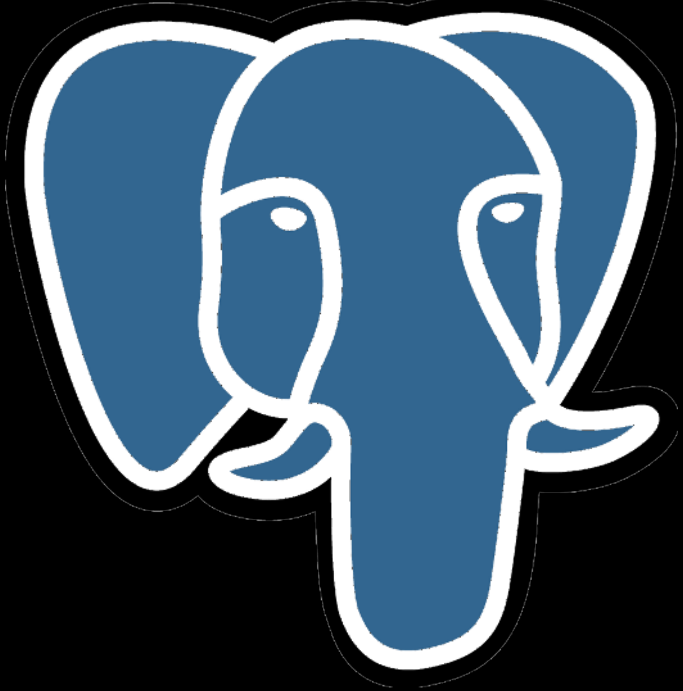
OSM
Data Processing
with
PostgreSQL / PostGIS

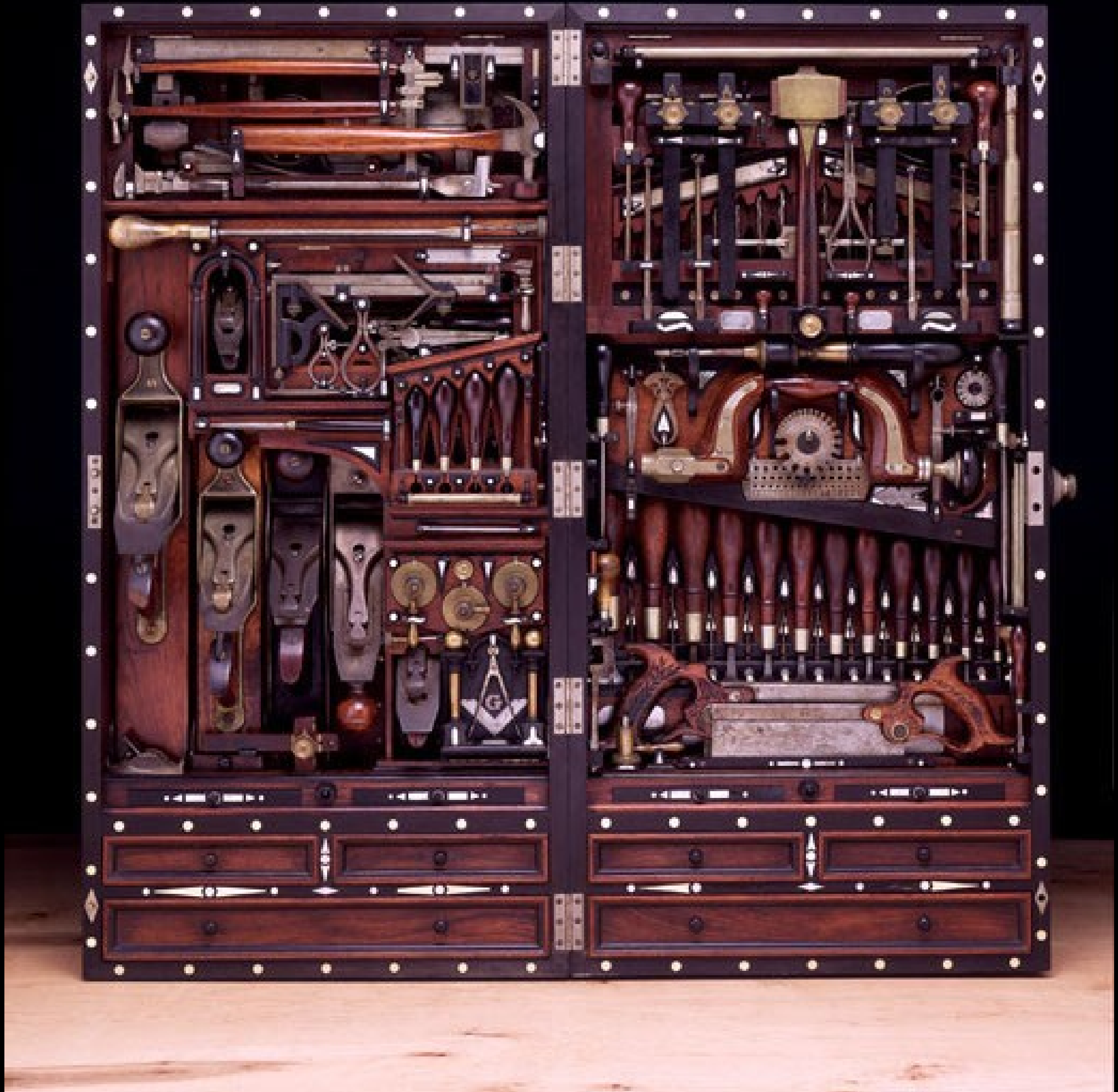
Jochen Topf
jochentopf.com

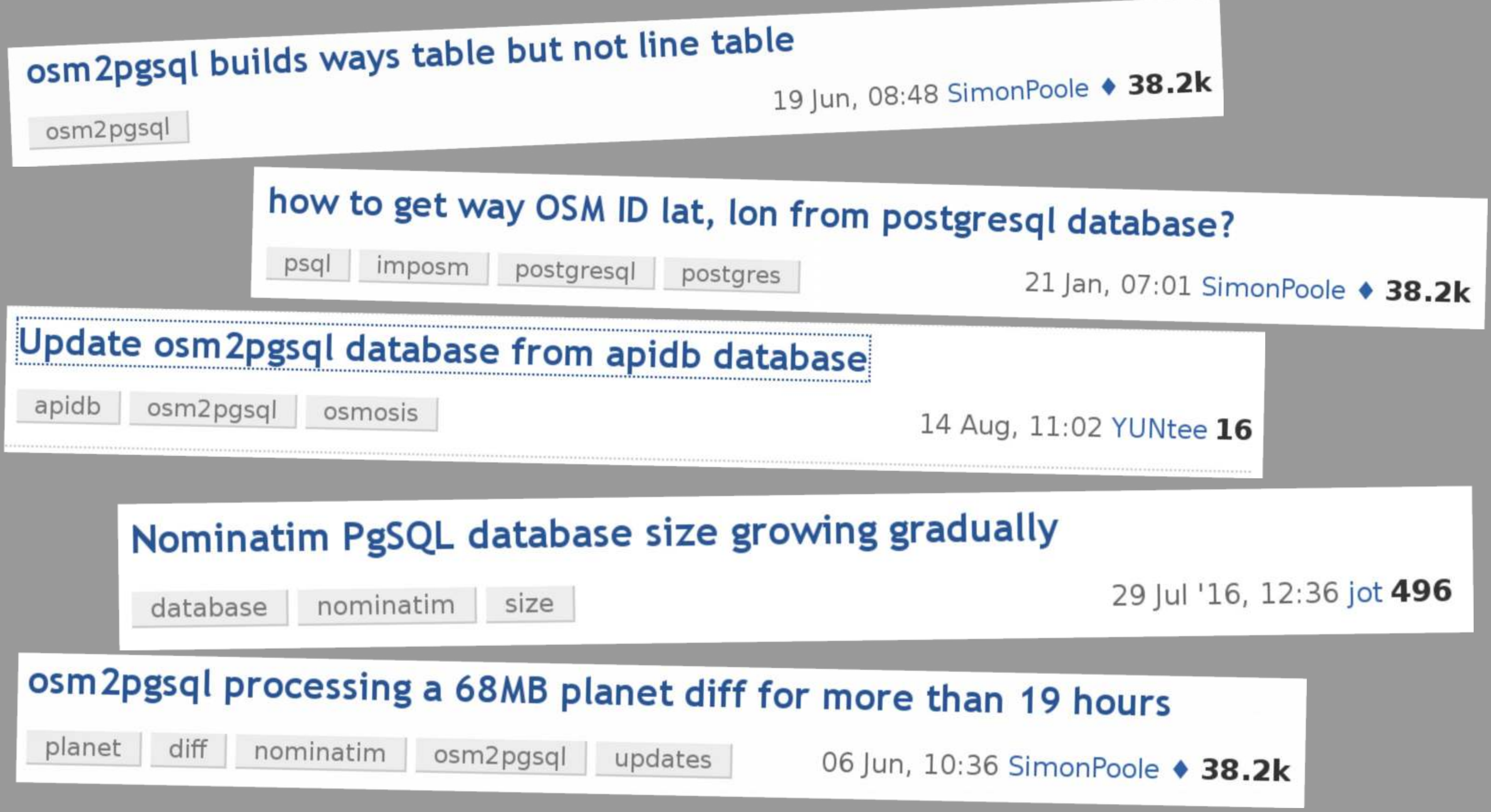
OpenStreetMap



PostgreSQL

Studley Tool Chest | CC-BY-SA | https://www.flickr.com/photos/publicresourceorg/493813720





osm2pgsql builds ways table but not line table

osm2pgsql

19 Jun, 08:48 SimonPoole ♦ 38.2k

how to get way OSM ID lat, lon from postgresql database?

psql imposm postgresql postgres

21 Jan, 07:01 SimonPoole ♦ 38.2k

Update osm2pgsql database from apidb database

apidb osm2pgsql osmosis

14 Aug, 11:02 YUNtee 16

Nominatim PgSQL database size growing gradually

database nominatim size

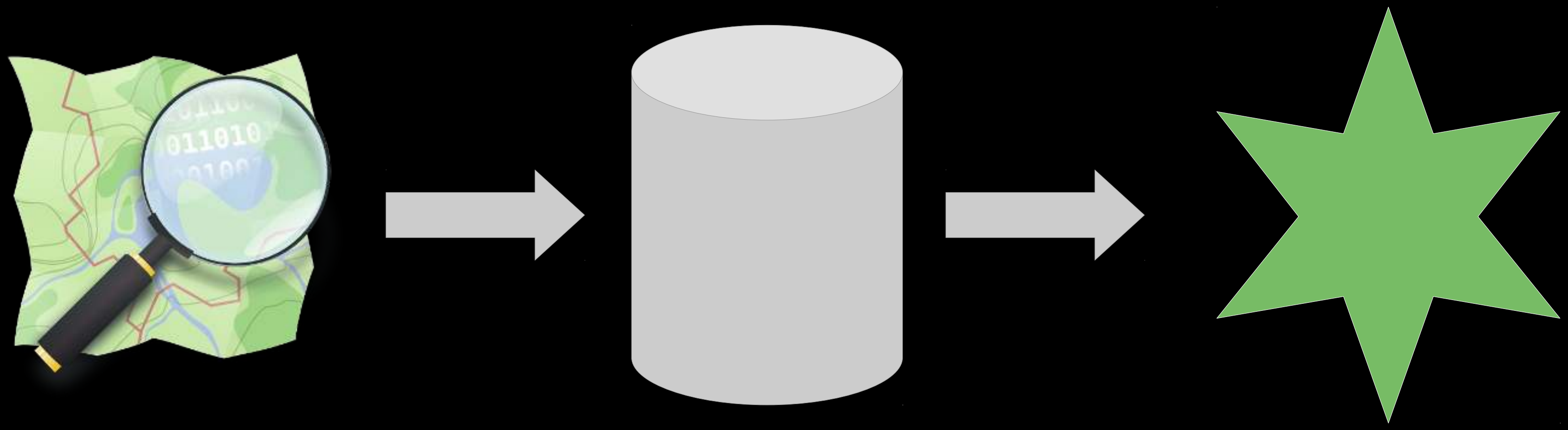
29 Jul '16, 12:36 jot 496

osm2pgsql processing a 68MB planet diff for more than 19 hours

planet diff nominatim osm2pgsql updates

06 Jun, 10:36 SimonPoole ♦ 38.2k

From help.openstreetmap.org



What we will talk about...

- Background: Relational Databases, Geodata
- Converting OSM Data
- Use Cases
- Tools
- Tips & Tricks, Odds & Ends

⏸ ▶

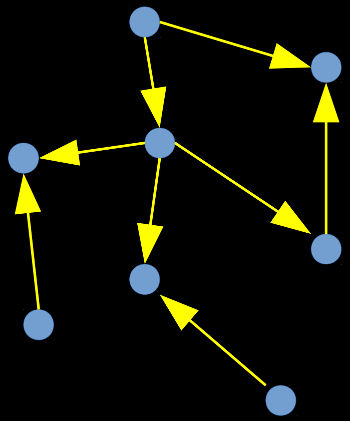
Background:

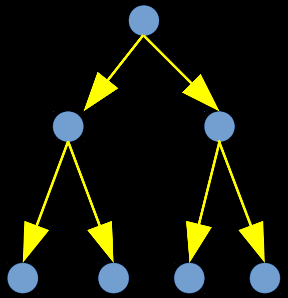
Relational Databases

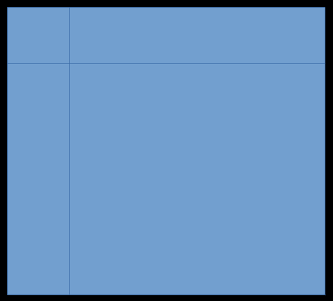
Databases

Databases store and manipulate data.

There are many different ways to organize data...







Relational Databases

All data is organized in Tables.

Relational Databases

Table **Members**:

ID	Name	Place	Age
1	Joe	Sydney	34
2	Jenny	New York	42
3	Jeremy	Moskow	55

Relational Databases

Table Members:

ID	Name	Place	Age
1	Joe	Sydney	34
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Relational Databases

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Relational Databases

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Relational Databases

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Data Types

Fields have a type:

Text
Integer
Numeric
Date
...

Relational Databases

Table **Members**:

ID	Name	Place	Age
1	Joe	Sydney	34
2	Jenny	New York	42
3	Jeremy	Moskow	55

Structured Query Language

Data Access using SQL

```
SELECT Name
    FROM Members;
```

Name
Joe
Jenny
Jeremy

Data Access using SQL

```
SELECT Name, Age
    FROM Members;
```

Name	Age
Jenny	42
Joe	34
Jeremy	55

Data Access using SQL

```
SELECT Name, Age
    FROM Members
    ORDER BY Age;
```

Name	Age
Joe	34
Jenny	42
Jeremy	55

Data Access using SQL

```
SELECT Name, Age
    FROM Members
    WHERE Age > 40
    ORDER BY Name;
```

Name	Age
Jenny	42
Jeremy	55

INSERT, UPDATE, DELETE

```
INSERT INTO Members (Name, Place, Age)
            VALUES (’Julia’, ’London’, 27);

UPDATE Members SET Place = ’Helsinki’
             WHERE Id = 2;

DELETE FROM Members
             WHERE Name = ’Jeremy’;
```

INSERT, UPDATE, DELETE

```
INSERT INTO Members (Name, Place, Age)
            VALUES (’Julia’, ’London’, 27);

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             WHERE Id = 2;

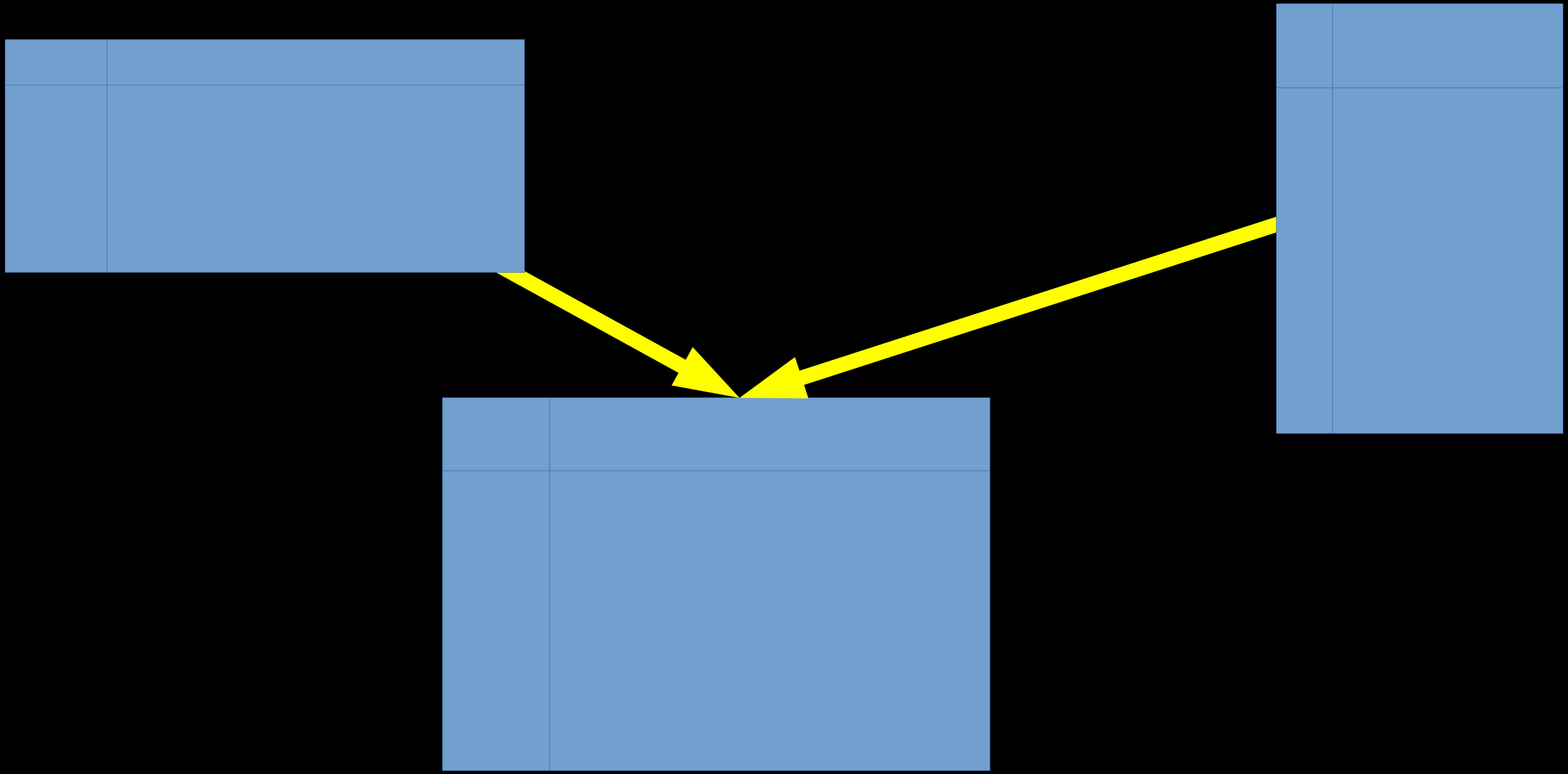
DELETE FROM Members
             WHERE Name = ’Jeremy’;
```

Advanced SQL: Aggregate Functions

```
SELECT Avg(Age)
  FROM Members;
```

Avg
43

Advanced SQL: JOIN



The Magic

You define a structure (“schema“).

You add data.

You ask for data back.

The database software does everything else.

Not so magic...

Performance can depend on structure

You still need to know a bit…

Indexes

Indexes allow faster access
for some queries

Tradeoff: Indexes need space and need to be
updated vs. faster queries

Relational Databases

PostgreSQL

MySQL, MariaDB

SQLite

...

Relational Databases

PostgreSQL

MySQL, MariaDB

SQLite

...

PostgreSQL

Open Source

lots of features

good documentation, books, etc.

popular, great eco-system, well-supported

powerful plugin system

Background:

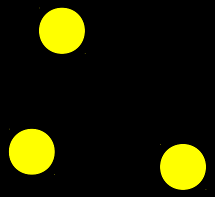
Geodata

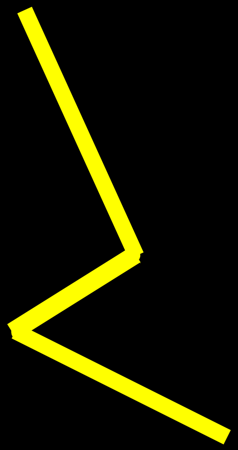
Simple Feature Model

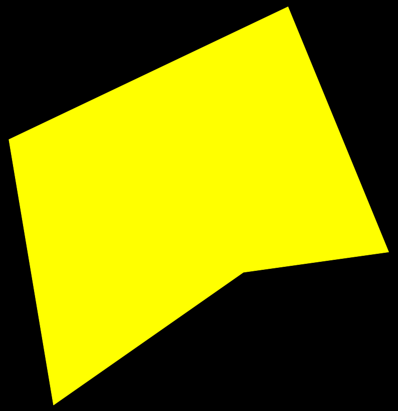
Point

LineString

Polygon







MultiPoint

MultiLineString

MultiPolygon

We want to store this
in a database

A Naive Approach...

ID	Name	X	Y
1	Joe	151.22	-33.85
2	Jenny	-74.01	40.70
3	Jeremy	37.61	55.95

A Better Approach...

Text

Integer

Numeric

Date

Geometry

...

A Better Approach...

ID	Name	Geom
1	Joe	POINT(151.22 -33.85)
2	Jenny	POINT(-74.01 40.70)
3	Jeremy	POINT(37.61 55.95)

PostGIS: Plugin

```
CREATE EXTENSION postgis;
```

PostGIS: Datatypes

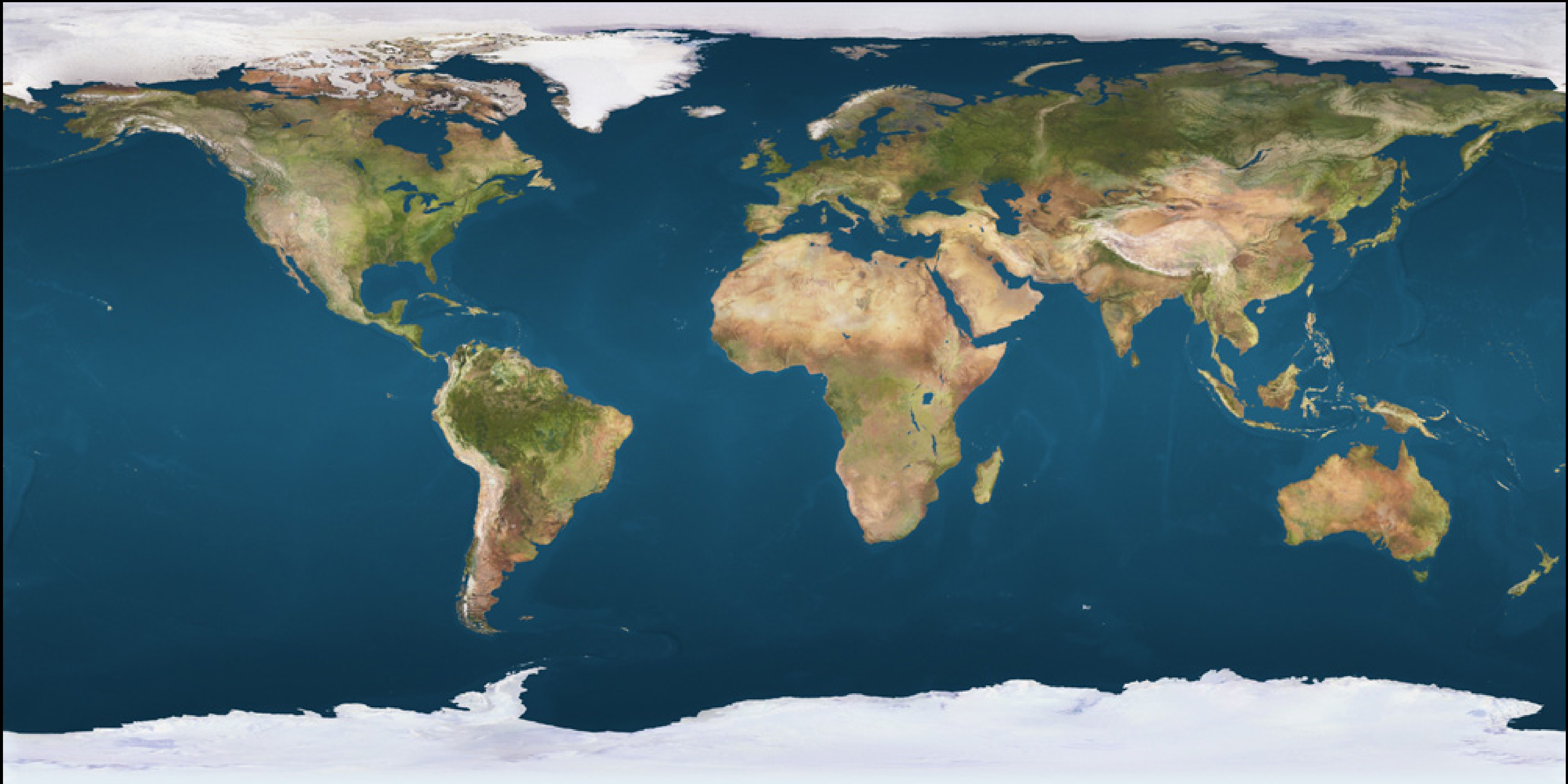
GEOMETRY

GEOMETRY (POINT)
GEOMETRY (LINESTRING)
GEOMETRY (POLYGON)

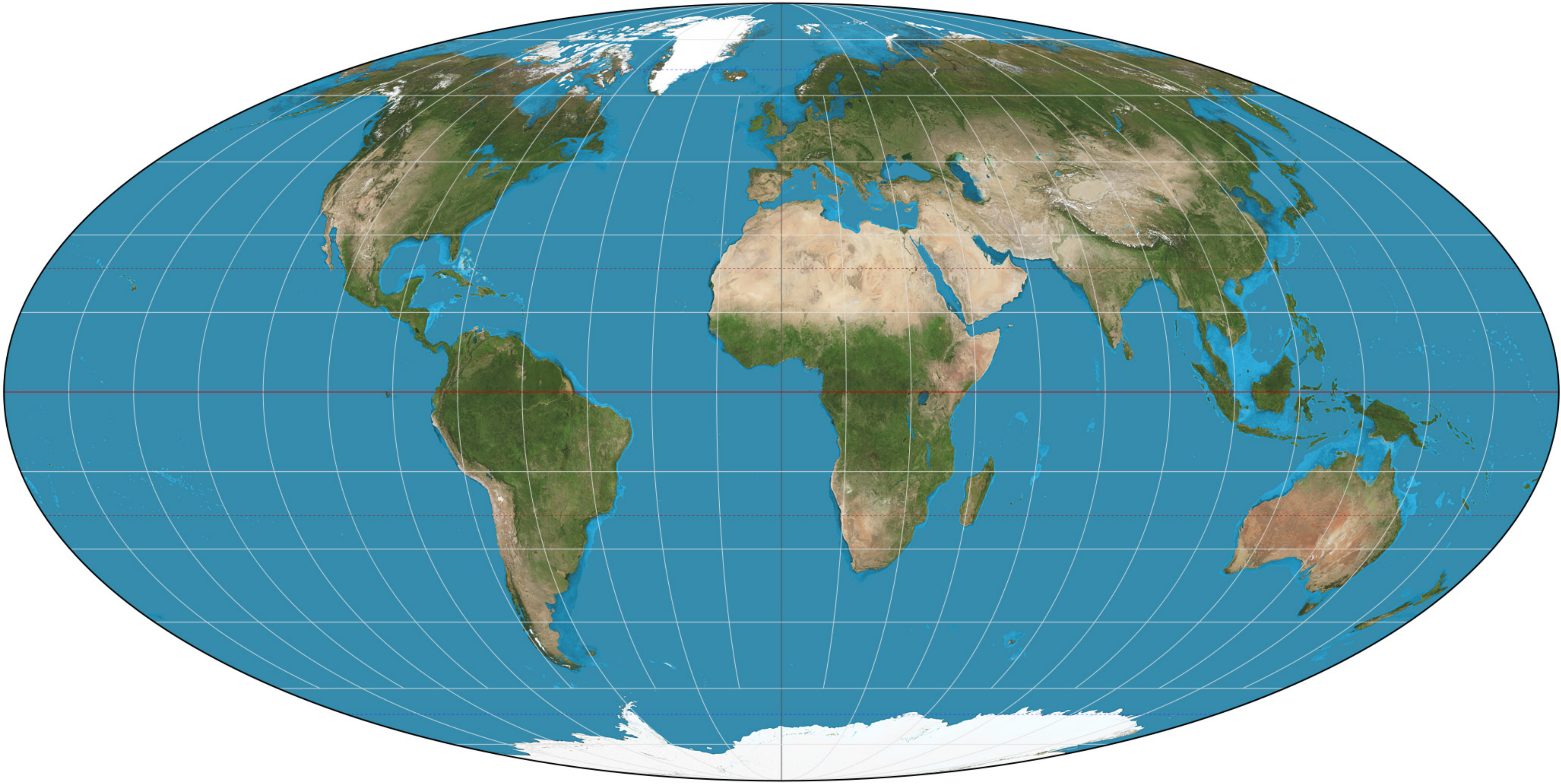
(also: GEOGRAPHY)

Source: Wikipedia

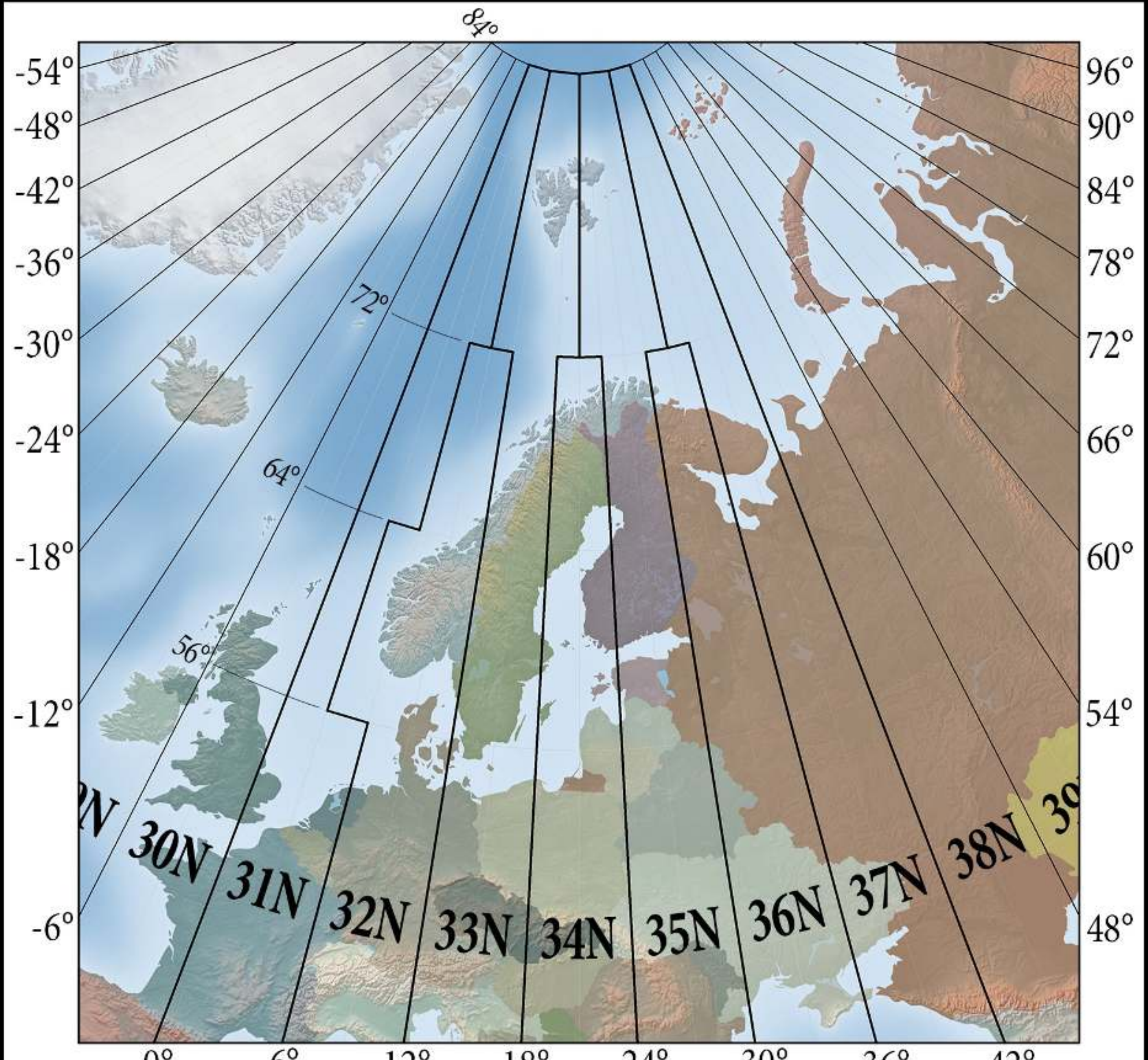
Source: Wikipedia



Source: Wikipedia



Source: Wikipedia



Modified UTM Zones - 31N thru 37N - Projection: Polar Sterographic

Source: Wikipedia

PostGIS: CRS

PostGIS knowns > 5000 Coordinate Systems (CRS/SRS)

Each Geometry associated with SRID.

Allows Transformations

Mix and match data sources

Most important CRSes:

WGS84 – EPSG:4326

Web Mercator – EPSG:3857

PostGIS: Datatypes

GEOMETRY (POINT, 4326)
GEOMETRY (LINESTRING, 4326)
GEOMETRY (POLYGON, 4326)

Coordinates

Always first X axis, then Y axis
(as in mathematics).

so: longitude first, then latitude.

Well Known Text (WKT)

POINT(4 3)

LINESTRING(12 4, 3 2, 7, 9)

POLYGON((0 0, 4 0, 4 4, 0 4, 0 0))

MULTIPOINT / -LINESTRING / -POLYGON

PostGIS: Indexes

Normal indexes are good for
1-dimensional data

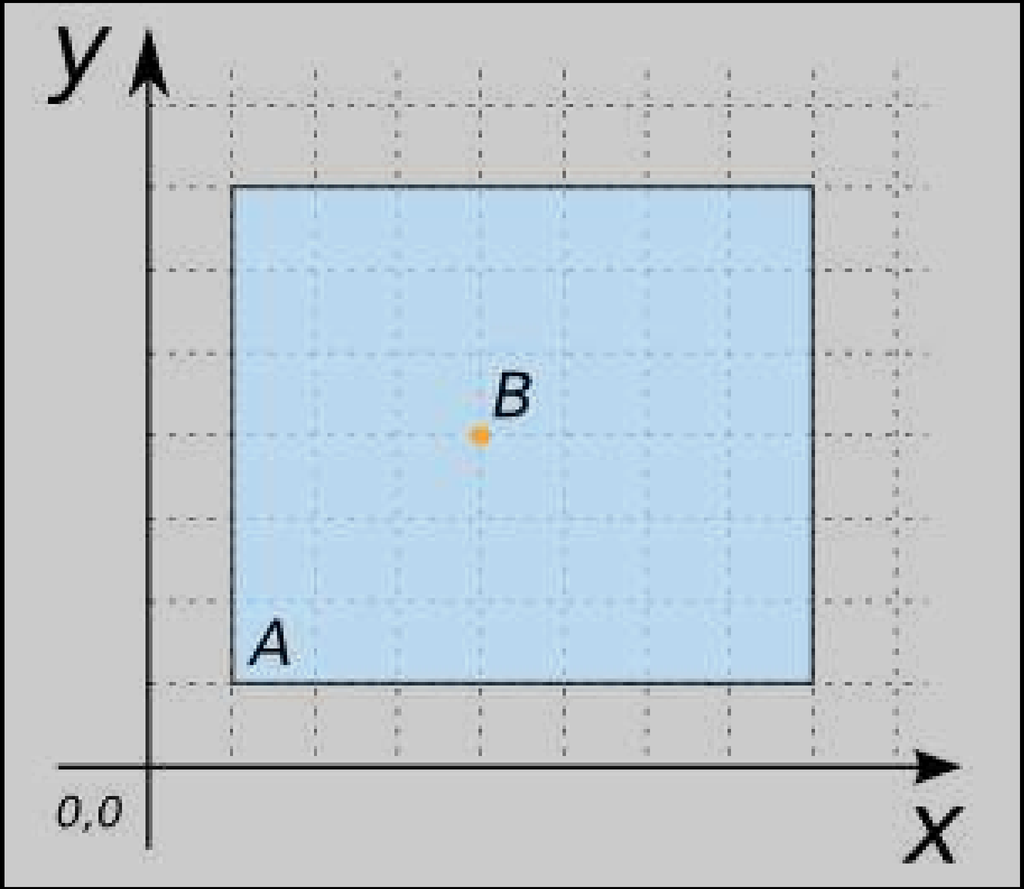
Spatial indexes are good for
2/3-dimensional data
(R -tree)

PostGIS: Operations

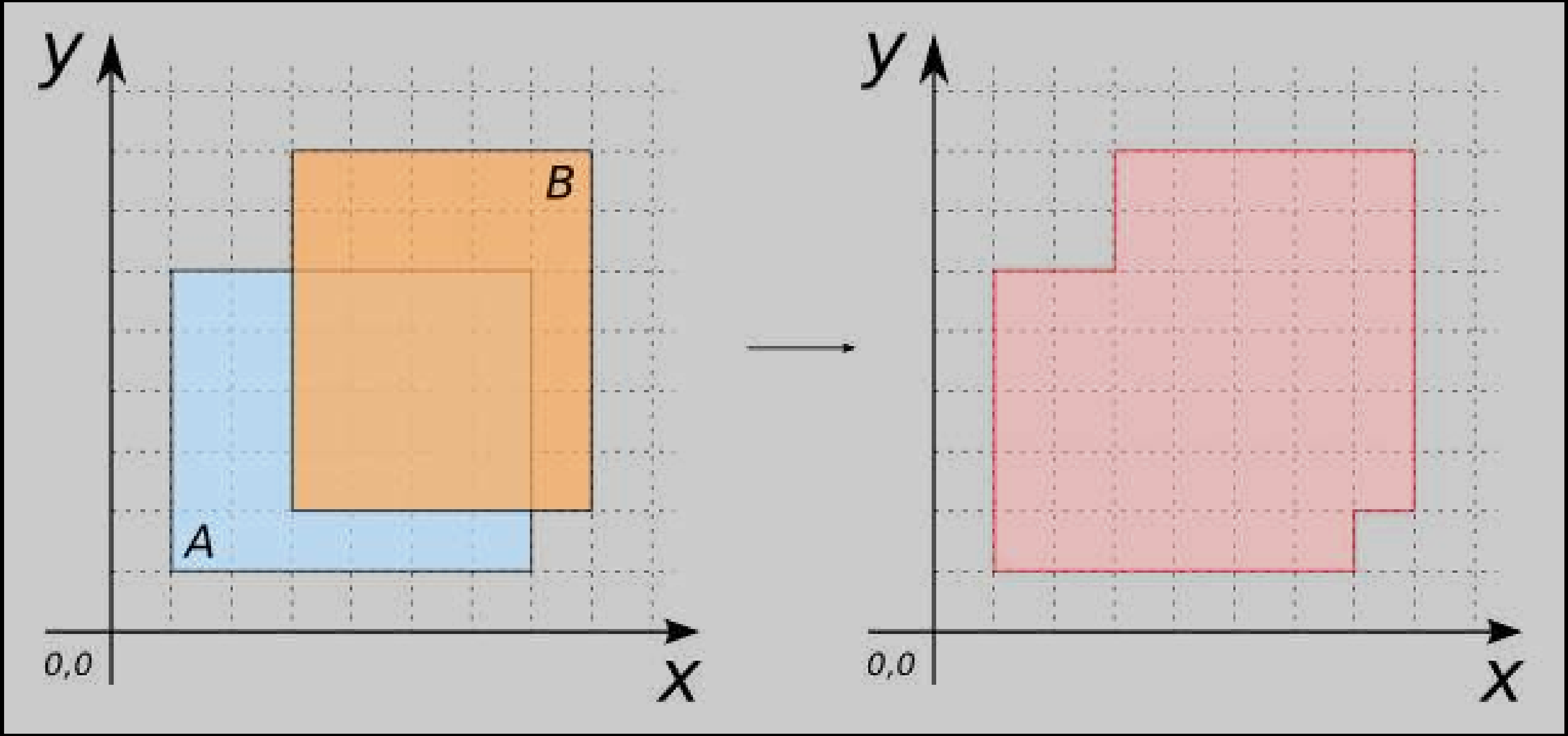
Huge number of

operations on spatial data

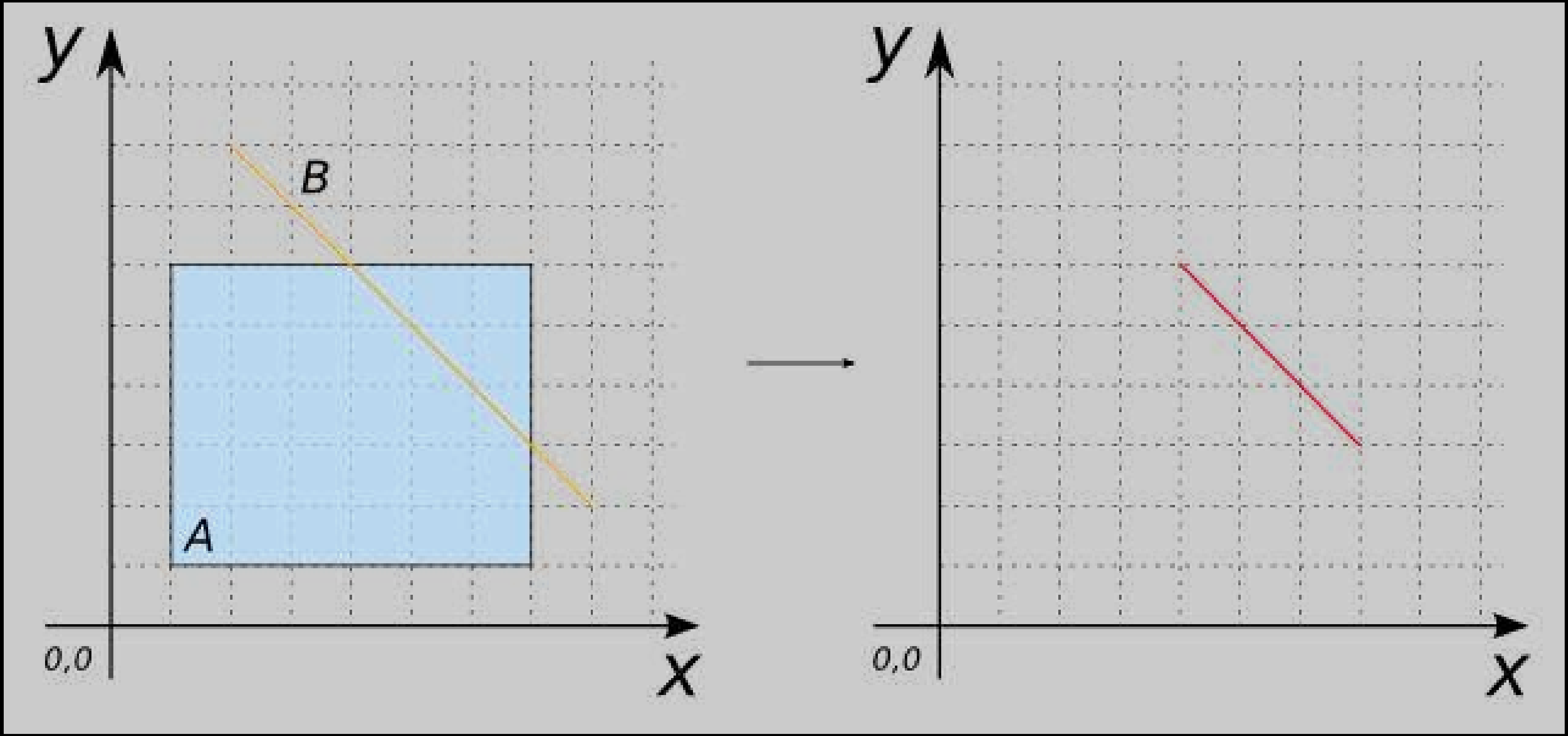
PostGIS: ST_Contains



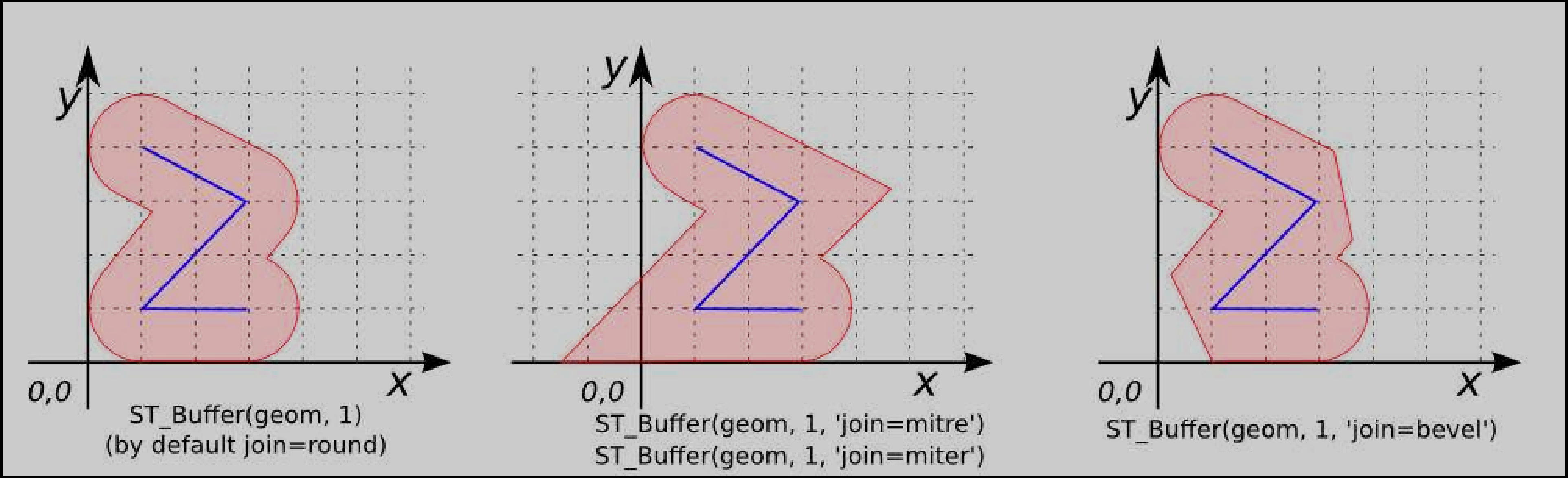
PostGIS: ST_Union



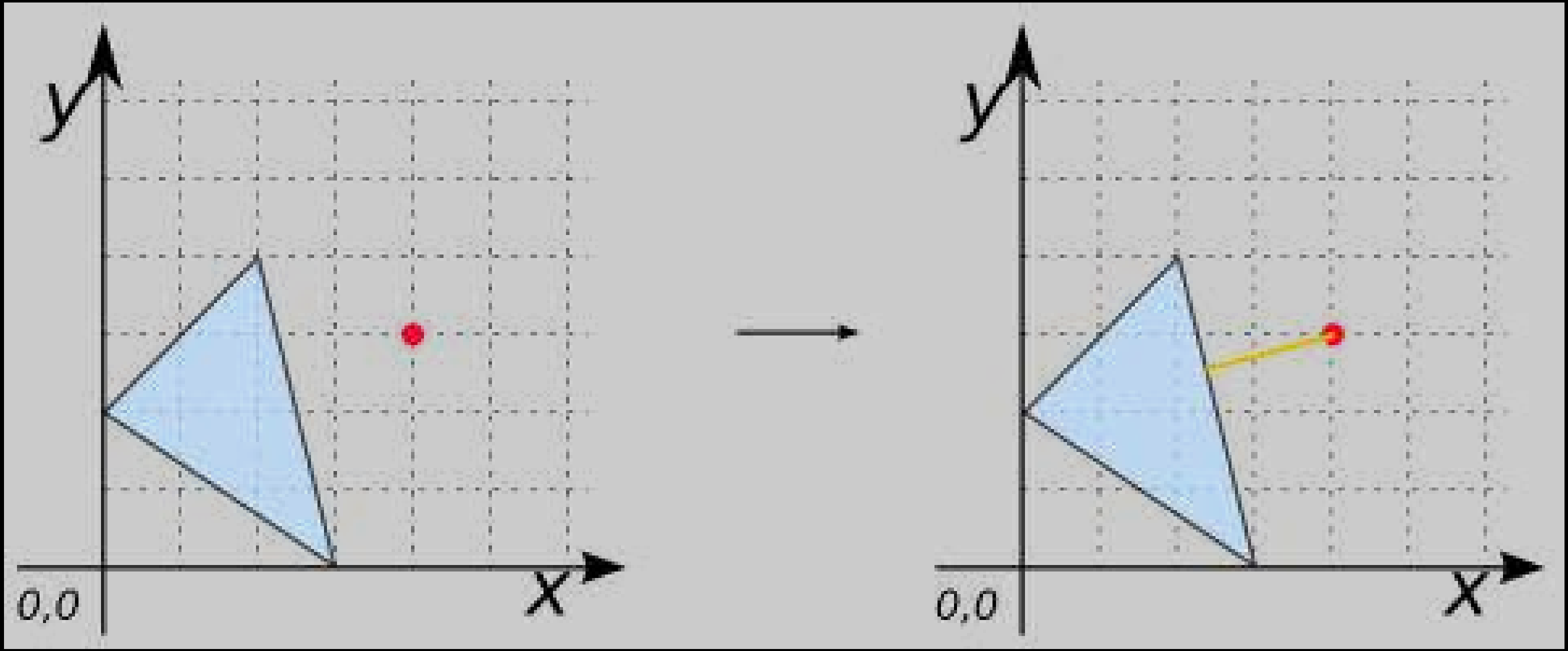
PostGIS: ST_Intersection



PostGIS: ST_Buffer

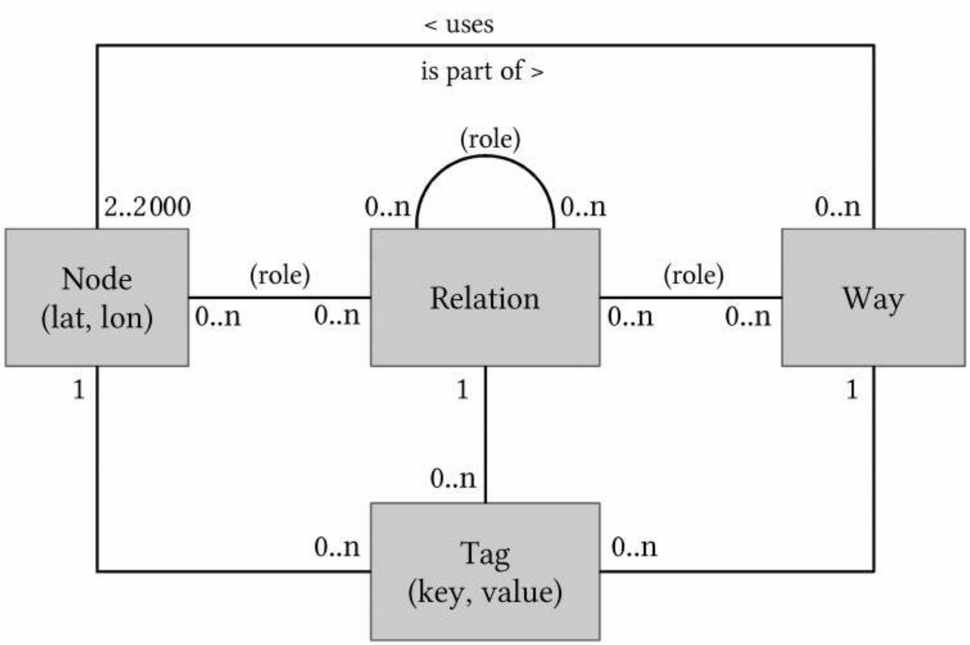

y
x
0,0
ST_Buffer(geom, 1)
(by default join=round)
y
x
0,0
ST_Buffer(geom, 1, 'join=mitre')
ST_Buffer(geom, 1, 'join=miter')
y
x
0,0
ST_Buffer(geom, 1, 'join=bevel')

PostGIS: ST_ShortestLine



Converting OSM Data

OSM Data Model

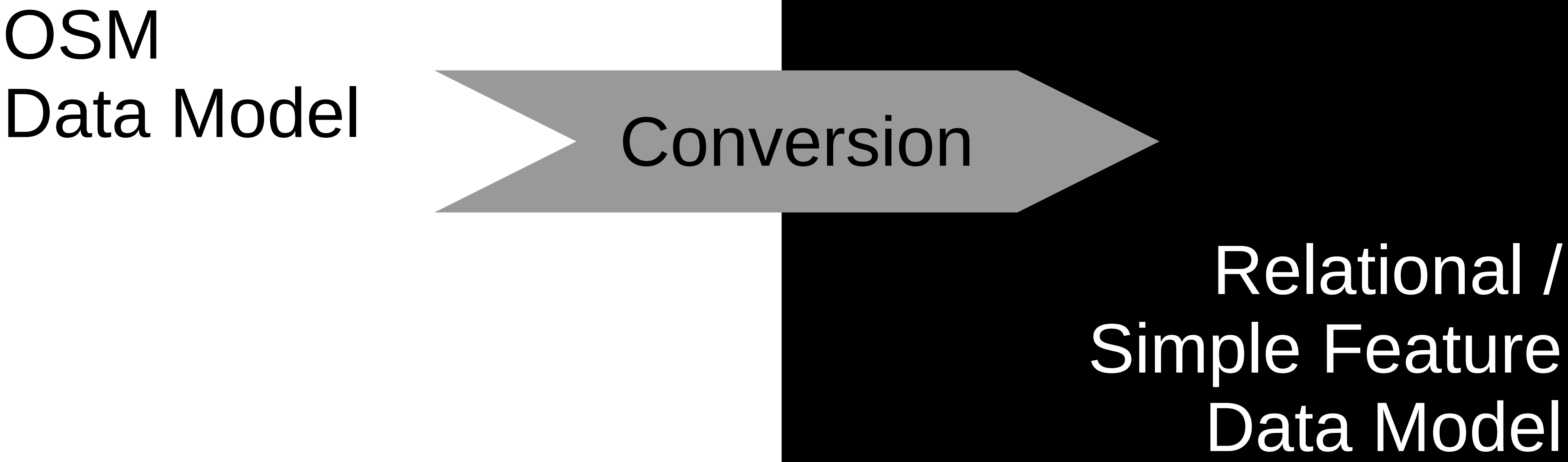


Mismatch

OSM
Data Model

Relational /
Simple Feature
Data Model

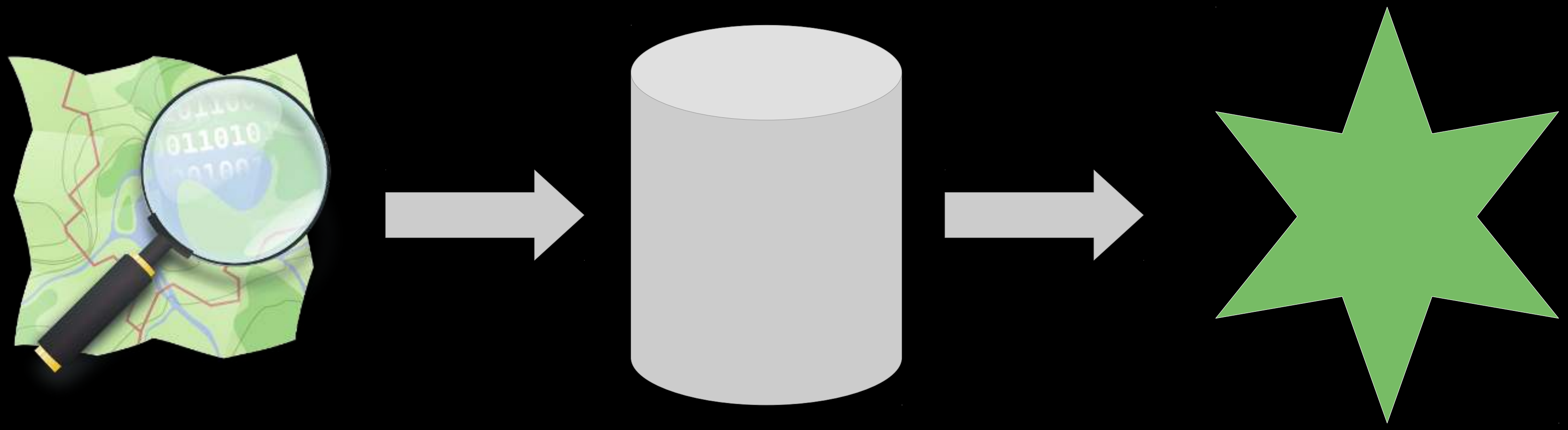
Mismatch

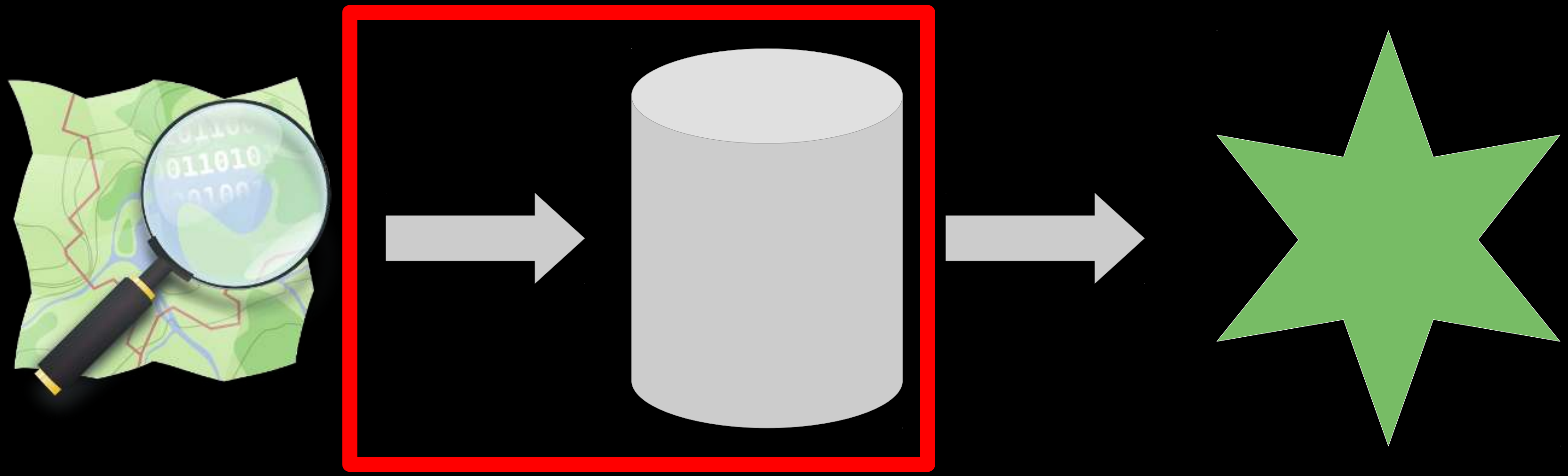


OSM
Data Model

Conversion

Relational /
Simple Feature
Data Model





Conversion: Selection

What data do we actually need?

nodes, ways, relations?

user id, timestamp, version, …?

which tags?

Conversion: Data Types

tags in OSM:
key → value (both text)

Map to:
text, integer, boolean, enums, ...

Conversion: Tags → Attributes

tags in OSM are flexible, table columns are fixed

Highway	Name	Oneway
primary	Main St	false
residential	Elm St	true
trunk		true

Conversion: Tags → Attributes

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Highway	Name	Oneway
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Conversion: Tags → Attributes

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Highway	Name	Oneway
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trunk		true

Conversion: hstore and JSON

Place	Name
city	de: München, en: Munich
city	de: Aachen, fr: Aix-la-Chapelle
village	de: Lübben, hsb: Lubin

Conversion: Tables

split data into tables…

few tables vs. many tables

by geometry type and/or by subject type

Split by Geometry Type

Tables:

nodes
ways
areas

Split by Geometry/Feature Class

Tables:

restaurants
bus_stops
addresses
places
...

highways
railways
rivers
powerlines
...

lakes
forests
countries
buildings
...

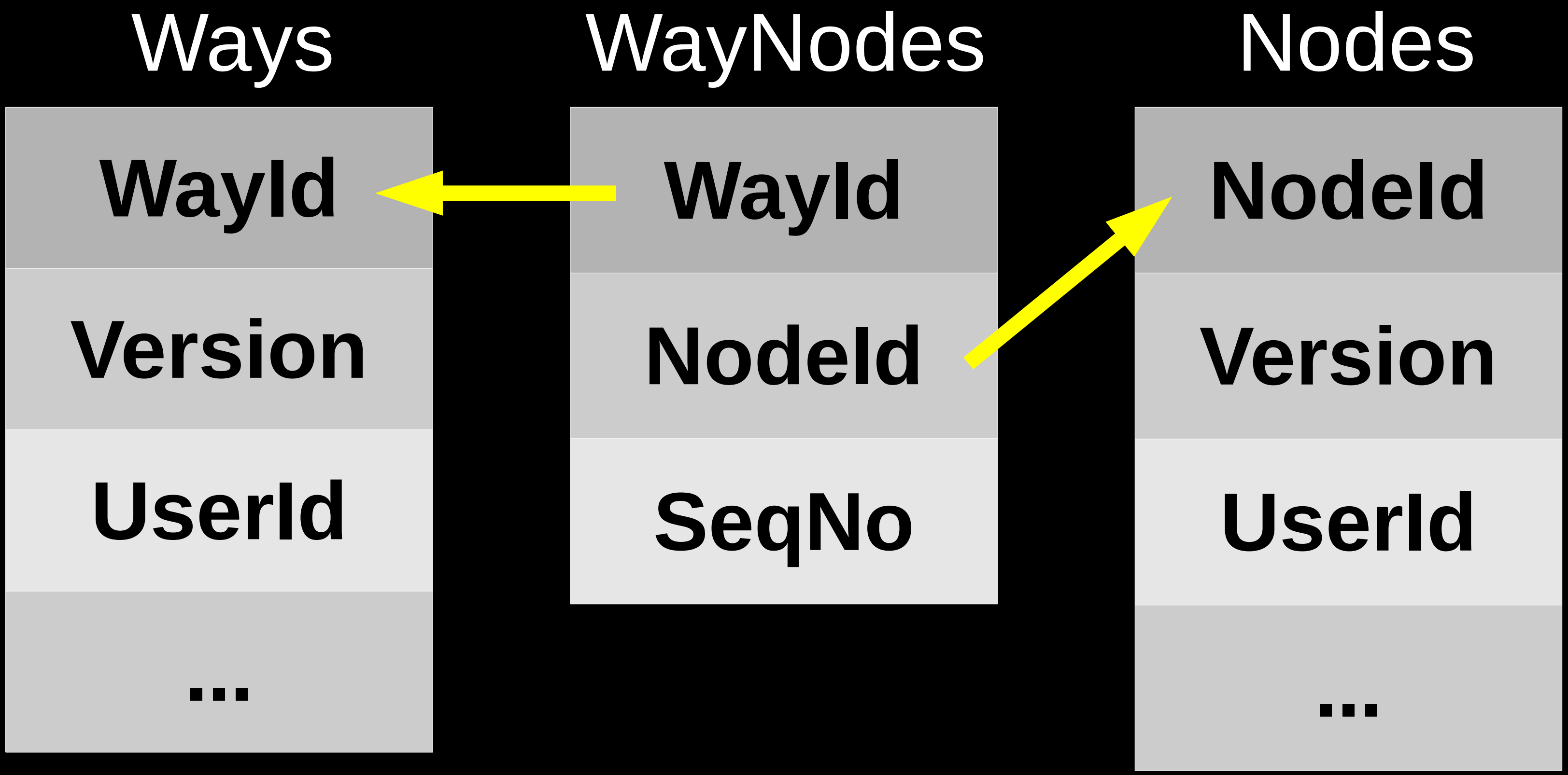
Conversion: Handling lists

nodes in ways

members in relations

tags in nodes, ways, or relations

Conversion: Way Nodes



Ways

WayId

Version

UserId

...

WayNodes

WayId

NodeId

SeqNo

Nodes

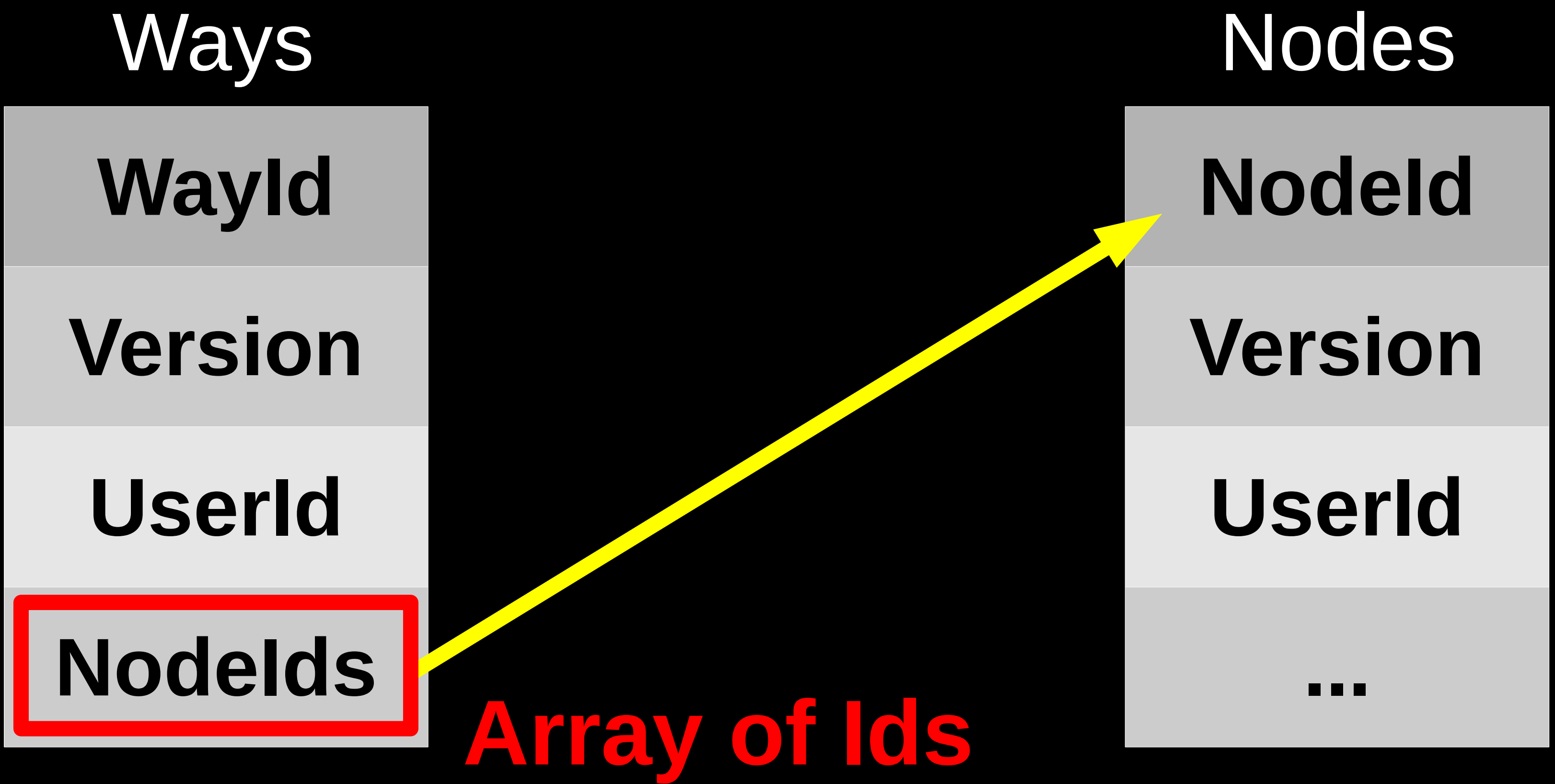
NodeId

Version

UserId

...

Conversion: Way Nodes



Ways

WayId
Version
UserId
NodeIds

Nodes

NodeId
Version
UserId
...

Array of Ids

Conversion: Relation Members

similar to way nodes

but

array of tuple (type, id, role)

Conversion: Geometry

Nodes → Points

Ways → LineStrings / Polygons

Multipolygon relations → Polygons

Route relations → MultiLineStrings

...

Conversion: Geometry

Generalized geometries

For lower zoom levels / small scales

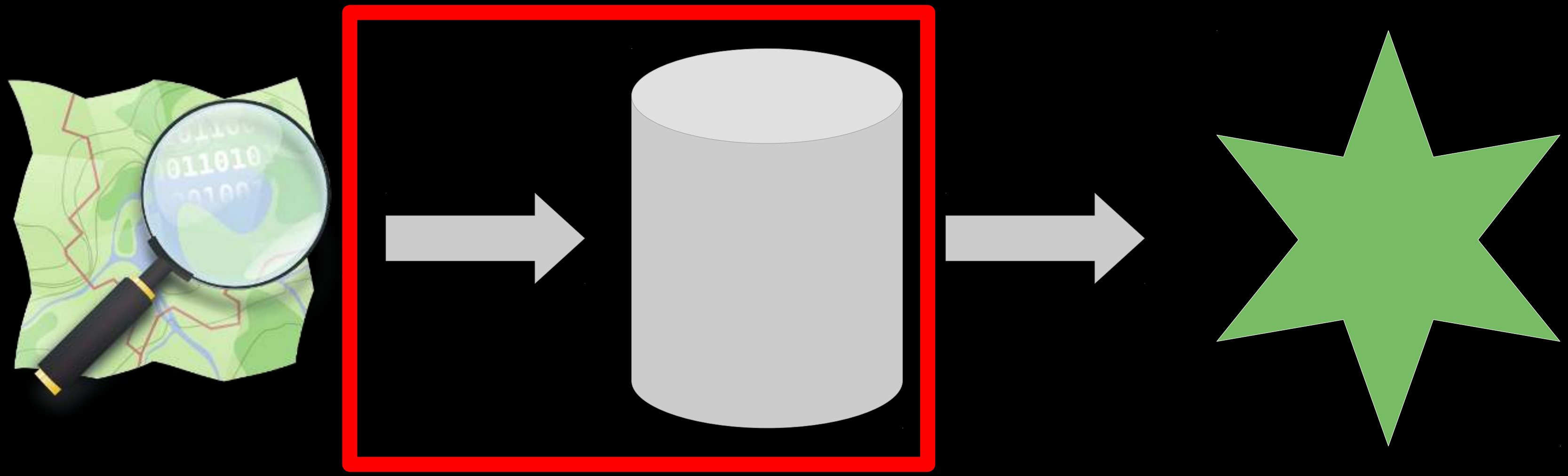
Selection – Merging – Simplification

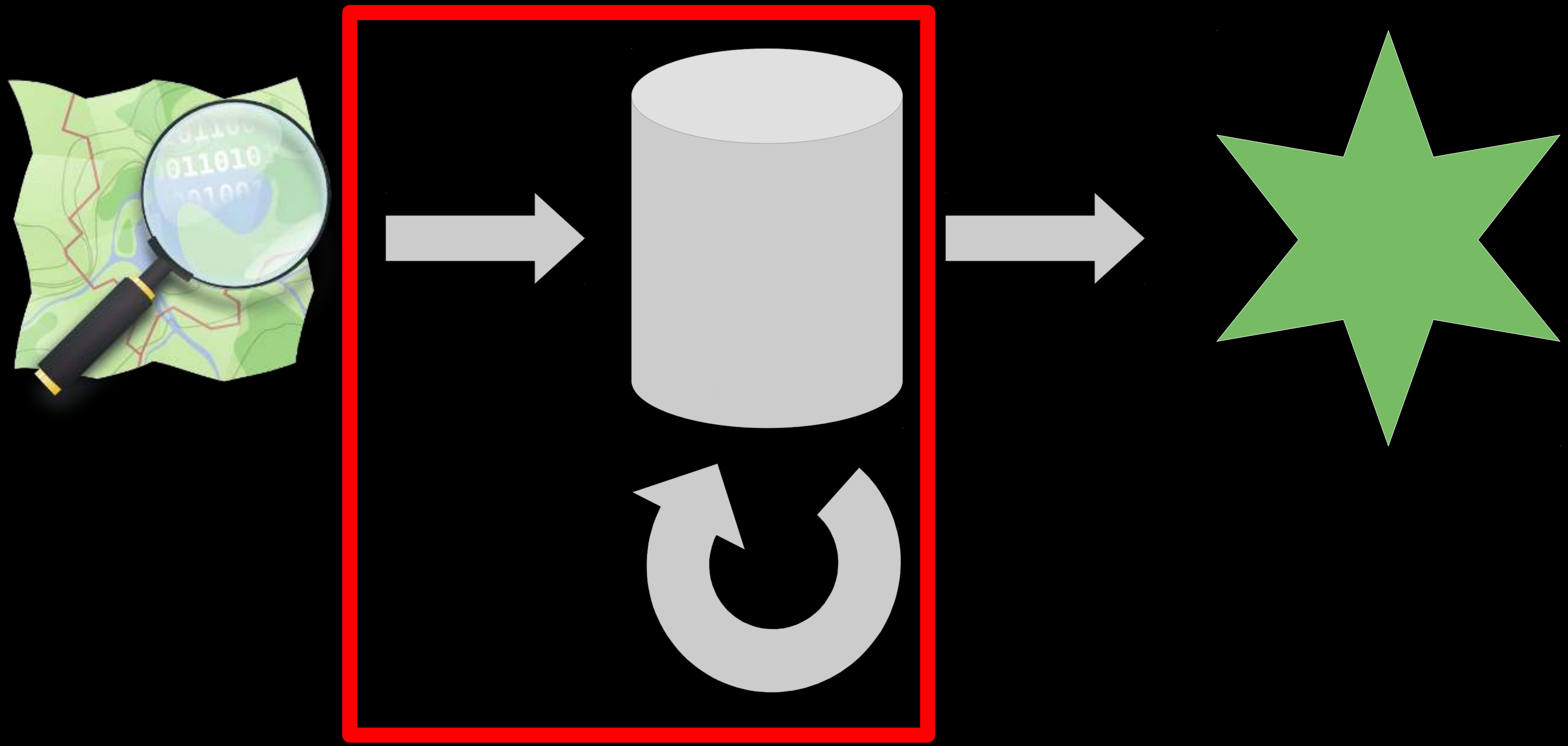
Conversion: Where?

Conversion can happen

1. before import in code

2. after import in the DB





Conversion: Where?

Conversion can happen

1. before import in code

2. after import in the DB

Conversion: Where?

Conversion can happen

fast

1. before import in code

2. after import in the DB

flexible

Conversion: Assemble Lines

Take Locations from Nodes

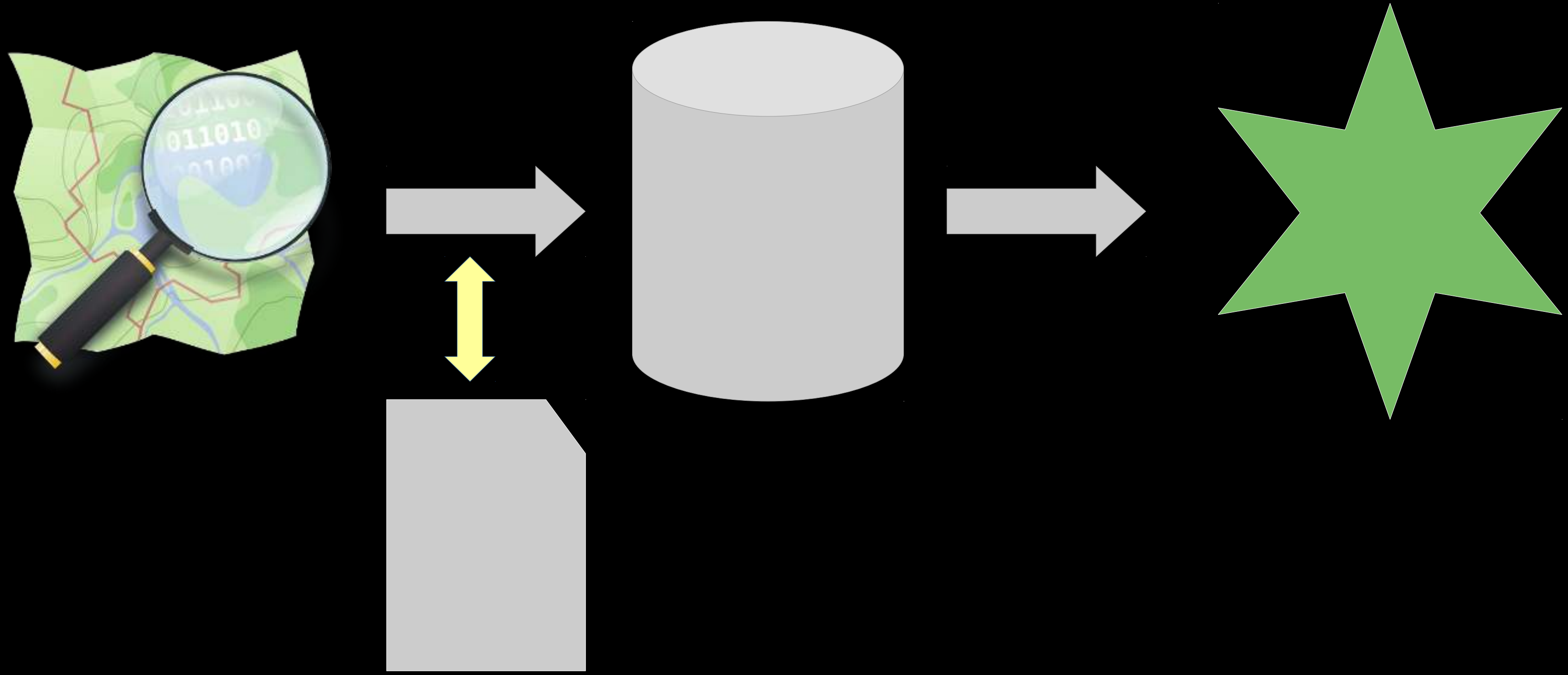
Assemble them into LineStrings

Conversion: Node locations

Where to store node locations?

1. in the database

2. in specialized index

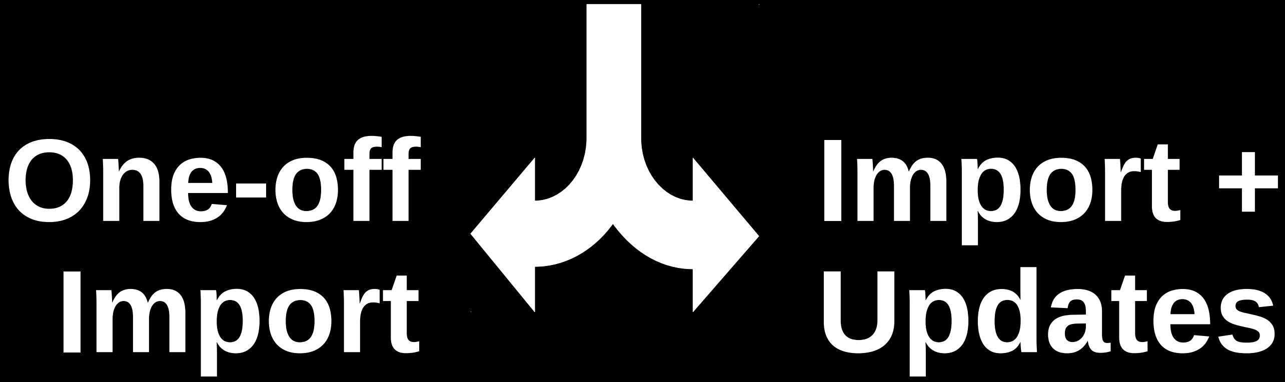


Node Location Store

Conversion: Polygons

Assemble (Multi)Polygons

from Ways/Relations



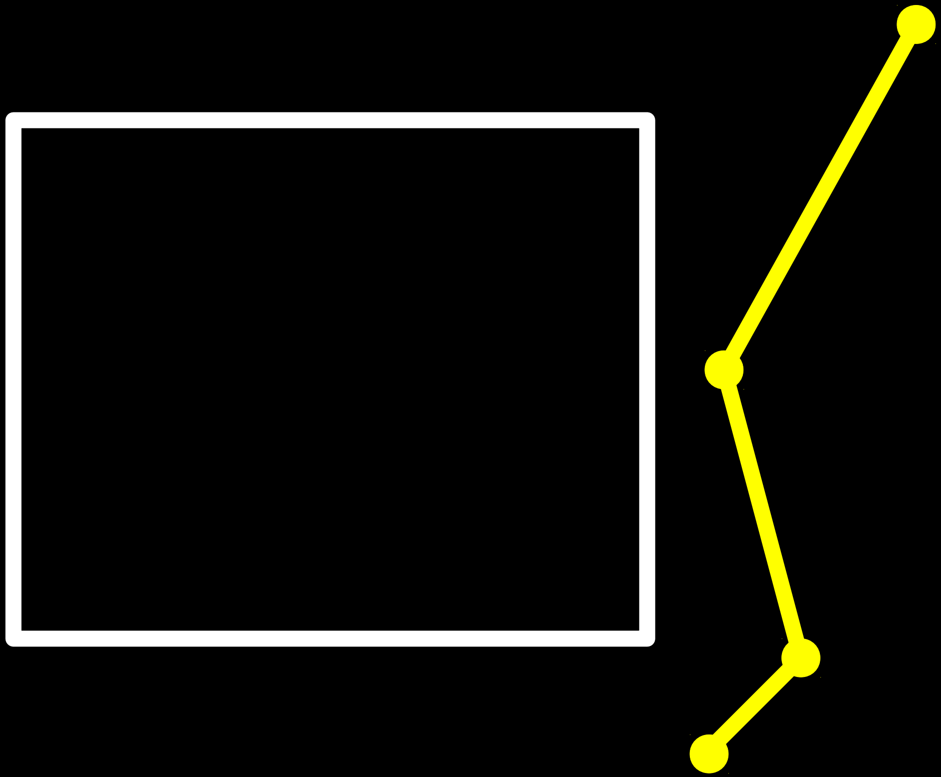
One-off Import

Import + Updates

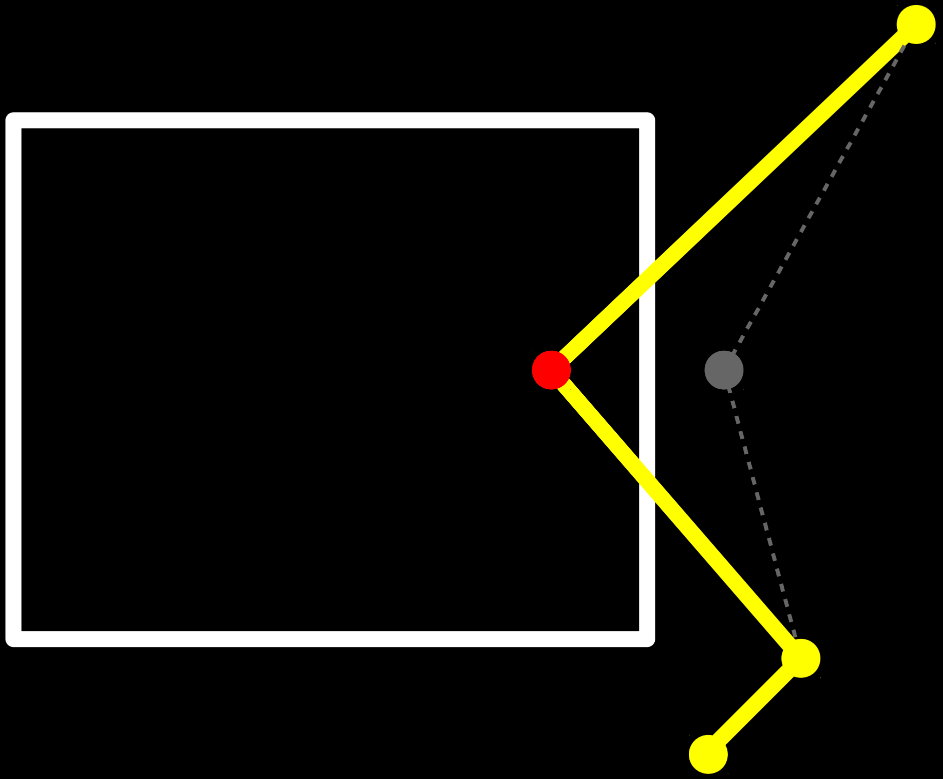
lots of trade-offs

not all software/schemas support updates

Complete data needed for updates



Complete data needed for updates



Complete data needed for updates

Two kinds of data:

1. The data you need for you application
2. The data needed to allow updating

Complete data needed for updates

Two kinds of data:

1. The data you need for you application
2. The data needed to allow updating

Where? Database? External Storage?

Snapshot vs. History

most use cases only need
current OSM data

some need
history of OSM data

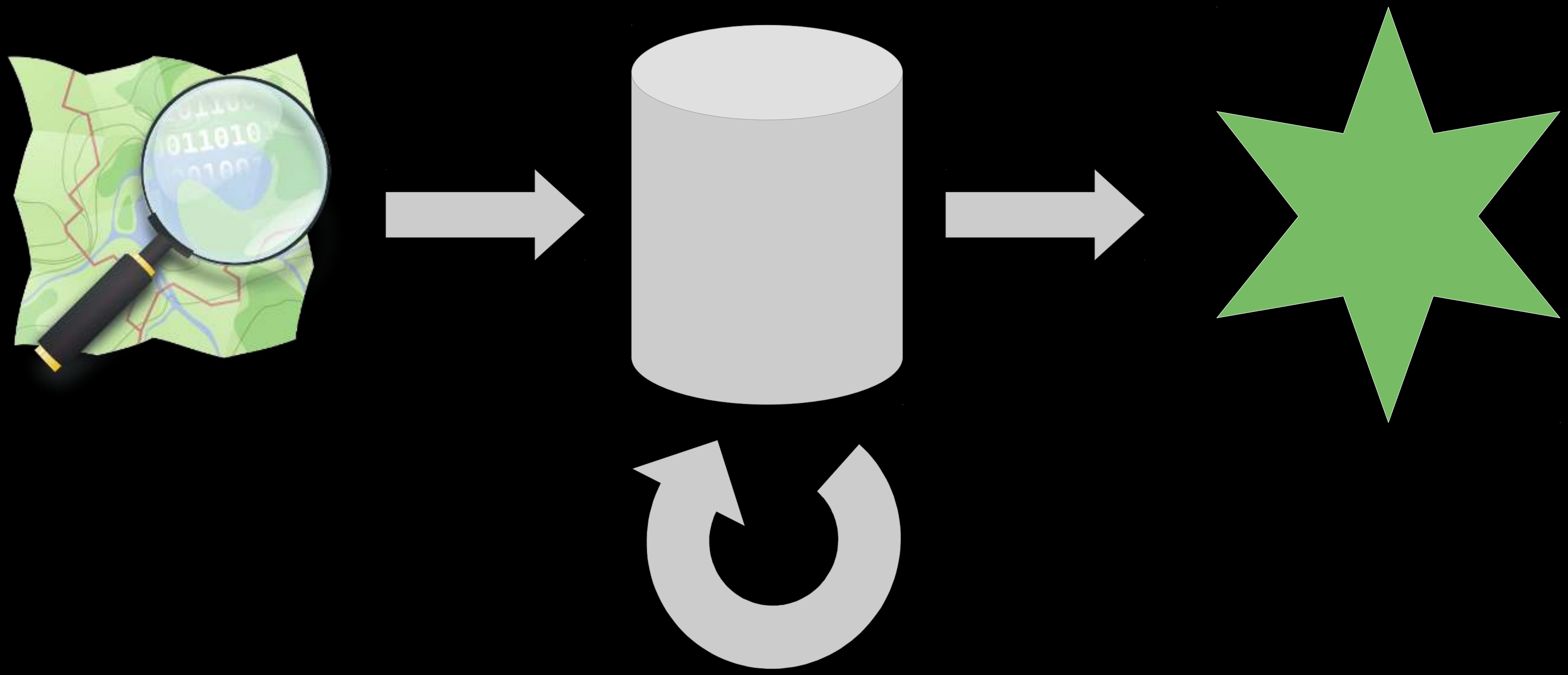
Snapshot vs. History

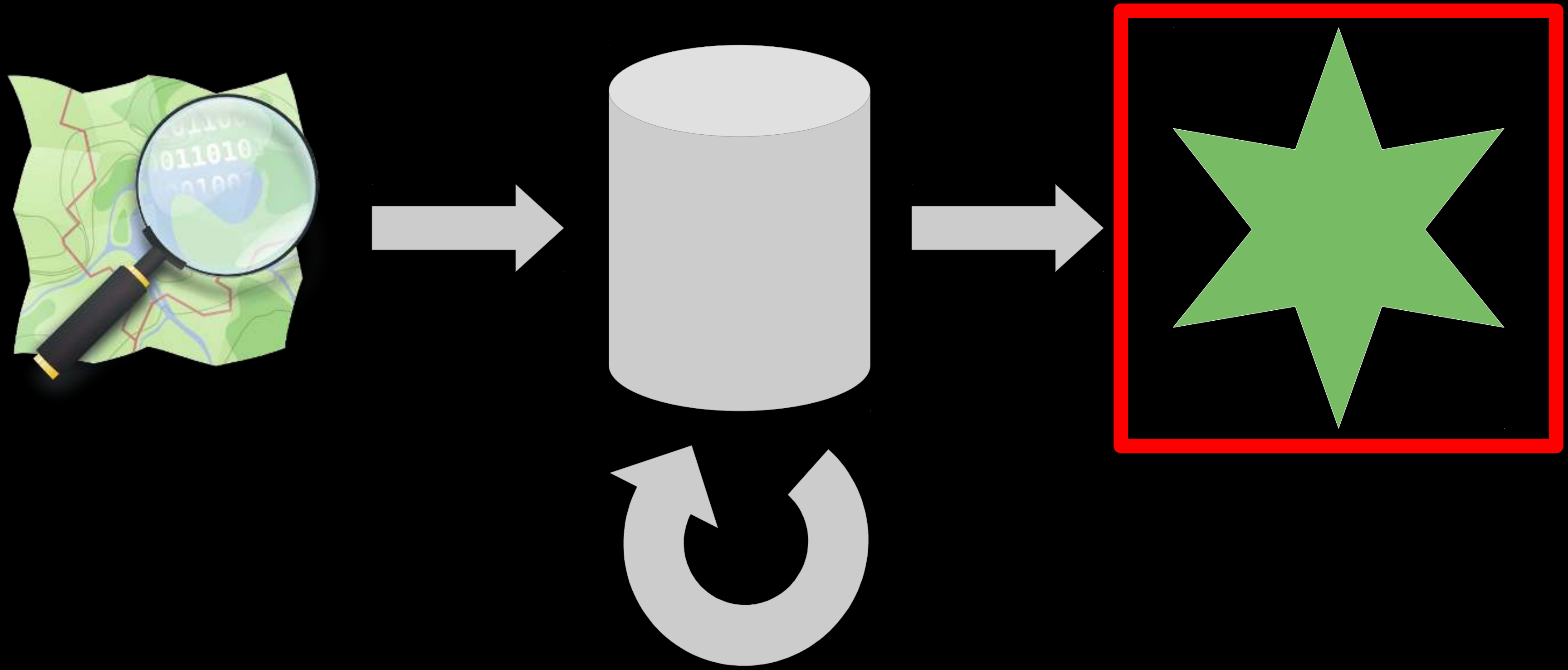
most use cases only need
current OSM data

some need
history of OSM data

Much more effort needed !

Use Cases





Use Cases

API DB

Rendering

Geocoding

Routing

Analytics

API DB

Schema used in the main OSM database

PostgreSQL - No PostGIS !

Normal access via HTTP API

You can run your own

API DB

Needs all (also historical) data

Multiple writers, transactions

Allow bounding-box download

Allow read/write access

Create full dumps and replication diffs

Rendering

Turning data into maps

Render into bitmap, vector tiles, etc.

Rendering

Get all data for an area quickly

Multiple layers

Create generalized geometries

One writer, multiple reader

Regular updates

Geocoding

“Search“

Geocoding – Address to Location

Reverse Geocoding – Location to Address

Geocoding

Build address hierarchy

Quick “fuzzy“ search

One writer, multiple reader

Regular updates

Routing

Using PostgreSQL plugin PgRouting

Flexible, but slow

Routing

Build network of streets

Calculate weights

Find route through network

Analytics

Statistics

Comparing data

Conflating data

Many diverse needs

Example 1: Wind Power

Find a place that …

… has lots of steady winds
… is near existing high voltage lines
… is far from residential areas

Example 2: Public Transport

How far is the nearest public transport stop?

How many people live where the nearest stop is more than x meters away?

Where should a new bus route go?

Example 3: OSM Contributors

Who are the most active OSM contributors?

What kinds of things do they map?

Where do they do their mapping?

Analytics

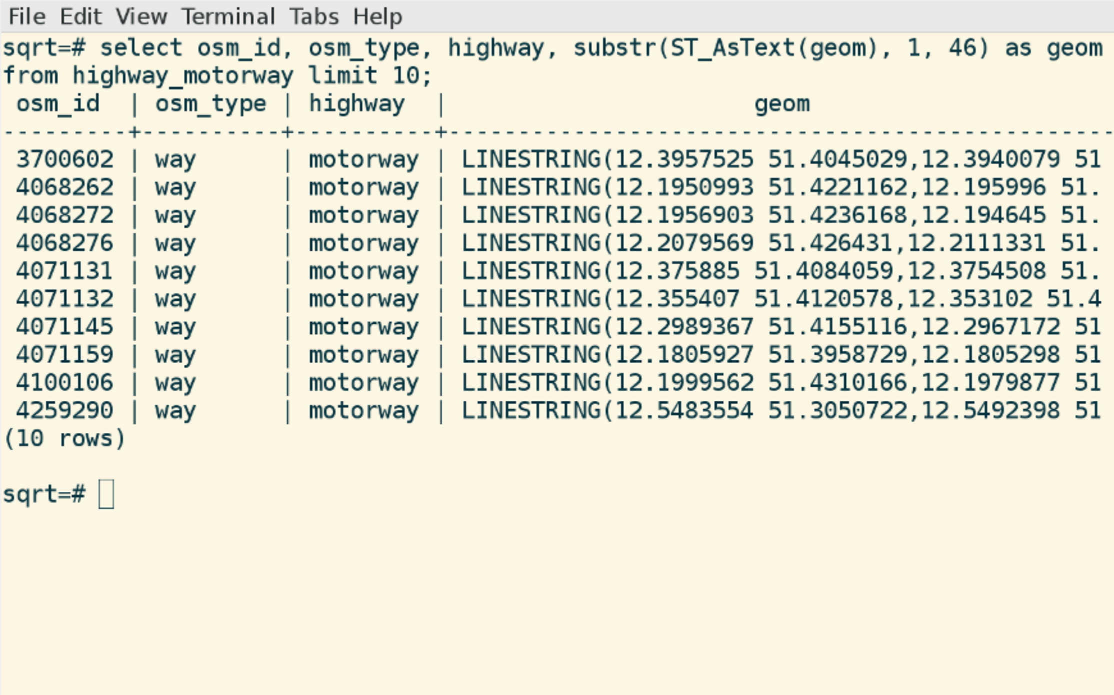
Flexible data model

Use of many geometric operations

Batch processing in multiple steps

Tools

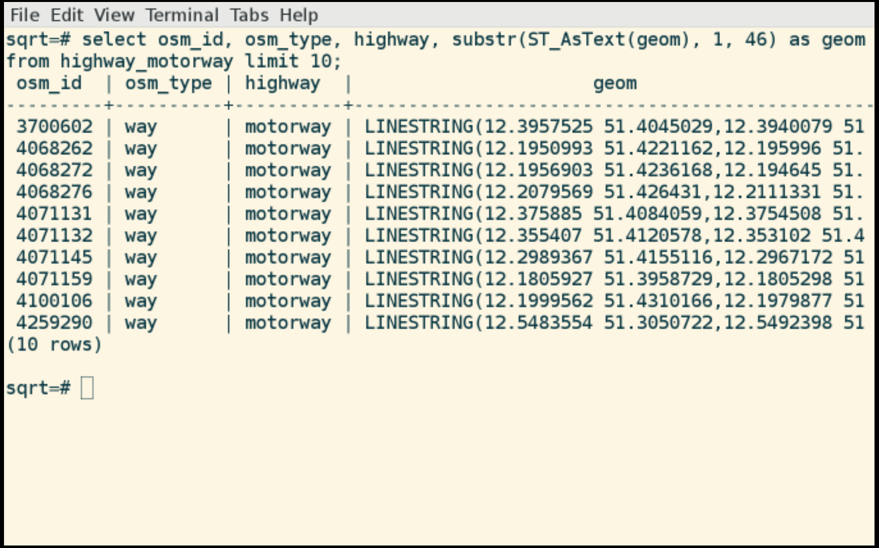
psql



```
sqrt=# select osm_id, osm_type, highway, substr(ST_AsText(geom), 1, 46) as geom
from highway_motorway limit 10;
 osm_id  | osm_type | highway  |                      geom
---------+----------+----------+------------------------------------------------
 3700602 | way      | motorway | LINESTRING(12.3957525 51.4045029,12.3940079 51
 4068262 | way      | motorway | LINESTRING(12.1950993 51.4221162,12.195996 51.
 4068272 | way      | motorway | LINESTRING(12.1956903 51.4236168,12.194645 51.
 4068276 | way      | motorway | LINESTRING(12.2079569 51.426431,12.2111331 51.
 4071131 | way      | motorway | LINESTRING(12.375885 51.4084059,12.3754508 51.
 4071132 | way      | motorway | LINESTRING(12.355407 51.4120578,12.353102 51.4
 4071145 | way      | motorway | LINESTRING(12.2989367 51.4155116,12.2967172 51
 4071159 | way      | motorway | LINESTRING(12.1805927 51.3958729,12.1805298 51
 4100106 | way      | motorway | LINESTRING(12.1999562 51.4310166,12.1979877 51
 4259290 | way      | motorway | LINESTRING(12.5483554 51.3050722,12.5492398 51
(10 rows)

sqrt=# 
```

psql



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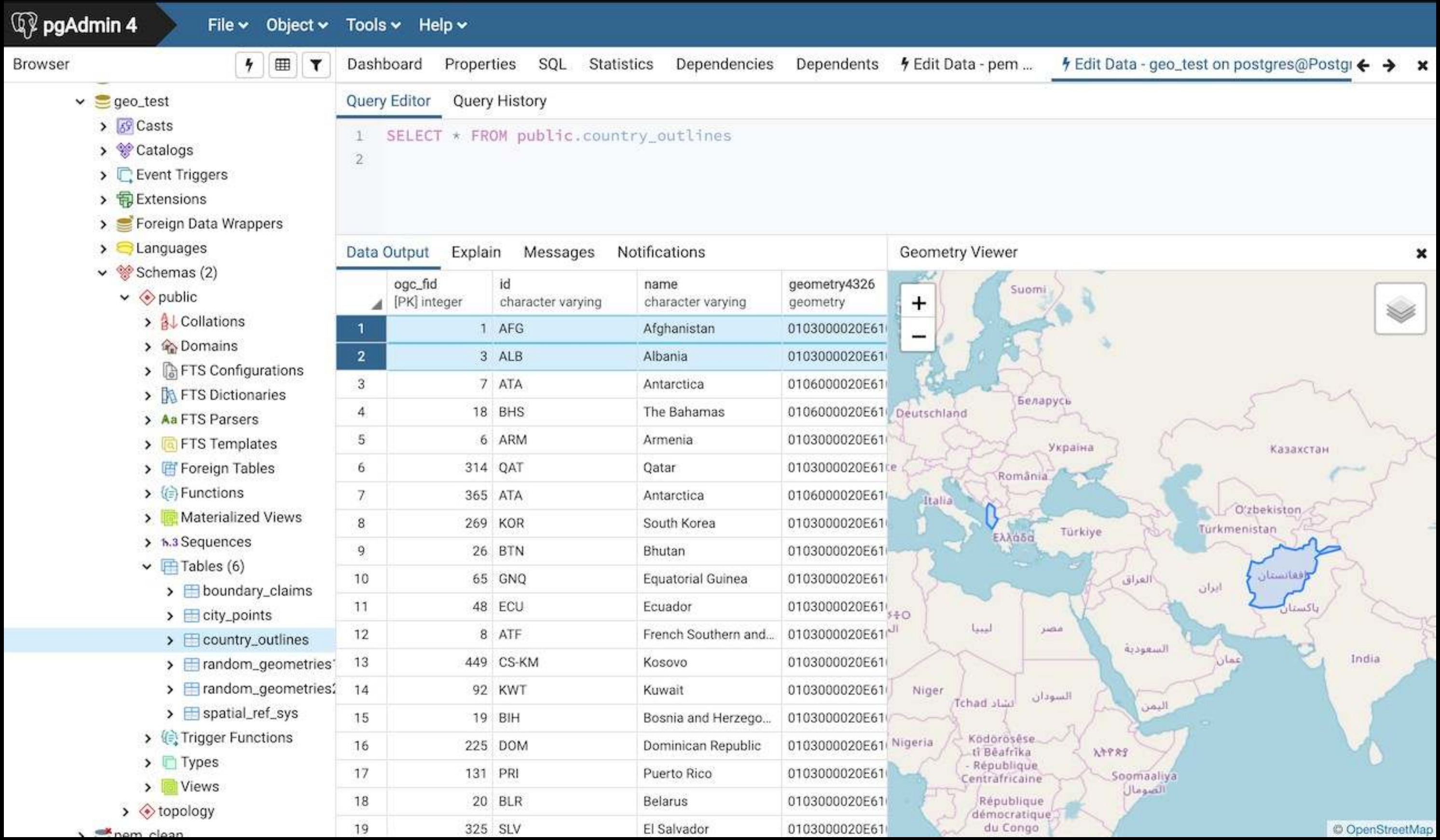
 4071159 | way      | motorway | LINESTRING(12.1805927 51.3958729,12.1805298 51
 4100106 | way      | motorway | LINESTRING(12.1999562 51.4310166,12.1979877 51
 4259290 | way      | motorway | LINESTRING(12.5483554 51.3050722,12.5492398 51
(10 rows)

sqrt=# 
```

⟷ Editor

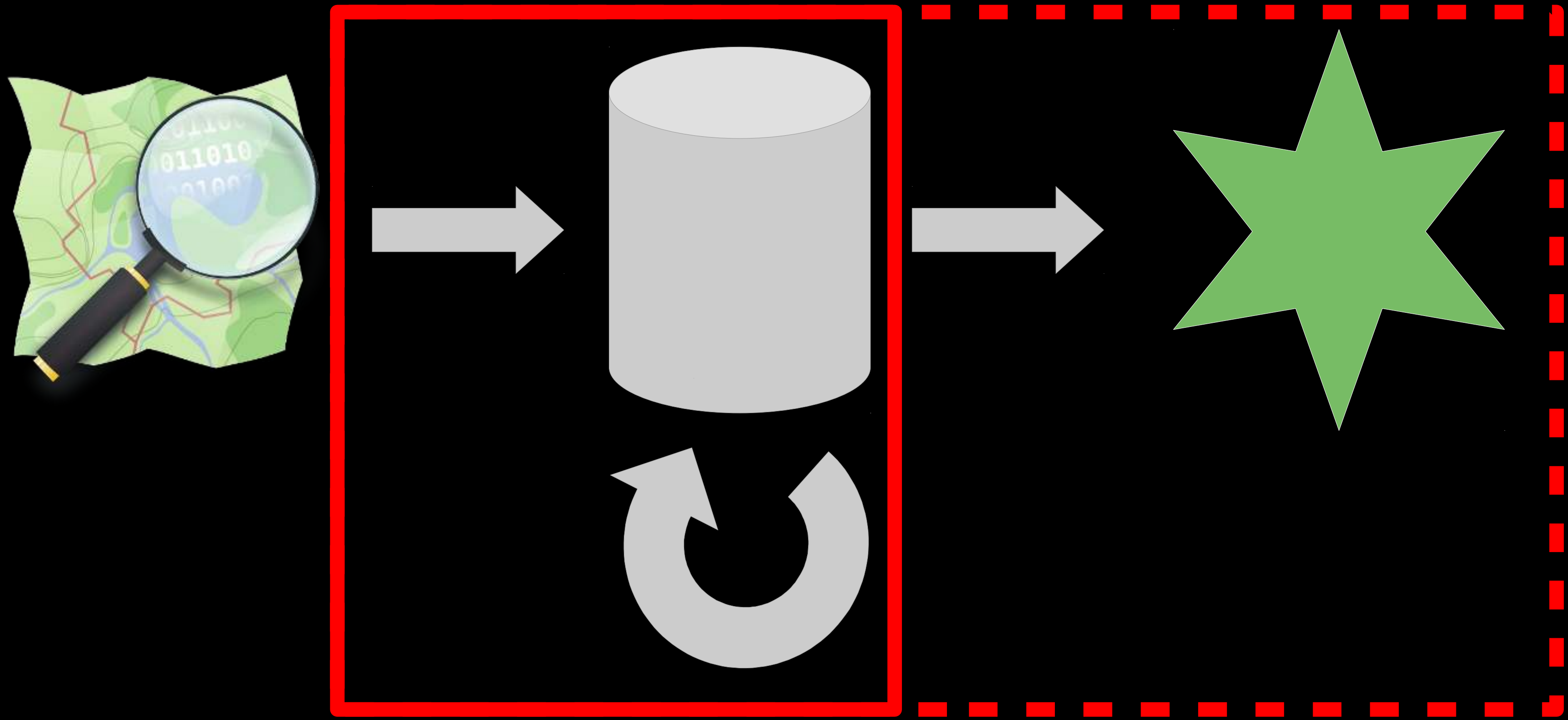
pgadmin



```
SELECT * FROM public.country_outlines
```

	ogc_fid [PK] integer	id character varying	name character varying	geometry4326 geometry
1	1	AFG	Afghanistan	0103000020E61
2	3	ALB	Albania	0103000020E61
3	7	ATA	Antarctica	0106000020E61
4	18	BHS	The Bahamas	0106000020E61
5	6	ARM	Armenia	0103000020E61
6	314	QAT	Qatar	0103000020E61
7	365	ATA	Antarctica	0106000020E61
8	269	KOR	South Korea	0103000020E61
9	26	BTN	Bhutan	0103000020E61
10	65	GNQ	Equatorial Guinea	0103000020E61
11	48	ECU	Ecuador	0103000020E61
12	8	ATF	French Southern and...	0103000020E61
13	449	CS-KM	Kosovo	0103000020E61
14	92	KWT	Kuwait	0103000020E61
15	19	BIH	Bosnia and Herzego...	0103000020E61
16	225	DOM	Dominican Republic	0103000020E61
17	131	PRI	Puerto Rico	0103000020E61
18	20	BLR	Belarus	0103000020E61
19	325	SLV	El Salvador	0103000020E61

QGIS



Osmosis

https://wiki.osm.org/wiki/Osmosis

Use case: API DB, Analytics
Updates: Yes
Schema: Several
Status: Not being maintained

Osmosis Schemas

API DB (version 0.6)

PostGIS Snapshot Schema (uses hstore)

PostGIS Simple Schema (no hstore)

(API DB MySQL <0.6)

osm2pgsql

Used in “standard“ OSM rendering toolchain

https://wiki.osm.org/wiki/Osm2pgsql

Use case: Rendering
Updates: Yes
Schema: Few tables (hstore optional)
Status: Maintained

Imposm3

Alternative rendering toolchain

https://imposm.org

Use case: Rendering
Updates: Yes
Schema: Many tables
Status: Actively maintained

Nominatim

Standard OSM search/geocoding

https://nominatim.org

Use case: (Reverse) Geocoding
Schema: Optimized for geocoding
Status: Actively maintained

Uses osm2pgsql (with special plugin)

Osmium

https://osmcode.org/osmium-tool/

Use case: Analytics, (Rendering)

Updates: No
Schema: Simple
Status: Actively maintained
Simple to run for ad-hoc use

osm-postgresql-experiments

Experimental, very flexible data import

https://github.com/osmcode/osm-postgresql-experiments

Use case: Rendering, Analytics
Updates: (Yes)
Schema: Flexible
Status: Experimental

osm2pgrouting

Importer für PgRouting

https://github.com/pgrouting/osm2pgrouting

Use case: Routing
Updates: No
Schema: PgRouting
Status: Maintained

Tips & Tricks

Odds & Ends

Quantity Structure

How much disk space do I need?

How much memory do I need?

How long will an import take?

Quantity Structure

hundreds of Gbytes
for full planet

How much disk space do I need?

How much memory do I need?

How long will an import take?

Quantity Structure

hundreds of Gbytes
for full planet

How much disk space do I need?

How much memory do I need?

More!

How long will an import take?

Quantity Structure

hundreds of Gbytes
for full planet

How much disk space do I need?

How much memory do I need?

More!

How long will an import take?

many hours
if not days for planet

Start small...

Do not try to import the whole planet at first!

Start small
(e.g. with data for a city)
and
work your way up

Minimize data

1. Filter data outside DB if you can

2. Import data into DB

Importing Data

1. load data
2. create indexes
3. ANALYZE

Performance Tuning

You will need to tune your PostgreSQL!

Settings in postgresql.conf:

shared_buffers, work_mem, maintenance_work_mem, fsync, synchronous_commit, checkpoint_timeout, checkpoint_completion_target, ...

Indexes

Learn how indexes work and when they are used

Also for spatial indexes!

Use EXPLAIN command

The COPY command

COPY instead of INSERT

more efficient, use it if possible

Learning Curve

PostgreSQL / PostGIS
is an incredible powerful tool

“Magic“ working of PostgreSQL
can be surprising

Configure the logs and look at them

Learning Curve

Spatial operations are extra magic!

Again: Start small

Always growing

Database will grow over time
(not only because of more OSM data)

VACUUM

Still grow more

Other SQL Databases

MySql, MariaDB

Oracle Spatial

Sqlite (Library, not Server)

Other SQL Databases

geodata support lacking

MySql, MariaDB

Oracle Spatial

Sqlite (Library, not Server)

Other SQL Databases

geodata support lacking

MySql, MariaDB

proprietary

Oracle Spatial

Sqlite (Library, not Server)

Other SQL Databases

geodata support lacking

MySql, MariaDB

proprietary

Oracle Spatial

Sqlite (Library, not Server)

not as powerful, problems with huge datasets,
but can be useful for some applications

https://www.floss-shop.de/de/floss-merchandise/stofftiere/40/postgresql-elefant

THE END

Jochen Topf
jochentopf.com
jochen@topf.org