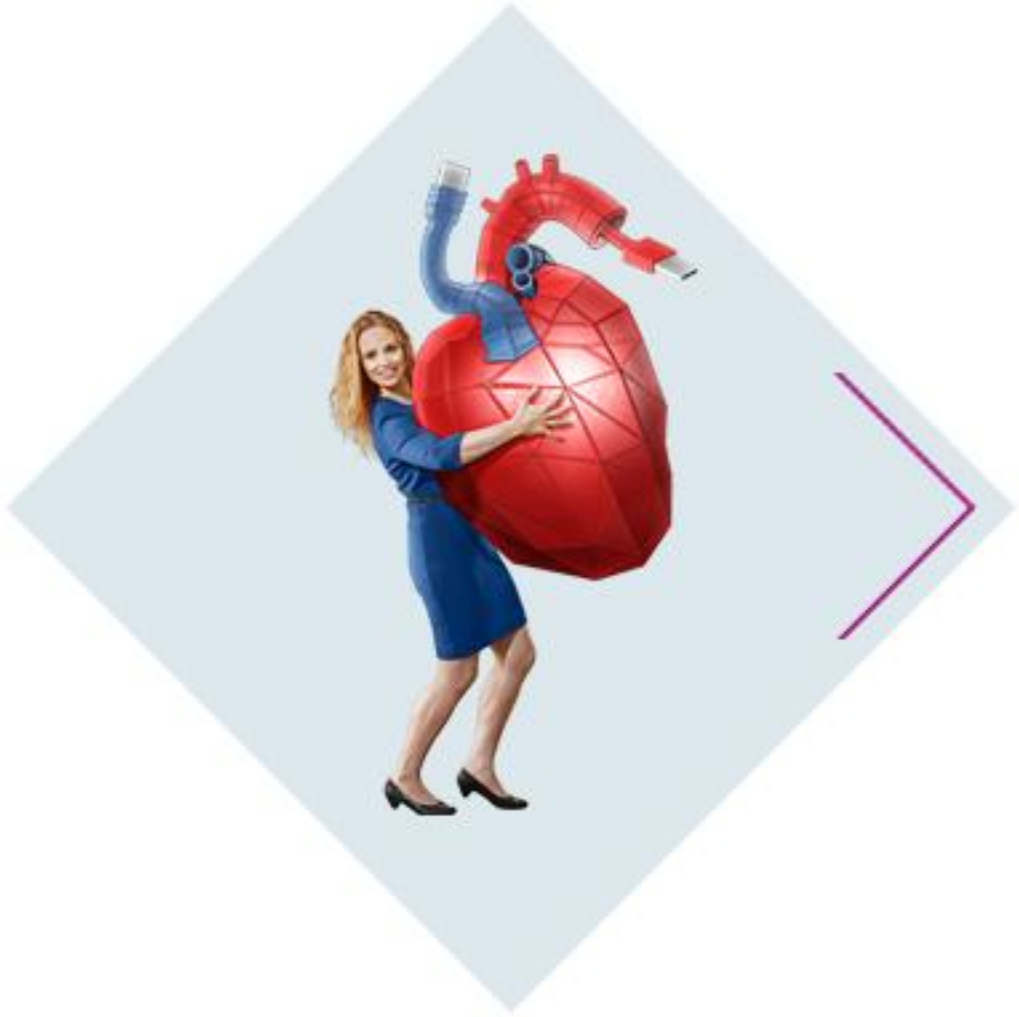


Use case “CAW”

Use case CAW

- **C**heck-in **A**t **W**ork: déclaration de présence sur un chantier (**P**lace **O**f **W**ork)
- Peut-être fait :
  - En direct : scan d'un QR code
  - À l'avance/distance
- Objectif : identifier les entreprises qui systématisent le principe de "check in everybody everywhere"
- Problèmes similaires:
  - Identifier un médecin qui envoie des certificats à des personnes "trop distantes" (INAMI ?)
  - Un indépendant qui déclare des chantiers trop distants (Fisc ?)

CAW : données en entrée

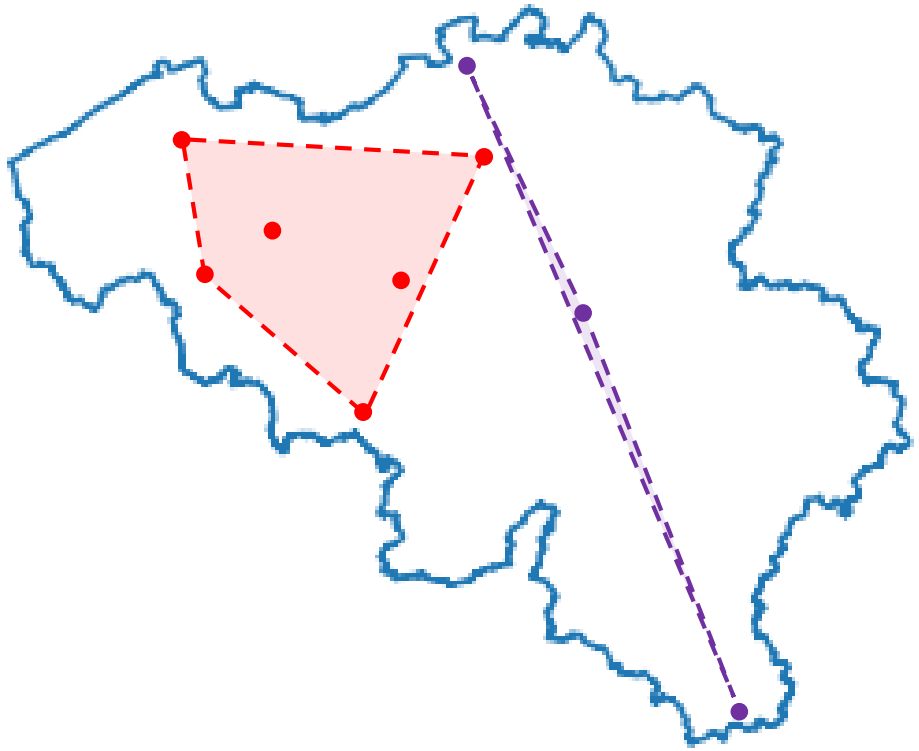
- Données en entrée (pour une date en particulier):

WORKER_ID	POW_ID	STATUS	ZIPCODE	GEOM
Wrk_1	Pow_1	OK	1060	POINT (4.34466 50.82946)
Wrk_1	Pow_2	OK	1160	POINT (4.43800 50.81019)
Wrk_2	Pow_3	NOK	5190	POINT (4.67619 50.47171)
Wrk_3	Pow_4	CANCELLED	6220	POINT (4.52807 50.47096)

- Pour éviter du géocodage, on se contente du code postal
- Jointure avec les données BPost

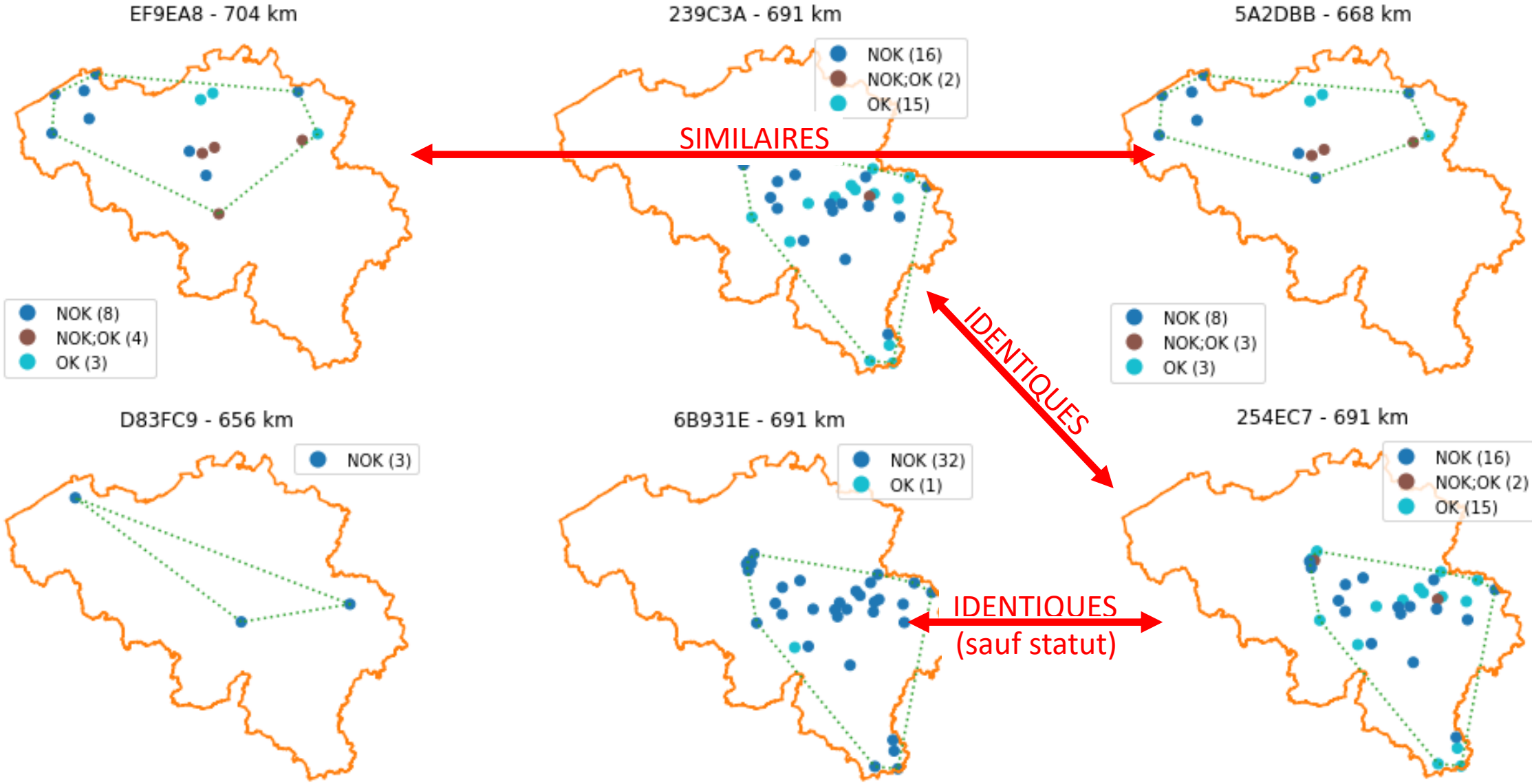
POW: Place Of Work

Enveloppe convexe



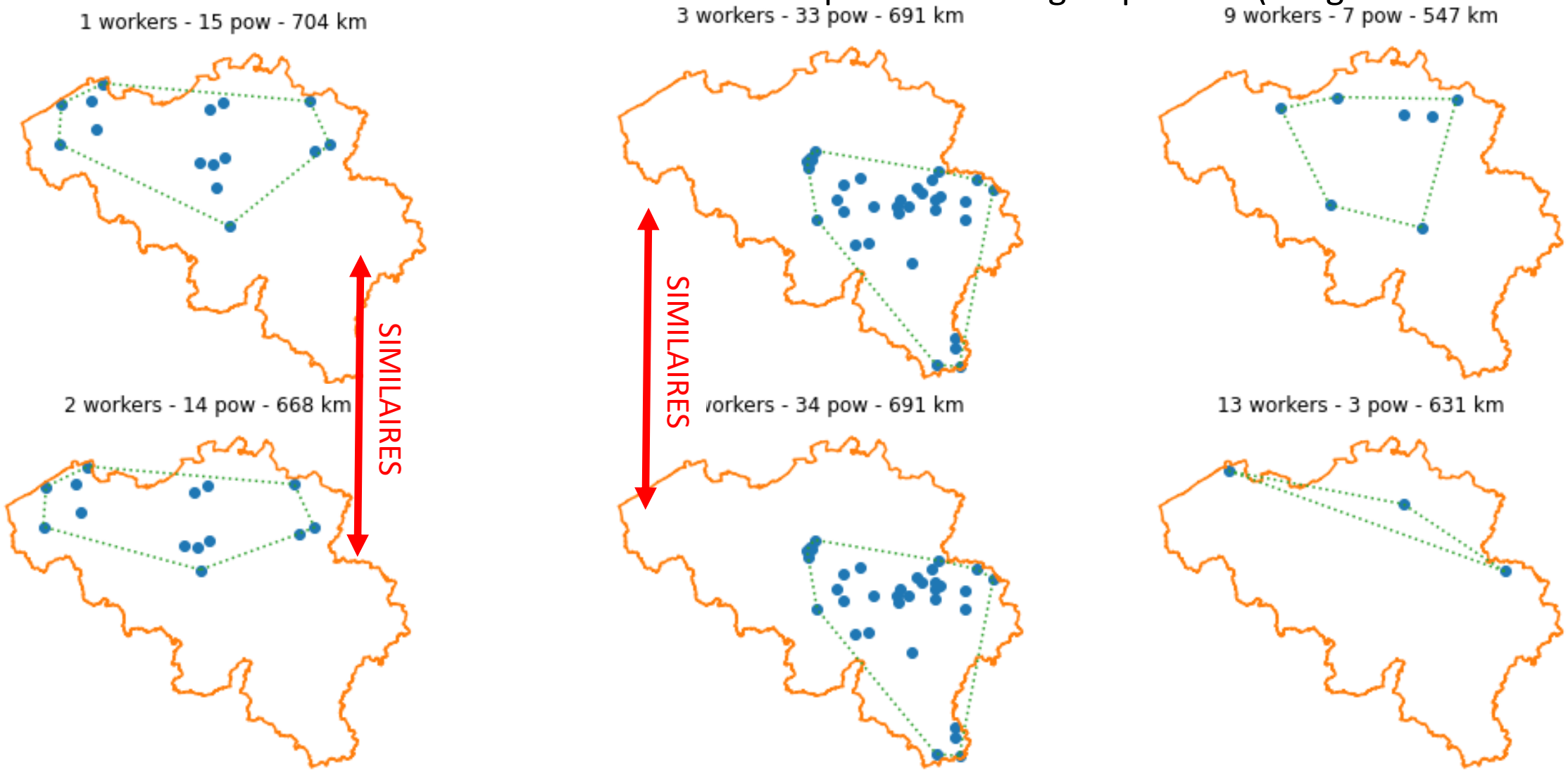
- Pour chaque travailleur, on rassemble tous les points
- On construit une “enveloppe convexe” (convex hull)
- Périmètre de l’enveloppe : borne inférieure de la distance à parcourir par le travailleur (retour au départ)
- Inférieure, car :
  - Ignore les points dans l’enveloppe
  - À vol d’oiseau
  - Supposant que le travailleur habite près d’un des points
- On peut aussi considérer l’aire de l’enveloppe, mais nulle si les points sont alignés (ou seulement 2 points)

Exemples


EF9EA8 - 704 km
NOK (8)
NOK;OK (4)
OK (3)
239C3A - 691 km
NOK (16)
NOK;OK (2)
OK (15)
SIMILAIRES
5A2DBB - 668 km
NOK (8)
NOK;OK (3)
OK (3)
IDENTIQUES
D83FC9 - 656 km
NOK (3)
6B931E - 691 km
NOK (32)
OK (1)
IDENTIQUES
(sauf statut)
254EC7 - 691 km
NOK (16)
NOK;OK (2)
OK (15)

Patterns identiques

Constat: de nombreux travailleurs ont le “même pattern” → regroupement (en ignorant le statut)



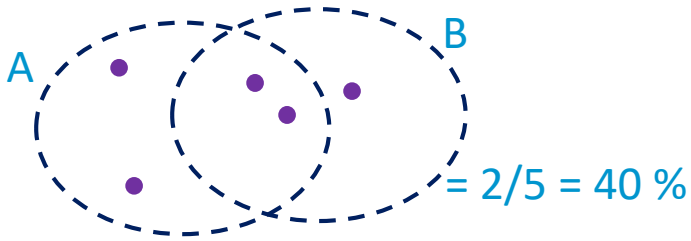
Patterns similaires

- On peut évaluer la proximité entre deux ensembles A et B par la “similarité de Jaccard” :

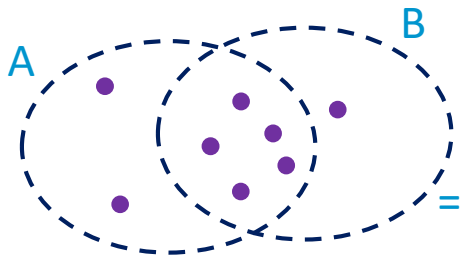
$$\frac{|A \cap B|}{|A \cup B|}$$

Taille de l’intersection

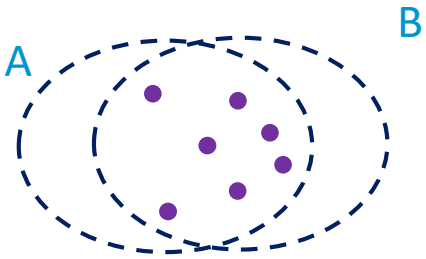
Taille de l’union



= 2/5 = 40 %



= 5/8 = 62,5 %



= 7/7 = 100 %

- “Point”= centre du code postal du POW

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Patterns similaires

Jaccard similarity: 97.1%

3 workers - 33 pow - 691 km

1 workers - 34 pow - 691 km

Points communs
Différences

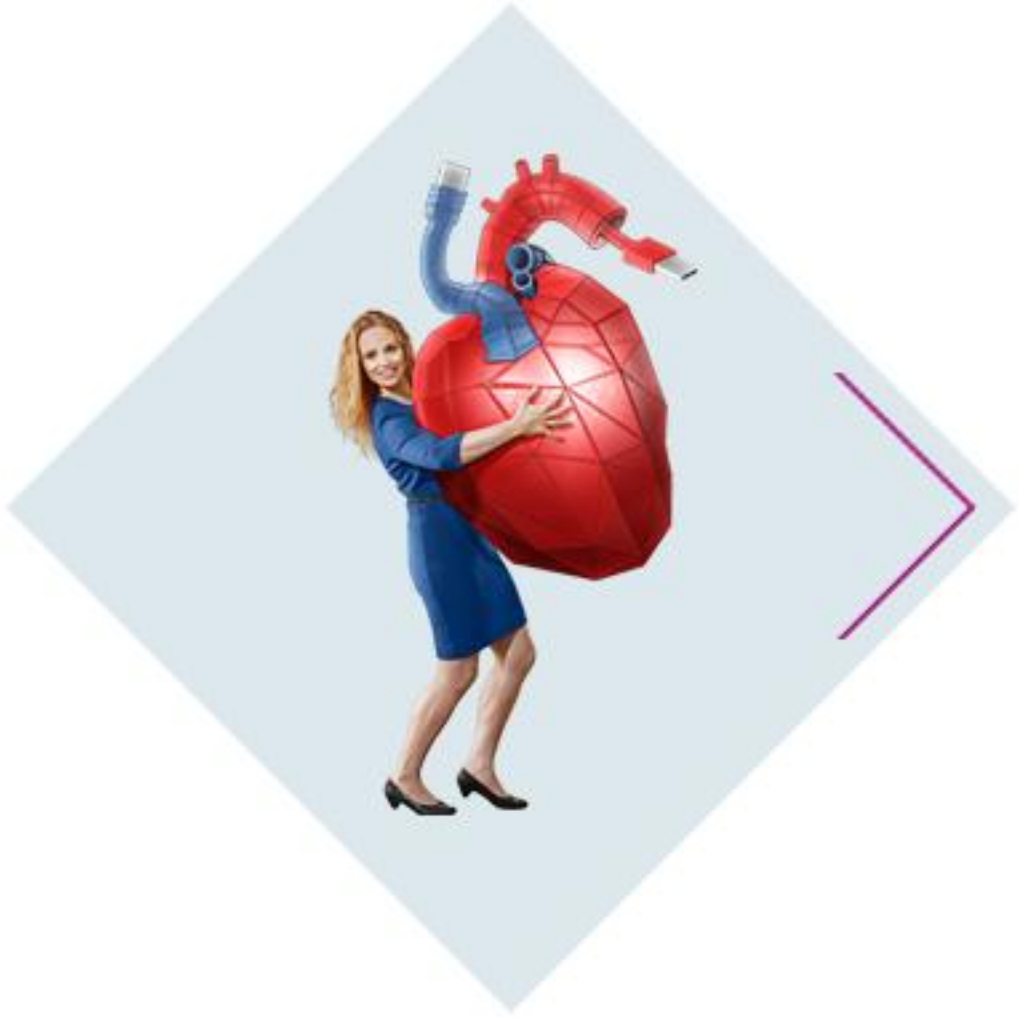
Jaccard similarity: 93.3%

2 workers - 14 pow - 668 km

1 workers - 15 pow - 704 km

Use case CAW: conclusions

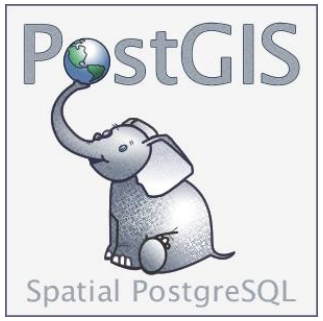
- Ceci est un simple POC “naïf”
- On se contente de la localisation du code postal
- On ignore le statut
- On ignore le “contenu de l’enveloppe"
- On ne regarde qu’un jour → l’aspect temporel est certainement crucial, mais “out of scope” de cette présentation
- Sans analytique géographique, ces cas auraient été difficiles à évaluer
- Extension possible : identifier les travailleurs qui ont (probablement) le même « patron »
- Distance totale à parcourir: problème du voyageur de commerce (Travelling salesman problem) !



Conclusions

Outils Open-source/gratuits

- Programmation :
  - Analytique : Python + Pandas + Geopandas/shapely
  - Visualisation (javascript) : leaflet.js, mapbox, google maps…
  - API : OSM, Here, Google maps…
- Database : Postgresql + PostGIS
- Desktop : QGIS



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Conclusions

- Les données géographiques sont partout dans les données “administratives”
- Ne concerne pas que les géographes/géologues/épidémiologistes/militaires !
- Plus-value indéniable pour l’analyse :
  - Statistiques
  - Détections d’anomalies/fraudes
  - Analyse d’impact (ouverture/fermeture d’antenne)
  - Optimisation (tournées/affectation d’agents…)
- Des outils gratuits/Open-sources sont souvent suffisants
- À la portée de tout data-scientist/technicien curieux

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