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Approximate Reasoning for the Semantic Web
Part V
Approximate Resolution for OWL

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Contents Part V

- **KAON2 – resolution-based reasoning with OWL**
- Approximate reasoning with Screech

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The KAON2 OWL Reasoner

- Completely new deduction algorithms.
- *Not* tableaux-based.
- Reasoning via reduction of OWL DL to (positive) disjunctive datalog.
- Goal: Efficient ABox reasoning.
- Current performance similar to state-of-the-art tableaux reasoners. Better for some tasks.
- Binaries available from http://kaon2.semanticweb.org
  - Implementation by **Boris Motik**.
  - Theory by B. Motik, U. Hustadt, U. Sattler, R. Studer.
- Treats all of OWL DL except nominals.

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KAON2: Basic Ideas

- ABox reasoning (instance retrieval) is more important for practice than TBox reasoning.
- Resolution ideal for ABox reasoning (Prolog).
- Similarly good: Deductive Database techniques

- $\rightarrow$ Resolution proofs for OWL DL?
  - Naive approach does not always terminate.
  - Reason: Transformation to FOL yields existential quantifiers which are Skolemised to function symbols.
  - Termination of algorithms not guaranteed in presence of function symbols.

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KAON2: How to deal with termination issue

- Finitely many usages of existential quantifiers suffice for sound and complete reasoning.
  – How many and which ones?
- First process TBox: Derive (all necessary) logical consequences using ordered resolution.
  – Finite Set!
  – Then generation of further individuals via function symbols no longer necessary!
- Existential quantifiers can then be removed!

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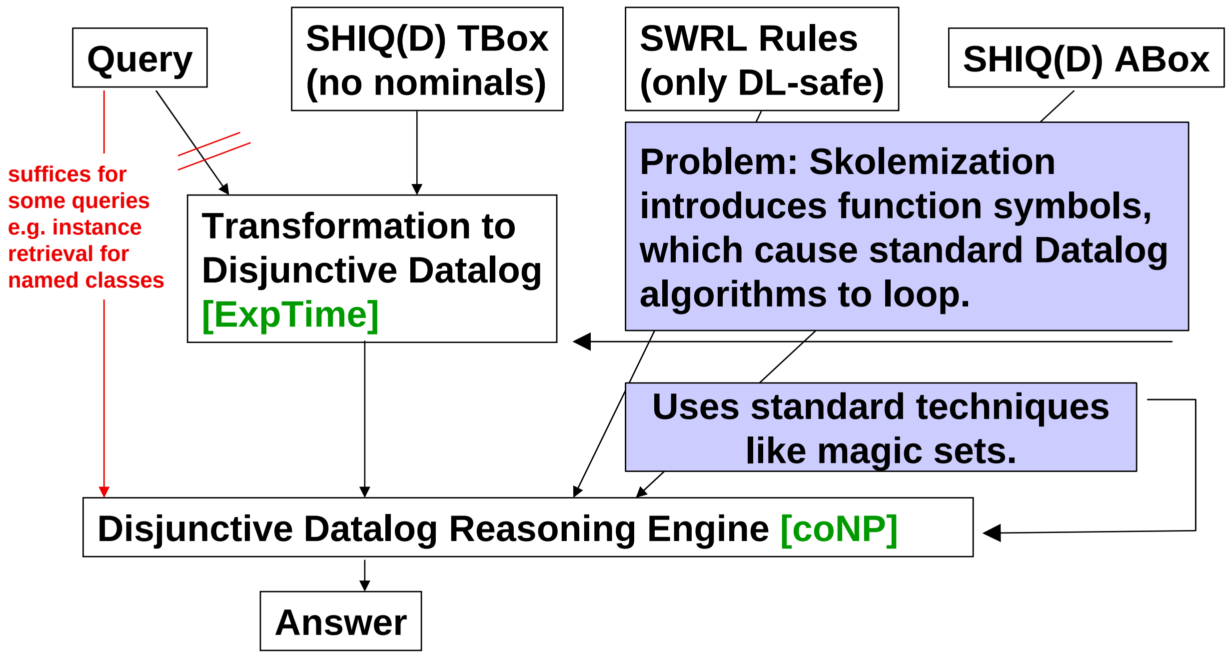
KAON2: Inference mechanism

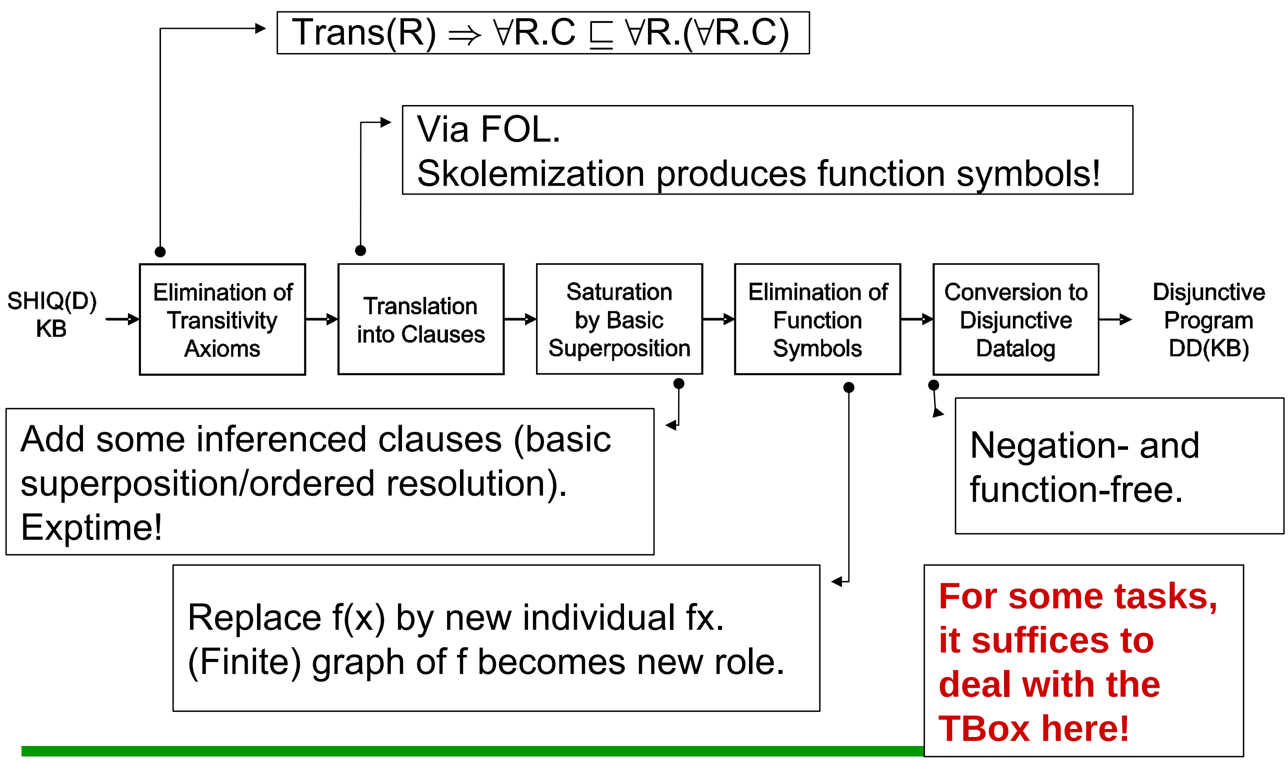
1. Translate TBox to function free clauses.
   (Exptime!)
2. Add ABox.
3. Employ standard reasoning methods for function-free clauses, e.g. magic sets.
   (NP-complete!)

- TBox needs to be processed only once!
- Algorithm is worst-case optimal!
- Data complexity is NP!

KAON2 Reasoner core architecture



KAON2 transformation algorithm



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Simple example for transformation (ALC only)

structural transformation & clausification

KB	FOL KB
Person ⊑ ∃ parent.Person	¬Person(x) ∨ parent(x,f(x))
	¬Person(x) ∨ Person(f(x))
∃ parent.(∃ parent.Person) ⊑ Grandchild	Grandchild(x) ∨ ¬parent(x,y) ∨ Q_1(y)
	¬Q_1(x) ∨ ¬parent(x,y) ∨ ¬Person(y)
Person(a)	Person(a)

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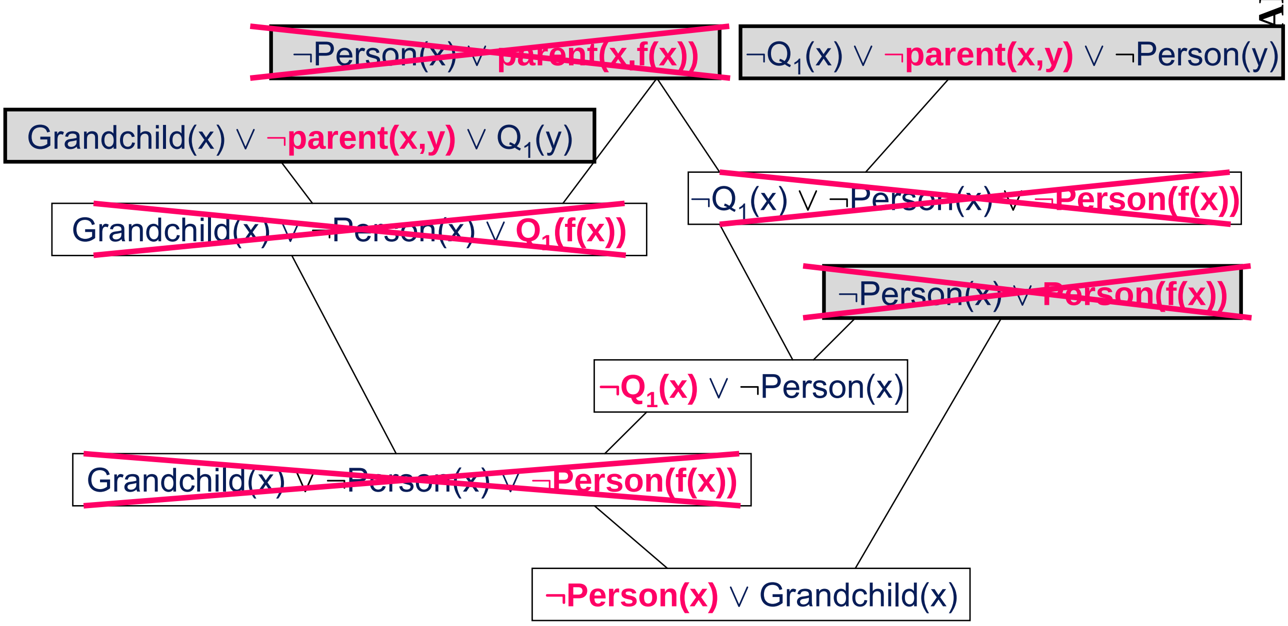
Saturation



Translate to Datalog

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Result: Disjunctive datalog program

KB
Person ⊑ ∃ parent.Person ∃ parent.(∃ parent.Person) ⊑ Grandchild Person(a)
DD(KB)
Q_1(x), Person(y) ← parent(x,y) ← parent(x,y), Q_1(y), Grandchild(x) ← Q_1(x), Person(x) Grandchild(x) ← Person(x) Person(a)

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A Theorem (Hustadt, Motik, Sattler 2004)

Let KB be an $\mathcal{ALCHIQ}$(D) knowledge base, defined over a concrete domain D, such that satisfiability of finite conjunctions over D can be decided in deterministic exponential time. Then, the following claims hold:

1. KB is unsatisfiable if and only if DD(KB) is unsatisfiable.
2. KB ⊨ α if and only if DD(KB) ⊨ α , where α is of the form A(a) or R(a, b), and A is an atomic concept.
3. KB ⊨ C(a) for a nonatomic concept C if and only if, for Q a new atomic concept, DD(KB ∪ {C ⊑ Q}) ⊨ Q(a).

Performance evaluation

- Different architectures difficult to compare.
  - caching mechanisms
  - preprocessing steps
  - etc.
- Generally, KAON2 seems to do better on ABox reasoning tasks, in particular if ABox is large and TBox is of medium size.
- Generally, KAON2 appears to be inferior on TBox reasoning tasks.

KAON2 additional features

- Additional features
  - an API for programmatic management of OWL-DL and SWRL and F-Logic ontologies,
  - a stand-alone server providing access to ontologies in a distributed manner,
  - an inference engine for answering queries (including support for SPARQL),
  - a DIG interface, allowing access from tools such as Protégé
  - efficient access to instances via relational databases
- Download: http://kaon2.semanticweb.org/

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Part V Contents

- KAON2 – resolution-based reasoning with OWL
- **Approximate reasoning with Screech**

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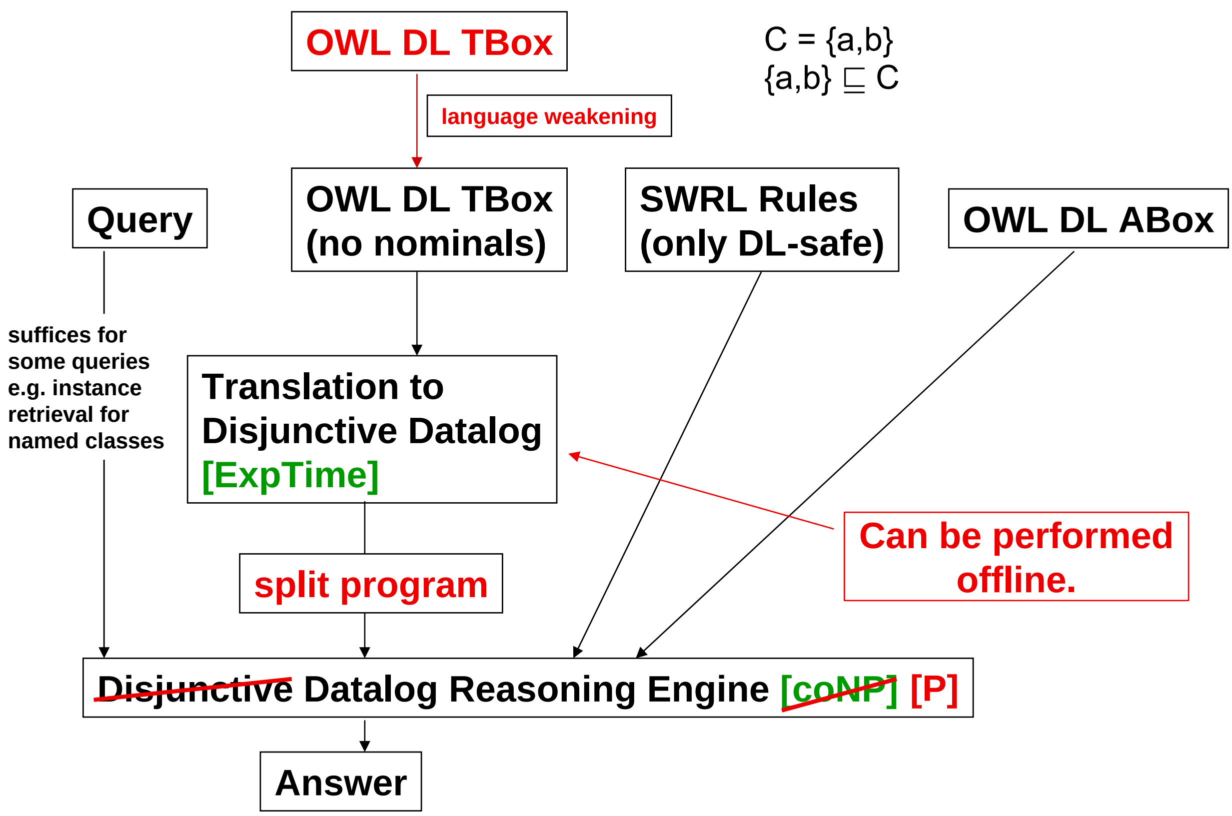
Problem Description

- Reasoning with OWL DL is hard. (Expressivity vs. scalability)
- For certain Semantic Web applications quick responses are more important than absolute accuracy of answering.
  e.g. SmartWeb scenario.
  - Answering of human queries in an open domain.
- We **trade soundess for time**, using **approximate reasoning**.

Approximate Reasoning

- do not confuse with *fuzzy* or *probabilistic* reasoning!
- speed up obtained by
  - modifying the underlying inference relation
  - in a semantically controlled and well-understood way.
- e.g. by decreasing the complexity class of a reasoning task
- e.g. by utilizing intimate knowledge of the bottlenecks in a reasoning algorithm.

Approximate reasoning with Screech for large ABoxes



Screech simple example

serbian $\sqcup$ croatian $\sqsubseteq$ european
eucitizen $\sqsubseteq$ european
german $\sqcup$ french $\sqcup$ beneluxian $\sqsubseteq$ eucitizen
beneluxian $\equiv$ luxembourgian $\sqcup$ dutch $\sqcup$ belgian

serbian(ljiljana).	serbian(nenad).	german(pascal).
french(julien).	croatian(boris).	german(markus).
german(stephan).	croatian(denny).	indian(sudhir).
belgian(saartje).	german(rudi).	german(york).

Screech simple example

beneluxian $\equiv$ luxembourgian $\sqcup$ dutch $\sqcup$ belgian
translates into the following four clauses:
~~luxembourgian(x) $\vee$ dutch(x) $\vee$ belgian(x) $\leftarrow$ beneluxian(x)~~
beneluxian(x) $\leftarrow$ luxemburgian(x)
beneluxian(x) $\leftarrow$ dutch(x)
beneluxian(x) $\leftarrow$ belgian(x)

split of first clause:
luxembourgian(x) $\leftarrow$ beneluxian(x)
dutch(x) $\leftarrow$ beneluxian(x)
belgian(x) $\leftarrow$ beneluxian(x)

$\vdash$ **luxembourgian(saartje)**
$\vdash$ **dutch(saartje)**
$\vdash$ **belgian(saartje)**

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Screech reasoning

- data complexity is **P**
- complete
- but unsound

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Screech Performance (not optimized yet)

Galen ontology
673 axioms, 175 classes
randomly populated with 500 individuals

267 disjunctions in 133 rules eliminated

Complete run:
- queried for the extensions of all 175 Galen classes
- resulting in 5809 classifications (Screech)
  - 5353 (i.e. **92.2%**) **correct**
- For 138 out of 175 classes: computed extension correct
- Average **time saved: 39.0%**

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Screech Performance example run

Time (DD)	Time (SPLIT)	Instances	Class Name
11036 ms	6489 ms	154/154	Biological_object
11026 ms	5959 ms	9/9	Specified_set
11006 ms	6219 ms	9/13	Multiple
11015 ms	5898 ms	16/16	Probe_structural_part_of_heart
11036 ms	7711 ms	4/4	Human_red_blood_cell_mature
11055 ms	5949 ms	24/58	Biological_object_that...

Table 2. Performance comparison for instance retrieval using disjunctive datalog (DD) vs. the corresponding split program (SPLIT), on the KAON2 datalog engine. *Instances* indicates the number of instances retrieved using DD versus SPLIT, e.g. class *Multiple* contained 9 individuals, while the split program allowed to retrieve 13 (i.e. the 9 correct individuals plus 4 incorrect ones). The full name of the class in the last row is Biological_object_that_has_left_right_symmetry.

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Screech conclusions

- Screech reasoner based on KAON2
- complete but unsound
- 40% speed-up with only 8% wrong answers

- future work
  - optimise further
  - tackle other parts of the KAON2 algorithms
  - combine with other approximate reasoning and optimization techniques

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One idea for improving Screech

- Use statistical knowledge about distribution of individuals among classes.
- E.g. there are few luxemburgians compared to dutch and belgians.

luxembourgian(x) $\vee$ dutch(x) $\vee$ belgian(x) $\leftarrow$ beneluxian(x)

split :

dutch(x) $\leftarrow$ beneluxian(x)

belgian(x) $\leftarrow$ beneluxian(x)

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Wrap-up: what we did

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Wrap-up: What we did

- Introduction Semantic Web
- OWL/Description Logics
  - Semantics
  - Tableau reasoning
  - Resolution-based reasoning
- General approximate reasoning
  - Cadoli-Schaerf
  - BCP, abstraction, knowledge compilation, Top-k,...
- Tableaux-based approximate reasoning for OWL
  - Cadoli-Schaerf
  - Approximate query answering
- Resolution-based approximate reasoning
  - Screech

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Wrap-up: Why you should do approximate reasoning

- We need expressive reasoning for the semantic web.
- Sound and complete algorithms are too slow.

- Hence: We need approximate reasoning!

- Lots of literature on approximate reasoning exists and has not yet been applied to the semantic web!

⇒ Go do it!

Discussion

- We think that approximate reasoning will help to make semantic web a reality.

- Objections?
- Questions?
- Remarks?

End of course

- Thanks for your interest.
- Feedback is most welcome!

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Additional semantic web applications

- **SmartWeb**
  See http://www.smartweb-project.org
- Semantic Mediawiki

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SmartWeb

- Film from
  http://smartweb.dfki.de/main_inf_de.pl?Bilder/index.html

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Additional semantic web applications

- SmartWeb
- **Semantic Mediawiki**
  See http://wiki.ontoworld.org/

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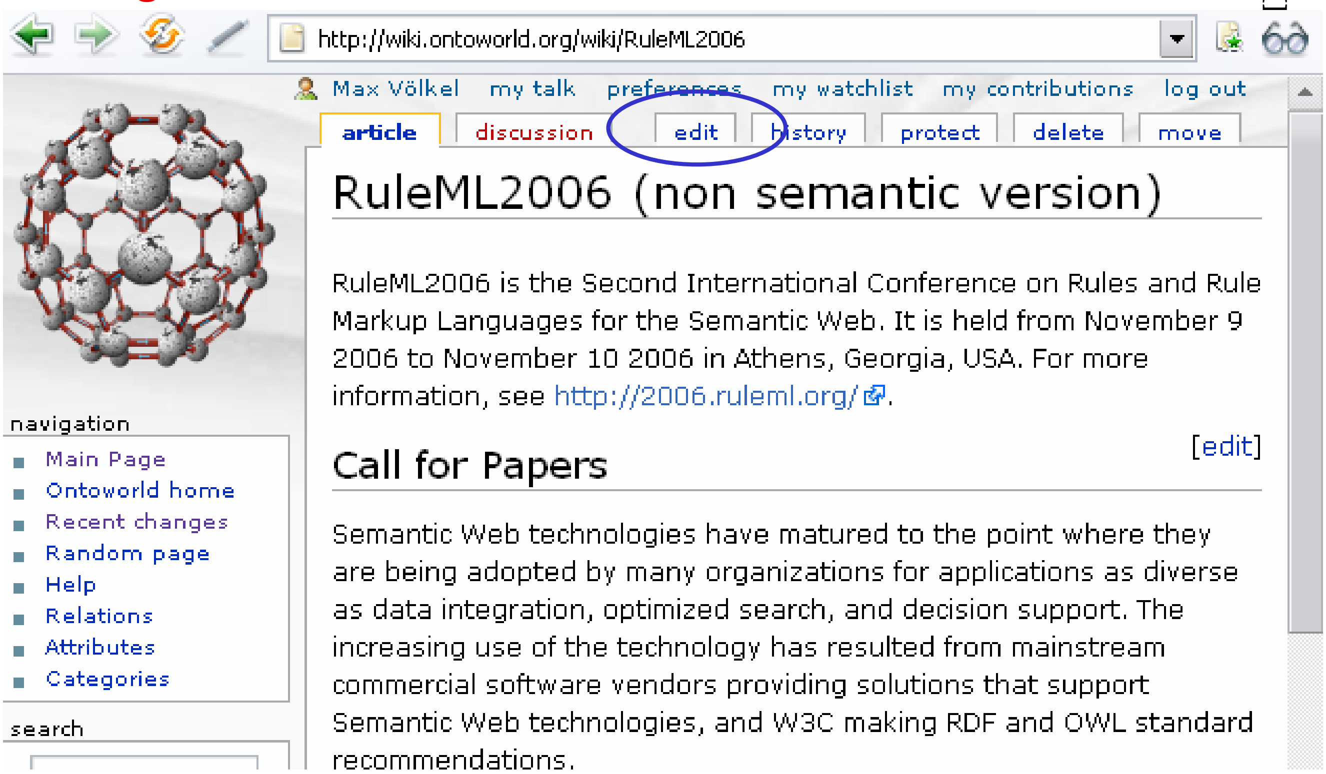
Semantic Mediawiki

- Enhancement of Mediawiki (used in Wikipedia)

- Simple knowledge representation techniques
- Added value for user

- In particular:
  - enhancement of querying
  - better data reuse

We go to the article on the RuleML2006 conference …



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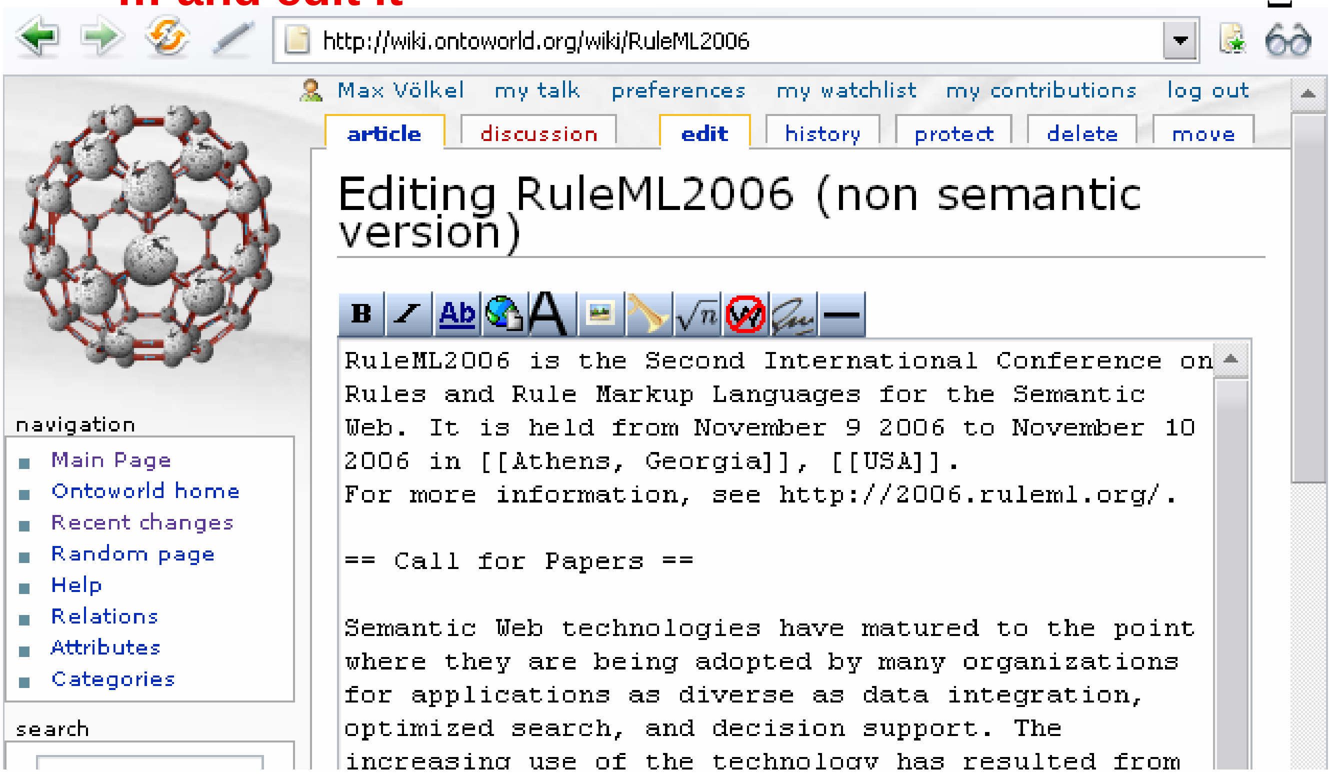
… and edit it



article | discussion | edit | history | protect | delete | move

RuleML2006 is the Second International Conference on Rules and Rule Markup Languages for the Semantic Web. It is held from November 9 2006 to November 10 2006 in [[Athens, Georgia]], [[USA]].
For more information, see http://2006.ruleml.org/.

There is already an ordinariy link to the article of „Athens, Georgia“

article | discussion | edit | history | protect | delete | move

RuleML2006 is the Second International Conference on Rules and Rule Markup Languages for the Semantic Web. It is held from November 9 2006 to November 10 2006 in [[located in::Athens, Georgia]], [[USA]].
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Just say what the relation between this page (RuleML2006) and „Athens, Georgia“ is.

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From links …

… in [[Athens, Georgia]], [[USA]]. …

… to typed links

… in [[located in::Athens, Georgia]], [[USA]]. …

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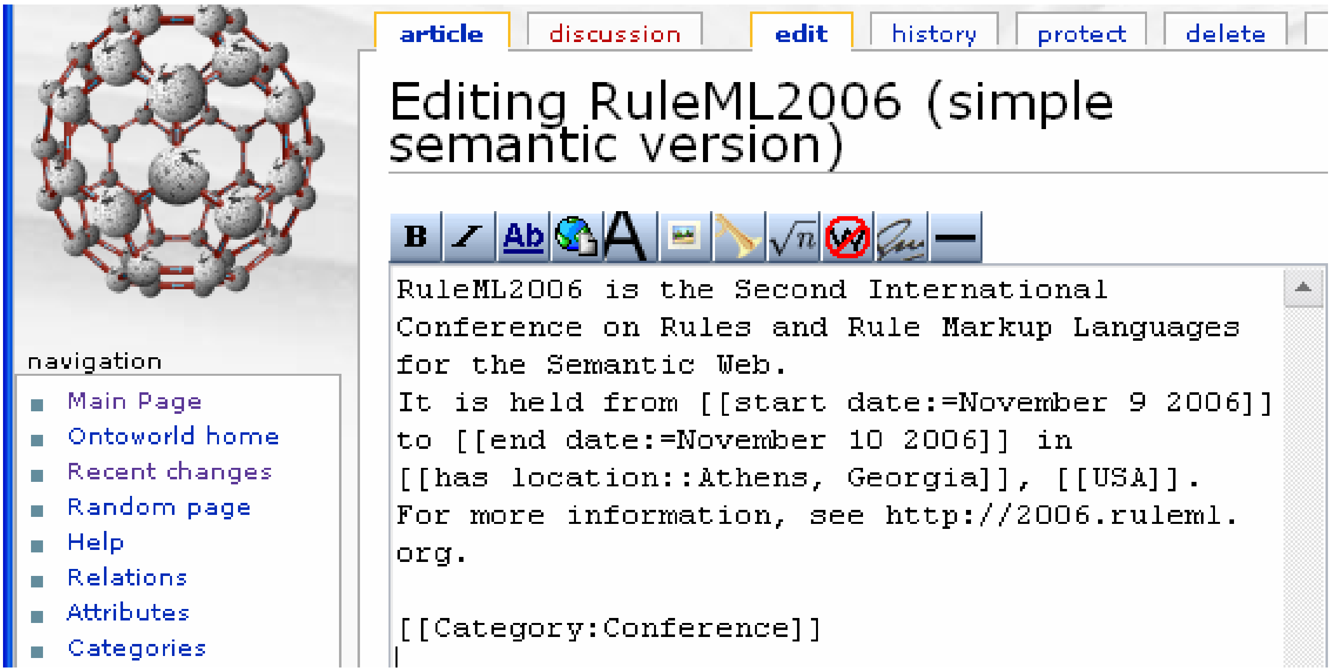
From values …

… It is held from November 9 2006 to November 10 2006 in…

… to attributes

… It is held from [[start date:=November 9 2006]] to [[end date:=November 10 2006]] in…

Save.



It looks exactly the same as before

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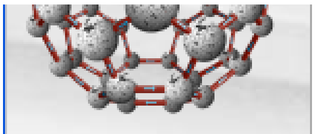
What the humans see, when they scroll down



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navigation
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- Attributes
- Categories

search

Go Search

toolbox
- What links here
- Related changes
- Special pages
- Printable version
- Permanent link

for demonstration purposes, we have
- RuleML2006 (non semantic verison)
- **RuleML2006 (simple semantic version)**

Relations to other articles — Click + to find similar articles.

RuleML2006 (simple semantic version) Has location Athens, Georgia +

Attributes of RuleML2006 (simple semantic version) — Click + to find similar articles.

Start date: 2006-11-09 +
End date: 2006-11-10 +

Editing help on relations and attributes View as RDF

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Editing help on relations and attributes View as RDF

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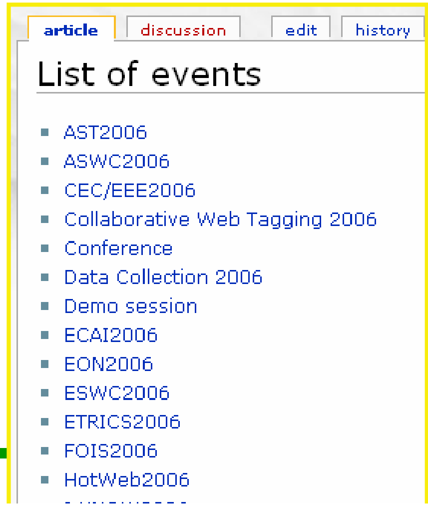
Benefits for Wikipedians: <ask> for your data

- Inline queries allow for questions like ...
  - ... movies from the 70s starring Sean Connery
  - ... list of events (all conferences and workshops)

```
<ask format="ul" link="all">
     [[Category:Event]]
</ask>
```



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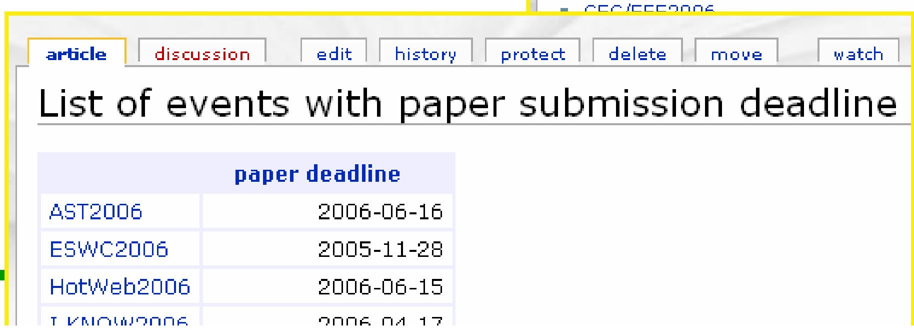
Benefits for Wikipedians: <ask> for your data

- Inline queries allow for questions like ...
  - ... movies from the 70s starring Sean Connery
  - ... list of events with their deadline

```
<ask format="ul" link="all">
     [[Category:Event]]
     [[paper deadline:=*]]
</ask>
```



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Benefits for Wikipedians: <ask> for your data

```
<ask format="ul" link="all">
  [[Category:Event]]
  [[paper deadline:=>June 1 2006]]
  [[paper deadline:=<December 31 2006]]
  [[title:=*]]
  [[paper deadline:=*]]
  [[Category:Topic Semantic Web query
languages]]
</ask>
```

	title	paper deadline
RuleML2006	Second International Conference on Rules and Rule Markup Languages for the Semantic Web	2006-06-05

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Applications

- Automatic tables and lists
  - E.g. Countries sorted by area, population, alphabet, ...
- **Maintenance** with hand crafted checks
  - Does every country have one capital?
- Integration in applications
  - ```
    latte = wikipedia.get("Latte Macchiatto");
    print latte["contains"]
    ```
- Visualization and browsing
- ... And many unexpected ones
    ```

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Who is using Semantic MediaWiki?

- Wikicompany ~ 9.000 pages, 227 user accounts
- The Bible Wiki ~ 40.000 pages, 156 user accounts
- WWW2006 Social Wiki ~ 40 pages, 34 user accounts
- Semantic eGovernment Community Portal, ~ 30 pages
- ScubaWiki, ~ 170 pages, 33 user accounts
- NeOn Wiki ~10 pages
- this wiki = Wiki.Ontoworld.org ~400 pages, 158 user accounts
- SourceryForge ~1864 pages, 272 user accounts

Demo and more information at
http://wiki.ontoworld.org/

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Semantic Mediawiki

- Lightweight use of metadata (no *semantics* in the stronger sense)
- *Already* added value for the user!

- Simple: Introduce background knowledge by means of *ontologies*.
  - Beware of scalability problems!
  - ... and others ...