Bridging RDF Graph and Property Graph Data Models

- LDBC 2016

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Oracle Spatial and Graph

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Safe Harbor Statement

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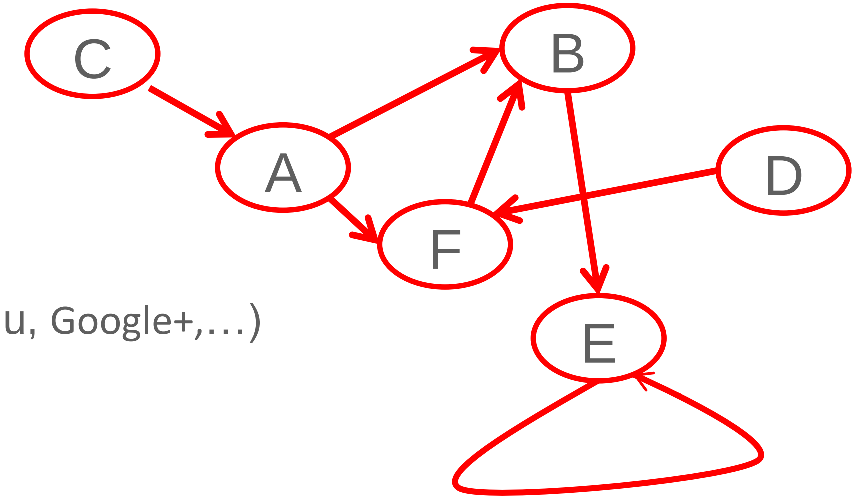
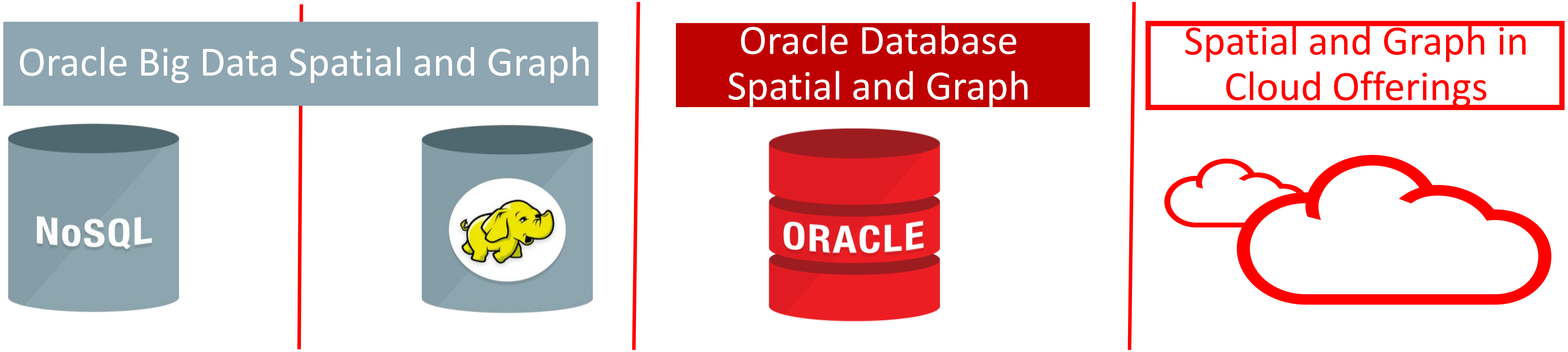
Overview of Graph

- What is a graph?
  - A set of vertices and edges (with optional properties)
  - A graph is simply **linked data**
- Why do we care?
  - Graphs are everywhere
    - Road networks, power grids, biological networks
    - Social networks/Social Web (Facebook, Linkedin, Twitter, Baidu, Google+,…)
    - Knowledge graphs (RDF, OWL)
  - Graphs are intuitive and flexible
    - Easy to navigate, easy to form a path, natural to visualize
    - Do not require a predefined schema



Oracle’s Graph Strategy

Enable Spatial and Graph use cases on every platform



Oracle Big Data Spatial and Graph

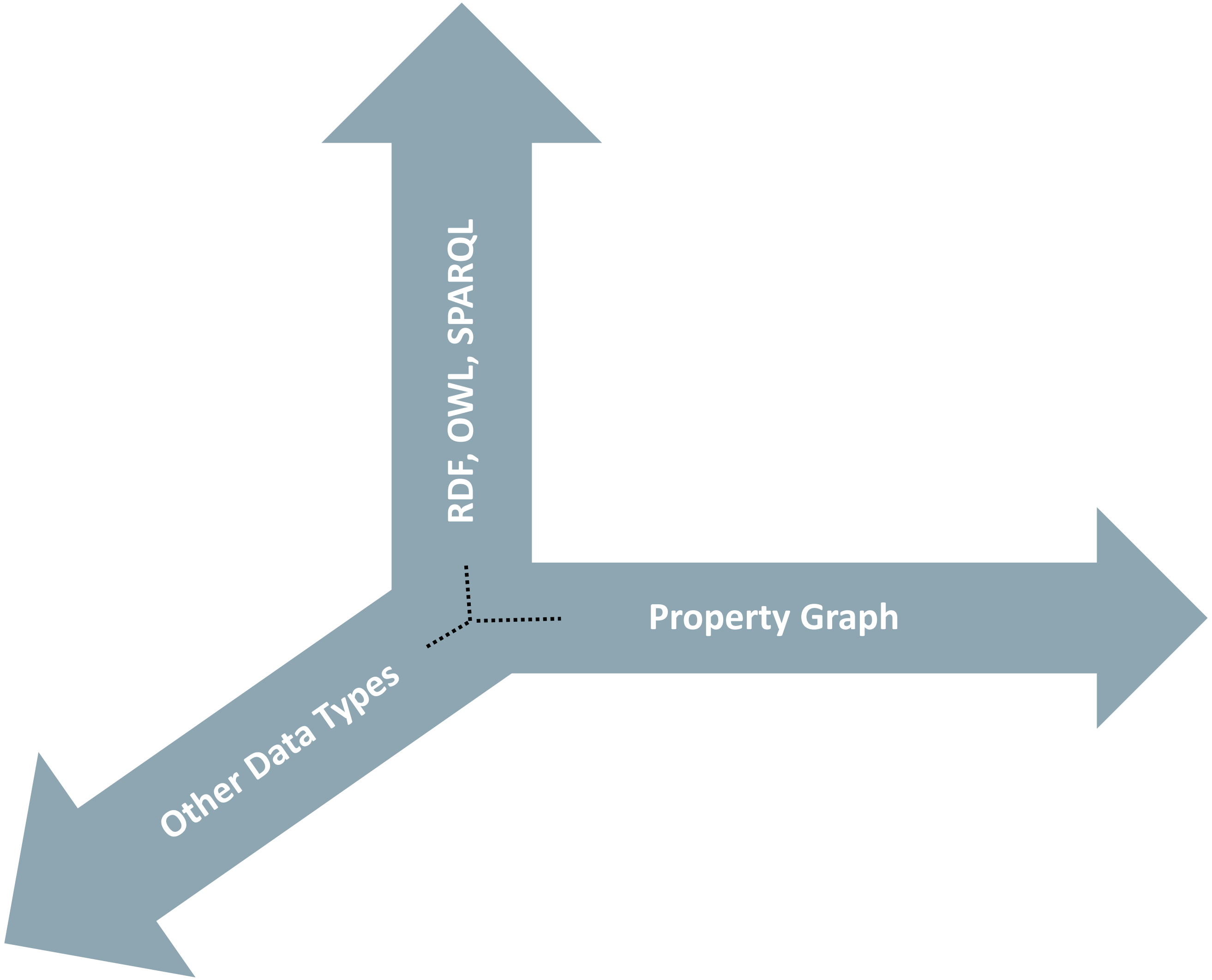
Oracle Database Spatial and Graph

Spatial and Graph in Cloud Offerings

Big Data:
Single Model Data Store

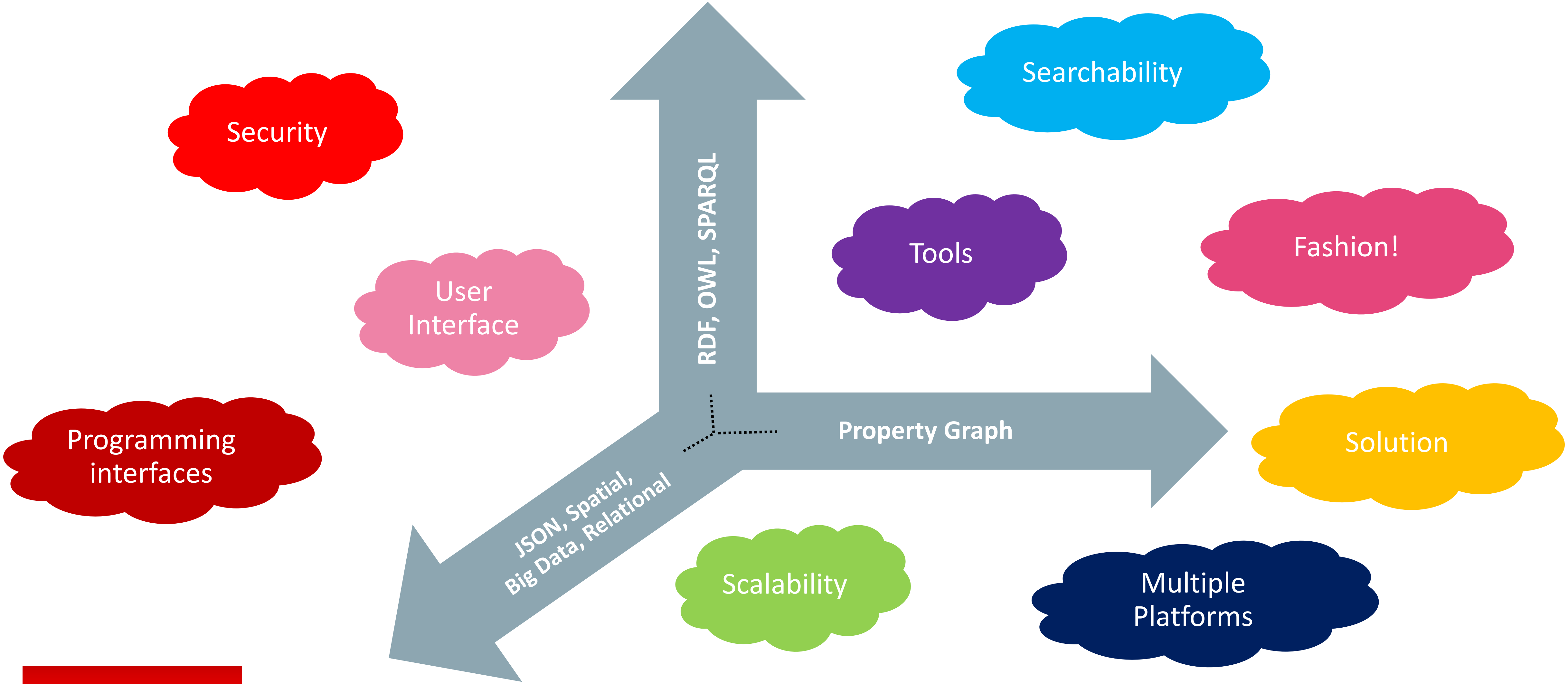
Database 12c:
Polyglot (Multi-model) Data Store

Direction of Development in Graph & Semantics Area



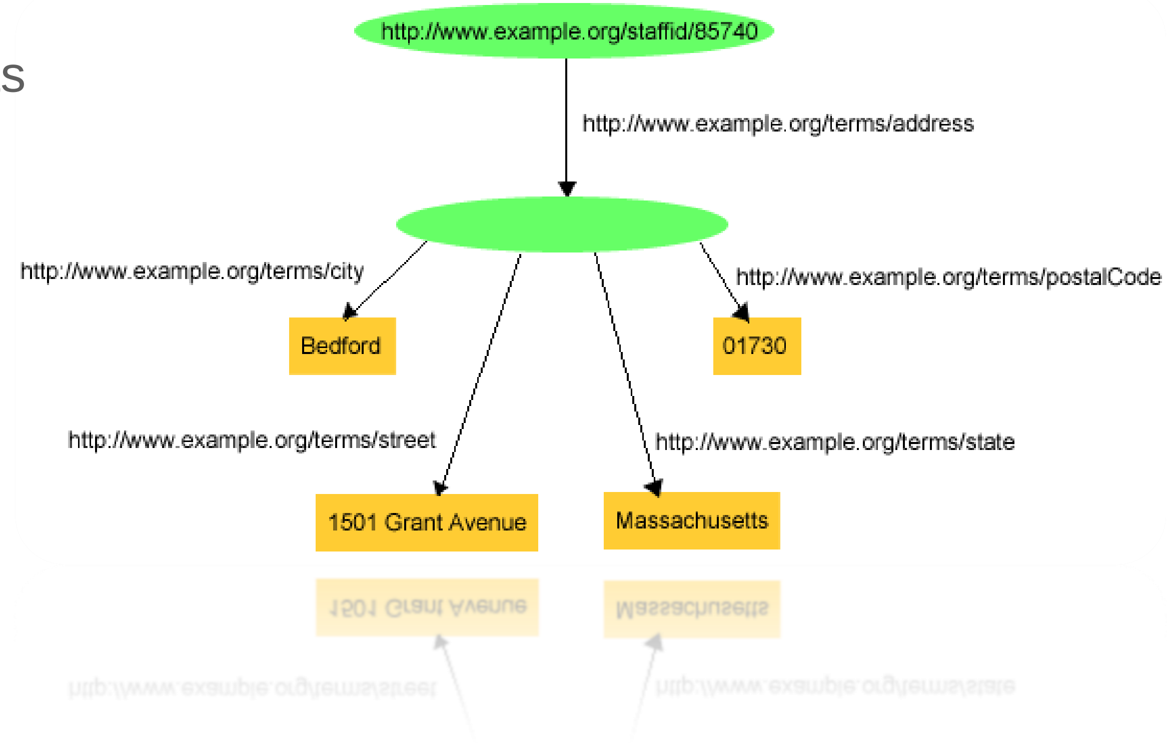
Direction of Development in Graph & Semantics Area

“Facets”

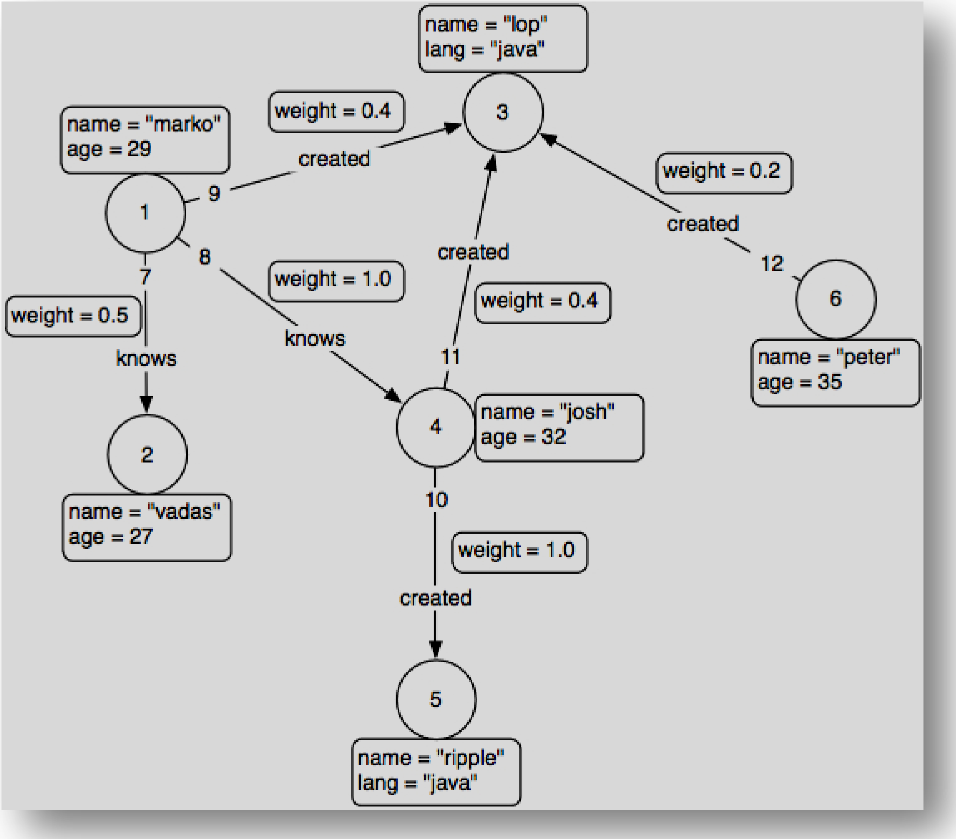


RDF Graph Data Model

- Resource Description Framework
  - URIs are used to identify
    - Resources, entities, relationships, concepts
    - Data identification is a *must* for integration
- RDF Graph defines semantics
- Standards defined by W3C & OGC
  - RDF, RDFS, OWL, SKOS
  - SPARQL, RDFa, RDB2RDF, GeoSPARQL
- Implementations
  - Oracle, IBM, Cray, Systap
  - Franz, Ontotext, Openlink, Jena, Sesame, …


http://www.example.org/staffid/85740
http://www.example.org/terms/address
http://www.example.org/terms/city
http://www.example.org/terms/postalCode
Bedford
01730
http://www.example.org/terms/street
http://www.example.org/terms/state
1501 Grant Avenue
Massachusetts

Property Graph Data Model



- A set of vertices (or nodes)
  - each vertex has a unique identifier.
  - each vertex has a set of in/out edges.
  - each vertex has a collection of **key-value** properties.
- A set of edges
  - each edge has a unique identifier.
  - each edge has a head/tail vertex.
  - each edge has a label denoting type of relationship between two vertices.
  - each edge has a collection of **key-value** properties.
- Blueprints Java APIs
- Implementations
  - Oracle, Neo4j, DataStax(Titan), InfiniteGraph, Dex, Sail, MongoDB …

https://github.com/tinkerpop/blueprints/wiki/Property-Graph-Model

2 Graph Data Management & Analysis Products
Property Graph & RDF Graph

ORACLE BIG DATA

Link Analysis

Property Graph Model

- Graph Search & Analysis
- Big Data analytics
- Entity analytics

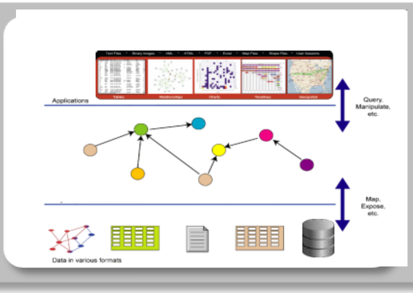
- National Intelligence
- Public Safety
- Social Media search
- Marketing - Sentiment

ORACLE DATABASE 12c

Data Integration
Semantic Web

RDF Data Model

- Data Integration
- Knowledge representation
- Inferencing



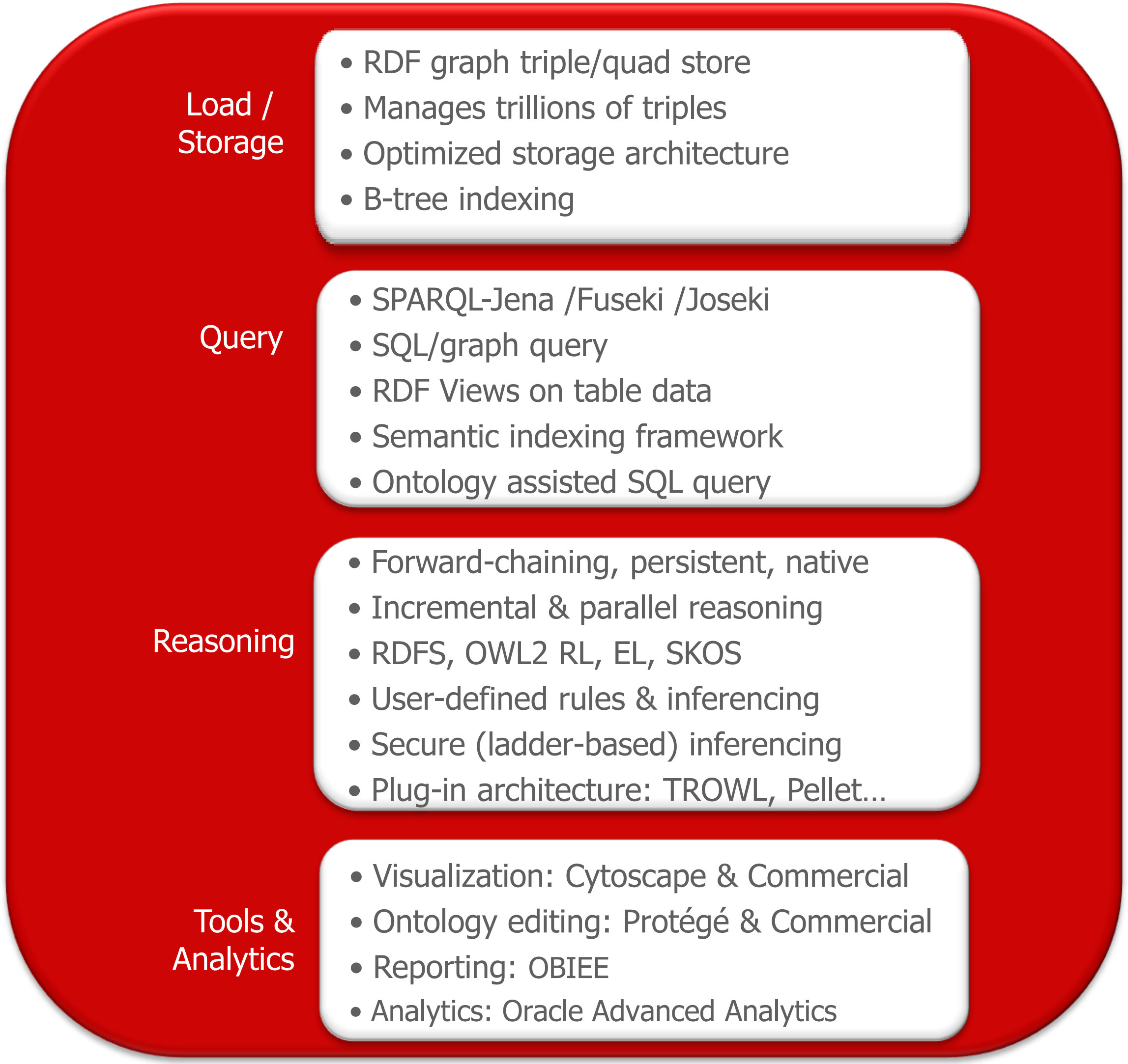
- Life Sciences
- Health Care
- Publishing
- Finance

Application Area **Graph Model** **Industry Domain**

RDF Graph Support

Oracle Spatial & Graph 12*c* RDF Semantic Graph

- Oracle Exadata Database Machine ready
- Compression & partitioning
- Parallelism: load, inference, query
- High availability
- Manageability
- Performance
  https://www.w3.org/wiki/LargeTripleStores
- Label security: triple-level
- Partners: ISVs, SIs, reasoners, ontologies
- W3C standards compliance
  - RDF, SPARQL, OWL, GeoSPARQL, RDB2RDF, SKOS



Load / Storage

- RDF graph triple/quad store
- Manages trillions of triples
- Optimized storage architecture
- B-tree indexing

Query

- SPARQL-Jena /Fuseki /Joseki
- SQL/graph query
- RDF Views on table data
- Semantic indexing framework
- Ontology assisted SQL query

Reasoning

- Forward-chaining, persistent, native
- Incremental & parallel reasoning
- RDFS, OWL2 RL, EL, SKOS
- User-defined rules & inferencing
- Secure (ladder-based) inferencing
- Plug-in architecture: TROWL, Pellet…

Tools & Analytics

- Visualization: Cytoscape & Commercial
- Ontology editing: Protégé & Commercial
- Reporting: OBIEE
- Analytics: Oracle Advanced Analytics

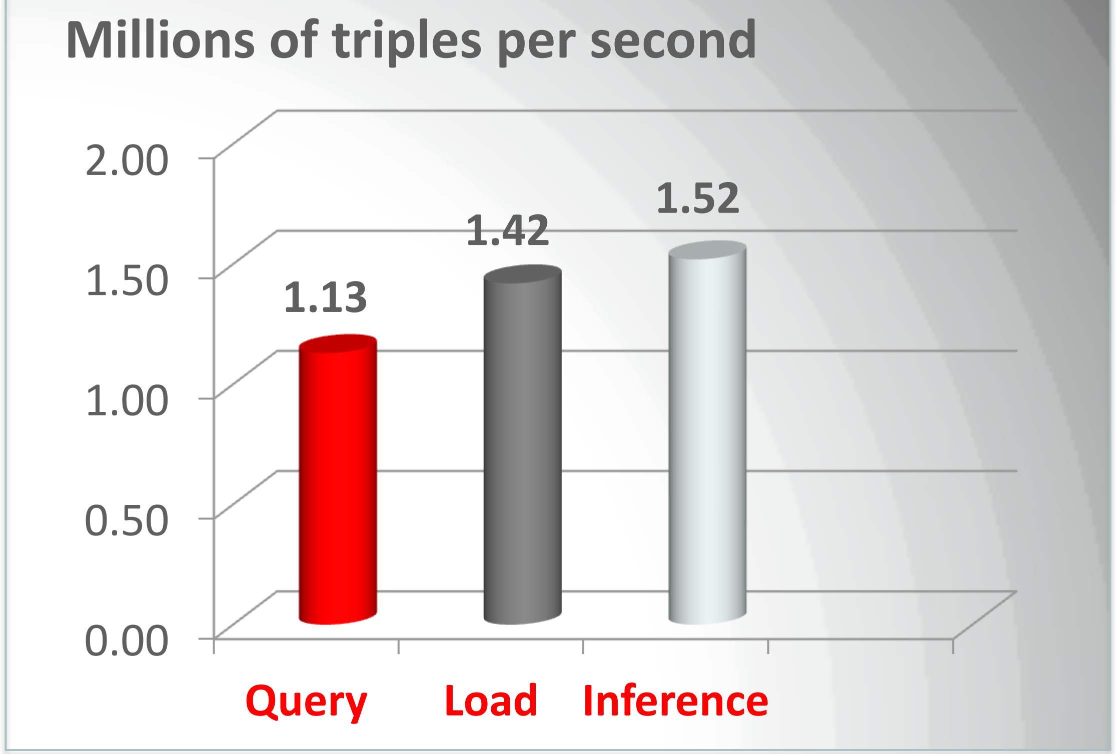
World’s Fastest Big Data Graph Benchmark

1 Trillion Triple RDF Benchmark with Oracle Spatial and Graph

- **World’s fastest data loading performance**
- **World’s fastest query performance**
- **Worlds fastest inference performance**
- **Massive scalability: 1.08 trillion edges**

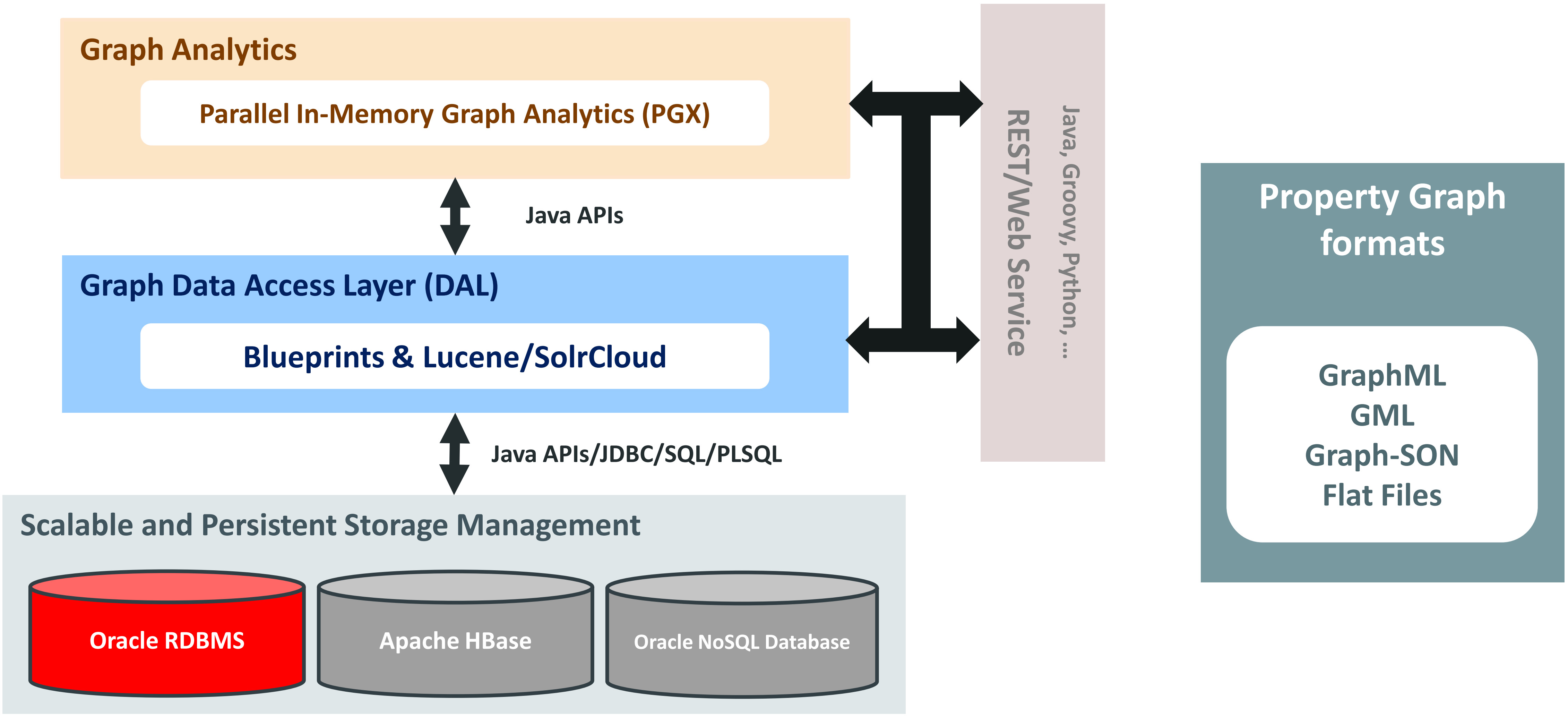
- **Platform**: Oracle Exadata X4-2 Database Machine
- **Source**: w3.org/wiki/LargeTripleStores, 9/26/2014

Oracle Database 12*c* can load, query and inference millions of RDF graph edges per second



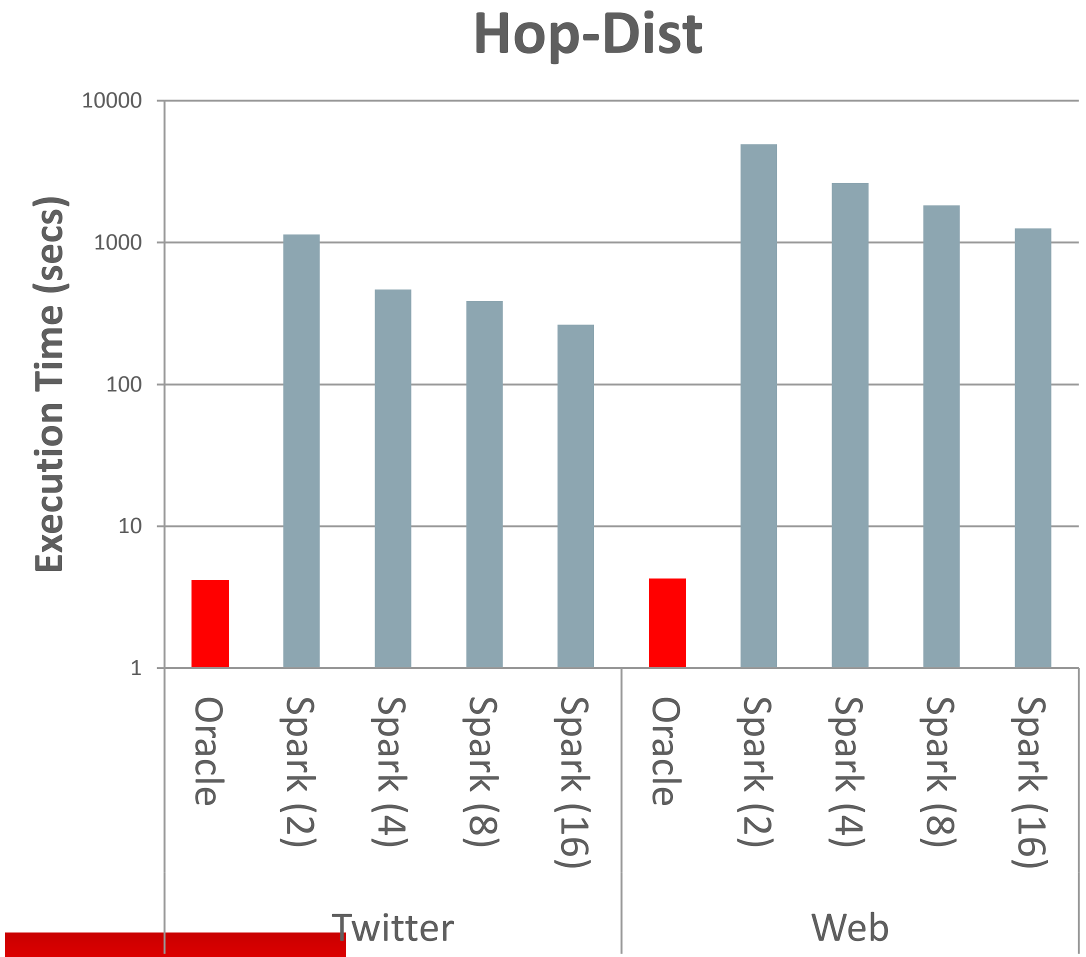
Property Graph Support

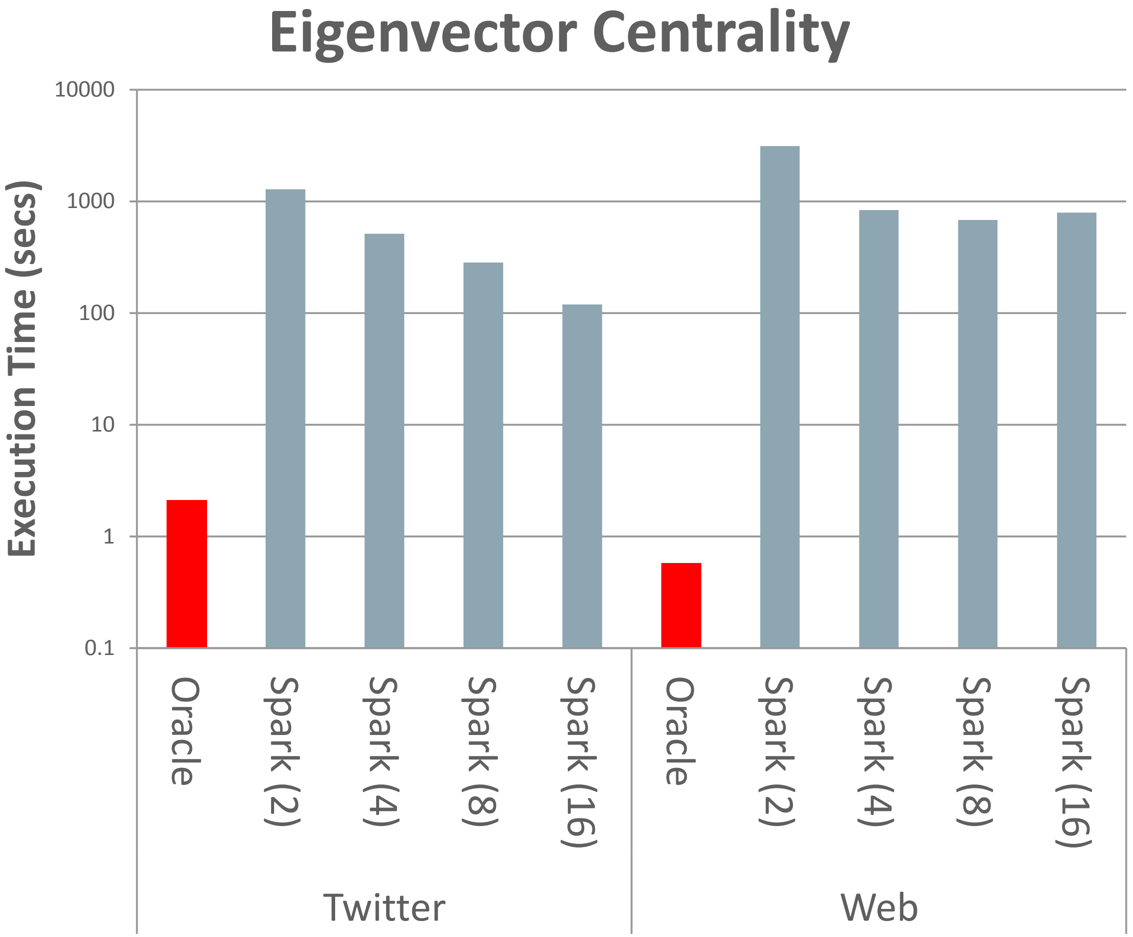
Architecture of Property Graph Support



Oracle's In-Memory Analyst vs Spark GraphX 1.1

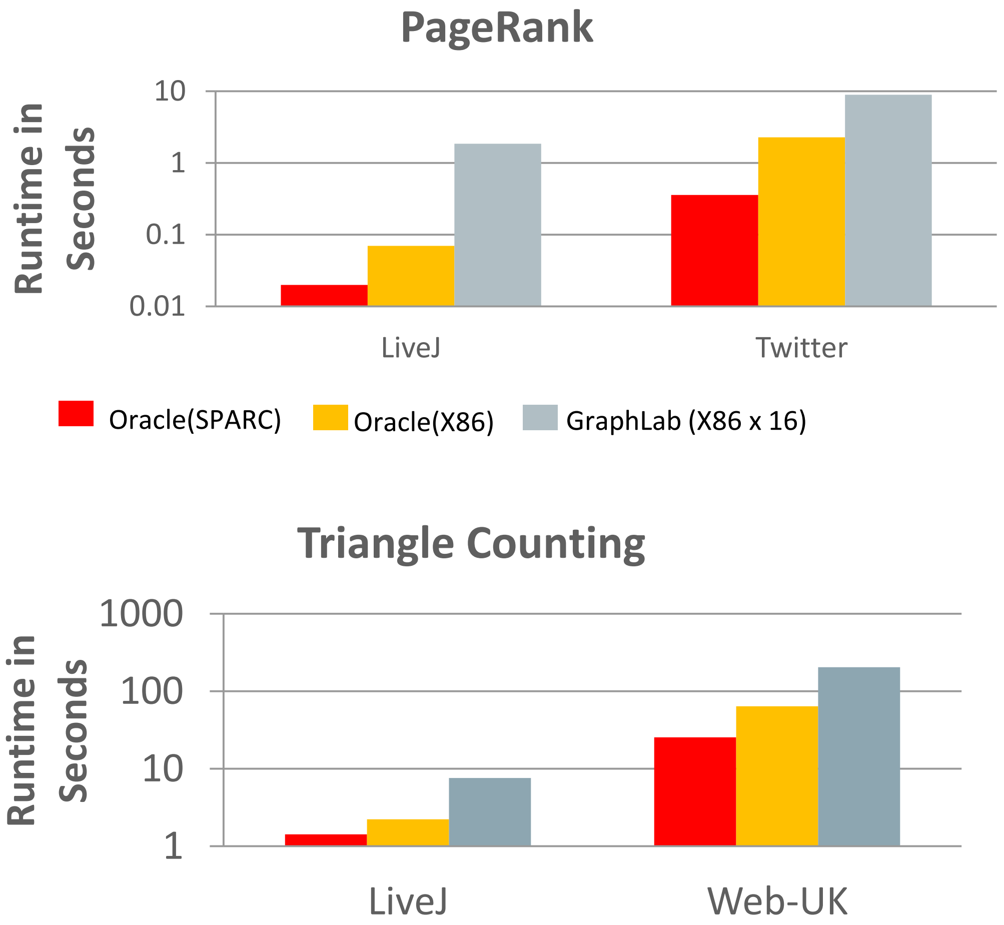
In-Memory Analyst on 1 node is up to 2 orders of magnitude faster than Spark GraphX distributed execution on 2 to 16 nodes





Oracle's In-Memory Analyst vs. Dato GraphLab Create

In-Memory Analyst on a single machine is 3x – 10x faster than a GraphLab 16-machine distributed execution

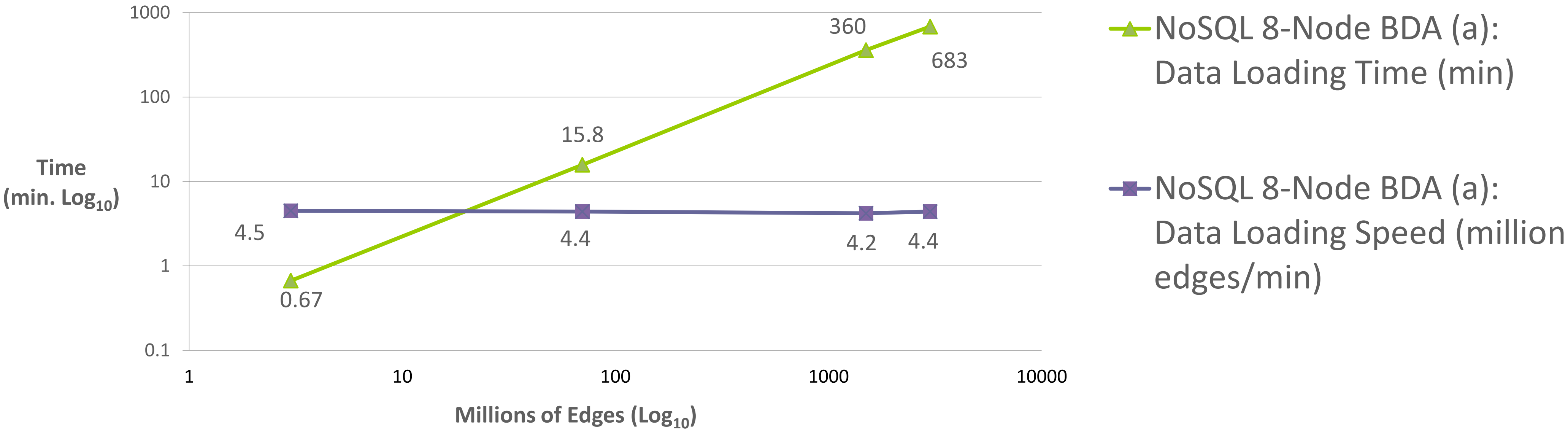


Linear Scalability Loading in NoSQL w/ Parallelism

Oracle Big Data Spatial and Graph: Property Graph – Data Access

Oracle NoSQL Database: Linear Scalability of Data Loading

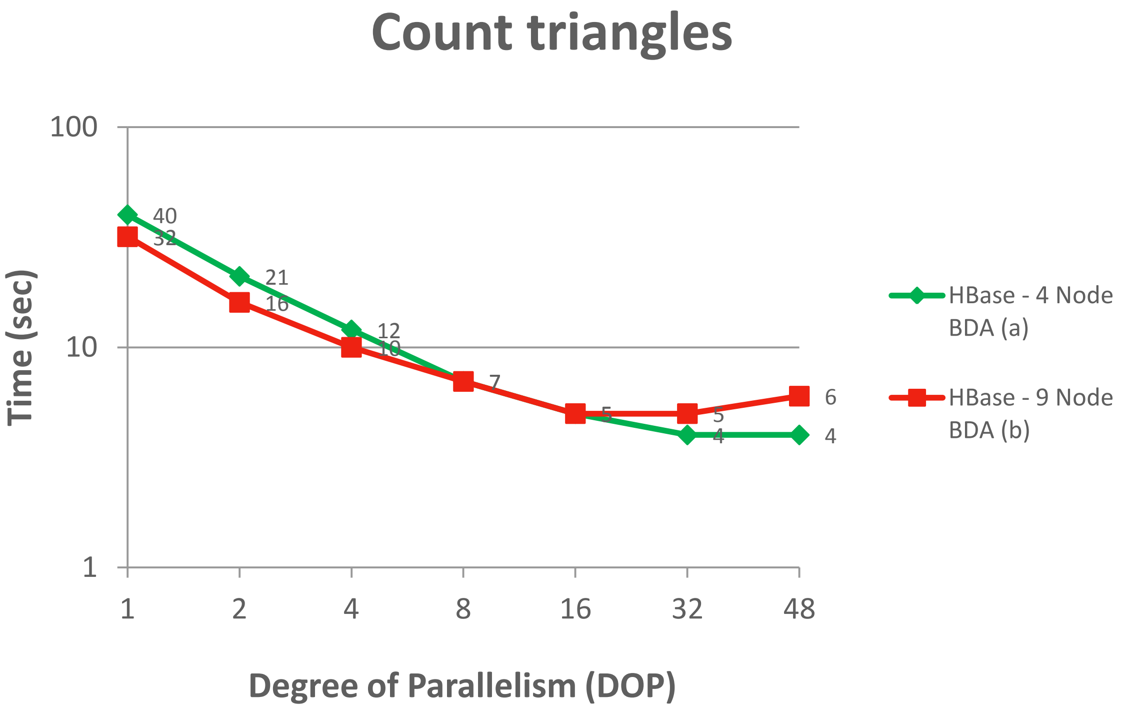
(Degrees of Parallelism (DOP) = 36)

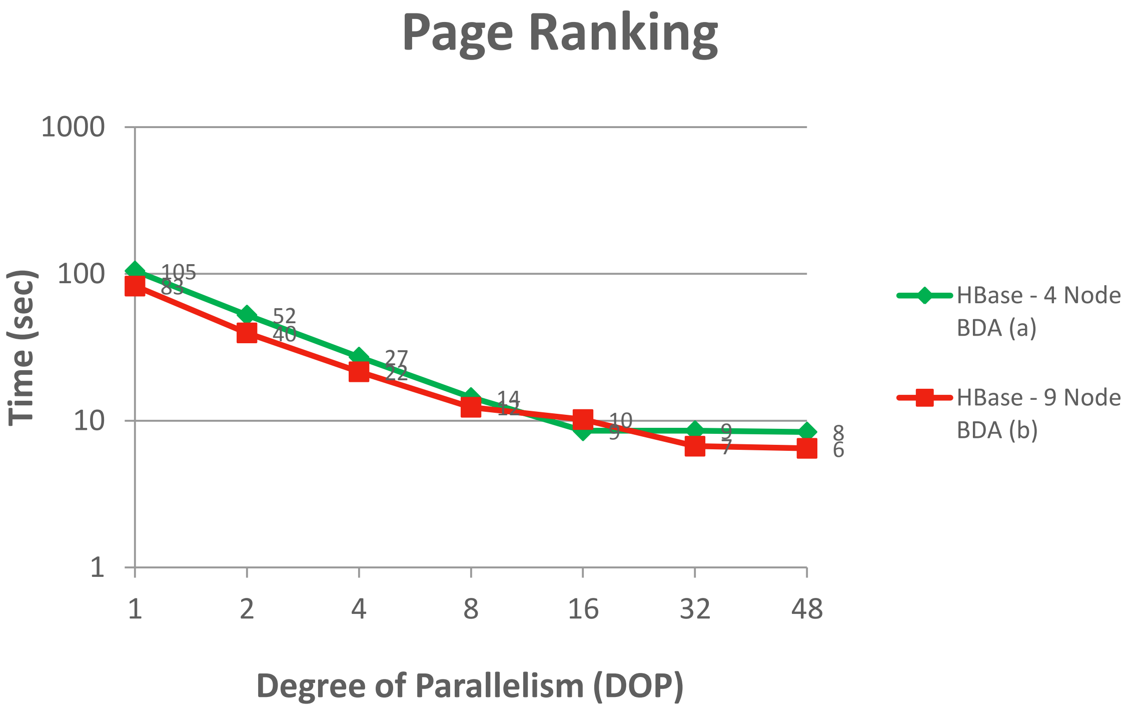


Data points for 3M, 70M, 1.5B, & 3B Edges

4-6 Seconds for Analytics on 4.8m Vertices w/ 68.9m Edges (2.9 GB) w/ Parallel In-Memory Analyst

Oracle Big Data Spatial and Graph: Property Graph - In-Memory Analyst
Apache HBase 1.0: Parallel Graph Analytics on LiveJ Data





Strengths and Weaknesses

- Semantic web/RDF graph
  - Formal theoretical foundation, precise, lots of standards/curated terms/vocabularies, linked data

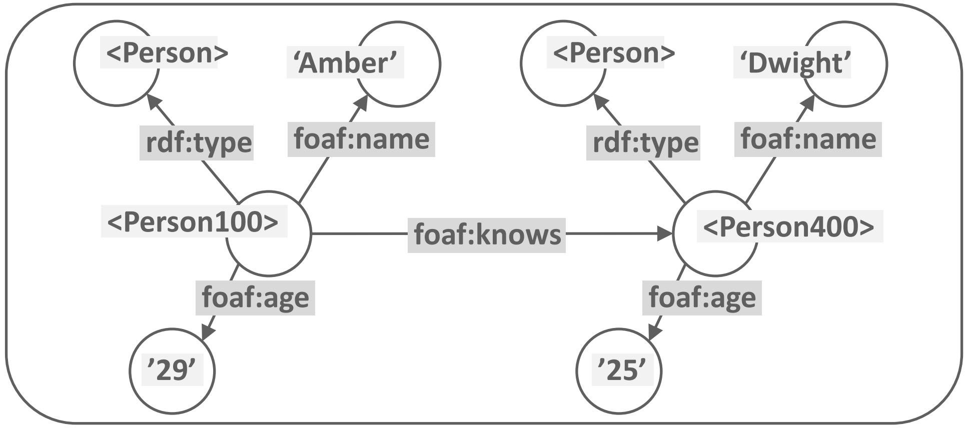
- Property graph
  - Easy to learn (actually not much to learn)
  - Suitable for social network analysis

- Semantic web/RDF graph
  - Steep learning curve
  - Hidden complexity

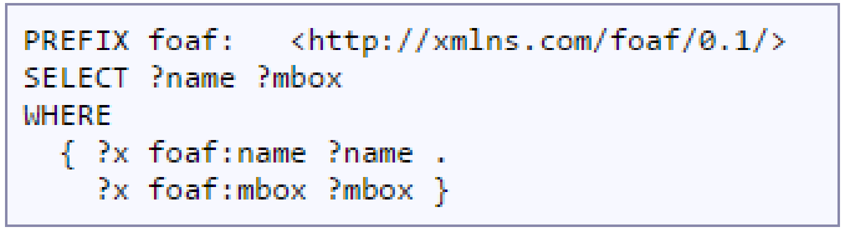
- Property Graph
  - **Lack of a standard query language**
  - Hard to deal with multiple property graphs

Query Languages for RDF Graph and Property Graph

RDF Graphs

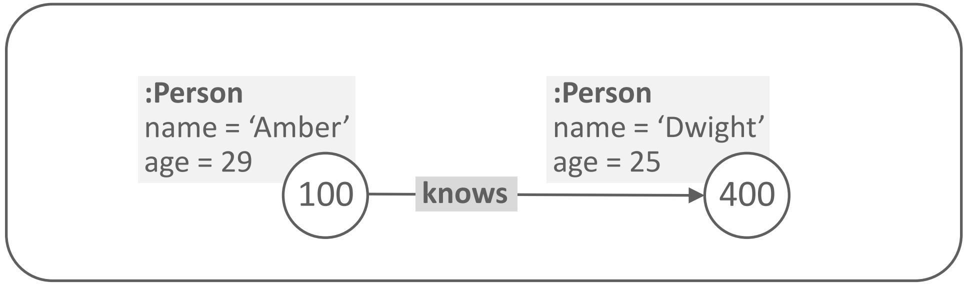


- Standard query language:
  - W3C **SPARQL 1.1**



```
PREFIX foaf:   <http://xmlns.com/foaf/0.1/>
SELECT ?name ?mbox
WHERE
  { ?x foaf:name ?name .
    ?x foaf:mbox ?mbox }
```

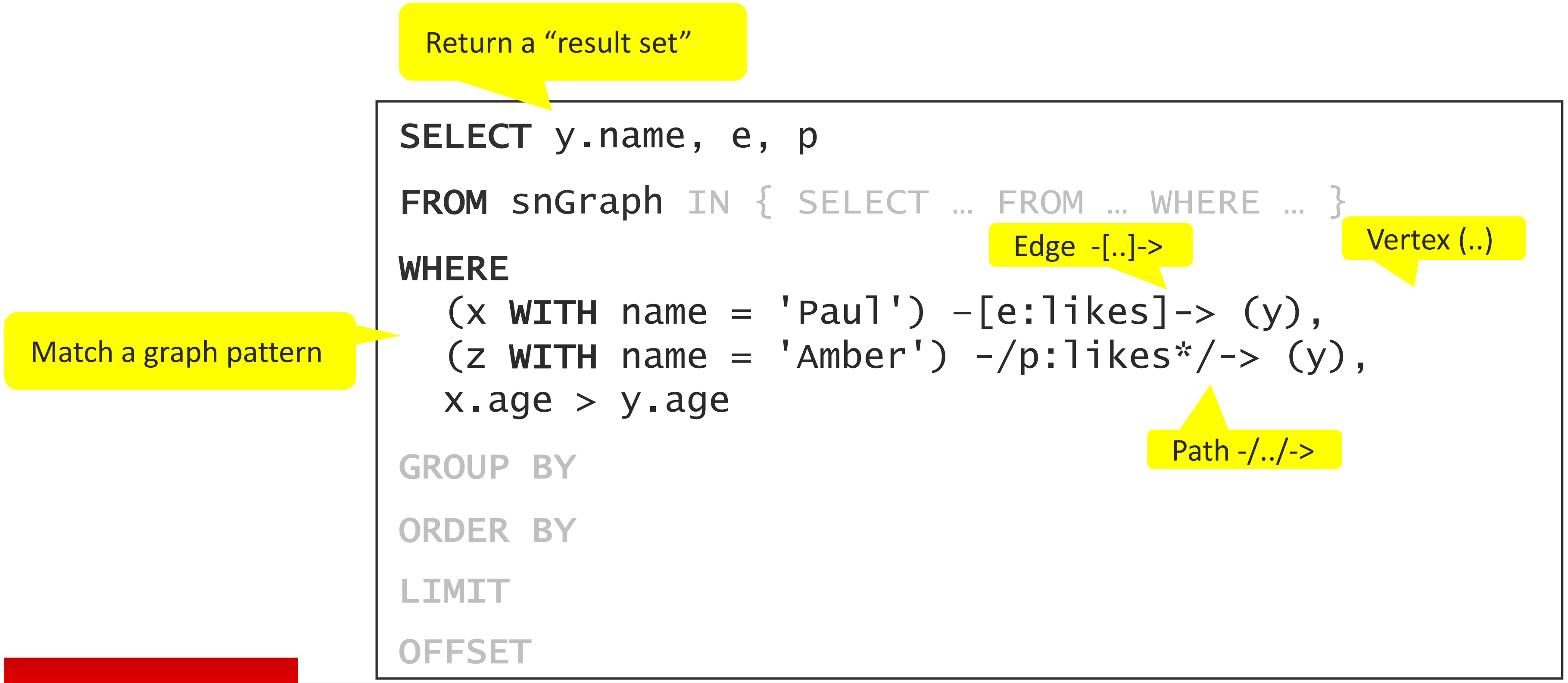
Property Graphs



- No standard query language
- Multiple languages proposals:
  - PGQL (Oracle)
  - Cypher (Neo4j)
  - Gremlin (Tinkerpop)
  - *GraphQL (LDBC)*

PGQL: a Property Graph Query Language

- Closer to SQL (compared to other proposals: Cypher, Gremlin)
- Shipped with Oracle Big Data Spatial and Graph v1.2.0



Return a “result set”

```
SELECT y.name, e, p

FROM snGraph IN { SELECT … FROM … WHERE … }

WHERE
  (x WITH name = 'Paul') -[e:likes]-> (y),
  (z WITH name = 'Amber') -/p:likes*/-> (y),
  x.age > y.age

GROUP BY

ORDER BY

LIMIT

OFFSET
```

Match a graph pattern

Edge -[..]->

Vertex (..)

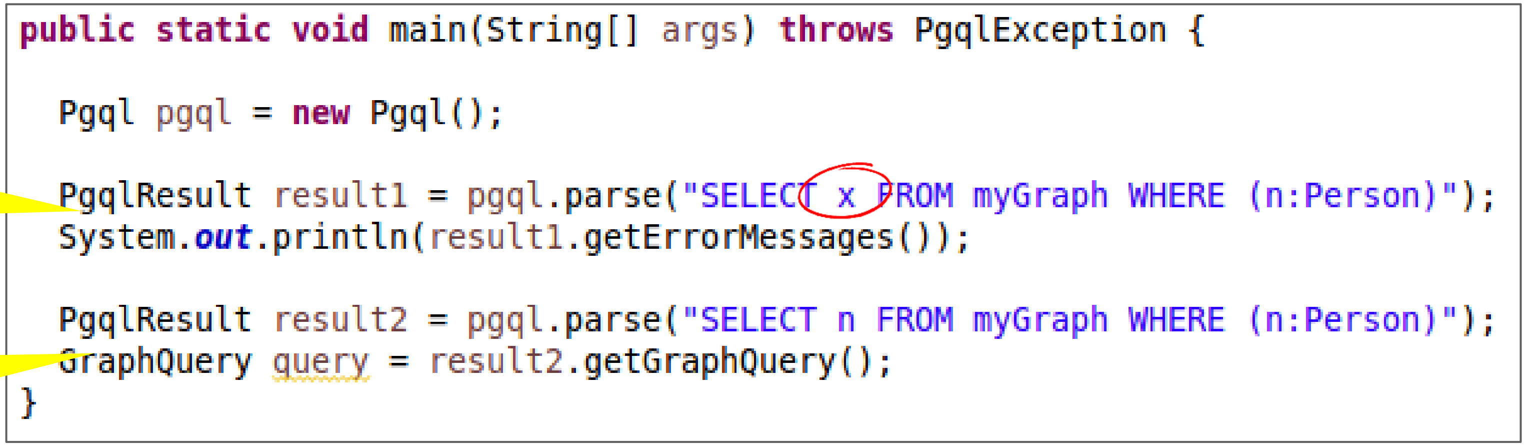
Path -/../->

Reference Implementation of PGQL Parser

- Open-sourced
  - https://github.com/oracle/pgql-lang
  - Apache 2.0 + Universal Permissive License (UPL) 1.0
- Example usage:

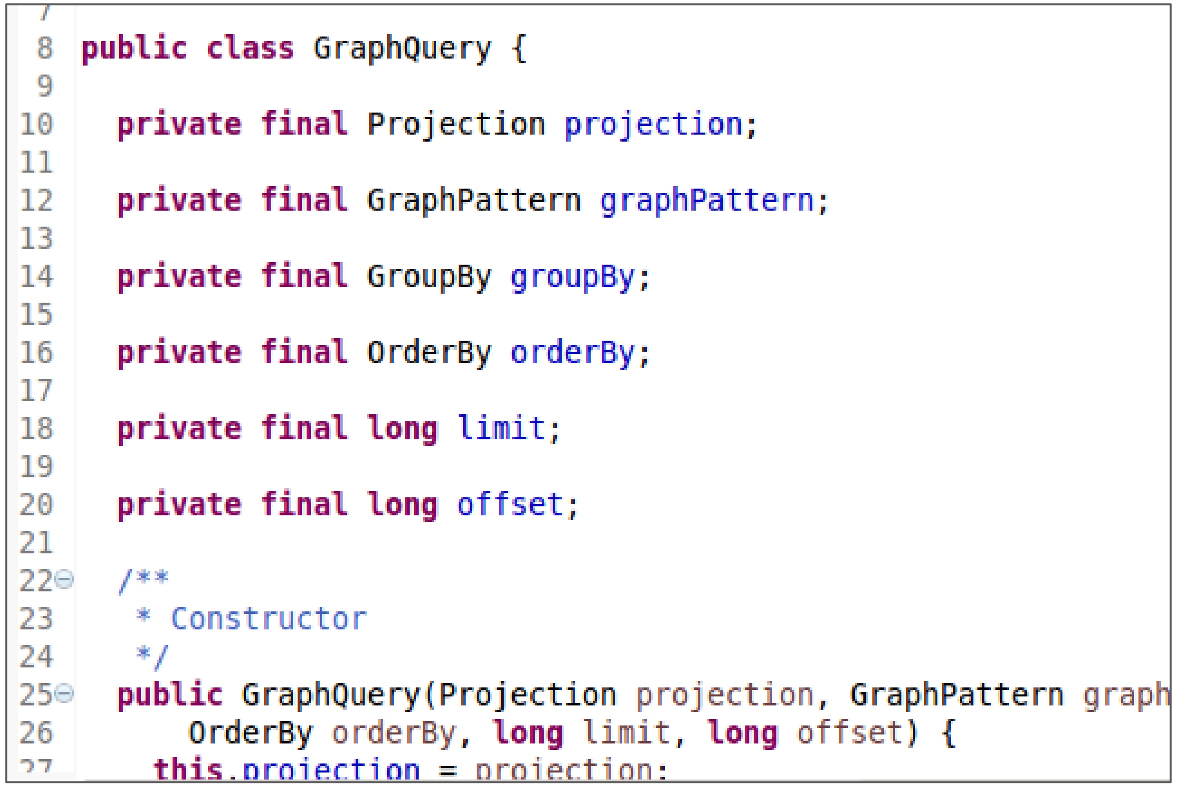
Built-in error checking e.g. ”Variable x is undefined”

Returns IR of query (see next slide)



```
public static void main(String[] args) throws PgqlException {

  Pgql pgql = new Pgql();

  PgqlResult result1 = pgql.parse("SELECT x FROM myGraph WHERE (n:Person)");
  System.out.println(result1.getErrorMessages());

  PgqlResult result2 = pgql.parse("SELECT n FROM myGraph WHERE (n:Person)");
  GraphQuery query = result2.getGraphQuery();
}
```

Intermediate Representation (IR) for Graph Queries

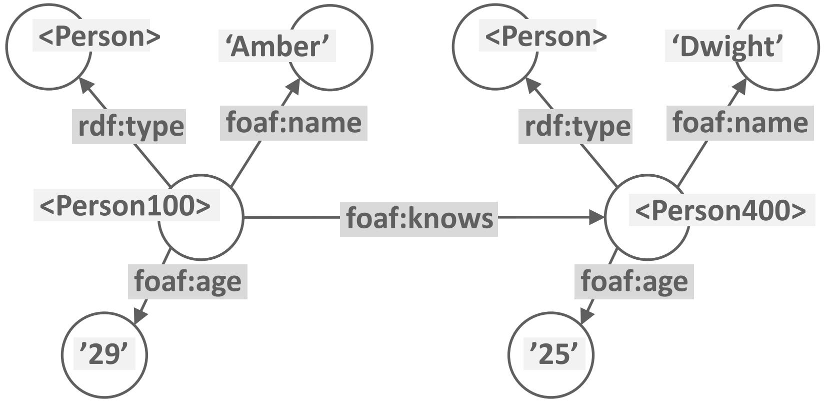


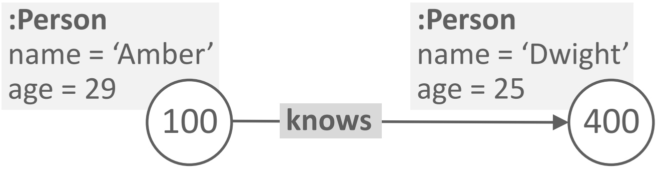
```
public class GraphQuery {

  private final Projection projection;

  private final GraphPattern graphPattern;

  private final GroupBy groupBy;

  private final OrderBy orderBy;

  private final long limit;

  private final long offset;

  /**
   * Constructor
   */
  public GraphQuery(Projection projection, GraphPattern graph
      OrderBy orderBy, long limit, long offset) {
    this.projection = projection;
```

- IR is independent of parser implementations
  - Parsers can be developed independently of query engines
  - Syntax changes (to PGQL) do not break existing query engines
- Can potentially be used in combination with other graph query languages

Bridging RDF Graph and Property Graph

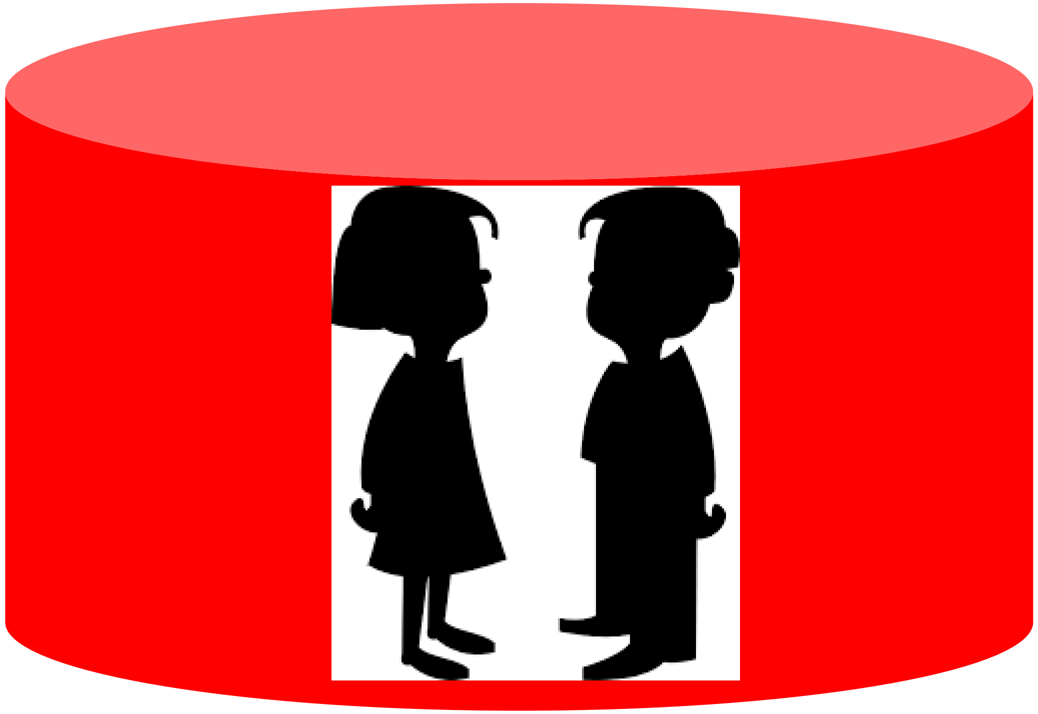
Can an application make use of **both** graph data models?





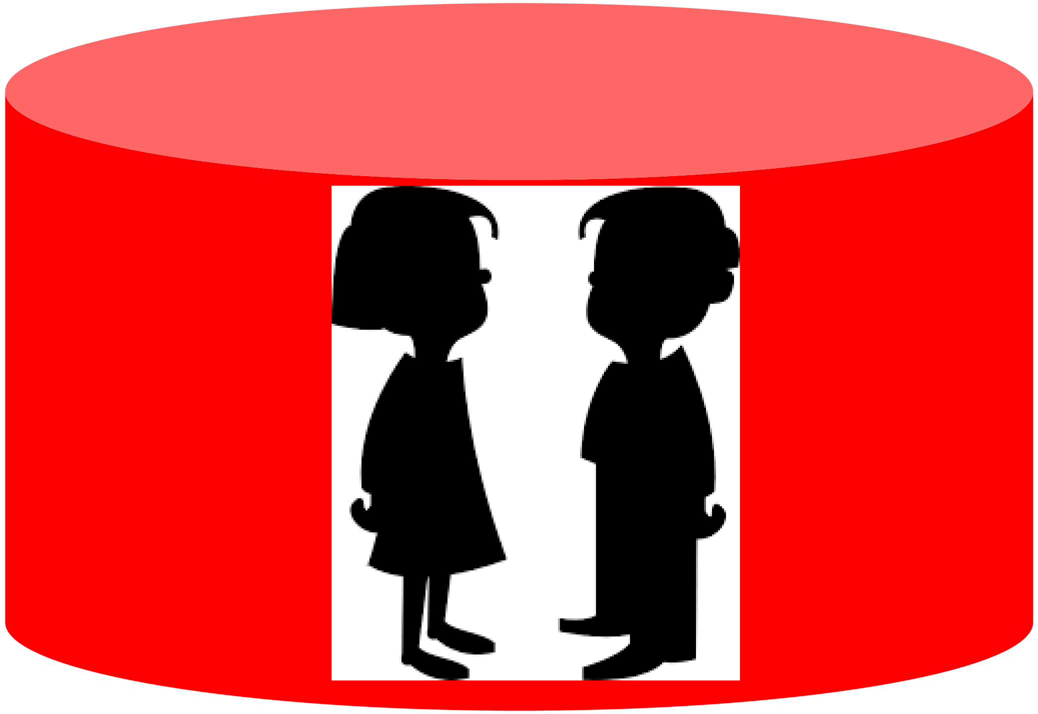
Semantic Web/RDF Graph Coexists with Property Graph

- Step 1: Stick them into the same repository



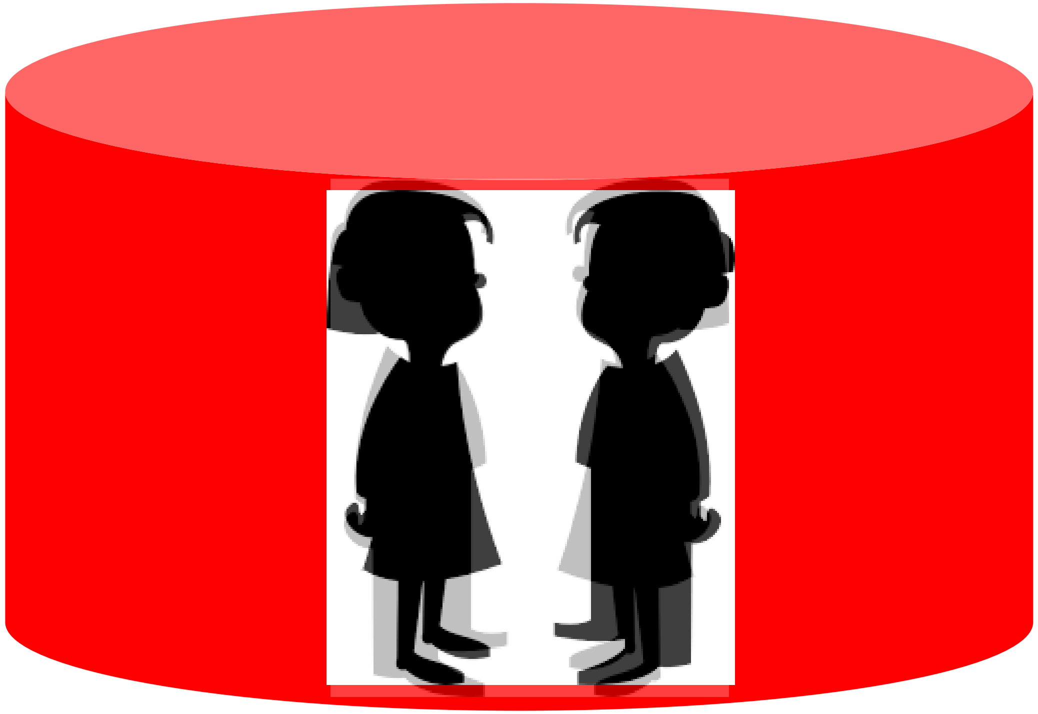
Semantic Web/RDF Graph Coexists with Property Graph

- Step 2: Force them to speak the same language (Java, SQL, REST, …)



Semantic Web/RDF Graph Coexists with Property Graph

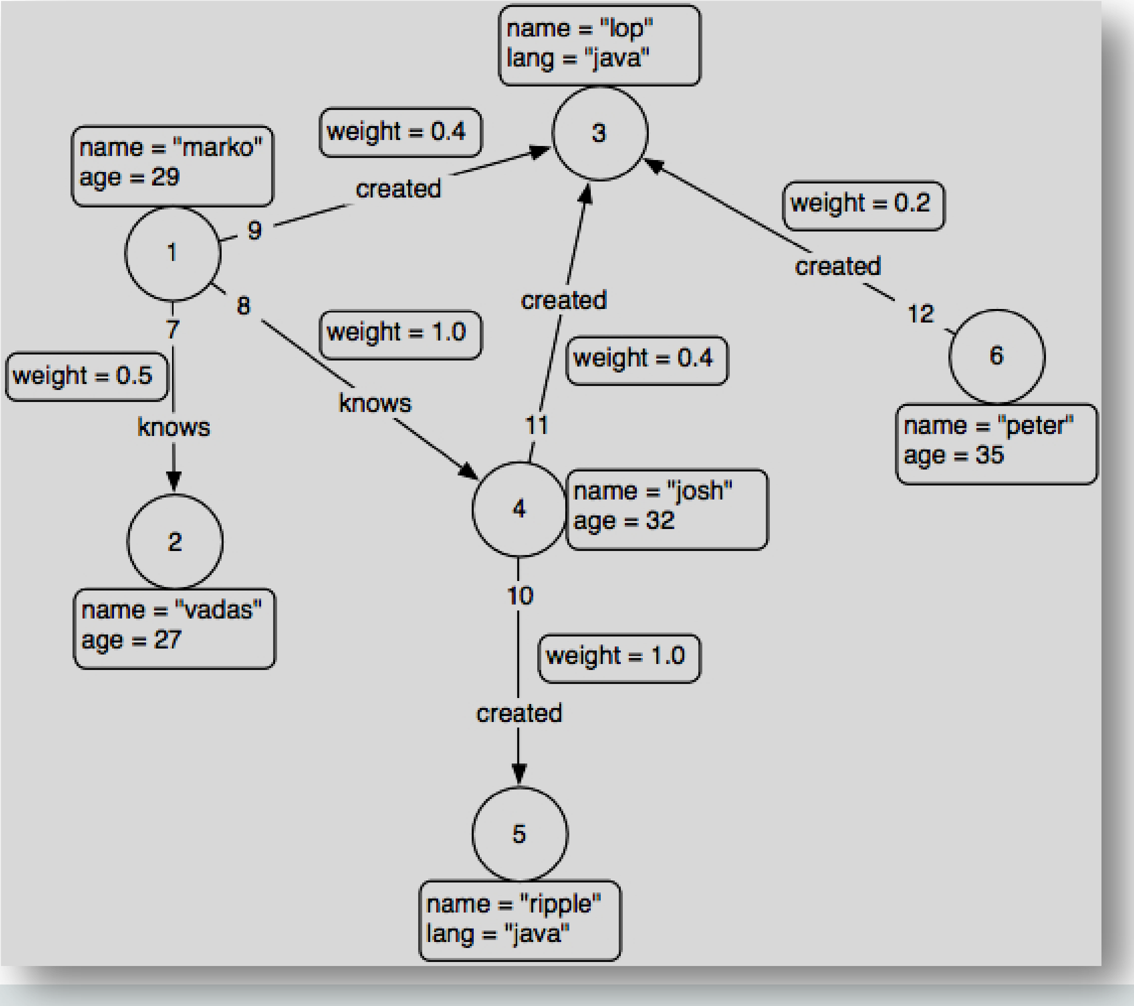
- Step 3: Disguise one as the other
  - Property graph view on RDF & RDF view on property Graph



Property Graph View on RDF Data

- Specify
  - Which set of assertions become “attributes”
  - Which set of assertions become edges

```
ns:vertex1   ns:name      “marko” .
ns:vertex1   ns:age       29 .
ns:vertex1   ns:created   ns:vertex3 .
```



Property Graph View on RDF Data

- Specify
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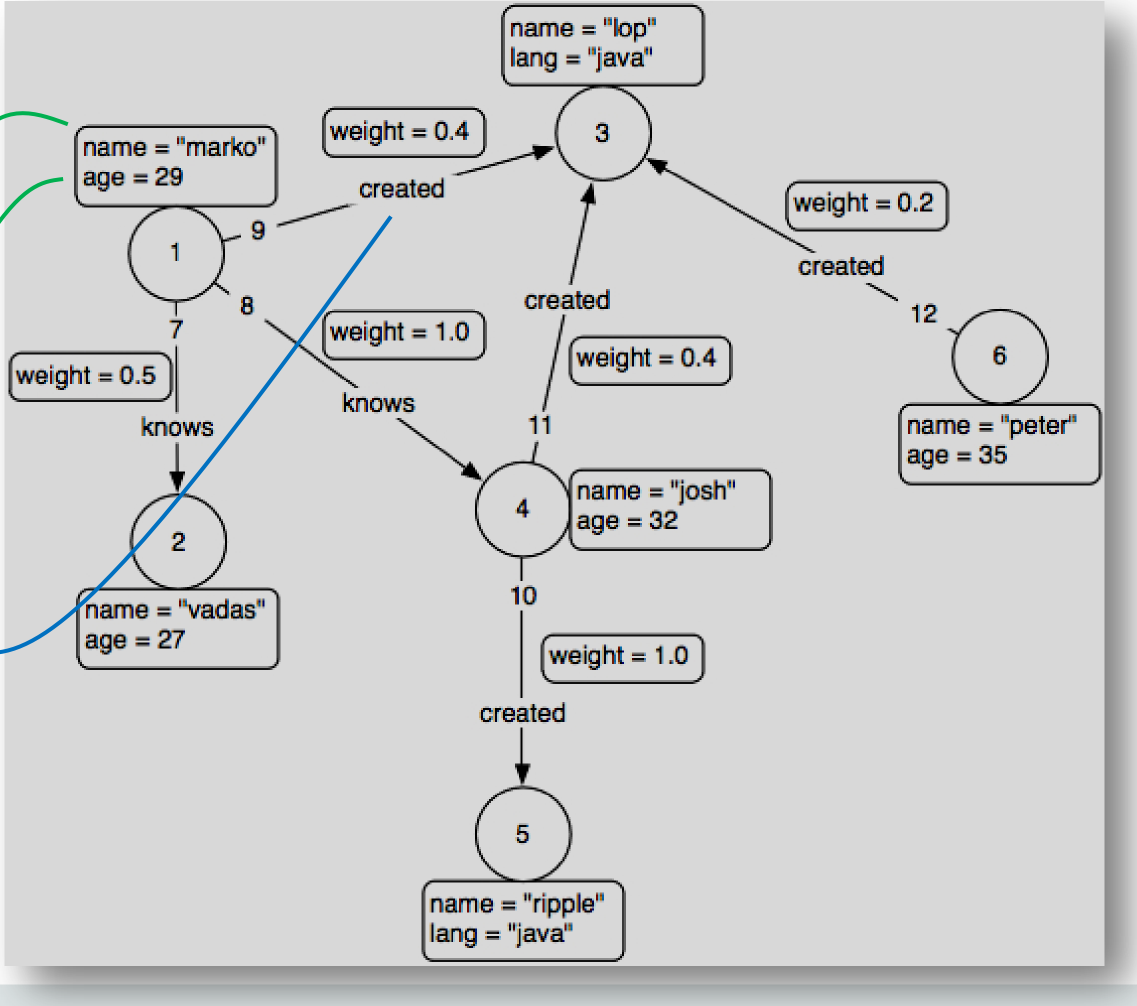
ns:vertex1 ns:name “marko” .

ns:vertex1 ns:age 29 .

ns:vertex1 ns:created ns:vertex3 .



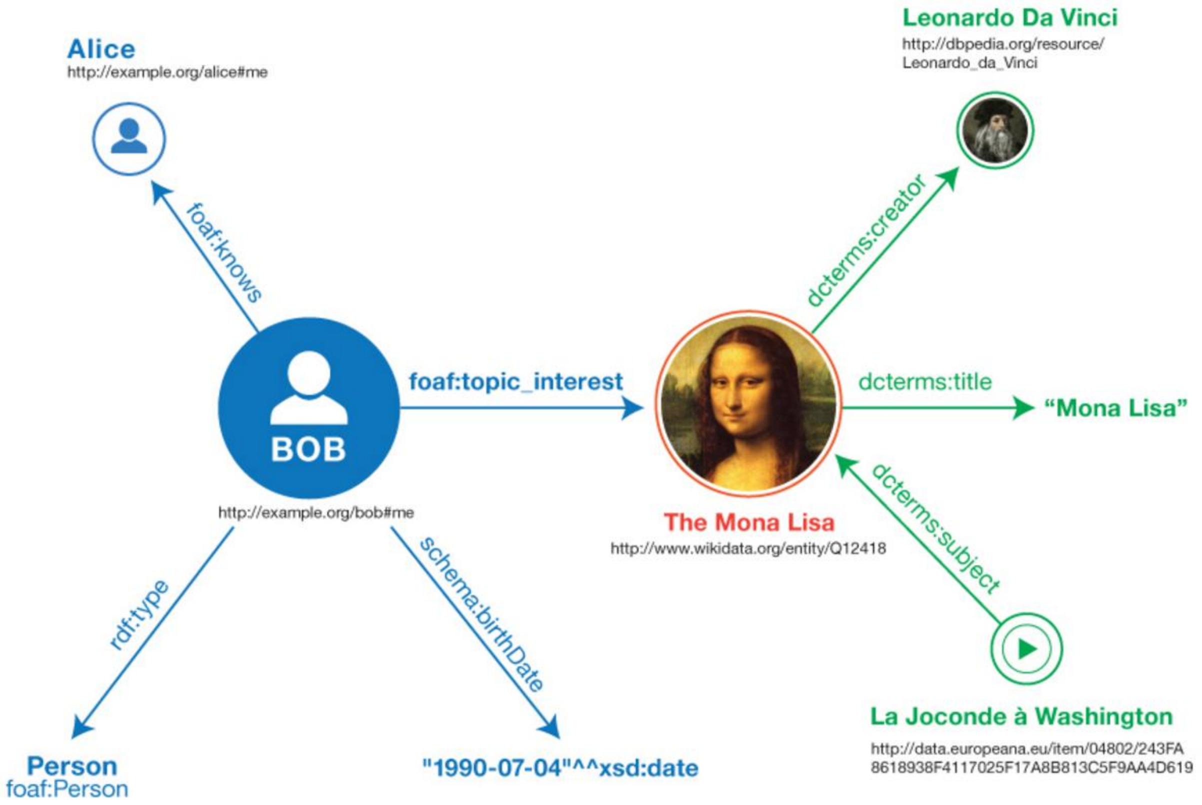
- Challenge: dealing with multiple values

RDF View on Property Graph Data

- Use W3C RDB2RDF
  - Property graph modeled with relational table

VID	K	T	V	VN
1	name	1	BOB	
2	name	1	The Mona Lisa	
…	…	…	…	…

  - Define an R2RML mapping


Alice
http://example.org/alice#me
Leonardo Da Vinci
http://dbpedia.org/resource/Leonardo_da_Vinci
foaf:knows
dcterms:creator
BOB
http://example.org/bob#me
foaf:topic_interest
dcterms:title
"Mona Lisa"
The Mona Lisa
http://www.wikidata.org/entity/Q12418
dcterms:subject
rdf:type
schema:birthDate
La Joconde à Washington
http://data.europeana.eu/item/04802/243FA8618938F4117025F17A8B813C5F9AA4D619
Person
foaf:Person
"1990-07-04"^^xsd:date

- Open question: can we **add** a bit of RDF to a PG graph?

Summary

- Under active development
  - Semantic web/RDF/OWL improvement
  - Property graph in Oracle RDBMS

- Common challenges for graph users
  - Lack of a ***standard*** property graph query language
  - ***Steep*** learning curve for RDF/OWL users

- **RDF Graph and Property graph data models can be used together**