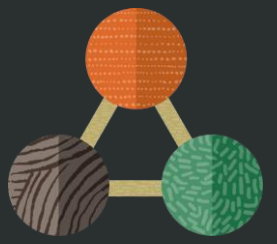
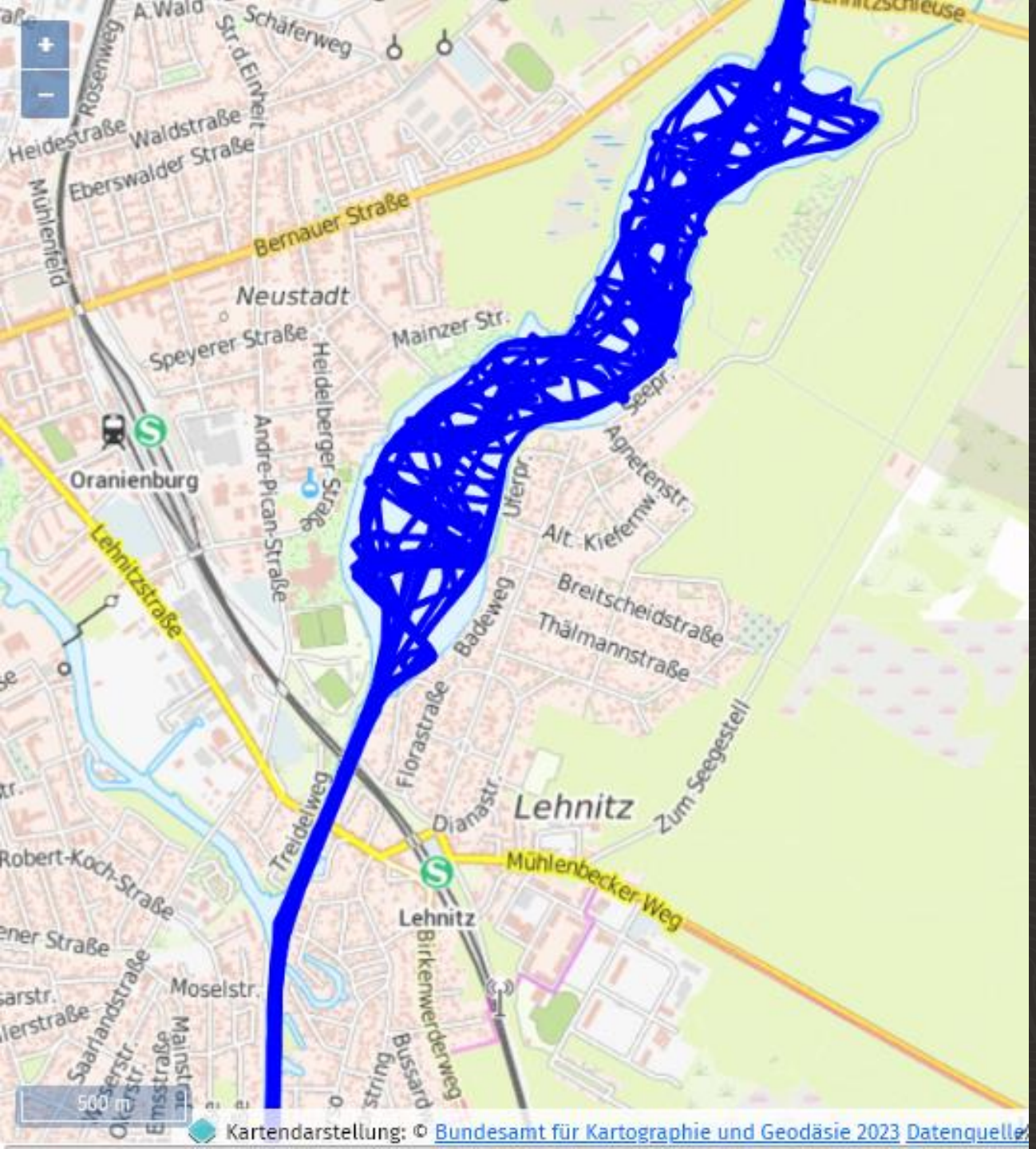
ORACLE



Was sind Wissensgraphen und wie baue ich einen?

Karin Patenge | karin.patenge@oracle.com
Senior Principal Product Manager | Oracle Spatial and Graph Technologies

DOAG Conference 2023 | Nuremberg | November 21-24



About me

- MSc. in Computer Science (Studies in Romania and Germany)
- Postgraduate studies in Geoinformatics (Austria)
- Worked for Oracle since 2007, many years as a Solution Engineer
- Joined the Oracle Spatial & Graph Product Management Team in 2022
- > 30 years in IT

Safe Harbor Statement

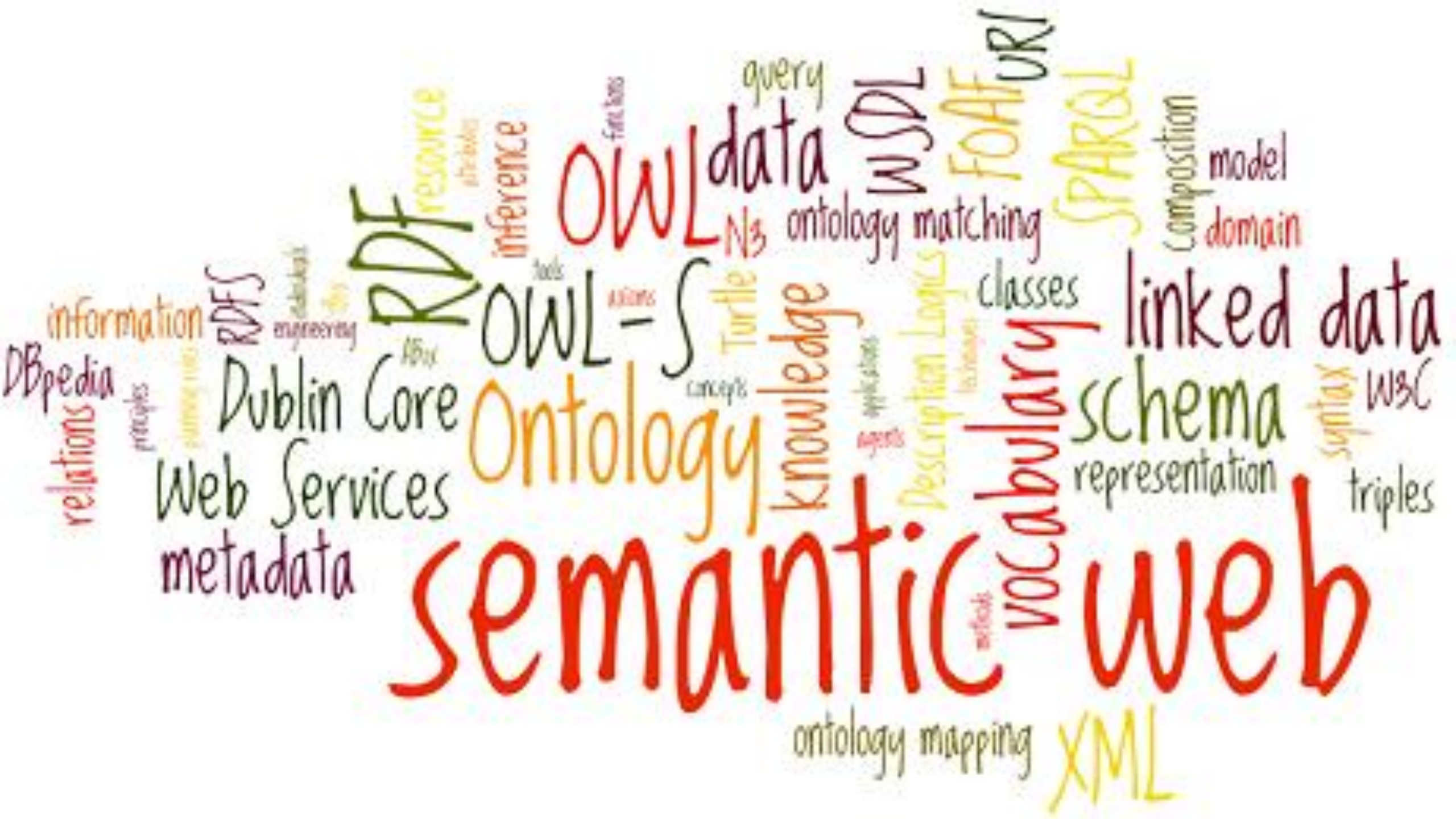
The following is intended to outline our general product direction. It is intended for information purposes only, and may not be incorporated into any contract. It is not a commitment to deliver any material, code, or functionality, and should not be relied upon in making purchasing decisions.

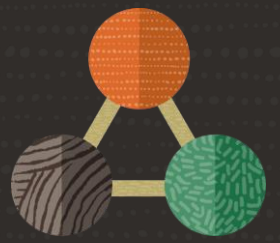
The development, release, timing, and pricing of any features or functionality described for Oracle's products may change and remains at the sole discretion of Oracle Corporation.

Download

Recordings of the demo parts can be downloaded from:
github.com/karinpatenge/DOAG2023/tree/main/RDF%20Knowledge%20Graphs/recordings

Scripts can be downloaded from:
github.com/karinpatenge/DOAG2023/tree/main/RDF%20Knowledge%20Graphs/scripts


semantic web
linked data
Ontology
OWL
OWL-S
RDF
data
schema
vocabulary
knowledge
Dublin Core
Web Services
metadata
information
DBpedia
relations
ontology matching
ontology mapping
representation
classes
model
domain
Composition
inference
resource
query
URI
FOAF
SPARQL
WSDL
N3
Turtle
RDFS
XML
triples
W3C
syntax



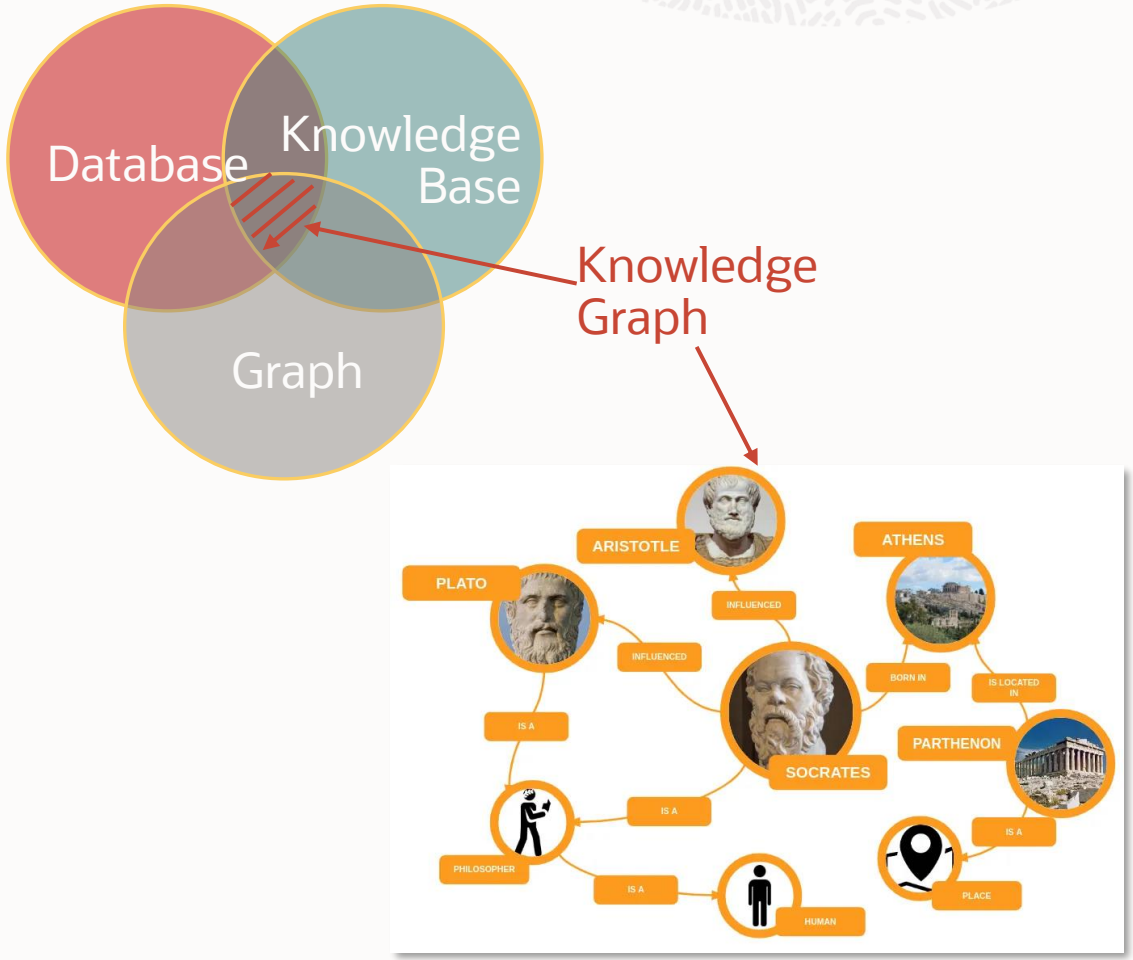
What are Knowledge Graphs?

Solving business problems by using Knowledge Graphs

Knowledge graphs are large networks of real-world entities, their semantic types, properties, and relationships between entities[1].

Key Features:

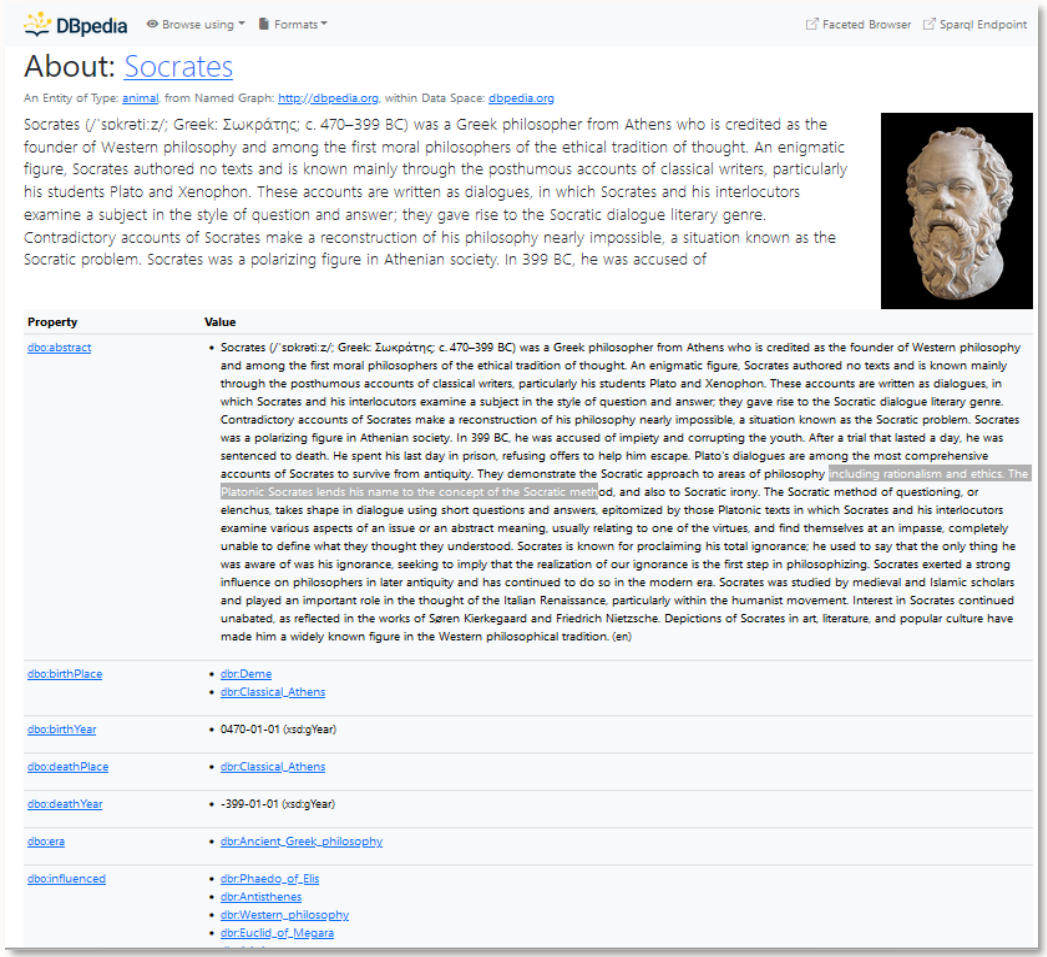
- Things not strings
  - Global unique identifiers
- Formal structure/semantics
  - Machine readable and processable, unambiguous
- Linked descriptions
  - Resources are described by their connections
- Formalized knowledge that enables programmatic reasoning using rulebases



Source: towardsdatascience.com/knowledge-graphs-at-a-glance-c9119130a9f0

[1] M. Kroetsch and G. Weikum. Journal of Web Semantics: Special Issue on Knowledge Graphs (www.websemanticsjournal.org)

Knowledge Graphs are machine-readable



DBpedia Browse using Formats Faceted Browser Sparql Endpoint

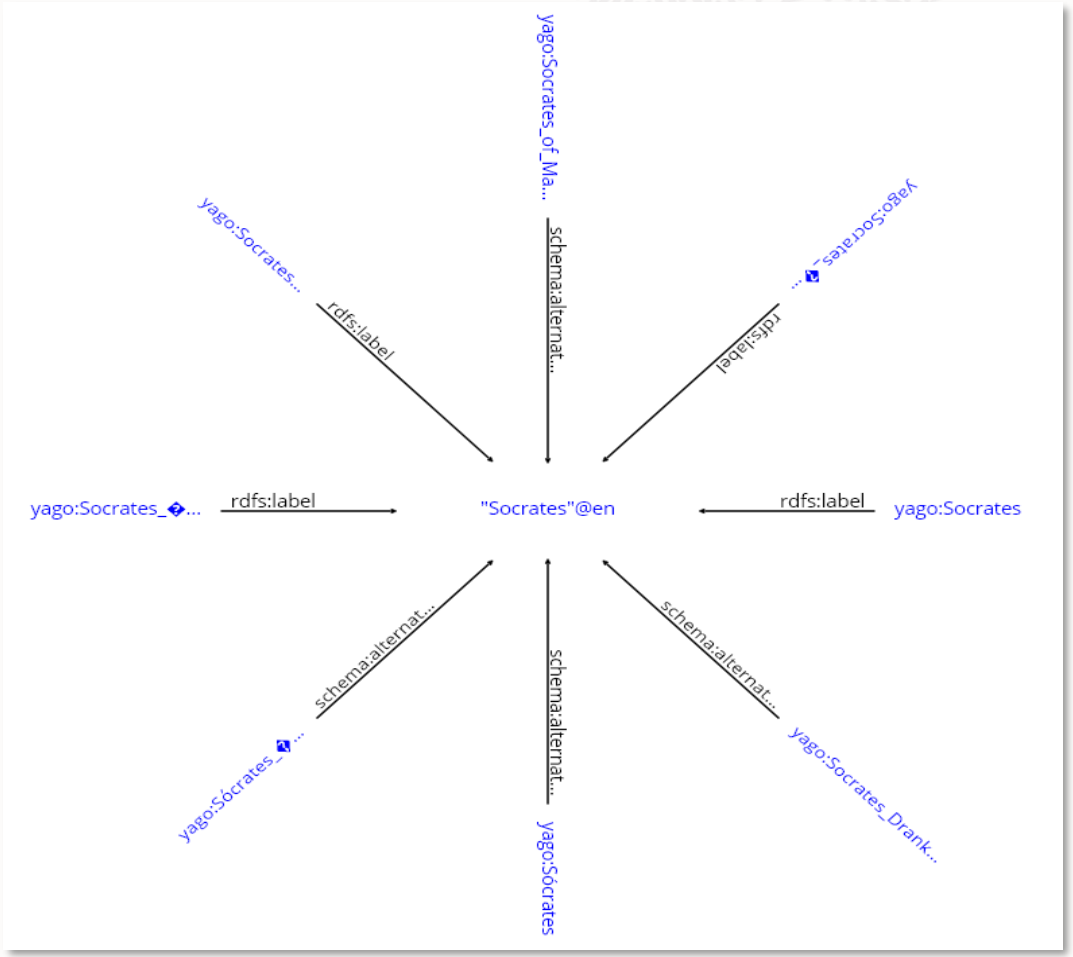
About: Socrates

An Entity of Type: animal, from Named Graph: http://dbpedia.org, within Data Space: dbpedia.org

Socrates (/ˈsɒkrətiːz/; Greek: Σωκράτης; c. 470–399 BC) was a Greek philosopher from Athens who is credited as the founder of Western philosophy and among the first moral philosophers of the ethical tradition of thought. An enigmatic figure, Socrates authored no texts and is known mainly through the posthumous accounts of classical writers, particularly his students Plato and Xenophon. These accounts are written as dialogues, in which Socrates and his interlocutors examine a subject in the style of question and answer; they gave rise to the Socratic dialogue literary genre. Contradictory accounts of Socrates make a reconstruction of his philosophy nearly impossible, a situation known as the Socratic problem. Socrates was a polarizing figure in Athenian society. In 399 BC, he was accused of

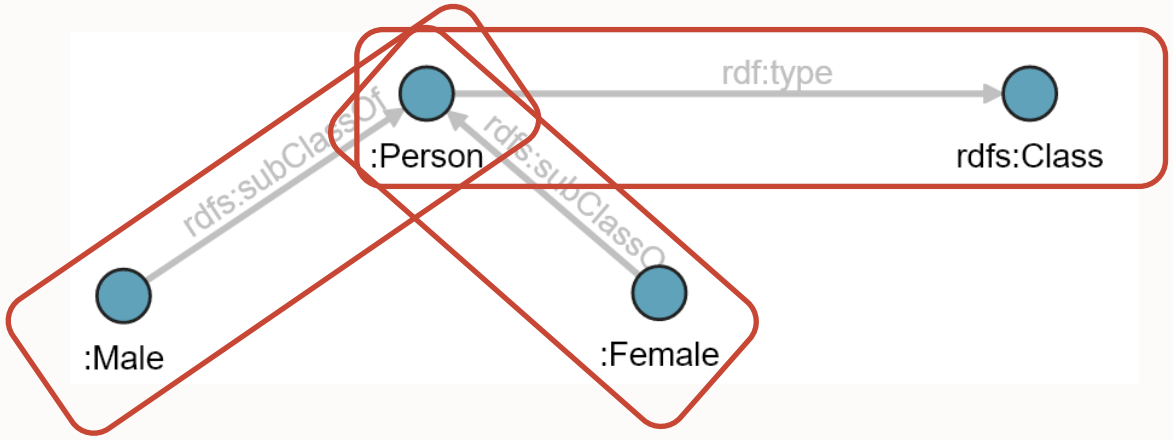
Property	Value
dbo:abstract	• Socrates (/ˈsɒkrətiːz/; Greek: Σωκράτης; c. 470–399 BC) was a Greek philosopher from Athens who is credited as the founder of Western philosophy and among the first moral philosophers of the ethical tradition of thought. An enigmatic figure, Socrates authored no texts and is known mainly through the posthumous accounts of classical writers, particularly his students Plato and Xenophon. These accounts are written as dialogues, in which Socrates and his interlocutors examine a subject in the style of question and answer; they gave rise to the Socratic dialogue literary genre. Contradictory accounts of Socrates make a reconstruction of his philosophy nearly impossible, a situation known as the Socratic problem. Socrates was a polarizing figure in Athenian society. In 399 BC, he was accused of impiety and corrupting the youth. After a trial that lasted a day, he was sentenced to death. He spent his last day in prison, refusing offers to help him escape. Plato's dialogues are among the most comprehensive accounts of Socrates to survive from antiquity. They demonstrate the Socratic approach to areas of philosophy including rationalism and ethics. The Platonic Socrates lends his name to the concept of the Socratic method, and also to Socratic irony. The Socratic method of questioning, or elenchus, takes shape in dialogue using short questions and answers, epitomized by those Platonic texts in which Socrates and his interlocutors examine various aspects of an issue or an abstract meaning, usually relating to one of the virtues, and find themselves at an impasse, completely unable to define what they thought they understood. Socrates is known for proclaiming his total ignorance; he used to say that the only thing he was aware of was his ignorance, seeking to imply that the realization of our ignorance is the first step in philosophizing. Socrates exerted a strong influence on philosophers in later antiquity and has continued to do so in the modern era. Socrates was studied by medieval and Islamic scholars and played an important role in the thought of the Italian Renaissance, particularly within the humanist movement. Interest in Socrates continued unabated, as reflected in the works of Søren Kierkegaard and Friedrich Nietzsche. Depictions of Socrates in art, literature, and popular culture have made him a widely known figure in the Western philosophical tradition. (en)
dbo:birthPlace	• dbr:Deme • dbr:Classical_Athens
dbo:birthYear	• 0470-01-01 (xsd:gYear)
dbo:deathPlace	• dbr:Classical_Athens
dbo:deathYear	• -399-01-01 (xsd:gYear)
dbo:era	• dbr:Ancient_Greek_philosophy
dbo:influenced	• dbr:Phaedo_of_Elis • dbr:Antisthenes • dbr:Western_philosophy • dbr:Euclid_of_Megara

Source: dbpedia.org/page/Socrates



Source: yago-knowledge.org/graph/%22Socrates%22@en?relation=all

Data Model for Knowledge Graphs



Subject	Predicate	Object
Type: - URI - Blank node	Type: - URI	Type: - URI - Blank node - Literal (string, int, …)

Triple

```
PREFIX    rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX   rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX       : <http://www.example.org/family/>
```

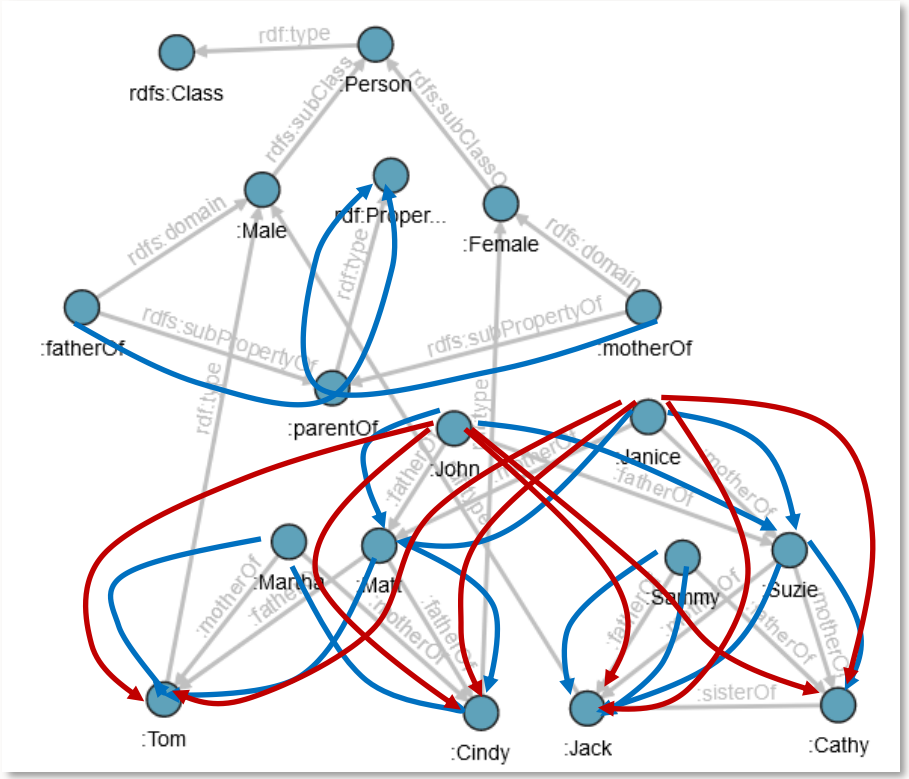
```
# Person is a class
:Person rdf:type rdfs:Class .

# Male is a subclass of Person
:Male rdfs:subClassOf :Person .

# Female is a subclass of Person
:Female rdfs:subClassOf :Person .
```

Inferring new data from existing data in a Knowledge Graph

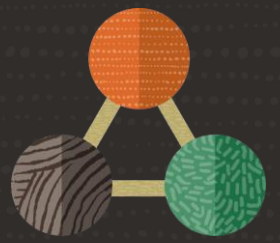
- We can draw conclusions and infer new data from existing data by applying a set of logical rules ☞ Inferencing / Reasoning



Inferencing using rule bases (built-in or custom)

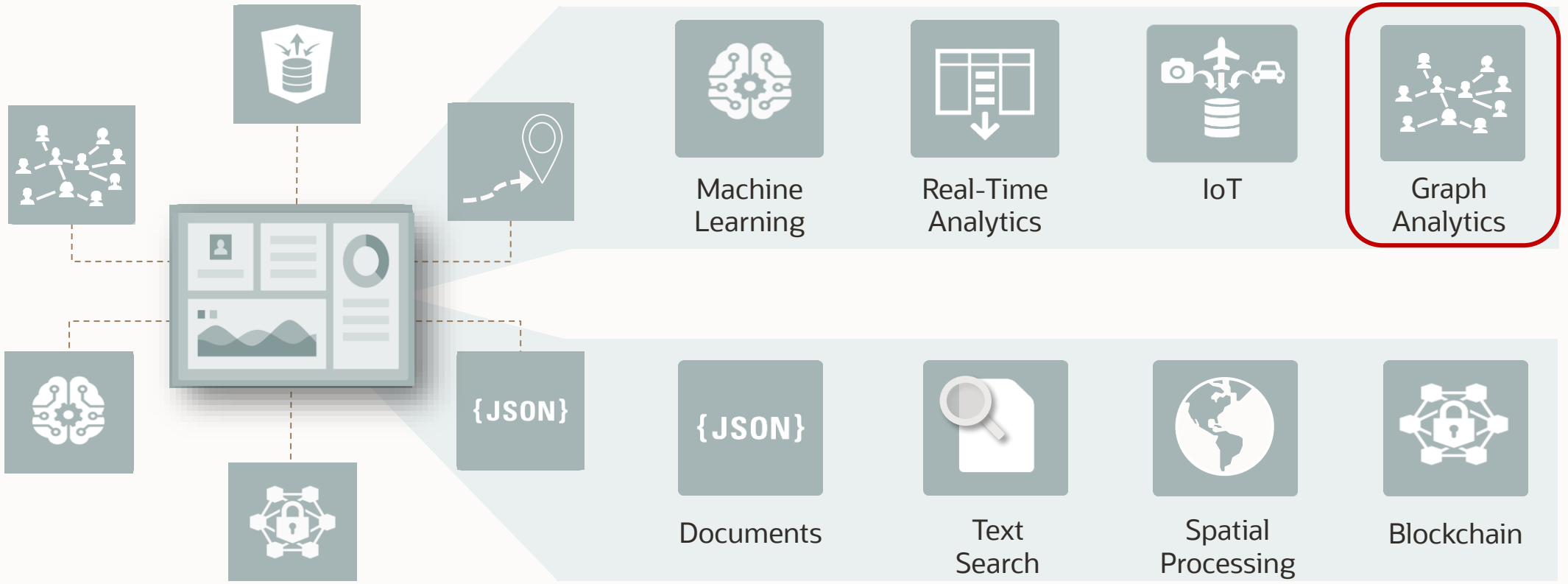
```
# Examples of built-in rules
ANTECEDENT
  :fatherOf – rdfs:subPropertyOf -> :parentOf
  :motherOf – rdfs:subPropertyOf -> :parentOf
CONSEQUENT
  :motherOf and :fatherOf ☞ :parentOf


# Example of a custom rule: Grandparent rule
ANTECEDENT
  (?x :parentOf ?y) (?y :parentOf ?z)
CONSEQUENT
  (?x :grandParentOf ?z)
```

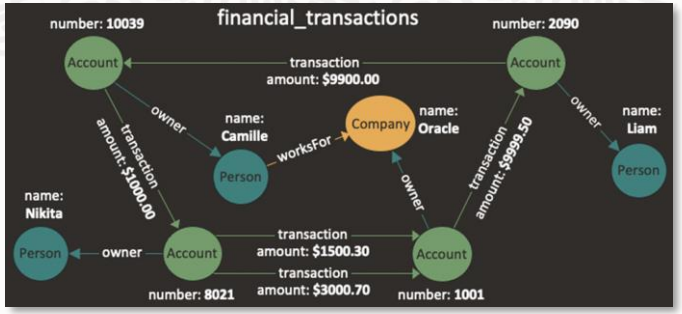


Technology Foundation for Knowledge Graphs

Modern Apps Need To Generate Value From Data in New Ways



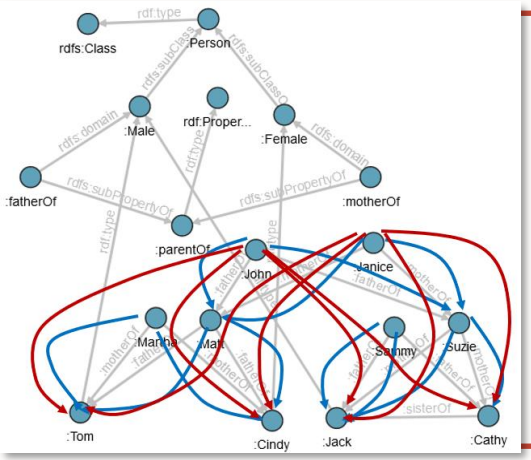
Two Graph Models supported by the Oracle Database



- Property Graph
  - Known as - Graph Database
  - Features - Intuitive data model, Graph Query Language (SQL/PGQ* and PGQL), Graph algorithms, Graph Machine Learning
  - Use cases - Fraud detection, Path-finding, Interlinked data management

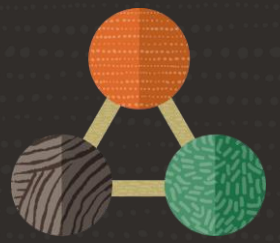
* Oracle DB 23c

- RDF Knowledge Graph
  - Known as - RDF Store, Triplestore, Knowledge Graph
  - Features - Semantic query, Ontology, Inference, W3C Standards: RDF, RDFS, OWL, SPARQL, …
  - Use cases - Data catalog, Linked Open Data (LOD), Data integration



Why is storing data as a graph essential?

	 **RELATIONAL DATA**	 **GRAPH DATA**
Data structure	tables with fields	all data elements stored individually
Connecting data	connected by joining on one data element at a time	connected via self-decribing relationships
Data retrieval	SQL (joining all tables together)	SPARQL (no joins necessary)



Building and Using Knowledge Graphs

Key Features

Options to create RDF Knowledge Graphs

- Load existing knowledge graphs (ontologies, vocabularies, taxonomies) into the Oracle Database and extend them
- Create RDF Views on relational tables using R2RML specification
- Build knowledge graphs from scratch (e.g., using SPARQL UPDATE)
- Machine Learning: Text to Graph using Transformer Models
  - Several steps including Named Entity Recognition, Relation Extraction, and more
  - *"Transforming Text Documents to Graphs"* by Doga Tekin, AndOUC TechCast June 2023 (youtube.com/watch?v=cJaxdkCYm2g)

Combine with existing Knowledge Graphs (Ontologies, Taxonomies, Vocabularies)

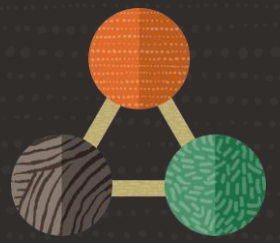
Store, manage, query, inference RDF data in Oracle Database

- Scalable RDF Graph database: Scales to billions of nodes and edges
- Full standards support: RDF, RDFS, OWL, SPARQL, R2RML, …
- Query: SPARQL or SPARQL inside SQL table function

RDF Server to support SPARQL endpoint

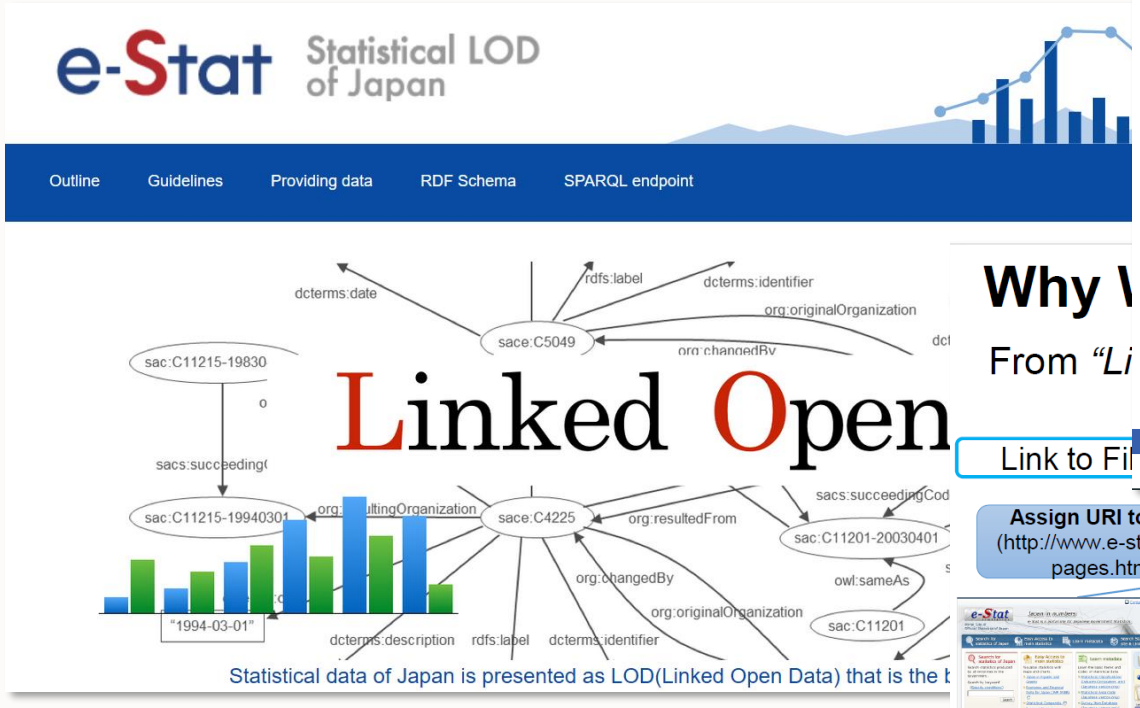
Enterprise capabilities – built on Oracle infrastructure

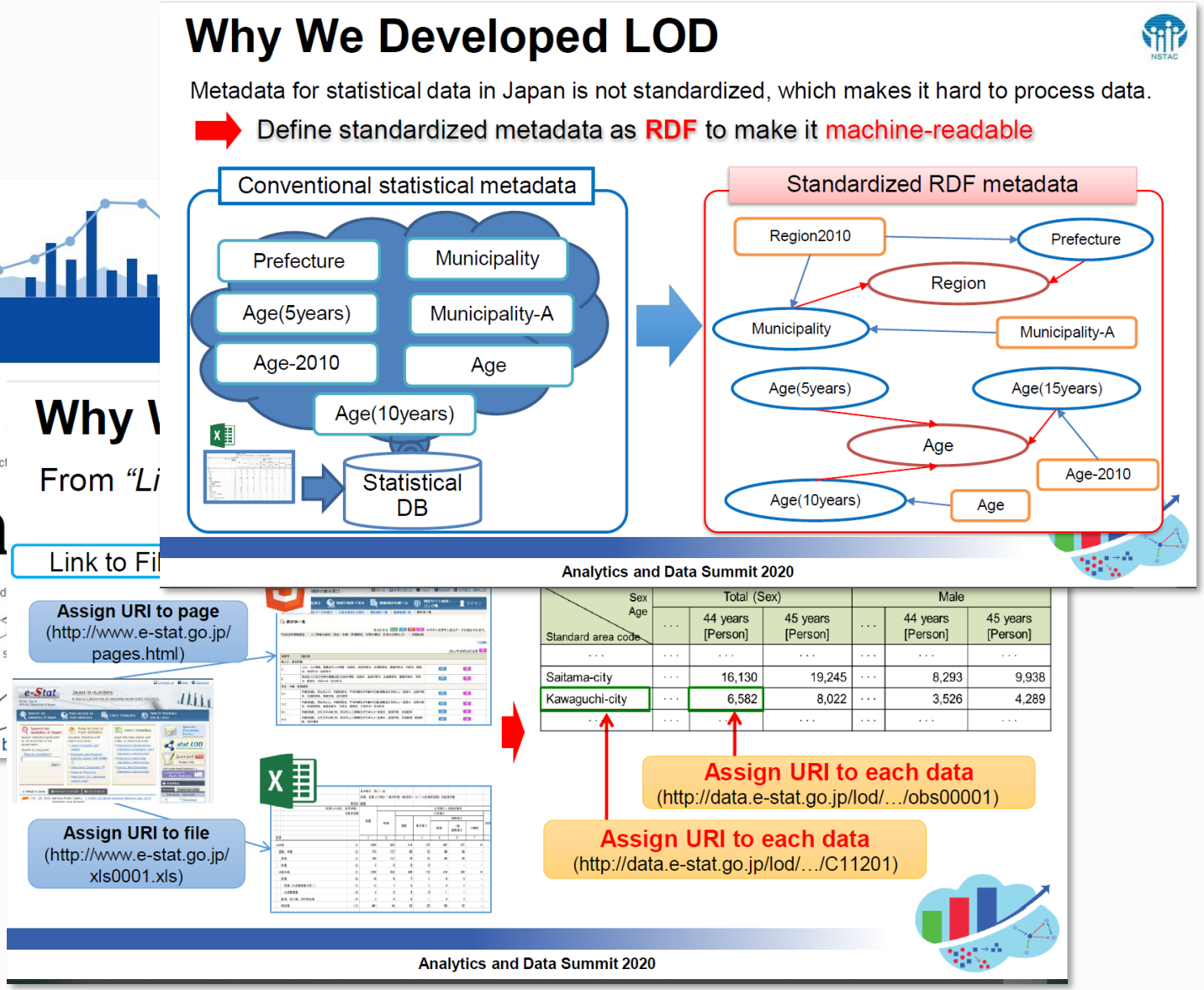
- Manageability, fine-grained security, high availability, integration, and more
- Use with in-memory database feature: 2x-10x faster
- Fine-grained security



Demo

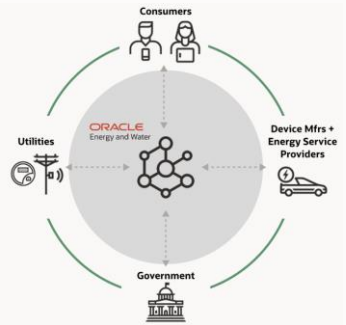
Linked (Open) Data

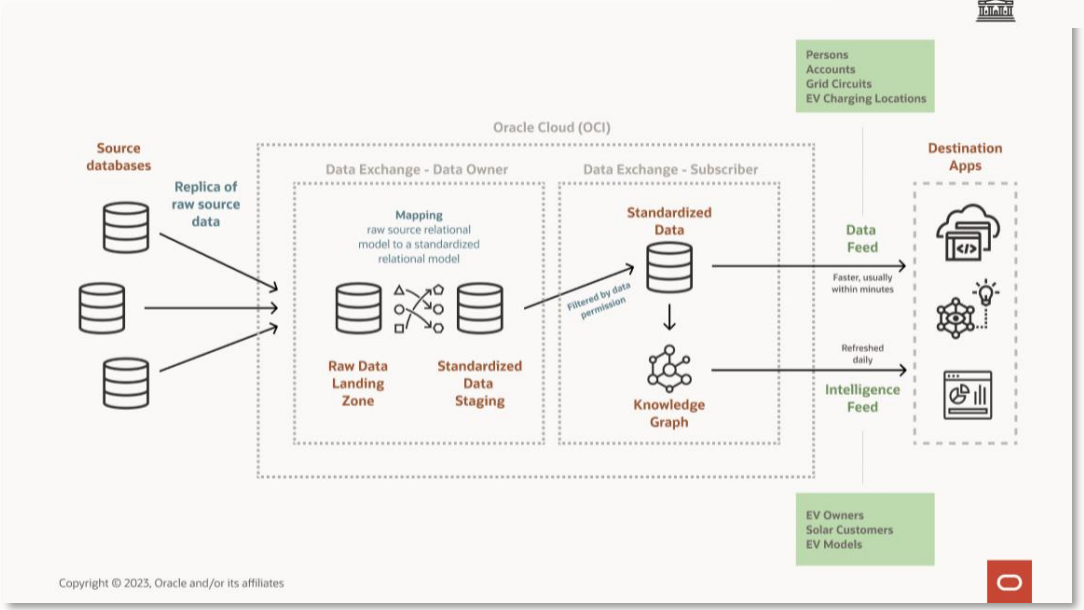


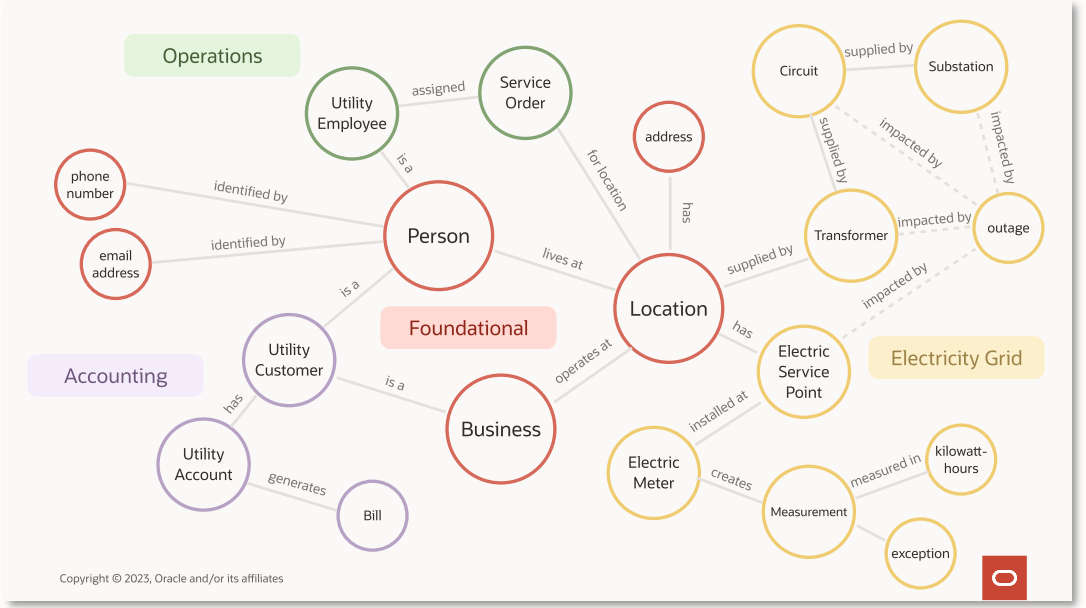


See also: download.oracle.com/otndocs/products/spatial/pdf/biwa2018/BIWA18_Statistical_Linked_Open_Data_in_Japan_with_RDF.pdf

Integrate and share data for critical networks







Source: Oracle Energy & Water Global Business Unit
See also:

- *"Exchanging Energy Data powered by Knowledge Graph"*, youtube.com/watch?v=-Gmfll9zp4Y
- "Oracle Industry Data Exchange", youtube.com/watch?v=0B51hPoPfqw

Use Case: Data Integration based on Linked Data

Business Objective	Solution
360-degree view on integrated data silos	Oracle Converged Database used for semantic metadata modeling, Federated queries
Real-time data retrieval from the existing data sources	Data integration without continuous physical data replication
Integration of knowledge models with existing vocabularies or ontologies	Support for standard vocabularies and ontologies like SKOS, SNOMED, CDM, or DCAT
Infer new knowledge from existing data	Support for RDFS*, OWL*, OWL2EL, and more

* W3C Standards

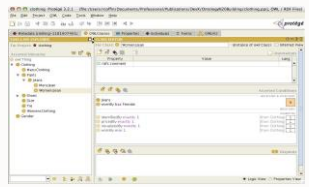
Use Case: Consolidated Enterprise Data Management

Business Objective	Solution
Consolidate departmental data sets and publish results as Linked Data, moving from files to a database	Single, integrated platform to manage, analyze and publish relational data and RDF triples
Improve accessibility, interoperability, and usability of statistical data	Leverage built-in database features for geospatial data (spatial analysis, GeoSPARQL* support) to access data by region
Increase automation in data production	Generate RDF* triples from source relational tables using R2RML*, supported by Oracle RDF Knowledge Graph
Improve search and provide data provenance	SPARQL endpoint for semantic search and analysis • Enables statisticians to run SPARQL* queries and use REST-based applications

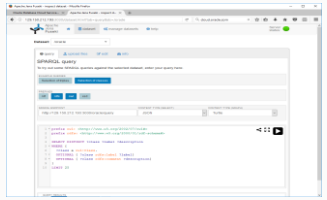
* W3C Standards

RDF Knowledge Graph: Oracle DB & Related Products

Protégé Plugin

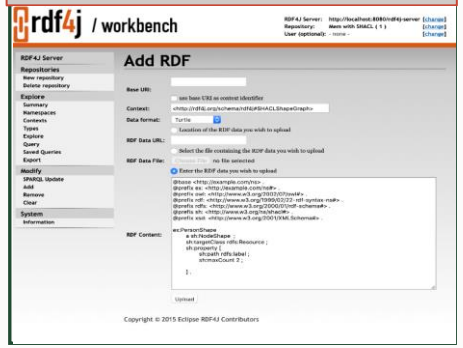


Fuseki Endpoint

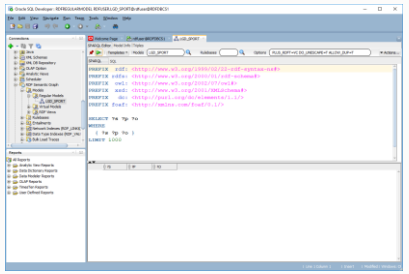


Support for Apache Jena (Java API)

Adapter for Eclipse RDF4J



SQL Developer RDF Support



RDF Server and Query UI

SQL and PL/SQL API

RDF Bulk Loader

Forward-chaining OWL Reasoner

SPARQL-to-SQL Query Translator

SPARQL Update Processor

RDF Data

Inferencing using Rule Bases

- Oracle provides native inference in the database for
  - RDFS, RDFS++
  - **OWLPRIME, OWL2RL, OWL2EL, SKOSCORE**
  - User-defined rules

- Inference done using forward chaining
  - Triples inferred and stored ahead of query time

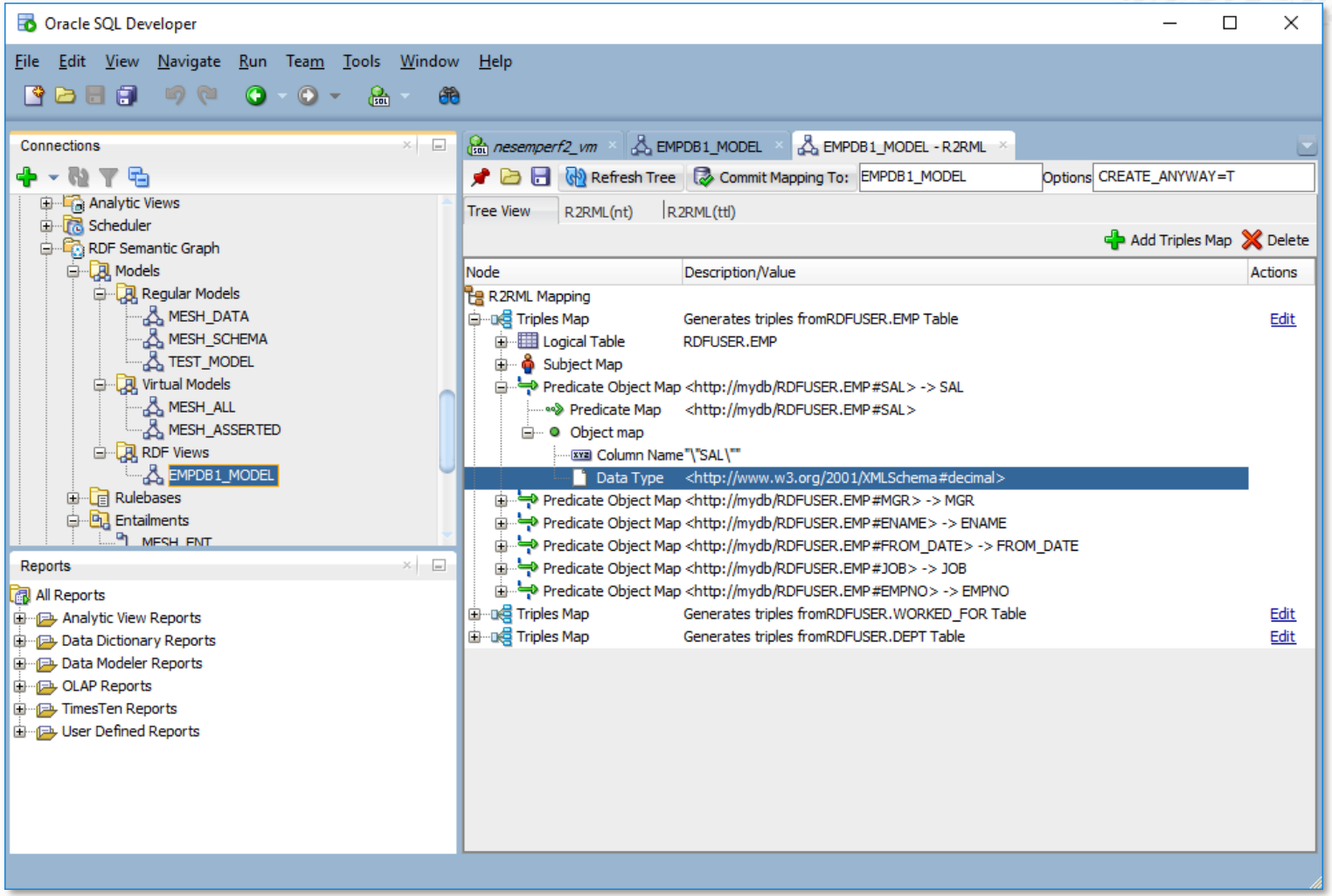
Querying using SPARQL

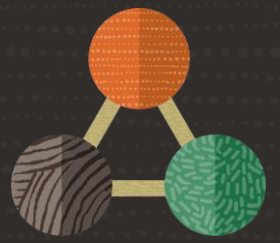
```
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX foaf: <http://xmlns.com/foaf/0.1/>
PREFIX vcard: <http://www.w3.org/2001/vcard-rdf/3.0#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
SELECT ?n ?b ?g
WHERE {
  ?p  foaf:name ?n .
  ?p  vcard:BDAY ?b .
  ?p  foaf:gender ?g
  FILTER ( ?b < "2000-01-01"^^xsd:date )
}
```

Querying using SQL with SPARQL embedded

```
SELECT n, b, g
FROM TABLE( SEM_MATCH('
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX foaf: <http://xmlns.com/foaf/0.1/>
PREFIX vcard: <http://www.w3.org/2001/vcard-rdf/3.0#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
SELECT ?n ?b ?g
WHERE {
  ?p  foaf:name ?n .
  ?p  vcard:BDAY ?b .
  ?p  foaf:gender ?g
  FILTER ( ?b < "2000-01-01"^^xsd:date )
}',
SEM_MODELS('M1'), ... );
```

SQL Developer supporting RDF Knowledge Graphs





More information

Useful resources

- Youtube channels
  - Analytics and Data TechCasts
    www.youtube.com/@analyticsanddatatechcasts90
    - Exchanging Energy Data powered by Knowledge Graph
      www.youtube.com/watch?v=-Gmfll9zp4Y
    - Integrating Data Silos with Linked Data in Oracle Database, Martien Vos
      www.youtube.com/watch?v=Qh3IlcuXHbY

- Blogs & articles
  - Oracle A-Team
    www.ateam-oracle.com/search.html?contentType=Blog-Post&default=%22Knowledge%20Graph%22*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