Ontology-based data access

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Semantic Web Technologies

Principle and hypotheses

- View datasets through an ontology, not through a database schema
- Hypotheses/observations
  - the main bottleneck in data access is the complexity of the database schemas
  - the vocabulary of an ontology is more understandable than the table and column names

Reference

- Kharlamov et al. (2016) Ontology Based Data Access in Statoil. Web Semantics: Science, Services and Agents on the World Wide Web 44 (2017) 3–36

Geological data at statoil

Exploration and Production Data Store (EPDS)

- 3000 tables and views
- about 37,000 columns
- naming conventions for schema elements, constraints, and the structure of EPDS's schema are complex and considerable parts of it have limited or no documentation.
- the major challenge with accessing EPDS is the schema complexity

Finding the right data is hard !

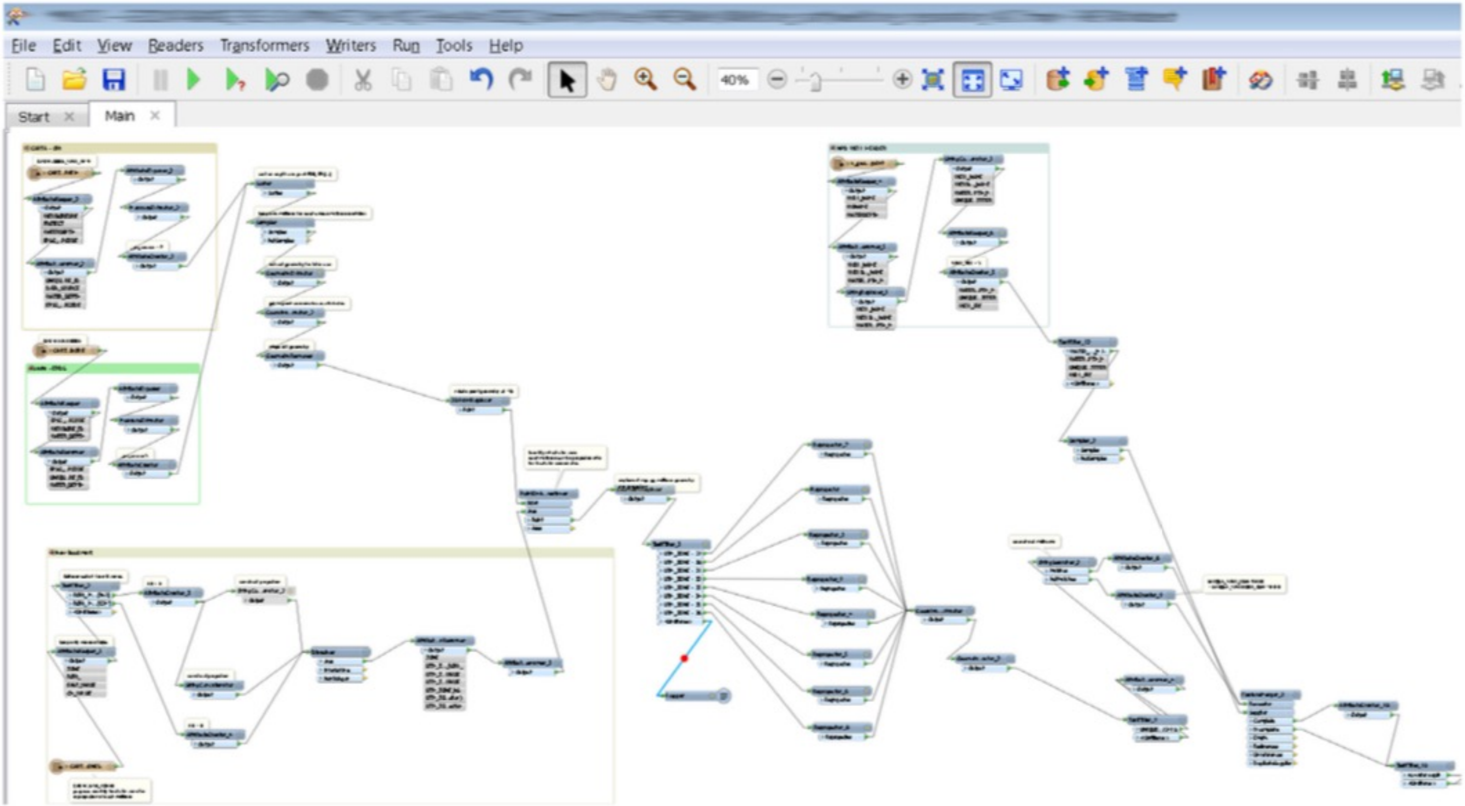
Table 1
Database metrics: Showing number of schema constructs for each database schema. Zero-values are removed from the table for readability.

	EPDS	GeoChemDB	Recall	CoreDB	OW	Compass
Overview						
Tables	1595	90	22	15	78	895
Mat. views	27	4				
Views	1703	41	12		1026	1004
Columns	8378	3396	430	63	16668	30638
Tables by no. rows						
0 rows	1130	3	2		15	512
1 row	1152	9	2		4	34
1 < rows ≤ 10	135	9	1	4	15	117
10 < rows ≤ 100	83	20	3	2	17	80
100 < rows ≤ 1 000	58	30	3	4	12	87
1 000 < rows ≤ 10 000	63	10	5	1	11	42
10 000 < rows ≤ 100 000	57	4	2	1	2	19
100 000 < rows ≤ 1000 000	35	3	4	2		4
1 000 000 < rows	12	3	2	1		

Access Points

- Access points are typically based on **materialized** special purpose database **views**.
- The process of making such view consists of the three **ETL** steps:
  - Extracting, Transforming, Loading data.
  - An SQL query for data extraction generated by the extraction tools may contain thousands of words and have 50–200 joins.
- Building an ETL process consists of a myriad of data access and processing steps, many of which require deep knowledge of the data that is being processed and how it is represented.
- IT staff become the de facto mediators between geologists and databases

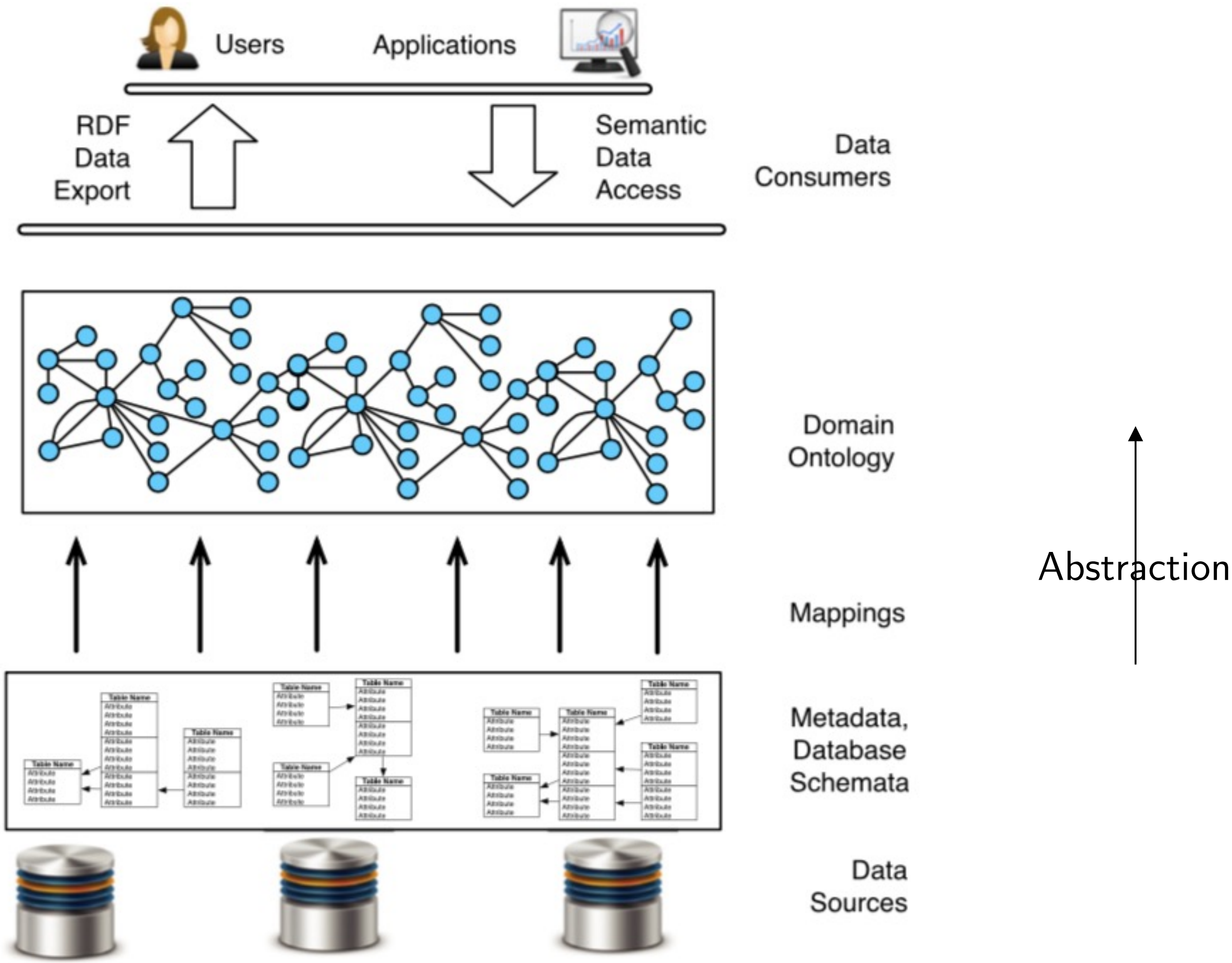
ETL process in FME



Ontology Based Data Access

- Use a familiar vocabulary
  - Provide the user with access to the data store via the use of a domain specific vocabulary of classes and properties that the user is familiar with.

- This vocabulary is related to the database schema via mappings
  - Technical details of the database schema are hidden from end-users.


Users
Applications
RDF
Data
Export
Semantic
Data
Access
Data
Consumers
Domain
Ontology
Mappings
Metadata,
Database
Schemata
Data
Sources
Abstraction

Principles

- query over the domain vocabulary $\rightarrow$
  - queries over the database schemas
  - executed over the data by DBMS.
- the domain vocabulary enhanced with formal axioms
  $\rightarrow$ an ontology
- exploit ontological axioms to enrich query answers with implicit information
  $\Rightarrow$ ontological reasoning
- data are treated under the Open World Assumption
  $\Rightarrow$ can be incomplete w.r.t. to the ontology axioms.

Query Answer Enrichment

Enrichment of answers is done via logical reasoning:

User query Q over the domain vocabulary

$\rightarrow$ rewriting $\rightarrow$

New query over this vocabulary

- logically equivalent to Q w.r.t. the ontology
- "absorbs" a fragment of the ontology relevant for answering Q

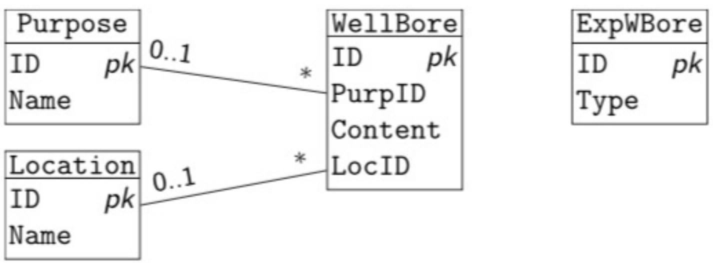
Example

The data may state that the rock layers in the area surrounding the Ekofisk field are chalk, but not their age

The user asks for *wellbores that penetrate rock from the Cretaceous era*

- Direct query: will not return the wellbores of Ekofisk
- Rewritten query: will also ask for wellbores that penetrate chalk, and thus return the Ekofisk's wellbores.
  - Using the knowledge Chalk has been formed in the Cretaaceous era

DB schema



(a) Database schema.

Location:

ID	Name
L1	Norway
L2	UK

Purpose:

ID	Name
P1	Shallow
P2	Injection

Wellbore:

ID	PurpID	Content	LocID
W1	P1	Dry	L1
W2	P2	Oil	L2

ExpWBore:

ID	Type
E1	Active
E2	Discovery

(b) Database instance.

Ontology

Classes

- Location
- Purpose
- WellBore
- ExplorationWellBore
- ShallowWelleBore
- Properties

Properties

- hasLocation
- hasPurpose
- hasName

Axioms

- ExploratioWellBore $\sqsubseteq$ WellBore
- ShallowWelleBore $\sqsubseteq$ WellBore
- WellBore $\sqsubseteq \exists$ hasContent . $\top$

Mappings

- "cast" functions
  - fo: Database entity identifier $\rightarrow$ URI   e.g. 'France' $\rightarrow$ http://example.com/country/France
  - fv: Database value $\rightarrow$ Literal

- translation functions
  - Class(fo(x)) $\mapsto$ SQL(x),   // fo(x) rdf:type Class
  - Property(fo(x),fo(y)) $\mapsto$ SQL(x,y),   // fo(x) Property fo(y)
  - Property(fo(x),fv(y)) $\mapsto$ SQL(x,y),   // fo(x) Property fv(y)

  - SQL(x) and SQL(x, y) are SQL queries with respectively one and two output variables

Example

$$\text{ExplorationWellBore}(f(\mathtt{ID})) \mapsto \tag{4}$$

```
SELECT ID
FROM ExpWBore
```

$$\text{ShallowWellBore}(f(\mathtt{W.ID})) \mapsto \tag{5}$$

```
SELECT W.ID
FROM WellBore W, Purpose P
WHERE W.PurpID = P.ID
  AND P.Name = "Shallow"
```

$$\text{hasLocation}(f(\mathtt{ID}), f(\mathtt{LocID})) \mapsto$$

```
SELECT ID, LocID
FROM WellBore
```

(e) Mappings.

- small SQL query compared to SQL code of ETL processes behind access points.
- SQL code of individual mappings more readable and more maintainable
- can be reused by many data access tasks: they ‘connect’ ontologies to DBs and then can be used for any query over the ontology,

Query answering over ontologies and in OBDA

```
SELECT ?x WHERE { ?x :hasContent ?y. }
```

- rewritten into a union query s.t. each query of Q′ is subsumed by Q .
  - compilation of relevant ontological information, similar to the resolution procedure in Prolog. Equivalent to DL-Lite reasoning (*)

```
SELECT ?x WHERE
{ ?x hasContent ?y. }
UNION { ?x a WellBore. }
UNION { ?x a ExplorationWellBore. }
UNION { ?x a ShallowWellBore. }
```

* D. Calvanese, G. De Giacomo, D. Lembo, M. Lenzerini, R. Rosati, Tractable reasoning and efficient query answering in description logics: The DL-Lite family, JAR 39 (3) (2007) 385–429.

unfolding

- based on the mappings

```
SELECT f(ID) AS x FROM ExpWBore
UNION
SELECT f(W.ID) AS x FROM WellBore W, Purpose P
WHERE W.PurpID = P.ID AND P.Name = "Shallow".
```

Bootstraping and Importing

- Given a relational database D, generate an instance (D, V, O, M).
  - Vocabulary and Ontology generation: Given D,
    - create a vocabulary V (e.g. using table and column names)
    - create an ontology O over V.
  - Mapping generation: Given D, V, and O create a set of mappings M relating D with V.
- Importing: Given an instance $(D, V, O1, M)$ and an ontology $O2$, return an instance (D, V, O, M), where O is the alignment of $O1$ and $O2$.

Bootstrap ontology

Extracted from the relational schemas

- mapping rules
  - mirror RDB schemata by essentially translating
    - each (non-binary) table into an OWL class;
    - each attribute not involved in a foreign key into an OWL datatype property;
    - each foreign key into an OWL object property.
  - detect patterns in the RDB
    - generate corresponding OWL axioms

Alignment

A way to extend a bootstrapped ontology is to align it with an existing high quality domain ontology.

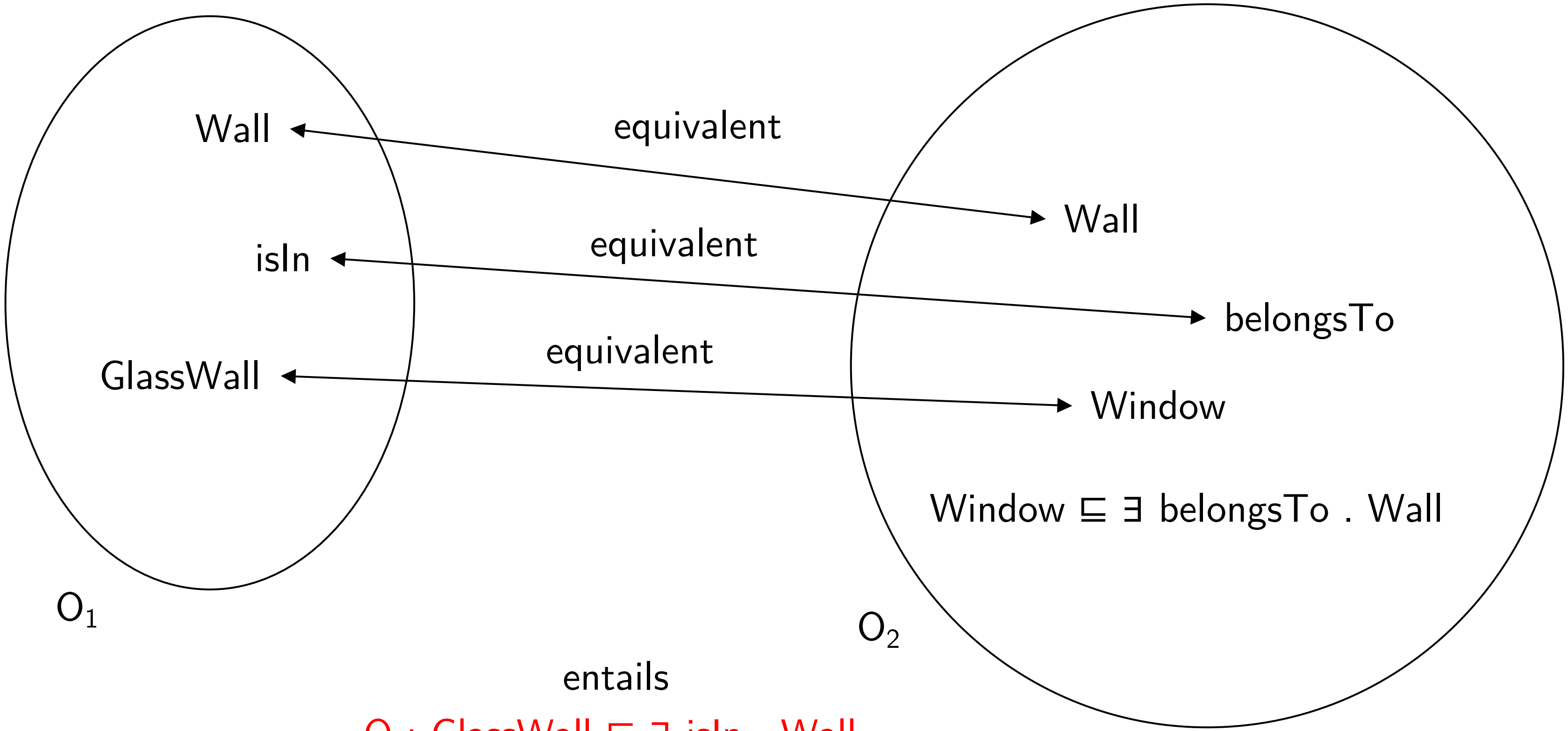
- Extended version of the ontology alignment system LogMap
  - derives OWL 2 equivalence and subclass(subproperty) axioms between the terms from O1's and O2's vocabularies.

Minimize the violations of the conservativity principle

- The resulting ontology O does not entail (many) axioms over O_1's and O_2 's vocabulary which are not already entailed by O_1 or O_2.

Necessity to avoid side-effects:

- query answering over O produces answers that are unexpected by domain experts, and that would not be obtained if one queries O_1 alone,
- O entails axioms over O_2 's terms that are unexpected and counter-intuitive for domain experts.



entails

O_1: GlassWall $\sqsubseteq \exists$ isIn . Wall