Reasonable Semantic Web

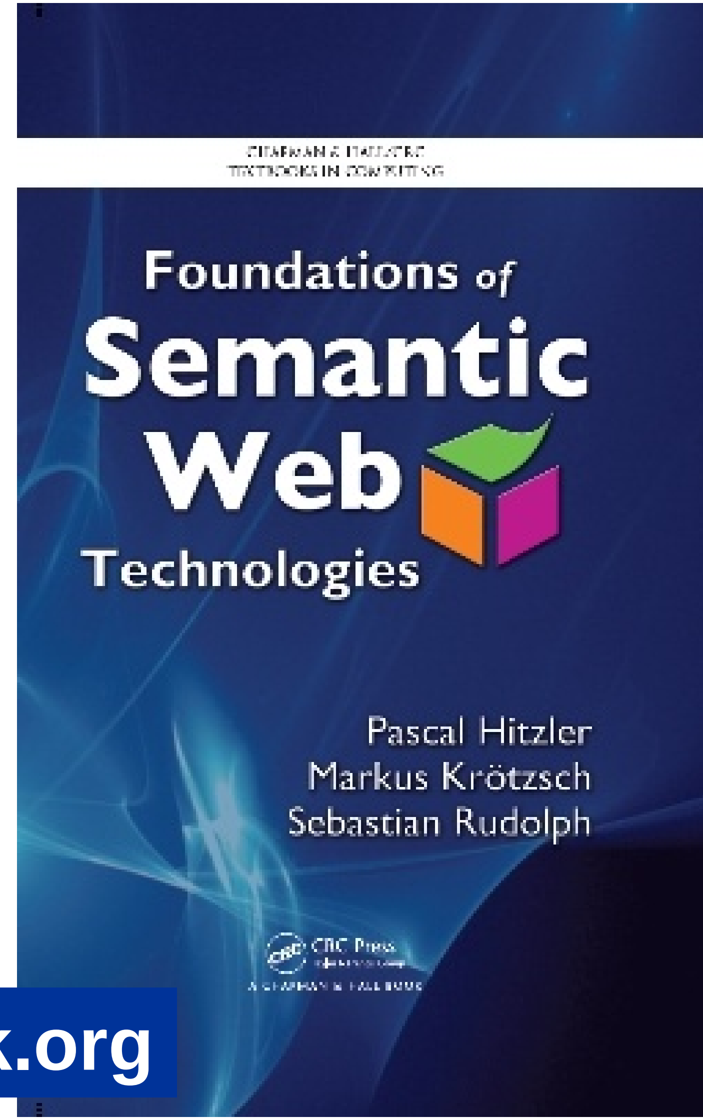
Pascal Hitzler
Kno.e.sis Center
Wright State University, Dayton, OH
http://www.knoesis.org/pascal/

New Book

Pascal Hitzler, Markus Krötzsch, Sebastian Rudolph

Foundations of Semantic Web Technologies
Chapman & Hall/CRC, 2009

Grab a flyer!

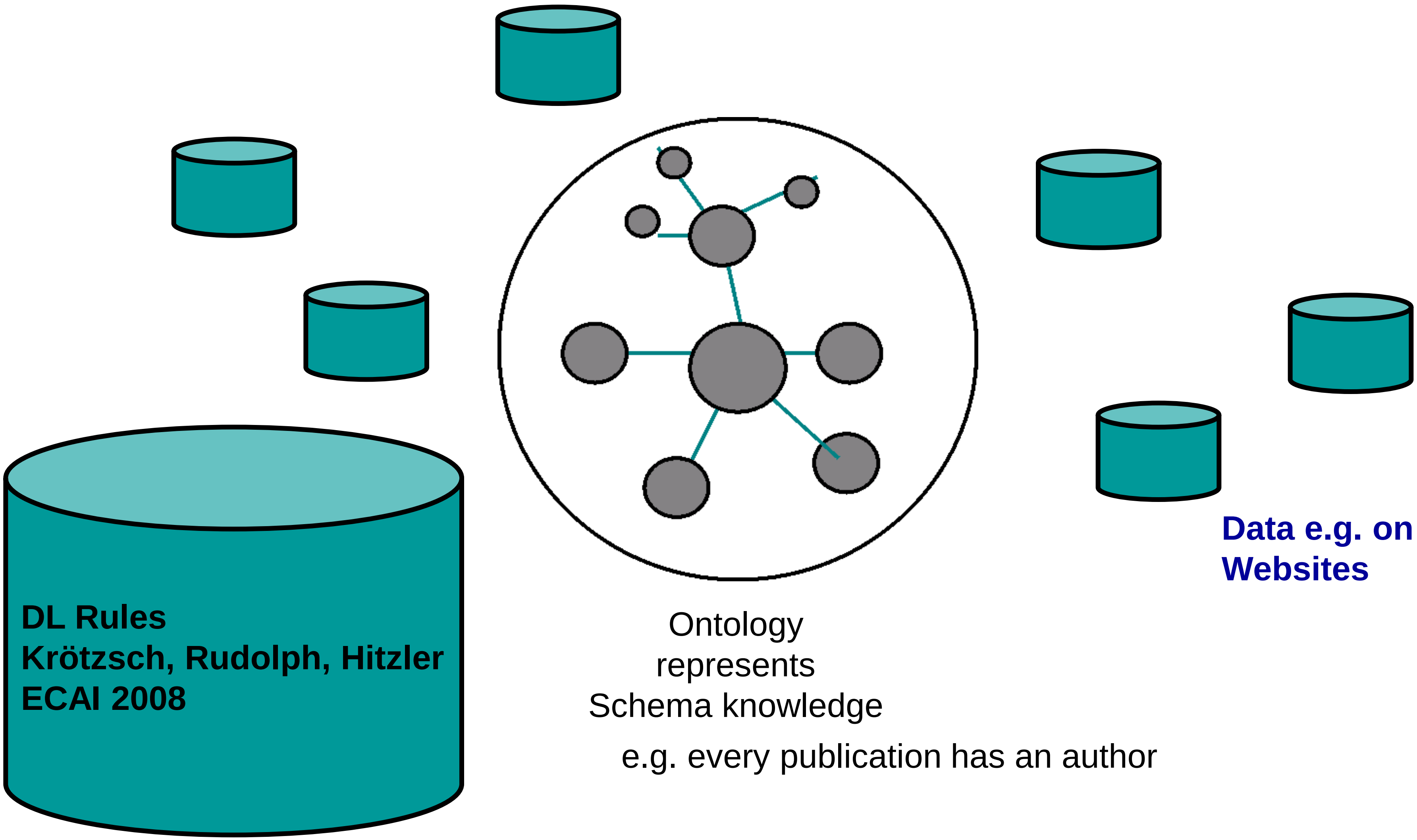


http://www.semantic-web-book.org

Contents

- Semantic Web Semantics
- Linked Open Data and its Limitations
- Future Directions

Basic Idea of the Semantic Web



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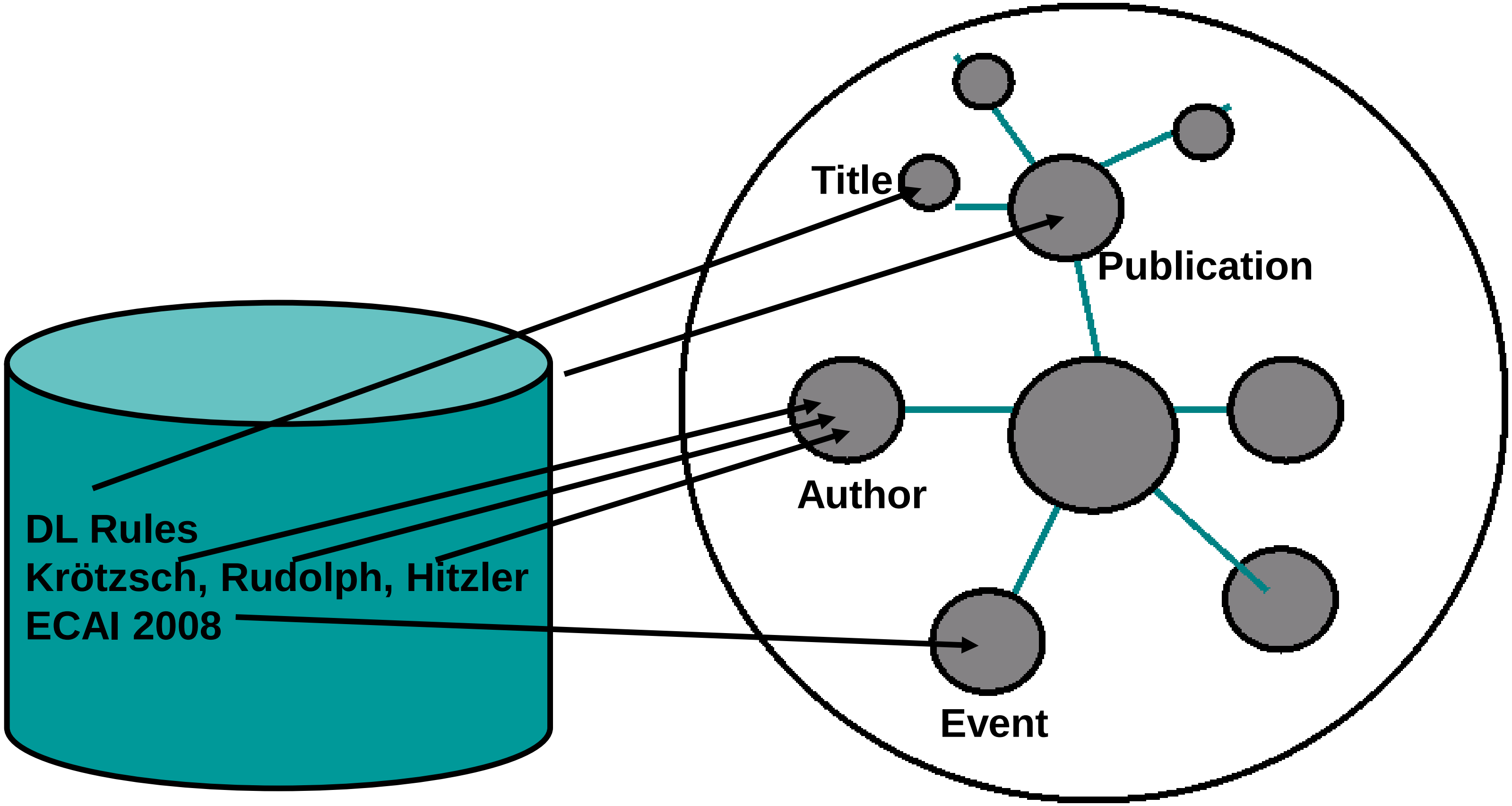
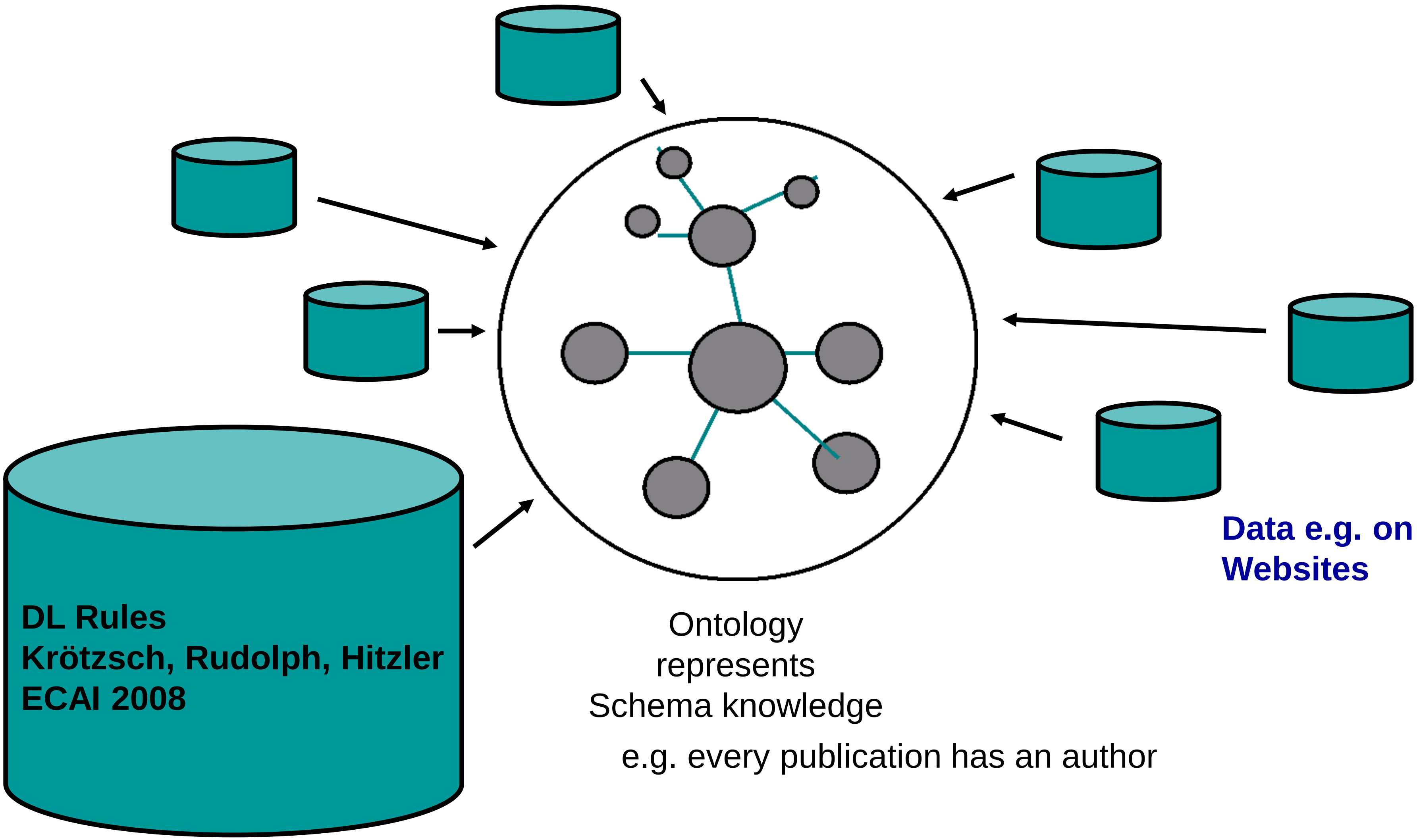


e.g. every publication has an author

Basic Idea of the Semantic Web



Data e.g. on Websites

Ontology
represents
Schema knowledge

e.g. every publication has an author

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 directly (which is impossible)
but by specifying

how information interacts with other information.

We describe the meaning indirectly through its effects.

Simple Logical Reasoning

If I ask for soccer team members, I also want to get the goalkeepers listed ...

If I ask for cities, I also want all capitals listed ...

inheritance reasoning

Less Simple Reasoning

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

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

Are lobsters spiders?

What is "Käuzchen" in english?

So what happened?

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

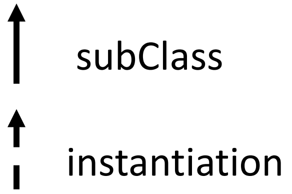
- OWL 2 update emerged 2009.
- RDF update is being discussed right now.

Ontology languages

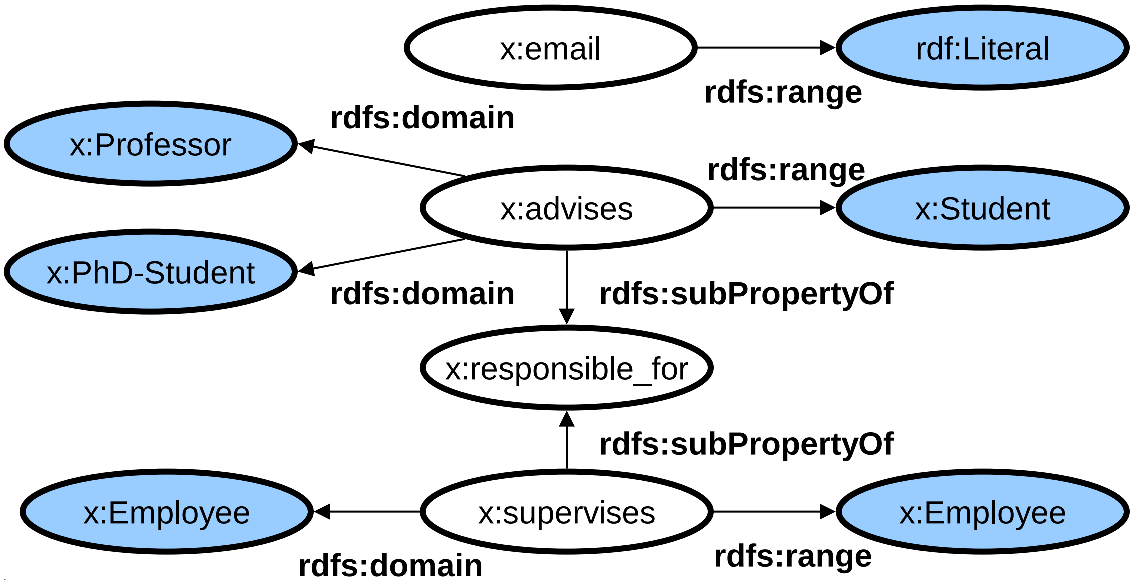
- **Of central importance for the realisation of Semantic Technologies are suitable representation languages.**
- **Meaning (semantics) provided via logic and deduction algorithms.**
- **Scalability is a challenge.**

Language standards recommended by W3C

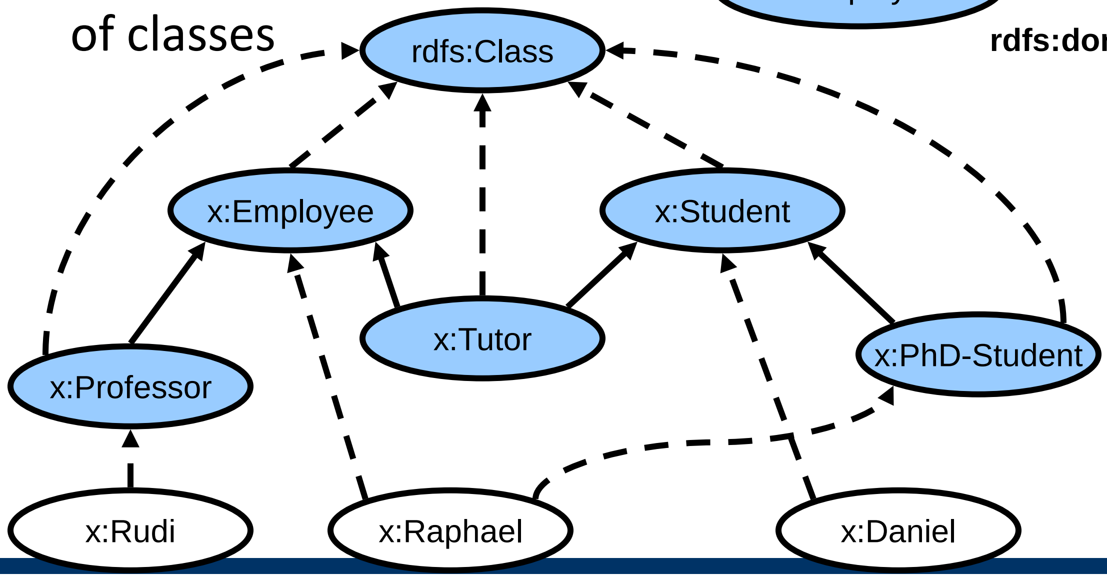
Ontology Example



Declaration of properties



Declaration of classes



schema knowledge
PhDStudent v 9advisedBy.Professor

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

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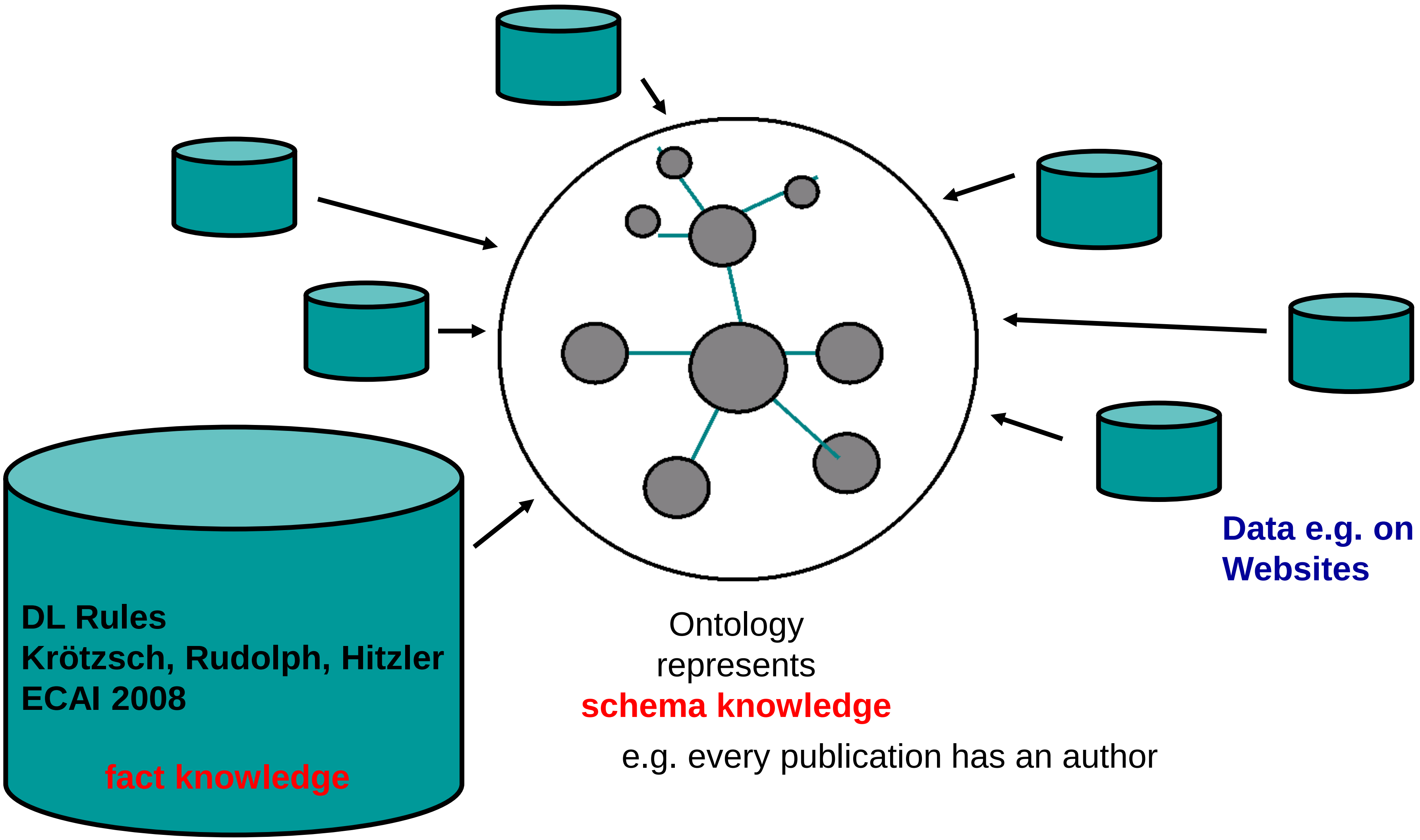
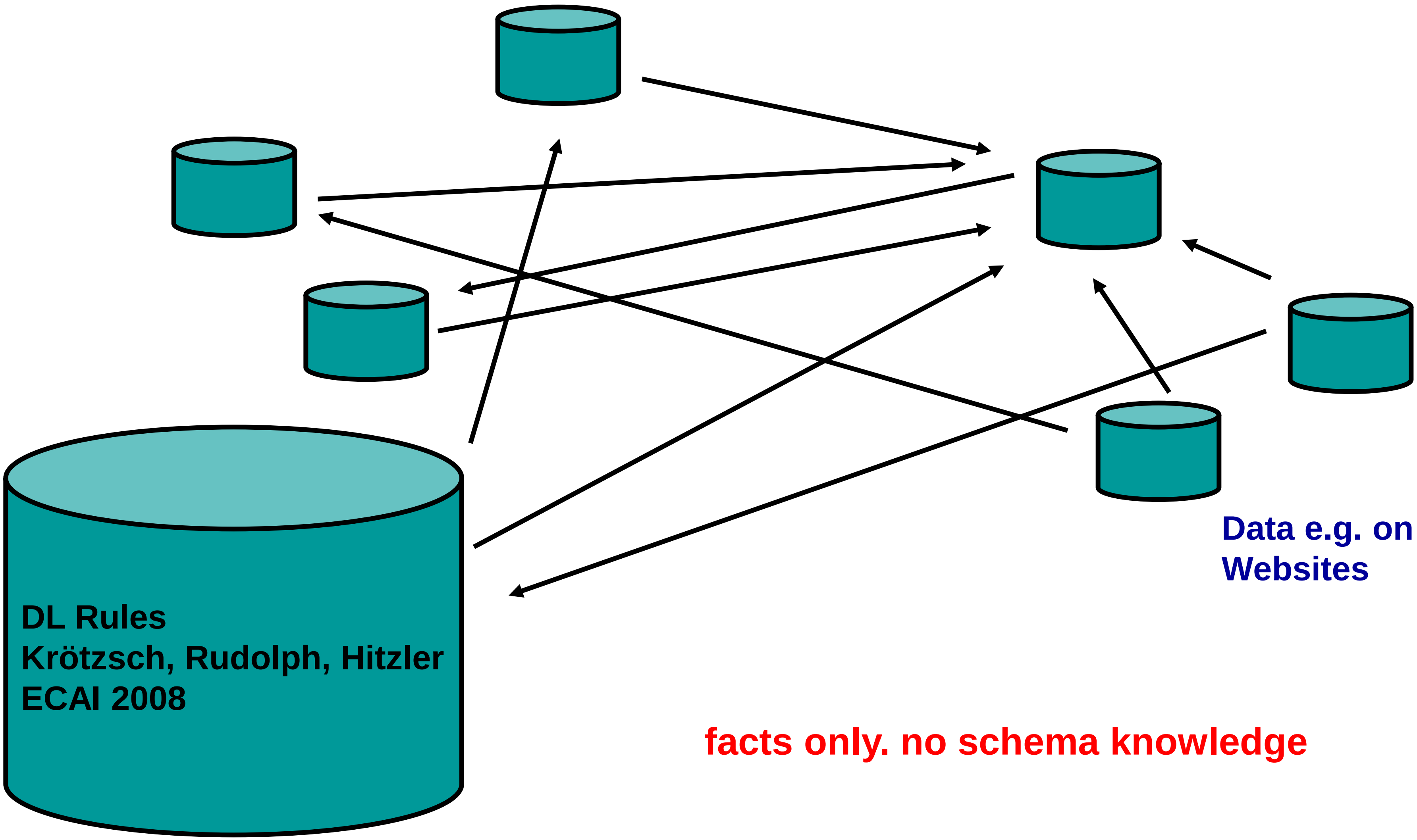


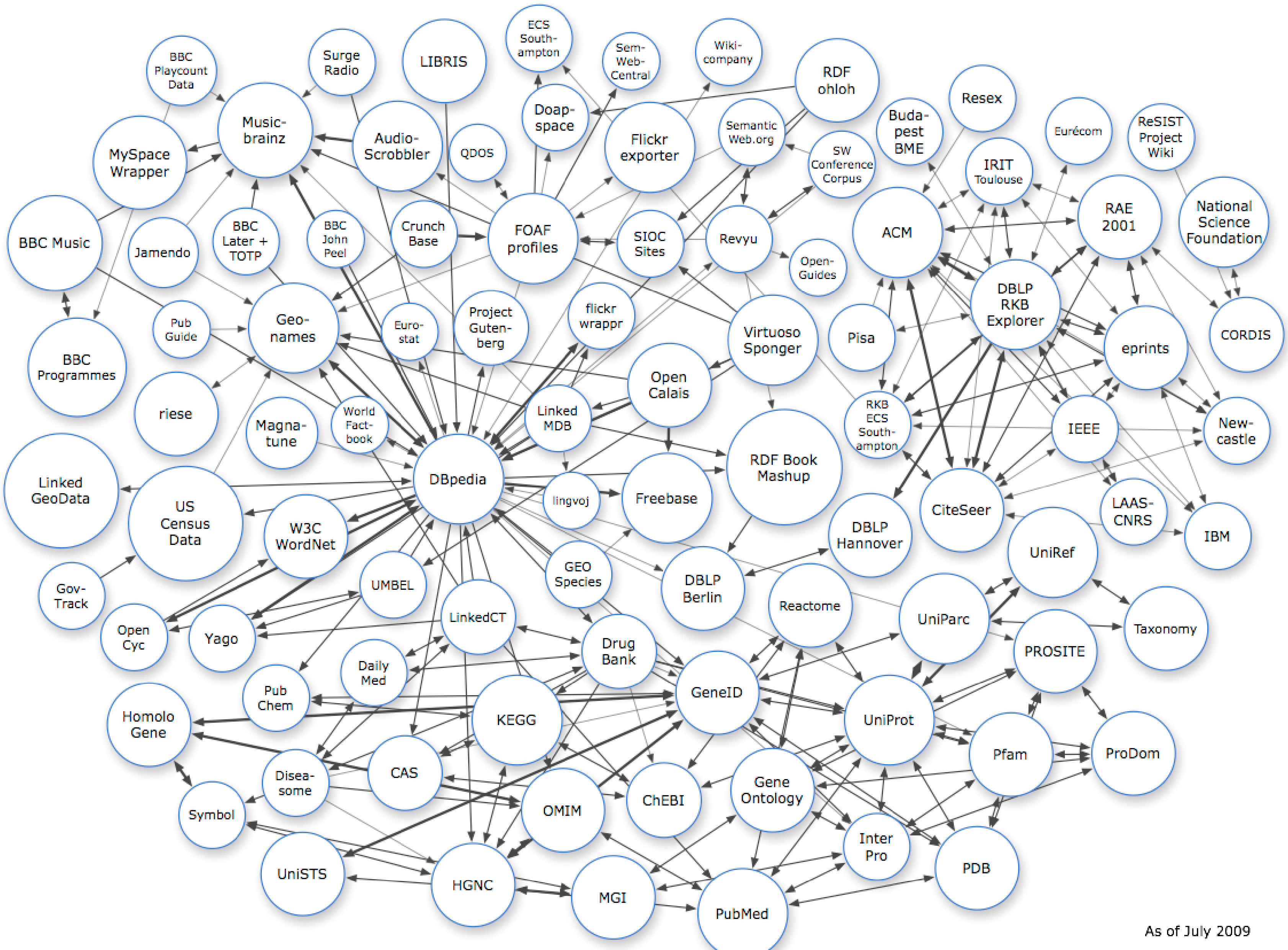
e.g. every publication has an author

Currently it's looking like this



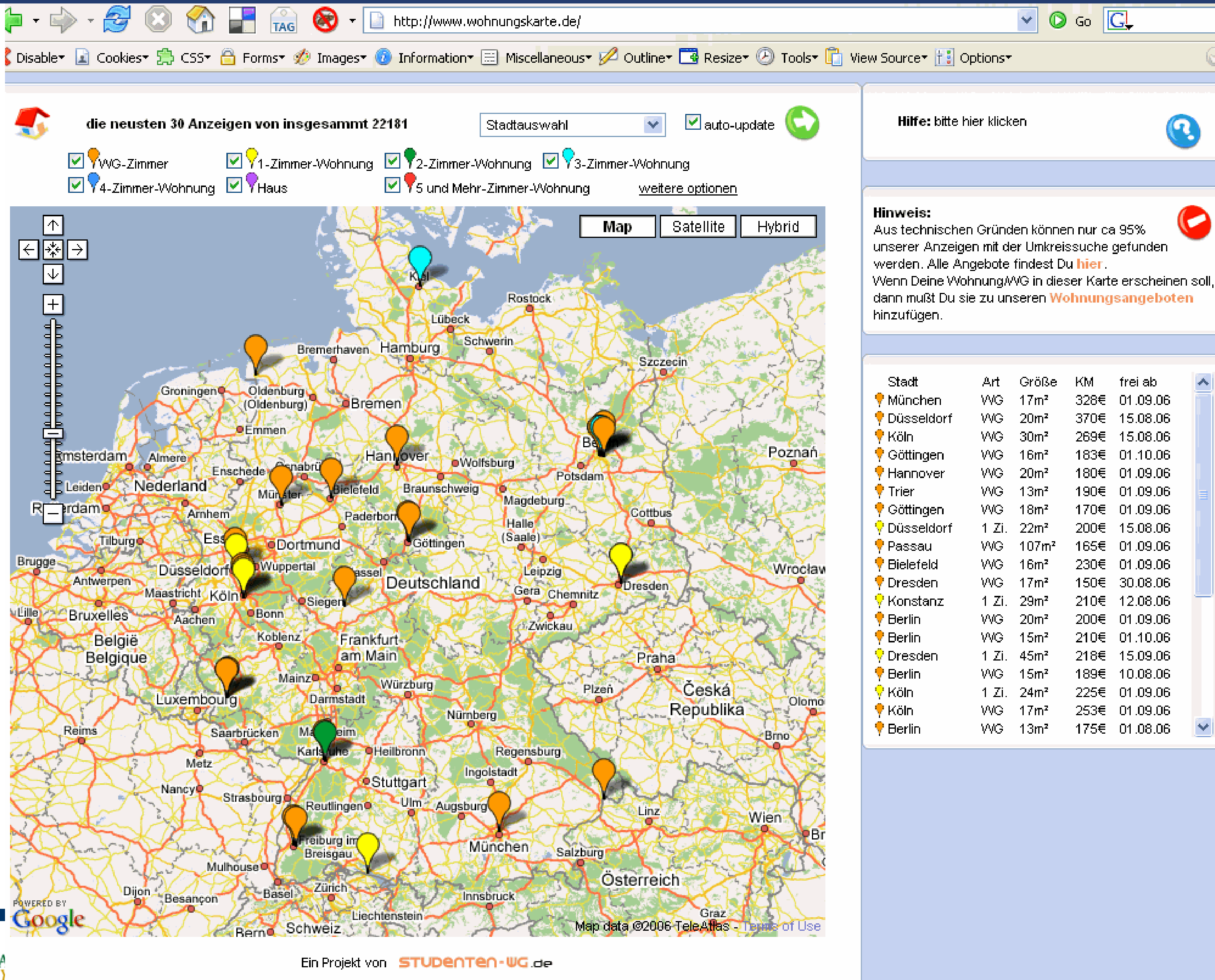
facts only. no schema knowledge

Linked Open Data



As of July 2009

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
München WG 17m² 328€ 01.09.06
Düsseldorf WG 20m² 370€ 15.08.06
Köln WG 30m² 269€ 15.08.06
Göttingen WG 16m² 183€ 01.10.06
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Passau WG 107m² 165€ 01.09.06
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Berlin WG 15m² 210€ 01.10.06
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Berlin WG 13m² 175€ 01.08.06
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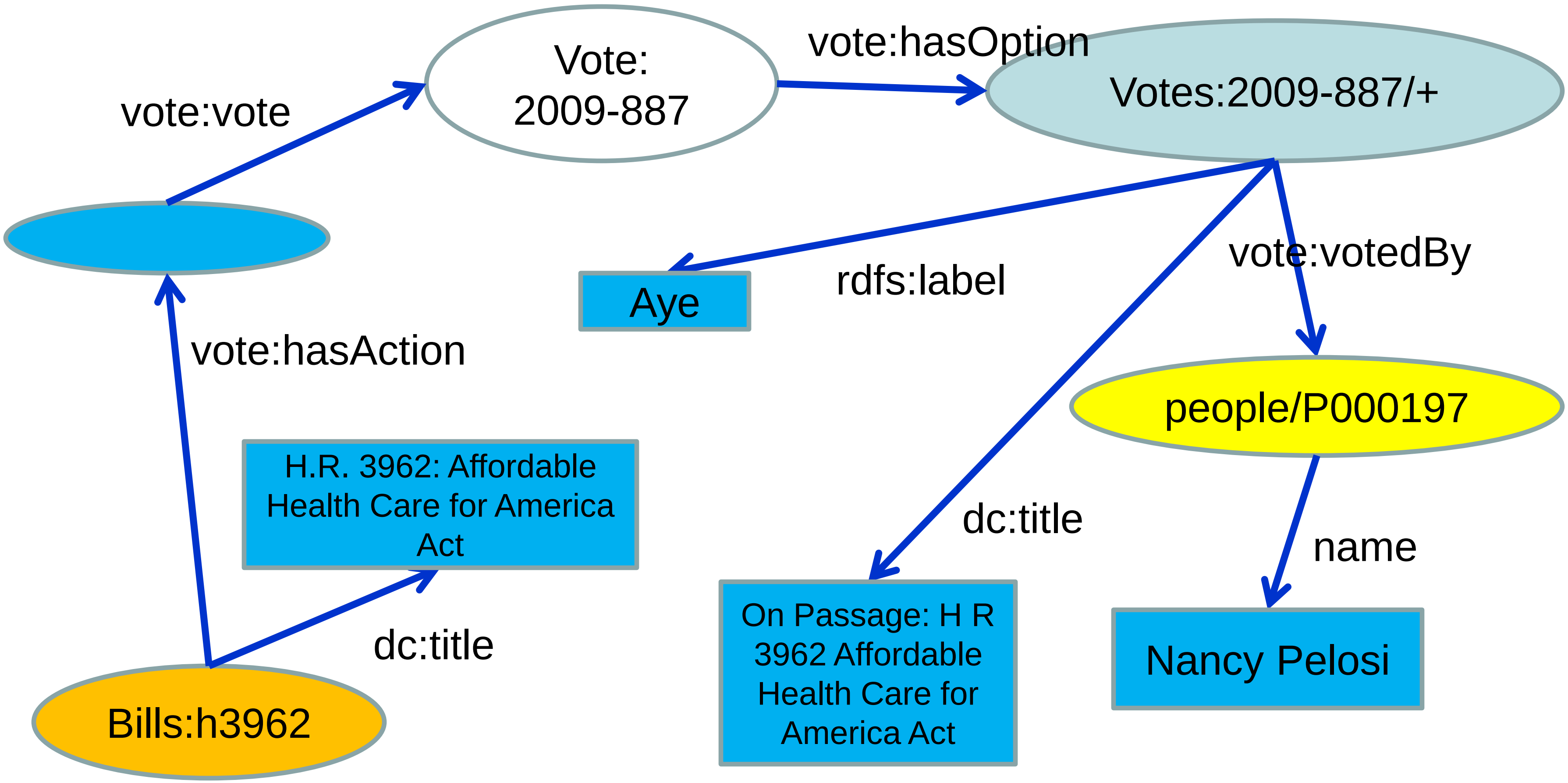
Example: GeoNames

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-o administrative d	
695	P.PPLA2	seat of a second 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!

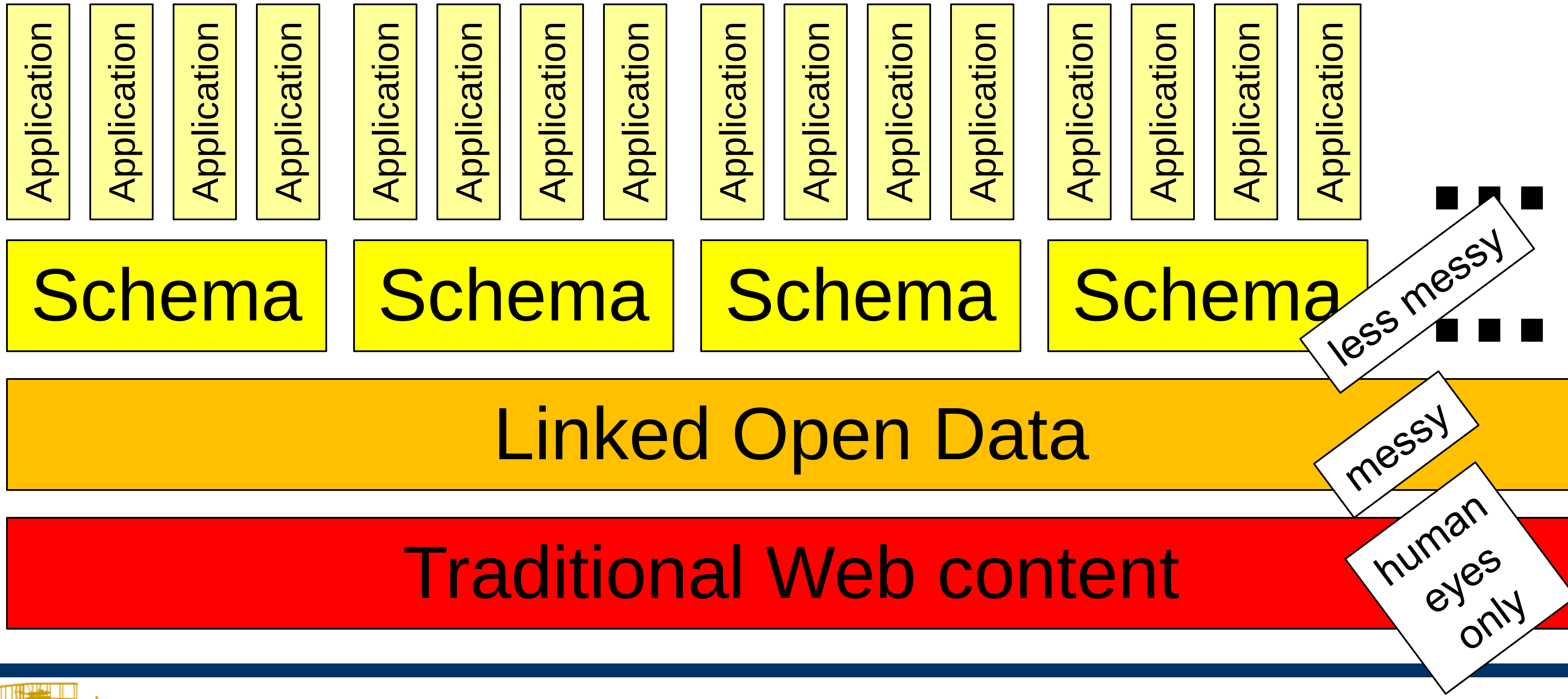
Contents

- **Semantic Web Semantics**
- **Linked Open Data and its Limitations**
- **Future Directions**

The Semantic Data Web Layer Cake

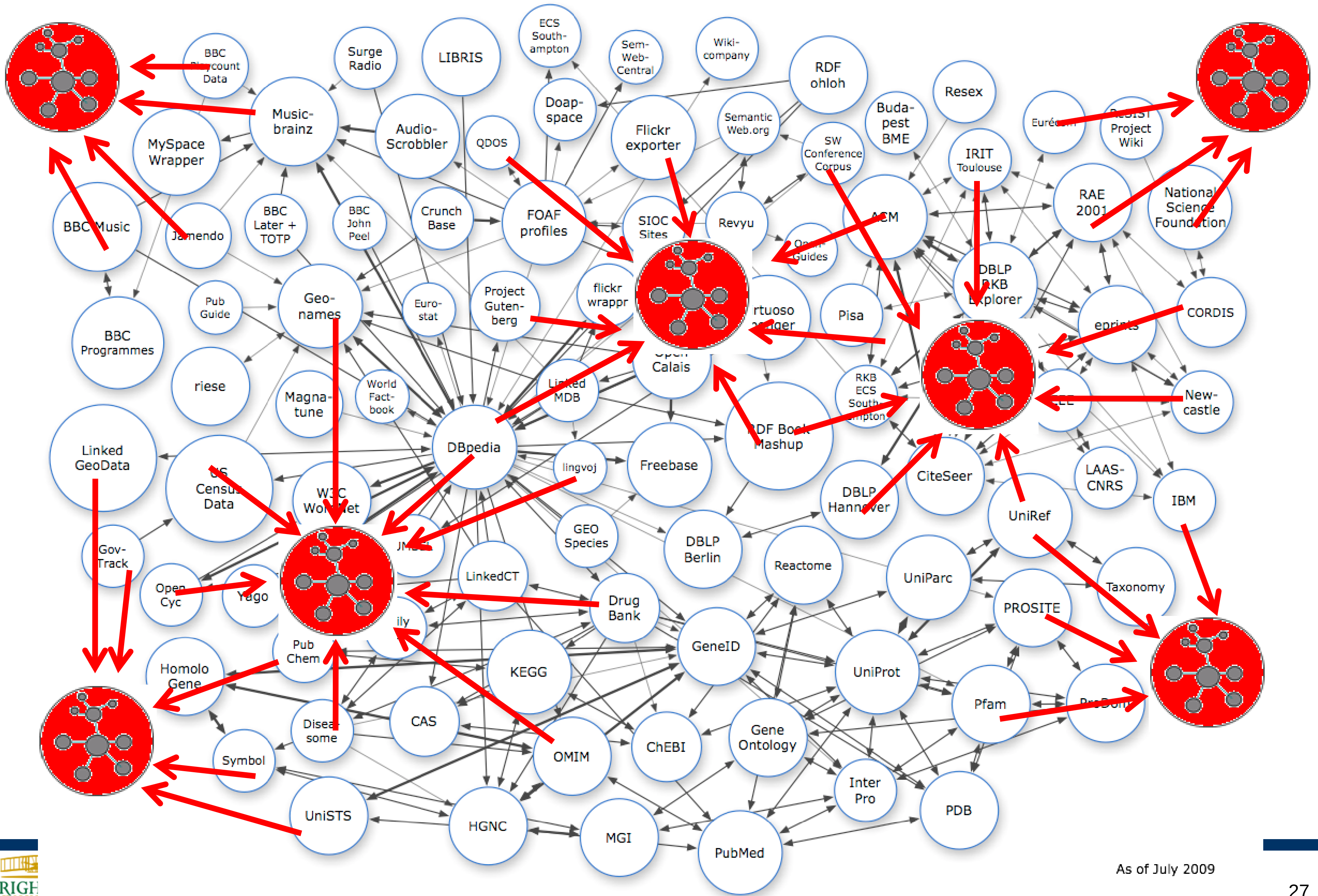
To leverage LoD, we require schema knowledge

- **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)**

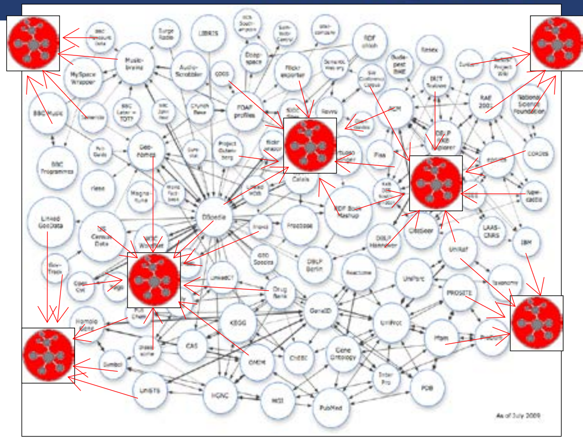


Schema on top of the LoD cloud

Kno.e.sis



How to get there



- Schema ontologies
  - made for specific purposes (e.g., querying)
  - spanning several LoD datasets
  - incorporating schema knowledge hidden in the LoD datasets
  - including additional background knowledge needed for design purpose
- Added reasoning capabilities extending OWL as needed.
  - rules
  - extended datatypes
  - spatial and temporal reasoning etc.
- Making use of ontology lifecycle state-of-the-art tools
  - ontology evaluation
  - ontology learning from texts
  - ontology evolution etc.

From no semantics to low semantics

1. **Take a no-semantics or low-semantics solution.**
   E.g., naive LoD querying using SPARQL.

2. **Identify where added value could be obtained by formal semantics.**
   E.g., by using schema knowledge as query entry points; by using schema knowledge to get better answers.

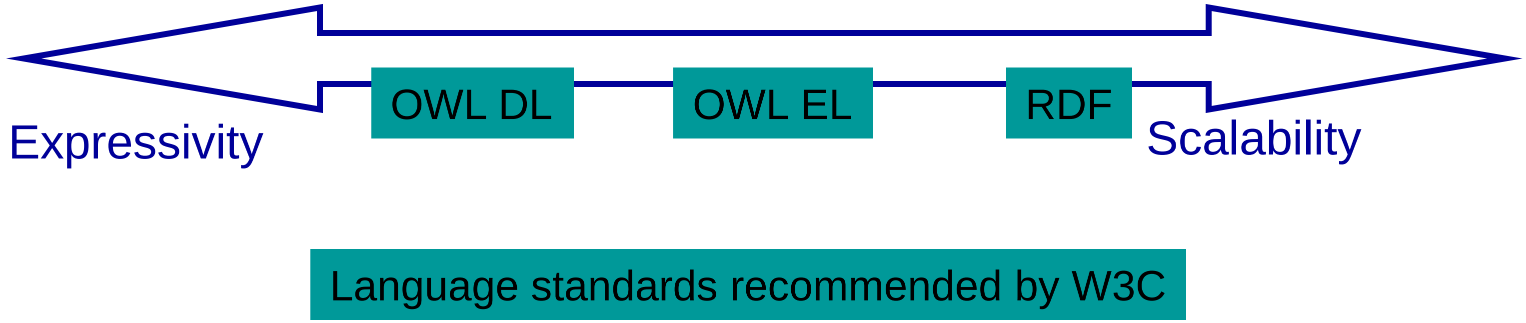
3. **Identify (or develop!) ontology language which has the required features (→ really interesting research!).**
   E.g., spatial reasoning.

4. **Realize application and publish (additional) data as LoD data.**

Important: **Keep it simple, stupid!**
A little semantics can go a long way.

The Reasoning Scalability Challenge

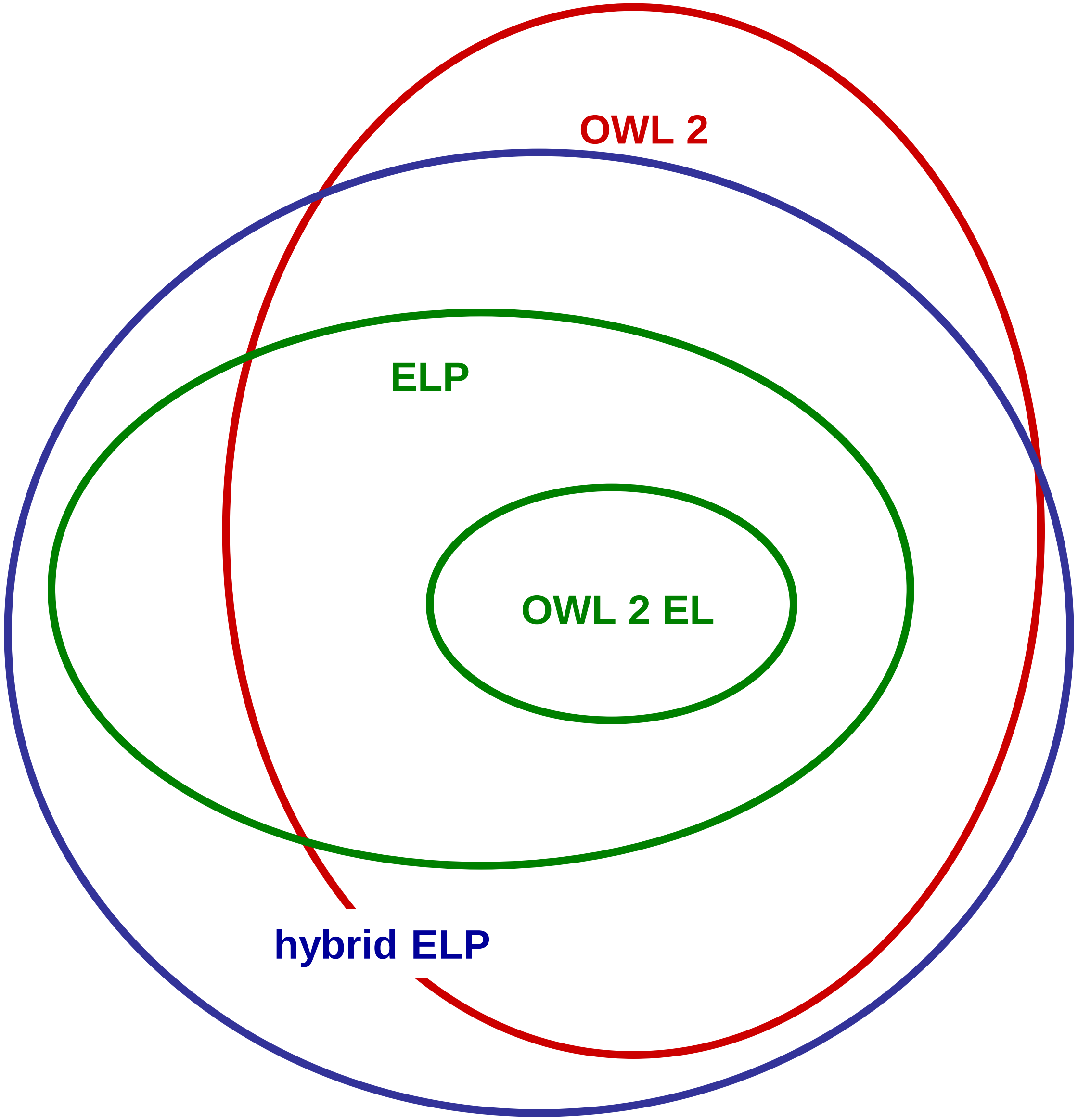
- **But these datasets are huge!**
- **How do you deal with that?**
  - **find useful languages which scale better**
  - **use parallelization/cloud computing**
  - **use heuristics/approximation algorithms**



Use parallelization/cloud computing

- Currently working on MapReduce for OWL 2 EL.
- We have the algorithm.
  We're currently implementing/optimizing using Hadoop.
- Previous work on RDF and OWL Horst reasoning encouraging.
- But we don't have experimental results yet.

Find useful scalable languages



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

Some things you can say in OWL

Rules are often considered an intuitive form of knowledge representation

- Man(x) ÆhasBrother(x,y) ÆhasChild(y,z) ! Uncle(x)
  - Man u 9hasBrother.9hasChild.> v Uncle
- ThaiCurry(x) ! 9contains.FishProduct(x)
  - ThaiCurry v 9contains.FishProduct
- kills(x,x) ! suicide(x)
  - 9kills.Self v suicide

  suicide(x) ! kills(x,x)

  suicide v 9kills.Self

Note: with these two axioms,
suicide is basically the same as *kills*

Some things you can say in OWL

- NutAllergic(x) ÆNutProduct(y) ! dislikes(x,y)
  - NutAllergic ´ 9nutAllergic.Self
    NutProduct ´ 9nutProduct.Self
    nutAllergic ± U ± nutProduct v dislikes

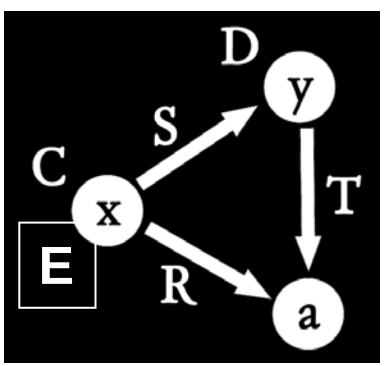
- dislikes(x,z) ÆDish(y) Æcontains(y,z) ! dislikes(x,y)
  - Dish ´ 9dish.Self
    dislikes ± contains¯ ± dish v dislikes

- worksAt(x,y) ÆUniversity(y) Æsupervises(x,z) ÆPhDStudent(z)
  ! professorOf(x,z)
  - 9worksAt.University ´ 9worksAtUniversity.Self
    PhDStudent ´ 9phDStudent.Self
    worksAtUniversity ± supervises ± phDStudent v professorOf

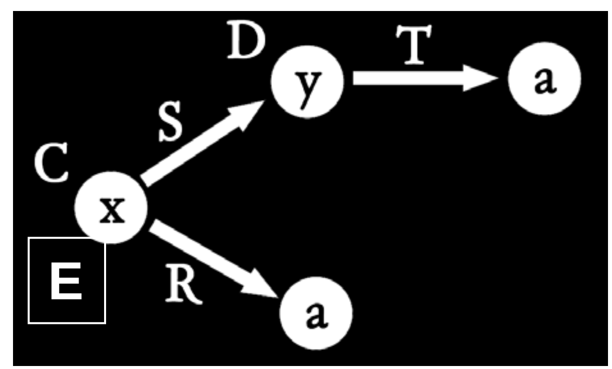
DL Rules: definition

- **Tree-shaped bodies**
- **First argument of the conclusion is the root**

- **C(x) ÆR(x,a) ÆS(x,y) ÆD(y) ÆT(y,a) ! E(x)**
  - **C u 9R.{a} u 9S.(D u 9T.{a}) v E**



duplicating nominals is ok

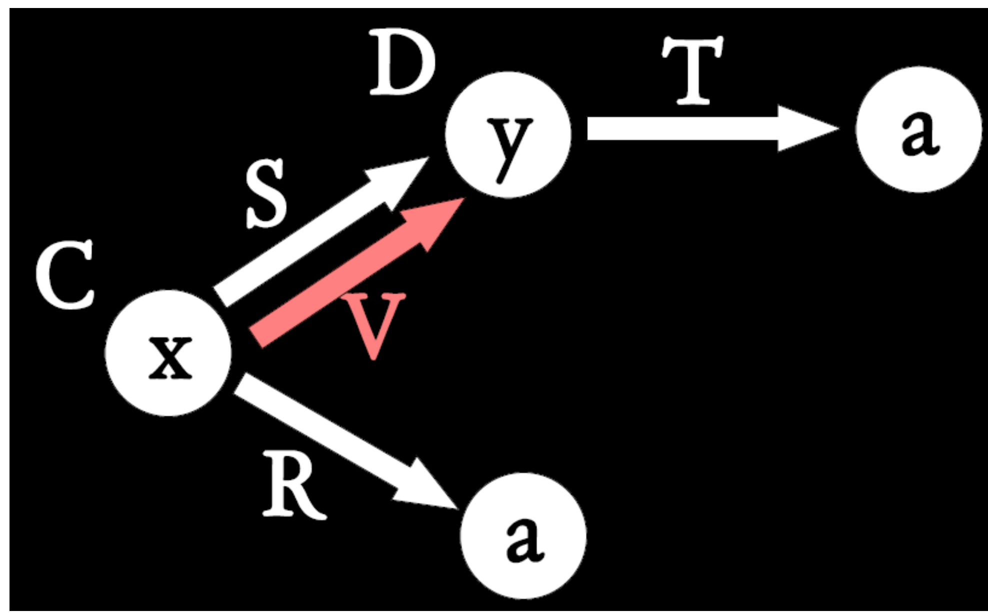


DL Rules: definition

- **Tree-shaped bodies**
- **First argument of the conclusion is the root**

- **C(x) ÆR(x,a) ÆS(x,y) ÆD(y) ÆT(y,a) ! V(x,y)**

C u 9R.{a} v 9R1.Self
D u 9T.{a} v 9R2.Self
R1 ± S ± R2 v V



DL Rules: definition

- Tree-shaped bodies
- First argument of the conclusion is the root

- complex classes are allowed in the rules
  - Mouse(x) Æ9hasNose.TrunkLike(y) !   smallerThan(x,y)
  - ThaiCurry(x) !   9contains.FishProduct(x)

    Note: This allows to reason with unknowns (unlike rules)
  - allowed class constructors depend on the chosen underlying description logic!

SROIQ Rules can be transformed back into SROIQ!

Outside SROIQ Rules

$$\texttt{Pair}(p) \wedge \texttt{consistOf}(p, x) \wedge \texttt{consistOf}(p, y) \wedge \texttt{differentFrom}(x, y) \wedge \texttt{River}(r) \wedge \texttt{inBetween}(r, p) \wedge \texttt{rightBankOf}(x, r) \rightarrow \texttt{leftBankOf}(y, r).$$

- **Cannot be expressed in SROIQ (is not a SROIQ Rule).**
- **Extending OWL with such more general rules leads to undecidability.**

[Example due to Dong-Po Deng, presented at GeoS2009]

SWRL

$$\texttt{Pair}(p) \wedge \texttt{consistOf}(p,x) \wedge \texttt{consistOf}(p,y) \wedge \texttt{differentFrom}(x,y) \wedge \texttt{River}(r) \wedge \texttt{inBetween}(r,p) \wedge \texttt{rightBankOf}(x,r) \rightarrow \texttt{leftBankOf}(y,r).$$

- **Read rule as a first-order predicate logic formula.**

  Semantically okay, but leads to undecidability in combination with OWL.

DL-safe SWRL

$$\texttt{Pair}(p) \wedge \texttt{consistOf}(p,x) \wedge \texttt{consistOf}(p,y) \wedge \texttt{differentFrom}(x,y) \wedge \texttt{River}(r) \wedge \texttt{inBetween}(r,p) \wedge \texttt{rightBankOf}(x,r) \rightarrow \texttt{leftBankOf}(y,r).$$

- **Semantically restrict rule, such that it applies only to individuals which are explicitly contained in the knowledge base. I.e., those with known URIs.**
- **DL-safe SWRL combined with OWL is decidable.**
- **Formalism supported, e.g., by Pellet.**

ELP Example

NutAllergic(sebastian)

NutProduct(peanutOil)

9orderedDish.ThaiCurry(sebastian)

ThaiCurry v 9contains.{peanutOil}

> v 8orderedDish.Dish

NutAllergic(x) ÆNutProduct(y) ! dislikes(x,y)

dislikes(x,z) ÆDish(y) Æcontains(y,z) ! dislikes(x,y)

orderedDish(x,y) Ædislikes(x,y) ! Unhappy(x)

Rules in SWRL (undecidable).

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9orderedDish.ThaiCurry(sebastian)

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actually, expressible in OWL 2

NutAllergic(x) ÆNutProduct(y) ! dislikes(x,y)

dislikes(x,z) ÆDish(y) Æcontains(y,z) ! dislikes(x,y)

orderedDish(x,y) Ædislikes(x,y) ! Unhappy(x)

Conclusions:

dislikes(sebastian,peanutOil)

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orderedDish rdfs:range Dish.

NutAllergic(x) ÆNutProduct(y) ! dislikes(x,y)

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orderedDish(x,y) Ædislikes(x,y) ! Unhappy(x)

Conclusions:

dislikes(sebastian,peanutOil)

orderedDish(sebastian,y_s)

ThaiCurry(y_s)

Dish(y_s)

ELP Example

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ThaiCurry(y_s)
Dish(y_s)

contains(y_s,peanutOil)

ELP Example

Step does not work with DL-safe SWRL!

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Conclusions:

dislikes(sebastian,peanutOil)

orderedDish(sebastian,y_s)

ThaiCurry(y_s)

Dish(y_s)

contains(y_s,peanutOil)

dislikes(sebastian,y_s)

ELP Example

Step does not work with DL-safe SWRL!

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orderedDish(x,y) Ædislikes(x,y) ! Unhappy(x)

Conclusions:

dislikes(sebastian,peanutOil)
orderedDish(sebastian,y_s)
ThaiCurry(y_s)
Dish(y_s)
contains(y_s,peanutOil)
dislikes(sebastian,y_s)
Unhappy(sebastian)

ELP Example

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NutProduct(peanutOil)
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ThaiCurry v 9contains.{peanutOil}
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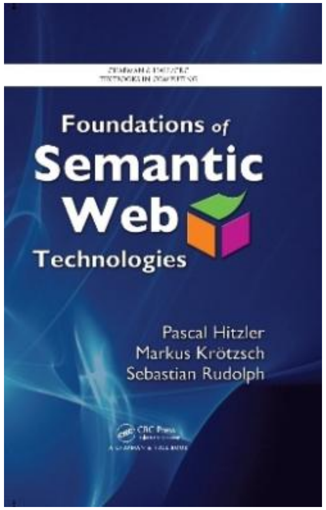
dislikes(x,z) ÆDish(y) Æcontains(y,z) ! dislikes(x,y)
orderedDish(x,y) Ædislikes(x,y) ! Unhappy(x)

Conclusion: Unhappy(sebastian)

Thanks!



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