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.

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 (agooleaday.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

“If 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

- **Person 1** and **Person 2** exchange symbols, "Duck".
- **Agent 1** and **Agent 2** also exchange symbols.
- **Ontology description** involves agreement on **Semantics**.
- **Logic Inside** is highlighted.
- **Specific Domain**, e.g., Animals.
Basic Idea of the Semantic Web

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

DL Rules
Krötzsch, Rudolph, Hitzler
ECAI 2008

Data e.g. on Websites

Logic Inside
Basic Idea of the Semantic Web

- DL Rules
  - Krötzsch, Rudolph, Hitzler
  - ECAI 2008

- E.g. “every publication has an author”

- Diagram showing relationships between entities:
  - Publication
  - Title
  - Author
  - Event

- Diagram illustrates semantic relationships and rules for identifying entities.
Basic Idea of the Semantic Web

Ontology
- represents Schema knowledge
- mediates implicit knowledge
- e.g. "every publication has an author"

DL Rules
Krötzsch, Rudolph, Hitzler
ECAI 2008

Data e.g. on Websites
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 often a *taxonomy*: classes of things, arranged in a hierarchy

Human

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

[every MaleHuman is a Human]
[every Son is a MaleHuman]
[every Father is a Son]
Ontologies

- Logically speaking ...

```
<table>
<thead>
<tr>
<th>Human</th>
</tr>
</thead>
<tbody>
<tr>
<td>MaleHuman</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>FemaleHuman</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

8x (MaleHuman(x) ! Human(x))
8x (Son(x) ! MaleHuman(x))
8x (Father(x) ! 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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**What would you like to know?**

Are Lobsters spiders?

- **No**

  Lobster
  Clawed lobstershola, comprising a family of large marine crustaceans
  [wikipedia](https://en.wikipedia.org/wiki/Lobster)

  Spider
  spider (the 8-legged invertebrate)
  [wikipedia](https://en.wikipedia.org/wiki/Spider)

**How do we know?**

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?

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?

See facts...

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 commonsense reasoning written by an Canadian researcher in 1980.

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

\[
\begin{align*}
\text{hasNationality}(\text{RaymondReiter,canadian}) & \quad [\text{Wikipedia}] \\
\text{hasTopic}(\text{paper3546, nonMonotonicLogic}) & \quad [\text{publisher}] \\
\text{hasAuthor}(\text{paper3546,RaymondReiter}) & \\
\text{hasYear}(\text{paper3546},1980) & \\
\text{hasCitations}(\text{paper3546},2011) & \quad [\text{microsoft acad. search}] \\
\text{subTopicOf}(\text{nonMonotonicLogic,commonsenseReasoning}) & \quad [\text{knowledge base}] \\
8x \ 8y \ 8z \ (\text{hasTopic}(x,y) \ \land \ \text{subTopicOf}(y,z) \ \lor \ \text{hasTopic}(x,z)) & \\
8x \ 8n \ (\text{hasCitations}(x,n) \ \lor \ \text{landmarkPaper}(x)) & \quad [\text{publication finder}]
\end{align*}
\]

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

\[
\text{landmarkPaper}(?x) \ \land \ \text{hasYear}(?x,1980) \ \land \\
\text{hasTopic}(?x,\text{commonsenseReasoning}) \ \land \\
\text{hasAuthor}(?x,?y) \ \land \\
\text{hasNationality}(?y,\text{canadian})
\]

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

\[ R = \text{Computer} \sqcap \exists \text{memory} \geq 512 \sqcap \forall \text{hasGfx} \sqcap \exists \text{output} \{ \text{DVI} \} \]

\[ 8 \times (\text{Computer}(x) \forall \exists n \ (\text{memory}(x,n) \forall n \geq 512) \forall y \ (\text{hasGfx}(x,y) \forall \exists \text{output}(y,\text{DVI})) \]
Supply and Demand

\[ S_A = \text{MiniTower} \sqcap \exists \text{hasGfx}.\text{DVIDualScreenGfxCard} \]
\[ D_1 = \text{Computer} \sqcap \exists \text{hasGfx}.\text{DualScreenGfxCard} \sqcap \forall \text{hasComponent} \cdot (\exists \text{supports}^{-}.\text{WindowsOS}) \]

8x \((S_A(x) \land (\text{MiniTower}(x) \land 9y (\text{hasGfx}(x,y) \land \text{DVIDualScreenGfxCard}(y))))\)

8x \((D_1(x) \land (\text{Computer}(x) \land 9y (\text{hasGfx}(x,y) \land \text{DualScreenGfxCard}(y)) \land 8z (\text{hasComponent}(x,z) \land 9w (\text{supports}(w,z) \land \text{WindowsOS}(z))))))\)

• Logical Consequence:

\[ S_A \cup D_1 \neq \]
\[ 9x (S_A(x) \land \text{D}_1(x)) \]

i.e., the supply meets the demand.
Supply and Demand

$S_A = MiniTower \sqcap \exists hasGfx \cdot DVIDualScreenGfxCard$

$D_2 = DesktopPC \sqcap \exists hasStorage \cdot RAIDStorage$

$\sqcap \exists runsOS.(\exists supports \cdot DualScreenGfxCard$

$\sqcap \exists supports \cdot RAIDStorage)$

- In this case,

$S_A \cup D_2 = ;$

$9x (S_A(x) \land D_2(x))$

(Complete example: Reference [3])
Semantic Web

• Large and active research area
• Recently considerable industrial impact

• Wright State University is one of the leading US players in this area.

• Interested in pursuing research? 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.
http://www.semantic-web-book.org

[2] Pascal Hitzler, Markus Krötzsch, Bijan Parsia, Peter F. Patel-Schneider, Sebastian Rudolph
OWL 2 Web Ontology Language: Primer.
W3C Recommendation, 27 October 2009.
http://www.w3.org/TR/owl2-primer/

Semantic Matchmaking of Web Resources with Local Closed-World Reasoning.