CS 499/699 – Logic for Computer Scientists

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Today's Session

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

The WWW is penetrating our society

- 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, ...)

The current 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.

Limitations of the current Web

- 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

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 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.]

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.

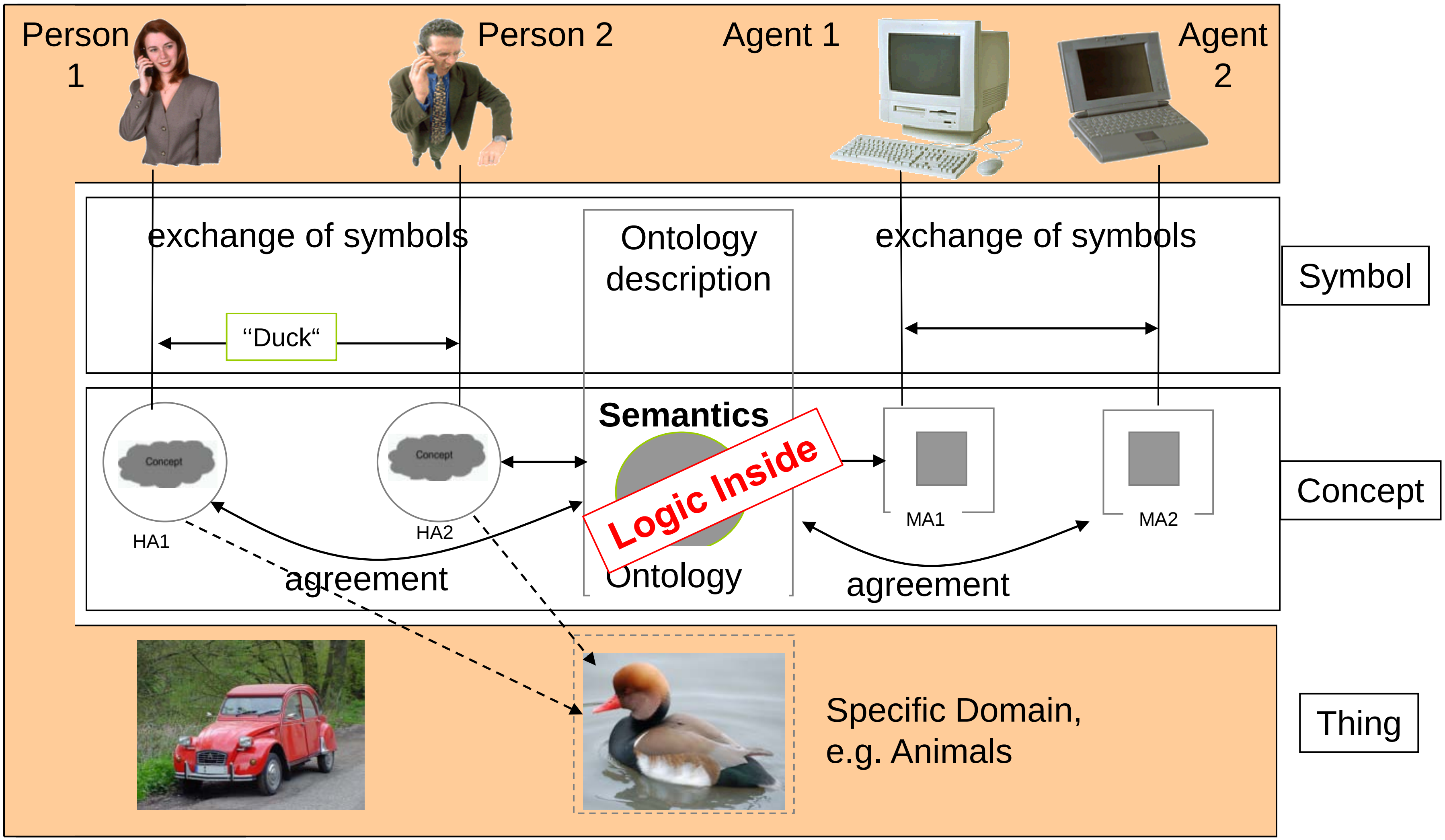
However, without automated processing and reasoning we cannot obtain a useful answer.

Basic ingredients for the Semantic Web

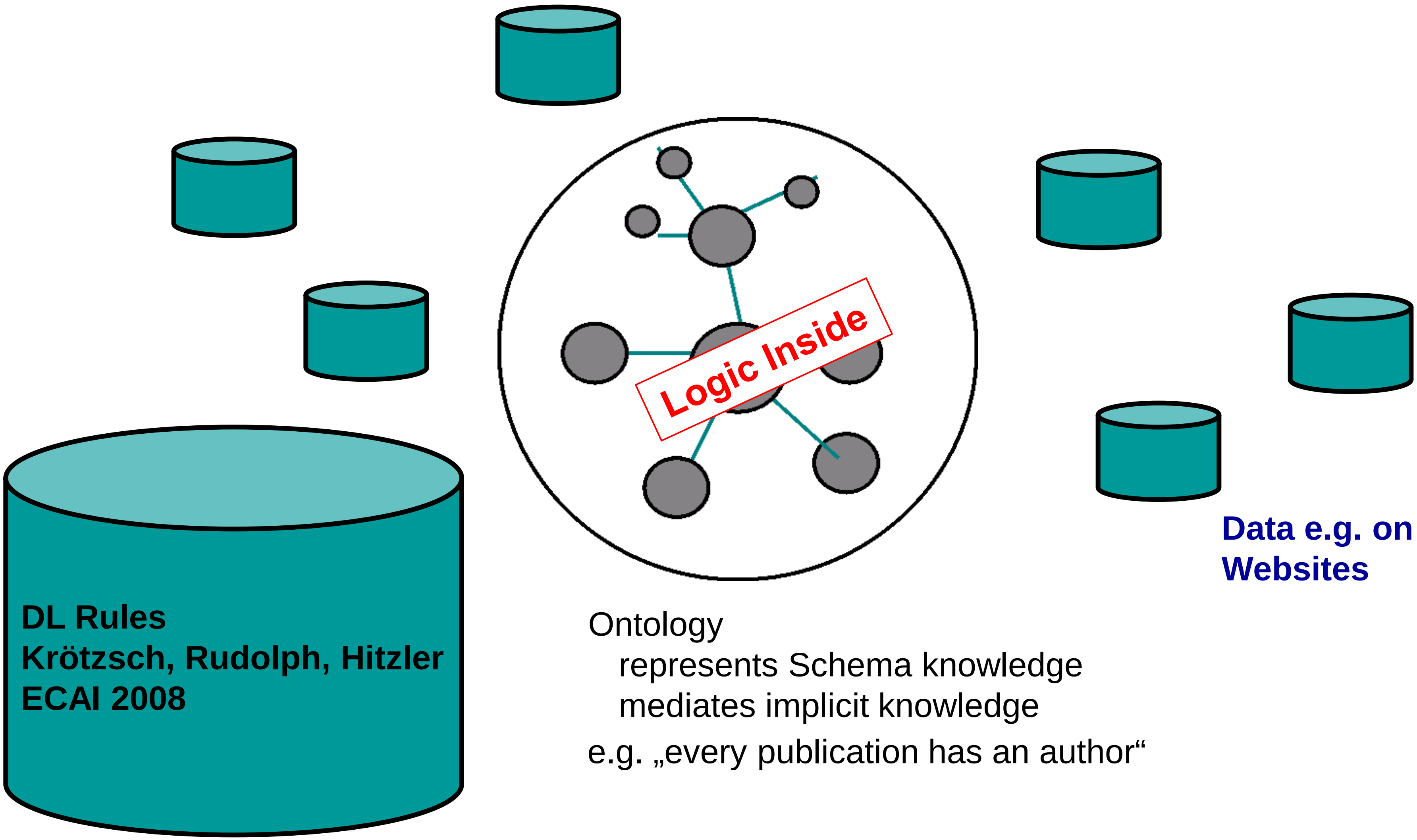
- **Open Standards for describing information on the Web**
- **Methods for obtaining further information from such descriptions**

  → e.g. by automated logical reasoning

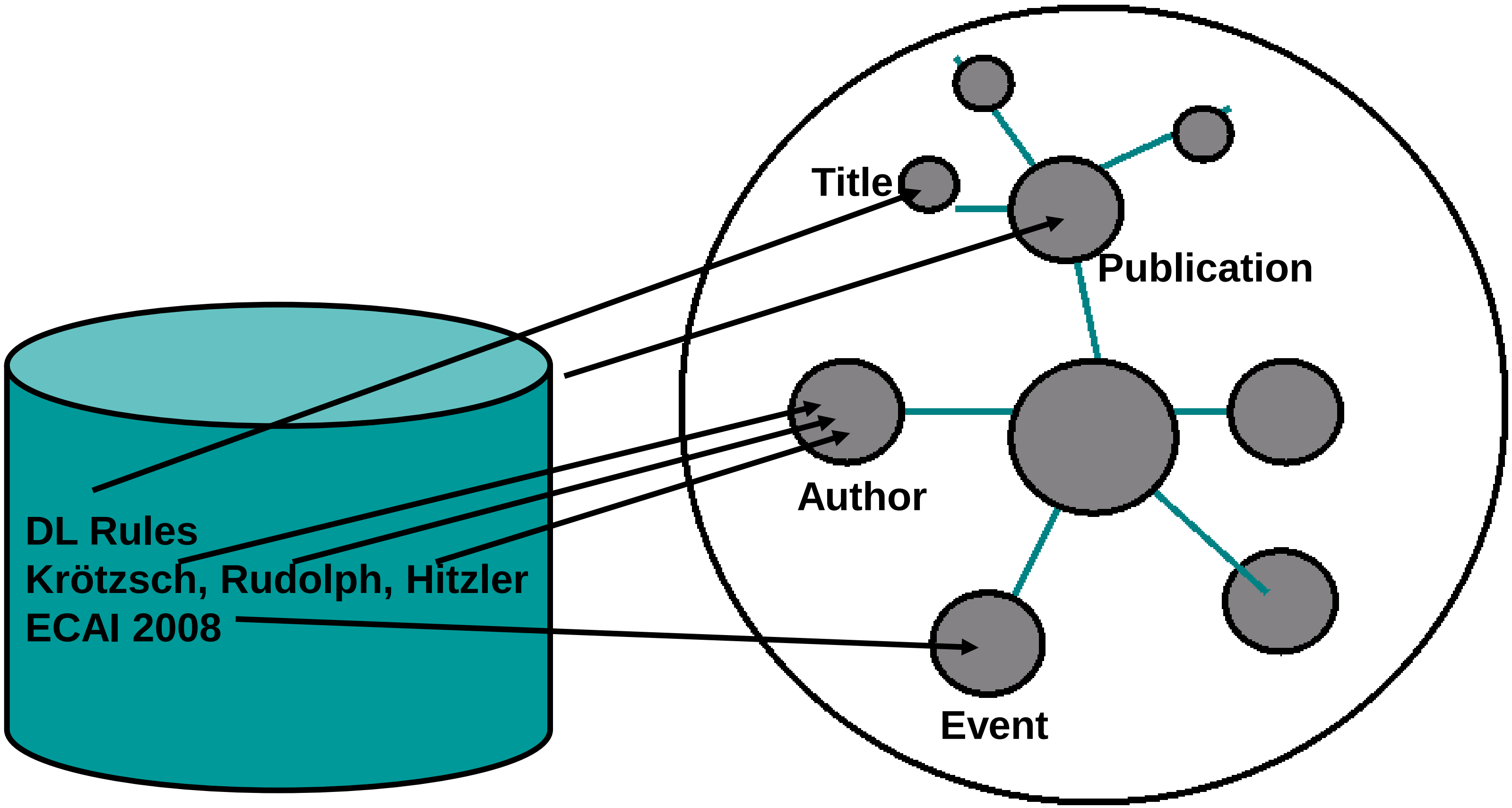
Basic Idea of the Semantic Web



Basic Idea of the Semantic Web

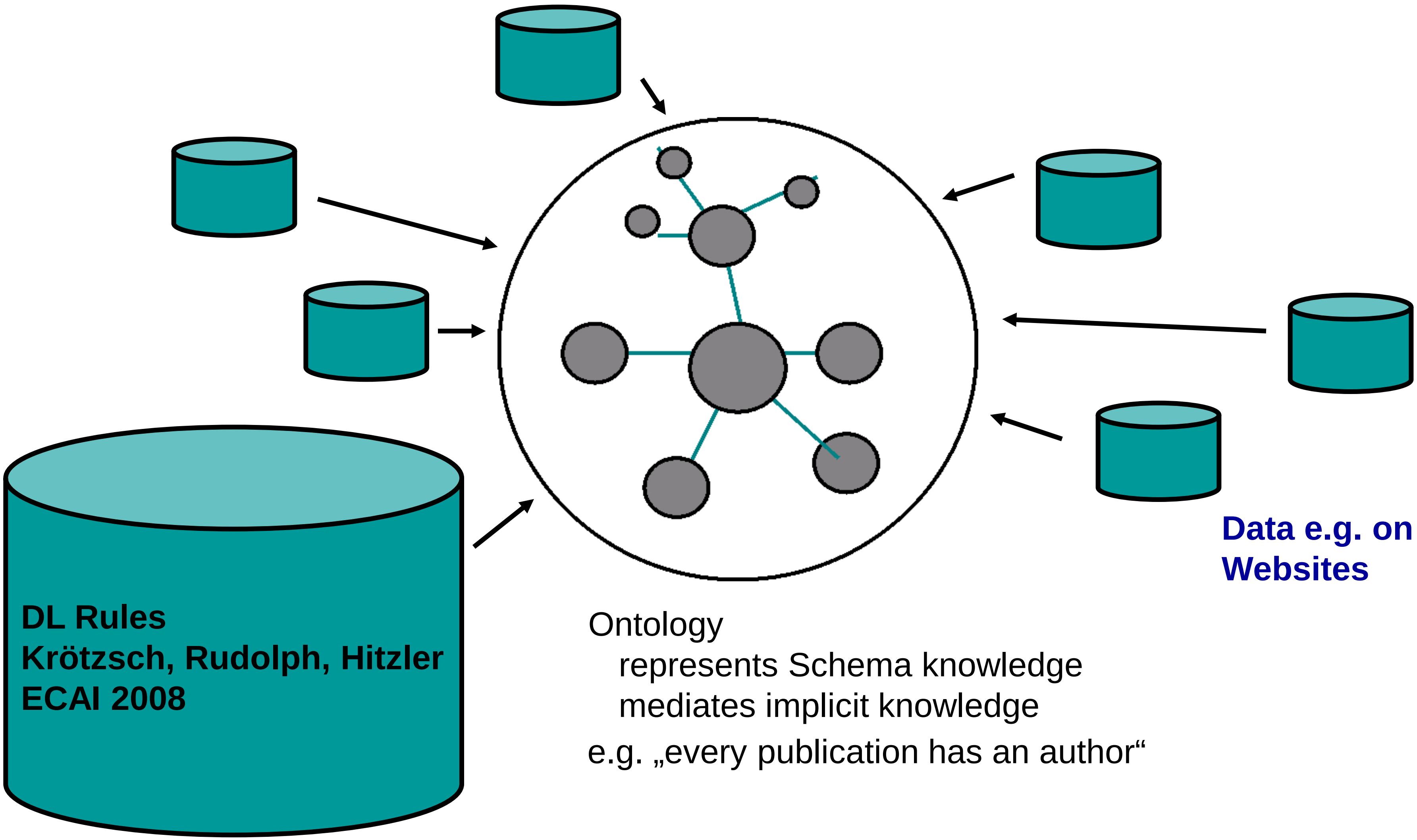


Basic Idea of the Semantic Web



e.g. „every publication has an author“

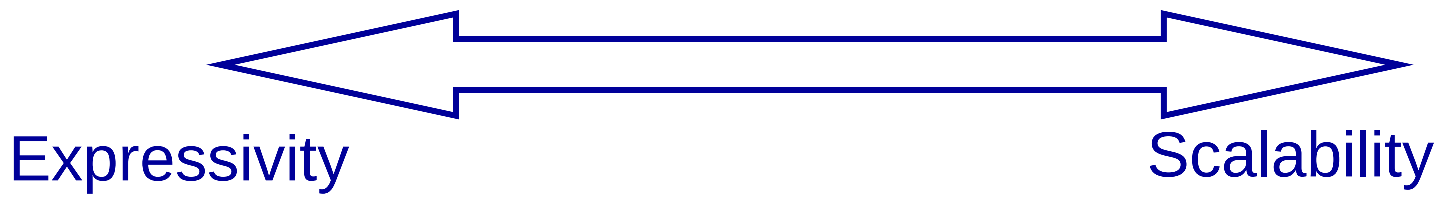
Basic Idea of the Semantic Web



Ontology
  represents Schema knowledge
  mediates implicit knowledge
e.g. „every publication has an author“

Ontology languages

- **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.**



Ontologies

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

```
Human
 ├─ MaleHuman                      [every MaleHuman is a Human]
 │    └─ Son                       [every Son is a MaleHuman]
 │         └─── Father             [every Father is a Son]
 └─ FemaleHuman
      └─ Daughter
           ├─ Aunt
           ├─ Niece
           └─ Mother
                └─ GrandMother
```

Ontologies

- **Logically speaking …**

Human
- **MaleHuman**
  - **Son**
    - **Father**
- **FemaleHuman**
  - **Daughter**
    - **Aunt**
    - **Niece**
    - **Mother**
      - **GrandMother**

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

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

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

Ontologies

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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Bookmarks Tools Help

http://www.trueknowledge.com/

True Knowledge®

The Internet Answer Engine™ BETA

register sign in

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

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A person open A business Anything else

Or teach us a fact:

Simply type your fact in here

Teach

e.g. I have always been unmarried

recent activity league table community

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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

TrueKnowledge

What would you like to know?

Are Lobsters spiders?

? 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

Garfield is not a cat

KNO.E.SIS

▼ 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

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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.

Modeling

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) ∧ hasYear(?x,1990) ∧ hasTopic(?x,dataIntegration) ∧ hasAuthor(?x,?y) ∧ hasNationality(?y,indian)

is a logical consequence of the above.

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Scenario

- Internet shops selling computers.
- You want to buy one which satisfies your specifications.

- Shop offers can be described using OWL.

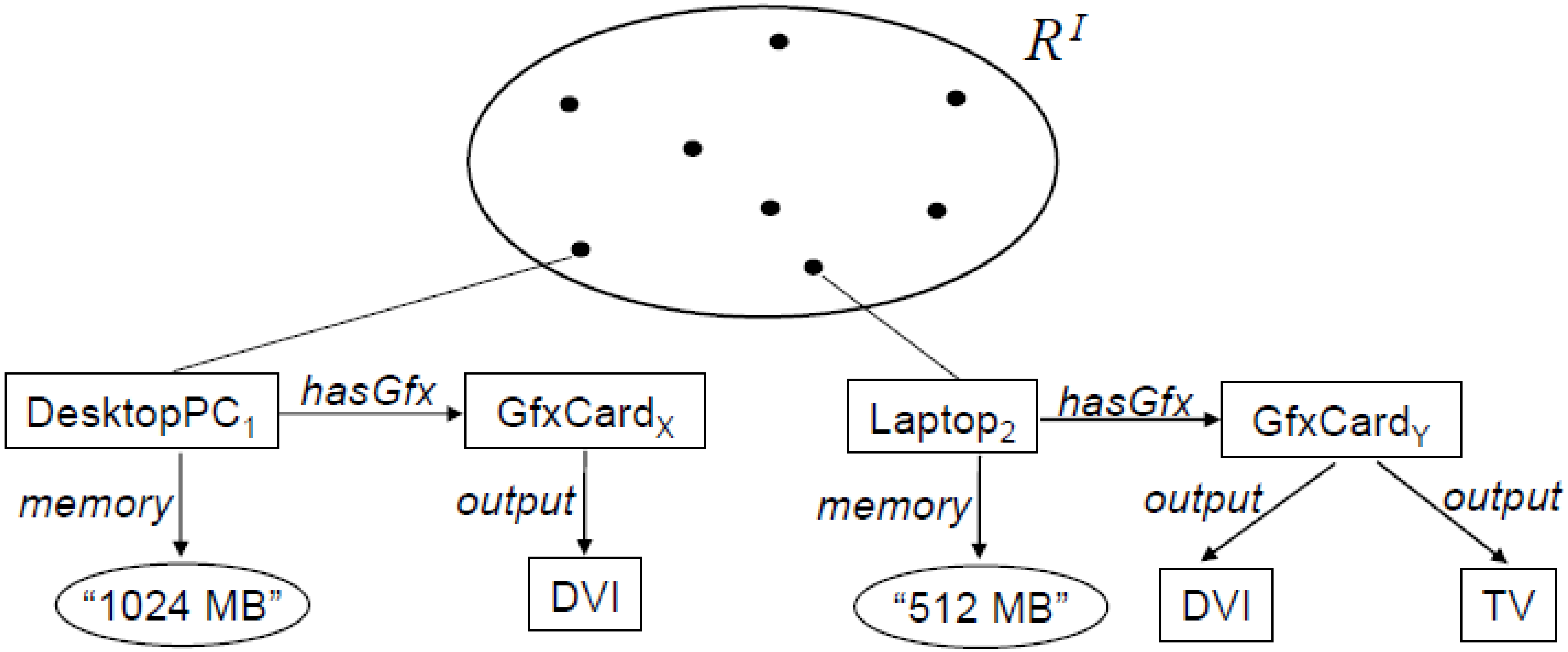
- Your specifications can be described using OWL.

- Automated reasoning can be used to see if there is a match.

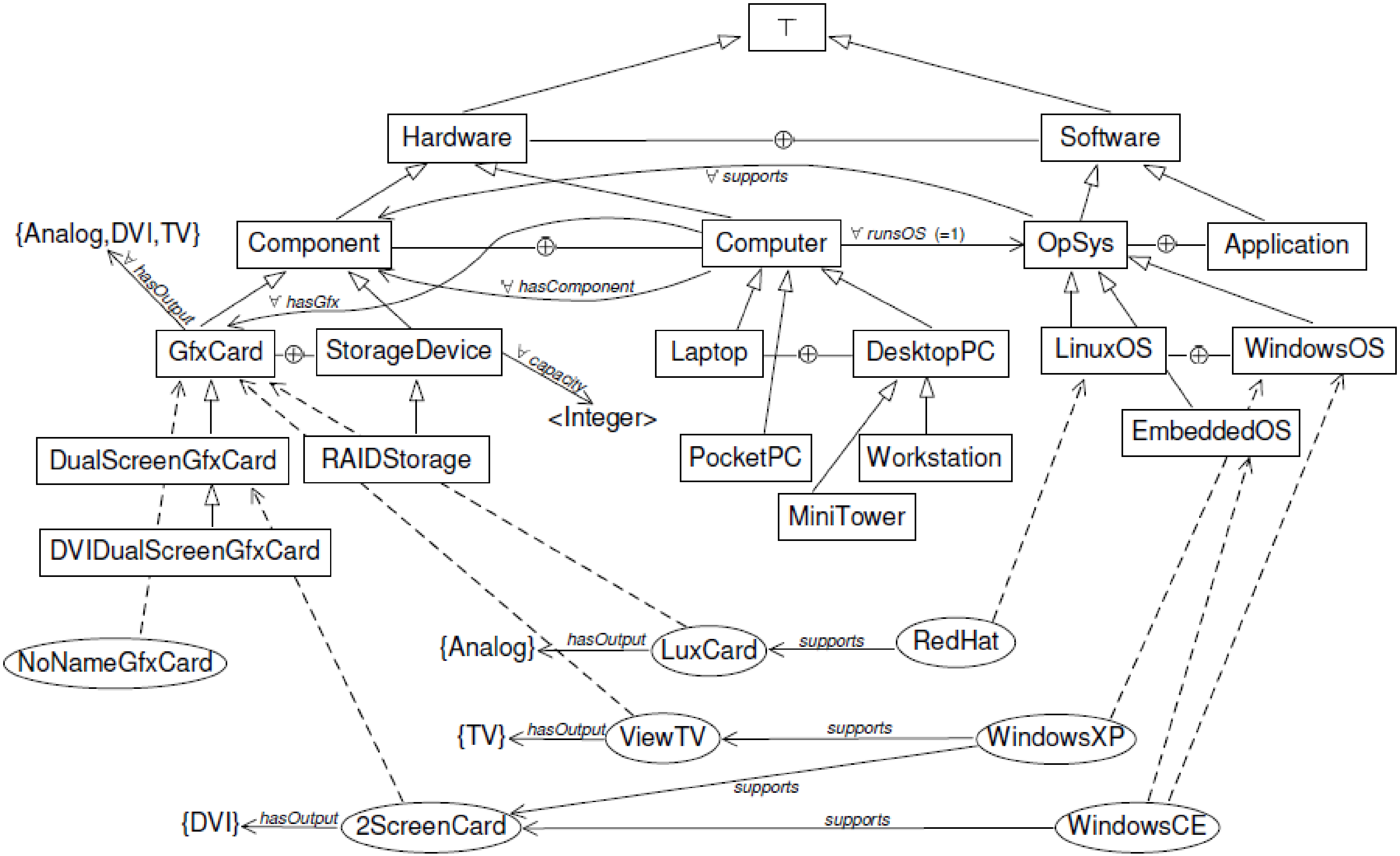
Resource description example

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

$$\forall x\ (Computer(x) \land \exists n\ (memory(x,n) \land n \geq 512) \land \forall y\ (hasGfx(x,y) \rightarrow output(y,DVI)))$$



Background Knowledge (part)



Supply and Demand

$$S_A = MiniTower \sqcap \exists\, hasGfx.DVIDualScreenGfxCard$$

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

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

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

- **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.

Supply and Demand

$$
\begin{aligned}
S_A &= MiniTower \sqcap \exists\, hasGfx\,.\,DVIDualScreenGfxCard \\
D_2 &= DesktopPC \sqcap \exists\, hasStorage\,.\,RAIDStorage \\
&\quad \sqcap \exists\, runsOS\,.(\exists\, supports\,.\,DualScreenGfxCard \\
&\qquad \sqcap \exists\, supports\,.\,RAIDStorage)
\end{aligned}
$$

- **In this case,**

$$\mathbf{S_A \sqcap D_2 = \emptyset}$$

$$\mathbf{\neg\exists x\, (S_A(x) \wedge D_2(x))}$$

(Complete example: Reference [3])

Semantic Web

- 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?
  $\Rightarrow$ just let me know, and we can talk about options.

References

[1] Pascal Hitzler, Markus Krötzsch, Sebastian Rudolph
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[3] Stephan Grimm, Pascal Hitzler
Semantic Matchmaking of Web Resources with Local Closed-World Reasoning.
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