# Semantic Web – State of the Art

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Wright State University, Dayton, OH
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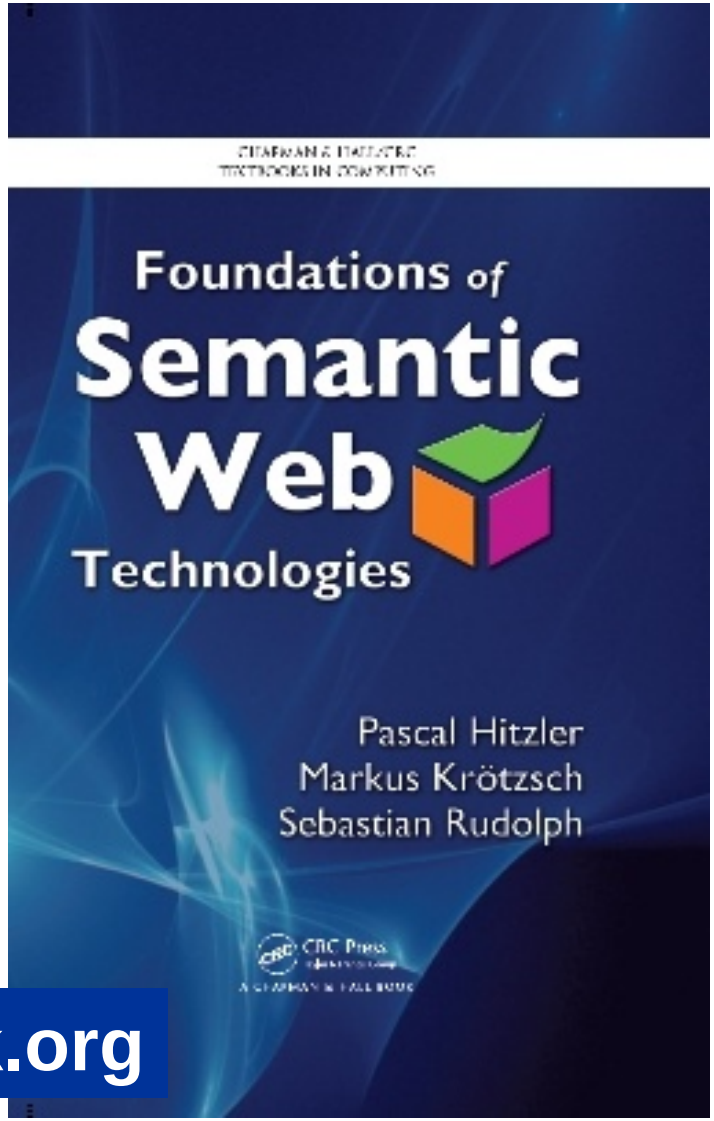
# New Book

**Pascal Hitzler, Markus Krötzsch, Sebastian Rudolph**

**Foundations of Semantic Web Technologies**
**Chapman & Hall/CRC, 2010**

**Grab a flyer!**




**http://www.semantic-web-book.org**

# Contents

- What is Semantic Web?
  - Limitations of the current World Wide Web
  - The basic Semantic Web idea
  - Semantic Web Semantics
- Semantic Data Web (state of the art)
  - its limitations
  - and how to overcome them
- And what about scalability?

# The current (World Wide) Web

- Immensely successful.
- Huge amounts of data.
- Syntax standards for transfer of structured data.
- Machine-processable, human-readable documents.

**BUT:**

- Content/knowledge cannot be accessed by machines.
  Meaning (semantics) of transferred data is not accessible.

# Examples

- **Find that landmark article on data integration written by an Indian researcher in the 1990s.**
  **[If you manage this without knowing the answer, let me know how you did it.]**

- **Are lobsters spiders?**
  **[This is getting easier these days, but was impossible a few years ago. It still needs finding and integrating over different websites, as well as some background knowledge.]**

- **Which car is called a “duck” in German?**
  **[This needs some intelligent integration of content from different websites plus background knowledge.]**

# Another example

**"Identify congress members, who have voted "No" on pro environmental legislation in the past four years, with high-pollution industry in their congressional districts."**

**In principle, all the required knowledge is on the Web – most of it even in machine-readable form.**

**However, without automated processing and reasoning we cannot obtain a useful answer.**

# Very brief history of the Semantic Web

- invented ca. 1989.
- 1990s: W3C metadata activity (lead to RDF(S))
- W3C semantic web activity: chartered 2001.

- USA: DAML-Programme 2000-2005
  approx. $90M.
- Many large scale EU projects since 2002 and ongoing.
  ! FP6/FP7
- Major IT companies and
  venture capital now investing.

# Semantic Technologies in Europe

- **E.g. EU ICT Work Programme 2009**
  - **Challenge 4: Digital Libraries and Content**
    - **Objective 4.2: Technology-Enhanced Learning**
    - **Objective 4.3: Intelligent Information Management**

Semantic web technologies are likewise starting to be used on an industrial scale by information providers and search engines alike to offer more sophisticated services.

hardware and software dependencies must be overcome. Keeping the associated semantics as well as the digital objects, should guarantee the integrity and authenticity of the information as originally recorded.

resources. The system should ensure that the representation of the objects and their embedded semantic knowledge in order to support their future re-use. Appropriate verification scenarios should be an integral component of the work.

resources across existing institutional digital libraries and repositories. Research should address scalability, interoperability and distributed architectures, aggregation and semantic search tools. Validation should address researchers and cultural heritage professionals but be

# Semantic Technologies in the US

- **Funding available e.g. via**
  - **NIH**
  - **NSF**
  - **DoD, DoE, AFRL**
  - **...**

- **Considerable industrial take-up**
  - **Annual Semantic Technology Conference in CA Taylored towards industry**
  - **Major IT players (Oracle, IBM, HP, ...) invest**
  - **Venture capital (e.g. Vulcan, Inc.).**

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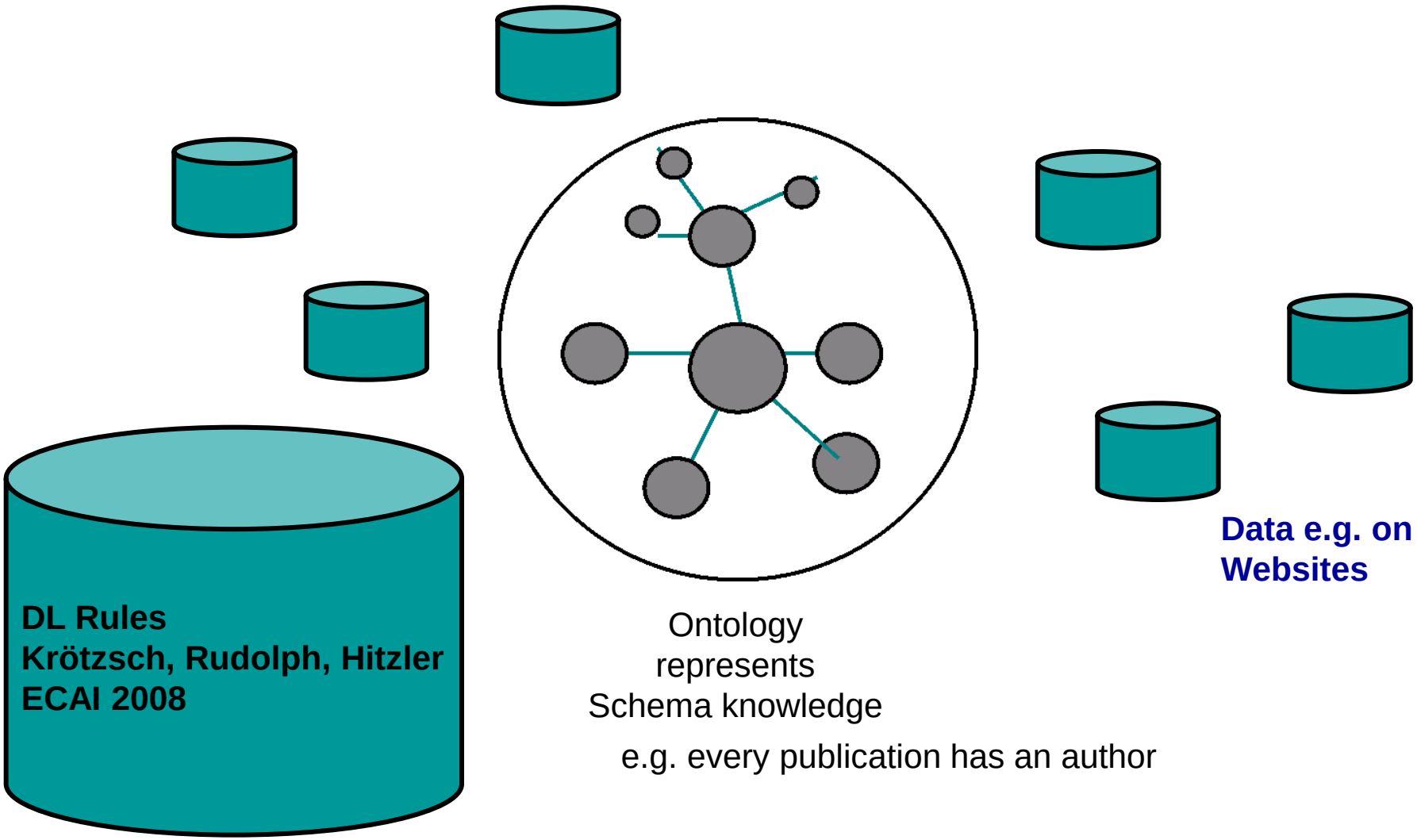
# Basic Idea of the Semantic Web



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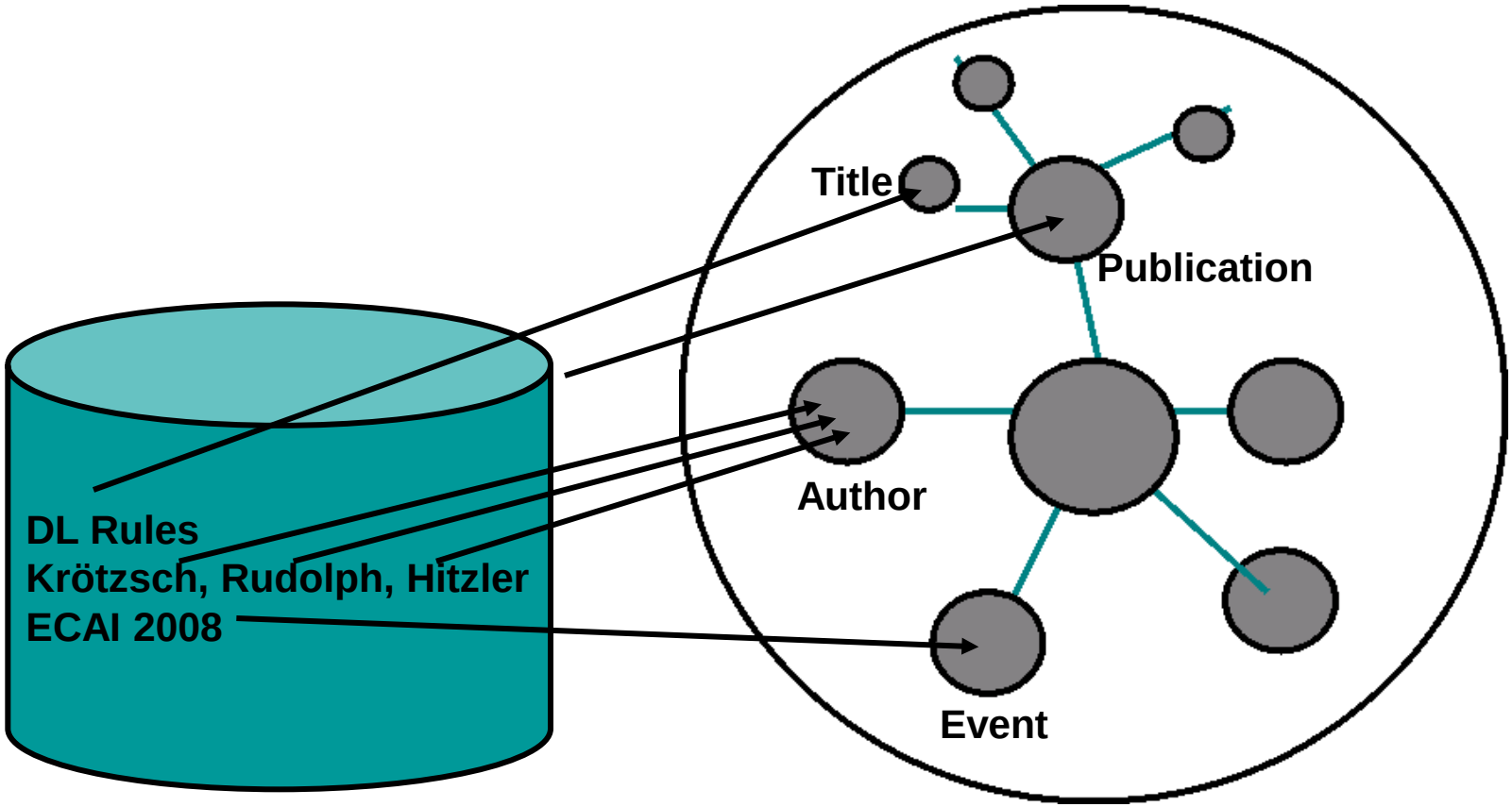
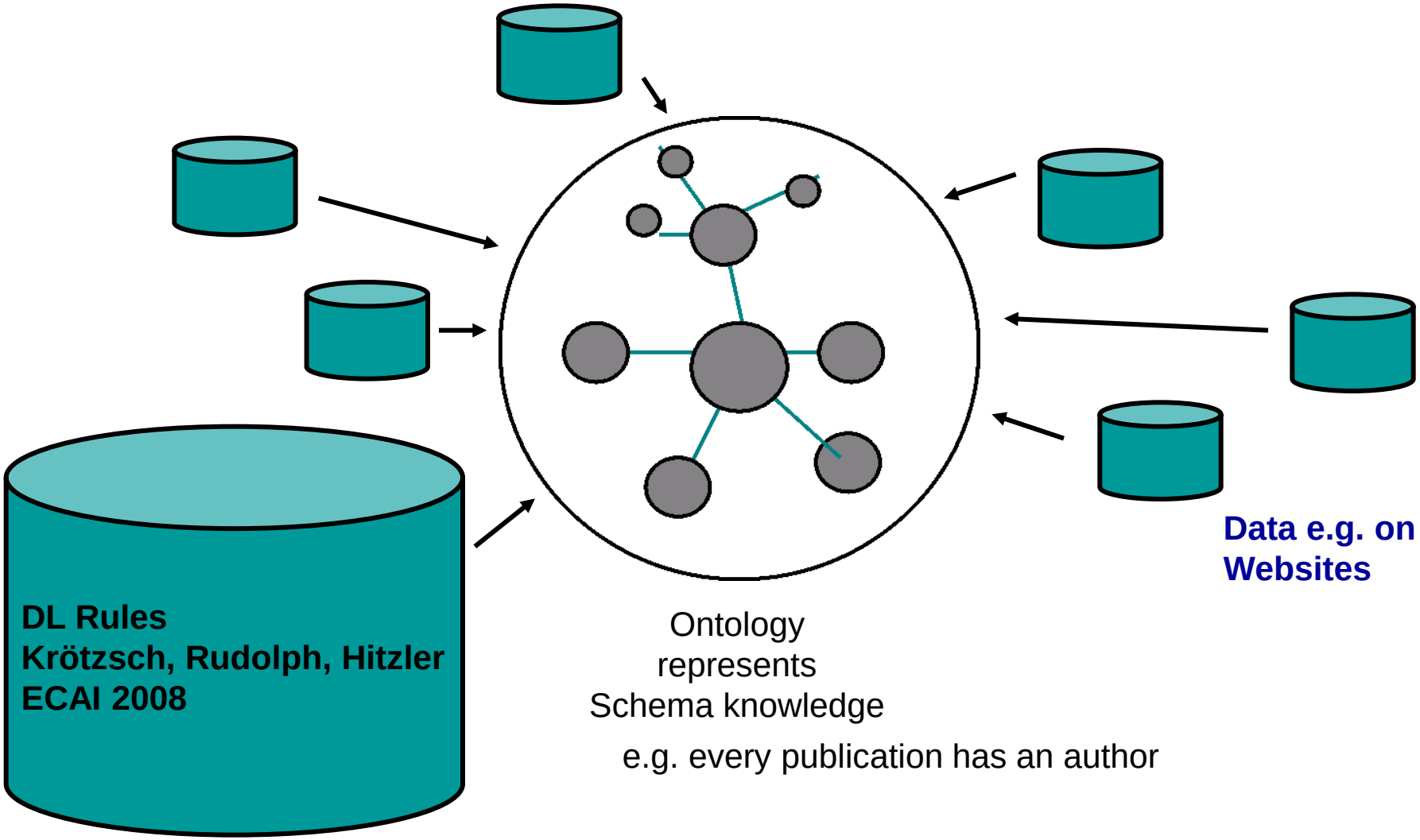



e.g. every publication has an author

# Basic Idea of the Semantic Web



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# What Is Semantic Web Semantics?

- **Opinions Differ. Here's my take.**

- **Semantic Web requires a shareable, declarative and *computable* semantics.**
- **I.e., the semantics must be a formal entity which is clearly defined and automatically computable.**

- **Ontology languages provide this by means of their formal semantics.**
- **Semantic Web Semantics is given by a relation – the *logical consequence* relation.**

- **Note: This is considerably more than saying that the semantics of an ontology is the set of its logical consequences!**

# In other words

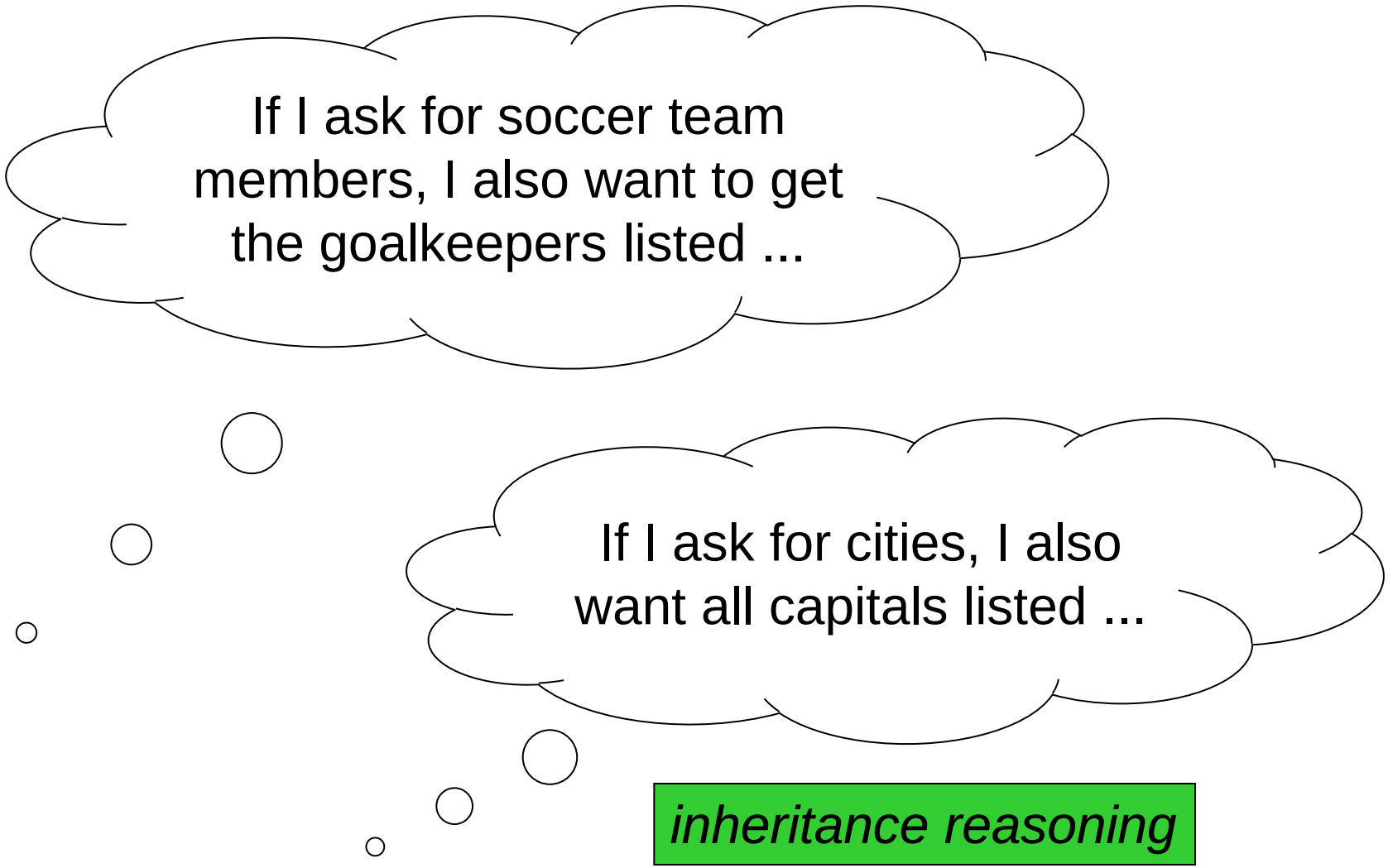
**We capture the meaning of information**

**not by specifying its meaning (which is impossible)**
**but by specifying**

**how information interacts with other information.**

**We describe the meaning indirectly through its effects.**

# Simple Logical Reasoning



# Less Simple Reasoning

*answering requires merging of knowledge from many websites and using background knowledge.*

What was again the name of that russian researcher who worked on resolution-based calculi for EL?

Are lobsters spiders?

What is "Käuzchen" in english?

# SNOMED CT

- **SNOMED CT: commercial ontology, medical domain ca. 300,000 axioms**

- $\text{InjuryOfFinger} \quad \acute{} \quad \text{Injury} \sqcap \exists \text{site.Finger}_S$
  $\text{InjuryOfHand} \quad \acute{} \quad \text{Injury} \sqcap \exists \text{site.Hand}_S$
  $\text{Finger}_S \quad \sqsubseteq \quad \text{Hand}_P$
  $\text{Hand}_P \quad \sqsubseteq \quad \text{Hand}_S \sqcap \exists \text{part.Hand}_E$

- **Reasoning has been used e.g. for**
  - **classification (computing the hidden taxonomy) e.g., InjuryOfFinger ⊑ InjuryOfHand**
  - **bug finding**

# So what happened?

- In 2004, two W3C Recommendations were completed:
  - RDF + RDF Schema with formal model-theoretic semantics
  - OWL with formal model-theoretic semantics

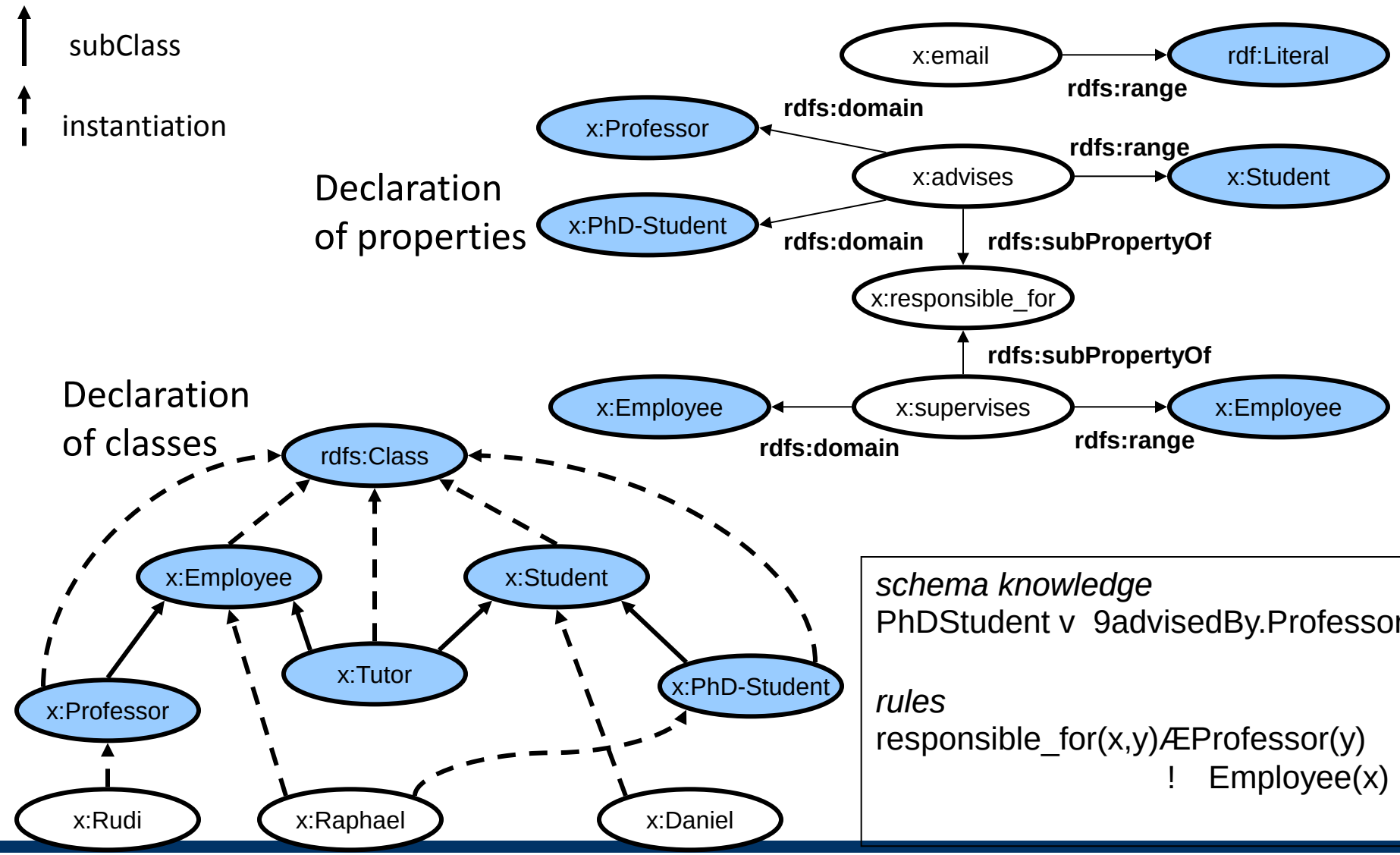
- OWL 2 update emerged 2009.
- RDF update is being discussed right now.

# Ontology languages

- **Of central importance for the realisation of Semantic Technologies are suitable representation languages.**
- **Meaning (semantics) provided via logic and deduction algorithms.**
- **Scalability is a challenge.**


Language standards recommended by W3C

# Ontology Example




*schema knowledge*
PhDStudent v 9advisedBy.Professor

*rules*
responsible_for(x,y)ÆProfessor(y)
! Employee(x)

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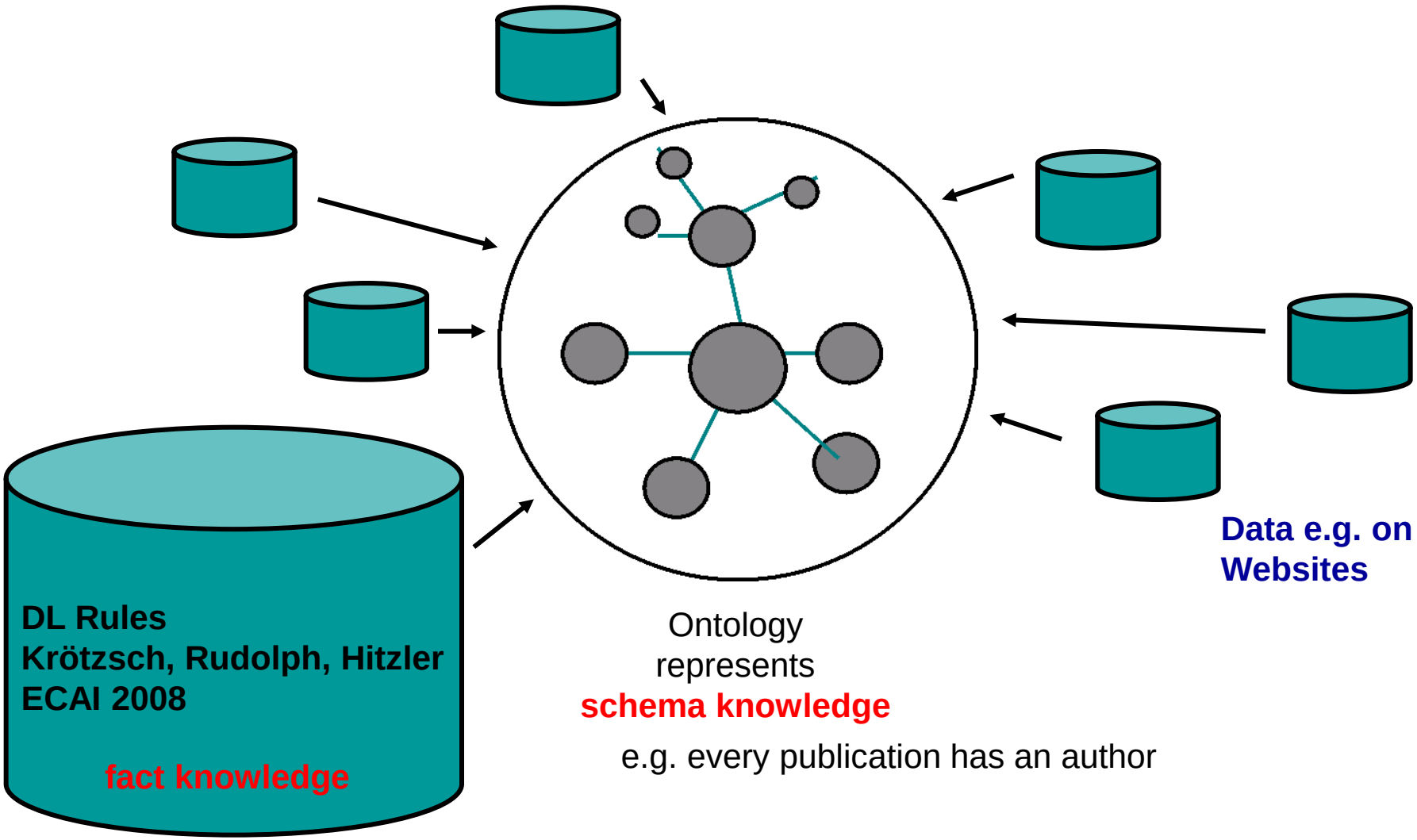
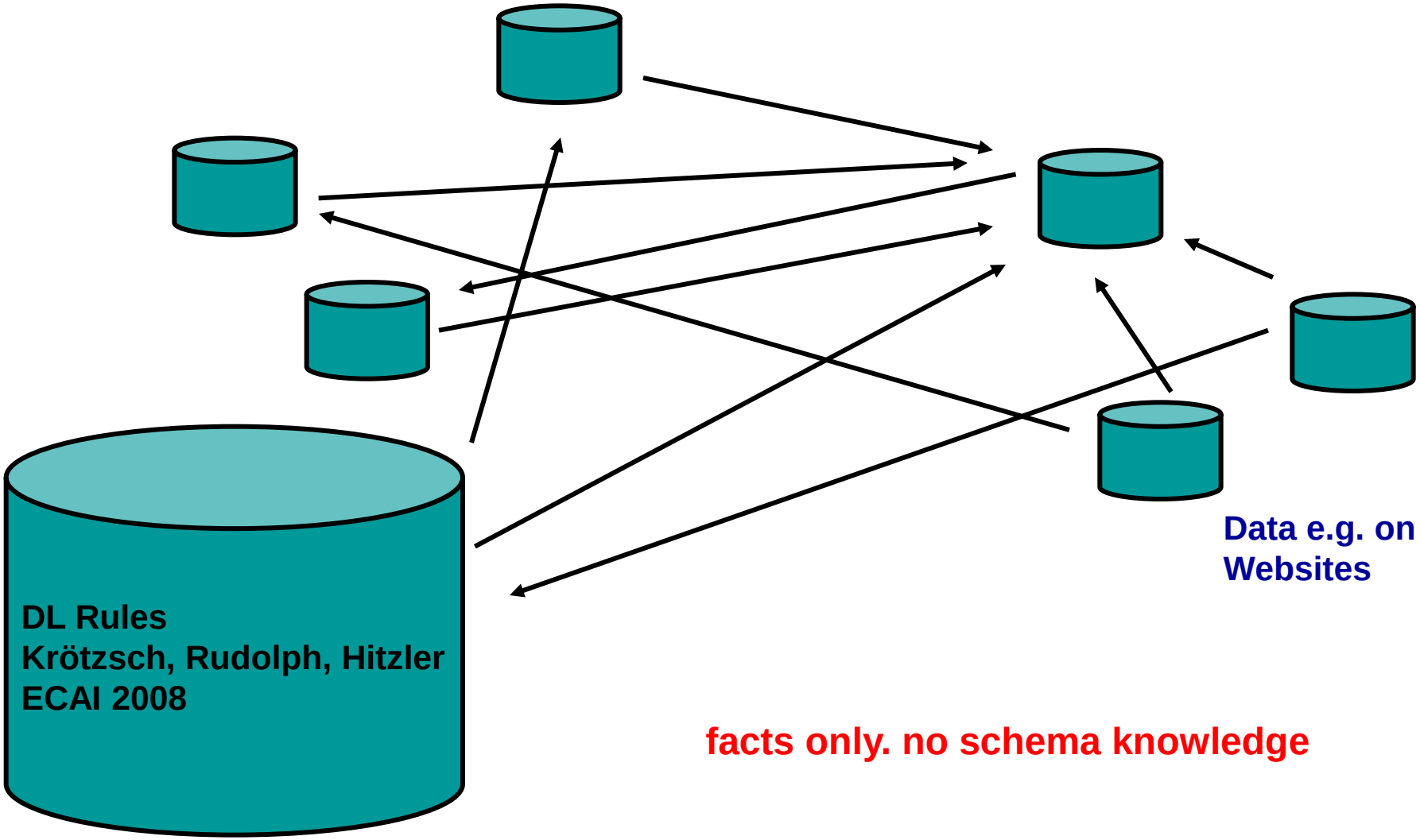
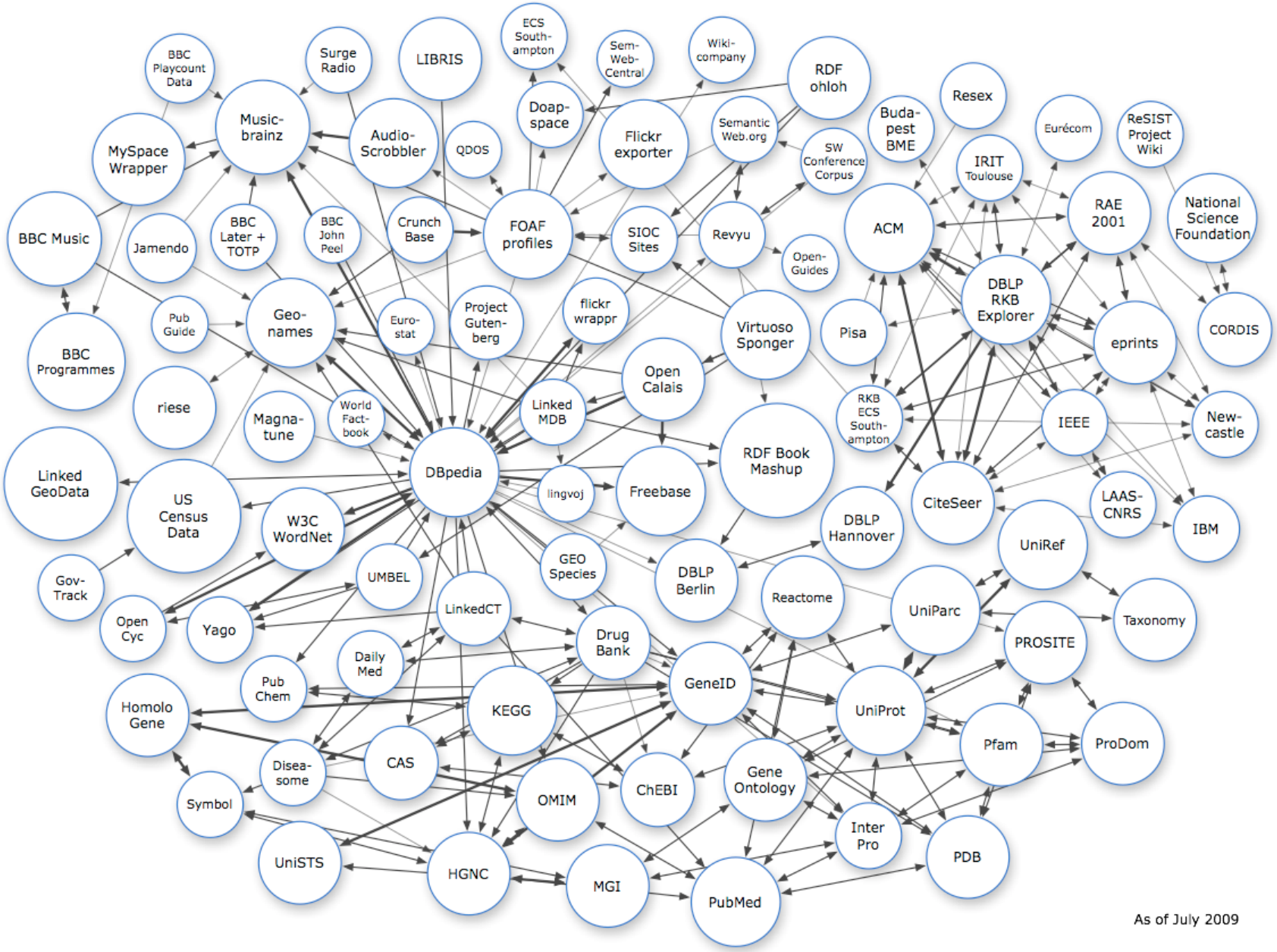


# Currently it‘s looking like this




facts only. no schema knowledge

# Linked Open Data

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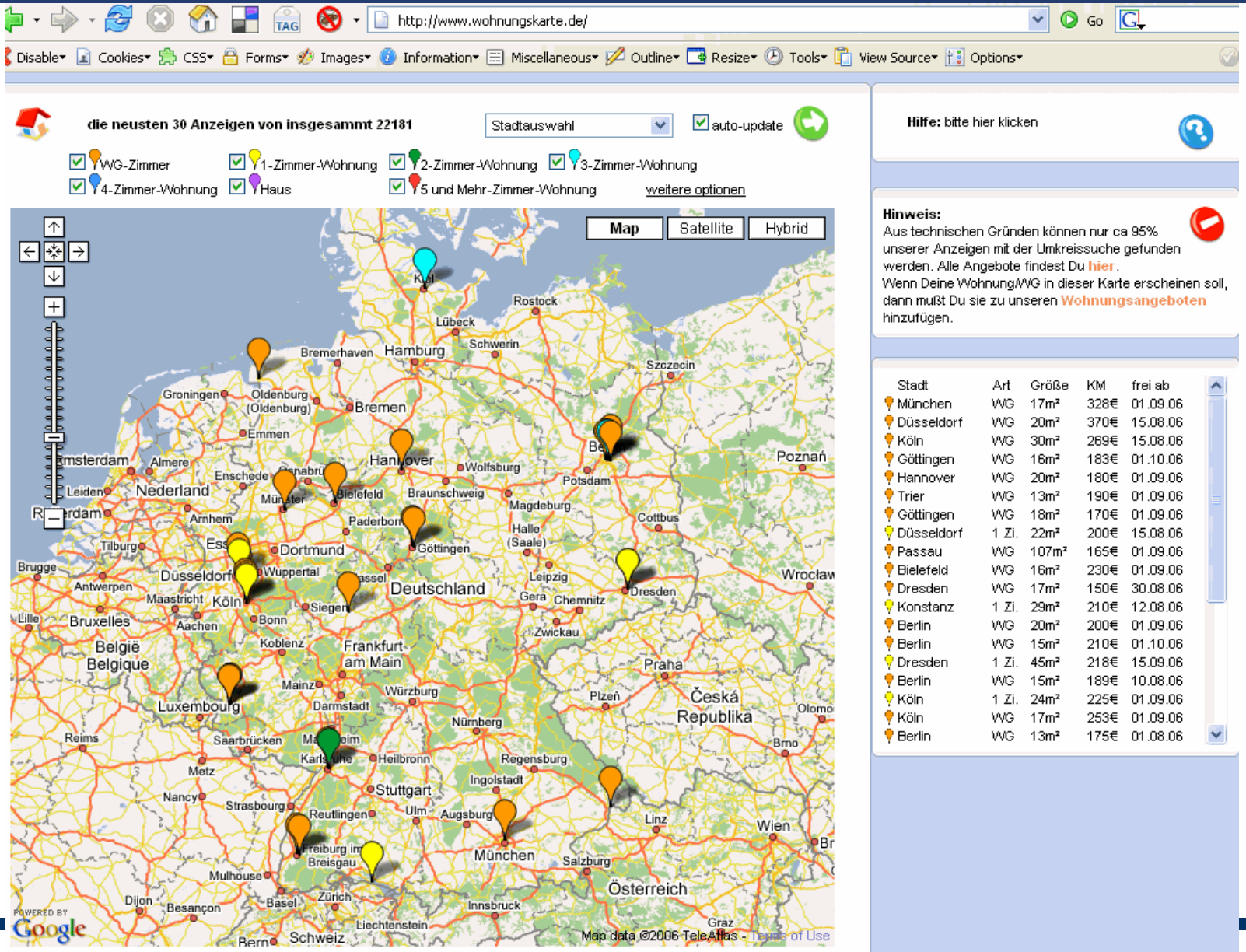
# Mashups


http://www.wohnungskarte.de/
die neusten 30 Anzeigen von insgesammt 22181
Stadtauswahl
auto-update
WG-Zimmer
1-Zimmer-Wohnung
2-Zimmer-Wohnung
3-Zimmer-Wohnung
4-Zimmer-Wohnung
Haus
5 und Mehr-Zimmer-Wohnung
weitere optionen
Map
Satellite
Hybrid
Hilfe: bitte hier klicken
Hinweis:
Aus technischen Gründen können nur ca 95% unserer Anzeigen mit der Umkreissuche gefunden werden. Alle Angebote findest Du hier.
Wenn Deine Wohnung/WG in dieser Karte erscheinen soll, dann mußt Du sie zu unseren Wohnungsangeboten hinzufügen.
Stadt Art Größe KM frei ab
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Düsseldorf WG 20m² 370€ 15.08.06
Köln WG 30m² 269€ 15.08.06
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Potsdam
Magdeburg
Arnhem
Paderborn
Cottbus
Halle (Saale)
Tilburg
Dortmund
Göttingen
Brugge
Düsseldorf
Wuppertal
Leipzig
Wrocław
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Maastricht
Köln
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Chemnitz
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België
Belgique
Koblenz
Frankfurt am Main
Praha
Mainz
Luxembourg
Darmstadt
Würzburg
Plzeň
Česká Republika
Nürnberg
Reims
Saarbrücken
Karlsruhe
Heilbronn
Regensburg
Brno
Metz
Ingolstadt
Nancy
Stuttgart
Strasbourg
Reutlingen
Ulm
Augsburg
Linz
Wien
Freiburg im Breisgau
München
Salzburg
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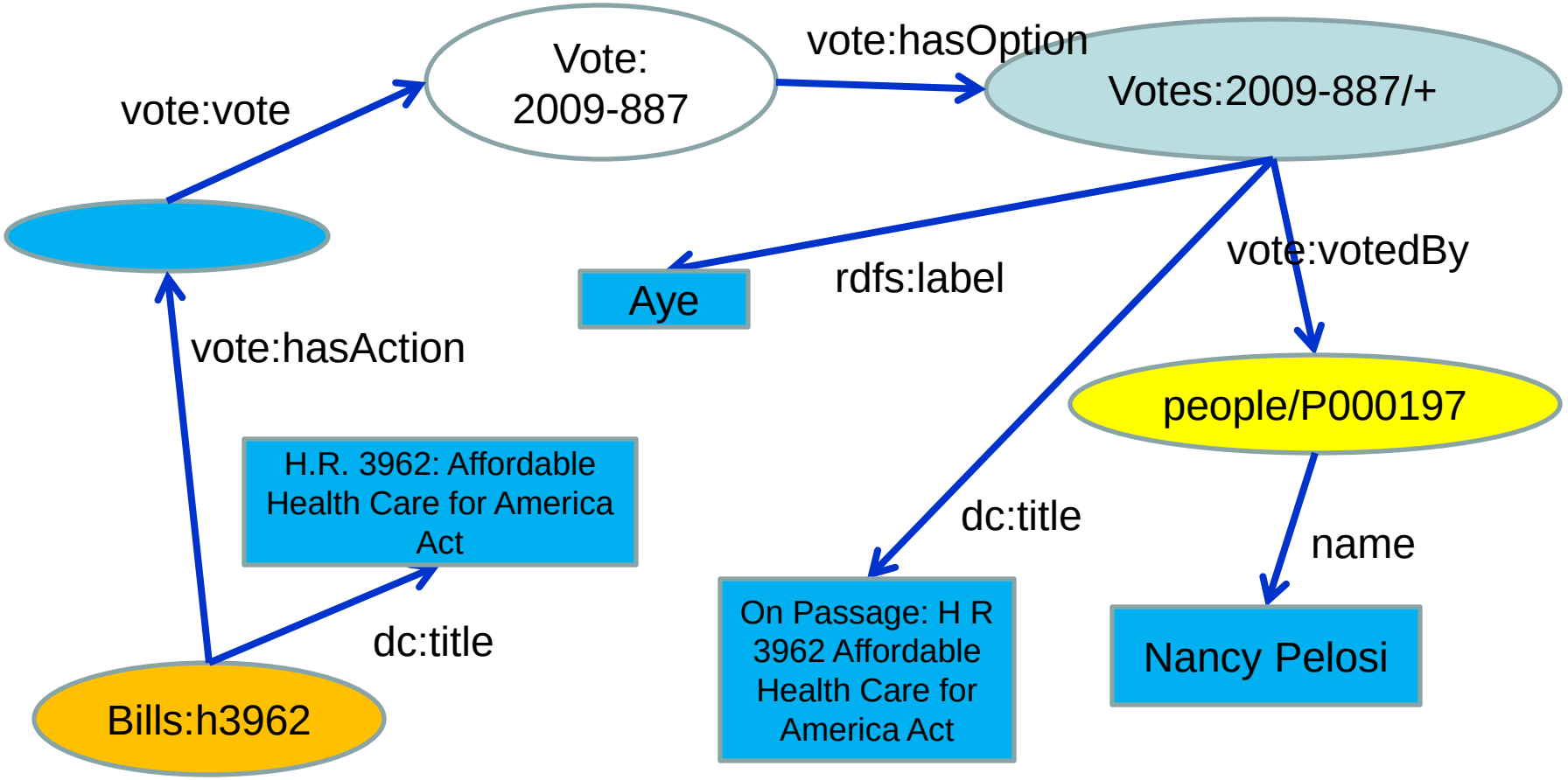
# Example: GeoNames

| Populated Place Features (city, village,...) | | | |
|---|---|---|---|
| 2,518,403 | P.PPL | populated place | a city, town, village, or other agglomeration of buildings where people live and work |
| 48,483 | P.PPLX | section of populated place | |
| 39,336 | P.PPLL | populated locality | an area similar to a locality but with a small group of dwellings or other buildings |
| 13,306 | P.PPLQ | abandoned populated place | |
| 2,684 | P.PPLA4 | seat of a fourth-order administrative division | |
| 2,028 | P.PPLA | seat of a first-order administrative division | seat of a first-order administrative division (PPLC takes precedence over PPLA) |
| 1,847 | P.PPLW | destroyed populated place | a village, town or city destroyed by a natural disaster, or by war |
| 1,006 | P.PPLF | farm village | a populated place where the population is largely engaged in agricultural activities |
| 930 | P.PPLA3 | seat of a third-order administrative division | |
| 695 | P.PPLA2 | seat of a second-order administrative division | |
| 253 | P.PPLS | populated places | cities, towns, villages, or other agglomerations of buildings where people live and work |
| 249 | P.STLMT | israeli settlement | |
| 235 | P.PPLC | capital of a political entity | |
| 57 | P. | | |
| 29 | P.PPLR | religious populated place | a populated place whose population is largely engaged in religious occupations |
| 6 | P.PPLG | seat of government of a political entity | |
| 2,629,547 | Total for P | | |

**rdfs:subClassOf?**

# Example: GovTrack

**“Nancy Pelosi voted in favor of the Health Care Bill.”**



# Example querying LoD

**"Identify congress members, who have voted "No" on pro environmental legislation in the past four years, with high-pollution industry in their congressional districts."**

**In principle, all the knowledge is there:**

- **GovTrack**
- **GeoNames**
- **DBPedia**
- **US Census**

**But even with LoD we cannot answer this query.**

# Example querying LoD

"Identify congress members, who have voted "No" on pro environmental legislation in the past four years, with high-pollution industry in their congressional districts."

Some missing puzzle pieces:

- Where is the data?
  - GovTrack
    GeoNames
    US Census
    requires intimate knowledge of the LoD data sets

# Example querying LoD

"Identify congress members, who have voted "No" on pro environmental legislation in the past four years, with high-pollution industry in their congressional districts."

Some missing puzzle pieces:

- Where is the data?
  (smart federation needed)
- Missing background (schema) knowledge.
  (enhancements of the LoD cloud)
- Crucial info still hidden in texts.
  (ontology learning from texts)
- Added reasoning capabilities (e.g., spatial).
  (new ontology language features)

# Don’t get me wrong

**Linked Open Data is great, useful, cool, and a very important step.**

**But if we stay semantics-free, Linked Open Data will not stand up to the Semantic Web vision!**

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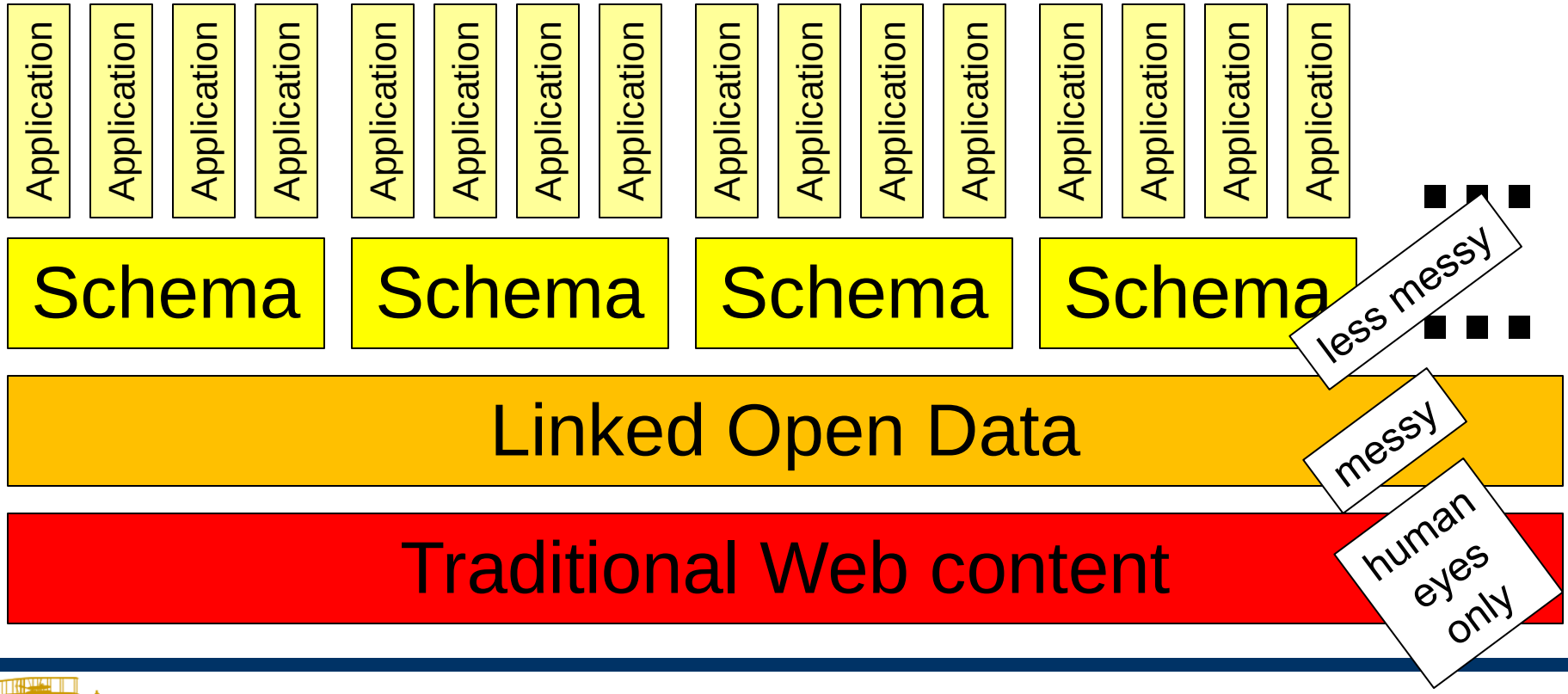
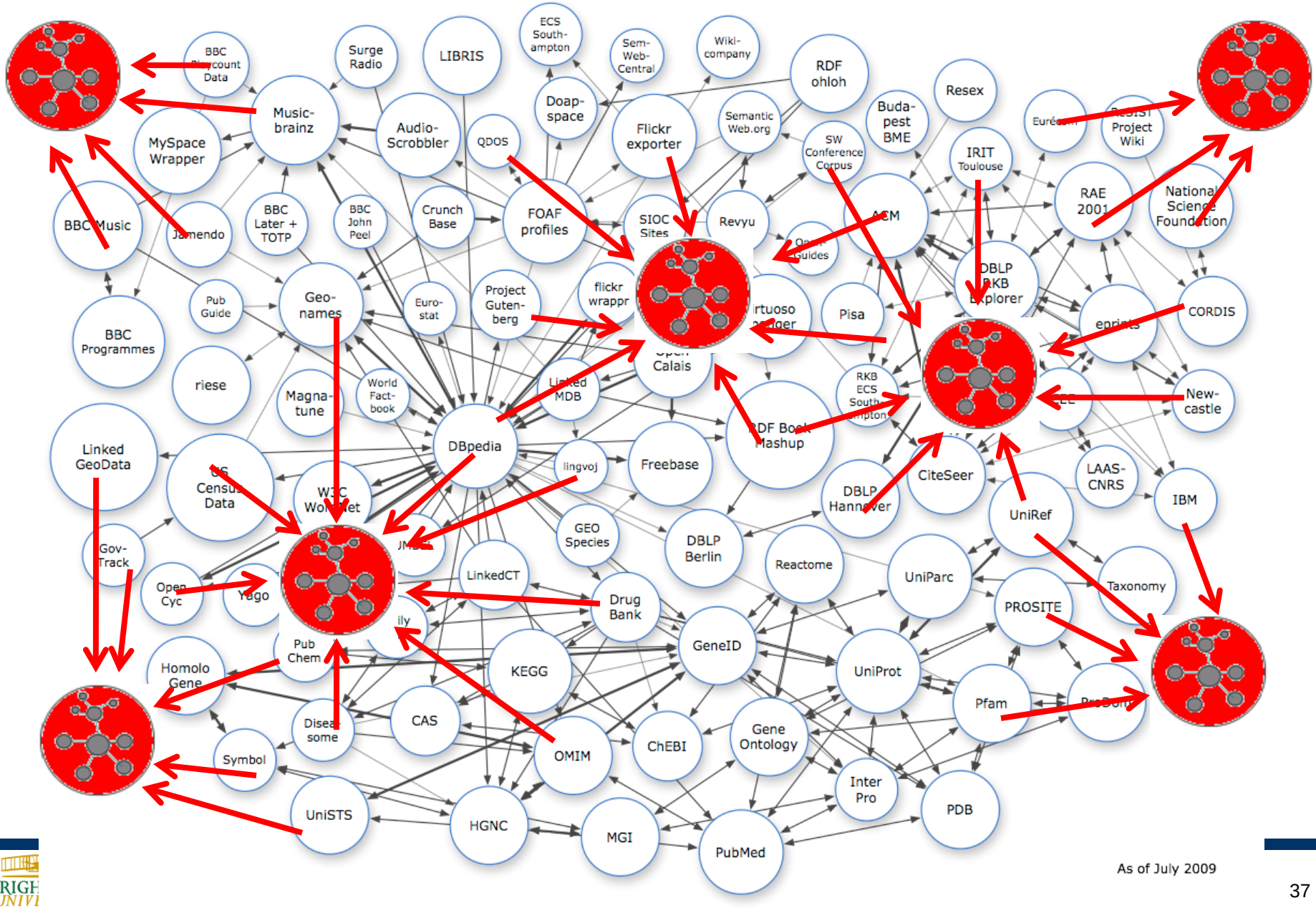
# The Semantic Data Web Layer Cake

**To leverage LoD, we require schema knowledge**

- **application-type driven (reusable for same kind of application)**
- **less messy than LoD (as required by application)**
- **overarching several LoD datasets (as required by application)**



# Schema on top of the LoD cloud




As of July 2009

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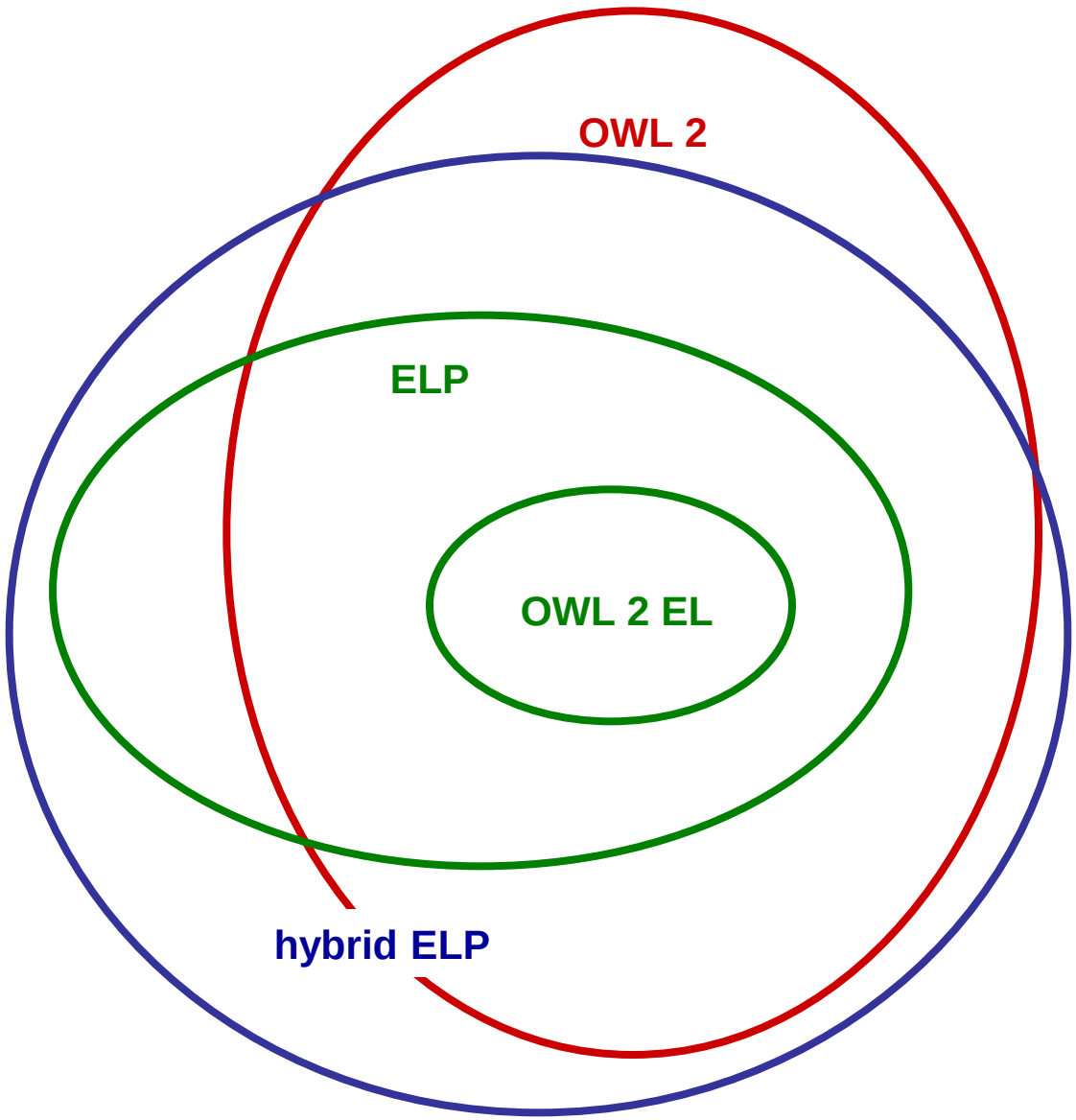
# The Reasoning Scalability Challenge

- **But these datasets are huge!**
- **How do you deal with that?**
  - **find useful languages which scale better**
  - **use parallelization/cloud computing**
  - **use heuristics/approximation algorithms**

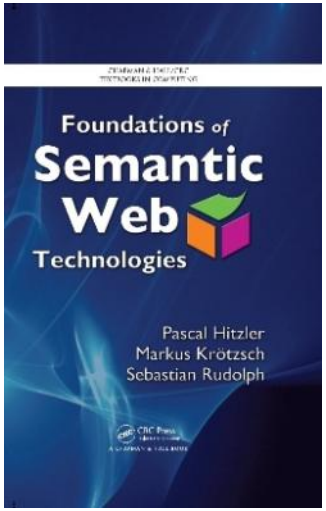

Language standards recommended by W3C

# Find useful scalable languages




- **OWL 2: complexity > exponential**
- **ELP: complexity = polynomial**
- **OWL 2 EL: complexity = polynomial**
- **hybrid ELP: data complexity = polynomial**

**Thanks!**




**http://www.semantic-web-book.org**

**http://www.semantic-web-journal.net**

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