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PGConf.EU 2023

PostGIS and pgRouting: Extensions for spatial data in PostgreSQL

Marion Baumgartner

About your Presenters

Marion Baumgartner

- Full stack GIS development
- ETL with geo-data
- https://github.com/marionb

About Camptocamp

Your partner for success.

- Founded in 2001
- Solid and controlled growth
- 160+ employees
- Offices in 3 countries:
  - France, Switzerland, Germany
- A major European player in Open Source

Agenda

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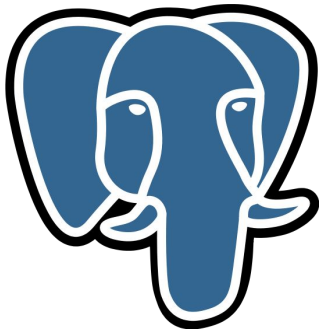
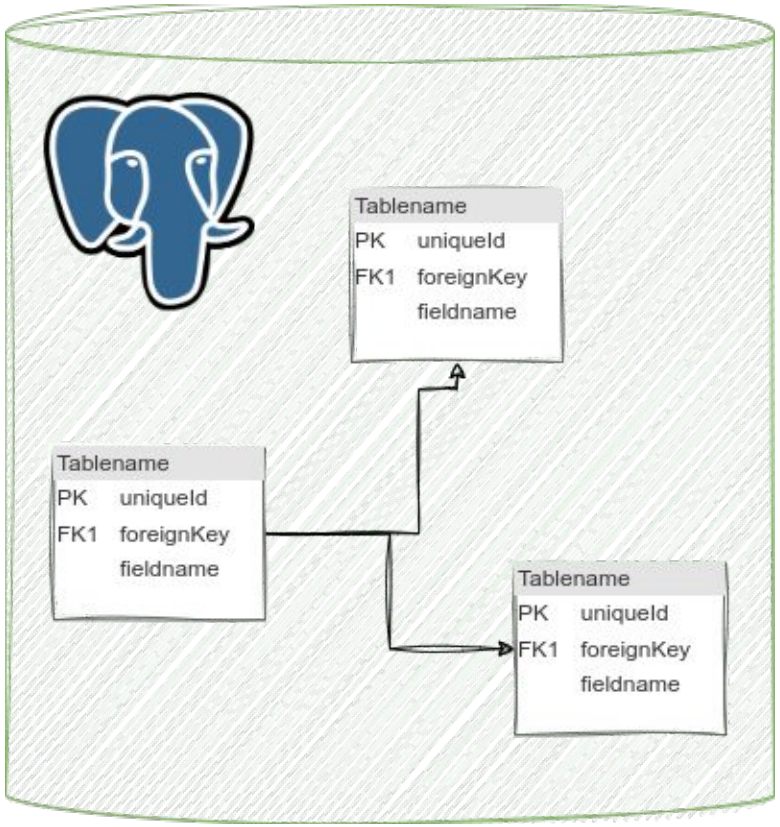
- PostGIS: how to handle geospatial data in PostgreSQL
  - Saving
  - Indexing
  - Querying
- pgRouting
  - Principles
  - Examples



PostGIS

Data


Tablename
PK uniqueId
FK1 foreignKey
fieldname
Tablename
PK uniqueId
FK1 foreignKey
fieldname
Tablename
PK uniqueId
FK1 foreignKey
fieldname

Data with a geospatial relation

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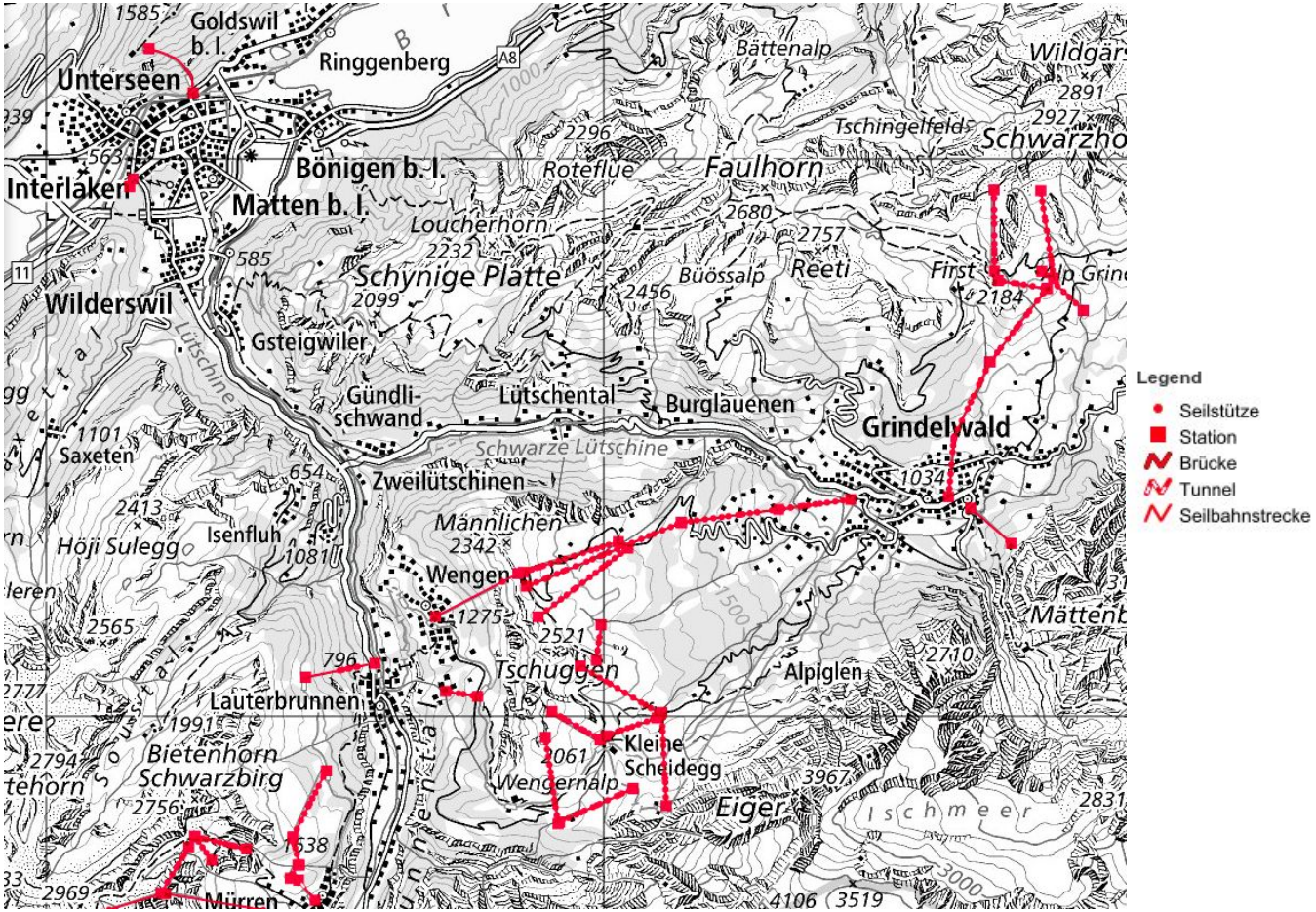

Complex Data with a Geospatial Relation that we Want to Aggregate

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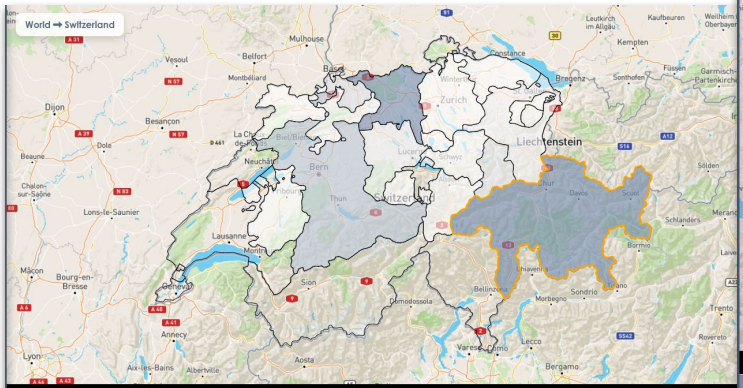
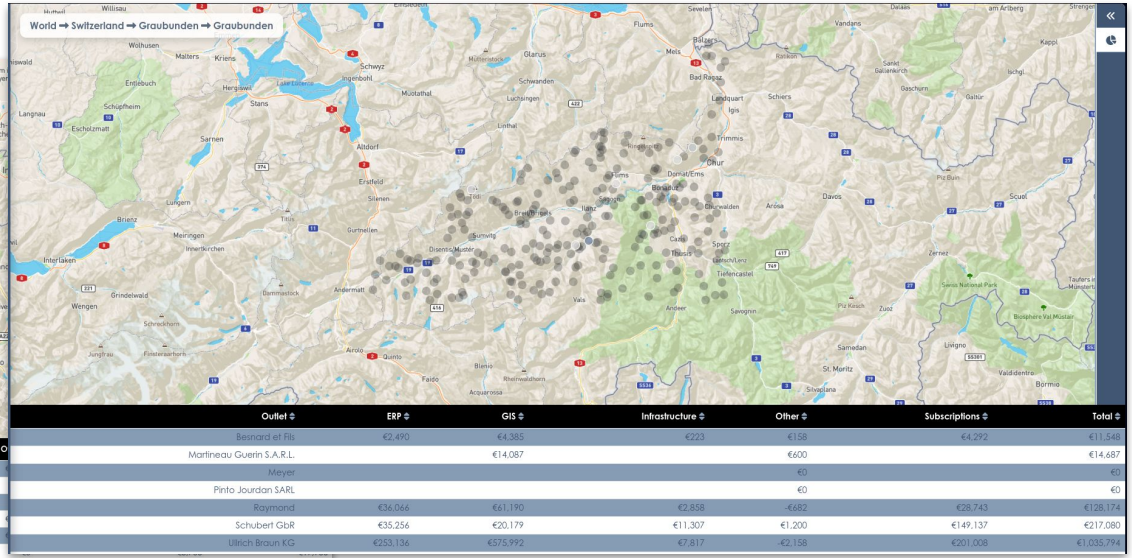


Region	ERP	GIS	Infrastructure	O
Aargau	€214,333	€526,586	€49,056	
Appenzell Ausser-rhoden				
Appenzell Inner-rhoden	€5,071	€6,383	€177	
Basel-landschaft	€60,784	€74,909	€14,107	
Bern	€140,097	€269,857	€11,771	
Fribourg	€2,962	€7,233	€1,038	
Glarus	€46,112	€75,455	€5,204	€431
Graubunden	€326,949	€675,832	€22,205	-€883
Jura	€1,079			-€1,079
Luzern	€28,953	€23,128	€5,640	€1,413
Obwalden	€9,003	€5,870		€0
Sankt Gallen	€11,330	€43,474	€4,409	€1,380
Schwyz				€0
Solothurn	€8,387	€15,374	€2,232	€0
Thurgau				€0
Uri	€1,099	€6,456	€496	€0
Zug				€0

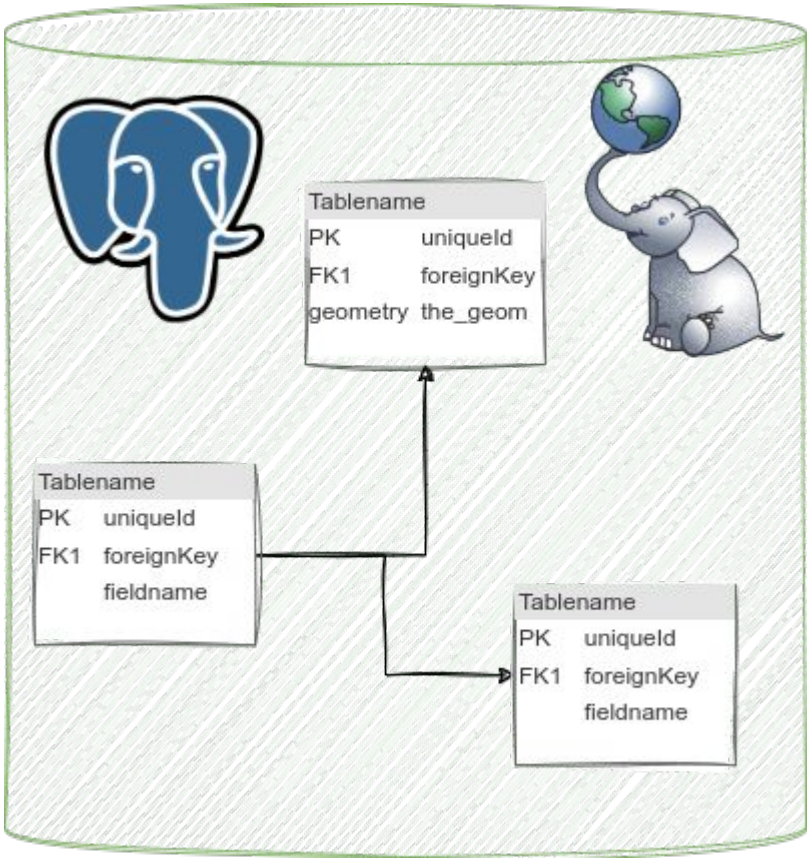


Outlet	ERP	GIS	Infrastructure	Other	Subscriptions	Total
Besnard et Fils	€2,490	€4,385	€223	€158	€4,292	€11,548
Martineau Guerin S.A.R.L.		€14,087		€600		€14,687
Meyer				€0		€0
Pinto Jourdan SARL				€0		€0
Raymond	€36,066	€61,190	€2,858	-€682	€28,743	€128,174
Schubert GbR	€35,256	€20,179	€11,307	€1,200	€149,137	€217,080
Ulrich Braun KG	€253,136	€575,992	€7,817	-€2,158	€201,008	€1,035,794

Map POIS into administrative regions

Data with a geospatial relation

camptocamp PostGIS




```
CREATE EXTENSION postgis;
```

What is PostGIS?

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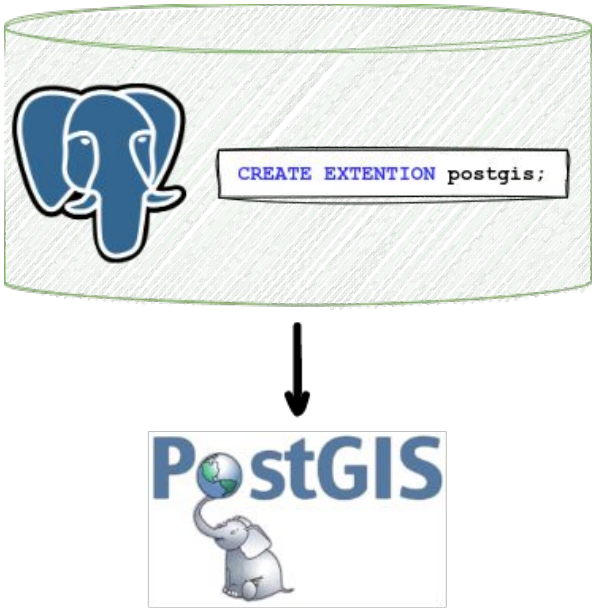
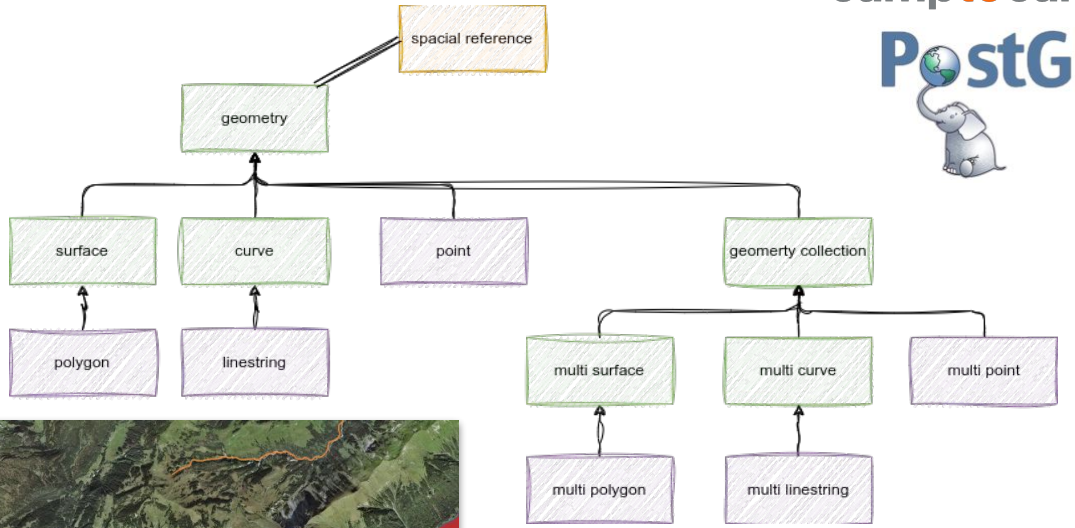


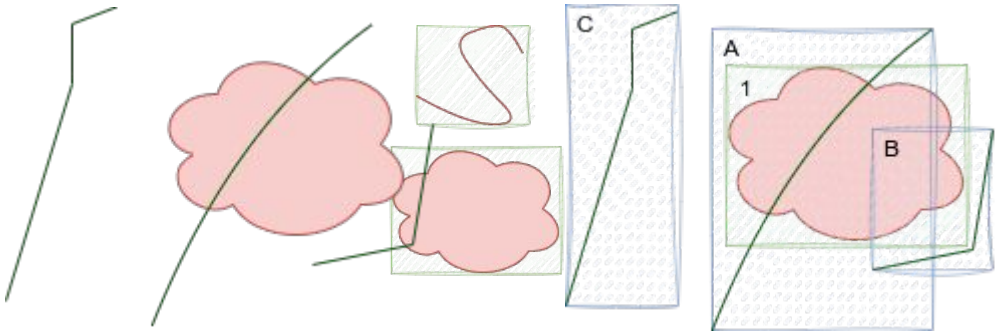
PostGIS is a spatial database:

- Spatial data types
  - geometry (point, lines, polygons)
  - raster
- Spatial indexing
  - Optimised for spatially related data
- Spatial functions
  - ST_...

Data Types


spacial reference
geometry
surface
curve
point
geomerty collection
polygon
linestring
multi surface
multi curve
multi point
multi polygon
multi linestring

Spatial Indexing



- Speeding up the query
- Using the help of bounding boxes to create indexes
  - BBoxes are simpler objects that can be compared quite fast
  - Often it is enough to answer a query using BBoxes
- Spatial objects are organized so that a search can be done in a quick walk through of a tree

Spatial Indexing

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- Only some postGIS functions automatically make use of spatial index.
- Including the most commonly used function:
  - ST_Intersects
  - ST_Contains
  - ST_Within
  - ST_DWithin
  - ...
- To explicitly perform a search using a BBox:
  - && → intersects →gist, spgis, BRIN
  - @ → contains →gist, BRIN
  - << → is strictly to the left →gist, spgist
  - ~= → is the same →gist, spgist
  - ...

Spatial Functions

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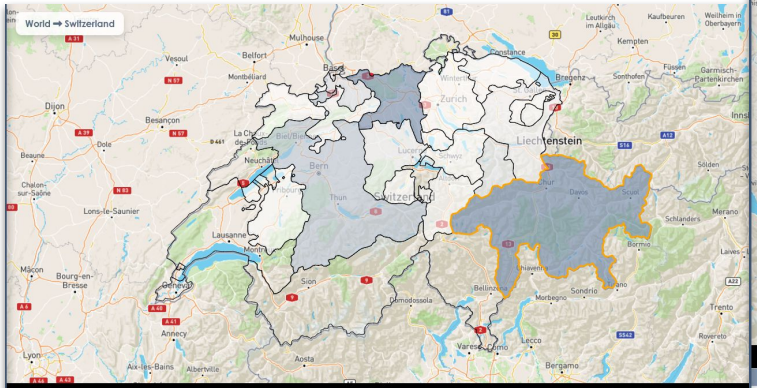

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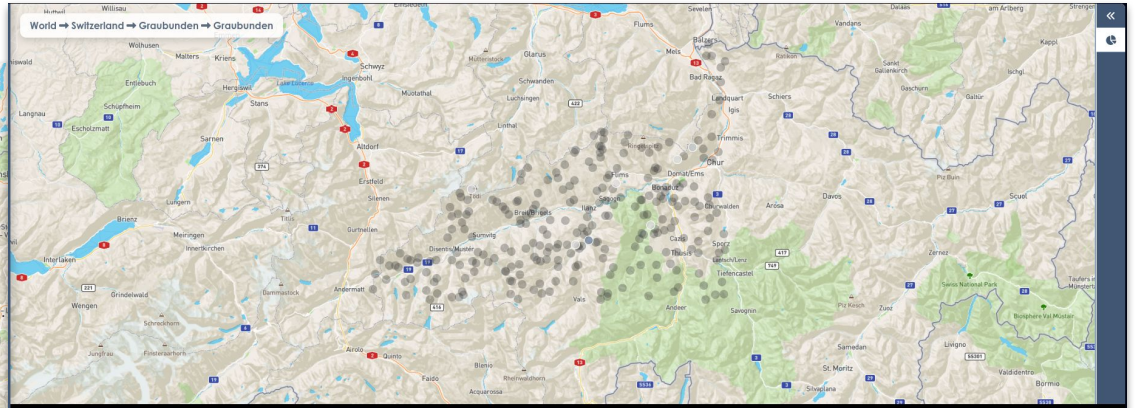

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Map POIS into administrative regions

ST_Contains(geometry A,geometry B) → boolean ⇒ A is in B

ST_Within(geometry A,geometry B) → boolean ⇒ B is in A

Spatial Functions

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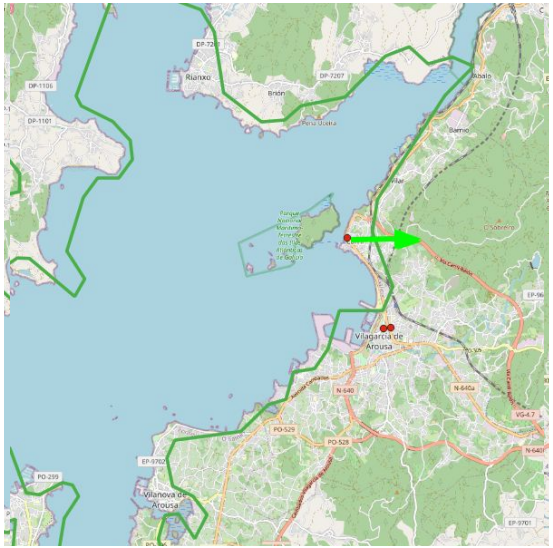
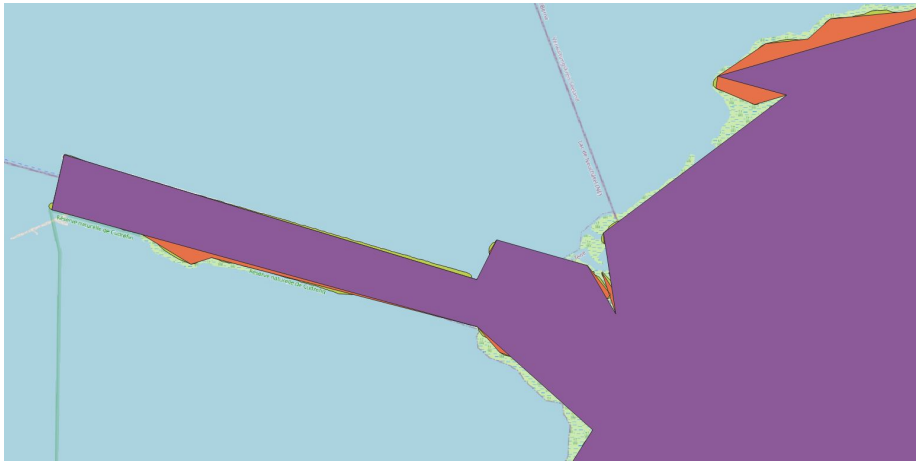
ST_Distance(geometry A,geometry B) → distance ⇒ distance from A to B

ST_DWithin(geometry A,geometry B,distance d) → boolean ⇒ B is within *d* of A



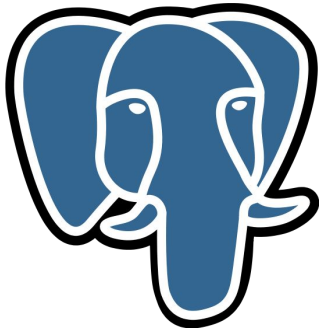
- → Correction of the allocated region for a POI with the next closest polygon
- → Corrections of POIs that are badly allocated and that are within a maxim distance from the next polygone
- → What is the shortest distance between point A and point B? → there is also a different approach to solve this

Spatial Functions



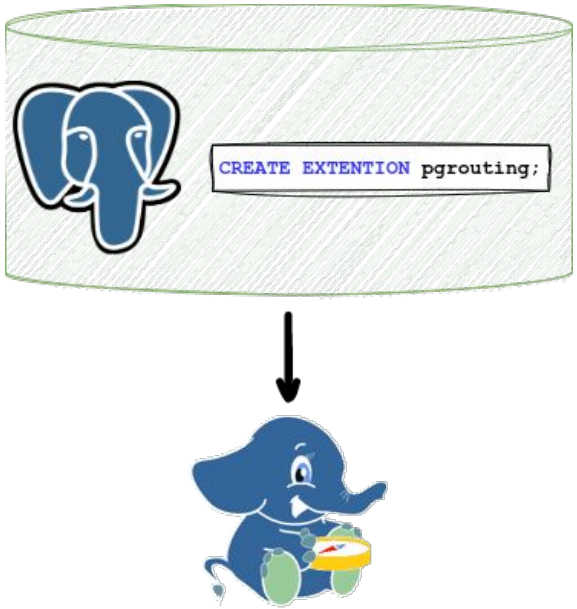
ST_Simplify(geometry A, float tolerance, [boolean preserveCollapsed]) → simplified geometry

- ➔ Simplify (multi)lines and (multi)polygons
- ➔ Use case: When geometries consist of many vertices and render too slow

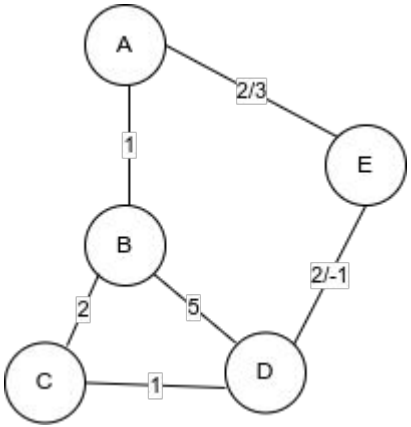


pgRouting

What is (pg)Routing?



- Finding the path with the minimal cost between two points on a graph.
  - nodes , vertices
  - orientation
  - cost



Translating the Graph in to a PostgreSQL Table

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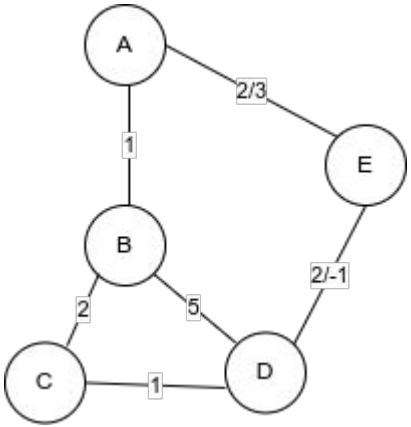

ID	source	target	cost	reverse cost
A_B	A	B	1	1
B_C	B	C	2	2
C_D	C	D	1	1
A_E	A	E	2	3
E_D	E	D	2	-1
B_D	B	D	5	5

The Data

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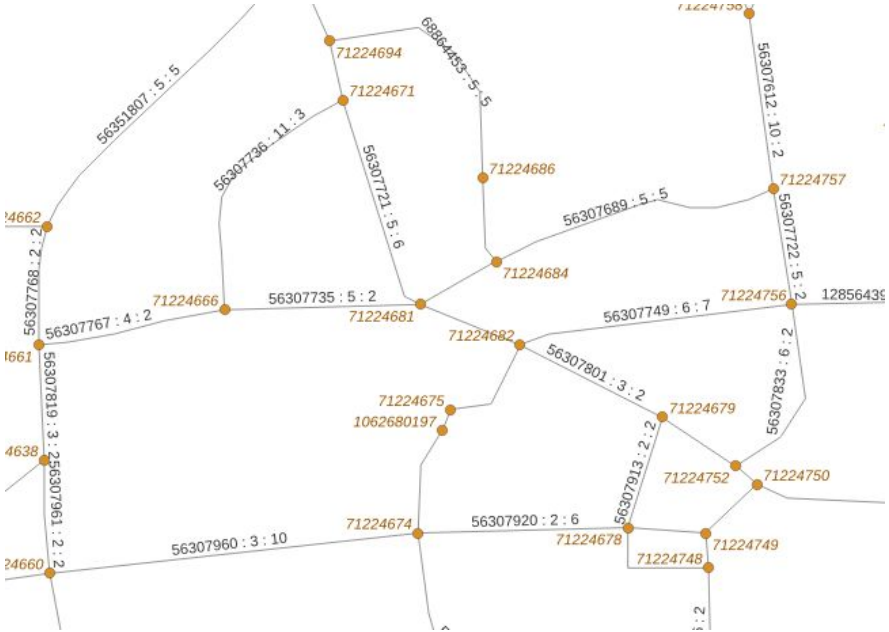
Example using HERE map date



	gid integer	source integer	target integer	cost smallint	reverse_cost smallint	the_geom geometry
1	928131604	80148107	955160491	8	8	0102000020E610...
2	71398108	80148106	80148134	8	8	0102000020E610...
3	928131605	955160491	80148135	−1	1	0102000020E610...
4	723428763	80148134	721745842	2	−1	0102000020E610...
5	123078040	80148135	1164666563	1	1	0102000020E610...
6	123078040	1164666563	1084808819	1	1	0102000020E610...
7	110572139	721745842	1084808818	4	4	0102000020E610...
8	110572139	1084808819	1084808820	18	18	0102000020E610...
9	110572139	1084808818	750787710	18	17	0102000020E610...
10	110572139	1084808820	750787703	2	2	0102000020E610...
11	590940936	750787710	580367923	6	6	0102000020E610...
12	590940931	750787703	750787702	6	6	0102000020E610...
13	110572139	750787702	1084808821	−1	1	0102000020E610...
14	821484345	580367923	80148902	16	15	0102000020E610...

Negative cost (e.g. -1) = direction not allowed

Why the pgRouting Extension?

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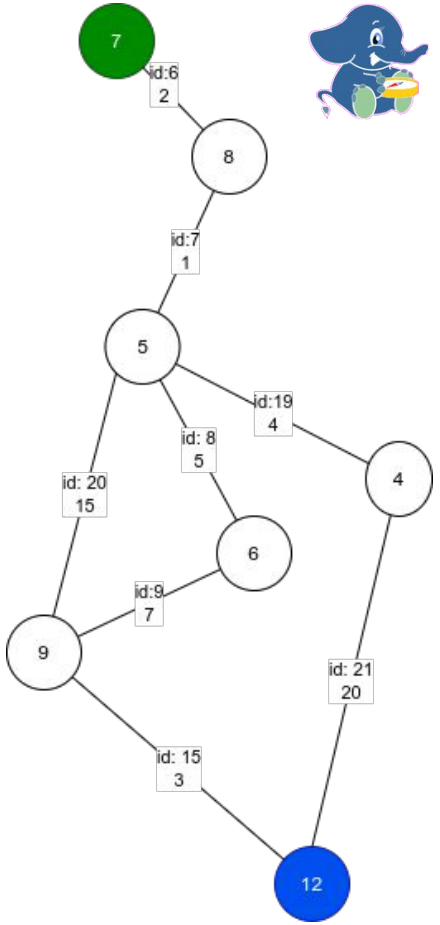
- Extends the set of available functions in PostgreSQL with routing functions:
  - Dijkstra
  - A*
  - ...
- Basic function structure:
  - `pgr_<name>(inner queries, parameters, [ Optional parameters ]);`
- Turn restricted shortest path:
  - `pgr_trsp(sql text, source integer, target integer,directed boolean, has_rcost boolean [,restrict_sql text]);`

pgRouting: an Example

```
SELECT *
FROM pgr_trsp(
    'SELECT gid, source, target, cost FROM edge_table',
    7,12, false, false)
```

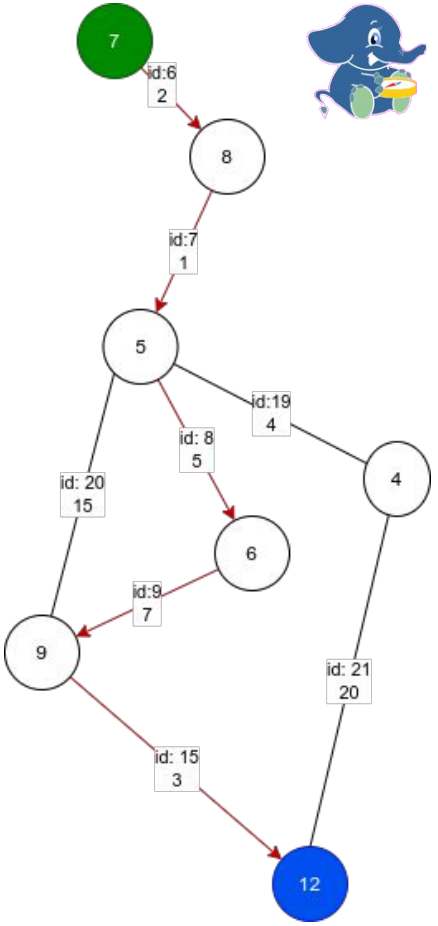


pgRouting: an Example


```
SELECT *
FROM pgr_trsp(
    'SELECT gid, source, target, cost FROM edge_table',
    7,12, false, false)
```

seq	Node	Edge	cost
0	7	6	2
1	8	7	1
2	5	8	5
3	6	9	7
4	9	15	3
5	12	-1	0

⇐



pgRouting: case study

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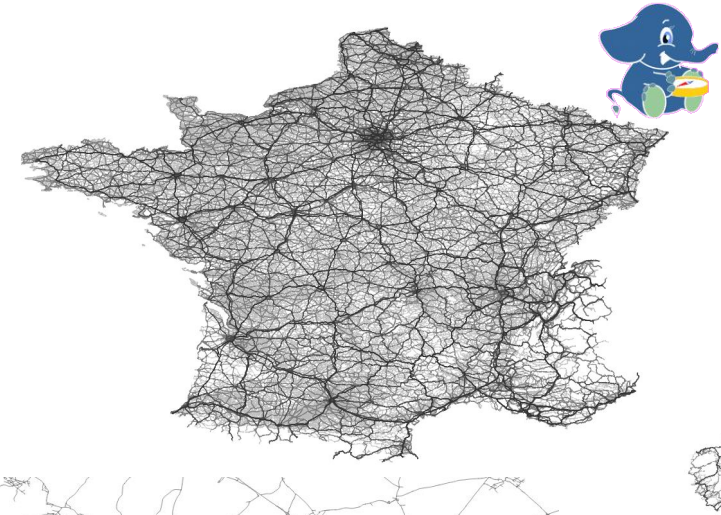
- French governmental agency providing **routing services** for various clients
- Objective: offering an **API** based on pgRouting and other open source components to compute:
  - **Shortest / fastest routes**
  - **Traveling Salesman Problem**
  - **Isochrones / isodistances**

Lieve Example

- Using the HERE data (https://www.here.com) to PostgreSQL (~11 mio. rows / road segments)
- For each segment: different costs with various parameters:
  - distance/time
  - car/truck/pedestrian,
  - traffic rules emergency/normal
- Performance requirements:
  - all queries under 1s (for long routes: < 5s)



Shortest / fastest route

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→ Fastest route to an emergency location (`pgr_trsp` / `pgr_dijkstra`)

Shortest / fastest route

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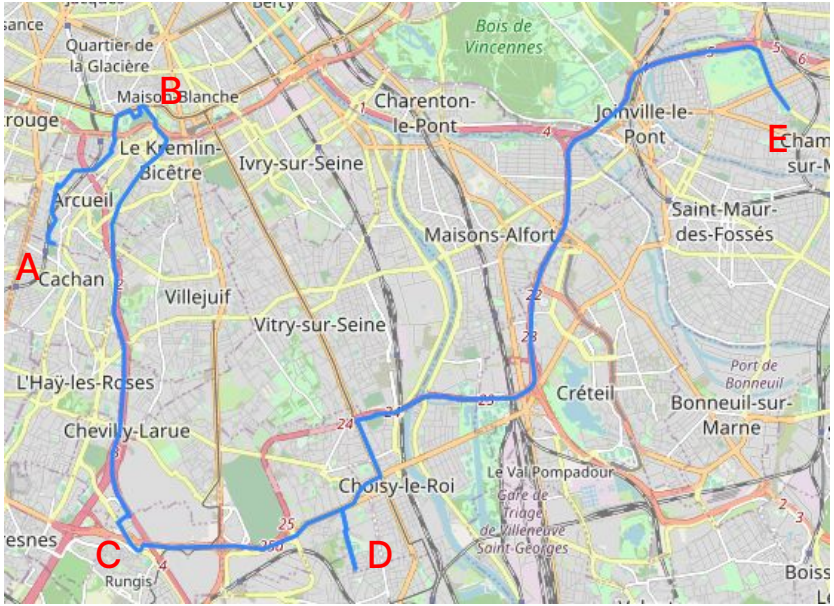
- Shortest / fastest route
  - Fastest route between many POIs for monitoring (`pgr_tsp` - travelling salesman)



Isochrones / Isodistances

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Estimate area of escape routes:

- ➔ based on `pgr_drivingDistance`
- ➔ Using postGIS functions:
  - build polygons from returned nodes/points:
  - `ST_ConcaveHull`

Isochrones / Isodistances

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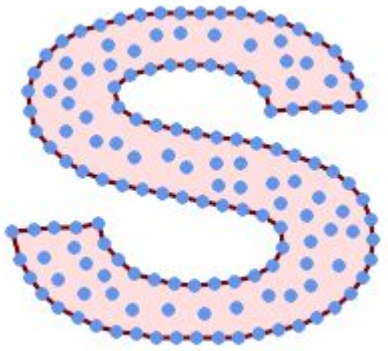
- `pgr_drivingDistance(Edges SQL, root vid, distance, [directed])`
  - Edges SQL ⇒ the graph
  - Root vid 0 ⇒ indicates the start point
  - Distance ⇒ the distance of the the end point

  ⇒ RETURNS SET OF (seq, node, edge, cost)

- Using postGIS functions: build polygons from returned nodes/points:

```
ST_ConcaveHull(ST_Collect(nodes.the_geom), 0.98) AS polygon
```



Isochrones / Isodistances

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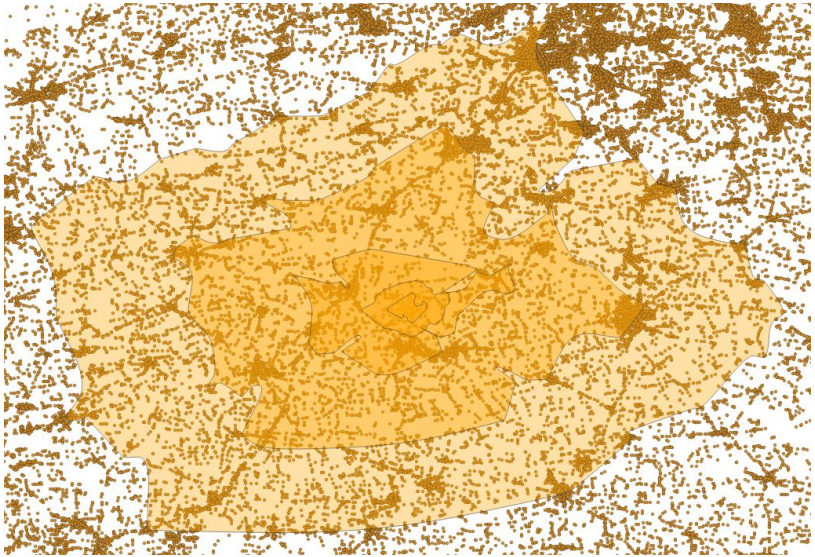
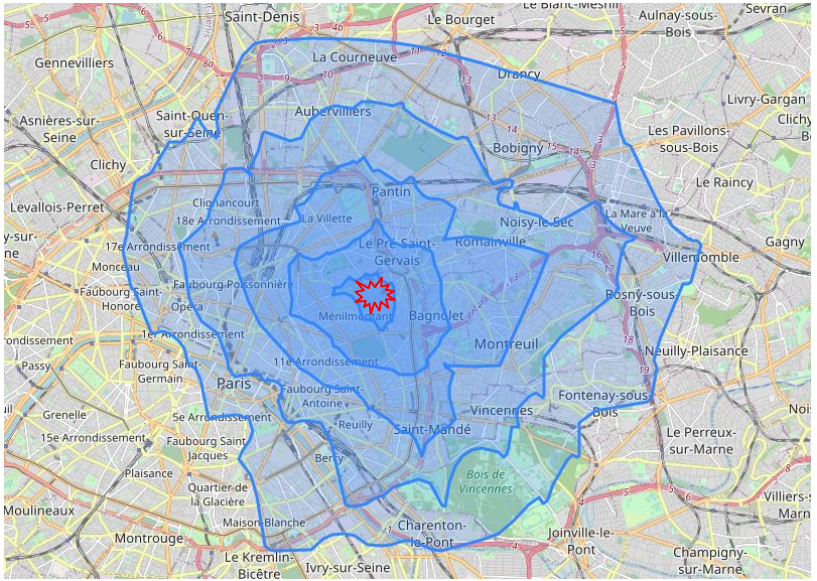
- Estimate area of escape routes from a crime location (e.g. max. 10 min with 2 min steps)





pgRouting

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Answer questions like:

- ➔ Shortest / fastest path between
  - A and B
  - Start at A and end at different points
  - Starte at different points points and end at A
  - Multiple start points and multiple endpoints
- ➔ Travel Salesman Problem (TSP)

pgRouting

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- Advantages:
  - Access to the functionalities of PostgreSQL/PostGIS
  - Flexible as SQL for queries
  - Many routing algorithms available
  - Many tools for graph/network analysis
  - “Cost” parameters can be changed dynamically

pgRouting and PostGIS

- Powerful PostgreSQL extensions that combine well
- Open source (GNU General Public License)
- A long history and active community
- Well documented
  - https://postgis.net/documentation/
  - https://docs.pgrouting.org/latest/en/index.html

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Thanks for your attention!

https://github.com/camptocamp/

https://www.camptocamp.com

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Literature References

- PostGIS in Action by Regina O. Obe, Leo S. Hus
- PostGIS Workshop: *https://www.postgis.net/workshops/postgis-intro*
- pgRouting doc: *https://pgrouting.org*

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