HOW TO SOLVE SPATIAL PROBLEMS USING LINKED-DATA : THE CASE OF PLANNING A SHOPPING CENTER IN DELFT.

Thesis Presentation

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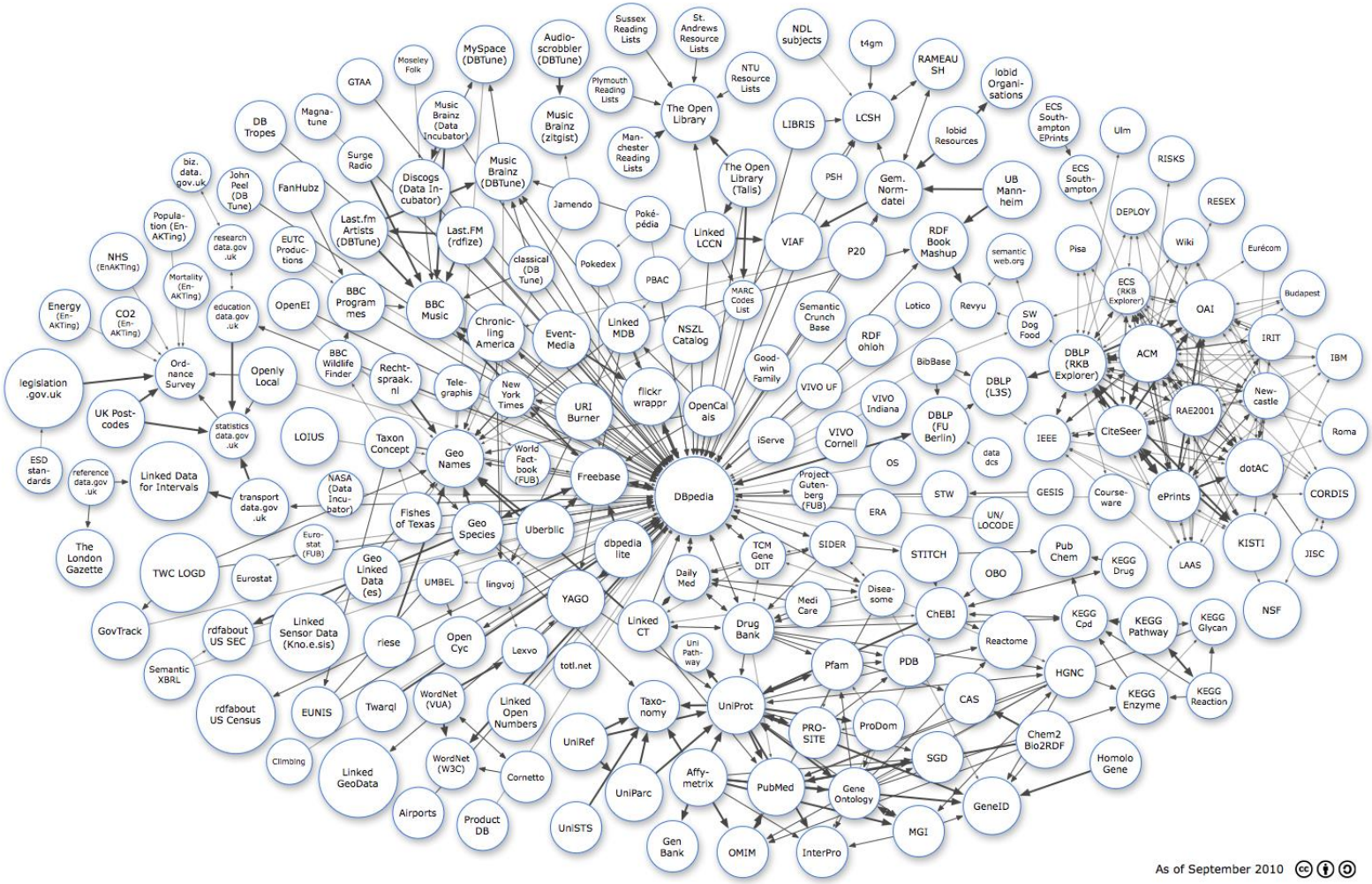
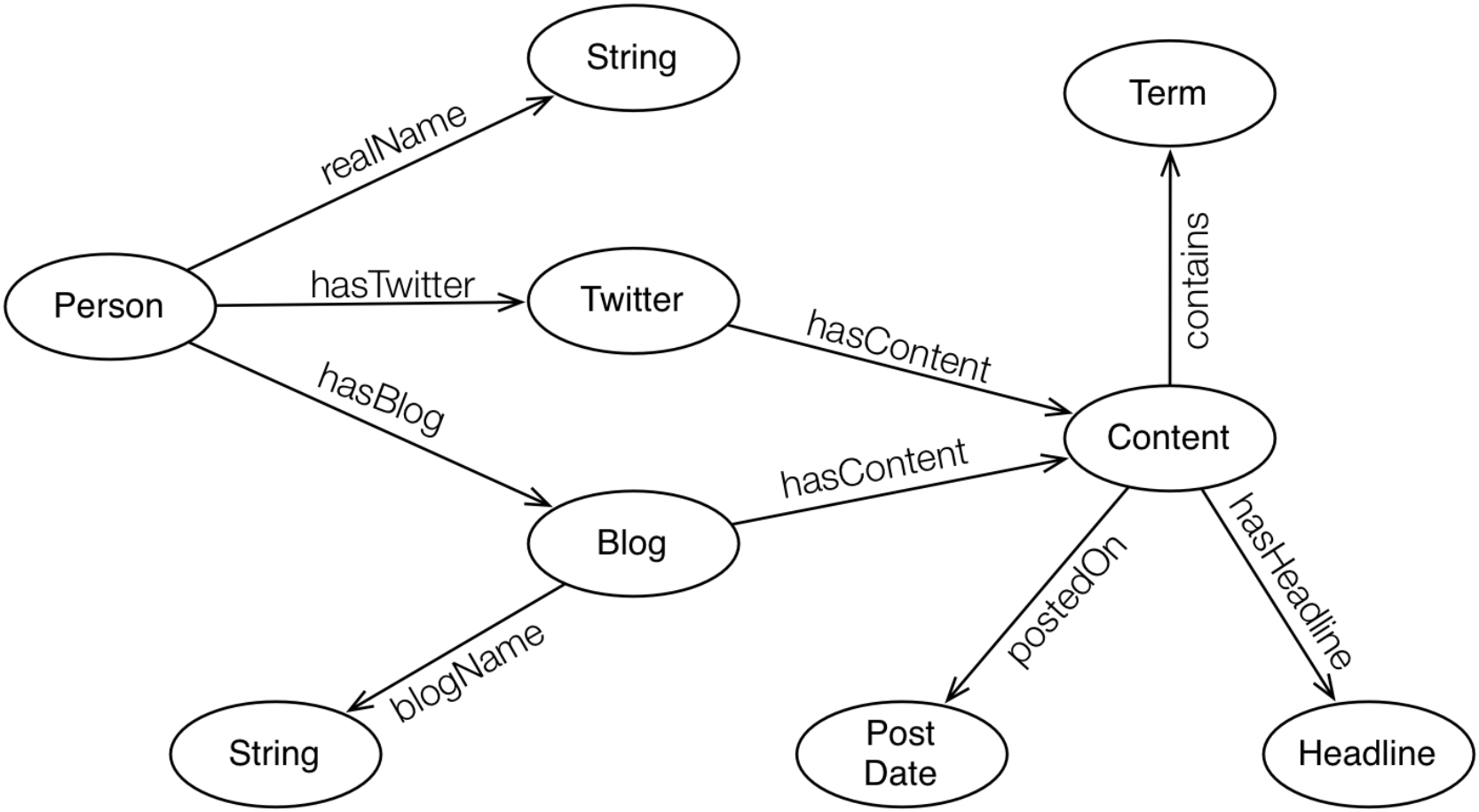
Thesis Presentation Outline

- What is Linked Data?
- Research question and Scope of Research
- Use Case
- Methodology
- Results and Problems
- Conclusion and Future Work

What is Linked Data?



What is RDF, SPARQL and GeoSPARQL?



Scope of research

Explore the possible Linked data approaches available to solve a spatial problem.

Linked data approaches to be compared based on:

- accuracy of the geometries.
- storage and speed efficiency.
- GeoSPARQL Specification compliance.

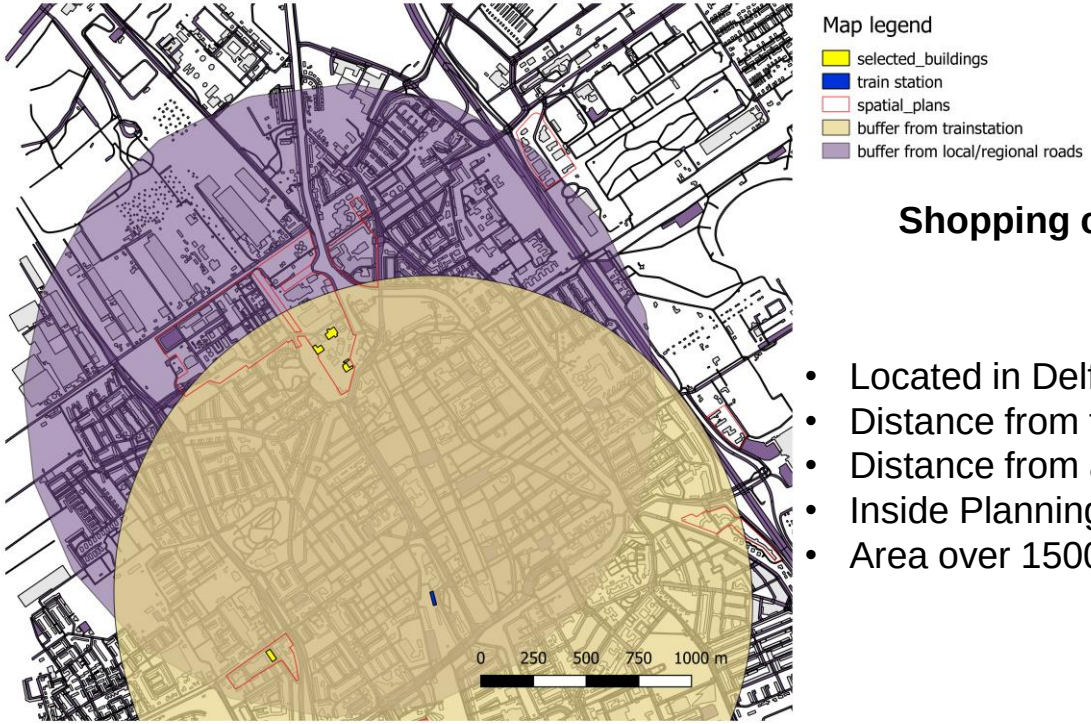
Research questions

To what extend is it feasible to solve spatial problems (positioning a shopping centre) with a linked data approach using relational spatial data?

To answer this question, a series of sub-questions should be answered:

- What are the possible linked-data approaches to position a new shopping centre in Delft?
- To what extend do the different approaches follow the GeoSPARQL specification?
- What benefits and drawbacks do the different linked-data approaches offer over approaches with relational data?
- How efficient is every approach, in terms of speed of execution and storage requirements?

Case study



Shopping center positioning criteria

- Located in Delft.
- Distance from train station <1500 m.
- Distance from a local main road <1500 m.
- Inside Planning zones
- Area over 1500 sq.m.

Materials and Methods

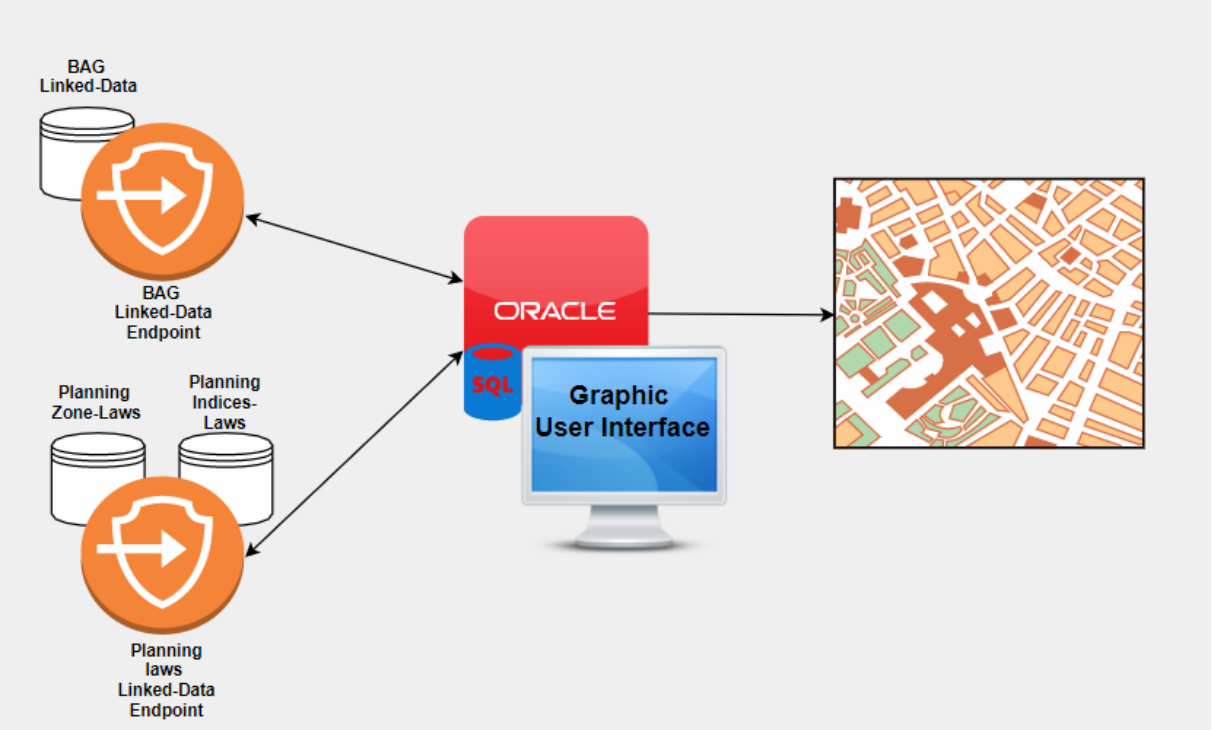
Tools

pdok

QGIS

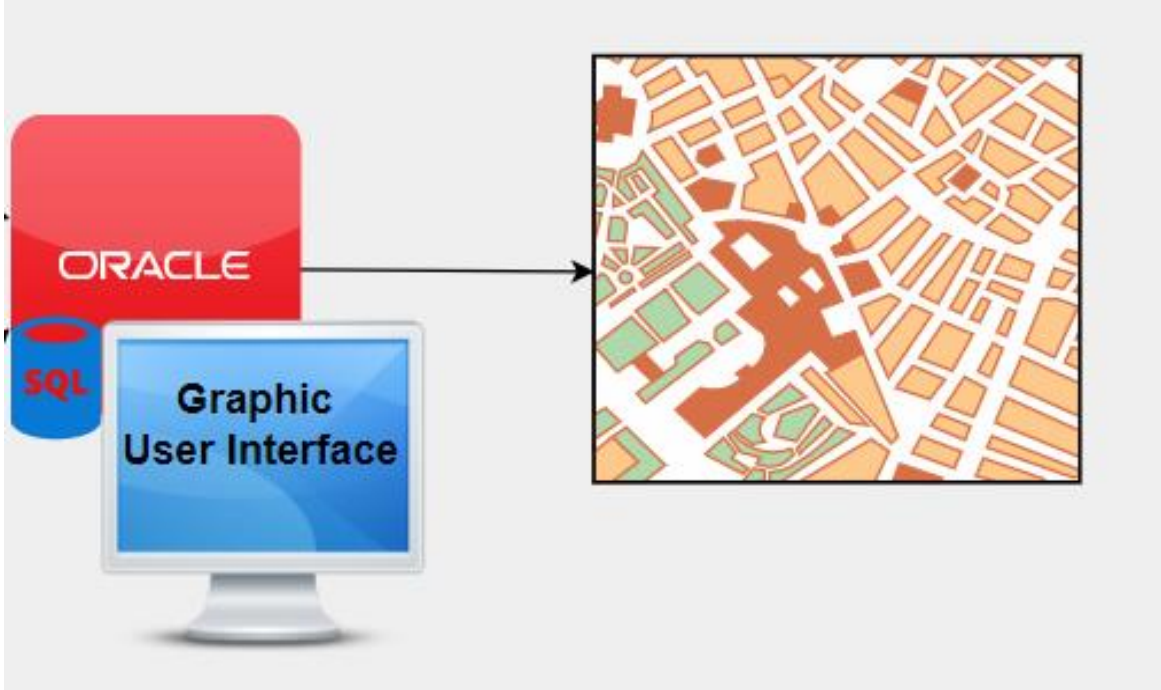
Materials and Methods

Ideal Linked data Architecture



Materials and Methods

Designed Linked data Architecture



Materials and Methods

Methodology

- Step 1: Dummy data and Oracle Spatial and Graph
- Step 2: Forming a Sample spatial query
- Step 3: Real Data Loading
- Step 4: QGIS approach
- Step 5: PDOK approaches - GeoSPARQL endpoint
- Step 6: PDOK approaches - API
- Step 7: Oracle Spatial and Graph approaches - Direct mapping
- Step 8: Oracle Spatial and Graph approaches - R2RML

Materials and Methods

Data

Dummy data-set

Results

Dummy data and Oracle Spatial and Graph

Dummy data: Linked-data solution

Highlights

- Supports spatial queries.
- Supports spatial queries with combination of different geometry serializations.

Problems

- Tolerance.
- Dummy data SRID.
- Duplicate geometries.
- IDs of triplets.
- Inference not 100% in SPARQL.
- Inference not successful.

Results

Forming a Sample spatial query

```
?oA rdf:type :lot. ?oA rdfs:label "train station"@EN.
?oA gsp:hasGeometry/gsp:asWKT ?wkt.
?oL rdf:type :lot. ?oL gsp:hasGeometry/gsp:asWKT ?wkt_l.
?oZ rdf:type :zone. ?oZ gsp:hasGeometry/gsp:asWKT ?wkt_z.
?obR rdf:type :road. ?obR gsp:hasGeometry/gsp:asWKT ?wkt_r.
?obR rdfs:label "main road"@EN.
BIND(ogcf:distance(?wkt_r, ?wkt_l,
<http://xmlns.oracle.com/rdf/geo/uom/M>) as ?main_road_dist).
BIND(ogcf:sfWithin(?wkt_l, ?wkt_z) as ?within_zone).
BIND(ogcf:distance(?wkt, ?wkt_l,
<http://xmlns.oracle.com/rdf/geo/uom/M>) as ?train_dist).
BIND(orageo:area(?wkt_l, "unit=SQ_M") as ?lot_area).
FILTER(?train_dist > 0 && ?train_dist < 1500 && (?within_zone = true)
&& ?lot_area > 1500&& ?main_road_dist < 1500)
```

Sample Query fulfilling the criteria.

Highlights

- Two geometries returned.
- One of the geometries returned is outside the planning zone (top one).

Problems

- It should be adjusted to match the different approaches.

Results
Data Loading

Highlights

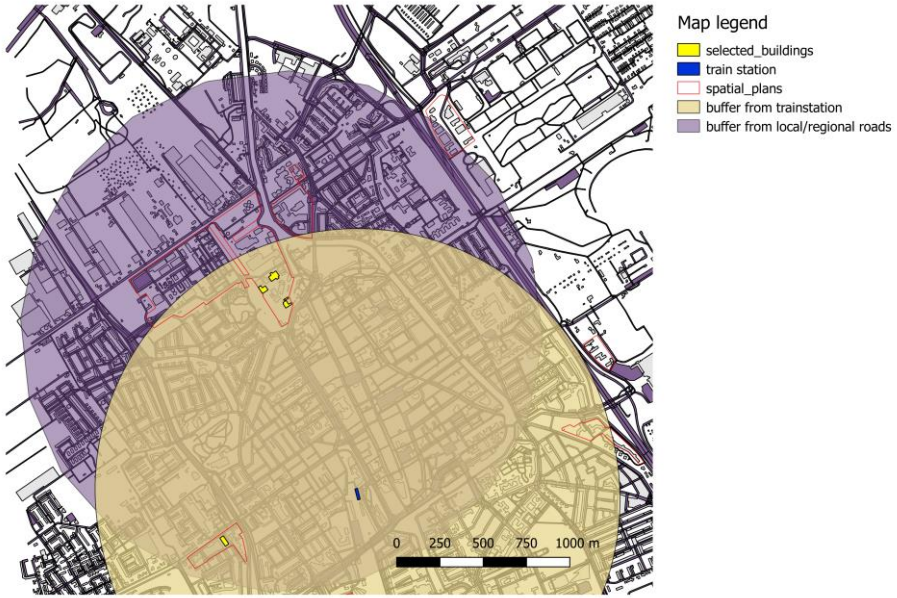
- Relational data needs spatial metadata update to create spatial index.
- Linked-data with more than 4000 bytes (or 4000 characters) need to be stored using CLOB datatype and methodology.

Problems

- SRID transformation on-the-fly might be missing accuracy.
- Huge volume of data (13Gb in compressed form) didn't allow CLOB transformation.

Results

QGIS solution (Benchmark solution)



QGIS Solution

Highlights

- Distances have been translated into buffers.
- 4 Geometries returned.
- Area of buildings calculated and stored.

Problems

- Crushing due to overload.
- Slow spatial analysis.
- Buffer accuracy depends on number of vertices.

Results

PDOK approaches - GeoSPARQL endpoint

```
SELECT  ?wkt2
where{
 ?gemeente a brt:Gemeente .
  ?gemeente rdfs:label  "Delft"@nl.
  ?gemeente brt:geometrie / geosparql:asWKT ?wkt1.


  ?gebouw a brt:Gebouw.
  ?gebouw brt:geometrie / geosparql:asWKT ?wkt2.
  ?gebouw brt:status ?status.
  filter(ogcf:sfWithin(?wkt2, ?wkt1))
} limit 5
```

Table | Response | Pivot Table | Google Chart | Geo

ip: Add a label variable prefixed with the geo variable name to show popups on the map. E.g. `wkt2Label`. Or, append `Color` to change the color of the shape or marker.

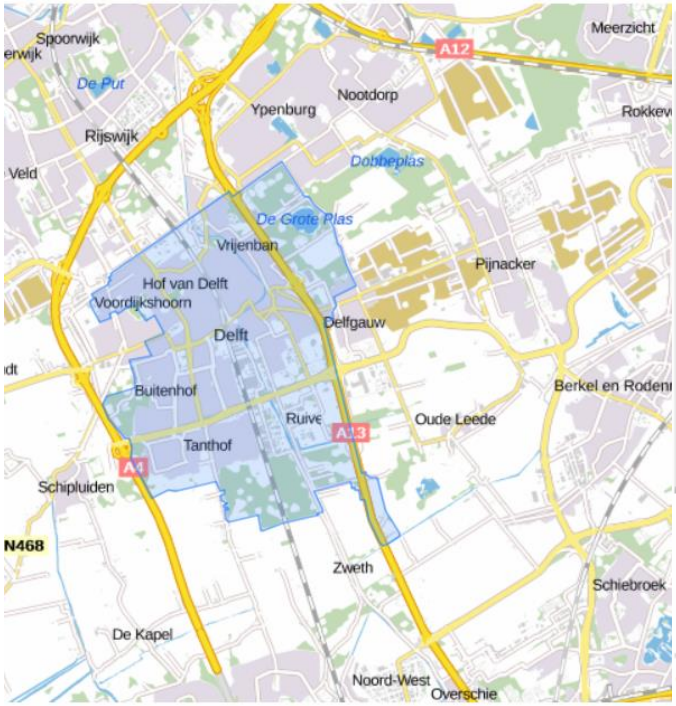
PDOK GeoSPARQL endpoint query

Highlights

- Wide range of data-sets among them BAG and BRT datasets.
- Supports spatial functions.
- Does not hold GML Serialization of geometries.
- Order of queries affects result.
- Supports immediate visualization.
- Feature class is not disjoint from geometry.

Results

PDOK approaches - GeoSPARQL endpoint



Gedefinieerde klassen | Query | Query 1 +

```
prefix owl: <http://www.w3.org/2002/07/owl#>
prefix brt: <http://brt.basisregistraties.overheid.nl/def/top10nl#>
prefix geosparql: <http://www.opengis.net/ont/geosparql#>
PREFIX ogcf: <http://www.opengis.net/def/function/geosparql/>
PREFIX og: <http://ogp.me/ns#>
PREFIX ogc: <http://www.opengis.net/def/>
select  ?gemeente  ?geom ?wkt
where {
    ?gemeente a brt:Gemeente .
  ?gemeente rdfs:label  "Delft"@nl.
  #?gemeent brt:geometrie / geosparql:asWKT ?wkt.
}
```

Table | Response | Pivot Table | Google Chart | Geo

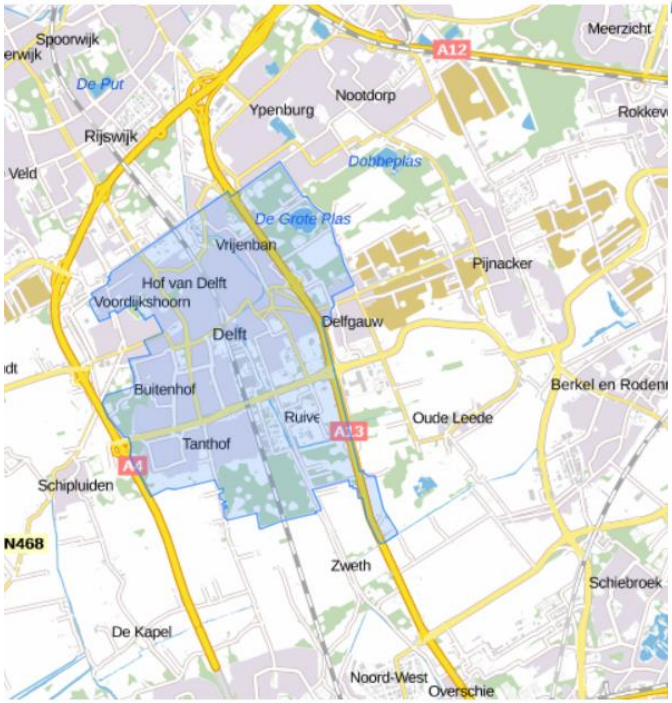
Showing 1 to 1 of 1 entries (in 0.041 seconds)

	gemeente
1	http://brt.basisregistraties.overheid.nl/top10nl/id/registratief-gebied/126538680

PDOK GeoSPARQL endpoint query Gemeente Delft

Results

PDOK approaches - GeoSPARQL endpoint



kadaster

Begrippen | Waardelijsten | Model | Objecten | Kaart | API Documentatie

Search

json ttl xml

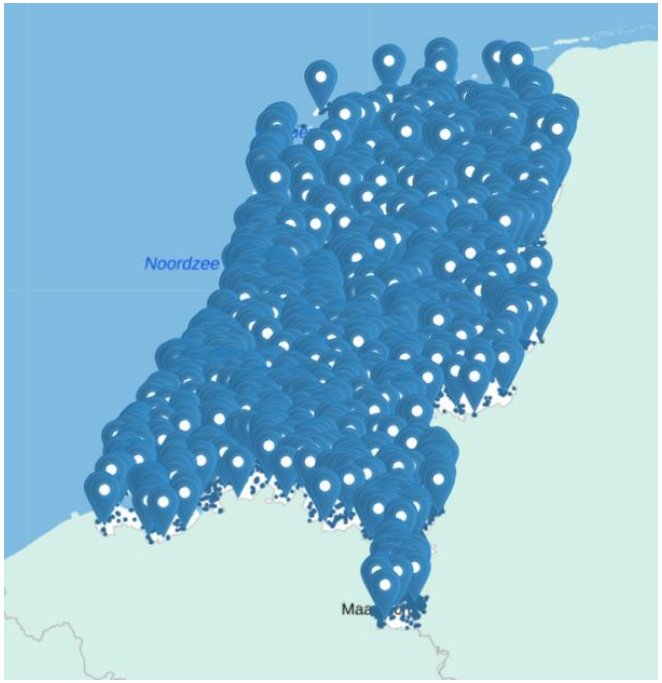
Delft

Type	Gemeente (Zelfstandig, zelfbestuur en autonomie bezittend onderdeel van de staat Nederland, onder het bestuur van een raad, een burgemeester en wethouders.) RegistratiefGebied (Op basis van wet- en regelgeving afgebakend gebied dat als eenheid geldt van politieke/bestuurlijke verantwoordelijkheid of voor bedrijfsvoering.)
brontype	externe data
visualisatieCode	17020
nummer	0503
bronnauwkeurigheid	20
naamOfficieel	Delft
tijdstipRegistratie	2015-03-28
bronactualiteit	2015-01-01
bronbeschrijving	Externe data: Gemeentegrenzen. Gemeentegrenzen gebaseerd op grenswijzigingen in de Basisregistratie Kadaster (BRK). De gemeentegrenzen zijn gegeneraliseerd in de BRT opgenomen.
objectBeginTijd	2013-10-26
tdnCode	801
naamNL	Delft
inDataset	http://brt.basisregistraties.overheid.nl/id/dataset/top10nl

PDOK GeoSPARQL endpoint query Gemeente Delft

Results

PDOK approaches - GeoSPARQL endpoint



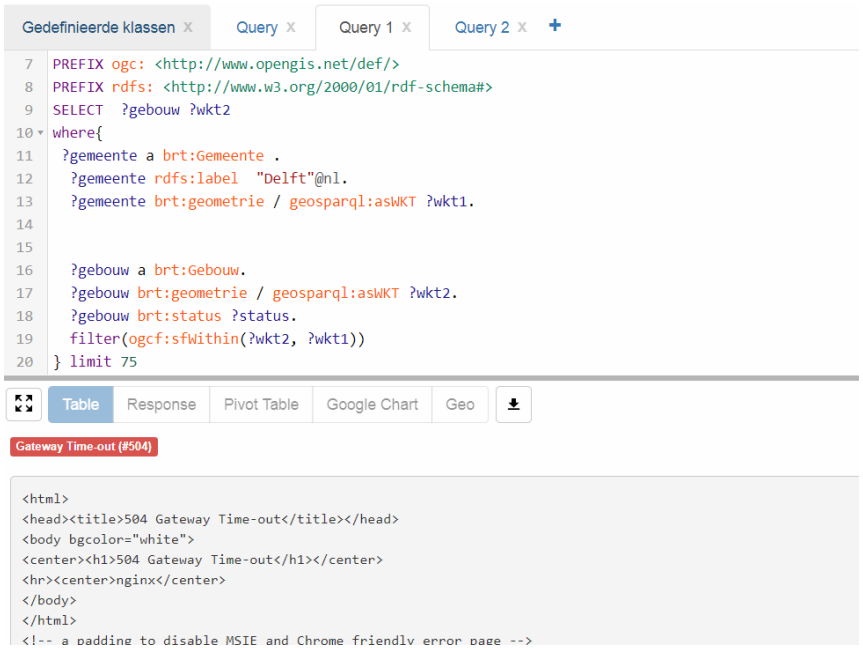
PDOK GeoSPARQL endpoint query misspelling error

Problems

- Misspelled queries return results.

Results

PDOK approaches - GeoSPARQL endpoint



PDOK GeoSPARQL endpoint query time out

Problems

- Server time out.

Results

PDOK approaches - GeoSPARQL endpoint

```
PREFIX ogcf: <http://www.opengis.net/def/function/geosparql/>
PREFIX geosparql: <http://www.opengis.net/ont/geosparql#>
SELECT  ?wkt2 WHERE {
 ?gemeente a brt:Gemeente.
  ?gemeente rdfs:label "Delft"@nl.
  ?gemeente brt:geometrie / geosparql:asWKT ?wkt1.
  ?gebouw a brt:Gebouw.
  ?gebouw brt:geometrie / geosparql:asWKT ?wkt2.
  ?plan a brt:Bedrijventerrein.
  ?plan brt:geometrie / geosparql:asWKT ?wkt3.
  BIND((ogcf:sfWithin(?wkt3, ?wkt1)) as ?res).
  BIND((ogcf:sfWithin(?wkt2, ?wkt3)) as ?res2).
  FILTER(?res=TRUE&&?res2=TRUE)
}limit 1
```

Table | Response | Pivot Table | Google Chart | Geo

Gateway Time-out (#504)

```
<html>
<head><title>504 Gateway Time-out</title></head>
<body bgcolor="white">
<center><h1>504 Gateway Time-out</h1></center>
<hr><center>nginx</center>
</body>
</html>
```

PDOK GeoSPARQL endpoint query time out

Problems

- Server time out.

Results

PDOK approaches - GeoSPARQL endpoint

```
7  PREFIX ogcf: <http://www.opengis.net/def/function/geosparql/>
8  PREFIX geosparql: <http://www.opengis.net/ont/geosparql#>
9  SELECT  ?wkt3 WHERE {
10  ?gemeente a brt:Gemeente.
11   ?gemeente rdfs:label "Delft"@nl.
12   ?gemeente brt:geometrie / geosparql:asWKT ?wkt1.
13   ?gebouw a brt:Gebouw.
14   ?gebouw brt:geometrie / geosparql:asWKT ?wkt2.
15   ?gebouw rdfs:label ?wkt2Label.
16   ?plan a brt:Bedrijventerrein.
17   ?plan brt:geometrie / geosparql:asWKT ?wkt3.
18   ?plan rdfs:label ?wkt3Label.
19   filter(ogcf:sfWithin(?wkt3, ?wkt1)).
20 }
```

Table | Response | Pivot Table | Google Chart | Geo

Showing 1 to 50 of 519 entries (in 60.175 seconds)

PDOK GeoSPARQL endpoint query Duplicate geometries

Problems

- Duplicate Results.

Results

PDOK approaches - GeoSPARQL endpoint


```
1  PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
2  PREFIX brt: <http://brt.basisregistraties.overheid.nl/def/top10nl#>
3  PREFIX ogcf: <http://www.opengis.net/def/function/geosparql/>
4  PREFIX geosparql: <http://www.opengis.net/ont/geosparql#>
5  SELECT distinct ?wkt3 WHERE {
6    ?gemeente a brt:Gemeente.
7    ?gemeente rdfs:label "Delft"@nl.
8    ?gemeente brt:geometrie / geosparql:asWKT ?wkt1.
9    ?plan a brt:Bedrijventerrein.
10   ?plan brt:geometrie / geosparql:asWKT ?wkt3.
11   FILTER (ogcf:sfWithin(?wkt3, ?wkt1))}
```

Table | Response | Pivot Table | Google Chart | Geo

Showing 1 to 20 of 20 entries (in 2.575 seconds)

PDOK GeoSPARQL endpoint spatial plans in Delft correct query

Results
PDOK approaches - API

API Link 1: https://data.pdok.nl/sparql
API Link 2: https://data.labs.pdok.nl/sparql

Highlights

- PDOK's API requires 3 certificates.
- Oracle Wallet Manager is used to store certificates to sites that have additional security.

Problems

- Unknown error did not allow Oracle to access the API.

Results

PDOK approaches - GeoSPARQL endpoint

```
'SELECT *
 WHERE {
  SERVICE <http://lod.openlinksw.com/sparql/> {

    SELECT ?s ?p ?o
    WHERE { ?s ?p ?o }
    LIMIT 10
```

	S$RDFTERM	P$RDFTERM	O$RDFTERM
1	<http://www.openlinksw.com/schemas/virtrdf#DefaultServiceMap-pquad>	<http://www.w3.org/1999/02/22-rdf-syntax-ns#type>	<http://www.openlinksw.com/schemas/virtrdf#QuadMapAT
2	<http://www.openlinksw.com/schemas/virtrdf#DefaultQuadMap-pquad>	<http://www.w3.org/1999/02/22-rdf-syntax-ns#type>	<http://www.openlinksw.com/schemas/virtrdf#QuadMapAT
3	<sys:qmv-bfd922693595ebbb4ef4058dc27adbb6-atable-r-DB.DBA.RDF_IRI_RANK_C>	<http://www.w3.org/1999/02/22-rdf-syntax-ns#type>	<http://www.openlinksw.com/schemas/virtrdf#QuadMapAT
4	<sys:qmv-e44f89e00951ace16b9a2e9df325f4c8-atable-r-DB.DBA.RDF_IRI_RANK_C>	<http://www.w3.org/1999/02/22-rdf-syntax-ns#type>	<http://www.openlinksw.com/schemas/virtrdf#QuadMapAT
5	<http://www.openlinksw.com/schemas/virtrdf#DefaultServiceMap-G-col-G>	<http://www.w3.org/1999/02/22-rdf-syntax-ns#type>	<http://www.openlinksw.com/schemas/virtrdf#QuadMapCo
6	<http://www.openlinksw.com/schemas/virtrdf#DefaultServiceMap-O-col-O>	<http://www.w3.org/1999/02/22-rdf-syntax-ns#type>	<http://www.openlinksw.com/schemas/virtrdf#QuadMapCo
7	<http://www.openlinksw.com/schemas/virtrdf#DefaultServiceMap-P-col-P>	<http://www.w3.org/1999/02/22-rdf-syntax-ns#type>	<http://www.openlinksw.com/schemas/virtrdf#QuadMapCo
8	<http://www.openlinksw.com/schemas/virtrdf#DefaultServiceMap-S-col-S>	<http://www.w3.org/1999/02/22-rdf-syntax-ns#type>	<http://www.openlinksw.com/schemas/virtrdf#QuadMapCo
9	<http://www.openlinksw.com/schemas/virtrdf#DefaultQuadMap-G-col-G>	<http://www.w3.org/1999/02/22-rdf-syntax-ns#type>	<http://www.openlinksw.com/schemas/virtrdf#QuadMapCo
10	<http://www.openlinksw.com/schemas/virtrdf#DefaultQuadMap-O-col-O>	<http://www.w3.org/1999/02/22-rdf-syntax-ns#type>	<http://www.openlinksw.com/schemas/virtrdf#QuadMapCo

Accessing bbc's (http) API using Oracle.

Results

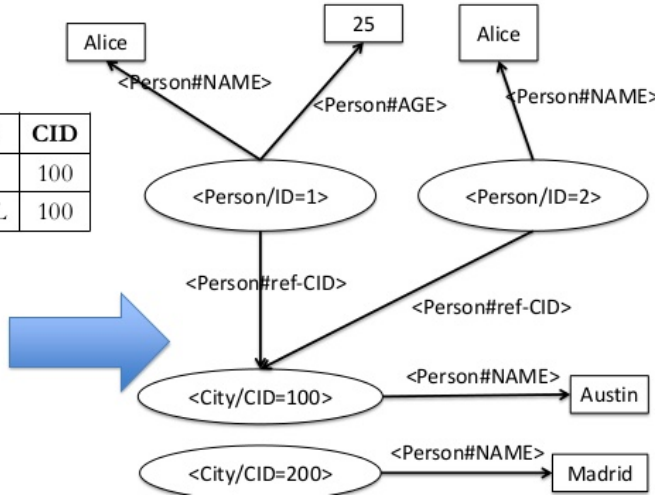
Oracle Spatial and Graph approaches - direct mapping

Person

ID	NAME	AGE	CID
1	Alice	25	100
2	Bob	NULL	100

City

CID	NAME
100	Austin
200	Madrid



Direct mapping example

Results

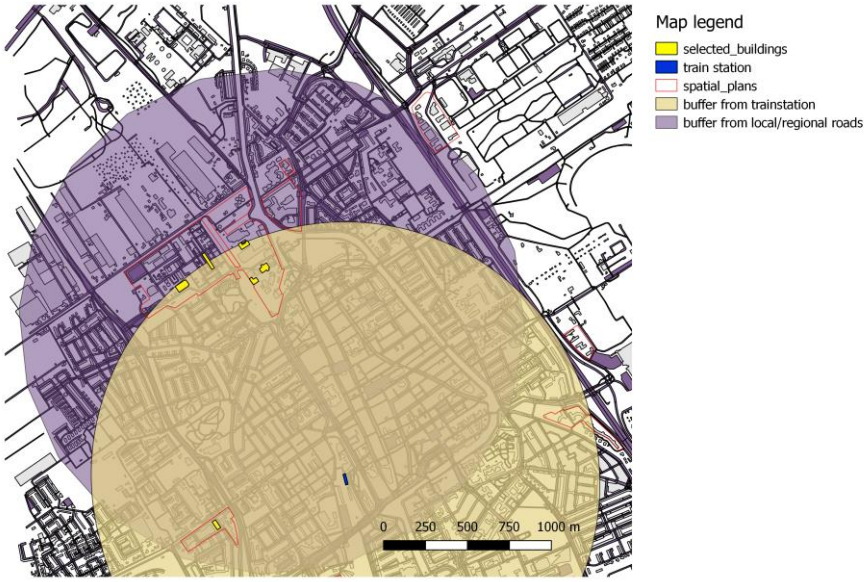
Oracle Spatial and Graph approaches - direct mapping

RML Mapping	
Triples Map	Generates triples fromEVANGELOS.DELFT_PARCELS_S Table
Logical Table	EVANGELOS.DELFT_PARCELS_S
Table Name	"\"EVANGELOS\".\"DELFT_PARCELS_S\""
Subject Map	
Term Type	<http://www.w3.org/ns/r2rml#BlankNode>
RDFS Class	<http://www.example.org/geometries/DELFT_PARCELS_S>
Predicate Object Map	<http://www.example.org/geometries/DELFT_PARCELS_S#OBJECT_ID> -> OBJECT_ID
Predicate Map	<http://www.example.org/geometries/DELFT_PARCELS_S#OBJECT_ID>
Object map	
Column Name	"\"OBJECT_ID\""
Data Type	<http://www.w3.org/2001/XMLSchema#integer>
Predicate Object Map	<http://www.example.org/geometries/DELFT_PARCELS_S#PARCEL_GEOM> -> PARCEL_GEC
Predicate Map	<http://www.example.org/geometries/DELFT_PARCELS_S#PARCEL_GEOM>
Object map	
Column Name	"\"PARCEL_GEOM\""
Data Type	<http://www.opengis.net/ont/geosparql#wktLiteral>
Triples Map	Generates triples fromEVANGELOS.GEBOUW_VLAK_S Table
Triples Map	Generates triples fromEVANGELOS.WEGDEEL_VLAK_S Table
Triples Map	Generates triples fromEVANGELOS.SPATIAL_PLANS Table

Direct mapping in Oracle

Results

Oracle Spatial and Graph approaches - direct mapping



Direct Mapping Solution

Highlights

- 6 Geometries returned.
- Supports data with different SRIDs.
- Supports spatial functions.
- Can hold GML Serialization of geometries.
- Order of queries affects performance.
- Can combine Linked-data with RDF Views.

Results

Oracle Spatial and Graph approaches - direct mapping

```
SELECT distinct l$rdfterm, p$rdfterm
FROM TABLE(SEM_MATCH( '
SELECT ?l ?p
WHERE {    {?l rdf:type :lot.
?l ogc:hasGeometry ?geom.
?geom ogc:asWKT ?wkt.} UNION{ SELECT *  WHERE {SERVICE orardbm:DELFT_PARCELS_view { select * where {?p rdf:type ex:DELFT_PARCELS_S.
    ?p p:PARCEL_GEOM ?wktp. } }}
}
}',
SEM_MODELS('geometries' )  , NULL, SEM_ALIASES(SEM_ALIAS('p','http://www.example/geometries/DELFT_PARCELS_S#'),
SEM_ALIAS('ex','http://www.example/geometries/'),
SEM_ALIAS('','http://www.example.org/geometries/')), NULL, NULL, 'PLUS_RDFT=VC')) order by 1,2;
```

	L$RDFTERM	P$RDFTERM
16	<http://www.example.org/geometries/lot24>	(null)
17	<http://www.example.org/geometries/lot2>	(null)
18	<http://www.example.org/geometries/lot3>	(null)
19	<http://www.example.org/geometries/lot4>	(null)
20	<http://www.example.org/geometries/lot5>	(null)
21	<http://www.example.org/geometries/lot6>	(null)
22	<http://www.example.org/geometries/lot7>	(null)
23	<http://www.example.org/geometries/lot8>	(null)
24	<http://www.example.org/geometries/lot9>	(null)
25	(null)	_:m222mBlankNode1002900C8B9FE322
26	(null)	_:m222mBlankNode100478CCEDE16473
27	(null)	_:m222mBlankNode100647A735B70BFC
28	(null)	_:m222mBlankNode1006D38F7EFDB3A8
29	(null)	_:m222mBlankNode100DAD9B89294CD7
30	(null)	_:m222mBlankNode100E2E22EEE5BA08
31	(null)	_:m222mBlankNode10107119CD40AC5D
32	(null)	_:m222mBlankNode10194EEBB3EC929
33	(null)	_:m222mBlankNode1019F6EF511FD08A

Combining Linked-data and RDF Views

Results

Oracle Spatial and Graph approaches - direct mapping

```
SELECT distinct b$rdfterm, wktb$rdfterm
FROM TABLE(SEM_MATCH( '
SELECT ?b ?wktb
WHERE
  { ?p rdf:type ex:DELFT_PARCELS_S.
    ?p pa:GEOM ?wktp.
    ?b rdf:type ex:GEBOUW_VLAK_S. ?b bu:GEOM ?wktb.
    ?b2 rdf:type ex:GEBOUW_VLAK_S. ?b2 bu:TYPEGEBOUW "overig|treinstation". ?b2 bu:GEOM ?wktb2.
    ?r rdf:type ex:WEGDEEL_VLAK_S. ?r ro:TYPEWEG "lokale weg|regionale weg". ?r ro:GEOM ?wktr.
    ?pl rdf:type ex:SPATIAL_PLANS. ?pl pl:GEOM ?wktpl.
    FILTER( (ogcf:distance(?wktb2, ?wktb, <http://xmlns.oracle.com/rdf/geo/uom/M>)) < 1500  &&
    (ogcf:distance(?wktb2, ?wktb, <http://xmlns.oracle.com/rdf/geo/uom/M>)) > 0 &&
    (orageo:area(?wktb, "unit=SQ_M")) > 1500 &&
    (ogcf:distance(?wktr, ?wktb, <http://xmlns.oracle.com/rdf/geo/uom/M>)) < 1500 &&
    (ogcf:sfWithin(?wktb, ?wktpa)) &&
    (ogcf:sfWithin(?wktb, ?wktp)))
    }',
SEM_MODELS('geometries_dir_view') , NULL, SEM_ALIASES(SEM_ALIAS('bu','http://www.example.org/geome
SEM_ALIAS('pa','http://www.example.org/geometries/DELFT_PARCELS_S#'),
SEM_ALIAS('pl','http://www.example.org/geometries/SPATIAL_PLANS#'),
SEM_ALIAS('ro','http://www.example.org/geometries/WEGDEEL_VLAK_S#'),
SEM_ALIAS('ex','http://www.example.org/geometries/')), NULL, NULL, ' PLUS_RDFT=VC ')) ;
```

SQL | All Rows Fetched: 6 in 141.72 seconds

	B$RDFTERM	WKTB$RDFTERM
1	<http://www.example.org/geometries/GEBOUW_VLAK_S/IDENT=NL.TOP10NL.102571240>	"<http://www.opengis.net/def/crs/EPSG/0/28992> POLYGON ((83778.824 448235.705, 83759.065 44
2	<http://www.example.org/geometries/GEBOUW_VLAK_S/IDENT=NL.TOP10NL.102555243>	"<http://www.opengis.net/def/crs/EPSG/0/28992> POLYGON ((83713.676 448155.01, 83697.903 448
3	<http://www.example.org/geometries/GEBOUW_VLAK_S/IDENT=NL.TOP10NL.102631523>	"<http://www.opengis.net/def/crs/EPSG/0/28992> POLYGON ((83375.052 448314.98, 83434.747 448
4	<http://www.example.org/geometries/GEBOUW_VLAK_S/IDENT=NL.TOP10NL.102637088>	"<http://www.opengis.net/def/crs/EPSG/0/28992> POLYGON ((83633.637 448402.686, 83590.984 44
5	<http://www.example.org/geometries/GEBOUW_VLAK_S/IDENT=NL.TOP10NL.102576876>	"<http://www.opengis.net/def/crs/EPSG/0/28992> POLYGON ((83296.529 448127.885, 83294.338 44
6	<http://www.example.org/geometries/GEBOUW_VLAK_S/IDENT=NL.TOP10NL.102579851>	"<http://www.opengis.net/def/crs/EPSG/0/28992> POLYGON ((83455.316 446733.893, 83435.339 44

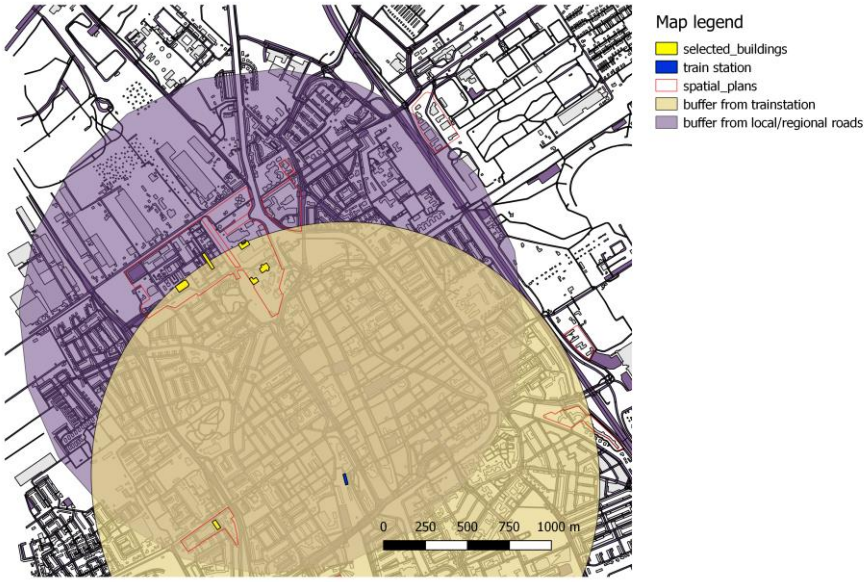
Direct Mapping Solution

Problems

- On-the-fly transformation from one SRID to another can lack in accuracy.
- Feature class can't be disjoint from geometry.
- Does not support inferencing without materialization of the view.
- Combining more views in a query can scale up the processing time significantly.
- Each table has a prefix.
- Misspelling creates results.
- It requires spatial index both in relational data tables and in Linked-data.

Results

Oracle Spatial and Graph approaches - R2RML



R2RML Mapping Solution

Highlights

- 6 Geometries returned.
- Supports data with different SRIDs.
- Supports spatial functions.
- Can hold GML Serialization of geometries.
- Order of queries affects performance.
- Can combine Linked-data with RDF Views.

Results
Oracle Spatial and Graph approaches - R2RML

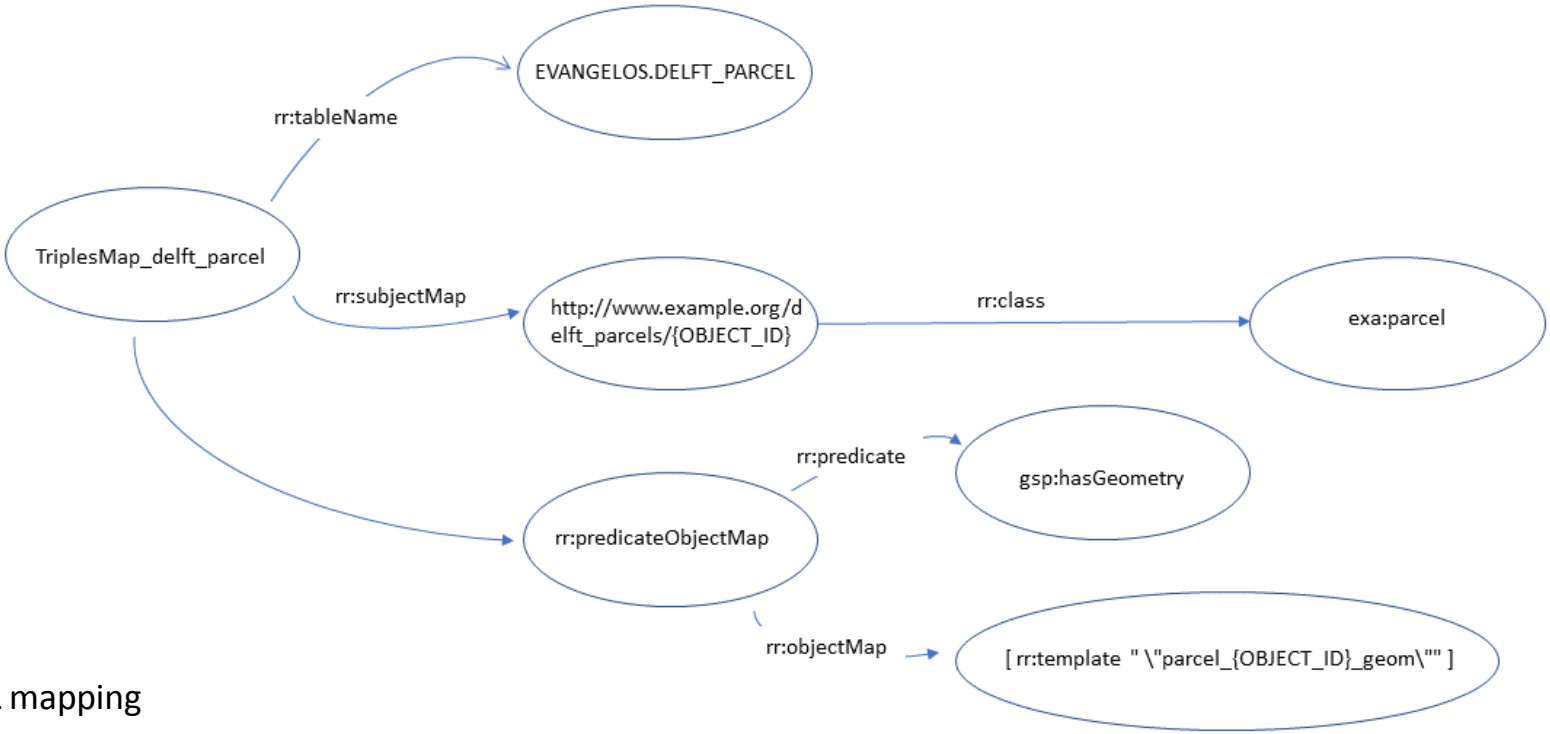
```
ex:TriplesMap_parcels
rr:logicalTable [ rr:tableName "DELFT_PARCELS" ];
rr:subjectMap [
rr:template "http://www.example.org/parcel#{OBJECT_ID}";
rr:class ex:parcel;];

rr:predicateObjectMap [
rr:predicate ex:id;
rr:objectMap [ rr:column "OBJECT_ID" ; rr:datatype xsd:integer ];];

rr:predicateObjectMap [
rr:predicate ex:geom;
rr:objectMap [ rr:column "PARCEL_GEOM" ];].
```

Results
Oracle Spatial and Graph approaches - R2RML

Node	Description/Value
R2RML Mapping	
Triples Map	Generates triples fromDELFT_PARCELS Table
Logical Table	DELFT_PARCELS
Table Name	"DELFT_PARCELS"
Subject Map	
String Template	"http://www.example.org/parcel#{OBJECT_ID}"
RDFS Class	<http://www.example.org/geometries#parcel>
Predicate Object Map	<http://www.example.org/geometries#id> -> OBJECT_ID
Predicate Map	<http://www.example.org/geometries#id>
Object map	
Column Name	"OBJECT_ID"
Data Type	<http://www.w3.org/2001/XMLSchema#integer>
Predicate Object Map	<http://www.example.org/geometries#geom> -> PARCEL_GEOM
Object map	
Column Name	"PARCEL_GEOM"
Predicate Map	<http://www.example.org/geometries#geom>
Triples Map	Generates triples fromGEBOUW_VLAK_S Table
Triples Map	Generates triples fromWEGDEEL_VLAK_S Table
Triples Map	Generates triples fromSPATIAL_PLANS Table

R2RML mapping in Oracle

Results
Oracle Spatial and Graph approaches - R2RML



R2RML mapping

Results
Oracle Spatial and Graph approaches - R2RML

Problems during the mapping process

- Can’t have Feature class with disjoint geometry.
- The mapping should be inserted using N-triples but it is written in Turtle.
- If the relational table column types are of fixed length
  it will produce Object string values with random number of
  preceding and/or trailing spaces that are translated into “%20”
  for each space.

Results
Oracle Spatial and Graph approaches - R2RML

```
SELECT distinct b$rdfterm, wktb$rdfterm
FROM TABLE(SEM_MATCH( '
SELECT ?b ?wktb
WHERE
  { ?p rdf:type ex:parcel.
    ?p ex:geom ?wktp.
    ?b rdf:type ex:building. ?b ex:geom ?wktb.
    ?b2 rdf:type ex:building. ?b2 ex:typegebouw "overig|treinstation". ?b2 ex:geom ?wktb2.
    ?r rdf:type ex:road. ?r ex:typeweg "lokale weg|regionale weg". ?r ex:geom ?wktr.
    ?pl rdf:type ex:plan.
    ?pl ex:geom ?wktpl.
    FILTER( (ogcf:distance(?wktb2, ?wktb, <http://xmlns.oracle.com/rdf/geo/uom/M>)) < 1500  &&
    (ogcf:distance(?wktb2, ?wktb, <http://xmlns.oracle.com/rdf/geo/uom/M>)) > 0 &&
    (orageo:area(?wktb, "unit=SQ_M")) > 1500 &&
    (ogcf:distance(?wktr, ?wktb, <http://xmlns.oracle.com/rdf/geo/uom/M>)) < 1500 &&
    (ogcf:sfWithin(?wktb, ?wktpl)) &&
    (ogcf:sfWithin(?wktb, ?wktp)))
    }',
SEM_MODELS('geometries_rv_r2r') , NULL, SEM_ALIASES(SEM_ALIAS('ex','http://www.example.org/geome
```

SQL | All Rows Fetched: 6 in 64.646 seconds

	B$RDFTERM	WKTB$RDFTERM
1	<http://www.example.org/gebouw_vlak#NL.TOP10NL.102555243>	"<http://www.opengis.net/def/crs/EPSG/0/28992> POLYGON ((83713.676 448155.01, 83697.903 448177.817, 83680.713
2	<http://www.example.org/gebouw_vlak#NL.TOP10NL.102571240>	"<http://www.opengis.net/def/crs/EPSG/0/28992> POLYGON ((83778.824 448235.705, 83759.065 448264.348, 83738.318
3	<http://www.example.org/gebouw_vlak#NL.TOP10NL.102579851>	"<http://www.opengis.net/def/crs/EPSG/0/28992> POLYGON ((83455.316 446733.893, 83435.339 446720.326, 83466.937
4	<http://www.example.org/gebouw_vlak#NL.TOP10NL.102631523>	"<http://www.opengis.net/def/crs/EPSG/0/28992> POLYGON ((83375.052 448314.98, 83434.747 448224.521, 83449.695
5	<http://www.example.org/gebouw_vlak#NL.TOP10NL.102637088>	"<http://www.opengis.net/def/crs/EPSG/0/28992> POLYGON ((83633.637 448402.686, 83590.984 448375.426, 83611.787
6	<http://www.example.org/gebouw_vlak#NL.TOP10NL.102576876>	"<http://www.opengis.net/def/crs/EPSG/0/28992> POLYGON ((83296.529 448127.885, 83294.338 448131.1, 83298.891 4

R2RML Mapping Solution

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Conclusion

Criteria	Dummy Data	GeoSPARQL endpoint	PDOK API	Direct Mapping	R2RML Mapping
SPARQL	✓	✗	✗	✓	✓
Spatial object disjoint from geometry	✓	✗	✗	✗	✗
WKT serialization	✓	✓	✗	✓	✓
GML serialization	✓	✗	✗	✓	✓
Topological functions	✓	✓	✗	✓	✓
Non-topological functions	✓	✓(GeoSPARQL)	✗	✓	✓
Topological Inference	✗	✗	✗	✗	✗
Non-topological Inference	✗	✗	✗	✗	✗
Solution on use case	✗(possible)	✗	✗	✓	✓
Speed of solution	✗	✗	✗	140 Second	61 Second
Storage requirements	Linked-data	✗	✗	Relational data + Meta-data	Relational data + Meta-data

Summary of solutions

Conclusion

Geometry results

Discrepancies between QGIS solution and proposed mapping solutions.

QGIS solution

Mapping solutions

Conclusion
on the Research Problem

Answering the sub-research questions:

- What are the possible linked-data approaches to position a new shopping center in Delft?
- To what extend do the different approaches follow the GeoSPARQL specification?
- What benefits and drawbacks do the different linked-data approaches offer over approaches with relational data?
- How efficient is every approach, in terms of speed of execution and storage requirements?

Answering the research question:

To what extend is it feasible to solve spatial problems (positioning a shopping center) with a linked-data approach using relational spatial data?

..further research

Maturation of Linked-data technology.

- Improve support for geometries in Linked-data format.
- Improve stability and optimization of queries.
- Allow visualization.
- Improve error reporting.

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Theo Tijsen

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Thank you for your attention!

TU Delft

Questions?