SPATIAL (LINKED) DATA

HOW TO HANDLE LOCATION

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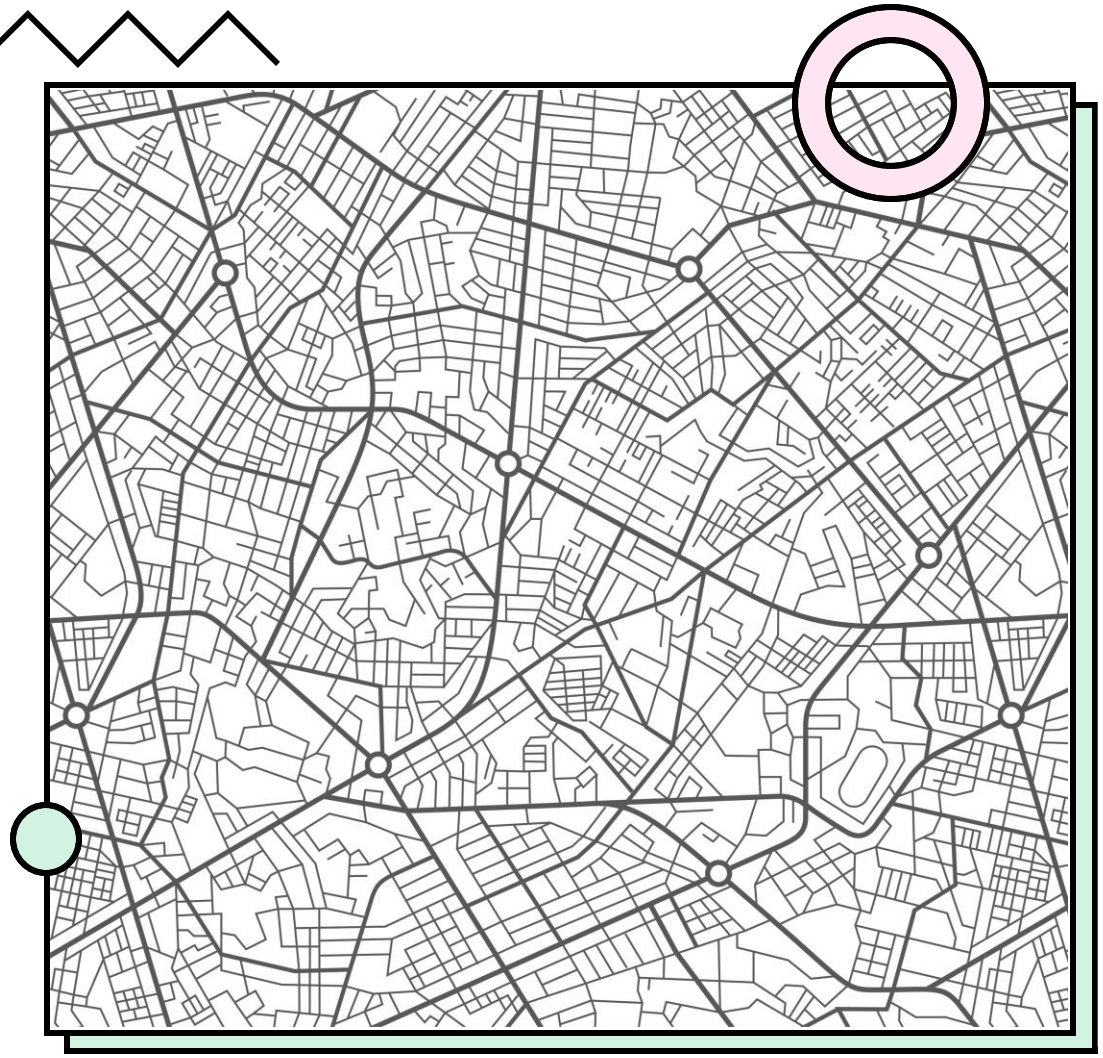
WHAT IS SPATIAL

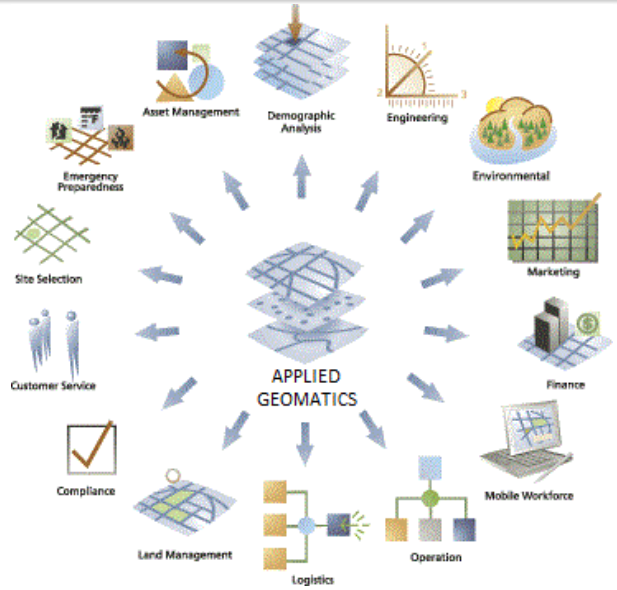


Spatial data questions

- How far is it ...
- Which way to take?
- Where is the highest mountain?
- Which bus stops are reachable on foot in 5 minutes from my home?
- Who has the largest farm?
- What historical monuments are visible from my hotel room?

Geomatics – ISO/TC 211

Discipline concerned with collection, distribution, storage, analysis, processing, presentation of geographic data or geographic information.



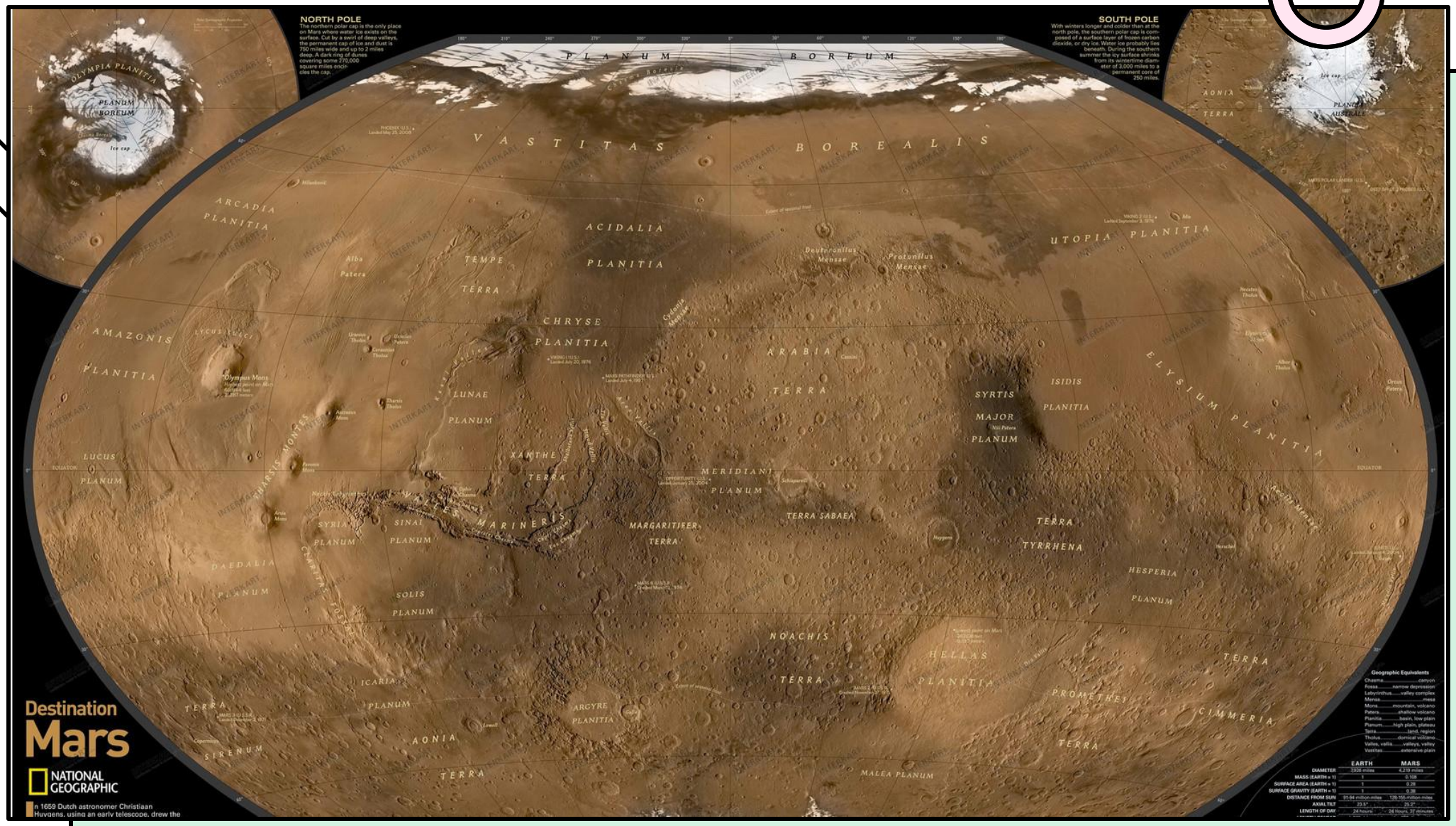
Geographic Data – ISO/TC 211

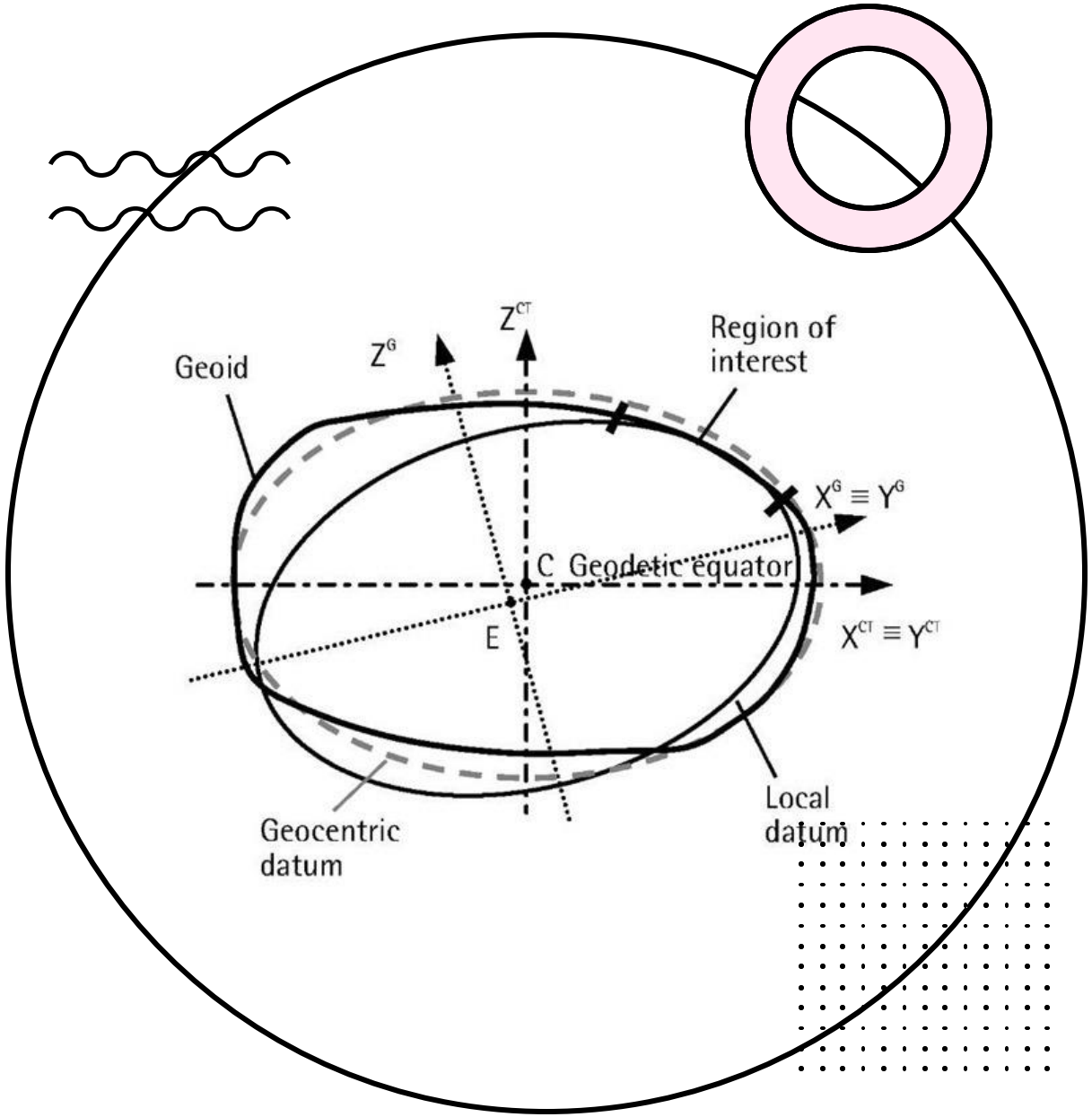
Data and information having an implicit or explicit association with a location relative to the Earth.

Terminology

- Geographic Information Systems
- Geoinformatics
- **Geomatics**

- **Geographic data**
- Geodata
- Spatial data
- Geospatial data and information
- Georeferenced data


NORTH POLE
The northern polar cap is the only place on Mars where water ice exists on the surface. Cut by a swirl of deep valleys, the permanent cap of ice and dust is 750 miles wide and up to 2 miles deep. A dark ring of dunes covering some 270,000 square miles encircles the cap.
SOUTH POLE
With winters longer and colder than at the north pole, the southern polar cap is composed of a surface layer of frozen carbon dioxide, or dry ice. Water ice probably lies beneath. During the southern summer the icy surface shrinks from its wintertime diameter of 3,000 miles to a permanent core of 250 miles.
PLANUM BOREUM
VASTITAS BOREALIS
ARCADIA PLANITIA
ACIDALIA PLANITIA
UTOPIA PLANITIA
TEMPE TERRA
CHRYSE PLANITIA
AMAZONIS PLANITIA
ARABIA TERRA
SYRTIS MAJOR PLANUM
ISIDIS PLANITIA
ELYSIUM PLANITIA
LUNAE PLANUM
XANTHE TERRA
MERIDIANI PLANUM
LUCUS PLANUM
SYRIA PLANUM
SINAI PLANUM
MARGARITIFER TERRA
TERRA SABAEA
TERRA TYRRHENA
HESPERIA PLANUM
DAEDALIA PLANUM
SOLIS PLANUM
NOACHIS TERRA
HELLAS PLANITIA
ICARIA PLANUM
ARGYRE PLANITIA
AONIA TERRA
SIRENUM TERRA
MALEA PLANUM
PROMETHEI TERRA
CIMMERIA TERRA
OLYMPIA PLANITIA
PLANUM AUSTRALE
Olympus Mons
Alba Patera
Valles Marineris
Destination Mars
NATIONAL GEOGRAPHIC
In 1659 Dutch astronomer Christiaan Huygens, using an early telescope, drew the
Geographic Equivalents
Chasma ... canyon
Fossa ... narrow depression
Labyrinthus ... valley complex
Mensa ... mesa
Mons ... mountain, volcano
Patera ... shallow volcano
Planitia ... basin, low plain
Planum ... high plain, plateau
Terra ... land, region
Tholus ... domical volcano
Valles, vallis ... valleys, valley
Vastitas ... extensive plain
EARTH MARS
DIAMETER 7926 miles 4,219 miles
MASS (EARTH = 1) 1 0.108
SURFACE AREA (EARTH = 1) 1 0.28
SURFACE GRAVITY (EARTH = 1) 1 0.38
DISTANCE FROM SUN 91.94 million miles 128.955 million miles
AXIAL TILT 23.5° 25.2°
LENGTH OF DAY 24 hours 24 hours, 37 minutes

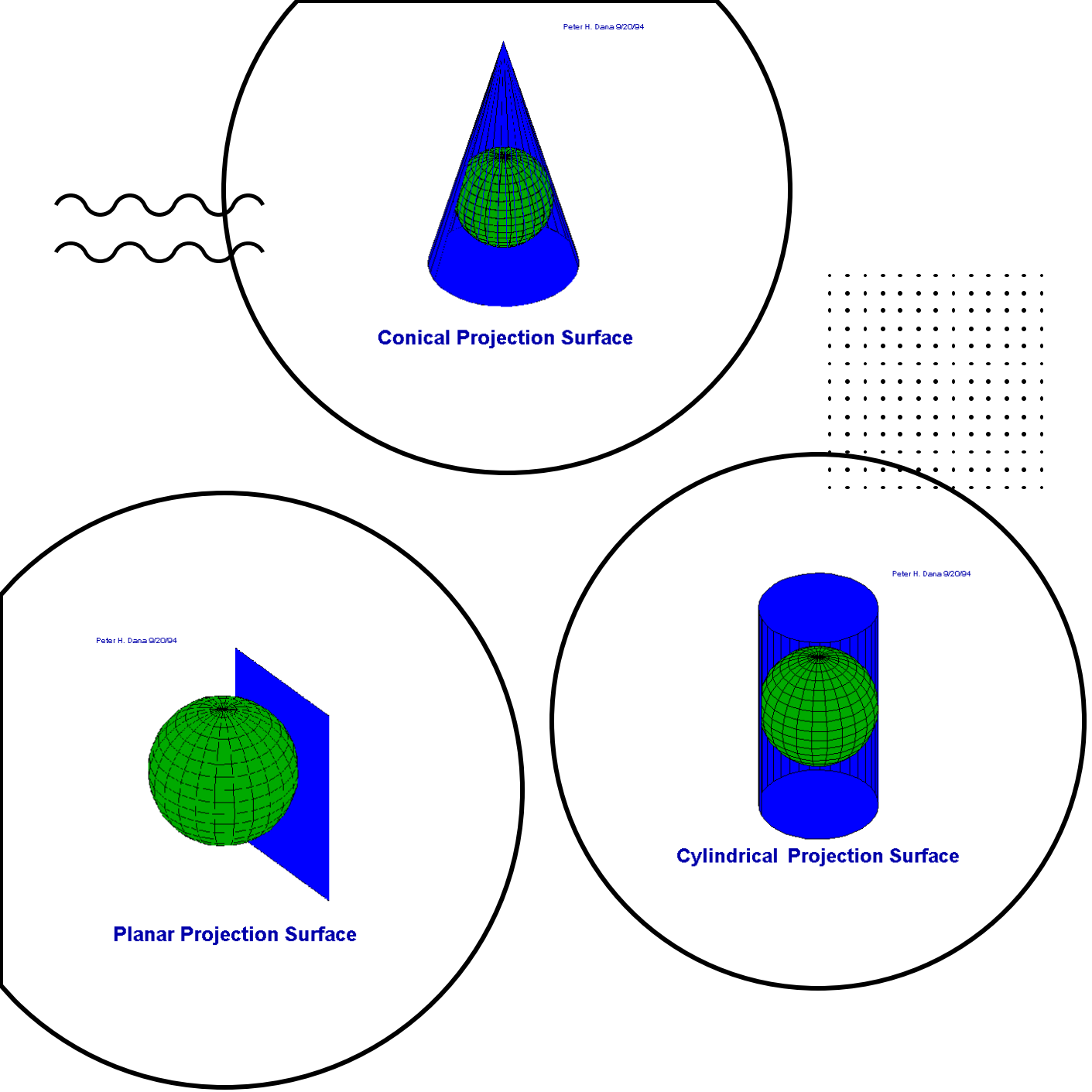


Coordinate Reference System

Reference ellipsoid

+

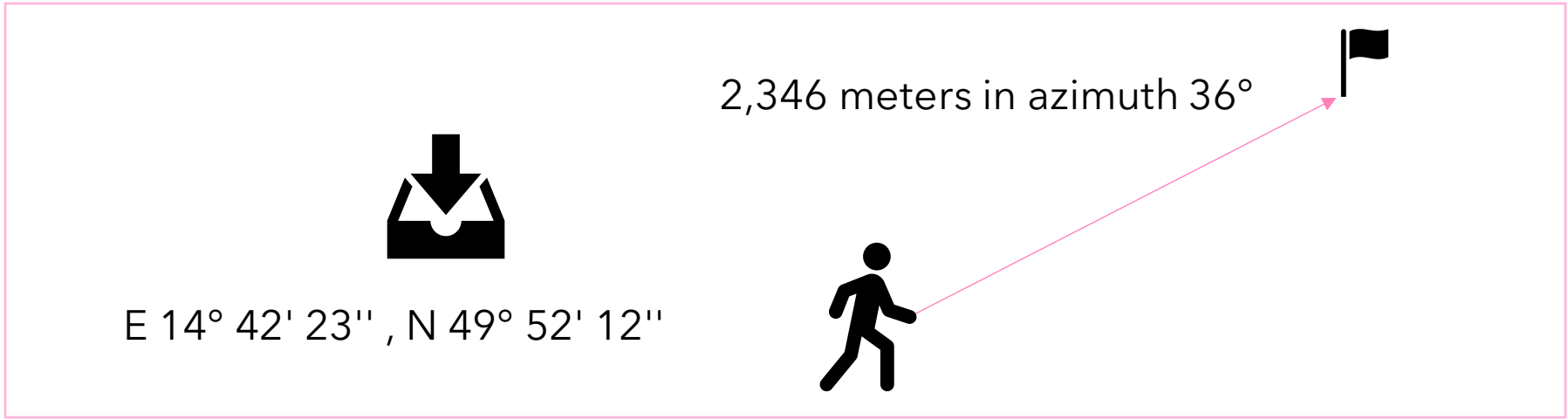
Datum



- **Coordinate Reference System**
- + Projection
- WGS-84
- S-JTSK
- ETRS-89
- http://epsg.io

WHAT IS GEODATA

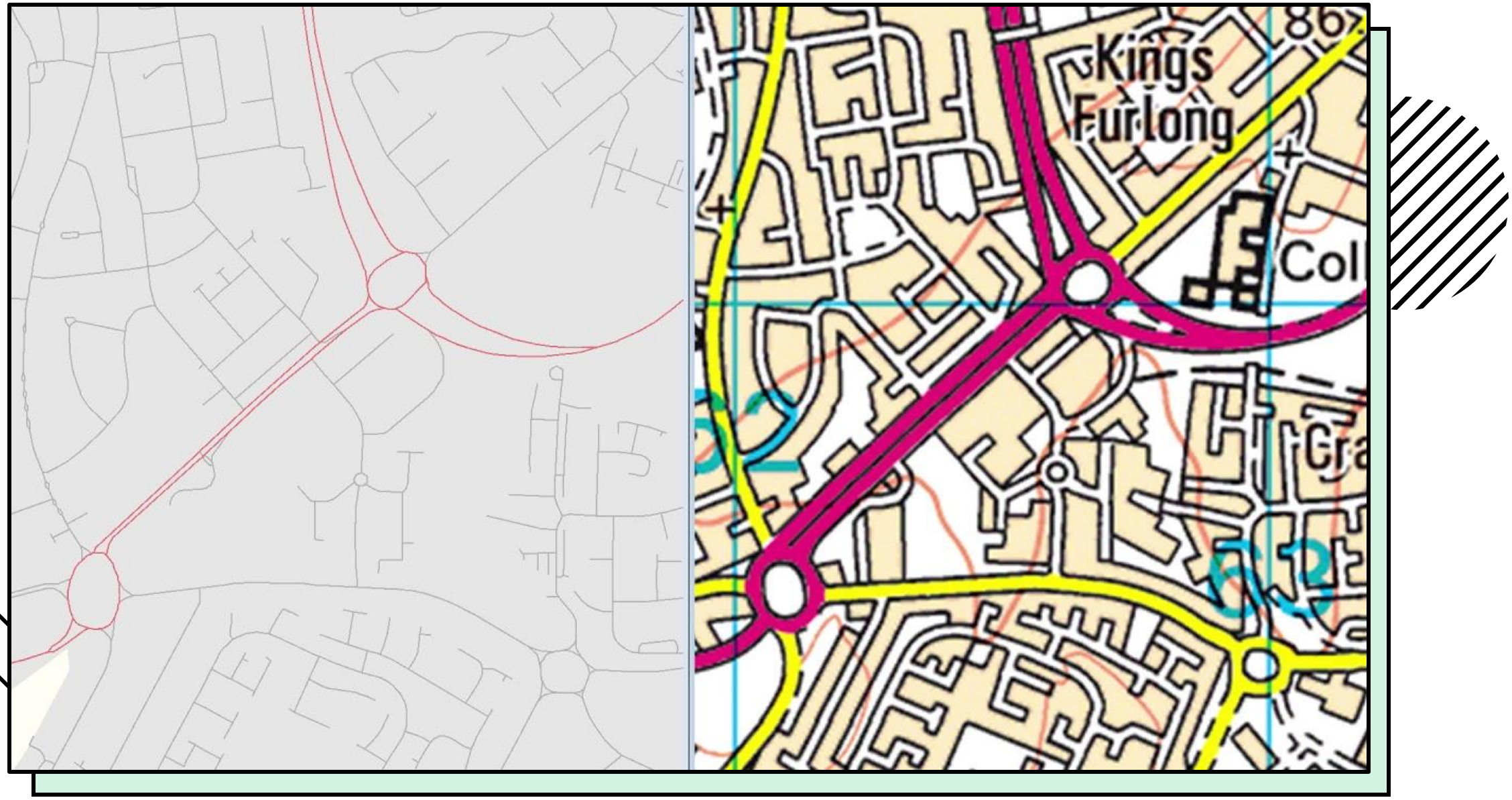
Implicit geodata – coordinates, distances, directions

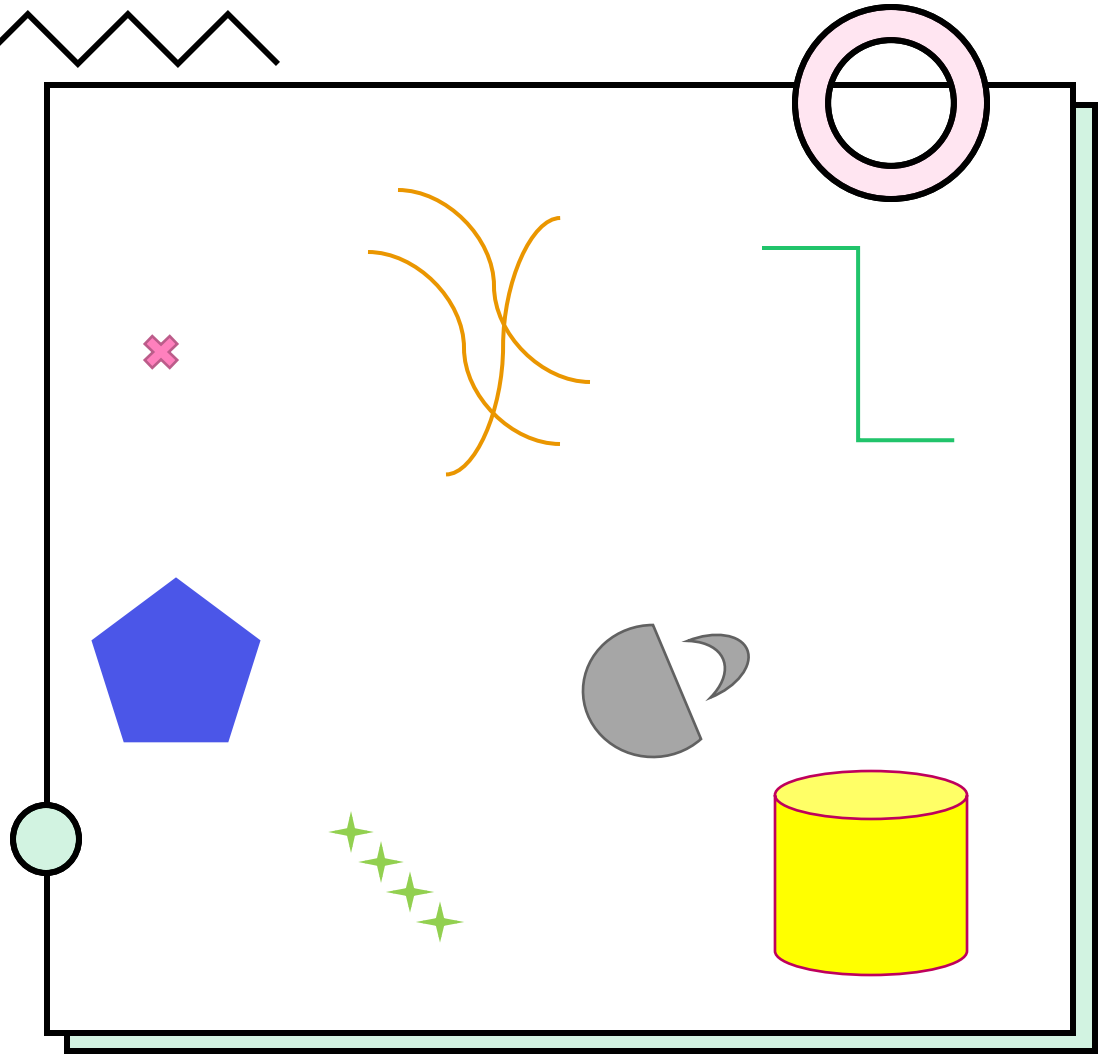


Explicit geodata – reference, address, geographical name

Vector representation

Raster representation



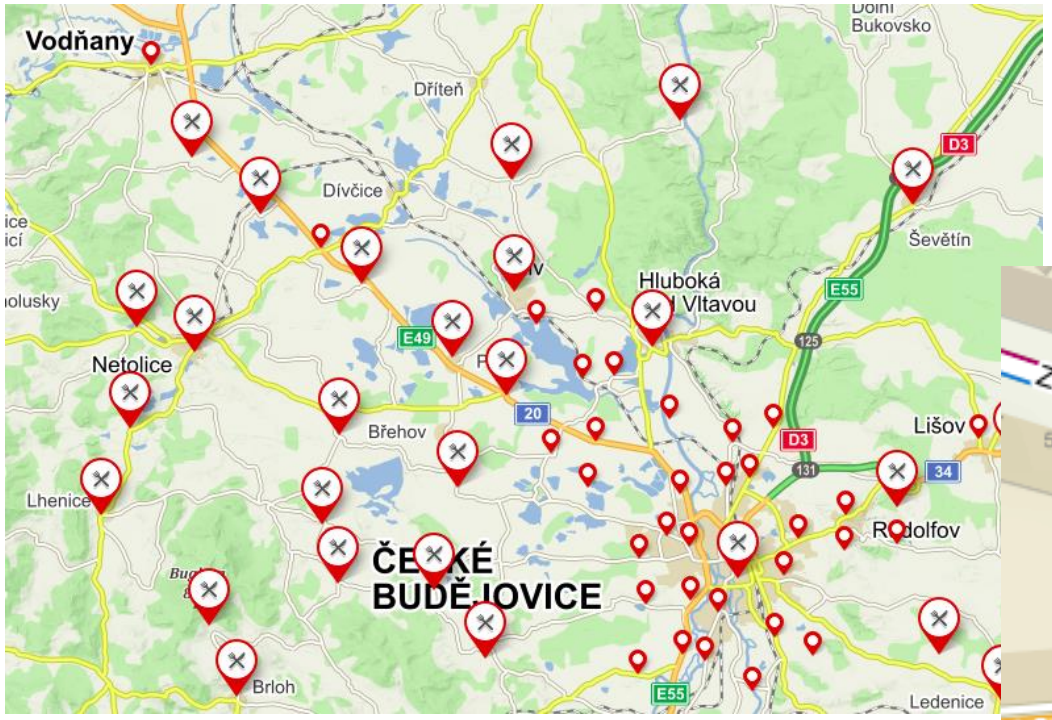


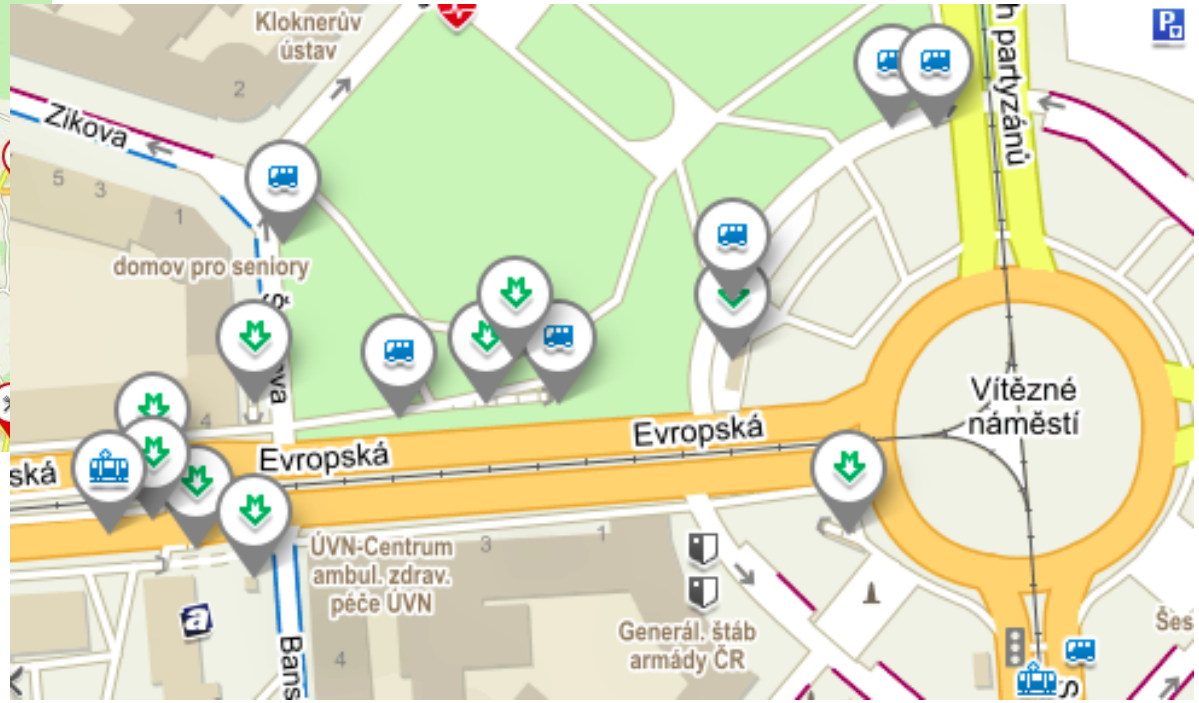
Geometry objects

- Points
- Multipoints
- Lines (Linestrings)
- Multilines
- Polygons
- Multipolygons
- Surface

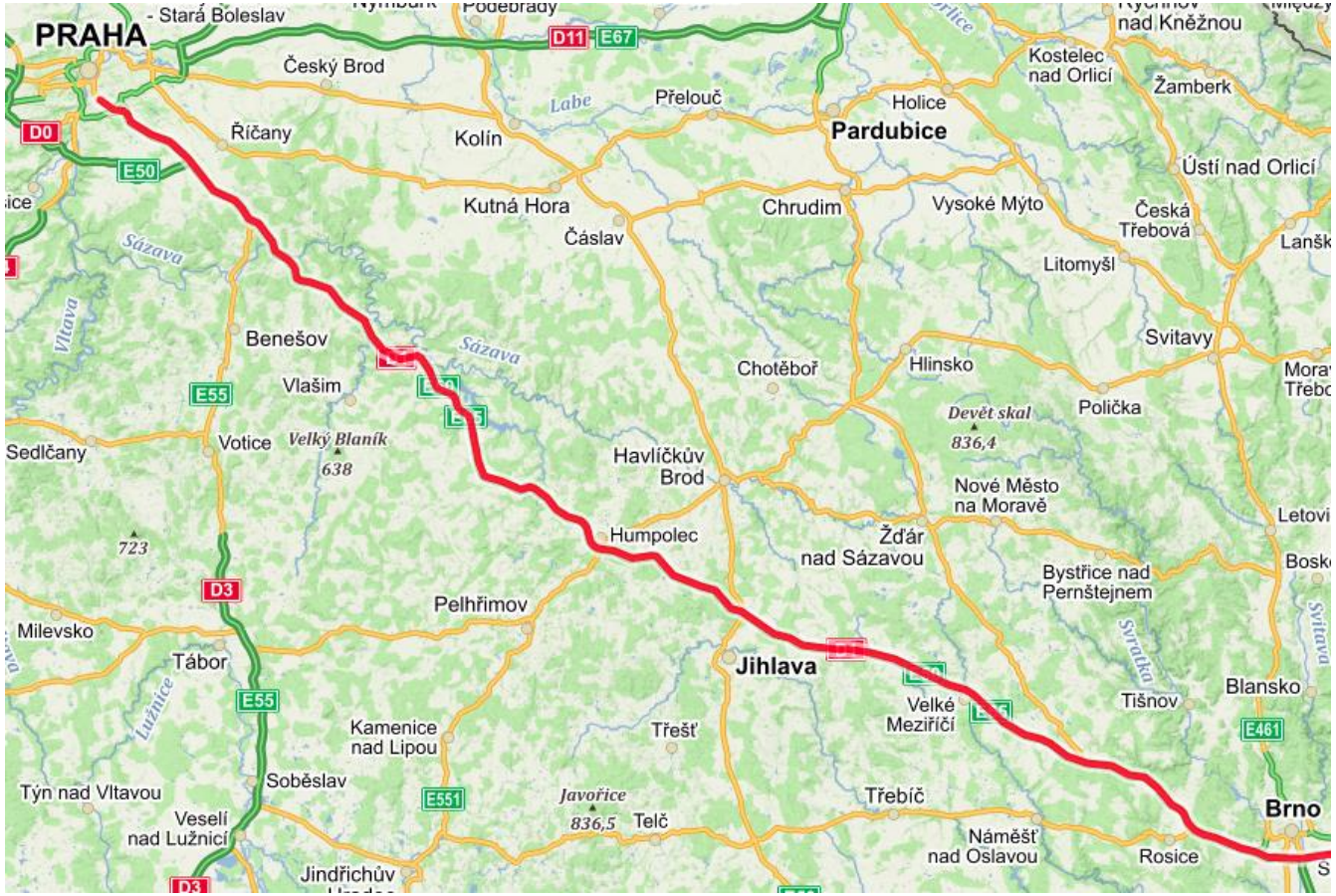
- w/o curves

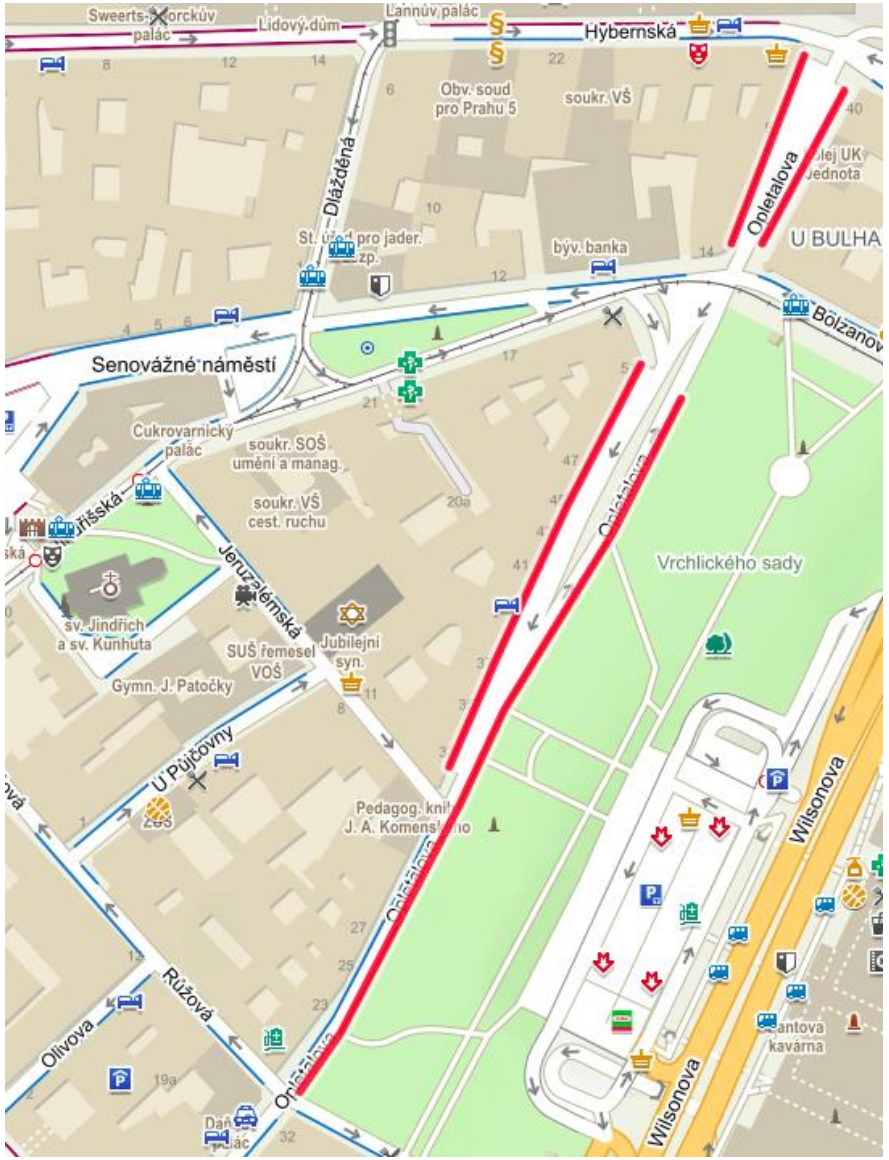
Geometrical objects – points



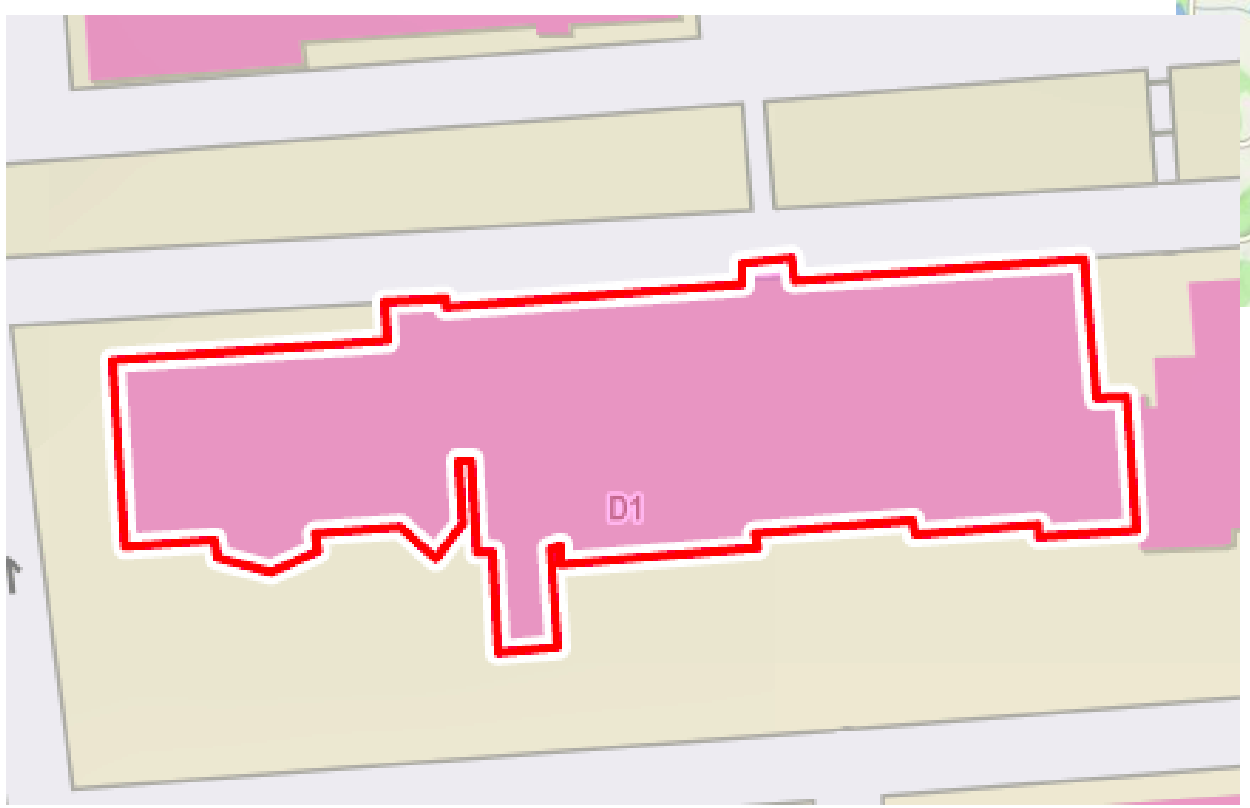


Geometrical objects – lines



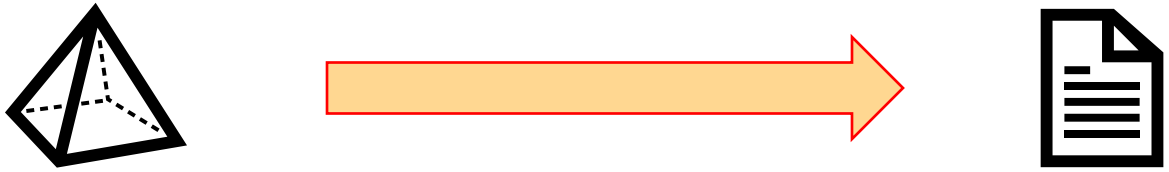


Geometrical objects – polygons



Geometry representation

- how to represent geometry objects in data



	X	Y
Point A	14.562°	49.8636°
Point B	14° 12' 56''	50° 02' 22''

Geometry representation

- how to represent geometry objects in data

	X	Y
Point A	14.562°	49.8636°
Point B	14° 12' 56''	50° 02' 22''

Usually this is very format specific, which can make things very complicated.

Do not forget data representation depends on coordinate reference system and geometry object type.

How to specify coordinate reference system?

How to represent polygon? Multipolygon?

Geometry representation - standard

Well-Known Text (WKT)

```
POINT(50.056 14.434)
LINESTRING(50.056 14.434, 50.064 14.442, 50.042 14.445)
```

- OGC standard
- Specified in Simple Features Access (https://www.opengeospatial.org/standards/sfa) and ISO 19125
- Well described in https://en.wikipedia.org/wiki/Well-known_text_representation_of_geometry
- Suitable for representation of 2D objects
- Most libraries expects WGS-84, but WKT supports various CRS

Geometry representation - standard

Geography Markup Language (GML)

```
<gml:Point srsName="http://opengis.net/def/crs/EPSG/0/4326" srsDimension="2">/
    <gml:pos>50.056 14.434</gml:pos>
</gml:Point>

<gml:Curve srsName="http://opengis.net/def/crs/EPSG/0/5514" srsDimension="2">
    <gml:segments>
      <gml:LineStringSegment>
        <gml:posList>-641126.76 -1093821.18 -641119.35 -1093831.05
                     -641109.75 -1093844.44</gml:posList>
      </gml:LineStringSegment>
    </gml:segments>
</gml:Curve>
```

- Defined in OGC standard https://www.ogc.org/standards/gml
- Very robust, supports various CRS, various geometry objects, curves, 3D objects, coverage, sensor data
- The writing method is rather complicated (see above)

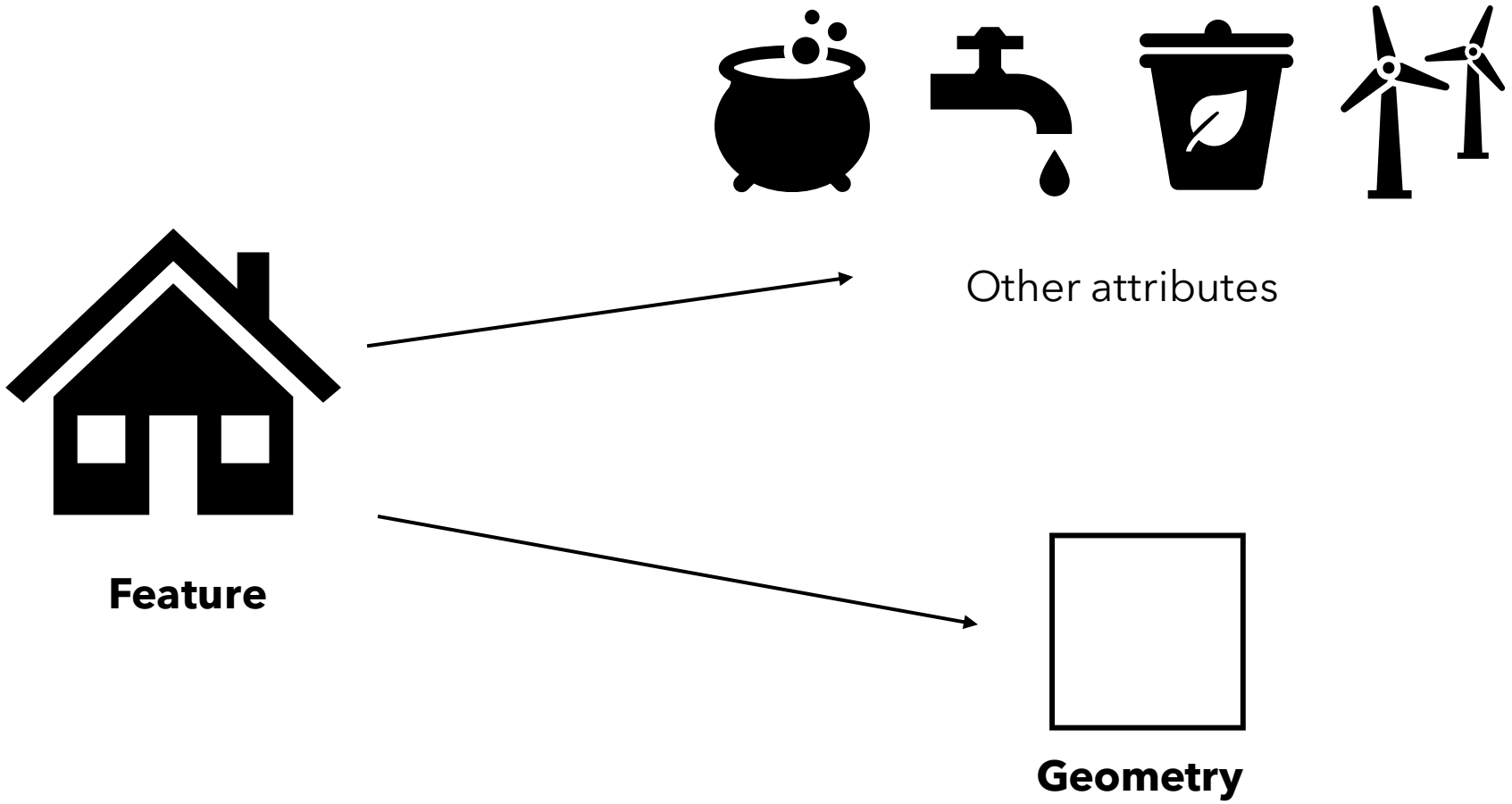
Geometry representation – format based

Some spatial data formats may be using non-standardized way of geometry representation

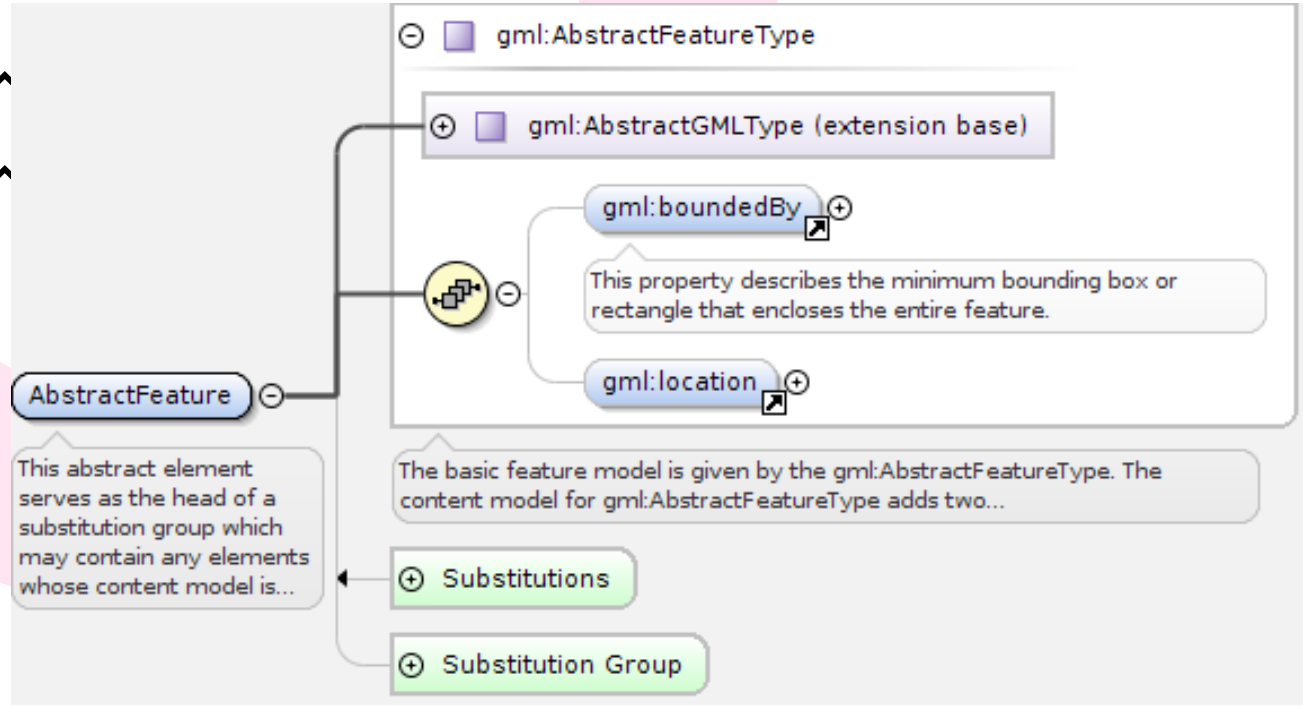
Data format	Geometry representation
GML	GML
GeoJSON	geojson
Shapefile	binary
GeoPackage	SQLite
CSV	any
GeoSPARQL	GML/WKT

SPATIAL DATA FORMATS

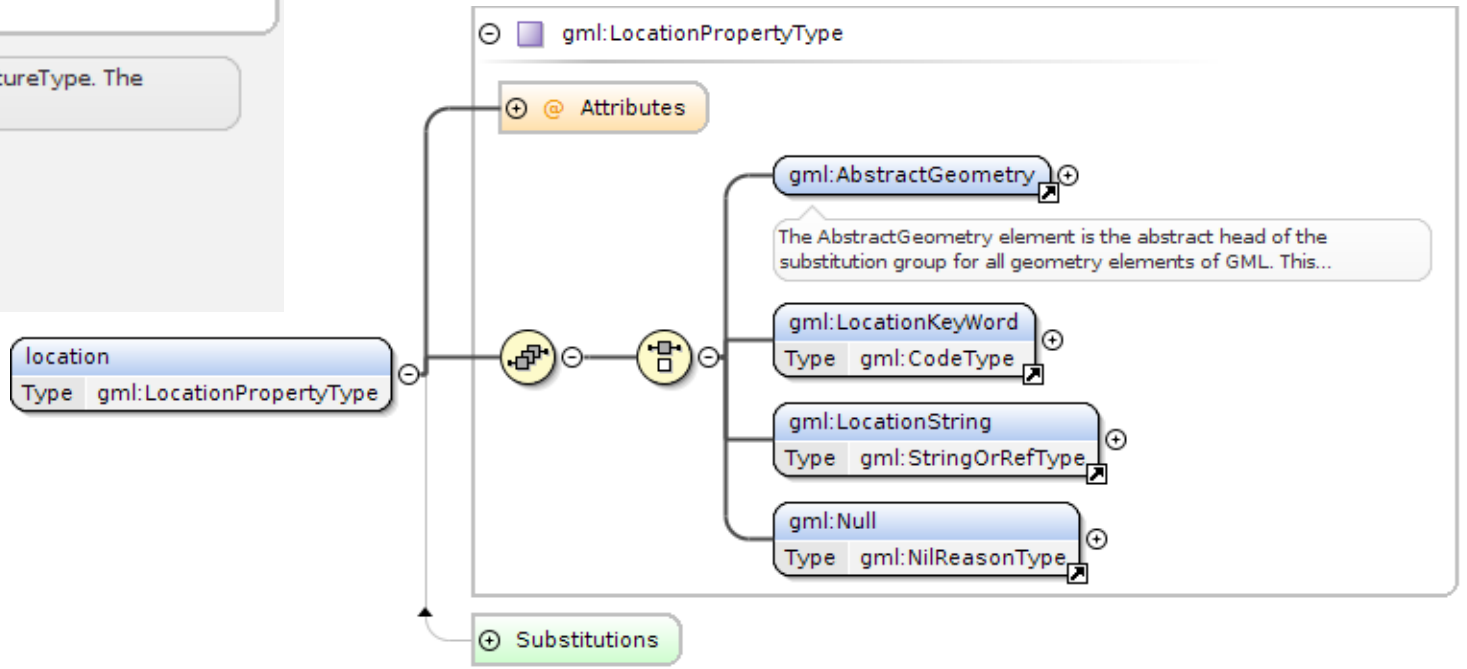
Spatial data logic



Geography Markup Language (GML)



XML based format, described by set of XSD files available
from: http://schemas.opengis.net/gml/3.2.1/



Geography Markup Language (GML)

```
<ad:Address gml:id="AD.22547665">
  <ad:inspireId>
    <base:Identifier>
      <base:localId>AD.22547665</base:localId>
      <base:namespace>CZ-00025712-CUZK_AD</base:namespace>
    </base:Identifier>
  </ad:inspireId>
  <ad:alternativeIdentifier>K Pitkovicům 1, Benice, 10300 Praha 10</ad:alternativeIdentifier>
  <ad:position>
    <ad:GeographicPosition>
      <ad:geometry>
        <gml:Point gml:id="P.AD.22547665" srsName="urn:ogc:def:crs:EPSG::5514" srsDimension="2">
          <gml:pos>-731037.56 -1053052.98</gml:pos>
        </gml:Point>
      </ad:geometry>
      <ad:specification xlink:href="http://inspire.ec.europa.eu/codelist/ GeometrySpecificationValue/entrance"
xlink:title="entrance"/>
      <ad:default>true</ad:default>
    </ad:GeographicPosition>
  </ad:position>
  <ad:component xlink:href="#AA.MOP.108" xlink:title="Praha 10"/>
  <ad:component xlink:href="#AA.MOMC.538078" xlink:title="Praha-Benice"/>
  <ad:component xlink:href="#AA.2585" xlink:title="Benice"/>
  <ad:component xlink:href="#TF.498211" xlink:title="K Pitkovicům"/>
  <ad:component xlink:href="#PD.10300" xlink:title="10300"/>
</ad:Address>
```

Geography Markup Language (GML)

GML is used in the Infrastructure for Spatial Information in Europe (INSPIRE) as the main format for data. Regulation aims at sharing (spatial) data about environment accross Europe in a standardized way.

Data catalogue is available from https://inspire-geoportal.ec.europa.eu/

GeoJSON


```
{
  "geometry":{
    "coordinates":[
    14.419134,
    50.090122
    ],
    "type":"Point"
  },
  "crs": {
    "type": "name",
    "properties": {
      "name": "urn:ogc:def:crs:EPSG::4326"
    }
  },
  "properties":{
    "cislo_orientacni":"22",
    "cislo_popisne":"128",
    "druh_mista":"RESTAURAČNÍZAHRÁDKY",
    "druh_zbozi":"",
    "momc":"Praha 1",
    "ulice":"Pařížská"
  },
  "type":"Feature"
}
```


- JSON based format
- Own geometry representation
- Does not support other CRS than WGS-84 (functionality was removed)
- Geometry objects supported: Point, Multipoint, LineString, MultiLineString, Polygon, Multipolygon
- http://geojson.io
- Supported visualization in GitHub

Shapefile

Jeskyne

	JMENO	DATA50_K	DATA50_P
1	Jáchymka	6260000	vstup do je…
2	Netopýrka	6260000	vstup do je…
3	*NULL*	6260000	vstup do je…
4	Zbrašovské…	6260000	vstup do je…
5	Černotínsk…	6260000	vstup do je…
6	Výpustek	6260000	vstup do je…
7	Pekárna	6260000	vstup do je…
8	Švédův stůl	6260000	vstup do je…
9	Ochozská j…	6260000	vstup do je…
10	Cikánská	6260000	vstup do je…
11	U jezevce	6260000	vstup do je…
12	U žida	6260000	vstup do je…
13	Šámalíkovy…	6260000	vstup do je…
14	Šipka	6260000	vstup do je…
15	Ledové sluje	6260000	vstup do je…
16	Na Turoldu	6260000	vstup do je…

Show All Features

- Format created by ESRI company, but the format itself is (yet) open
- Native format for most used GIS in Czech Republic
- Consist of multiple files
- Restricted number of characters per column name
- Only one feature type per dataset
- Lot of known issues

OGC GeoPackage

- SQLite database file
- Supports simple and complex geometry structures (as an attribute)
- Supports both vector and raster data (in one file)
- Very fast and very complex

Comma Separated Values

```
1  Kód,Název ulice,Kód Obce,Název Obce,Kód Okresu,Název Okresu,WKT_Geometry,CRS
2  442666,Adamovská,554782,Praha,3100,Hlavní město
   Praha,"LINESTRING(14.450325965881346 50.05789646795757, 14.450948238372803
   50.05791713211645, 14.45121645927429   50.05803422884852, 14.451420307159424
   50.058764354966634, 14.451624155044554 50.0591569653608, 14.451828002929688
   50.059460030836206, 14.45177435874939 50.059522021265785)",http://
   www.opengis.net/def/crs/EPSG/0/4258
3  442674,Africká,554782,Praha,3100,Hlavní město
   Praha,"LINESTRING(14.349464178085329 50.09616500163075, 14.349786043167112
   50.096075528282334, 14.349968433380127 50.09575892893866, 14.350258111953734
   50.09575892893866, 14.350826740264893 50.09566257220141, 14.352350234985352
   50.09597228959578, 14.354592561721802 50.096399008059755, 14.355171918869019
   50.096392125534024, 14.355483055114746 50.09633018275811, 14.355762004852295
   50.09634394782634, 14.358251094818113 50.096791310391346, 14.358723163604736
   50.096873899946615, 14.359141588211058 50.09697713669046, 14.359956979751587
   50.09699778401253, 14.36085820198059 50.09715607985288, 14.362660646438599
   50.09761031718664, 14.363701343536377 50.09788561044452, 14.363905191421507
   50.09789937506589, 14.364173412322996 50.09786496350506, 14.364463090896606
   50.09773419934845)",http://www.opengis.net/def/crs/EPSG/0/4258
4  442682,Akátová,554782,Praha,3100,Hlavní město
   Praha,"LINESTRING(14.41953420639038 50.077619800339754, 14.41979169845581
   50.077647341221535, 14.421336650848389 50.07749586617591, 14.42479133605957
   50.077330620125764, 14.429275989532469 50.07717914407949, 14.431657791137694
   50.07711029117297)",http://www.opengis.net/def/crs/EPSG/0/4258
```

- Very easy
- MS Excel friendly
- Does not have recommended geometry (can be WKT)
- Geometry objects usually contain commas – must be escaped

SPATIAL LINKED DATA FORMATS

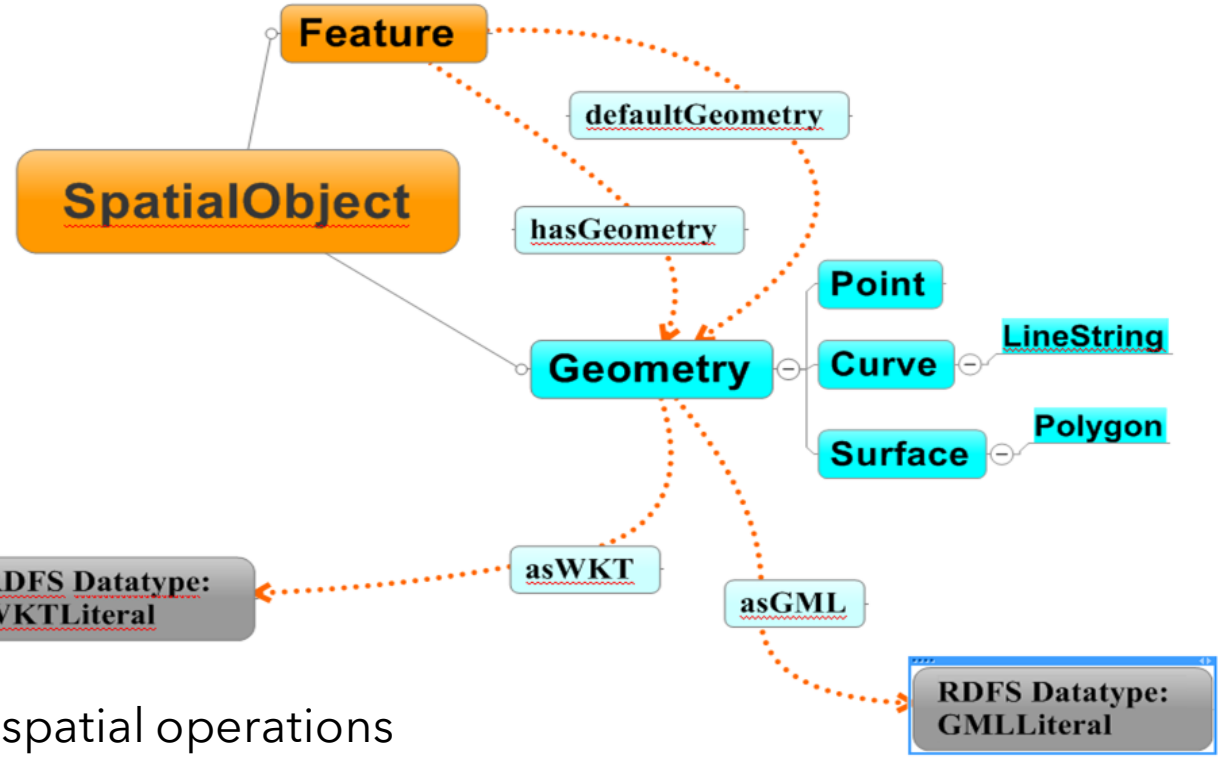
Geo WGS-84

```
<rdf:RDF xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
         xmlns:geo="http://www.w3.org/2003/01/geo/wgs84_pos#">
  <geo:Point>
    <geo:lat>49.701</geo:lat>
    <geo:long>14.552</geo:long>
  </geo:Point>
</rdf:RDF>
```

Perfectly represents points in WGS-84

Cannot represent anything else
'lat' and 'long' are standalone tropes (in geo, we usually use 3-letters shorts 'lat' and 'lon')

GeoSPARQL



Ontology + query language supporting spatial operations
Geometry representation in both GML and WKT
Support various CRS

May be too complicated for beginners
Seems overpowered for simple representation of points

GeoSPARQL

```
@prefix rdfs: <http://www.w3.org/2000/01/rdf-schema#> .
@prefix geosparql: <http://www.opengis.net/ont/geosparql#> .
@prefix ds-par: <http://onto.fel.cvut.cz/ontologies/town-plan/parcely/> .
@prefix databaseTableParcely: <http://onto.fel.cvut.cz/ontologies/town-plan/databaseTableParcely/>
@prefix par-geometry: <http://onto.fel.cvut.cz/ontologies/town-plan/parcelakn_dokm_p/geometry/>
@prefix townplan: <http://onto.fel.cvut.cz/ontologies/town-plan/>

townplan:parcelakn_dokm_p/1/2018-01-29T14:36:24.178617 a ds-par:Parcely,
        geosparql:Feature ;
    rdfs:label "parcelakn_dokm_p/1/2018-01-29T14:36:24.178617" ;
    databaseTableParcely:dat_vznik "2008-09-25"^^xsd:date ;
    databaseTableParcely:existujedi "A" ;
    databaseTableParcely:id 2087553101.0 ;
    databaseTableParcely:id_poskyt 397 ;
    databaseTableParcely:katuze_kod 727164 ;
    databaseTableParcely:nazev_ku "Vinohrady" ;
    databaseTableParcely:ogc_fid 1 ;
    databaseTableParcely:par_id 2087553101.0 ;
    databaseTableParcely:parcela "1057" ;
    databaseTableParcely:shape_area 260.475900002 ;
    databaseTableParcely:shape_length 65.6304823872 ;
    databaseTableParcely:tid_parcelakn_dokm_p 61534.0 ;
    databaseTableParcely:vymera 260 ;
    geosparql:hasGeometry par-geometry:1/2018-01-29T14:36:24.178617 .

    par-geometry:1/2018-01-29T14:36:24.178617 a geosparql:Geometry ;
    rdfs:label "parcelakn_dokm_p/geometry/1/2018-01-29T14:36:24.178617" ;
    geosparql:asWKT "MULTIPOLYGON(((-742241.02 -1045480.81,-742242.84 -1045482.35,
                    -742257.059 -1045469.76,-742246.0798 -1045456.9,-742237.98
                    -1045465.82,-742241.02 -1045480.81)))" .
```

GeoJSON-LD

```
{
  "@context": https://ofn.gov.cz/umístění/2020-07-01/kontexty/umístění.jsonld,
  "typ": "Umístění",
  "název":
  {
    "cs": "Národní park Šumava"
  },
  "geometrie":
  {
    "type": "Point",
    "coordinates": [13.6309462, 48.9720309]
  }
}
```

```
{
  "@context":
  {
    "@version": 1.1,
    "locn": "http://www.w3.org/ns/locn#",
    "dcterms": http://purl.org/dc/terms/,
    ...
    "geometrie":
    {
      "@id": "locn:geometry",
      "@context": "https://geojson.org/geojson-ld/geojson-context.jsonld"
    }
  }
}
```

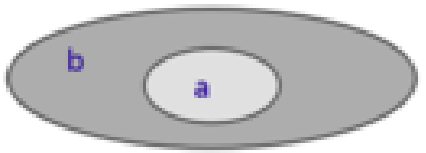
SPATIAL RELATIONS AND OPERATIONS

Spatial relations

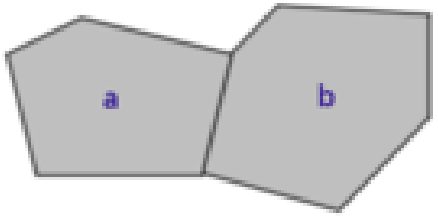
Relation between two (or more) spatial objects, usually based on location and/or shape:

- **Topological**
- Directional
- Distance
- Temporal

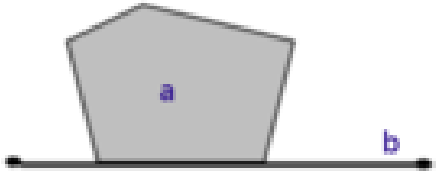
Within(a,b)



Touches(a,b)



Touches(a,b)



Crosses(a,b)

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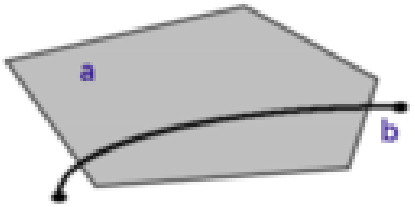
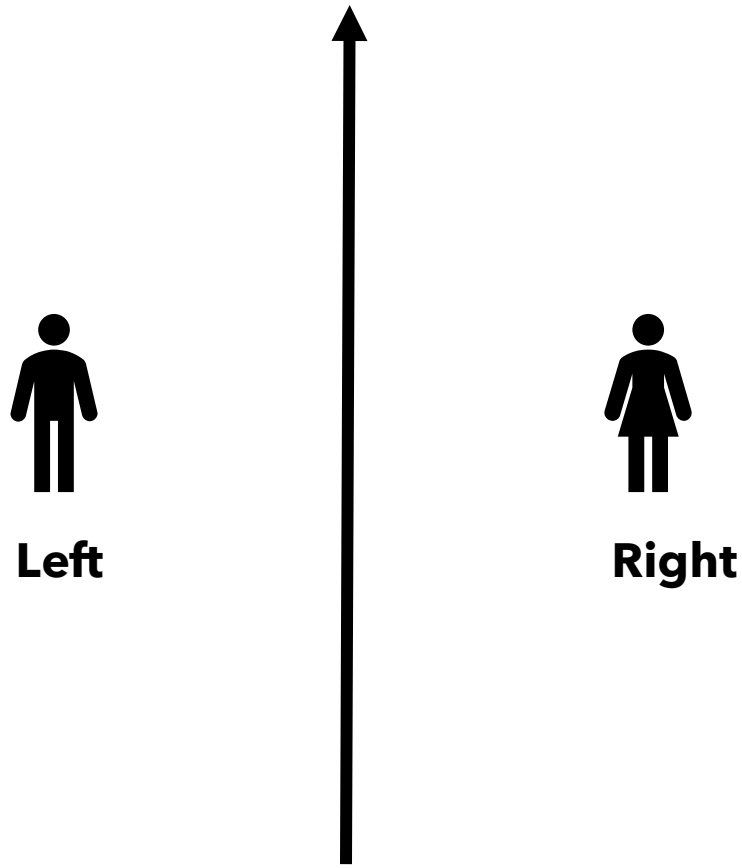


Overlaps(a,b)

Spatial relations

Relation between two (or more) spatial objects, usually based on location and/or shape:

- Topological
- **Directional**
- Distance
- Temporal



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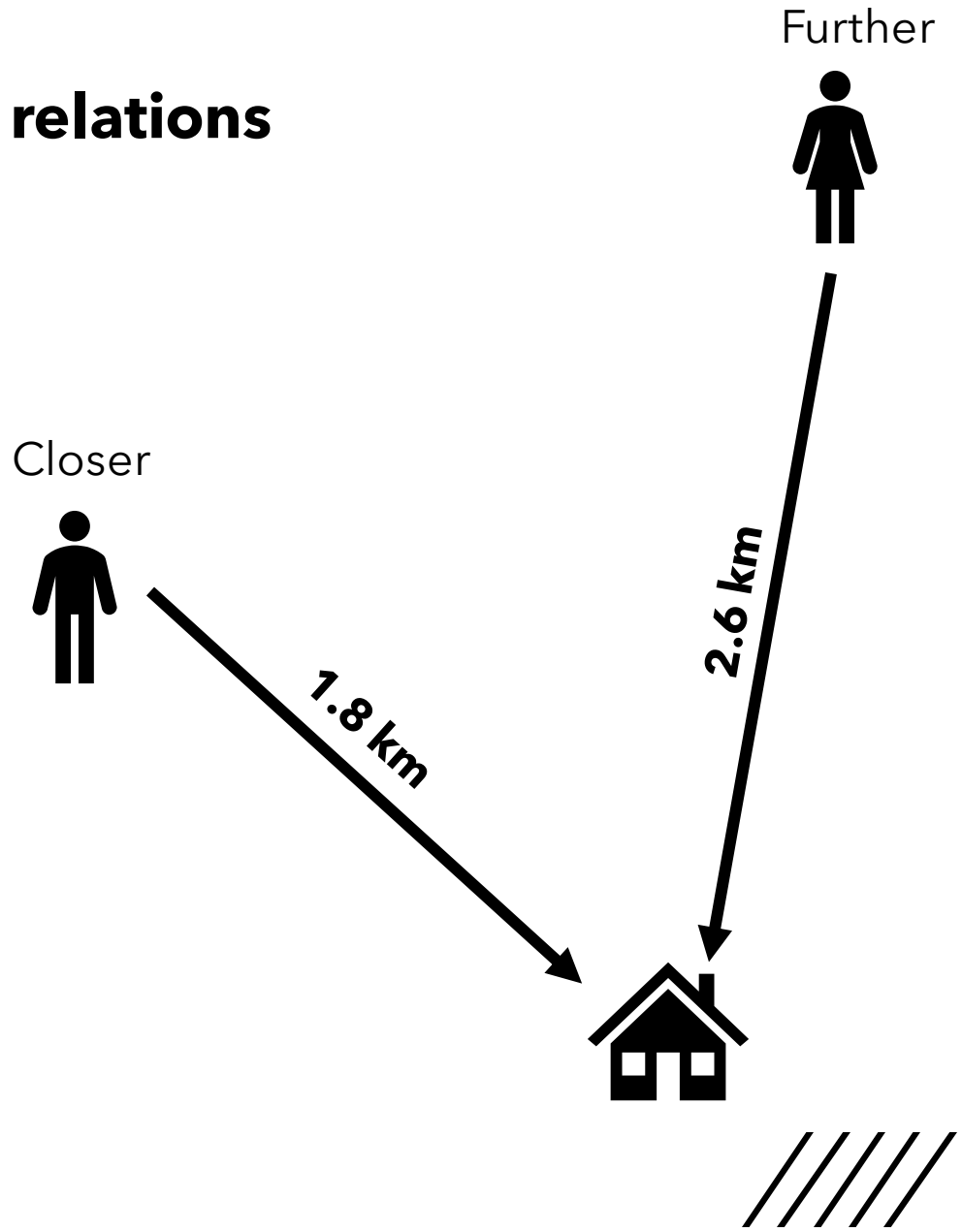

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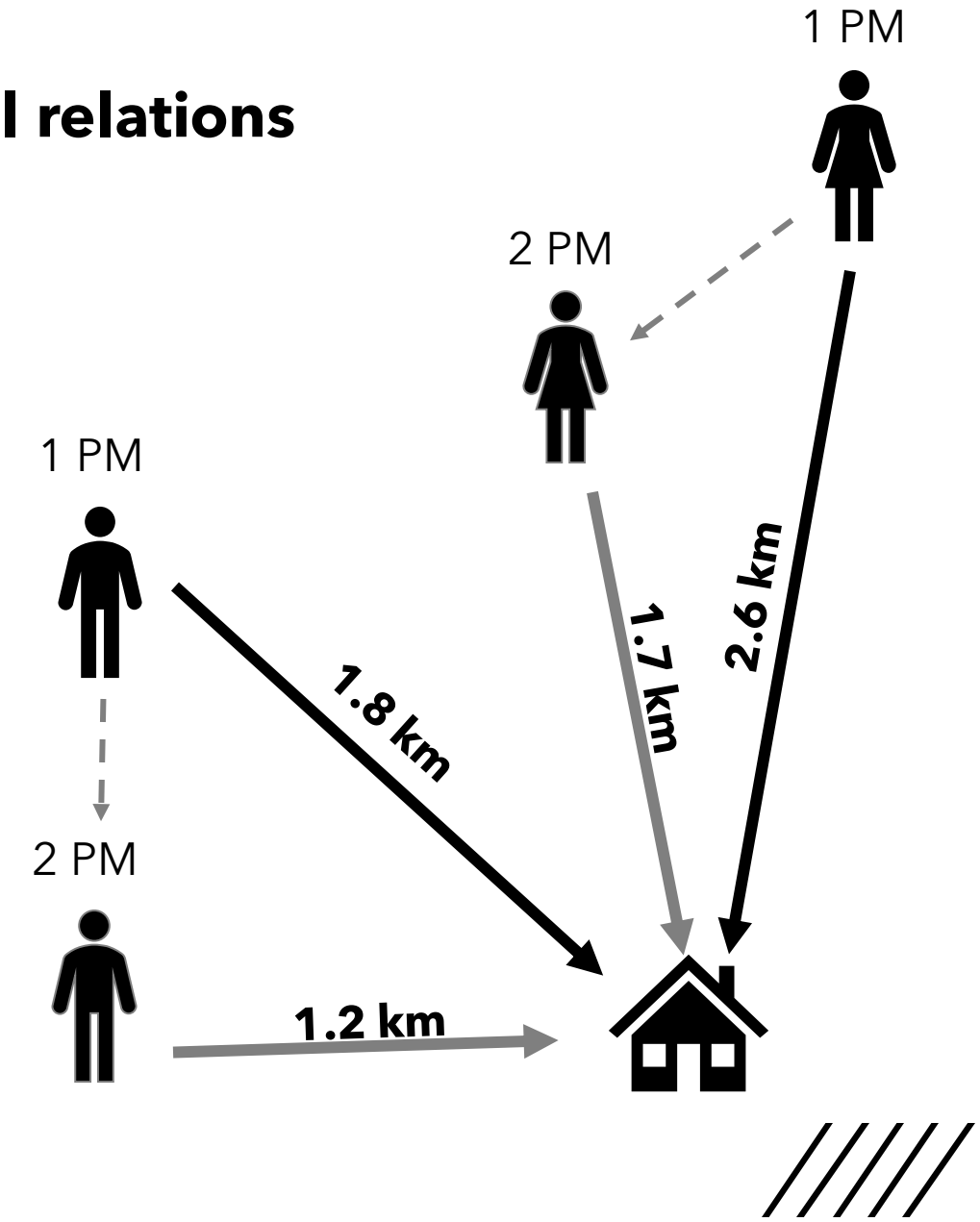
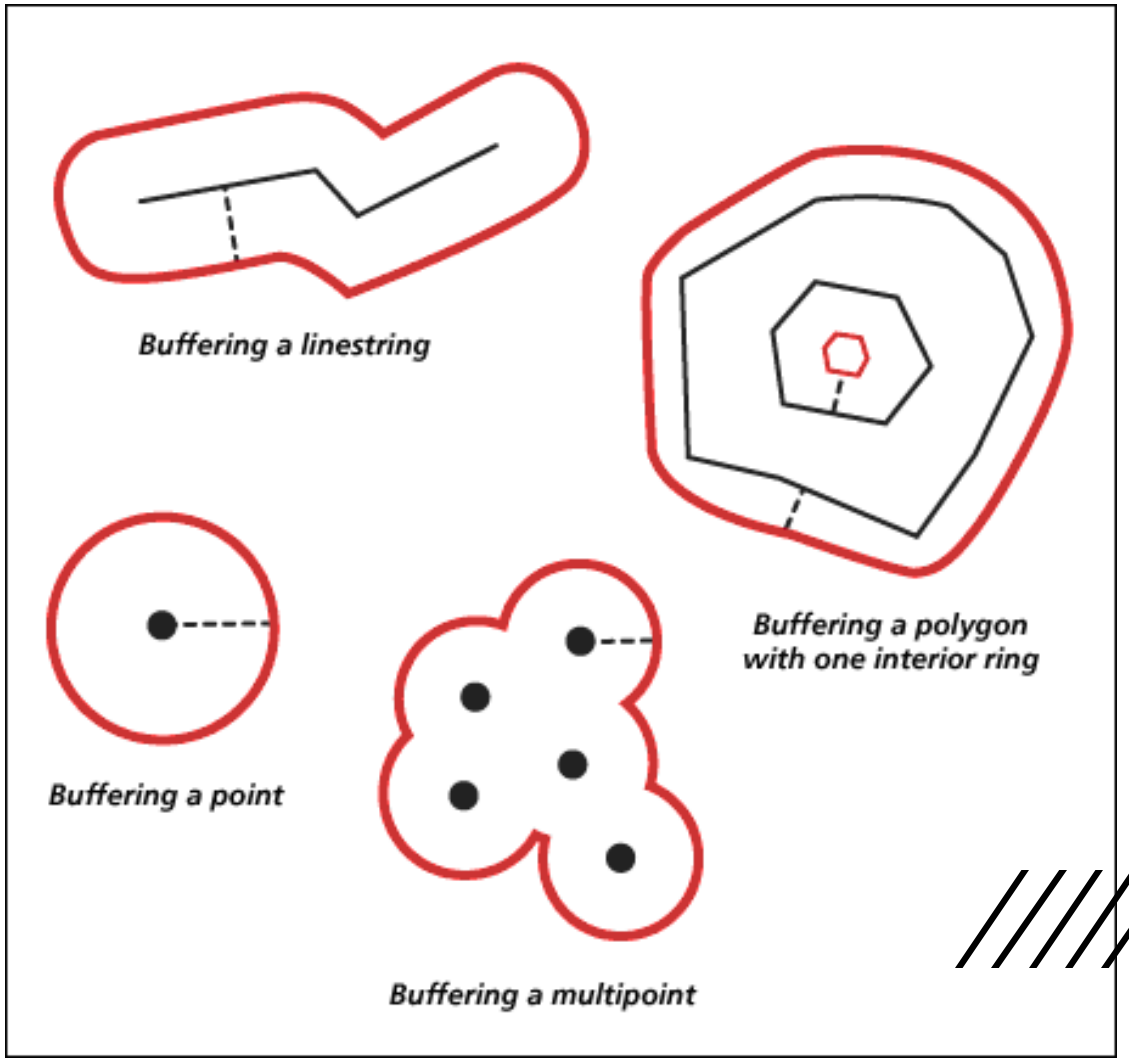


Buffer
Union
Difference
Clip
Intersection
Interpolation
Distance
Convex Hull
Thiessen/Voronoi

Spatial operations



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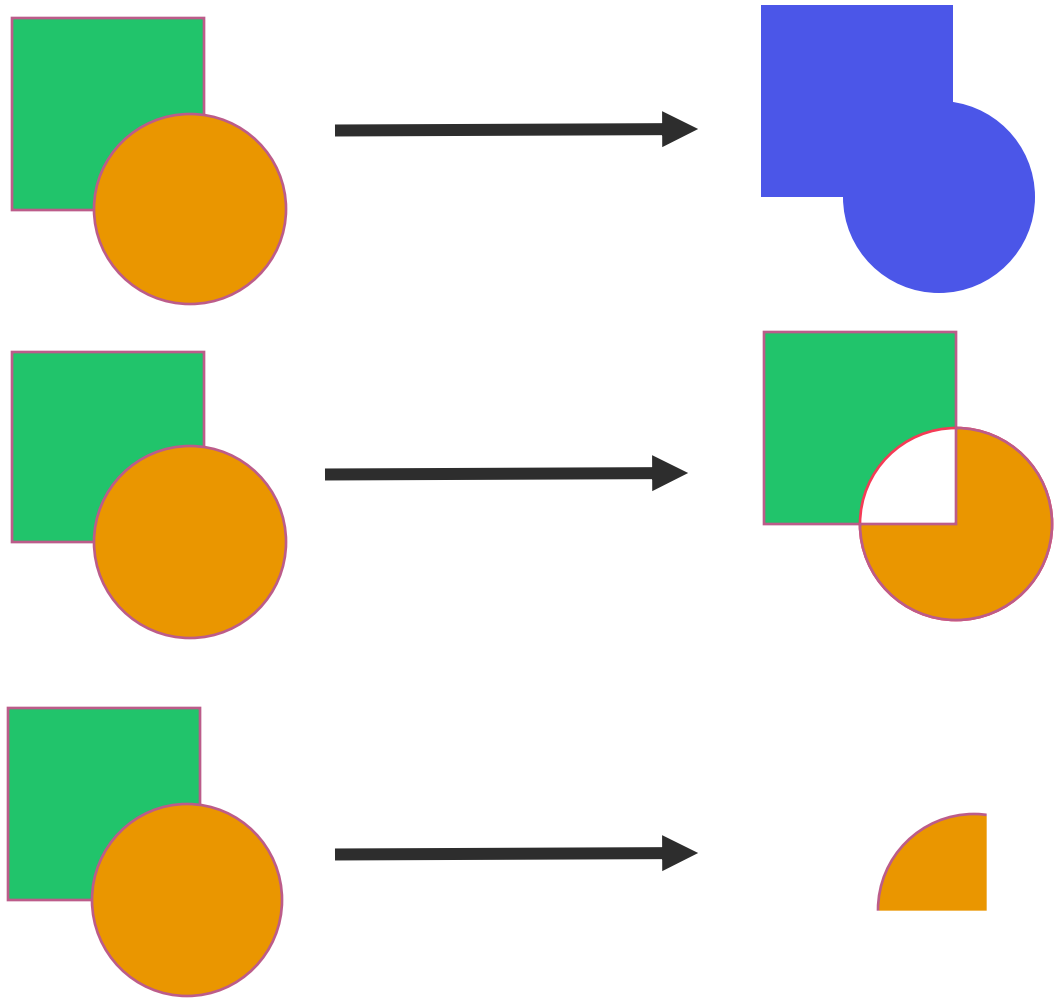
Spatial operations



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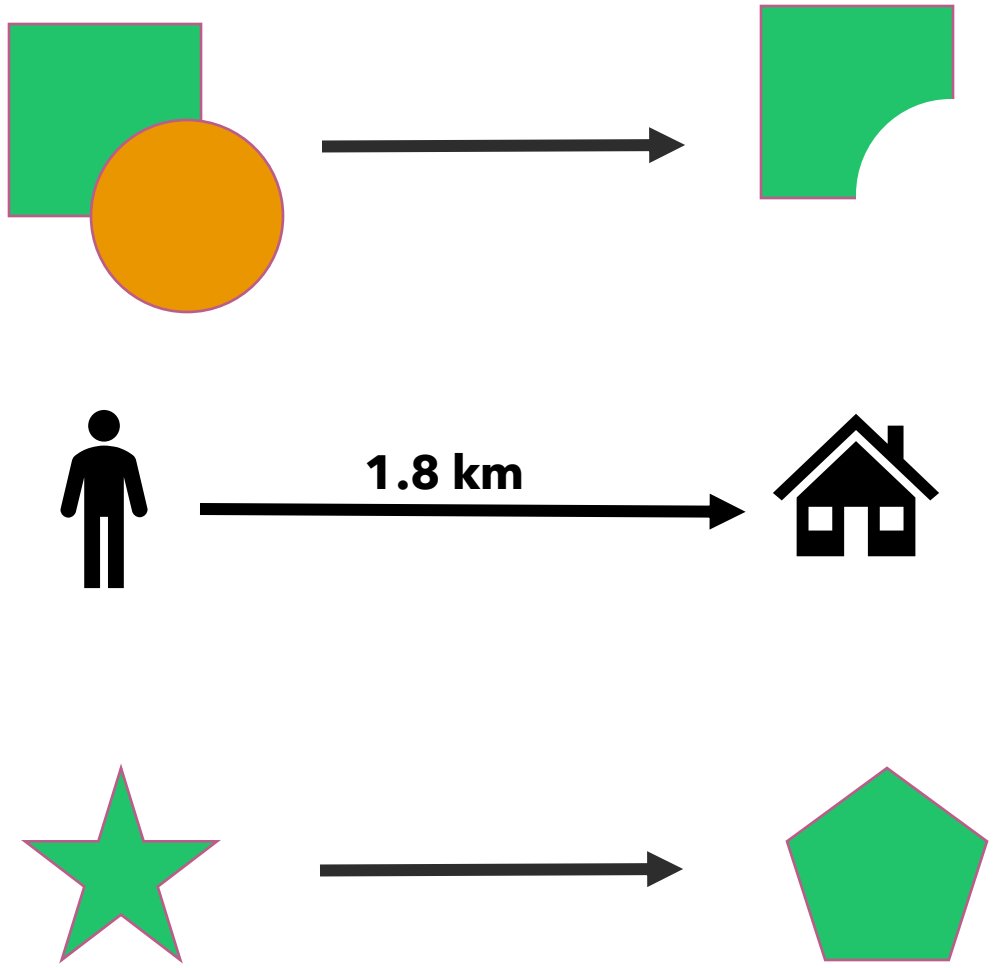
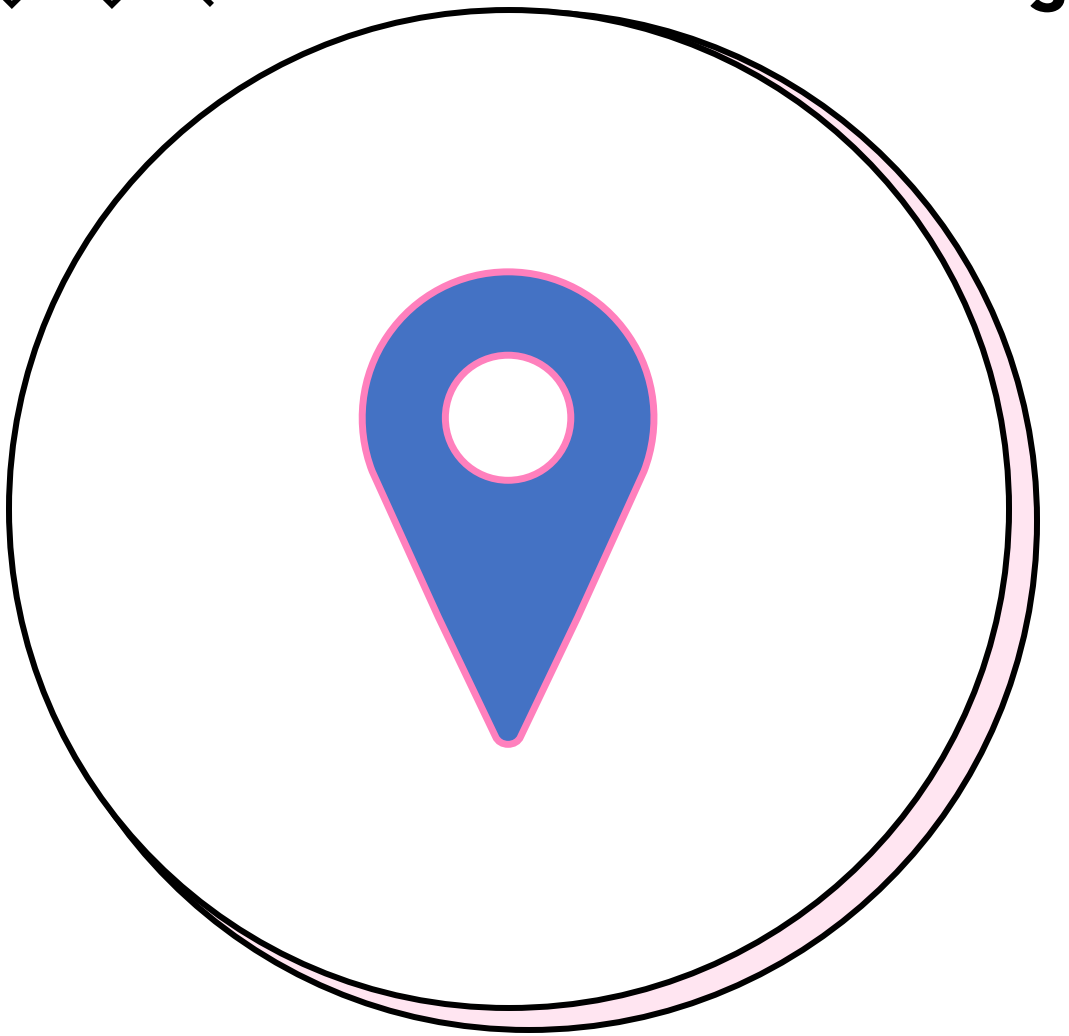
Spatial operations



GIS SOFTWARE AND SPATIAL LIBRARIES

GIS Software

- QGIS
  - https://qgis.org/en/site/
  - Very powerful open source projects
- PostGIS
  - Spatial Extension for PostgreSQL
- ESRI ArcGIS
  - https://www.arcgis.com/index.html
  - large commercial project



Spatial libraries

- Leaflet
  - https://leafletjs.com/
  - Lightweight JS library for maps
  - Also as a react component
- OpenLayers
  - https://openlayers.org/
  - JS API for maps
- MapServer, GeoServer
  - "heavy" solutions
  - Data stored in spatial database on the server, supports wide portfolio of operations
  - Usually used for serving data (as data or maps)