CS 499/699 – Logic for Computer Scientists

Winter Quarter 2012

Slides 2 – March 8, 2012

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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 (from agoogleaday.com)

- What tribe has lived since 1300 AD near the canyon you'd explore from Bright Angel Trail?
- The highway that runs through Rachel, Nevada draws enthusiasts who probably enjoy what movie genre?
- If you key in international dialing code 40, how would you say "good morning" in the language of the country you're calling?
- What word will you use for "taxi" if the airport code of your destination is OSL?
- What single state is home to all of the following U.S. cities: Madrid, Toronto, Cincinnati, Denver, Hartford, and Norway?

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.

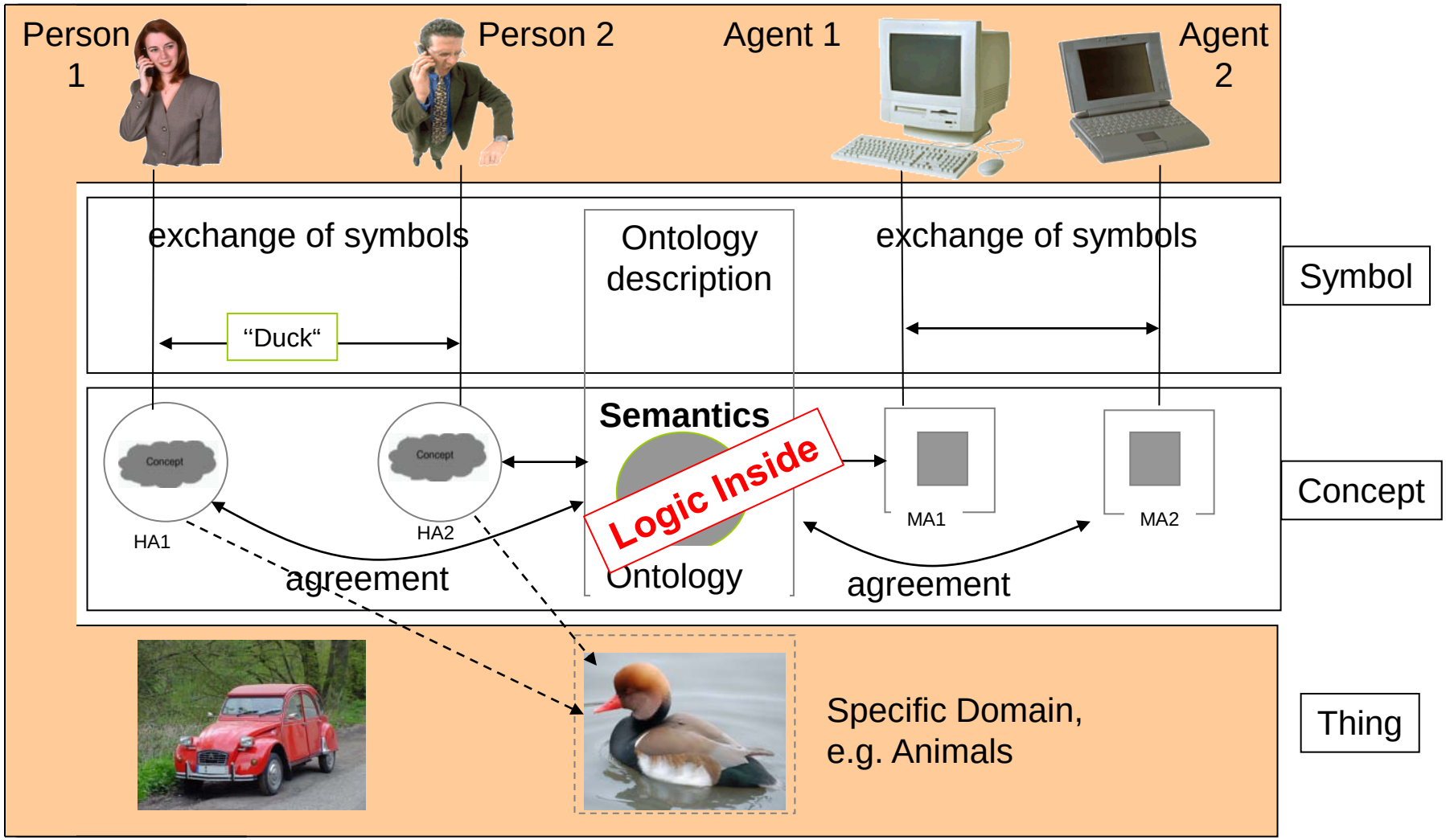
However, without automated processing and reasoning we cannot obtain a useful answer.

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



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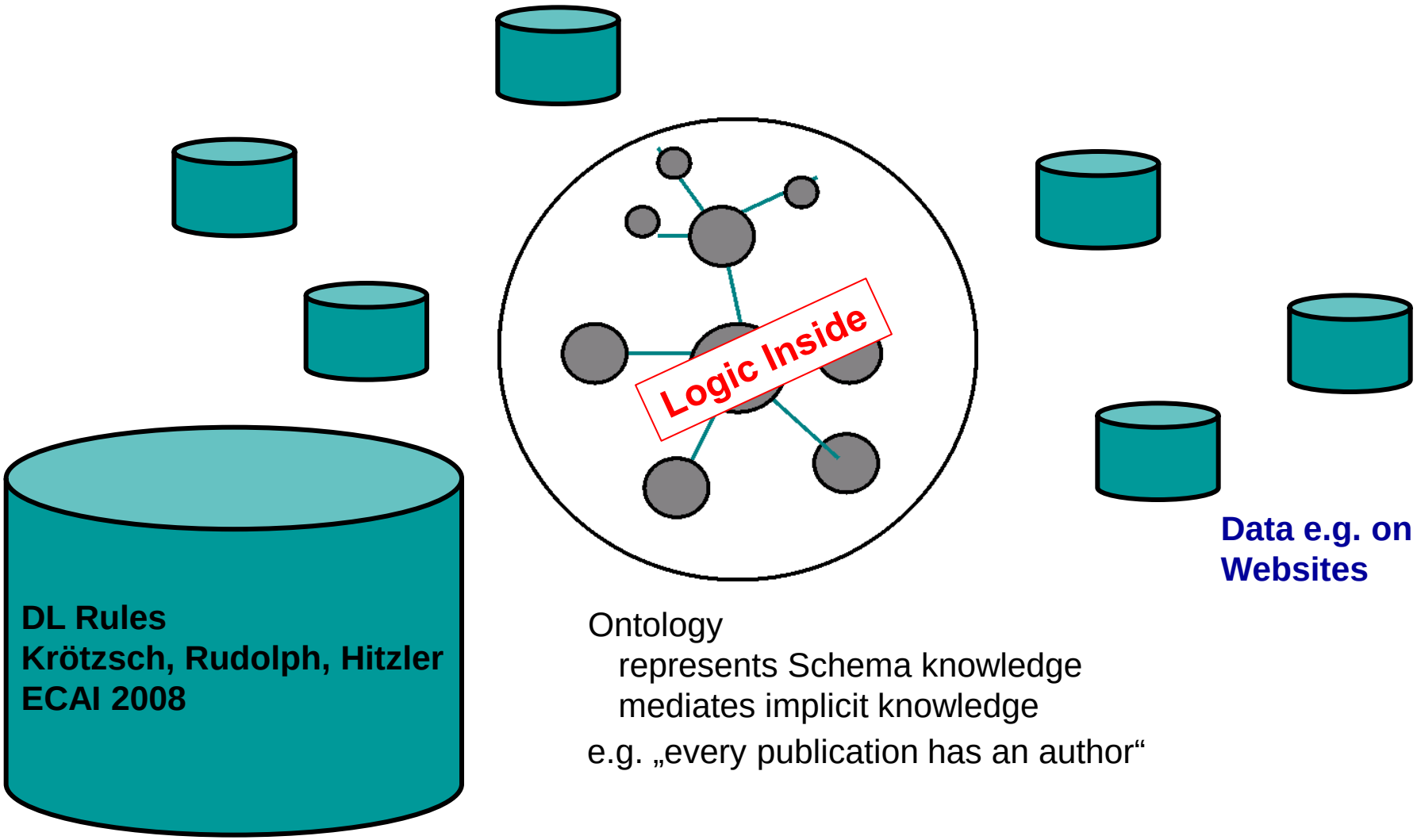
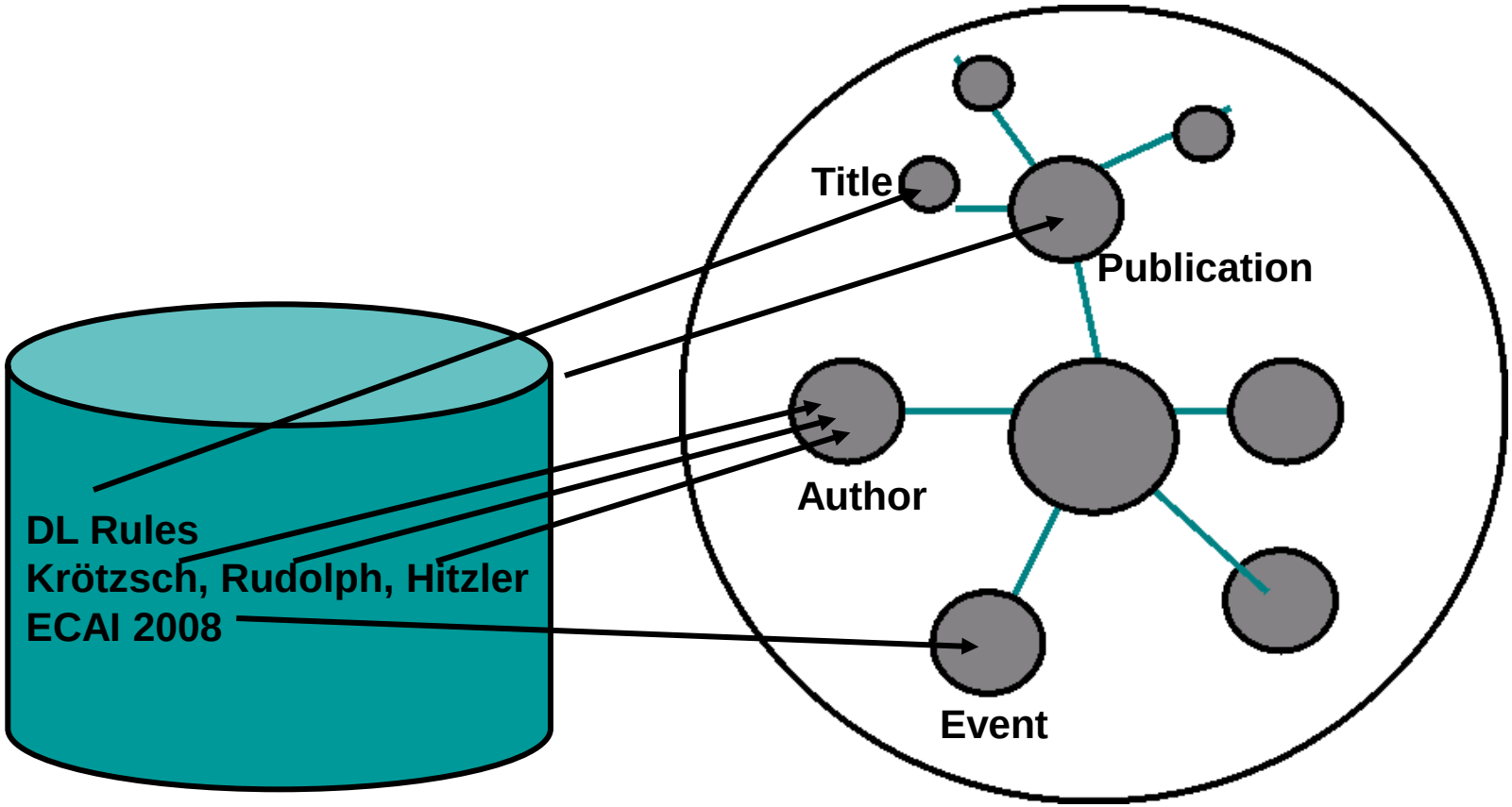


Ontology
- represents Schema knowledge
- mediates implicit knowledge

e.g. „every publication has an author“

Basic Idea of the Semantic Web



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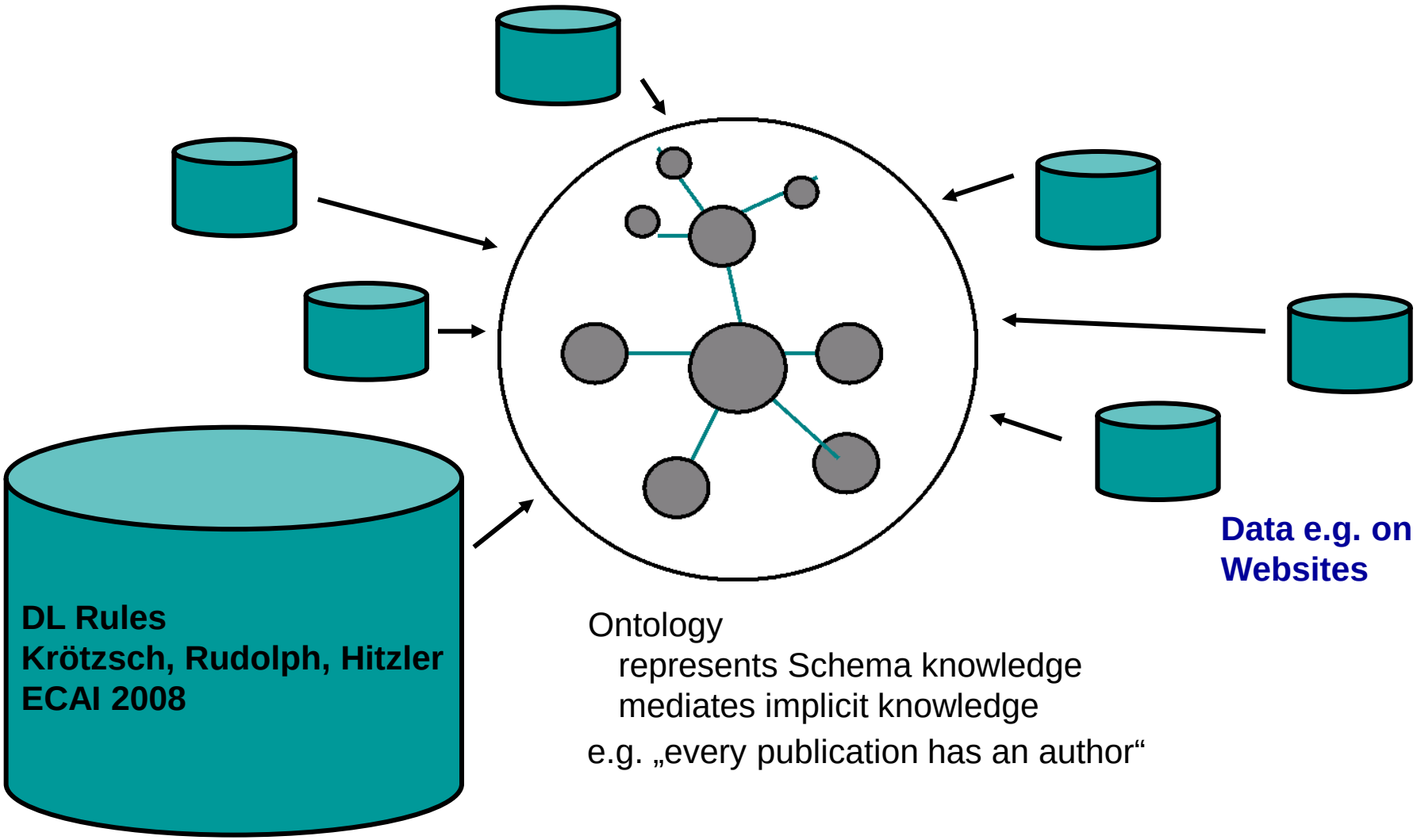
Basic Idea of the Semantic Web



Ontology
- represents Schema knowledge
- mediates implicit knowledge

e.g. „every publication has an author“

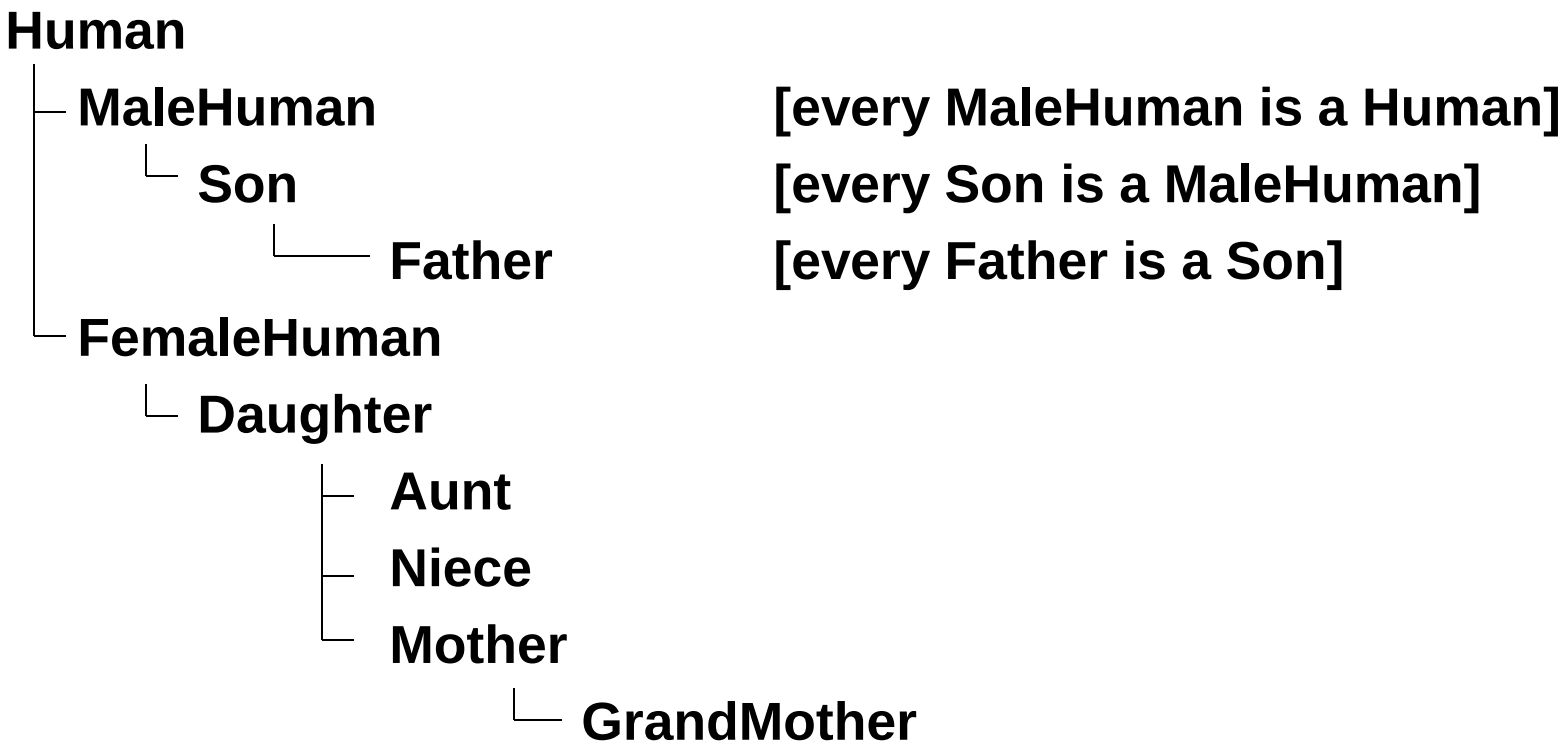
Ontology languages

- **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.**

Expressivity Scalability

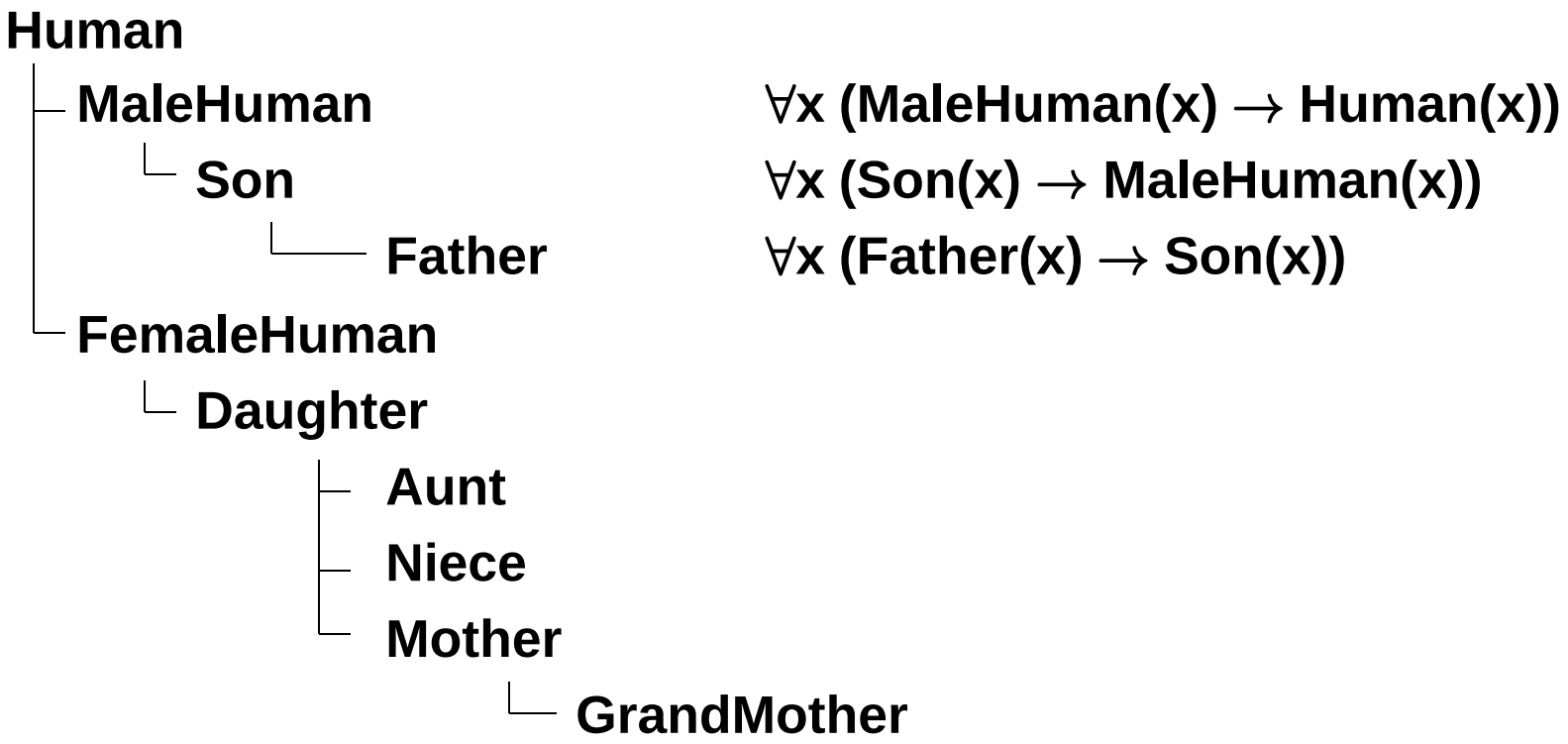
Ontologies

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



Ontologies

- **Logically speaking …**



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

The world's first AI question-answering platform.

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A person | open A business | Anything else

Or teach us a fact:

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recent activity league table community

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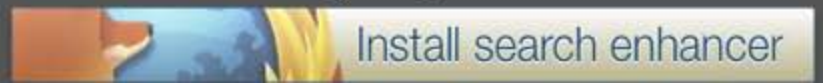
Enhanced Search

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.



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

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]

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

$\forall x \forall n$ (hasCitations(x,n) $\wedge$ x$\geq$n $\rightarrow$ 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.

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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.

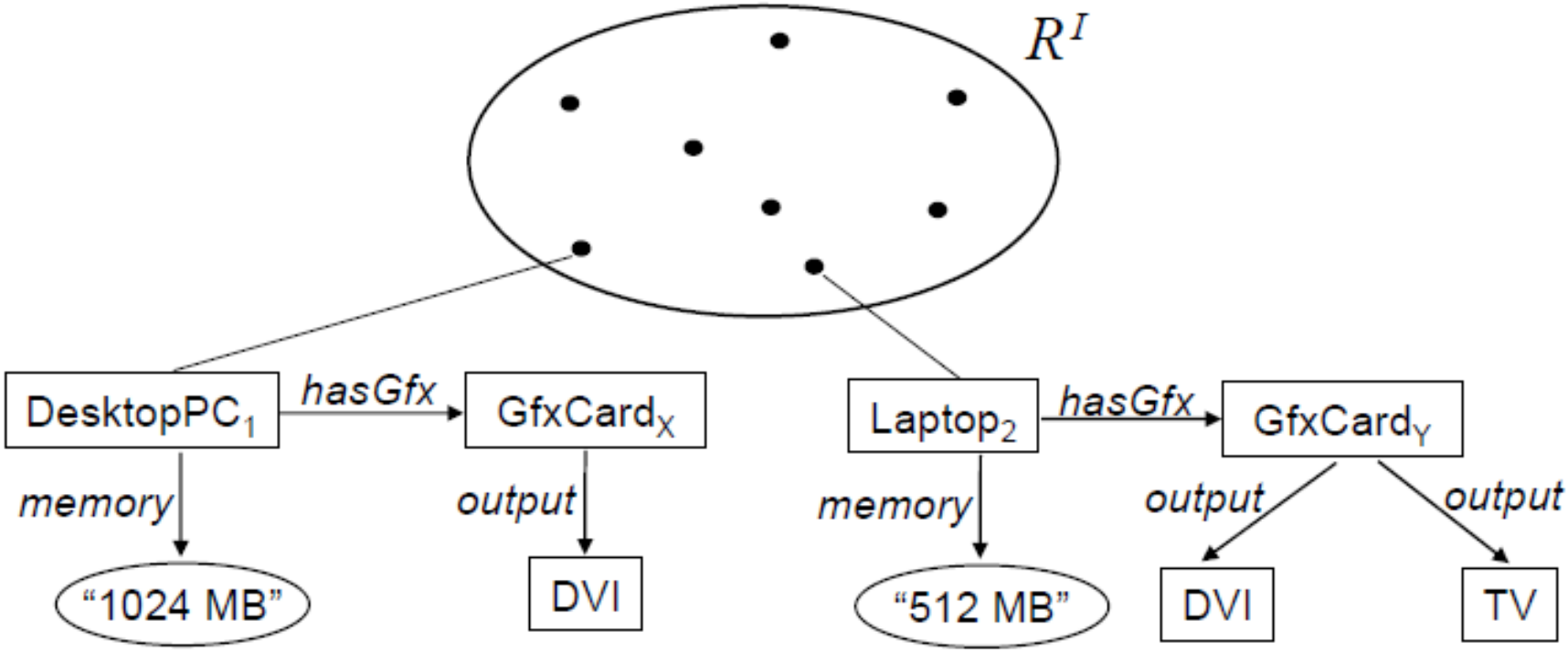
- Your specifications can be described using OWL.

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

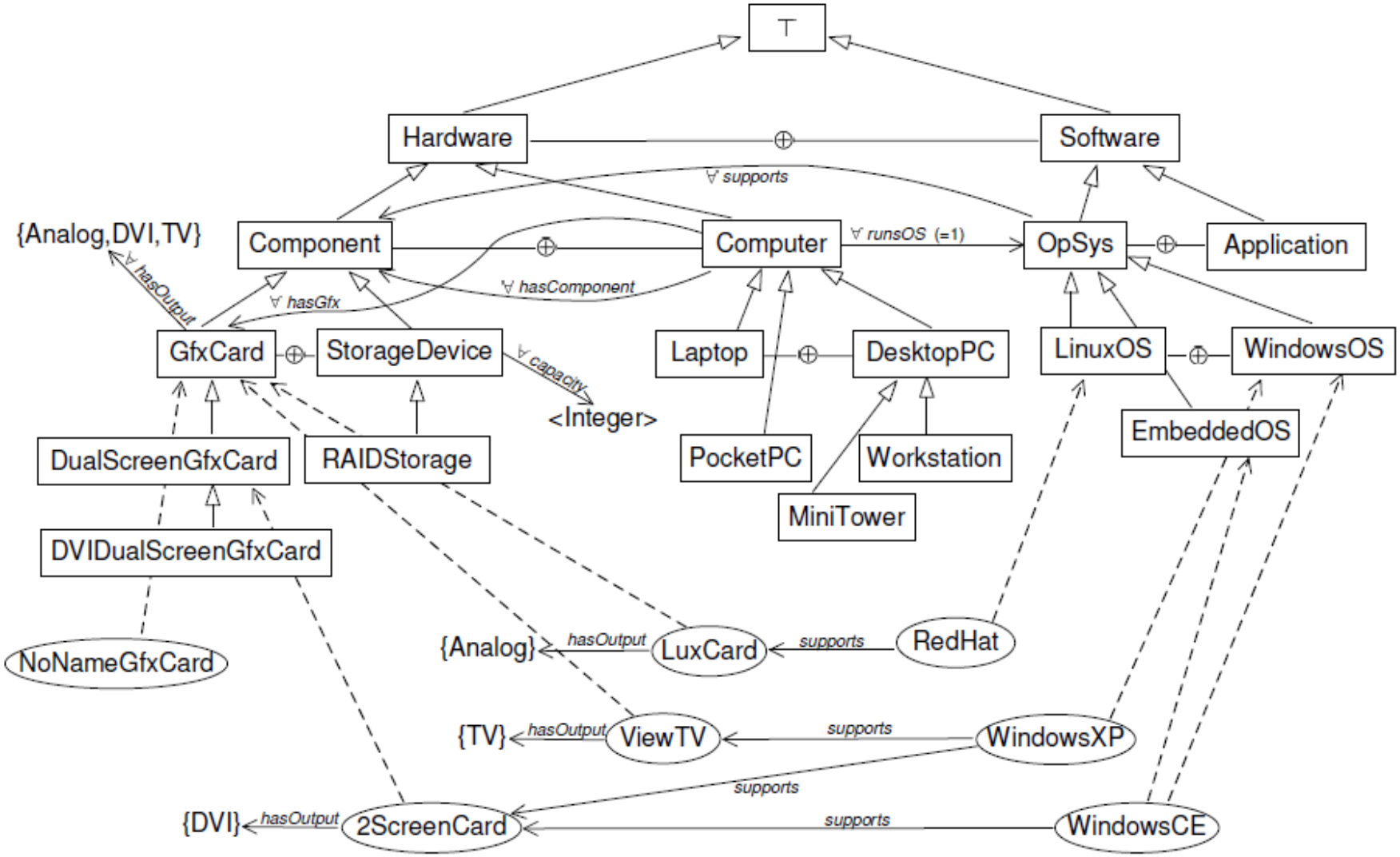
Resource description example

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

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



Background Knowledge (part)



Supply and Demand

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

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

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

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

- **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

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

$$D_2 = DesktopPC \sqcap \exists\, hasStorage\,.\,RAIDStorage \sqcap \exists\, runsOS\,.\,(\exists\, supports\,.\,DualScreenGfxCard \sqcap \exists\, supports\,.\,RAIDStorage)$$

- **In this case,**

$$S_A \sqcap D_2 = \emptyset$$

$$\neg\exists x\, (S_A(x) \wedge D_2(x))$$

(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? ⇒ just let me know, and we can talk about options.**

References

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[3] Stephan Grimm, Pascal Hitzler
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