The Next Industrial Revolution - The Semantic Web

Dr. Uwe Aßmann
Research Center for Integrational Software Engineering
Keynote at Lund University, 2001

Linköpings Universitet

Contents

- The Semantic Web - and why it qualifies for the next an industrial revolution
- The underlying technology
- The influence on the industrial markets
- The Swedish Semantic Web Initiative

Has the First Web Been an Industrial Revolution?

What Makes Up an Industrial Revolution?

- New Technology
  - Simple enough
  - General enough
  - Piecemeal growth
  - Well, but that's not enough!!
- Standards
  - The Euro
  - Written language standards (cf Duden)
  - Ford's assembly line
  - ASCII code
  - The linear file of bytes (UNIX)

RISE
WEB

The First Generation Web - An Industrial Revolution

- 1990 HTML
  - *electronic paper*
  - Technology: hypertext, SGML-like markup
  - Standard: yes, de facto by the W3C
  - But: not generic
- 1998 XML, the uniform document format
  - *electronic forms*
  - Technology: hyperlinks, SGML grammar-like approach
  - Standard: yes, de facto by the W3C
  - But: context free language

RISE
WEB

However...
The Chomsky Hierarchy

		Natural Language?
Chomsky-0	Generatable languages	Computable Problems
Chomsky-1	Context sensitive languages	..where context matters constraint descriptions context conditions
Chomsky-2	Context free languages	..where context does not matter only structure, no context only trees, no nets, no relations
Chomsky-3	Regular languages	only lists, no trees

RISE

WEB

Example: The MOST Standard

- A large German car manufacturer and his suppliers develop a new standard for car data: MOST
- Parts, parts, piece lists,...
- The megabytes of specifications are inconsistent
- What to do?

- Answer: use XML
  - Write a XML schema for MOST
  - Context free language CH-2
  - XML context free structure, typing, parsing help a lot

RISE

WEB

However... How to Express Context Constraints?

- The right back wheel must has the same type as the left
- The right front wheel must have the same type as the left
- However, the front and back wheels may be different

?

The Second Generation Web - The Next Industrial Revolution

- 2001 The Semantic Web
  - *Intelligent paper*
  - Technology: descriptions of static document semantic
    - context-sensitive languages CH-1
  - Standards: RDF, RDFS, **DAML&OIL**, DAML-L
    - Upward compatible to XML
    - Applicable to all XML documents
    - Piecemeal growth

RISE

WEB

The Second Generation Web - The Next Industrial Revolution

- For the first time: an executable standard on CH-1, context sensitive languages!
- Uniform treatment of all kinds of documents
  - Consistency checking: constraint checking of contextsensitive constraints
  - Searching: for content, not only for surface
  - Match making (comparisons)
    - using content, not only structure
  - Measuring quality
- All tasks will be done uniformly by DAML&OIL evaluators, built into standard browsers

RISE

WEB

The Difference of Static Semantics

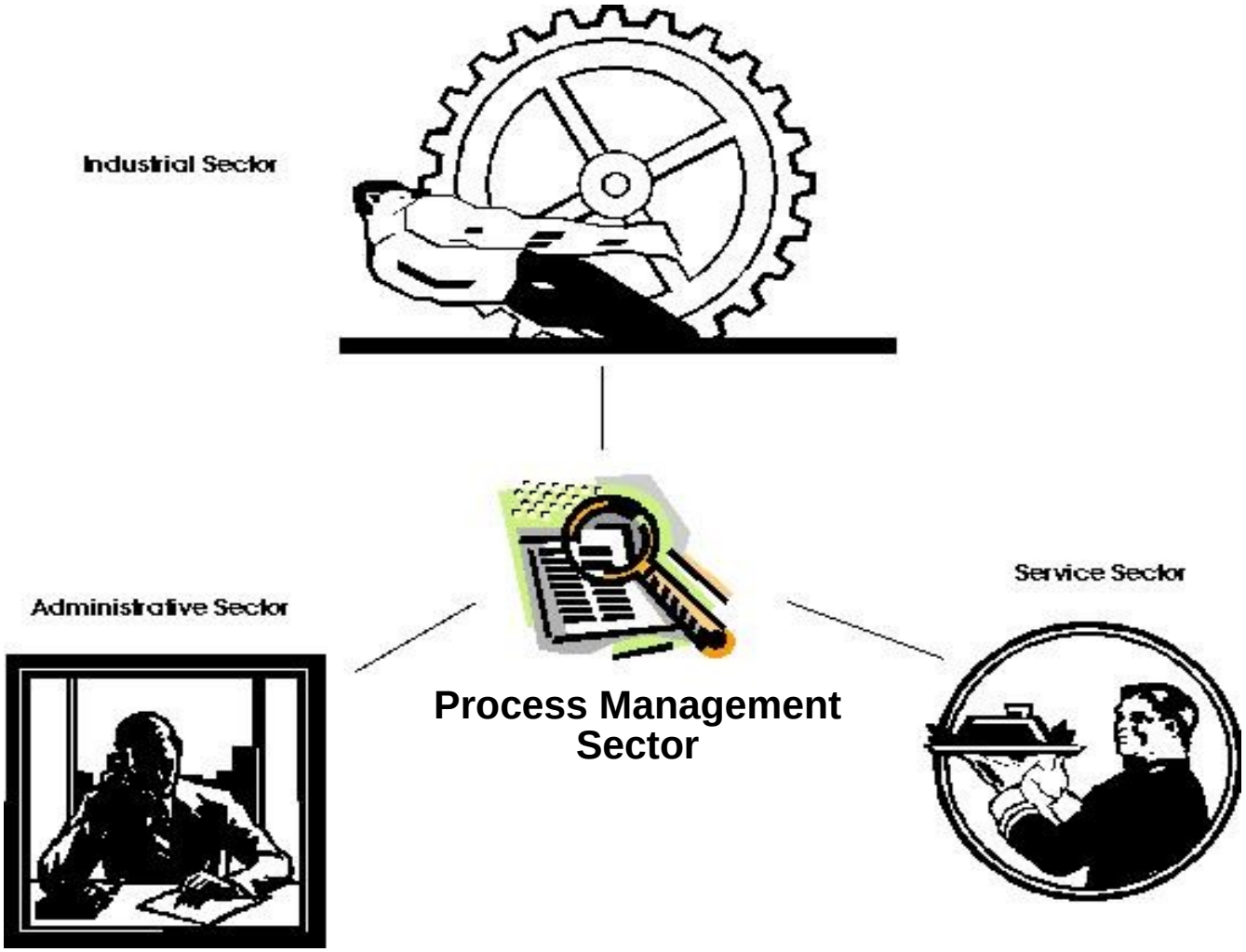
The Semantic Web is The Next Industrial Revolution

- All industrial sectors with administrative tasks will be automized
- Automatic process management
- Workflows of all kinds of documents for all kinds of businesses
  - Tax documents, Migration documents, ...
  - E-commerce: Searching, Comparing prices, Ordering, Billing, Web Services...
  - Customer Relationship Management
  - Dynamic Supply Chain Management
- Production Data, Workflow data

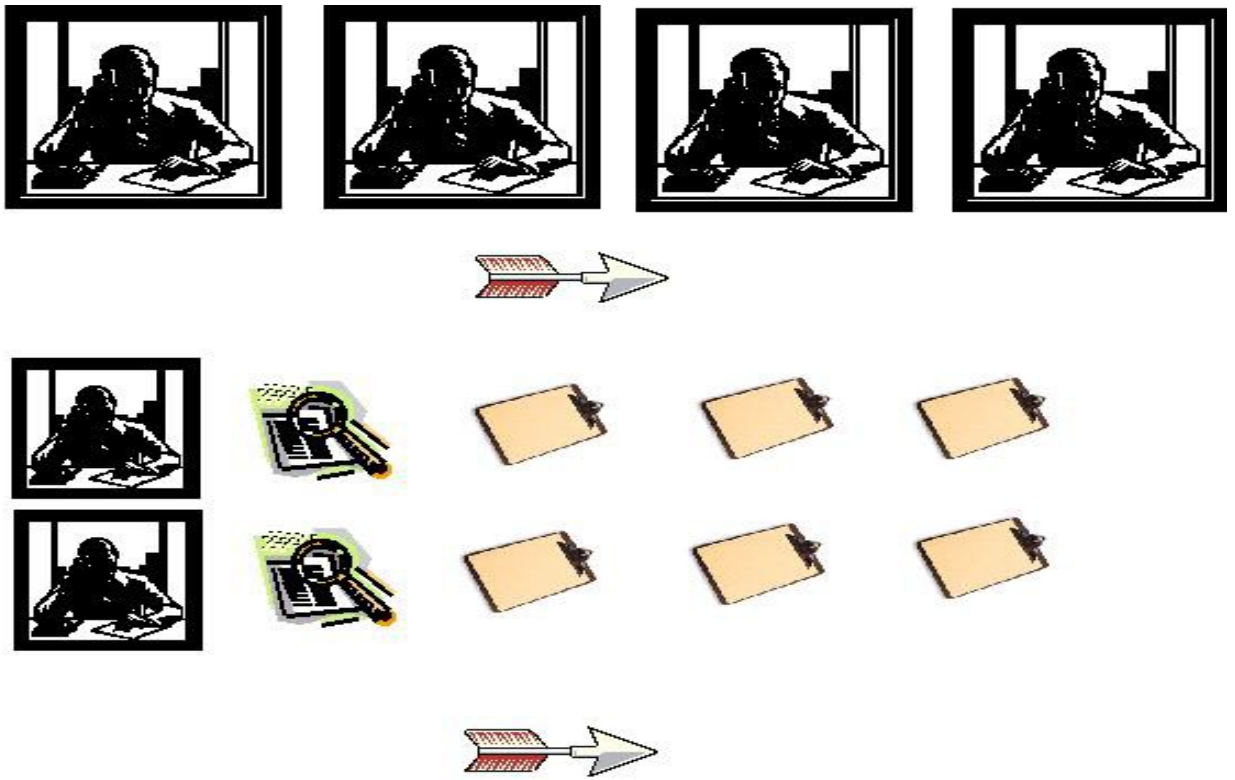
RISE

WEB

The Process Management Market



Tax Declarations of the Future



It's Not the Technology,

It's the Standard

The Technology

Exponential Growth: The Semantic Web

- 1995-2000: James Hendler (Michigan U.) develops SHOE
  - Ontologies (i.e., static semantic descriptions) for HTML
- August 2000: DARPA DAML program
  - $70 Mio are put to one language for ontologies (Darpa Agent Markup Language) for ontologies
  - J. Hendler chairs
- Winter 2001: OIL, the European competitor, is merged with DAML (DAML+OIL)
  - OIL is the leading European technology for ontologies
  - European projects Ontoknowledge, IBROW (Fensel)

RISE

WEB

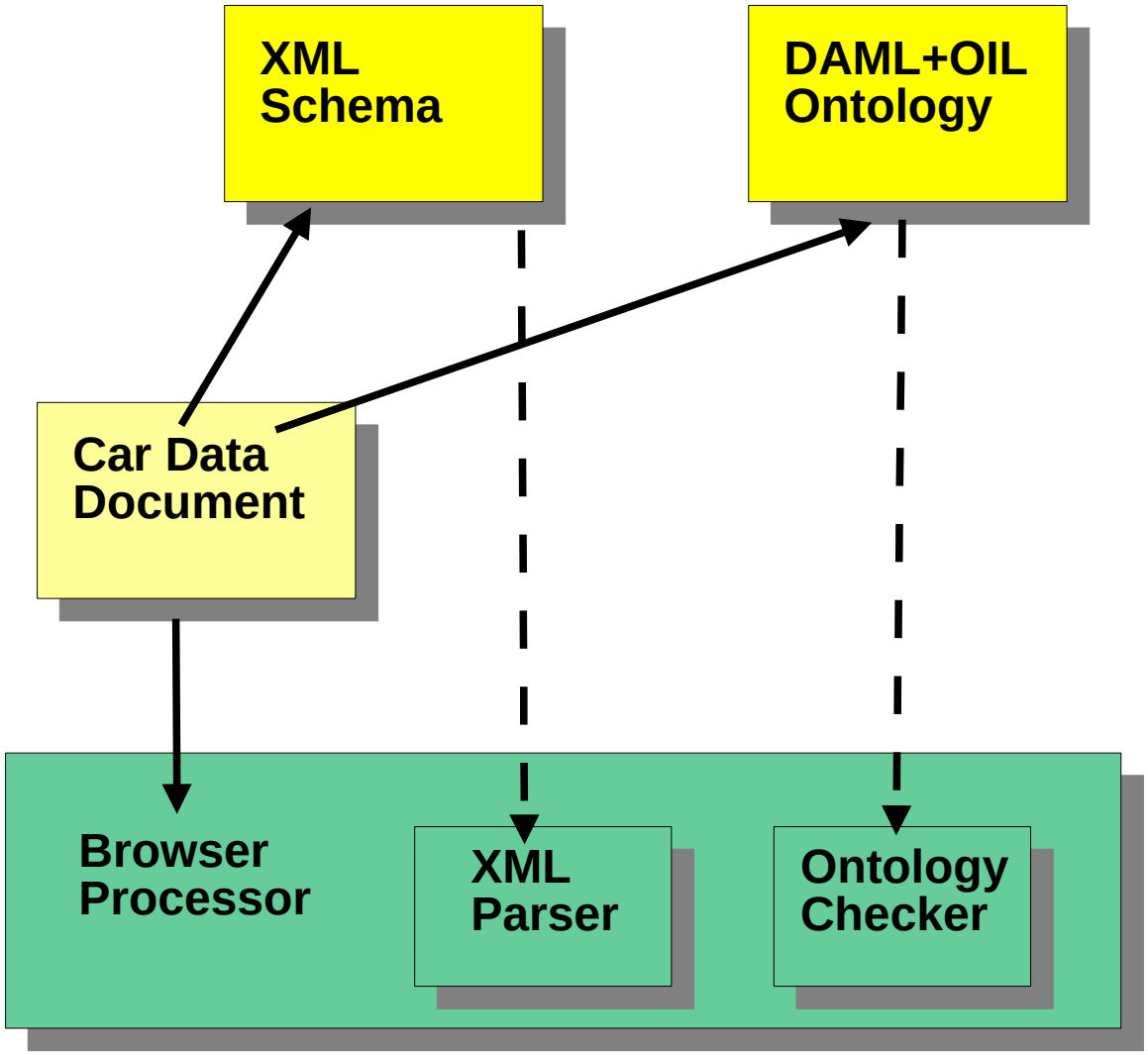
Exponential Growth: The Semantic Web

- February 2001:
  - T. Berners-Lee announces the Semantic Web initiative of the Web consortium
- May 2001: Berners-Lee, Lassila, Hendler announce the Semantic Web in Scientific American
- June 2001: The CEC opens a call for the Semantic Web, closed on Oct 17
- Aug 2001: W3C Semantic Web activity founded
- End of 2001: W3C Standardization Group starts

RISE

WEB

How It Works


XML
Schema
DAML+OIL
Ontology
Car Data
Document
Browser
Processor
XML
Parser
Ontology
Checker

What is the Idea?

- Programming Language Person:
  - Normalize a compiler with XML
  - Extend its application to all kind of documents
- AI Guy:
  - Standardize a language for knowledge representation in the tradition of Semantic Nets, KL-ONE, Description Logic
  - Use XML syntax and apply it to XML
- Logic Programmer:
  - Strip off Prolog, type it
  - And use XML syntax

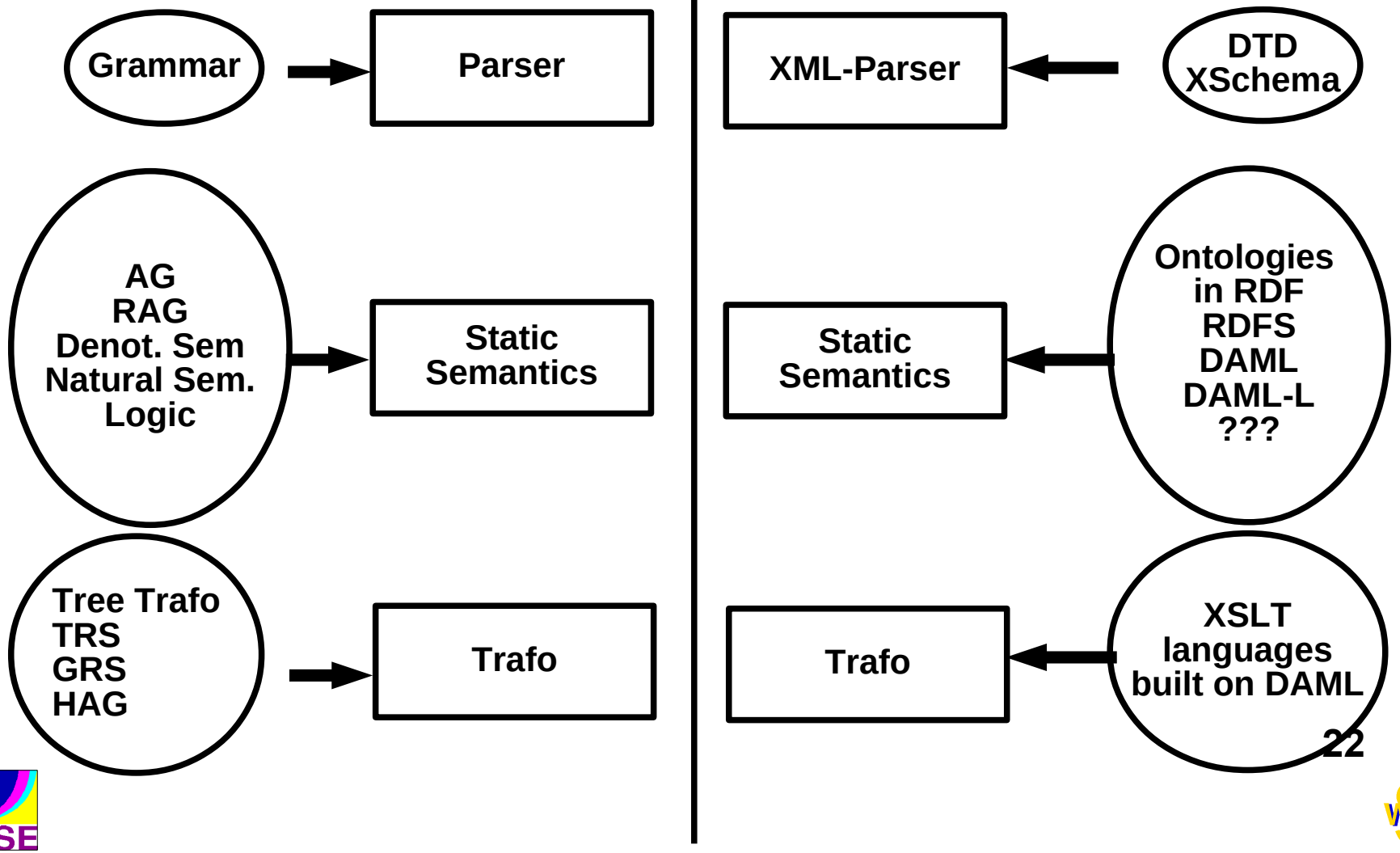
RISE

WEB

What is the Idea?

- Linguist:
  - Standardize a language for ontologies
- Document mark-up guy:
  - Distort SGML
- Database person:
  - Strip Datalog and allow classes and inheritance
- UML freak:
  - Enrich UML with inheritance on relations
- Mechanical engineer:
  - Put STEP/Express into XML syntax

What is the Idea?



Ontologies...

- An *ontology* is a specification of a representational vocabulary for a shared domain of discourse [T. Gruber]
- An *ontology* is an explicit specification of a conceptualization
  - A body of formally represented knowledge is based on a *conceptualization*
- An *ontology* is a glossary with constraints
- An *ontology* is a description of static semantics in logic (DAML+OIL: description logic)
- An *ontology* is a UML structure diagram with inheritance on relations

RISE
WEB

The Layer of Semantic Languages

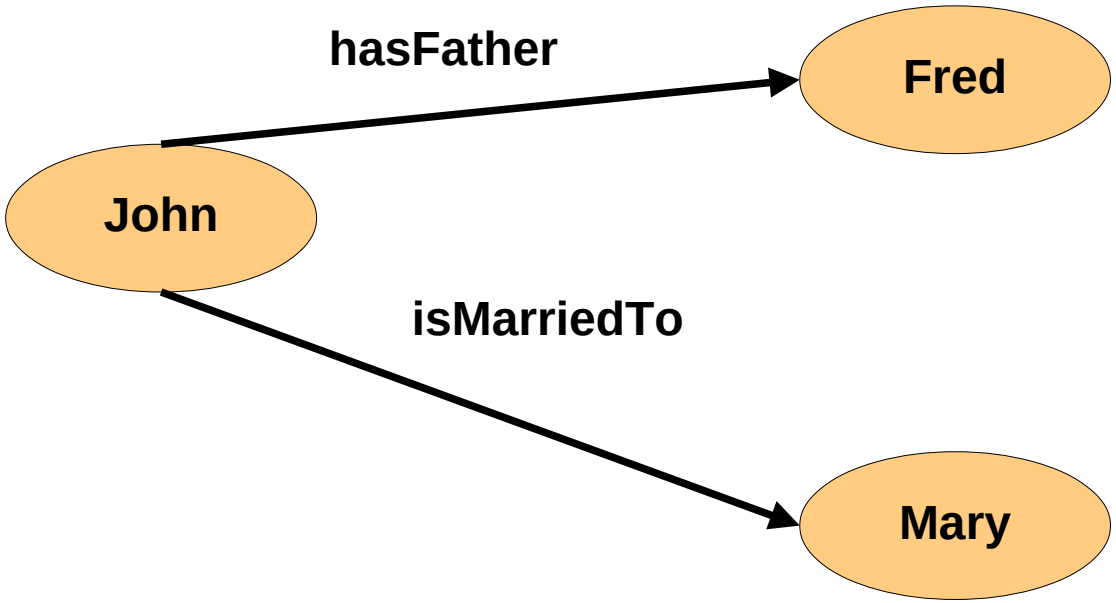
DAML-L RuleML	More powerful rules
DAML-S	Language for Web Services
DAML+OIL	Cardinality constraints Inheritance on relations (simple inference)
RDFS	Classes and inheritance on nodes and relations
RDF	Graphs (nodes, relations) Binary data model

RISE
WEB

Resource Description Format (RDF)

- A "minimalistic" data format
- Triples over URIs
  - Subject, predicate, object
  - Object, property, value
  - Object, relations, object
- Binary databases, untyped graphs of URI
- Already realized in several databases
  - Conceptbase
  - Graph Databases
  - Sesame (OntoKnowledge)

Resource Description Format (RDF)

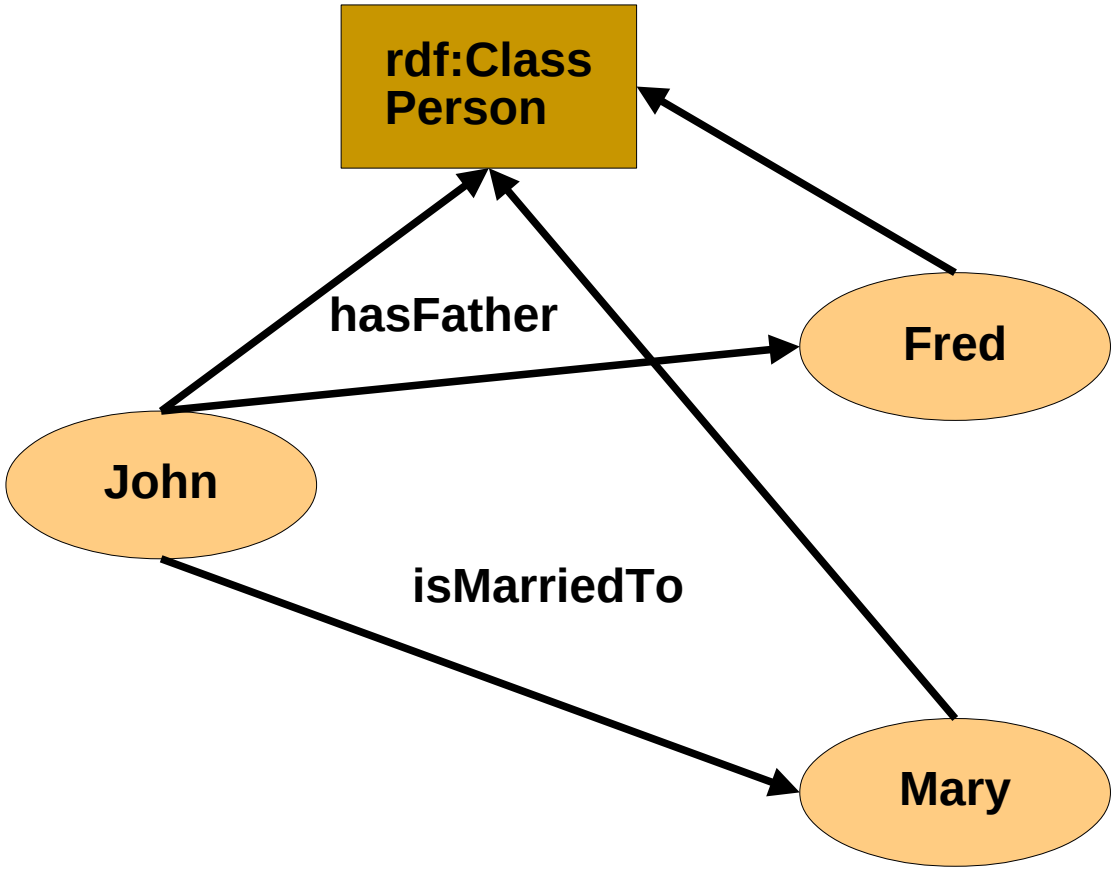


RDF Schema (RDFS)

- Adds
  - Classes (RDF resources get a type)
  - Inheritance between classes
  - RDF properties (relations) get a type, i.e., a domain and range class
- Instances are *typed graphs*
- Corresponds to ER diagrams plus inheritance on classes (simple UML structure diagrams)

RISE
WEB

RDF Schema (RDFS)



RDF Schema (RDFS)

```
<rdf:RDF xml:lang="en"
   xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
   xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#">

 <rdfs:Class rdf:ID="Person">   <rdfs:comment>The class of people.</rdfs:comment>
  <rdfs:subClassOf rdf:resource="
  http://www.w3.org/2000/03/example/classes#Animal"/>
 </rdfs:Class>

 <rdf:Property ID="maritalStatus">
  <rdfs:range rdf:resource="#MaritalStatus"/>
  <rdfs:domain rdf:resource="#Person"/>
 </rdf:Property>

 <rdf:Property ID="ssn">   <rdfs:comment>Social Security Number</rdfs:comment>
  <rdfs:range rdf:resource="http://www.w3.org/2000/03/example/classes#Integer"/>
  <rdfs:domain rdf:resource="#Person"/>
 </rdf:Property>

 <rdfs:Class rdf:ID="MaritalStatus"/>
 <MaritalStatus rdf:ID="Married"/>
 <MaritalStatus rdf:ID="Divorced"/>
 <MaritalStatus rdf:ID="Single"/>
 <MaritalStatus rdf:ID="Widowed"/>
 </rdf:RDF>
```

NameSpaces

Classes

Relations

[From: RDFS specification, W3C]

DAML+OIL

- Adds
  - Inheritance on relations
  - Cardinality constraints on domains and ranges of relations (similar to UML)
  - Disjointness specifications for classes and relations
  - Transitive relations
- Formally based on decidable description logic
- In contrast to UML, DAML+OIL can be evaluated by checker tools
- DAML+OIL ontologies can easily be made consistent

DAML+OIL vs Prolog

- <class> Person </class>
- <relation> subPropertyOf S </relation>
- AND, OR on relations
- Cardinality constraints
- Value types are reused from XML Schema

- person(X).
- s(X,Y) :- r(X,Y).
- s(X,Y) :- r(X,Z), t(Z,Y).
- Komma Operator
- Arithmetic
- No typing

DAML-L:

- <rule>
  <if> … <then> <end>
  </rule>
- Terms?

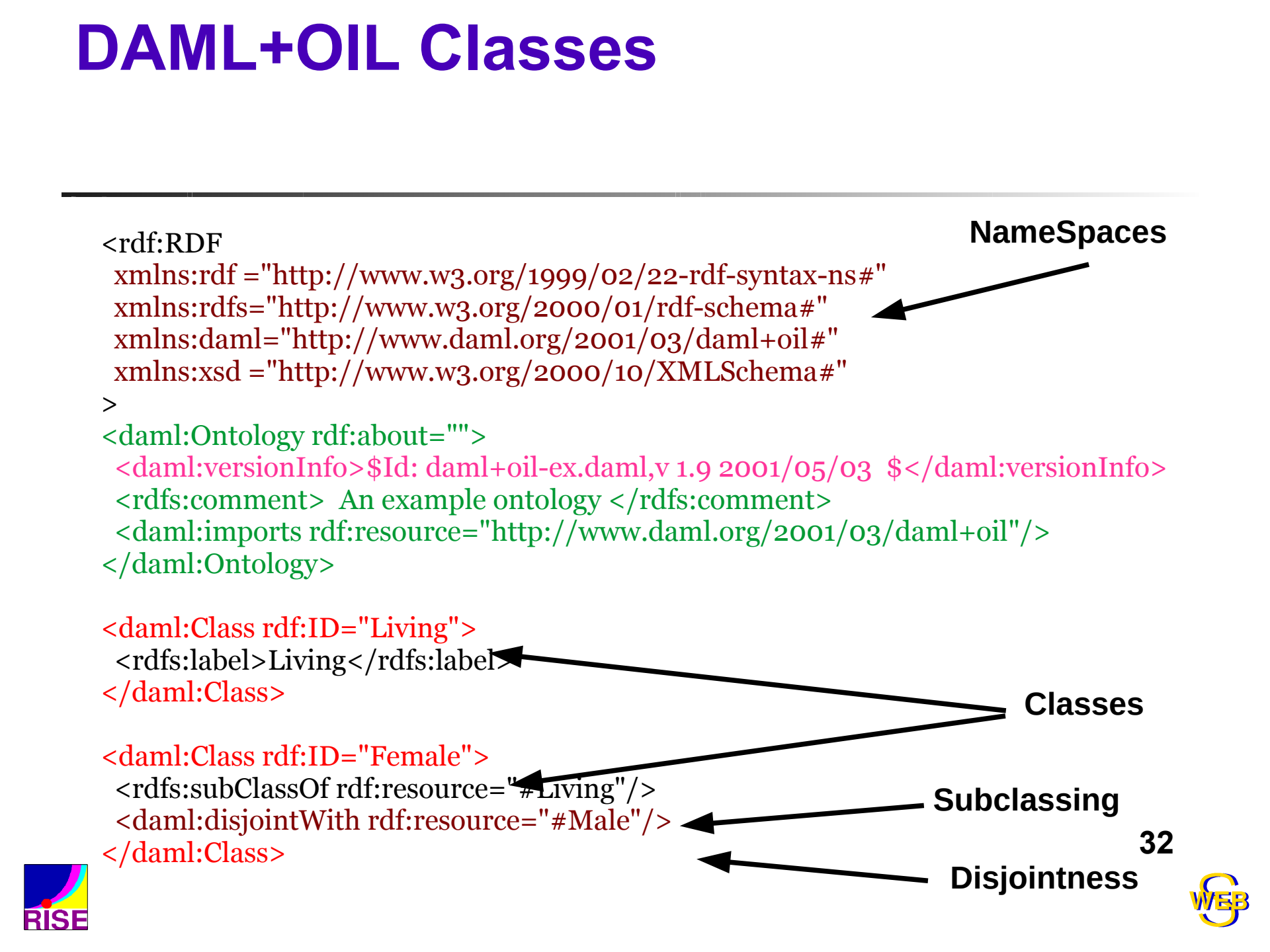
- conclusion :- premise.

RISE

WEB

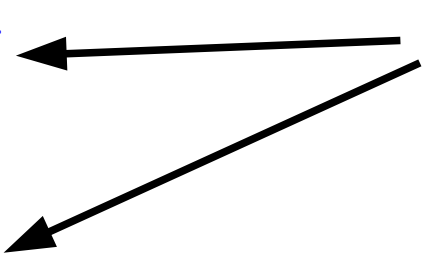
DAML+OIL Classes

```
<rdf:RDF
 xmlns:rdf ="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
 xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#"
 xmlns:daml="http://www.daml.org/2001/03/daml+oil#"
 xmlns:xsd ="http://www.w3.org/2000/10/XMLSchema#"
>
<daml:Ontology rdf:about="">
 <daml:versionInfo>$Id: daml+oil-ex.daml,v 1.9 2001/05/03  $</daml:versionInfo>
 <rdfs:comment>  An example ontology </rdfs:comment>
 <daml:imports rdf:resource="http://www.daml.org/2001/03/daml+oil"/>
</daml:Ontology>

<daml:Class rdf:ID="Living">
 <rdfs:label>Living</rdfs:label>
</daml:Class>

<daml:Class rdf:ID="Female">
 <rdfs:subClassOf rdf:resource="#Living"/>
 <daml:disjointWith rdf:resource="#Male"/>
</daml:Class>
```



DAML+OIL Relations

```
<daml:ObjectProperty rdf:ID="hasParent">
  <rdfs:domain rdf:resource="#Animal"/>
  <rdfs:range rdf:resource="#Animal"/>
</daml:ObjectProperty>

<daml:ObjectProperty rdf:ID="hasFather">
  <rdfs:subPropertyOf rdf:resource="#hasParent"/>
  <rdfs:range rdf:resource="#Male"/>
</daml:ObjectProperty>

<daml:DatatypeProperty rdf:ID="shoesize">
  <rdfs:comment>
    shoesize is a DatatypeProperty whose range is xsd:decimal.
    shoesize is also a UniqueProperty (can only have one shoesize)
  </rdfs:comment>
  <rdf:type rdf:resource="http://www.daml.org/2001/03/daml+oil#UniqueProperty"/>
  <rdfs:range rdf:resource="http://www.w3.org/2000/10/XMLSchema#decimal"/>
</daml:DatatypeProperty>
```



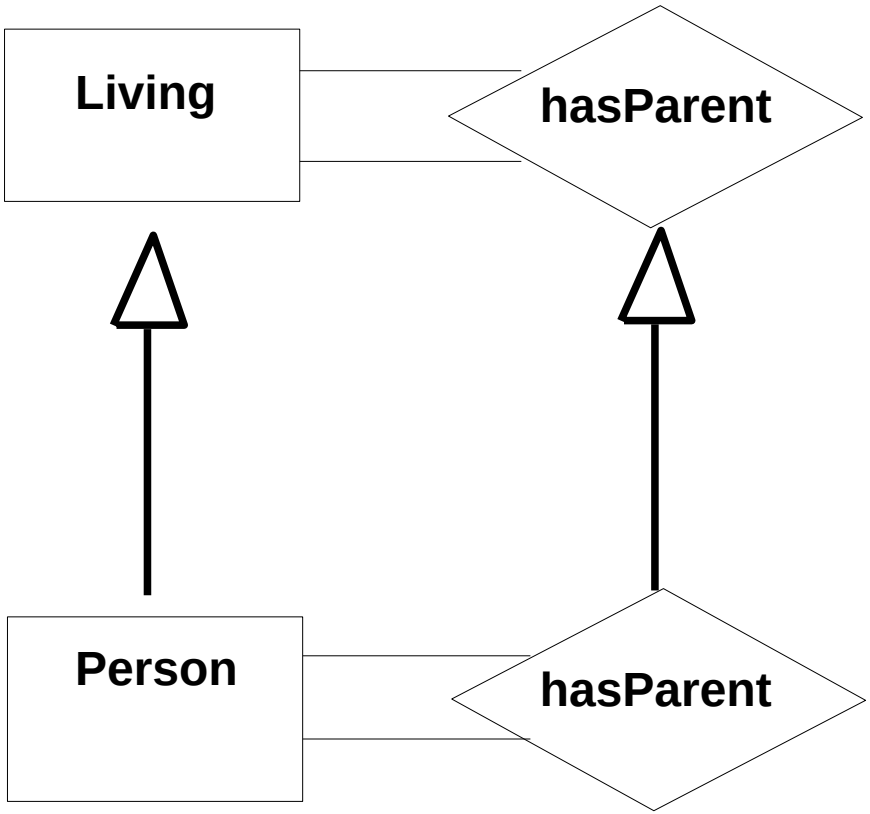
DAML+OIL Restrictions on Relations

```
<daml:Class rdf:ID="Person">
 <rdfs:subClassOf rdf:resource="#Living"/>

 <rdfs:subClassOf>
  <daml:Restriction>
   <daml:onProperty rdf:resource="#hasParent"/>
   <daml:toClass rdf:resource="#Person"/>
  </daml:Restriction>
 </rdfs:subClassOf>

 <rdfs:subClassOf>
  <daml:Restriction>
   <daml:onProperty rdf:resource="#shoesize"/>
   <daml:minCardinality>1</daml:minCardinality>
  </daml:Restriction>
 </rdfs:subClassOf>
</daml:Class>
```

Relation Restriction (Relation Inheritance)

Cardinality Restriction

DAML+OIL Inheritance on Relations



Further Languages

Disjunctive logic

Horn Clause Logic

DAML-L

Natural Semantics

Monotone Abstract Interpretation

Datalog
(Relational Algebra with recursion)

Edge Addition Systems EARS
Distributive DFA

Remote Attribute Grammars

Relational Algebra

Attribute Grammars

Description logics

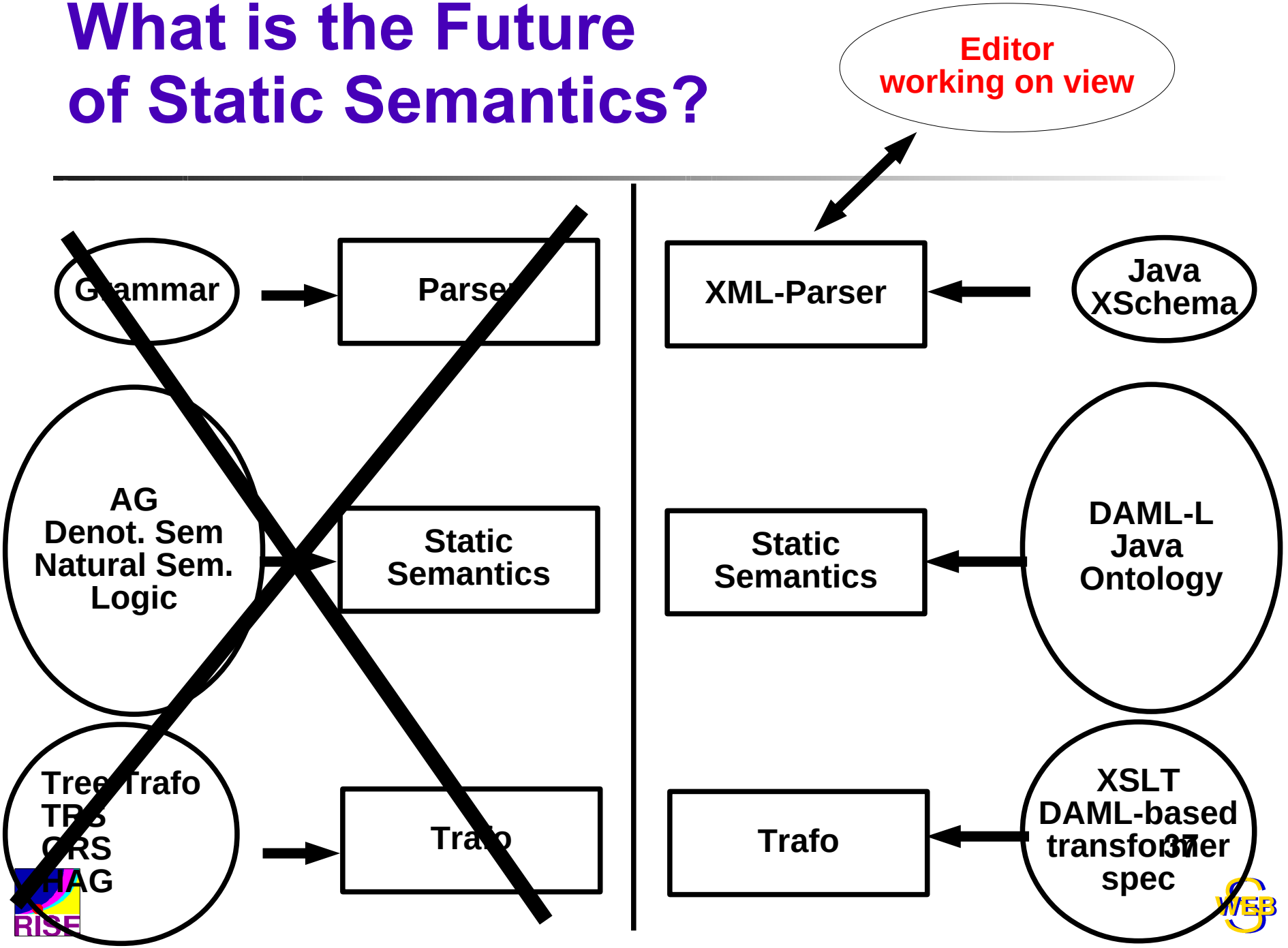
DAML

UML Structure Diagrams

RISE

WEB

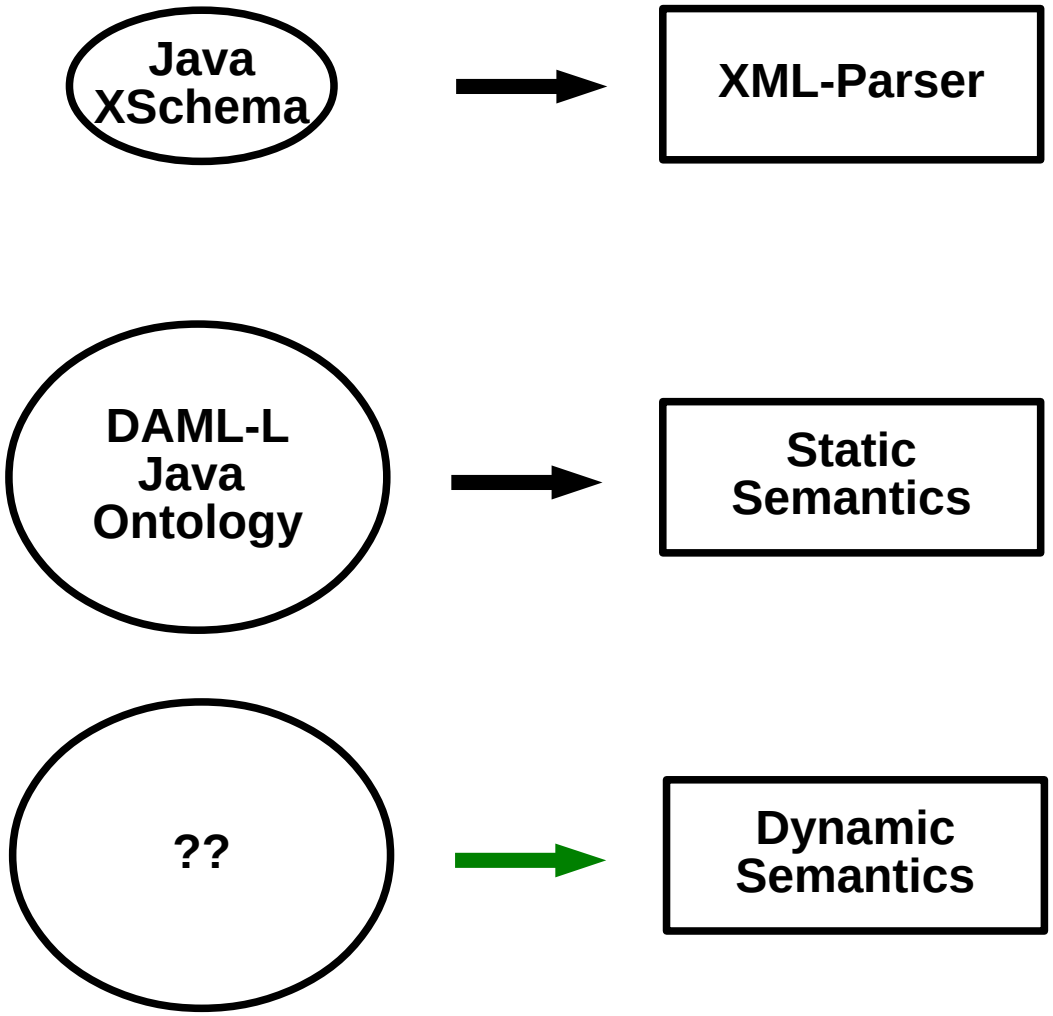
What is the Future of Static Semantics?



Static Semantics vs....

... Dynamic Semantics

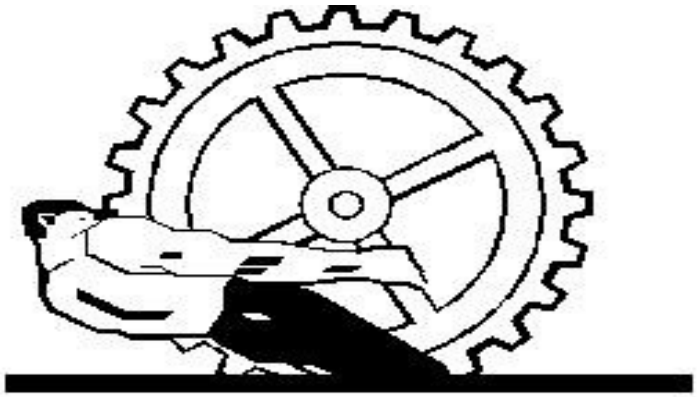
Future:
Dyamic Semantics



The Influence on the Industrial Markets

The Process Management Market

Industrial Sector



Process Management Sector

Administrative Sector

Service Sector

Submarkets of the Process Managment Sector PM

- PM-1 Ontology Languages
  - DAML+OIL, RuleML, ...
- PM-2 Ontology Development
  - Editors, component models
- PM-3 Ontology Tools
  - Knowledge mining, evaluators
- PM-4 Application Markets
  - e-commerce
  - Administrative processes
  - Production and business workflows
  - Evernet, home computing

RISE

WEB

Example Applications

- Semantic Email
- Semantic Document Libraries
- Semantic Component Supermarkets
- Semantic Refactoring
- Semantic Domain Specific Languages
- Semantic WebServices
- Semantic WAP
- Dynamic Supply Chain Management
- Personalization
- Context Aware Services
- Semantic Knowledge Reengineering

RISE

WEB

What People Say

- H. Ait-Kaci (Life, Feature Logic)
  - Databases (Datalog), AI (frame logic, problem-based reasoning), Programming languages, Logics (resolution, bottom-up), Constraint systems
  - all will unite!
- Berners-Lee, Hendler, Lassila
  - The Semantic Web is.. an extension of the current one, in which information is given well-defined *meaning*, better enabling computers and people to work in cooperation.

Berners-Lee, Hendler, Lassila

- Traditional knowledge-representation systems typically have been *centralized*,
  - requiring everyone to share exactly the same definition of common concepts such as "parent" or "vehicle."
  - *But central control is stifling*, and increasing the size and scope of such a system rapidly becomes unmanageable.
- The challenge of the Semantic Web, therefore, is to provide
  - a language that expresses both *data* and *rules for reasoning* about the data and
  - that allows rules from any existing knowledge-representation system to be exported onto the Web.

RISE
WEB

What Sweden Should Do

The Development in the Submarkets

- PM-1 Ontology Languages
  - Immediate Action Necessary
  - Window closes mid of 2002, when W3C committee will release the language
- PM-2 Ontology Development
  - Window closes 1-2 years later
- PM-3 Ontology Tools
  - 5-10 years competition
- PM-4 Application Markets
  - Be early, earn early

Will It Suceed?
The Horse Effect

- Failed:
  - The 5th Generation Project
  - The General Problem Solver (GPS)
  - Expert Systems
- Suceeded
  - C (riding on UNIX)
  - Microsoft (riding on the PC)
  - Java (riding on the Web)
  - HTML (riding on the internet)
- The Semantic Web is riding on HTML

RISE

WEB

Wakeling's Steamroller Law

Be Part of the Steamroller

or

Part of the Road....

(David Wakeling)

The SWEB
Swedish Semantic Web Initiative

- Semantic Web Awareness Actions
  - Dec 5: Prof. Norman Sadeh in Linköping
    - European Commission and CMU
  - How the Semantic Web will Change Business
    - B2B, Dynamic Supply Chain Management
- Mailing List
- Strategic Projects in PM-1,2,3
- Application Projects in PM-4
  - Home communication
  - Workflow management

RISE

What You Can Do

- Register in SWEB
  - www.ida.liu.se/sweb
- Participation in European network **OntoWeb**
  - www.ontoweb.org
  - OntoWeb meets in Amsterdam again on Dec 6-8, 2001
- Prepare Yourself for the Revolution!

RISE

WEB

What Would You Have Done If You Had Foreseen the First Web In 1990?

Ressources

- www.ida.liu.se/sweb The SWEB Initiative
- www.daml.org The DAML+OIL comittee
- www.w3c.org/2001/sw The Semantic Web activity of the W3C
- www.semanticweb.org A nice portal
- www.ontoweb.org The OntoWeb European Network
- www.easycomp.org (LIU's project on component composition for the Web)
- www.ontology.org A website for ontologies

RISE

WEB