ISWC2022
Hangzhou, China

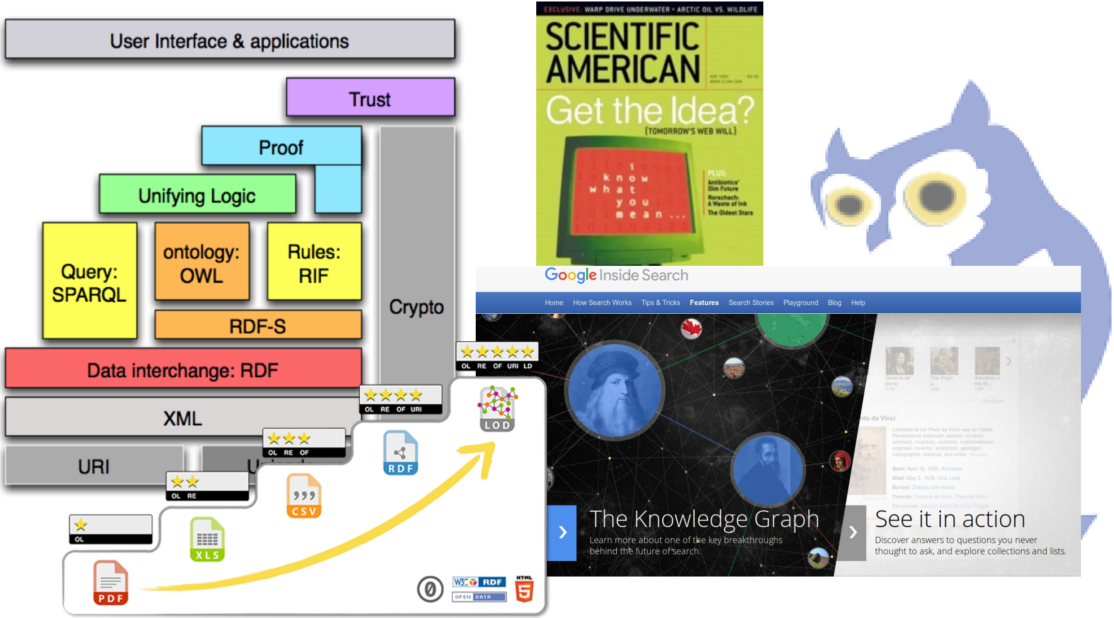
Data, Ontologies, Rules, and the Return of the Blank Node

Markus Krötzsch
Knowledge-Based Systems, TU Dresden

Virtual

23-27 October 2022, Hangzhou, China

TECHNISCHE UNIVERSITÄT DRESDEN


User Interface & applications
Trust
Proof
Unifying Logic
Query: SPARQL
ontology: OWL
Rules: RIF
RDF-S
Crypto
Data interchange: RDF
XML
URI
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PDF
XLS
CSV
RDF
LOD
W3C RDF
OPEN DATA
HTML
EXCLUSIVE: WARP DRIVE UNDERWATER • ARCTIC OIL VS. WILDLIFE
SCIENTIFIC AMERICAN
Get the Idea?
(TOMORROW'S WEB WILL)
I know what you mean...
Google Inside Search
Home
How Search Works
Tips & Tricks
Features
Search Stories
Playground
Blog
Help
The Knowledge Graph
Learn more about one of the key breakthroughs behind the future of search.
See it in action
Discover answers to questions you never thought to ask, and explore collections and lists.

Insights that Unite Us

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Vocabulary has Meaning

- Identity of “resources”
- Important online (HTTP semantics)
- Important in ontologies (vocabulary)

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Knowledge is for Sharing

- Shared conceptualisation
- Declarativity
- Openness & standards

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Being Pedantic is OK

- Specifications are valued
- Formal semantics matters
- Caring about details

The Triple

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Great Advantages

- uniformity & simplicity
- scalability
- structural compatibility
- and the powerful "graph" metaphor

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But . . . the world is complex

- Other communities prefer less normalisation (RDBs, JSON, . . .)
- OWL axioms and ShaCL shapes do not fit into single triples
- Modern Knowledge Graphs are not so simple . . .

The Knowledge Graph of Wikipedia

- Free, community-built knowledge base
- Large and dynamic:
  - >100,000,000 items
    (since 19 Oct 2022)
  - >10,000 properties
  - >14.2B Triples in RDF
  - >20,000,000 edits/month
- International, active community
  - >20,000 active users
    (contributing during a month)
- Many uses

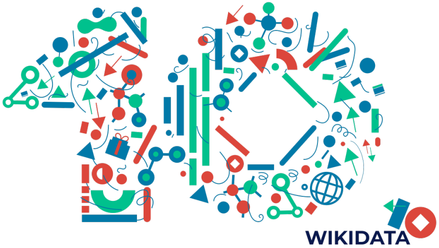

Fig.: Wikidata is celebrating its 10th Birthday on 29th Oct 2022

Tim Berners-Lee (Q80)

British computer scientist

edit

TimBL | Sir Tim Berners-Lee | Timothy John Berners-Lee | TBL | Tim Berners Lee | T. Berners-Lee | T Berners-Lee | Tim Berners-Lee | T.J. Berners-Lee

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instance of	human 1 reference	edit

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instance of	human 1 reference	edit
employer	CERN start time 1984 end time 1994 position held Fellow 0 references + add reference	edit

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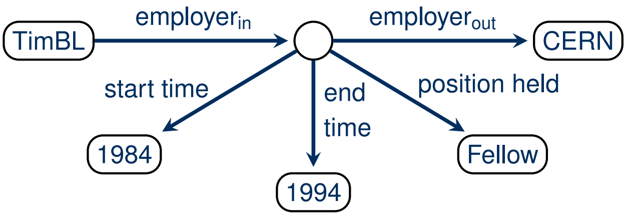
instance of	human		edit
	1 reference		
employer	CERN		edit
	start time	1984	
	end time	1994	
	position held	Fellow	
	0 references		
			+ add reference
award received	Queen Elizabeth Prize for Engineering		edit
	point in time	2013	
	together with	Robert Kahn	
		Vint Cerf	
		Louis Pouzin	
		Marc Andreessen	
	1 reference		

Wikidata and the Semantic Web

Each Wikidata statement turns into several triples

Fig. Sketch of reified statement ►



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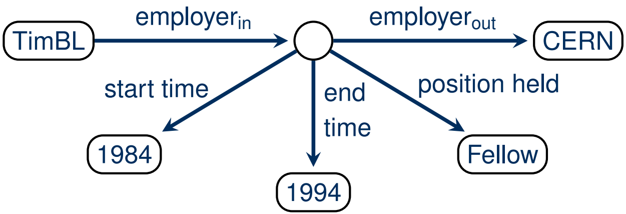

Wikidata SPARQL & RDF usage

- Official IRI mapping and vocabulary
- Free RDF dumps + LOD exports
- Public live SPARQL endpoint at `https://query.wikidata.org/` (BlazeGraph)

Key technologies for community and 3rd party users!

From objects to triples . . . and back?

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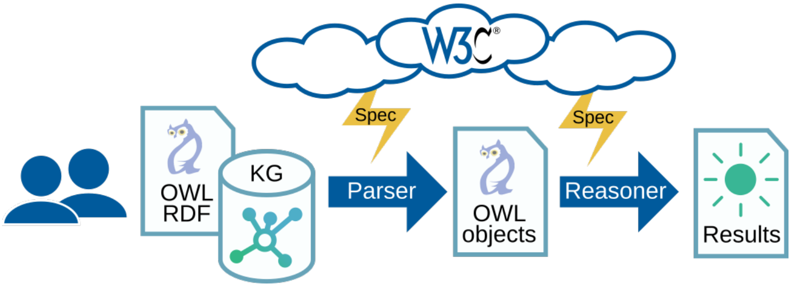
The OWL approach:



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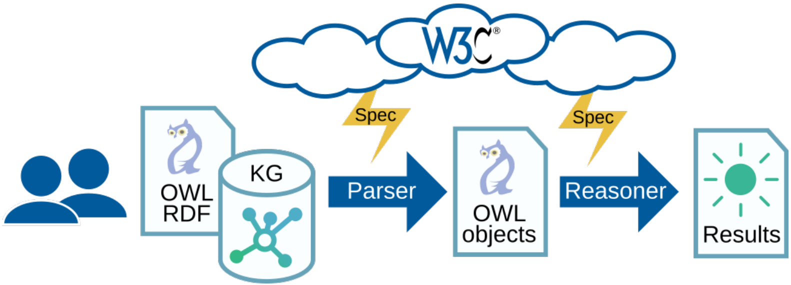

Great for what it does . . . but not always what we need

- Ontological information may be intertwined with KG
- What reasoning we want may depend on context
- We may need new semantic interpretations for our data

New semantic interpretations for data

Wikidata says: “universe — has part(s) of the class — astronomical object”

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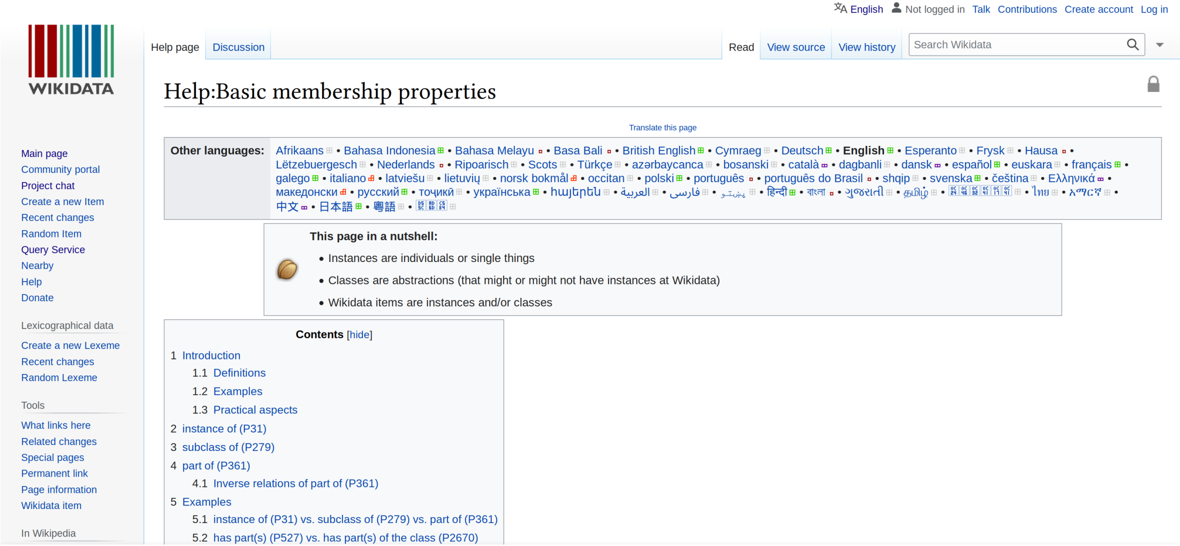

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This page in a nutshell:

- Instances are individuals or single things
- Classes are abstractions (that might or might not have instances at Wikidata)
- Wikidata items are instances and/or classes

Contents [hide]

Main page
Community portal
Project chat
Create a new Item
Recent changes
Random Item
Query Service
Nearby
Help
Donate

Lexicographical data

Create a new Lexeme
Recent changes
Random Lexeme

Tools

What links here
Related changes
Special pages
Permanent link
Page information
Wikidata item

In Wikipedia

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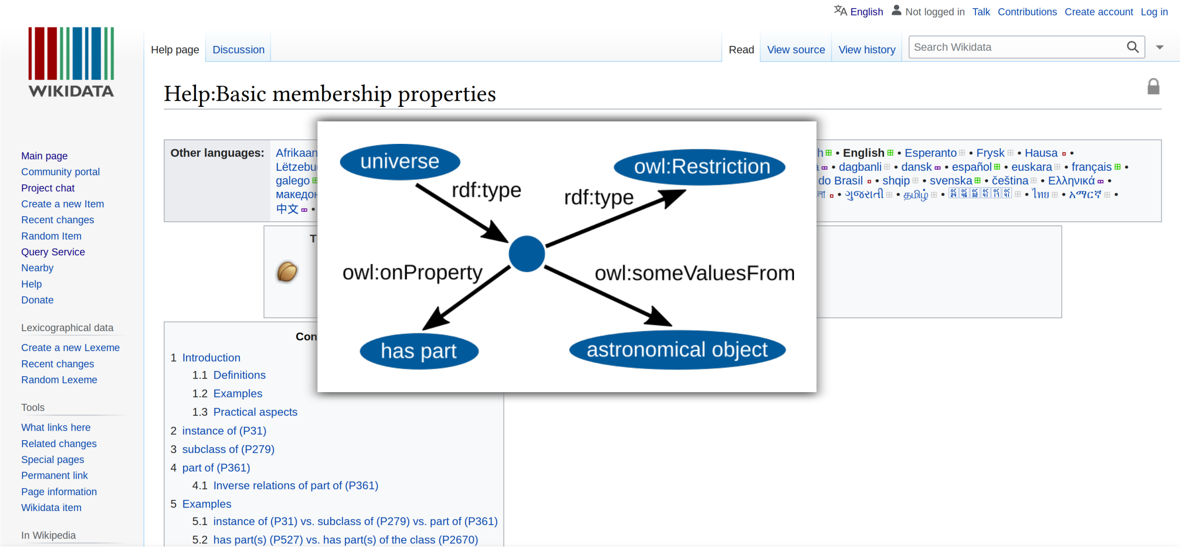
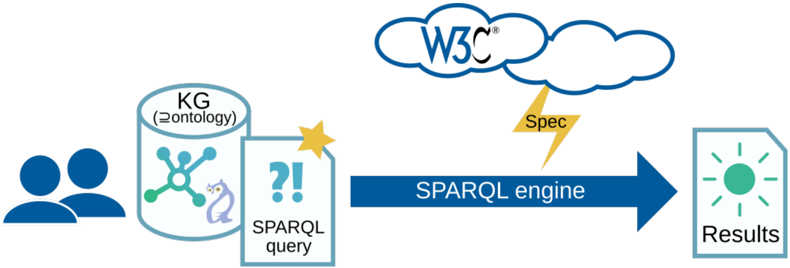


SPARQL to the Rescue



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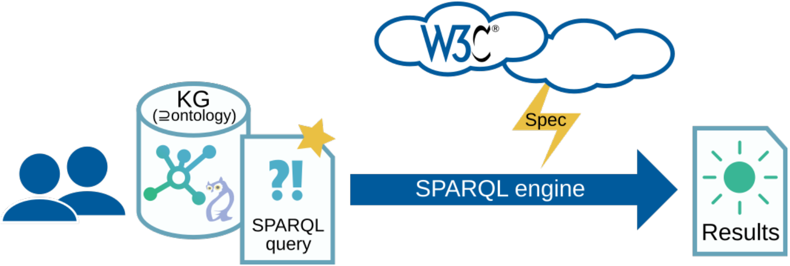

Example: Find all cities

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SELECT ?city WHERE {
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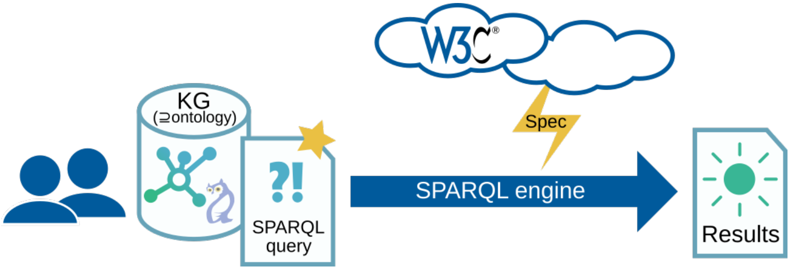

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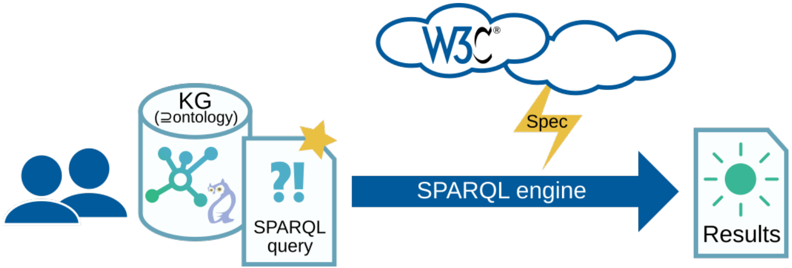

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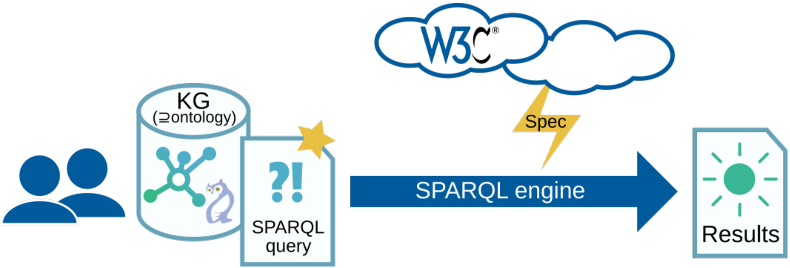

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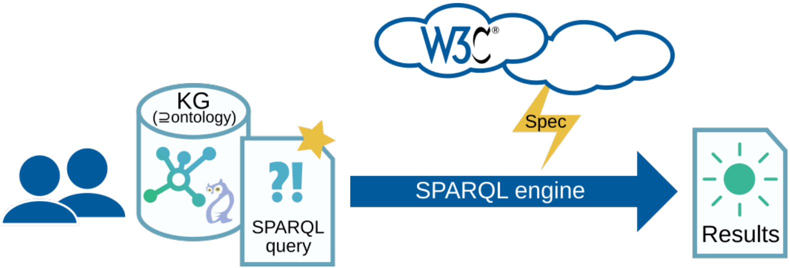

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- OWL QL
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Fig. SPARQL pattern for finding empty OWL QL classes from [Bischof et al. ISWC 2014]

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The Rules Layer on the Cake

Where do we get something more powerful than SPARQL?

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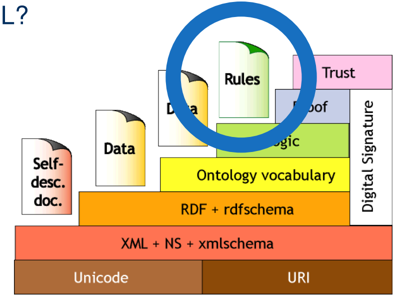
Where do we get something more powerful than SPARQL?

Well, it has always been there . . .



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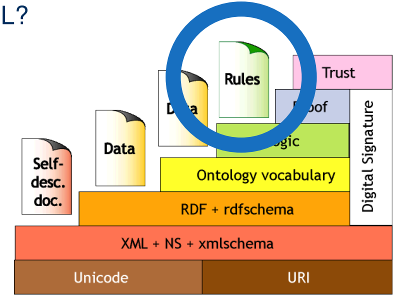

A Complicated Relationship

- since 2000: **Notation 3 Logic** developed (incl. RDF rules)
- 2004: **SWRL** W3C member submission
- 2005: W3C charters WG for **Rule Interchange Format** (RIF)
- 2009: **OWL RL** becomes W3C Rec
- 2010: RIF enters recommendation
- 2010: 1st **Datalog 2.0 Workshop**
- all this time: SemWeb practitioners use various forms of rules (except RIF)

The Simplest Rule Language

Datalog: a very simple rule language

- Simple predicate-logic rules:
  rdf:type$(X, Y) \wedge$ rdfs:subClassOf$(Y, Z) \rightarrow$ rdf:type(X, Z)
- Conjunctive query patterns + recursion
- Polynomial time data complexity
- Fast reasoners with RDF support:
  RDFox [Nenov et al. ISWC 2015],
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Nothing complicated

- No negation
- No disjunction
- No built-ins or filters

OWL with Datalog

	SPARQL	Datalog	
RDFS	✓	✓	
OWL QL	✓	✓	[Bischof et al., ISWC 2014] + SPARQL as Datalog
OWL RL	×	✓	[Krötzsch, ISWC 2012]
OWL EL	×	✓	[Krötzsch, IJCAI 2011]
OWL DL	×	×	Too complex: N2ExpTime $>$ P

How complicated are these rules?

$$\text{subClassOf}(?C, ?D1) \wedge \text{subClassOf}(?C, ?D2) \wedge \\ \text{isInter}(?D12, ?D1, ?D2) \rightarrow \text{subClassOf}(?C, ?D12)$$

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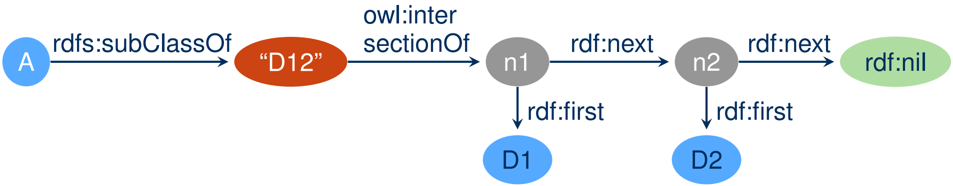
RDF encoding of `SubClassOf(`A` ObjectIntersectionOf( `$D1$` `$D2$` ) )`**:**



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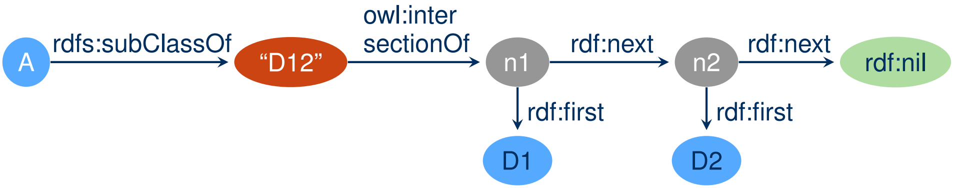
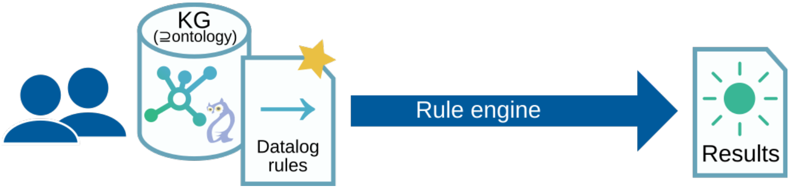


$$\text{TRIPLE}(?D12, \text{owl:intersectionOf}, ?L1) \wedge \text{TRIPLE}(?N1, \text{rdf:next}, ?N2) \wedge \text{TRIPLE}(?N2, \text{rdf:next}, \text{rdf:nil}) \wedge \text{TRIPLE}(?N1, \text{rdf:first}, ?D1) \wedge \text{TRIPLE}(?N2, \text{rdf:first}, ?D2) \rightarrow \text{isInter}(?D12, ?D1, ?D2)$$

$\leadsto$ **10 reasoning rules and 36 parsing rules for much of OWL EL** [ECAI Tutorial 2020]

So . . . what have we accomplished?

- From ontologies to data
- From W3C semantics to user-space semantics
- From dedicated reasoners to <50 lines of code



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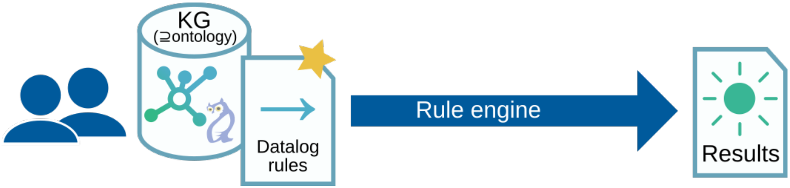

However . . .

- Triples are not enough! [Krötzsch, IJCAI 2011 & ISWC 2012]
- Flexibility has a performance cost (VLog on Snomed: 2min)
- Getting rules right is not easy

Why Datalog is not enough

Observation 1: Encoding complex objects in RDF requires auxiliary nodes
Observation 2: Datalog can only produce new relationships among existing nodes

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$\leadsto$ **Major Weakness:** We can parse complex RDF structures but not create them!

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$\leadsto$ **Major Weakness:** We can parse complex RDF structures but not create them!

Solution: Enable value invention in rules

$$\begin{aligned}\mathrm{isInter}(?D12, ?D1, ?D2) \to{} & \mathrm{TRIPLE}(?D12, \mathrm{owl{:}intersectionOf}, \_{:}n1) \land \\ & \mathrm{TRIPLE}(\_{:}n1, \mathrm{rdf{:}next}, \_{:}n2) \land \mathrm{TRIPLE}(\_{:}n2, \mathrm{rdf{:}next}, \mathrm{rdf{:}nil}) \land \\ & \mathrm{TRIPLE}(\_{:}n1, \mathrm{rdf{:}first}, ?D1) \land \mathrm{TRIPLE}(\_{:}n2, \mathrm{rdf{:}first}, ?D2)\end{aligned}$$

$\leadsto$ "Existential Rules"

From Datalog to Existential Rules

Existential Rules: a simple rule language

- Simple predicate-logic rule, like Datalog
- Conjunctive query patterns + recursion + value invention
- Query answering **undecidable**
- Fast reasoners with RDF support: RDFox [Nenov et al. ISWC 2015], VLog [Carral et al. ISWC 2019]

Still nothing complicated

- No negation
- No disjunction
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Reasoners recursively apply rules and add new values, hoping for termination

⇝ Most tool support is for rule sets that “terminate”

The Power of Terminating Existential Rules

Recall:

- Datalog cannot see negative information (no negation)
- Datalog cannot solve non-polynomial tasks

Clear:

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Theorem* [Bourgaux et al., KR 2021]

Terminating existential rules can solve every computable task that does not depend on negative information.

* Terms and conditions apply; see paper

The Return of the Blank Node?

Summary: User-level specifications for interpreting triples

	SPARQL	Triples-only Datalog	Datalog	Existential Rules
RDFS	✓	✓	✓	✓
OWL QL	✓	✓	✓	✓
OWL RL	×	×	✓	✓
OWL EL	×	×	✓	✓
OWL DL	×	×	×	✓

Summary: What really matters

We have split the world into triples, but still struggle to put it back together

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- Our needs change from context to context
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. . . but declarative, shareable meaning is more relevant than ever.

- Explanation and accountability requires shared concepts
- Declarativity is key to interoperability and scalability
- Knowledge is human, it will not go away

What's next for the "Semantic Web"?

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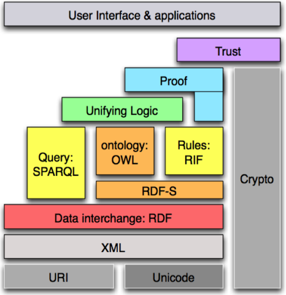
What shall we do about it?

1. Appreciate what we stand for



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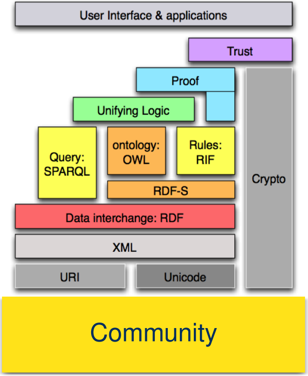

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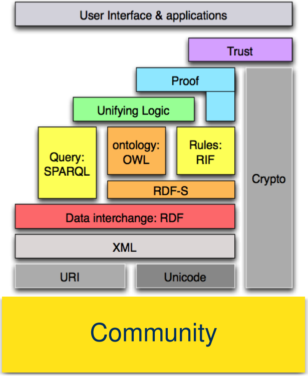
What shall we do about it?

1. Appreciate what we stand for
2. Spread our values:
   meaning, sharing, precision
3. Focus on big challenges:
   flexibility, scalability, human collaboration, . . .
4. Find new ways to agree:
   on "standards", on concepts, on models
5. Engage with communities
   who care and can help



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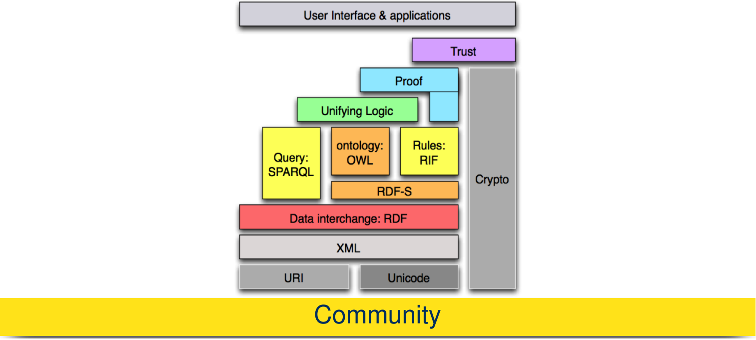

“Knowledge is human, it will not go away”

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We are always looking for new ideas. How about joining us?
(Just get in touch, and we will see what can be done :-)