

Intelligent Systems on the World Wide Web

OWL

Lecture Slides
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Inhalt

- Ontologies
- Language Stack
- OWL
- Example
- OWL and Logics
- Outlook and Conclusion

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Ontologies

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Ontology – Philosophical Definition

- Ontology
defined in a philosophical sense, is the study of the nature of
being.
- Aristotle, Metaphysics, IV, 1
- Questions:

What is the meaning of „to be“?

Which properties are shared by all things?

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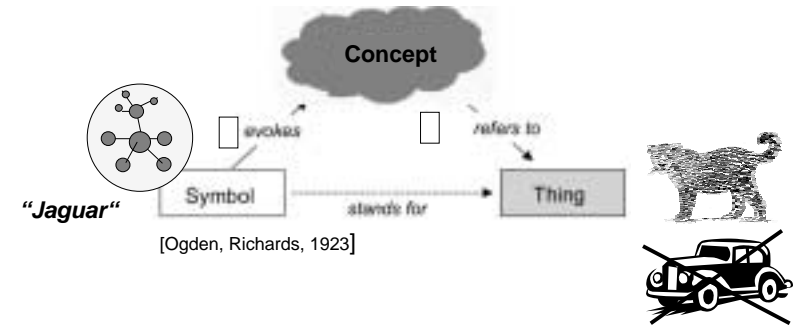
Ontology – Definition in Computer Science

Gruber 93:

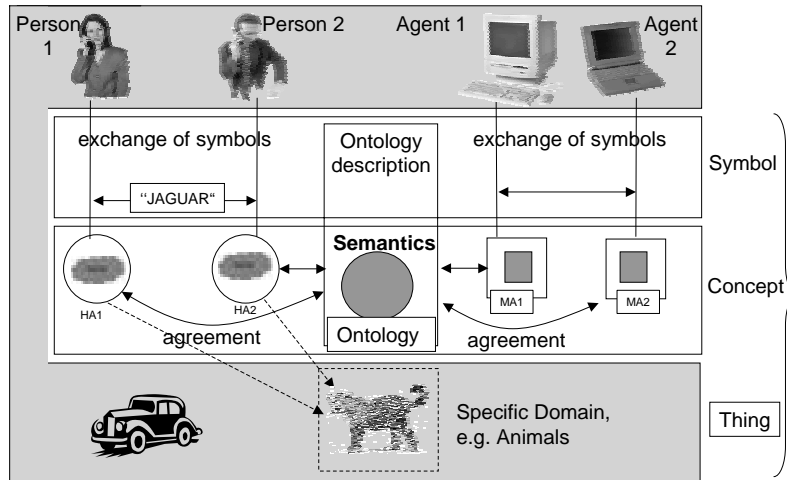
An Ontology is a formal specification of a shared conceptualization of a domain of interest

- ⇒ machine-understandable
- ⇒ group of people
- ⇒ about concepts
- ⇒ between general description and individual use

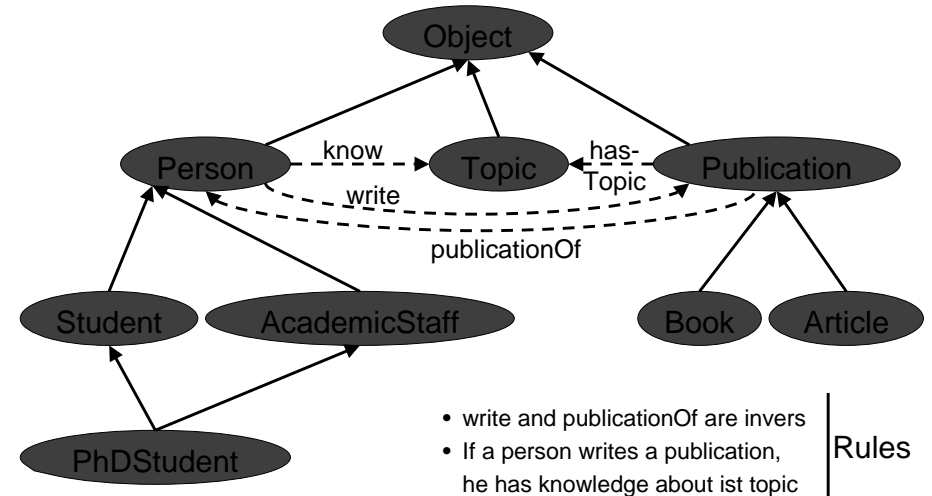
Triangle of Meaning



Communication



An Example Ontology



Language Stack

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Is XML sufficient for semantic annotation?

- XML: user definable and domain specific markup
- XML document is a labeled tree
- constraints on structure via DTD or XML Schema

```
<animal>
  <name>Tux</name>
  <species>penguin</species>
  <eats>fish</eats>
  ...
</animal>
```

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Shortcomings of XML (for our purposes)

XML makes no commitment on:

- 1 Domain specific ontological vocabulary
- 2 Ontological modeling primitives

⇒ requires pre-arranged agreement on 1 & 2

Only feasible for closed collaboration

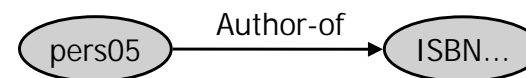
- agents in a small & stable community
- pages on a small & stable intranet

not for sharable Web-resources

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Is RDF(S) sufficient for semantic annotation?

- RDF provides metadata about Web resources
- Object -> Attribute-> Value triples



- RDF Schema
 - Defines vocabulary for RDF
 - Organizes this vocabulary in a typed hierarchy
 - Class, subclassOf, type
 - Property, subPropertyOf
 - domain, range
 - Cyclical hierarchies allow to state equivalence

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Conclusions about RDF(S)

- Next step up from plain XML:
 - (small) ontological commitment to modeling primitives
 - possible to define vocabulary
- However:
 - no precisely described meaning
 - unclear semantics, no clean separation between:
 - Instances
 - Ontologies
 - meta-ontologies (e.g. RDFS language itself)
 - no inference model

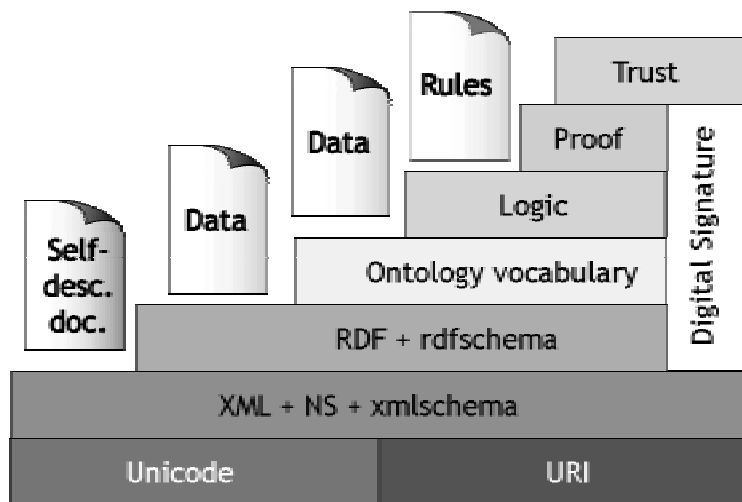
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Need for Higher Expressivity

- Property characteristics
 - Complex class constructors
 - (In)equality of instances
 - Rules
- Elements of Description Logic

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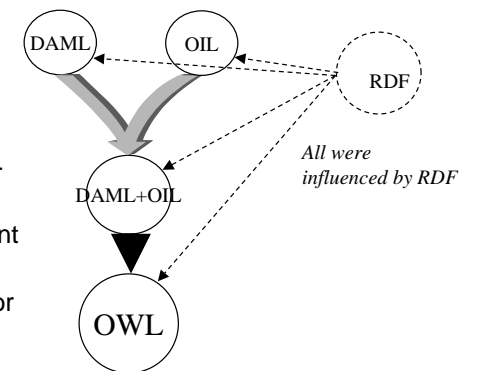
Stack of languages:



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History: DAML+OIL

- OIL : developed by group of (largely) European researchers.
- DAML- ONT: developed by group of (largely) US researchers (in DARPA DAML programme).
- Efforts merged to produce DAML+OIL.
- Development was overseen by joint EU/ US committee.
- Now submitted to W3C as basis for standardisation WebOnt working group developing language standard.



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WebOnt working group

- <http://www.w3.org/2001/sw/WebOnt/>
- Started in November 2001
- Currently 53 Members
- Last call went out in April 2003
- OWL is now on track to become a W3C Recommendation!

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Web Language Stack summary

- **XML:**
 - interchange syntax, no semantics
- **RDF:**
 - Data model, some semantics & inference (recent!)
- **RDF Schema:**
 - concept modelling, more semantics & inference
- **DAML+OIL / OWL:**
 - more expressive ontology language;
 - quite expressive; expensive inference

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OWL Web Ontology Language



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A first example...

```
<?xml version="1.0" ?>
<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:xsd="http://www.w3.org/2000/10/XMLSchema#"
  xmlns:owl="http://www.w3.org/2003/03/owl#">

  <owl:Ontology rdf:about="">
    <rdfs:comment>An example OWL ontology</rdfs:comment>
  </owl:Ontology>
  <owl:Class rdf:ID=„WineDescriptor“/>
  <owl:Class rdf:ID=„WineColor“>
    <rdfs:subClassOf rdf:resource=„#WineDescriptor“/>
  </owl:Class>
  <owl:ObjectProperty rdf:ID=„hasWineDescriptor“>
    <rdfs:domain rdf:resource=„#Wine“/>
    <rdfs:range rdf:resource=„#WineDescriptor“/>
  </owl:ObjectProperty>
  <owl:ObjectProperty rdf:ID=„hasColor“>
    <rdfs:subPropertyOf rdf:resource=„#hasWineDescriptor“/>
    <rdfs:range rdf:resource=„#WineColor“/>
  </owl:ObjectProperty>

</rdf:RDF>
```

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OWL Extends RDF

- RDF-schema
 - Class, subclass
 - Property, subproperty
- + Combinators
 - Union, Intersection
 - Complement
 - Symmetric, transitive
- + Restrictions
 - Range, domain
 - Local, global
 - Existential
 - Cardinality
- + Mapping
 - Equivalence
 - Inverse

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Property characteristics I

- inverseOf
 - *e.g. emptiesInto and feedsFrom are defined to be Inverse properties*
 - *The Yangtze emptiesInto the EastChinaSea. Then we can infer that: The EastChinaSea feedsFrom the Yangtze.*
- transitive
- symmetric

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Property characteristics II

Cardinality constraints

- Cardinality
- MinCardinality
- MaxCardinality

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Property characteristics III

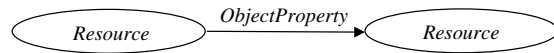
- Functional
 - *a short hand for assigning min. Cardinality 0 and max. Cardinality 1*
 - *E.g. property „primary residence“ of a Person*
 - *cannot be combined with transitivity to remain decidable (See Horrocks, Sattler, Tobies)*
- InverseFunctional
 - *instances can be distinctly identified via the property value*
 - *(~ primary keys)*
 - *E.g. no two people can hold the same passport.*

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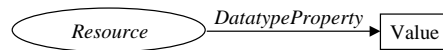
Property characteristics IV

ObjectProperty vs. DatatypeProperty

An ObjectProperty relates one Resource to another Resource:



A DatatypeProperty relates a Resource to a Literal or an XML Schema datatype:



Property characteristics V

- Local Range Constraints
 - *Restricts property ranges locally*
- allValuesFrom
 - *universal quantification (Allquantor)*
 - *E.g. Humans can only give birth to humans, whereas Animals give birth to animals*
- someValuesFrom
 - *existential quantification*
 - *E.g. EngineeringStudents must take at least one MathClass whereas Students can take arbitrary classes*

Class definitions I

- Defined Classes
 - Class extension is (partly) virtual, also made up by instances that additionally meet class definition constraints
 - Class Descriptions can be arbitrarily complex and combine all available class definition constructs
- Enumerated Classes

Set of instances is closed

e.g. Continents is the class of {Africa, Antarctica, Asia, Australia, Europe, North and South America}

Class definitions II

Class Definition Constraints

- Property fillers
 - Selection on instances
 - *e.g. DINKs are those Couples that have dual income and no kids*
- boolean combinations
 - Union, Intersection, Complement
 - *e.g. AcademicStaff is the union of Lecturers, Researchers and Professors*
- Disjoint Classes

E.g. Male and Female are disjoint

(In)Equality

- sameClassAs
- samePropertyAs
- sameIndividualAs
- differentIndividualAs

→ Very usefull for information integration,
facilitates content interoperability

OWL „Extra-Logical“ features

- Inclusion of other ontologies
- Assignment of dublin core metadata to ontology definitions
 - Via Dedicated AnnotationProperties
 - „OntoDoc“

Example

Robber drops gun while fleeing!

First of all a robbery takes place. The robber drops his gun while fleeing. This report is filed by the investigating officers:

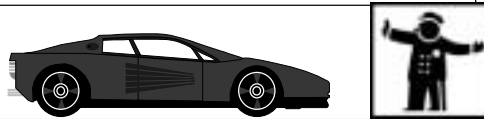
```
<RobberyEvent>
  <date>...</date>
  <description>...</description>
  <evidence>
    <Gun>
      <serial>ABCD</serial>
    </Gun>
  </evidence>
  <robber>
    <Person /> <!-- an unknown person -->
  </robber>
</RobberyEvent>
```



Speeder stopped

Subsequently a car is pulled over for speeding. The traffic officer files this report electronically while issuing a ticket:

```
<SpeedingOffence>
  <date>...</date>
  <description>...</description>
  <speeder>
    <Person>
      <name>Fred Blogs</name>
      <driversLicenseNumber>ZXYZXY</driversLicenseNumber>
    </Person>
  </speeder>
</SpeedingOffence>
```



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Analysis

At police headquarters (HQ), a computer analyzes each report as it is filed.

```
<GunLicense>
  <registeredGun>
    <Gun>
      <serial>ABCD</serial>
    </Gun>
  </registeredGun>
  <holder>
    </Person James_Brown>
  </holder>
</GunLicense>
```

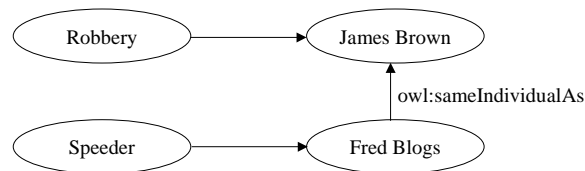
```
<Person Fred_Blogs>
  <name>Fred Blogs</name>
  <driversLicenseNumber>ZXYZXY</driversLicenseNumber>
</Person>
```

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Any Relationship between the Robber and the Speeder?

The Central Intelligence Agency (CIA) has a file on Fred Blogs:

```
<Person rdf:about="http://www.person.org#Fred_Blogs">
  <owl:sameIndividualAs rdf:resource="http://www.person.org#James_Brown"/>
</Person>
```



The local police, state troopers, and CIA share their information, thus enabling the following inference to be made:

Inference: The Robber and the Speeder are one and the same!

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Case Solved?

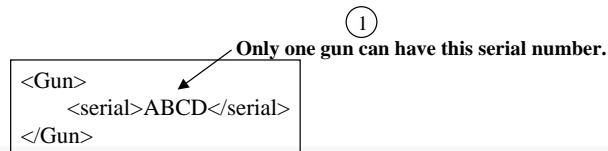
- Not yet! These questions must be answered before the speeder can be arrested as the robbery suspect:
 - ① – Can multiple guns have the same serial number?
 - If so, then just because Fred Blogs owns a gun with the same serial number as the robbery gun does not mean it was his gun that was used in the robbery.
 - ② – Can multiple people have the same driver's license number?
 - If so, then the gun license information may be for someone else.
 - ③ – Can a gun be registered in multiple gun licenses?
 - If so, then the other gun licenses may show the holder of the gun to be someone other than Fred Blogs.
 - Can a gun license have multiple holders of a registered gun?
 - If so, then there may be another gun license document (not available at the police HQ) which shows the same registered gun but with a different holder.
 - ④
- The OWL Gun License Ontology provides the information needed to answer these questions!

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Can multiple guns have the same serial number?

This OWL statement tells the computer at police HQ that *each gun is uniquely identified by its serial number*:

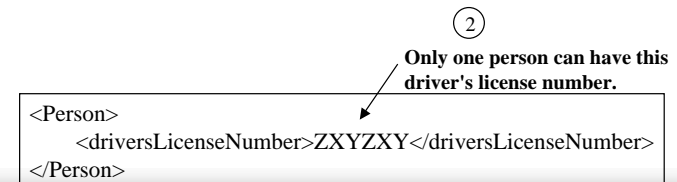
```
<owl:InverseFunctionalProperty rdf:ID="serial">
  <rdfs:domain rdf:resource="#Gun"/>
  <rdfs:range rdf:resource="http://www.w3.org/2000/01/rdf-schema#Literal"/>
</owl:InverseFunctionalProperty>
```



Can multiple people have the same driver's license number?

The following OWL statement tells the computer that *a driver's license number is unique to a Person*:

```
<owl:InverseFunctionalProperty rdf:ID="driversLicenseNumber">
  <rdfs:domain rdf:resource="#Person"/>
  <rdfs:range rdf:resource="http://www.w3.org/2000/01/rdf-schema#Literal"/>
</owl:InverseFunctionalProperty>
```



Can a gun be registered in multiple gun licenses?

The next OWL statement tells the computer that the registeredGun property uniquely identifies a GunLicense, i.e., *each gun is associated with only a single GunLicense*:

```
<owl:InverseFunctionalProperty rdf:ID="registeredGun">
  <rdfs:domain rdf:resource="#GunLicense"/>
  <rdfs:range rdf:resource="#Gun"/>
</owl:InverseFunctionalProperty>
```



Can a gun license have multiple holders of a registered gun?

The police computer uses the following OWL statement to determine that the gun on the license is the same gun used in the robbery. This final statement seals the speeder's fate. It tells the computer that *each GunLicense applies to only one gun and one person*. So, there is no doubt that the speeder is the person who owns the gun:

```
<owl:Class rdf:ID="GunLicense">
  <owl:intersectionOf rdf:parseType="Collection">
    <owl:Restriction>
      <owl:onProperty rdf:resource="#registeredGun">
        <owl:cardinality>1</owl:cardinality>
    </owl:Restriction>
    <owl:Restriction>
      <owl:onProperty rdf:resource="#holder">
        <owl:cardinality>1</owl:cardinality>
    </owl:Restriction>
  </owl:intersectionOf>
</owl:Class>
```

OWL and Logics

Description Logics and
Inferencing

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Description Logic I

- OWL equivalent to very expressive Description Logic
- Description Logic
 - Family of languages rather than one language
 - Leading Language in Knowledge Representation (KR) [→ www.kr.org]
 - ... 25 years of research ...
→ only shallow introduction possible
- Core distinction between
 - **class definitions** (T-Box ≈ Ontology)
 - **instance definitions** (A-Box ≈ Knowledge Base)

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Description Logic II

- Logic-based:
 - Very expressive, model is a set of theories, well defined semantics, reasoning.
 - Automatic derived classification taxonomies.
 - Concepts are defined and primitive.
 - Expressivity vs. computational complexity balance.

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Description Logic III

- Benefits for OWL
 - Well defined semantics
 - Formal properties well understood (complexity & decidability)
 - Known reasoning algorithms
 - Implemented systems
- Expressive Power determined by
 - Kinds of constructor provided
 - Kinds of axiom allowed

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Inference engine bit... reasoning support in DAML+OIL/OWL

- **Consistency** — check if knowledge is meaningful
- **Subsumption** — structure knowledge, compute taxonomy
- **Equivalence** — check if two classes denote same set of instances
- **Instantiation** — check if individual i instance of class C
- **Retrieval** — retrieve set of individuals that instantiate C



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Problems all **recucible** to consistency (satisfiability):

FACT, Racer, Cerebra

Semantics matters

A hacker who studied ontology
Was famed for his sense of frivolity
When his program inferred
That Clyde ISA Bird†
He blamed – not his code – but zoology

†Clyde ISA Elephant

“Al limericks” by Henry Kautz
<http://www.cs.washington.edu/homes/kautz/misc/limericks.html>

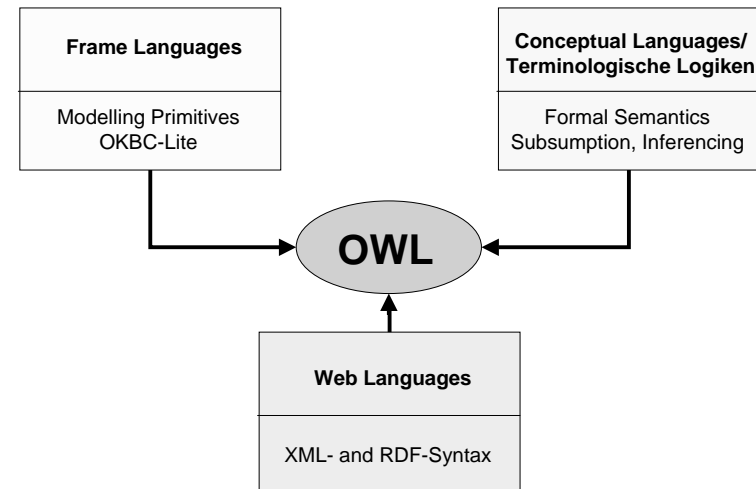
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OWL is not

- OWL is not a “knowledge representation language” per se
 - Definitely not “The standard: for KR”
- OWL is not a “Description Logic” per se
 - It does support DL “idioms”
 - E.g. “Lymphoma” is restricted to be a subclassOf those things whose “disease” property is “Cancer”
 - It includes a “subset” which is complete, and decidable
 - But, it will allow uses that DLs do not

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OWL brings together three families of languages

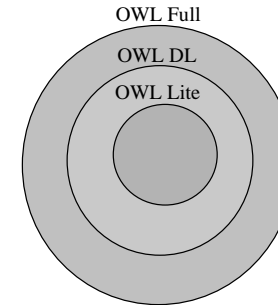


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Outlook and Conclusion

OWL Full, OWL DL, and OWL Lite

- Not everyone will need all of the capabilities that OWL provides. Thus, there are three versions of OWL:



The Species of OWL

- *OWL Lite* supports those users primarily needing a classification hierarchy and simple constraint features. It should be simpler to provide tool support for OWL Lite than its more expressive relatives, and provides a quick migration path for thesauri and other taxonomies.

The Species of OWL

- *OWL DL* supports those users who want the maximum expressiveness without losing computational completeness and decidability of reasoning systems. OWL DL was designed to support the existing Description Logic business segment.

The Species of OWL

- OWL Full is meant for users who want maximum expressiveness and the syntactic freedom of RDF with no computational guarantees. It allows an ontology to augment the meaning of the pre-defined (RDF or OWL) vocabulary.

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Expressiveness

- *OWL Lite* supports cardinality constraints, but it only permits cardinality values of 0 or 1.
- In *OWL DL*, a class cannot also be an individual or property, a property can not also be an individual or class.
- In *OWL Full* a class can be treated simultaneously as a collection of individuals and as an individual in its own right.

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Evaluation of OWL

Advantages

- Decidable
- Subsumption reasoning
- Consistency checking
- Dynamically post-coordinate rather than have to pre-enumerate.
- Support for evolution, merging, large scale building
- Can publish the ontologies as static lattices.
- W3C standard (so tools etc)

Disadvantages

- Different modeling style if want to take advantage of reasoning.
- Limited support for A-Box reasoning (on instances) in tractable DL versions

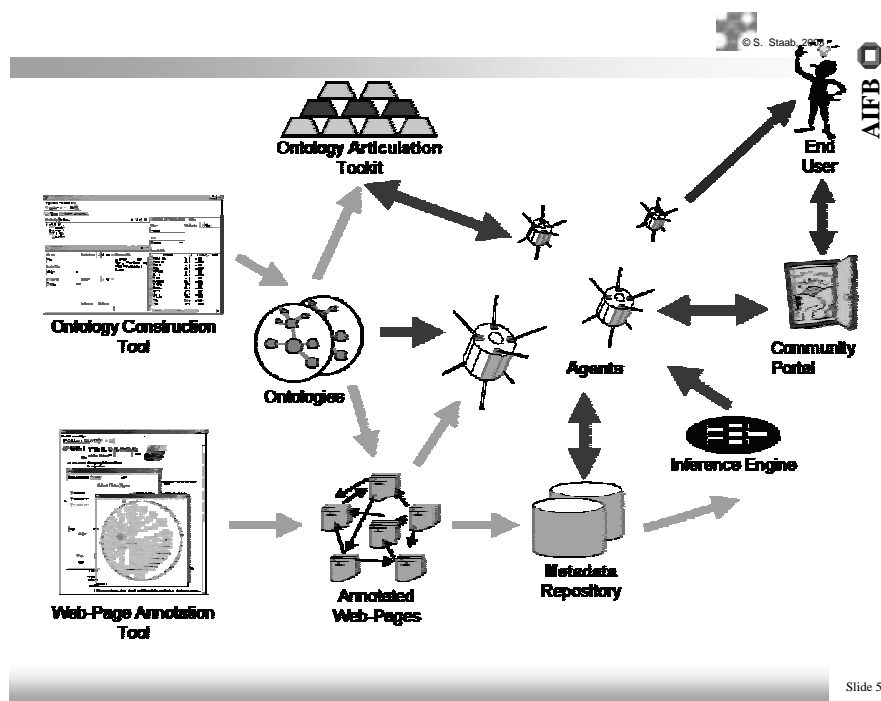
“As simple as required
but as complex as
necessary”

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Tools

- Being able to express ontologies is not enough...we need tools!
- Existing tools, especially DAML+OIL, are adapting to OWL
- Available for use in the lifetime of this group

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Conclusions

- OWL is more expressive than RDF(S)
- OWL is expressive enough to model ontologies
- OWL supports Description Logics

- OWL evolved from DAML+OIL
- There are three species of OWL

- OWL nearing completion and documents are available
- Tools are increasingly available

References

- WebOnt working group:
<http://www.w3.org/2001/sw/WebOnt/>
- OWL Tutorial:
<http://www.xfront.com/owl/>