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Spatial Databases (1)

PostgreSQL+ PostGIS

Parya Pasha Zadeh
Utrecht, February 2020

Introduction and structure

Beginner	Introduction to databases and its advantages, Principles of relational data model, installation and data import, Database access through pgAdmin and QGIS Simple (spatial) SQL queries Views and tables
Intermediate	OGC simple features standards, Spatial data ingestion, Advanced spatial queries and analysis, Raster data handling in Postgres
Advanced	Integrity constraints implementation, Database functions and triggers, Server-side programming

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Today's schedule

09:00 – 10:30	intro lecture relational databases, software installations materials access
10:30 – 10:45	*Coffee break*
10:45 – 12:30	non-spatial queries and SQL recap spatial data handling (spatial_ref_sys and geometry columns, OGC SFS)
12:30 – 13:15	*Lunch break*
13:15 – 15:00	spatial queries spatial functions invalid geometries
15:00 – 15:15	*Coffee break*
15:15 – 17:00	dynamic queries (views vs tables) PK-FK, GiST indexes The way forward

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https://github.com/paryapasha/Cursus_PostGIS_n1

Objectives

Upon completion of this training you will be able to:

- Explain the concepts and structure of relational (spatial) databases;
- Understand the client-server architecture
- Recognize the differences between spatial and non-spatial DBMS
- Perform systematic query formulation using SQL
- Extend your SQL knowledge and use spatial functions in your queries.

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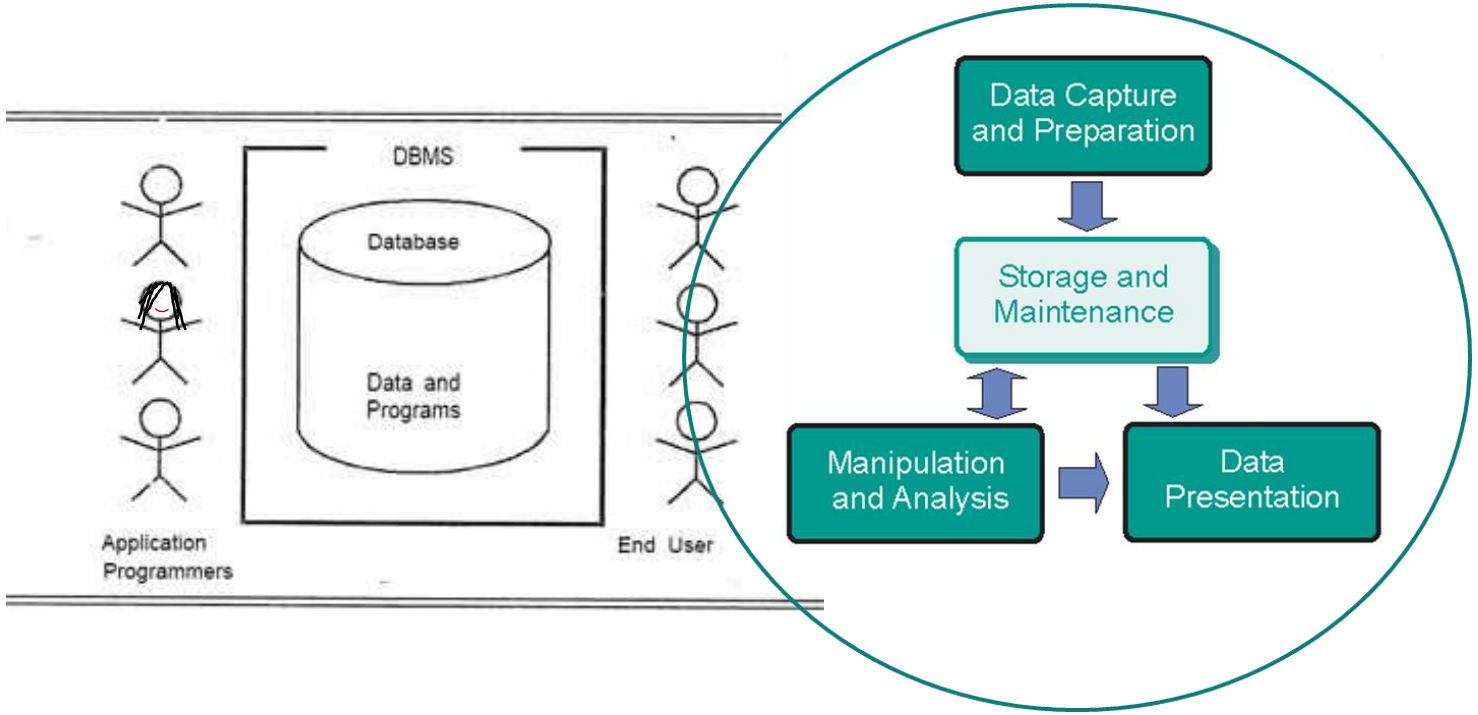
Data, Dataset, Database, DBMS and DB system

- Data
  - Is a resource held on paper or in digital format that serves to record or administer some facts and description of phenomena of interest.
- Data set (or dataset):
  - A homogeneous collection of data normally describing a single kind of phenomenon
- Database
  - A *collection of interrelated data sets* properly *structured* by means of, and stored through a DBMS.

Data, Dataset, Database, DBMS and DB system

- Database management system (DBMS)
  - A *software package* that is designed for the purpose of managing databases. This means, DBMS allows to **set-up**, **maintain** and **interact with** one or more databases.
  - DBMS uses a *data model* that is a collection of data structuring primitives, rules of how to structure, and mechanisms to handle the data in a database.



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Database management system (DBMS)

- Supports the storage and manipulation of very large data sets.
- Can be instructed to guard over data correctness.
- Supports the concurrent use of the same data set by many users.
- Provides a high-level, declarative query language.
- Includes data backup and recovery functions to ensure data availability at all times.
- Allows the control of data redundancy.
- Supports the use of data model.

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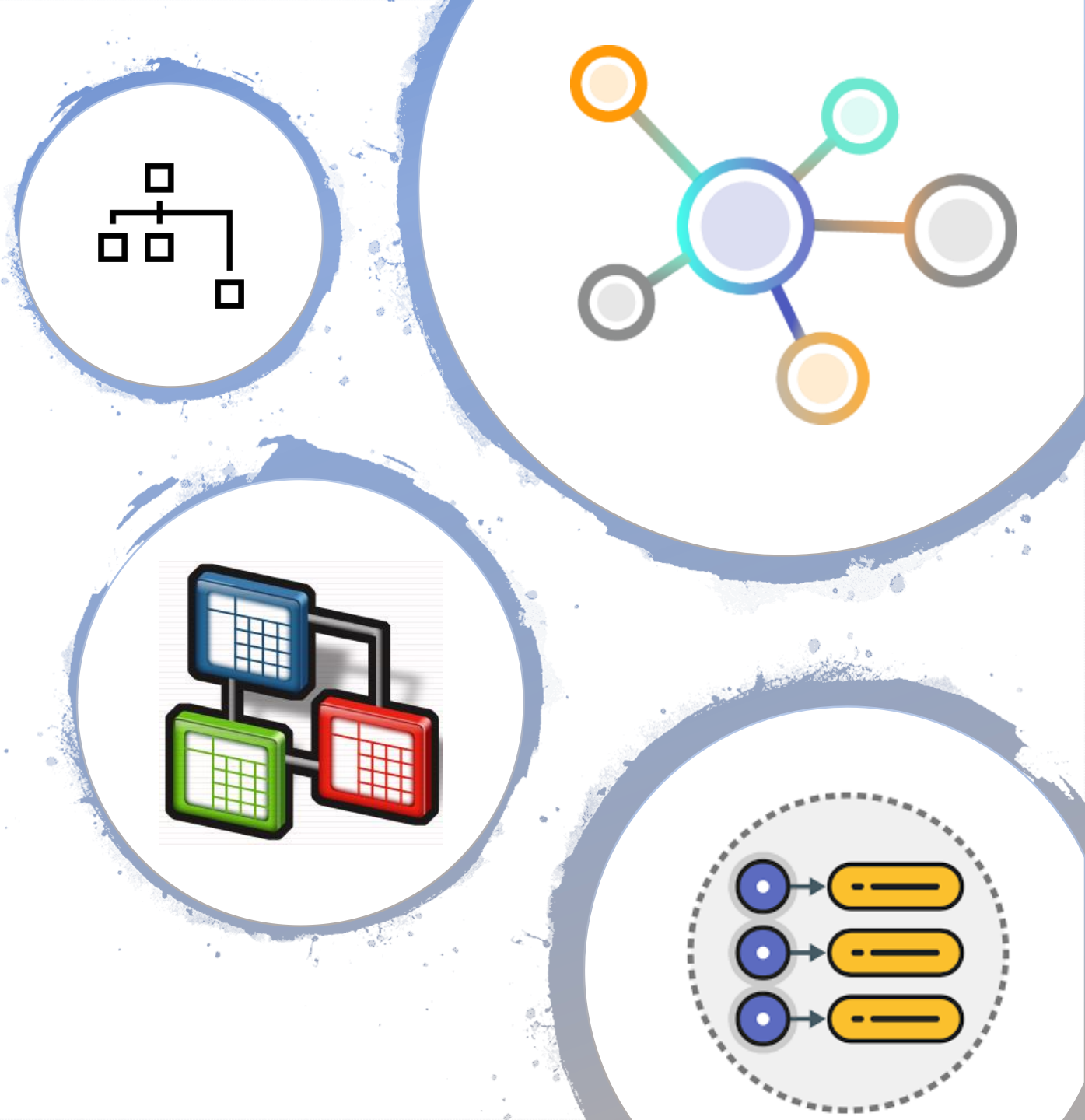
Data Model

A DBMS supports the use of a *data model*.

- Data model is an integrated collection of:
  - Data structuring primitives,
  - Rules of how to structure, and
  - Mechanisms to handle the data in a database.

In other words, a data model is a *toolbox* that allows us to *create/define a* database structure and *manipulate* the data stored in it.



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PostgreSQL and PostGIS

- **PostgreSQL** is a database management system
- It has a Server-Client architecture
- It runs on every main operating system
- It ensures purely **ACID** transactions:
  - **A**tomicity - (a transaction only knows two states – unstarted or finished)
  - **C**onsistency - (a transaction always complies with the constrains of the DB)
  - **I**solation - (how concurrent operations became visible to each other)
  - **D**urability - (after a transactions is terminated its effects remain)

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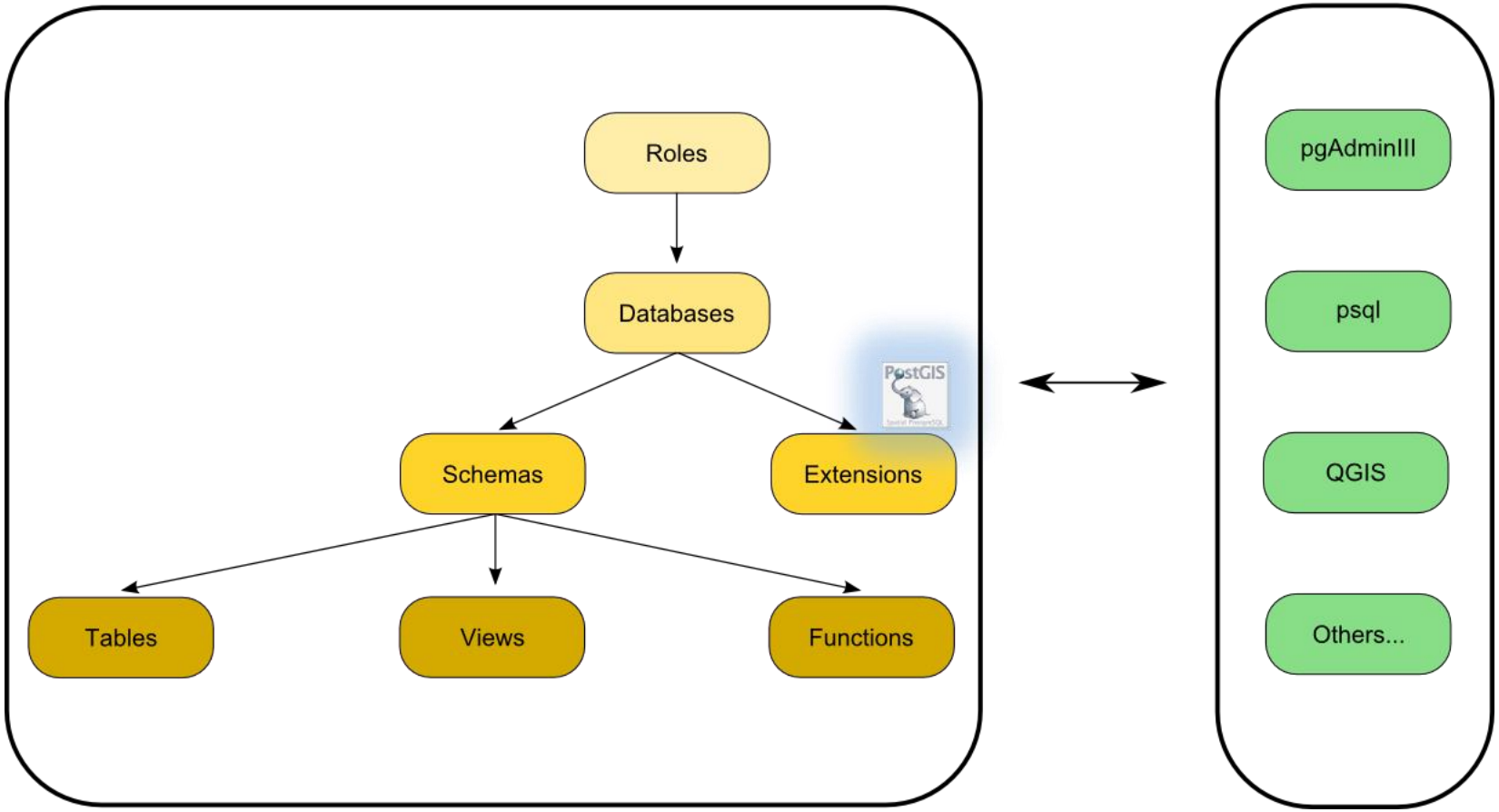
PostgreSQL and PostGIS - System Architecture



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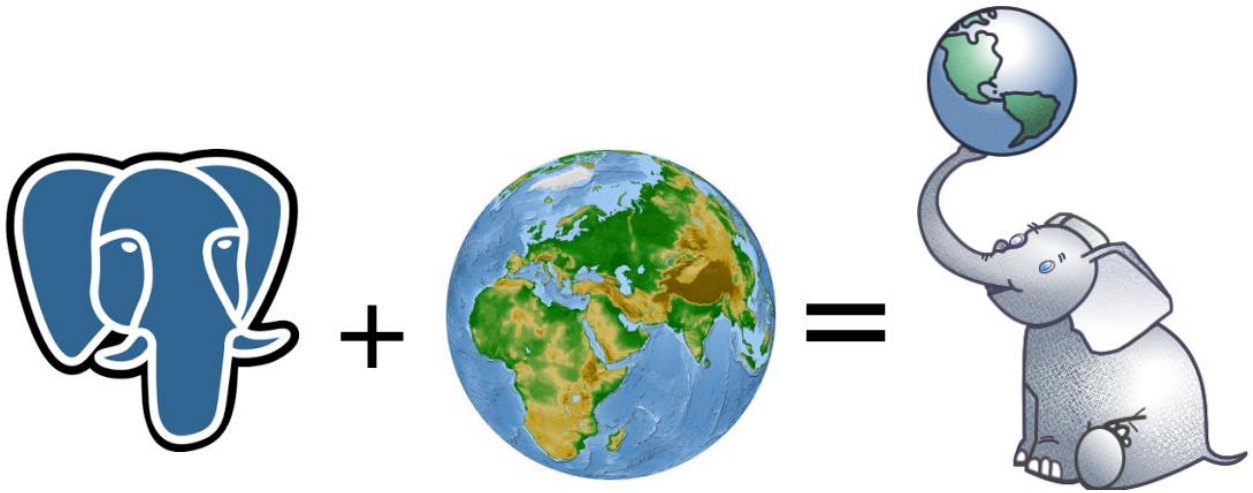
PostgreSQL and PostGIS

- A spatial database allows users to store, query and manipulate collections of ***spatial data***.
- Spatial data is stored in as a geometry data type which complies with OGC standards.
- Spatial database is not constrained by the need to present data visually
- PostGIS is an extension that enable PostgreSQL with spatial data handling



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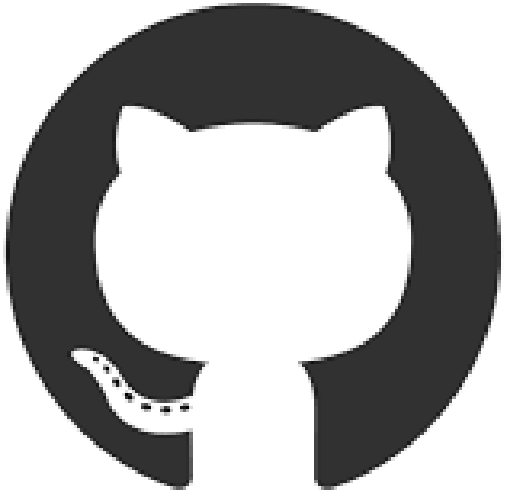
Let’s get started!

Materials and software

- Access the course at Github

https://github.com/paryapasha/Cursus_PostGIS_n1



- Open Source software
  - PostgreSQL + PostGIS + pgAdmin

    https://www.enterprisedb.com/downloads/postgres-postgresql-downloads

  - QGIS (latest long term release 3.10)

    https://qgis.org/en/site/forusers/download.html#

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Query formulation

Relation/ Table

	id [PK] bigint	geom geometry	dimune_code character varying (254)	neighborhood character varying (254)	municipality character varying (254)	district character varying (254)
1	1	0106000020B30...	130103	Ansiães	AMARANTE	PORTO
2	2	0106000020B30...	130107	Candemil	AMARANTE	PORTO
3	3	0106000020B30...	130112	Fregim	AMARANTE	PORTO
4	4	0106000020B30...	130115	Fridão	AMARANTE	PORTO
5	21	0106000020B30...	130143	União das freguesias de Bu...	AMARANTE	PORTO
6	5	0106000020B30...	130117	Gondar	AMARANTE	PORTO
7	6	0106000020B30...	130118	Jazente	AMARANTE	PORTO
8	7	0106000020B30...	130119	Lomba	AMARANTE	PORTO
9	8	0106000020B30...	130120	Louredo	AMARANTE	PORTO
10	9	0106000020B30...	130121	Lufrei	AMARANTE	PORTO
11	10	0106000020B30...	130123	Mancelos	AMARANTE	PORTO

Tuples/Records/Rows

Attributes/Columns/Fields

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Query formulation
Simple Method of query definition

Steps:

1. INPUT RELATION
   - On which relation is the query based?
   - What will be the tuple variable?
2. SELECTION CONDITION
   - What is the condition that the selected tuple for the output must fulfill?
3. OUTPUT RELATION
   - What are the attributes in the output?

In SQL:

```
SELECT output tuple definition
(step 3)
FROM input tuple declaration
(step 1)
WHERE selection condition
(step 2)
```

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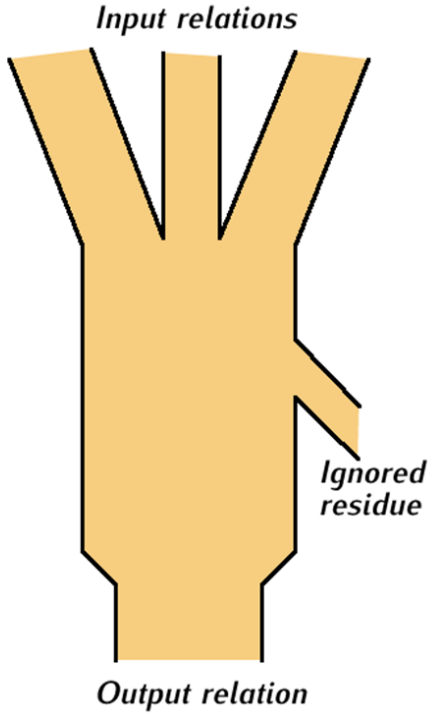
JSP queries
Join, Select, Project

Very often, to extract required data from a database, there is a need to combine data from two or more relations in one query. In such query, selection condition depends on a relationship of relations involved in the query.

Phases of JSP query:

1. Cartesian product of input relations
   - *Which relations are involved in a query?*
2. Tuple selection
   - *What is the join condition?*
   - *What is the selection condition?*
3. Output tuple creation
   - *What attributes will the output relation have?*



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Creating a table
Primary Key

- The key of a relation R is a set K of R's attributes such that:

1. It is **unique** – there are no two distinct tuples of K that have the same attribute values.
2. It is **minimal** – there is no proper subset of K that is unique.
3. And it cannot be **NULL**

If there is more than one key for R, the database designer chooses one of them to become the primary key. The other remain candidate keys.

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Referential integrity
Foreign Key

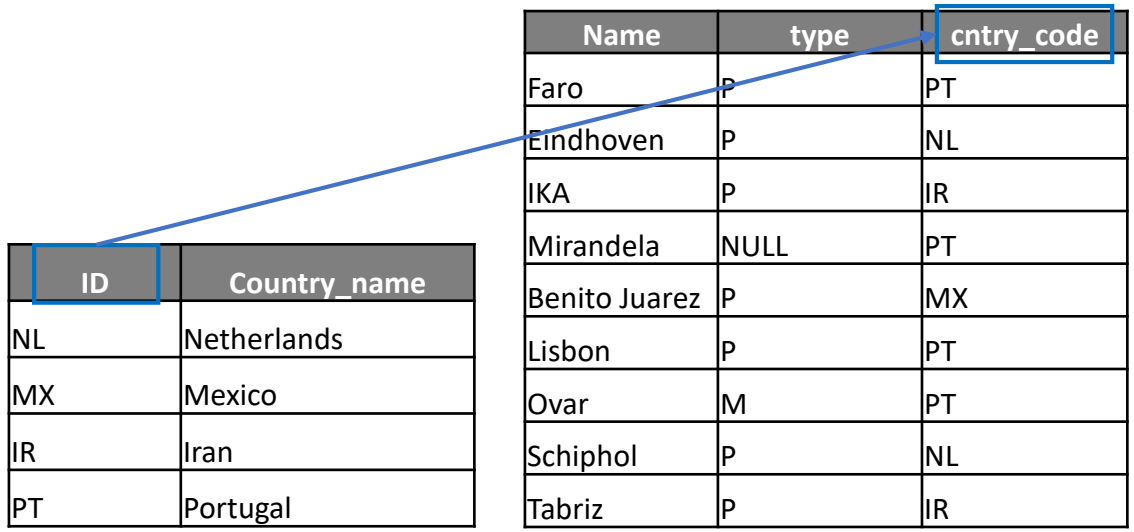
A foreign key is a set of attributes that is used to refer to a tuple in another relation.

- It must correspond with a primary key value in the second relation.
- A foreign key behaves like a 'logical pointer'.

```
SELECT *
FROM table1, table2
WHERE  join condition
```

OR

```
SELECT *
FROM table 1 INNER JOIN
        table2 ON join condition
```



ID	Country_name
NL	Netherlands
MX	Mexico
IR	Iran
PT	Portugal

country

Name	type	cntry_code
Faro	P	PT
Eindhoven	P	NL
IKA	P	IR
Mirandela	NULL	PT
Benito Juarez	P	MX
Lisbon	P	PT
Ovar	M	PT
Schiphol	P	NL
Tabriz	P	IR

airport

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Referential integrity
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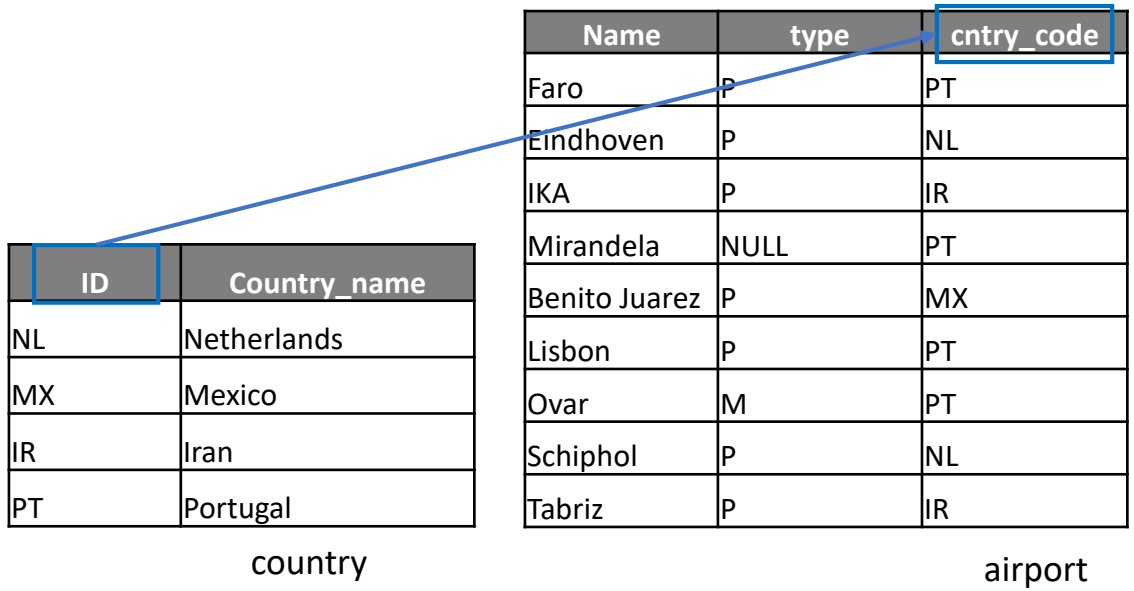
```
SELECT a.type
FROM airport AS a, country AS c
WHERE c.ID = a.cntry_code
```

```
SELECT a.type
FROM airport AS a INNER JOIN
     country AS c ON c.ID = a.cntry_code
```



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Summary queries

- A ***summary query*** is a query that infers statistical information from the tuples in the database.

- It involves ***aggregate functions***: functions that operate on a set (bag) of tuples and produce a single value. Examples are:
  - counting tuples: *count*
  - summing up attribute values: *sum*
  - computing averages, minimum, maximum values from existing attribute values: *avg, min, max*
  - computing standard deviations, variances: *sdev*, *var*

```
SELECT attributename, aggregate(*)
FROM tablename
WHERE selection condition
GROUP BY attributename
HAVING groupselection condition
```

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Spatial databases

Spatial data handling

What if you want to know…

- What is the area of a district?
- Do any of the countries in my table share a boundary?
- Which railroads pass through a city?
- How many schools are within a distance of 5 km to your house?

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Spatially enabling Postgres

What happens when we enable PostGIS in our PostgreSQL database?

- Hundreds of *spatial functions* became available within the database;

- *Metadata views* are created:
  - geography columns
  - geometry columns
  - raster columns
  - raster overviews

- *Metadata table* is created:
  - spatial_ref_sys (**SRID**s are the primary key to this table)

❖ All these metadata views and table are necessary in order to add support for OGC Simple Feature Model

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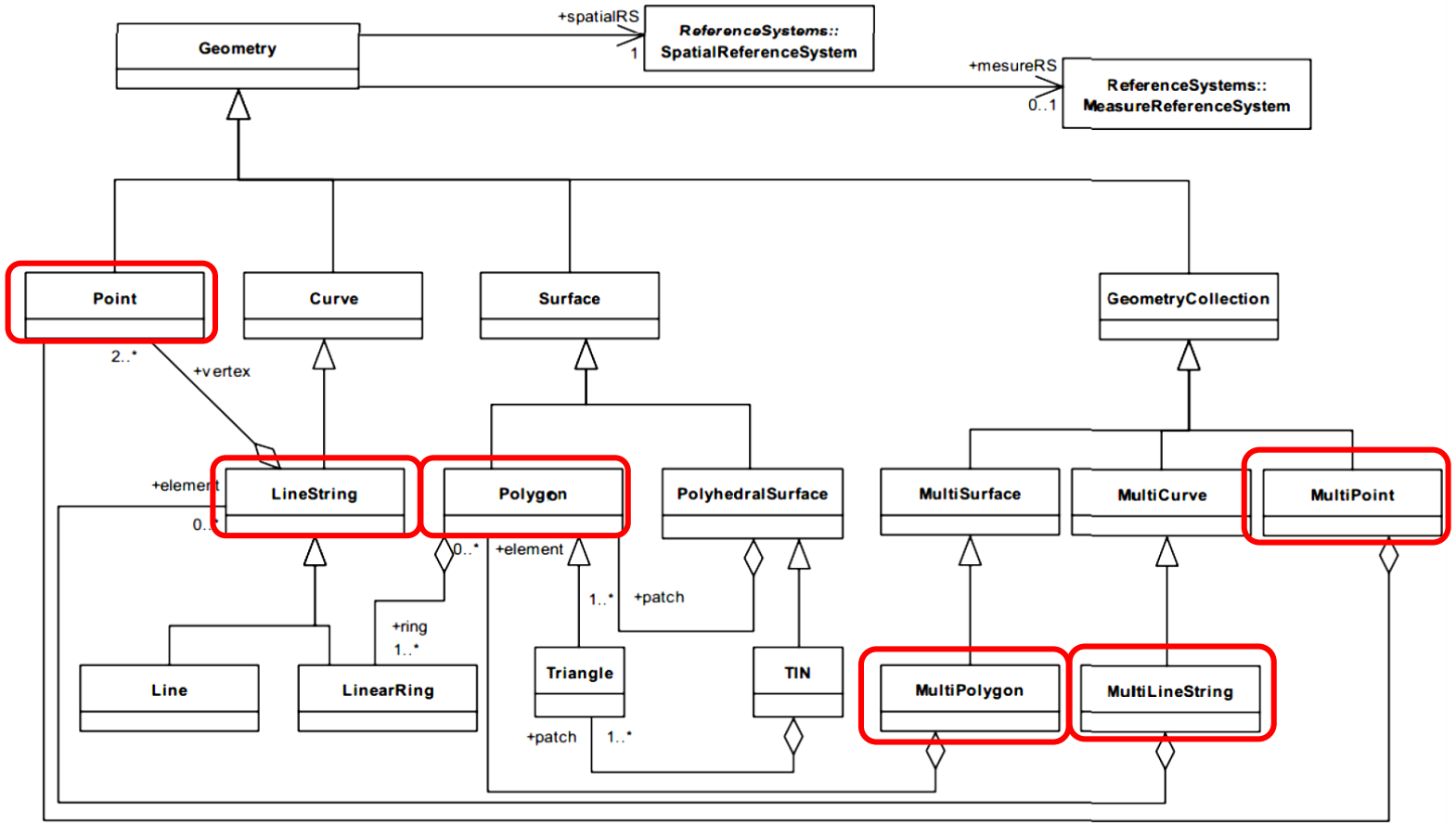
OGC Simple Features Specification

- The Simple Feature Specification (SFS) is a standard from OGC on how data should be stored.
- It also defines functions for accessing, operating, and constructing data.



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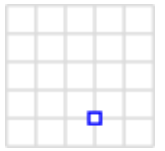
OGC Simple Features Specification
Geometry types

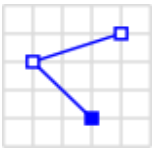
- Point

  POINT (30 10)



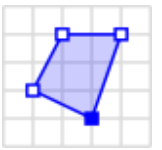
- Linestring

  LINESTRING (30 10, 10 30, 40 40)



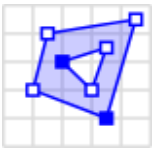
- Polygon

  POLYGON ((30 10, 40 40, 20 40, 10 20, 30 10))



- Polygon (with “hole”)

  POLYGON ((35 10, 45 45, 15 40, 10 20, 35 10), (20 30, 35 35, 30 20, 20 30))



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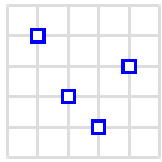
OGC Simple Features Specification
Geometry types

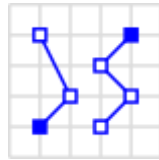
- MultiPoint

  MULTIPOINT ((10 40), (40 30), (20 20), (30 10))



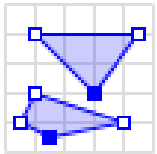
- MultiLinestring

  MULTILINESTRING ((10 10, 20 20, 10 40), (40 40, 30 30, 40 20, 30 10))



- MultiPolygon

  MULTIPOLYGON (((30 20, 45 40, 10 40, 30 20)), ((15 5, 40 10, 10 20, 5 10, 15 5)))



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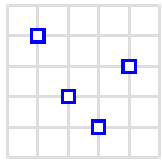

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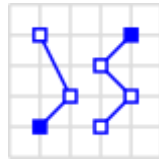

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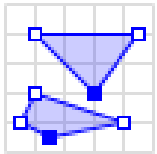

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Some famous (!) Spatial functions

ST_Length

```
SELECT  id, st_length(geom)
FROM    rivers
WHERE   rivername = 'IJssel'
```

output: length of the line/multiline

ST_Area

```
SELECT  st_area(s.geom)
FROM    squares as s
```

output: area of the polygon/multipolygon

ST_Centroid

```
SELECT  b.id, st_centroid (b.geom)
FROM    buildings as b
```

output: a point geometry, centroid of input geometry

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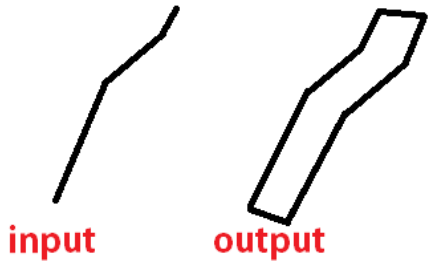
Some famous (!) Spatial functions

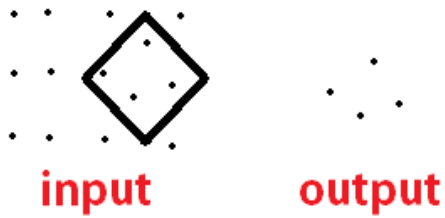
ST_Buffer

```
SELECT  id, st_buffer(geom, 100)
FROM    rivers
WHERE   rivername = 'Tejo'
```



ST_Within (check st_dwithin and st_contains)

```
SELECT  l.id, st_within(l.geom, s.geom)
FROM    lamps as l, squares as s
```



ST_Intersection (check st_intersects)

```
SELECT  b.id, st_intersection(b.geom, s.geom)
FROM    buildings as b, squares as s
```

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More Spatial function to explore

- `ST_transform`
- `ST_distance`
- `ST_dwithin`
- `ST_crosses`
- `ST_overlaps`
- `ST_disjoint`
- `ST_contains`
- …

In addition to the functionality, try to understand the number and type of input features and the type of output.

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On DB design and integrity

Creating a table

```
CREATE TABLE vectors.porto_neighborhood
(
    id bigint NOT NULL,
    geom geometry(MultiPolygon,3763),
    dimune_code character varying(254) ,
    neighborhood character varying(254) ,
    municipality character varying(254) ,
    district character varying(254),
    area_ha character varying(254) ,
    neighborhood_shortname character varying(254) ,
    CONSTRAINT porto_neighborhood_pkey PRIMARY KEY (id)
)
```

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Create Views

View vs. Table

- A view is a stored query in a form of a table which is not physically materialized;
- A view table can be queried but cannot be directly updated;
- A view changes every time the underlying data changes;
- Views are therefore dynamic;

```
CREATE VIEW expansion AS
        SELECT id, area, st_buffer(geom, 10)
        FROM landplot;
```

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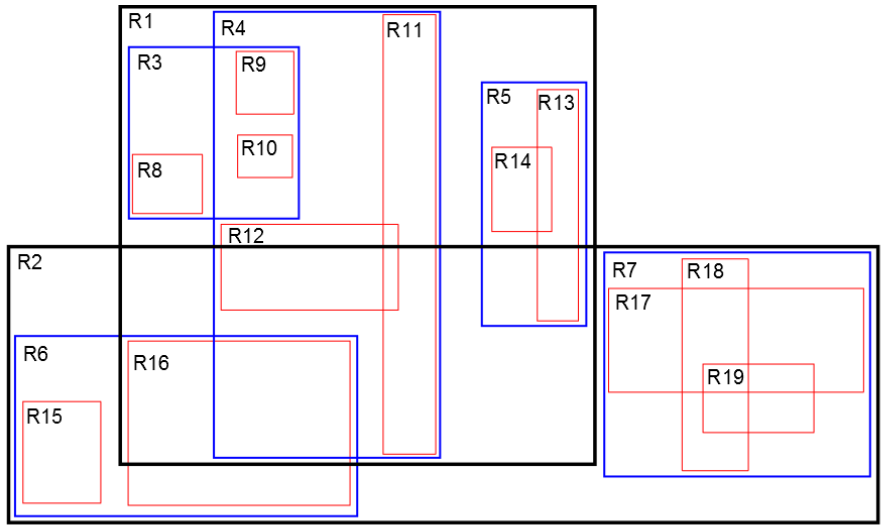
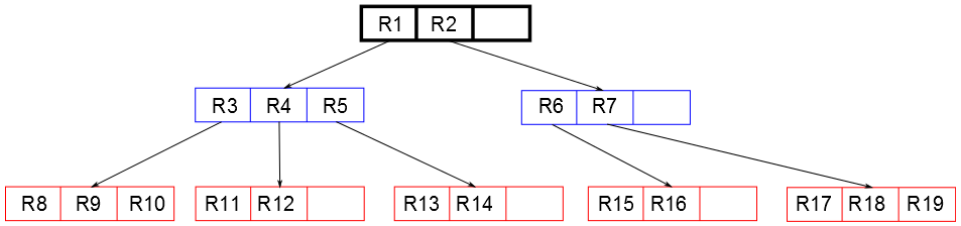
Spatial indexing

- An important feature of spatial databases is the support of Spatial Indexes.
- PostGIS uses GIST Indexation.



- Can simply be created on a table

```
CREATE INDEX index_name ON tablename
USING GIST (geomcolumnname);
```



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Spatial indexing

- Which features intersect (st_intersects)?

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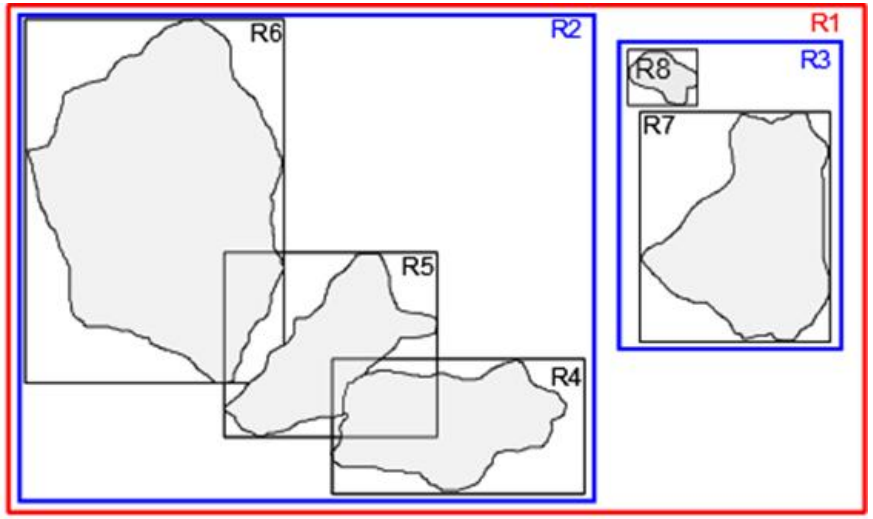
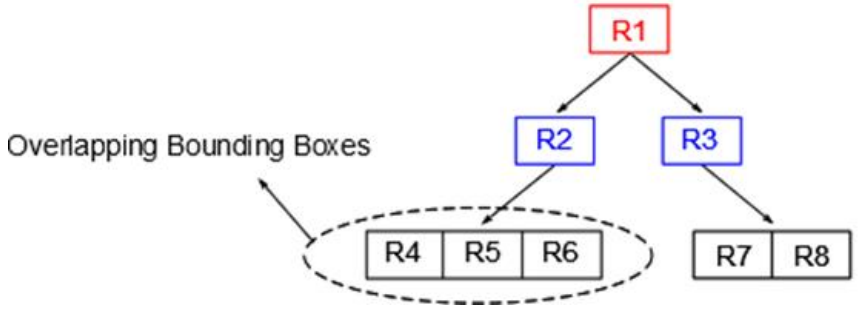
Spatial indexing

- First the database starts by identifying the overlapping bounding boxes:





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Spatial indexing

- Then the actual topological operation takes place on the geometries whose bounding boxes overlap, giving us the result

- Most of the commonly used functions in PostGIS (ST_Contains, ST_Intersects, ST_DWithin, etc) include an index filter automatically. But some functions (e.g., ST_Relate) do not include and index filter.
- To do a bounding-box search using the index (and no filtering), make use of the **&&** operator.
- For geometries, the **&&** operator means “bounding boxes overlap or touch” in the same way that for number the = operator means “values are the same”.

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How to continue…

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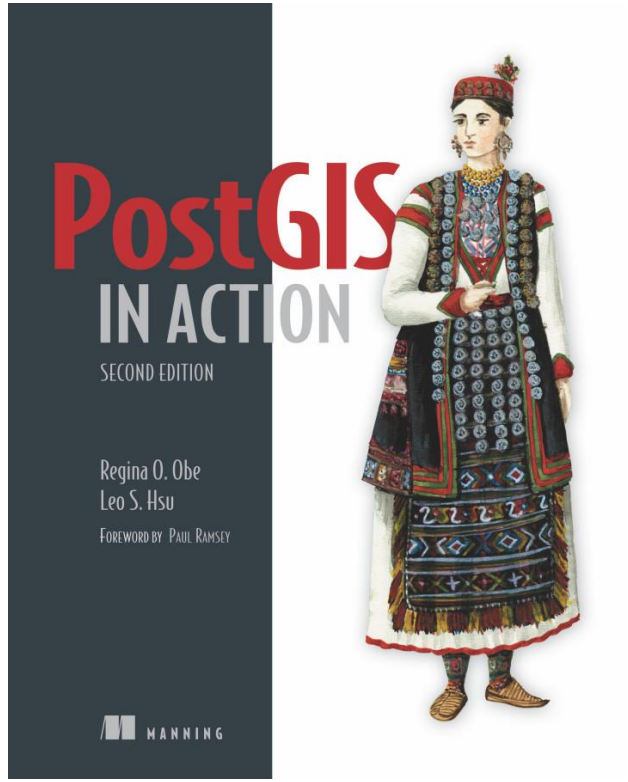
Continue

- PostGIS in Action 2nd edition
  - Find our all about it here
  - Download the code and the data here
  - Purchase here

- Simple Feature Access
  - Part 1: Common Architecture (pg 25-40)
  - Part 2: SQL Option

- Manuals
  - PostgreSQL
  - PostGIS



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Spatial vs non-spatial queries

neigbourhood (
  neigh_name *String*,
  pop *Double*,
  geom *(Polygon,28992)*
)

bus_stop(
  stop_name *String*,
  geom *(Point,28992)*
)

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Spatial vs non-spatial queries

```
SELECT bus_stop.stop_name, neighborhoods.neigh_name,
       neighborhoods.pop
FROM neighborhoods JOIN bus_stop
ON   ST_Intersects(neighborhoods.geom, bus_stop.geom)
```

SELECT *
FROM table1, table2
WHERE join condition

OR

SELECT *
FROM table 1 INNER JOIN
table2 ON join condition

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