

# CS 499/699 – Logic for Computer Scientists

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## Semantic Web as an Application Area for Logic

1. **What is Semantic Web?**
2. Query Answering on the Web
3. Semantic Search
4. Semantic Web Services

- **Social contacts (social networking platforms, blogging, ...)**
- **Economics (buying, selling, advertising, ...)**
- **Administration (eGovernment)**
- **Education (eLearning, Web as information system, ...)**
- **Work life (information gathering and sharing)**
- **Recreation (games, role play, creativity, ...)**

- 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.

- **Too much information with too little structure and made for human consumption**
  - **Content search is very simplistic**
  - **future requires better methods**
- **Web content is heterogeneous**
  - in terms of content**
  - in terms of structure**
  - in terms of character encoding**
    - **future requires intelligent information integration**
- **Humans can derive new (implicit) information from given pieces of information**  
**but on the current Web we can only deal with syntax**
  - **requires automated reasoning techniques**

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

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

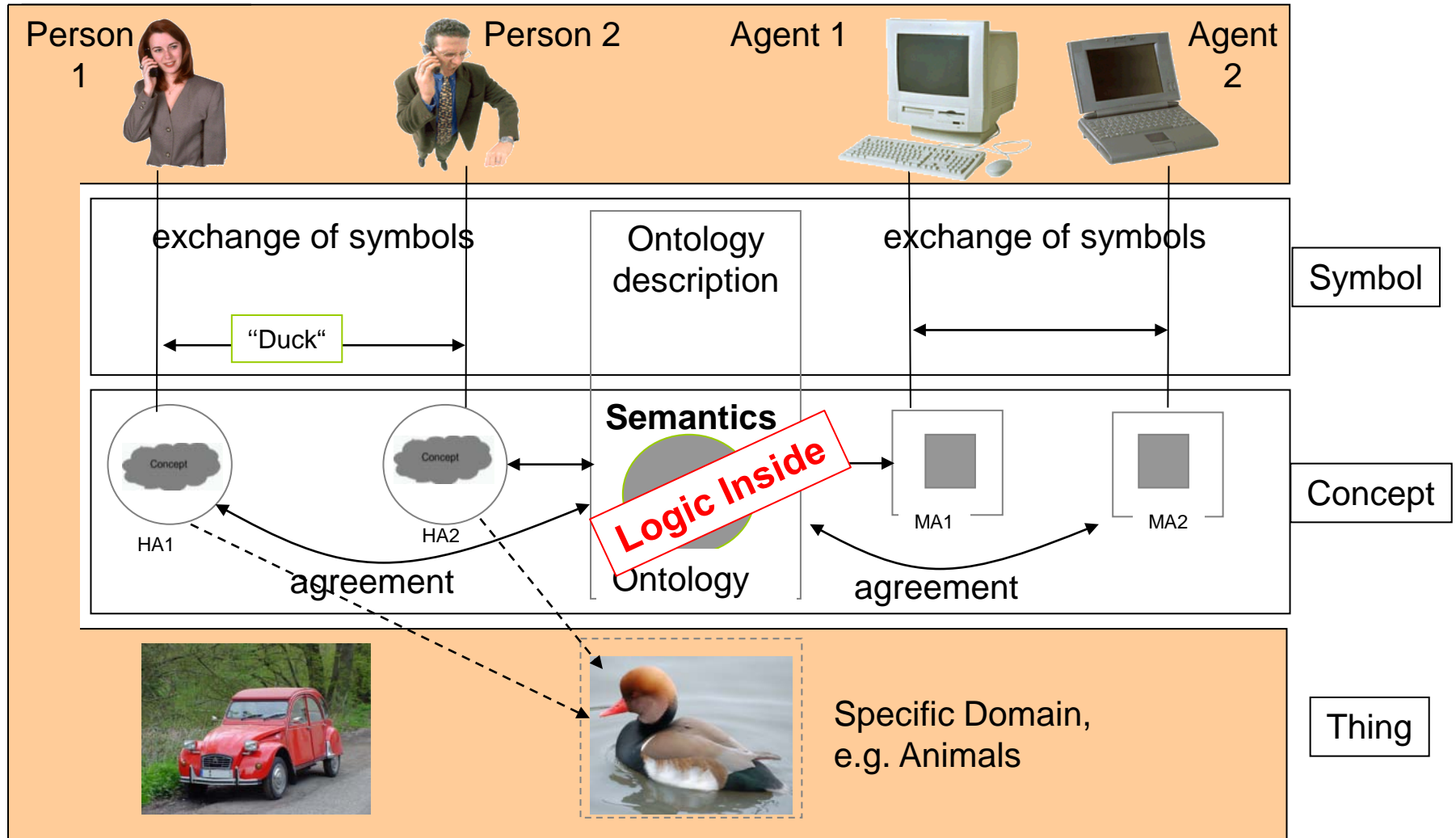
**In principle, all the required knowledge is on the Web – most of it even in machine-readable form.**

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

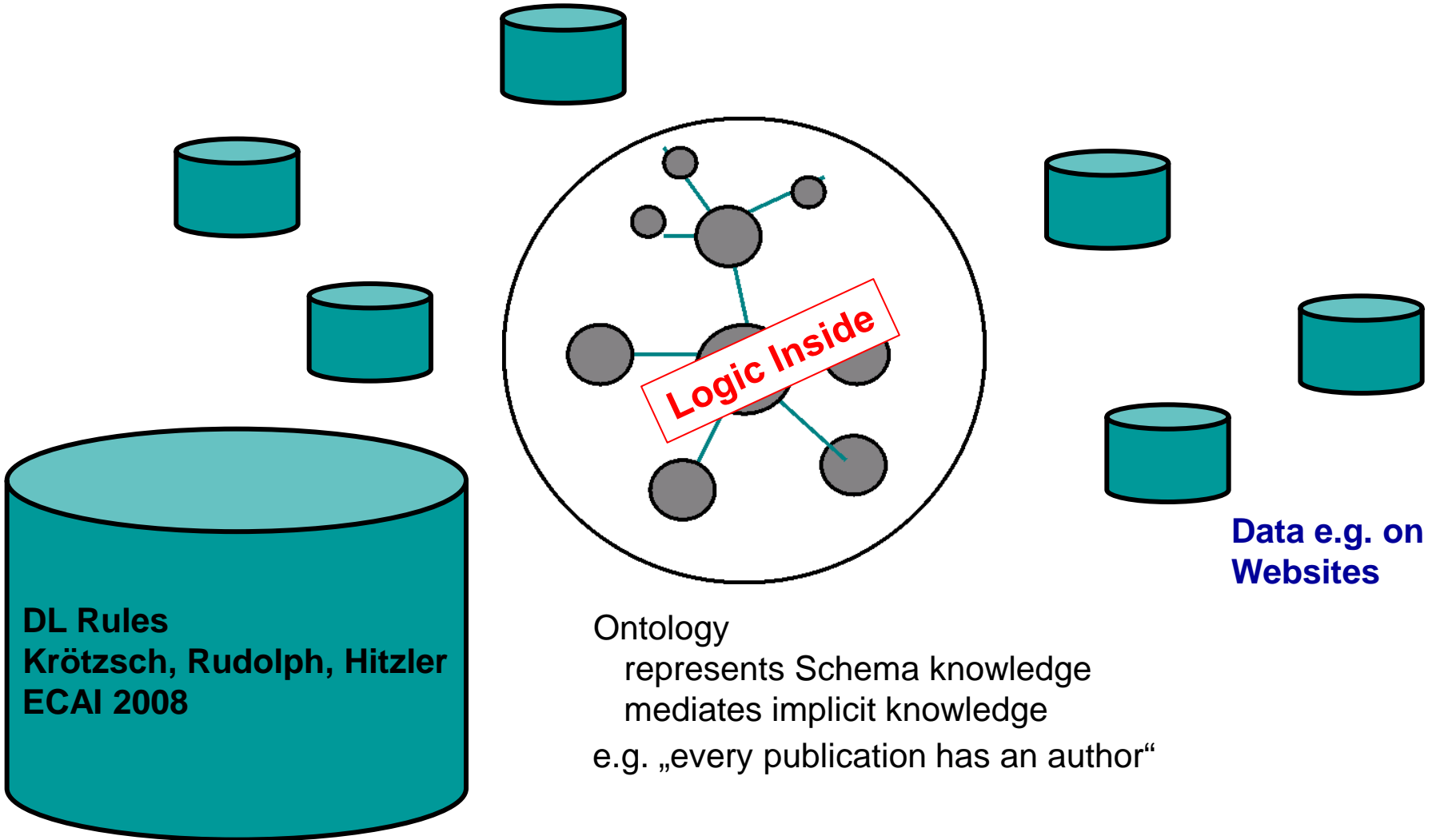
- **Open Standards for describing information on the Web**
- **Methods for obtaining further information from such descriptions**
  - e.g. by automated logical reasoning

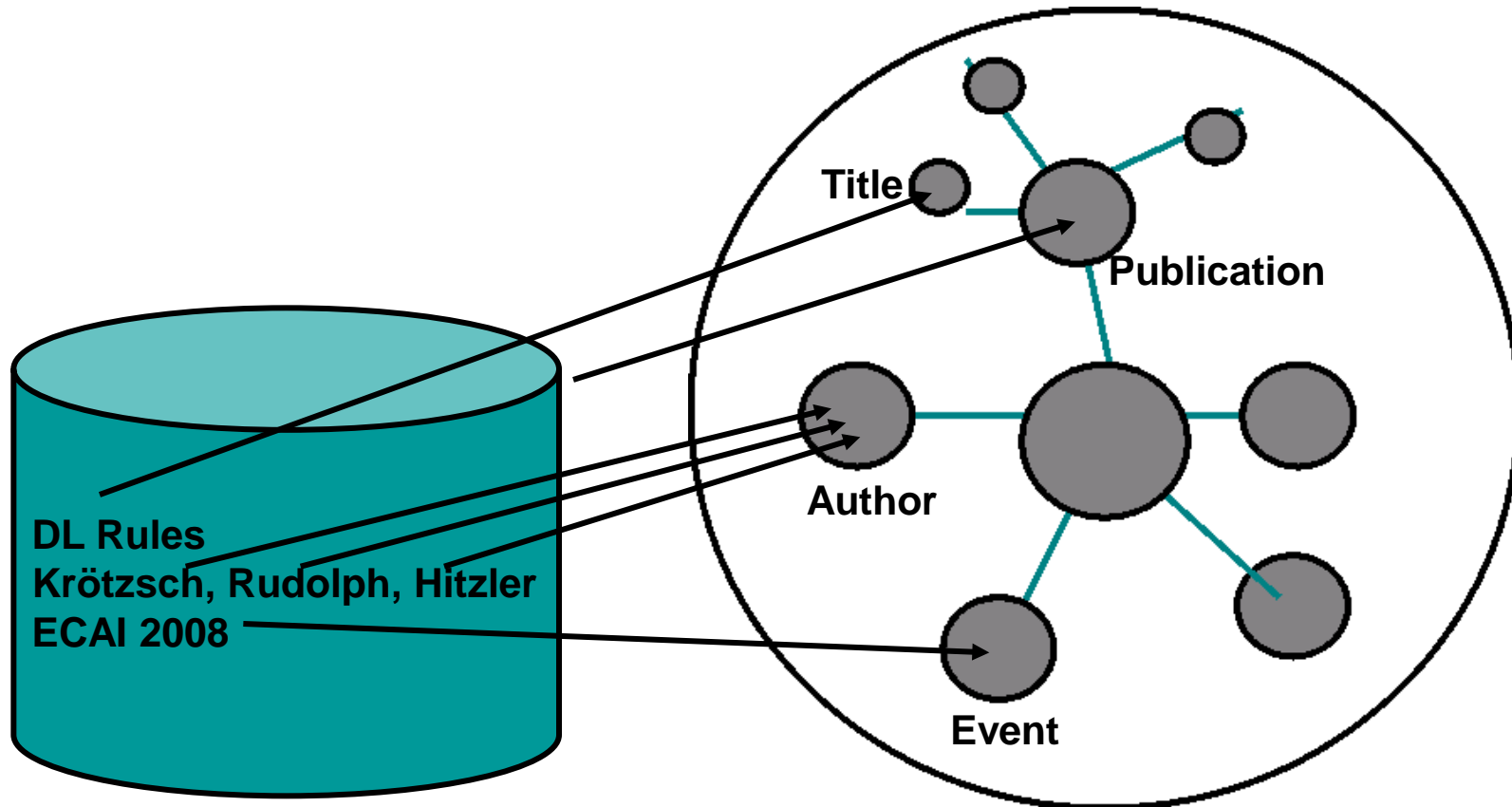


# Basic Idea of the Semantic Web



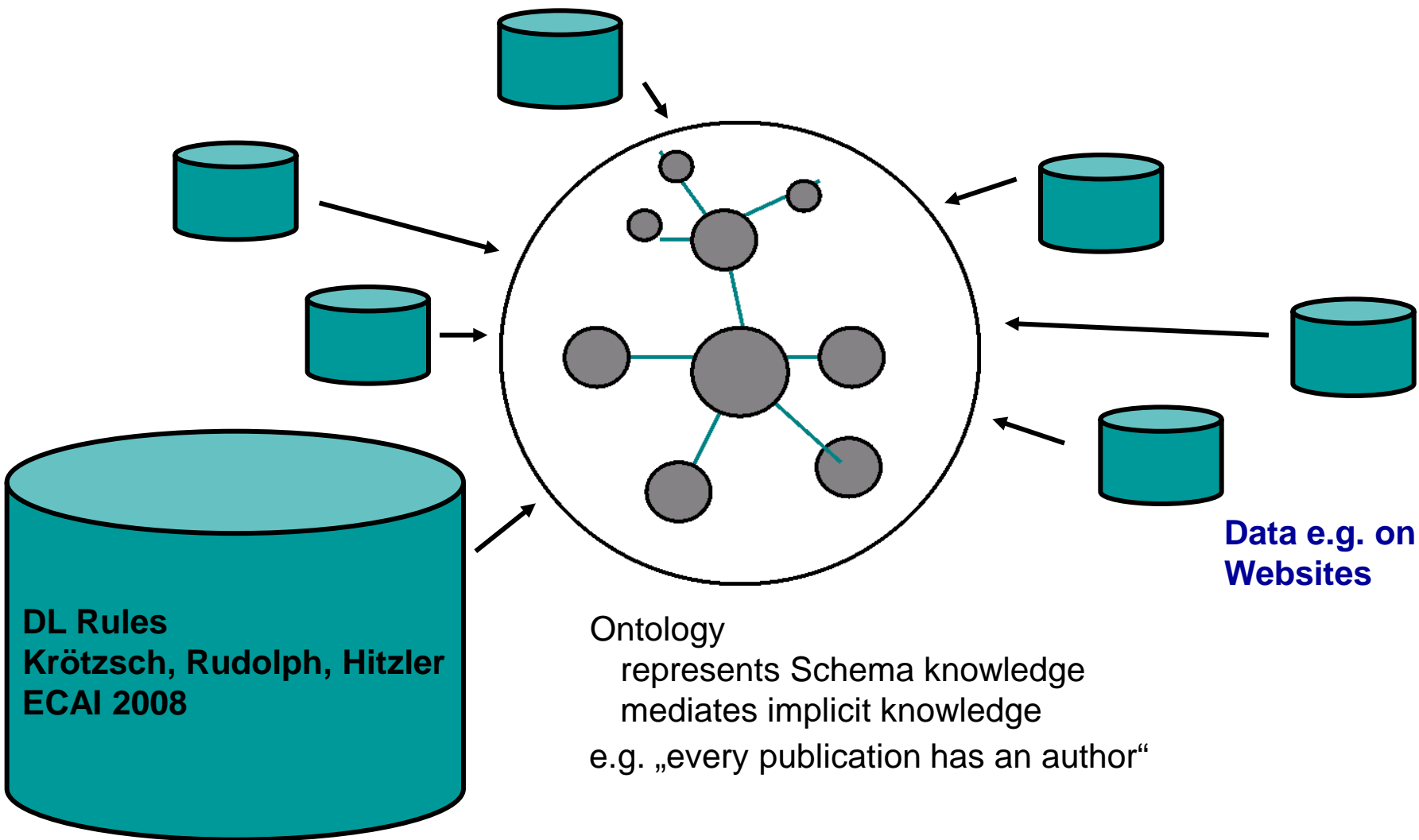
# Basic Idea of the Semantic Web



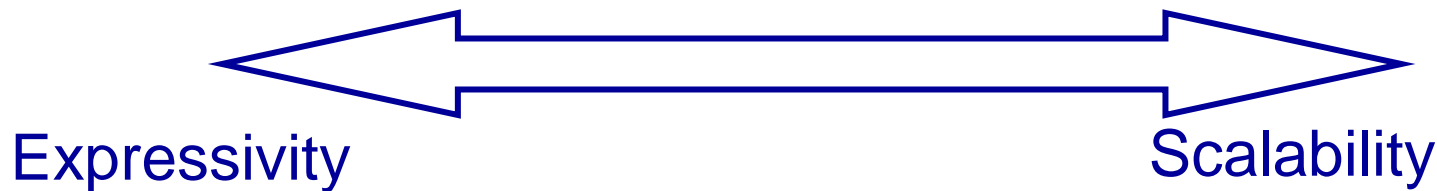


e.g. „every publication has an author“

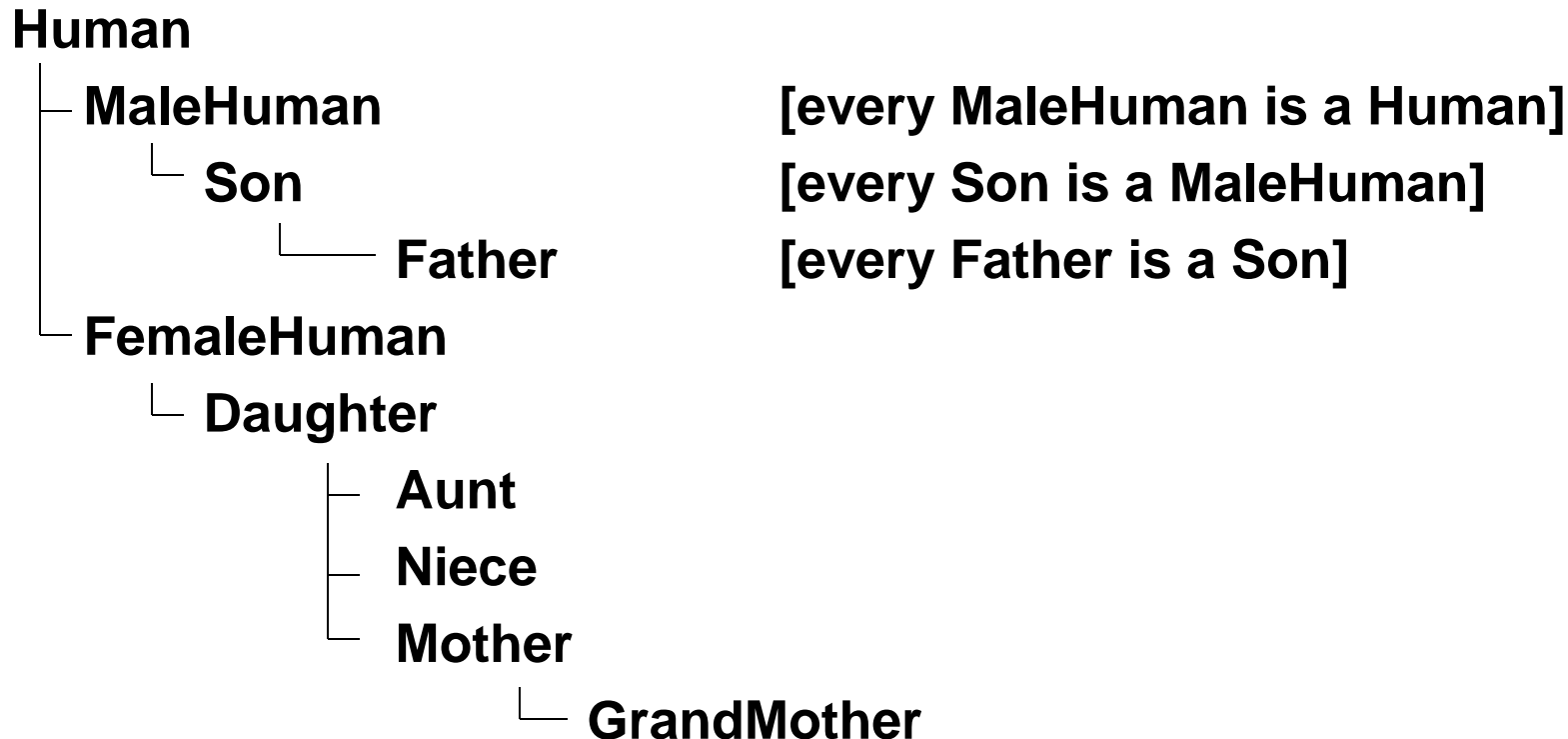
# Basic Idea of the Semantic Web



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

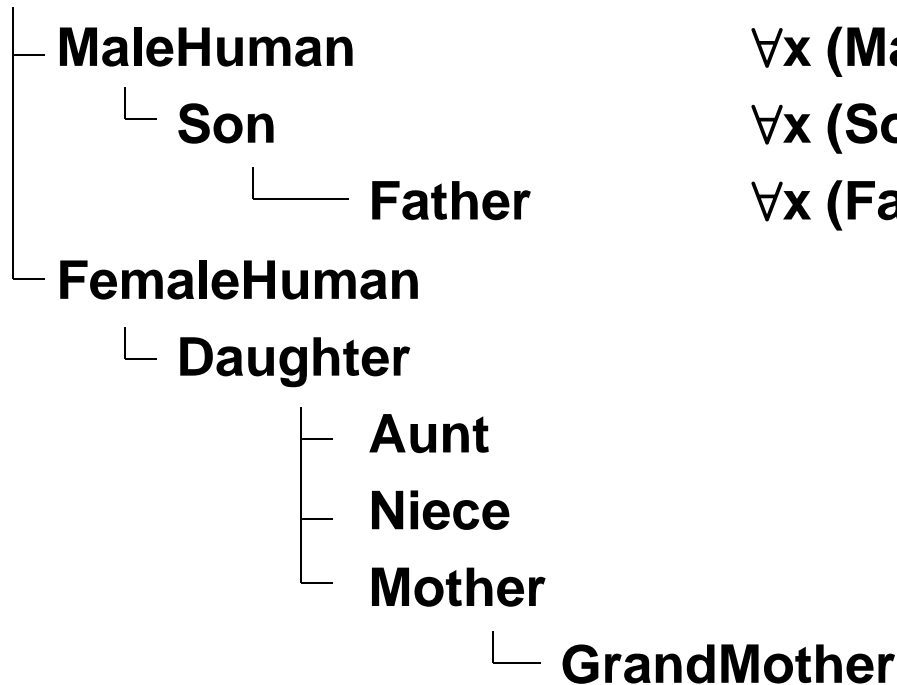


- The core of an ontology is usually a *taxonomy*:
  - classes of things, arranged in a hierarchy



- Logically speaking ...

**Human**



$\forall x (\text{MaleHuman}(x) \rightarrow \text{Human}(x))$

$\forall x (\text{Son}(x) \rightarrow \text{MaleHuman}(x))$

$\forall x (\text{Father}(x) \rightarrow \text{Son}(x))$

But you can do much more, e.g.

- ***Web Ontology Language* OWL**  
W3C Recommendation 2004 (OWL 2: 2009)
- **OWL is essentially a sublanguage of First-order Predicate Logic**
- **For OWL reasoning, (a suitable variant of the) tableaux algorithm is commonly used.**



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Just learned 79°26'01.86"W is the longitude of Dufferin Mall

*What would you like to know?*

are lobsters spiders?

? answer

e.g. Is Chris Evert male or female? What is another word for fantastic? [more...](#)

Answering questions based on 274,033,896 facts on 8,992,129 things


**Live questions:** [rebeca linares birthday](#) ? [population of california 2010](#) ? [convert 250 kmh to mph](#) ? [population of paraguay in 2010](#) ? [more](#)

## The world's first AI question-answering platform.

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### Teach True Knowledge

You can contribute to True Knowledge by teaching it something new. You can add:

 A person  A business  Anything else

Or teach us a fact:

Simply type your fact in here

e.g. I have always been unmarried

Teach

[recent activity](#) [league table](#) [community](#)

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We are looking for passionate and talented individuals to join our growing team. Visit our [jobs pages](#) to see if True Knowledge is right for you.

### Enhanced Search

Traditional search engines don't understand what your question actually means — they simply scan web pages for matching words. Use our search enhancer to add intelligence to your search results.



[Install search enhancer](#)

What would you like to know?

? answer

Are Lobsters spiders?

Share this:   

Rate this answer:  vote up  vote down  report abuse

No



Lobster

Clawed lobstershola, comprising a family of large marine crustaceans  
[wikipedia](#)



spider

spider (the 8-legged invertebrate)  
[wikipedia](#)

▼ How do we know?

Analyse this question

✓ See facts...

Reasoning 

I followed this chain of reasoning...

I know from locally stored knowledge that:

[Lobster](#) is a subclass of [Crustacean](#) (fact: ["130986959@trueknowledge.com"])

Therefore (generator: ["dc2@trueknowledge.com"]):

[Lobster](#) is a distinct class from [spider](#)

Therefore (generator: ["subclassdistinct1@trueknowledge.com"]):

[Lobster](#) is not a subclass of [spider](#)

# Is Garfield a cat?

What would you like to know?

Is garfield a cat?

? answer

Is garfield a cat?

Share this:



Rate this answer:



vote up



vote down



report abuse

No



[domestic cat](#)

cat, also known as the domestic cat or house cat to distinguish it from other felines, a small carnivorous species of nocturnal mammal that is often valued by humans for its companionship and its ability to hunt vermin

[wikipedia](#)



[James Garfield](#)

James A Garfield, the 20th President of the USA

[wikipedia](#)

▼ How do we know this?

Analyse this question

✓ See facts...

Reasoning 

I followed this chain of reasoning...

I know from locally stored knowledge that:

Fact 1: James Garfield is a President ([fact: ["378042683@trueknowledge.com"]])

Fact 1: is true for March 5th 1881 - September 19th 1881 ([fact: ["378042691@trueknowledge.com"]])

President is a subclass of person ([fact: ["123985229@trueknowledge.com"]])

Therefore (generator: ["dc2@trueknowledge.com"]):

President is a distinct class from domestic cat

Therefore (generator: ["distinct1@trueknowledge.com"]):

Fact 2 James Garfield is not a domestic cat

By calculation (generator: ["distinct1@trueknowledge.com"]) I know that:

Fact 2: is true for March 5th 1881 - September 19th 1881

## Semantic Web as an Application Area for Logic

1. What is Semantic Web?
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3. **Semantic Search**
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**Find that landmark article on data integration written by an Indian researcher in 1990.**

**The information is on the web.  
We just cannot combine it easily.**

**hasNationality(AmitSheth,indian)** [homepage]  
**hasTopic(paper3546, federatedDatabases)** [publisher]  
**hasAuthor(paper3546,AmitSheth)**  
**hasYear(paper3546,1990)**  
**hasCitations(paper3546,2497)** [google scholar]  
**subTopicOf(federatedDatabases,dataIntegration)** [ACM]

$\forall x \forall y \forall z (\text{hasTopic}(x,y) \wedge \text{subTopicOf}(y,z) \rightarrow \text{hasTopic}(x,z))$

$\forall x \forall n (\text{hasCitations}(x,n) \wedge x \geq n \rightarrow \text{landmarkPaper}(x))$

[publication finder]

Then we can ask, for which ?x and ?y the formula

**landmarkPaper(?x)  $\wedge$  hasYear(?x,1990)  $\wedge$   
hasTopic(?x,dataIntegration)  $\wedge$  hasAuthor(?x,?y)  $\wedge$   
hasNationality(?y,indian)**

is a logical consequence of the above.



## Semantic Web as an Application Area for Logic

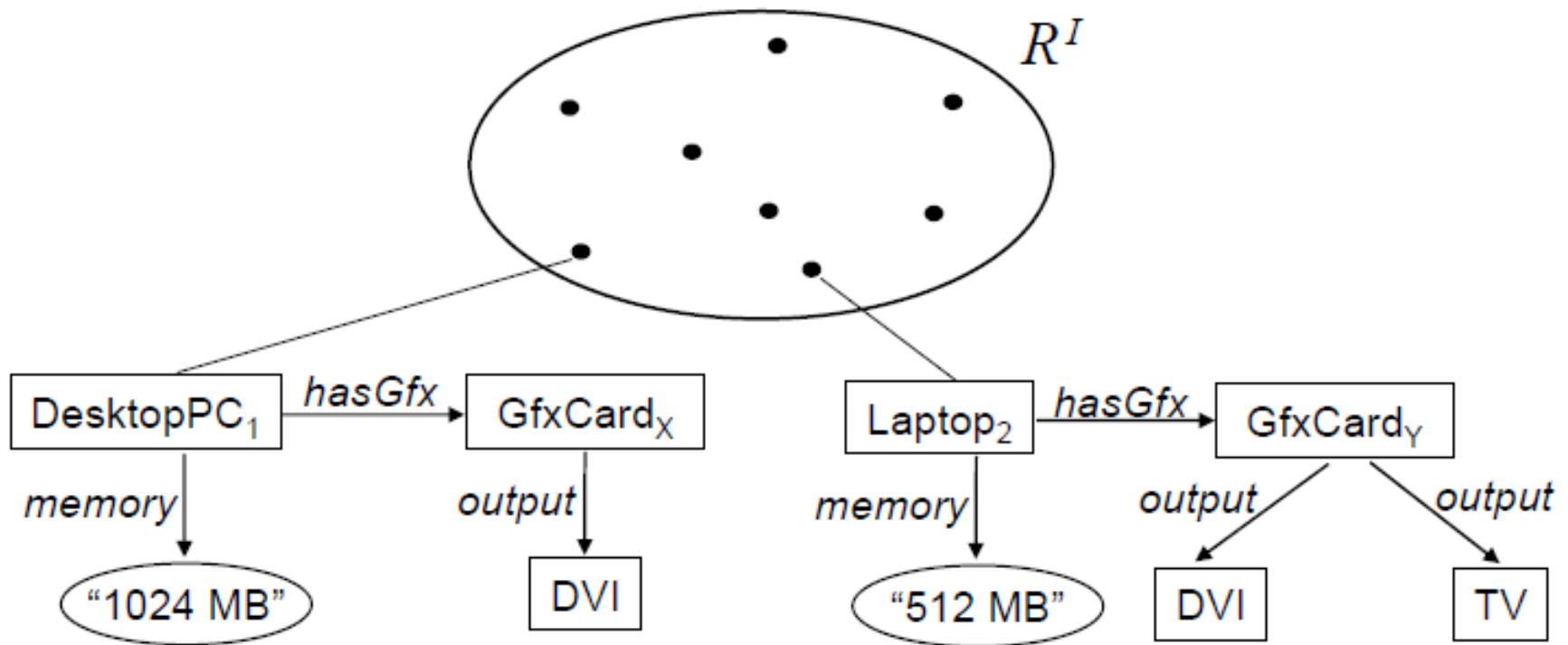
1. What is Semantic Web?
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4. **Semantic Web Services**

- **Internet shops selling computers.**
- **You want to buy one which satisfies your specifications.**
- **Shop offers can be described using OWL.**
- **Your specifications can be described using OWL.**
- **Automated reasoning can be used to see if there is a match.**

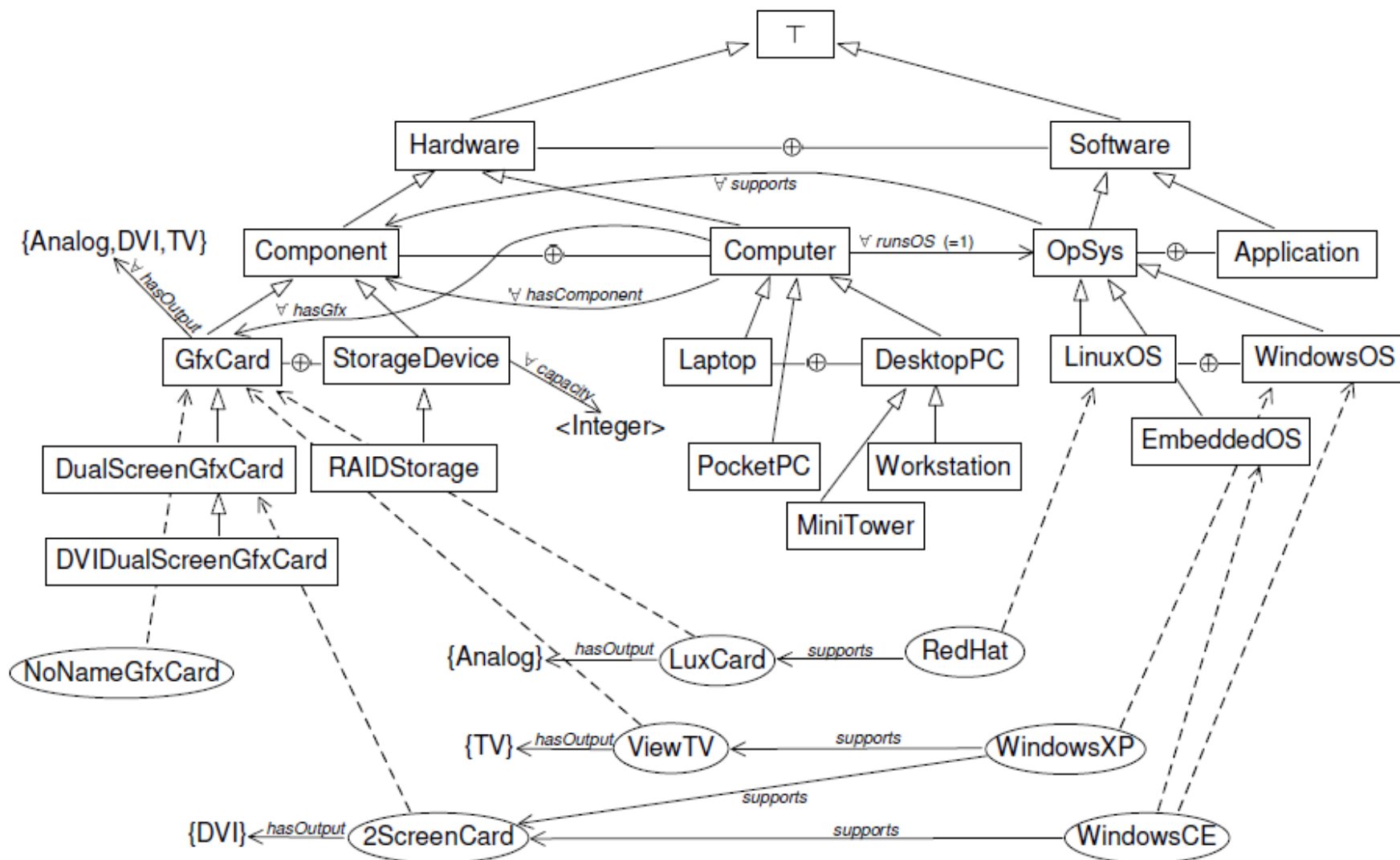
# Resource description example

$$R = \text{Computer} \sqcap \exists \text{memory}.\geq_{512} \sqcap \forall \text{hasGfx}.\left(\exists \text{output}.\{DVI\}\right)$$

$$\forall x (\text{Computer}(x) \wedge \exists n (\text{memory}(x,n) \wedge n \geq 512) \wedge \forall y (\text{hasGfx}(x,y) \rightarrow \text{output}(y,DVI)))$$



# Background Knowledge (part)



$$S_A = \text{MiniTower} \sqcap \exists \text{hasGfx} . \text{DVIDualScreenGfxCard}$$

$$D_1 = \text{Computer} \sqcap \exists \text{hasGfx} . \text{DualScreenGfxCard} \\ \sqcap \forall \text{hasComponent} . (\exists \text{supports}^- . \text{WindowsOS})$$

$$\forall x (S_A(x) \leftrightarrow (\text{MiniTower}(x) \wedge \exists y (\text{hasGfx}(x,y) \wedge \text{DVIDualScrGfxCard}(y))))$$

$$\forall x (D_1(x) \leftrightarrow (\text{Computer}(x) \wedge \exists y (\text{hasGfx}(x,y) \wedge \text{DualScreenGfxCard}(y)) \wedge \\ \forall z (\text{hasComponent}(x,z) \rightarrow \exists w (\text{supports}(w,z) \wedge \text{WindowsOS}(z))))))$$

- **Logical Consequence:**

$$S_A \sqcap D_1 \neq \emptyset \\ \exists x (S_A(x) \wedge D_1(x))$$

i.e., the supply meets the demand.

$$S_A = \text{MiniTower} \sqcap \exists \text{hasGfx} . \text{DVIDualScreenGfxCard}$$

$$D_2 = \text{DesktopPC} \sqcap \exists \text{hasStorage} . \text{RAIDStorage} \\ \sqcap \exists \text{runsOS} . (\exists \text{supports} . \text{DualScreenGfxCard} \\ \sqcap \exists \text{supports} . \text{RAIDStorage})$$

- In this case,

$$\mathbf{S_A \sqcap D_2 = \emptyset} \\ \neg \exists \mathbf{x (S_A(x) \wedge D_2(x))}$$

(Complete example: Reference [3])

- **Large and active research area**
- **Recently considerable industrial impact**
  
- **The Kno.e.sis Center at Wright State University is one of the leading centers in this area.**
  
  
- **Interested in pursuing reseach? Thesis? Independent Study?  
⇒ just let me know, and we can talk about options.**

- [1] Pascal Hitzler, Markus Krötzsch, Sebastian Rudolph  
Foundations of Semantic Web Technologies.  
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- [2] Pascal Hitzler, Markus Krötzsch, Bijan Parsia, Peter F. Patel-  
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OWL 2 Web Ontology Language: Primer.  
W3C Recommendation, 27 October 2009.  
<http://www.w3.org/TR/owl2-primer/>**
- [3] Stephan Grimm, Pascal Hitzler  
Semantic Matchmaking of Web Resources with Local Closed-  
World Reasoning.  
International Journal of e-Commerce 12 (2), 89-126, Winter 2007-8.**