An Introduction to OWL

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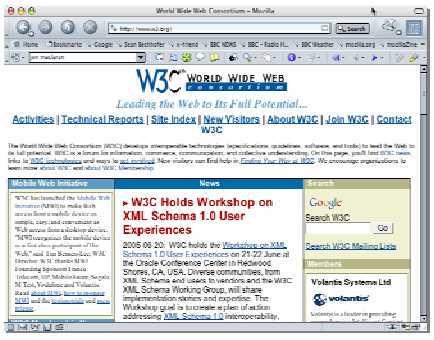
OWL: Web Ontology Language

- OWL is an ontology language designed for the Semantic Web
  - It provides a rich collection of operators for forming concept descriptions
  - It is a W3C standard, promoting interoperation and sharing between applications
  - It has been designed to be compatible with existing web standards
- In this talk, we'll see some of the motivation behind OWL and some details of the language

The Semantic Web Vision

- The Web was made possible through established standards
  - TCP/IP for transporting bits down a wire
  - HTTP & HTML for transporting and rendering hyperlinked text
- Applications able to exploit this common infrastructure
  - Result is the WWW as we know it
- 1st generation web mostly handwritten HTML pages
- 2nd generation (current) web often machine generated/active
  - Both intended for direct human processing/interaction
- In next generation web, resources should be more accessible to automated processes
  - To be achieved via semantic markup
  - Metadata annotations that describe content/function

What's the Problem?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Mobile Web Initiative

W3C has launched the Mobile Web Initiative (MWI) to make Web access from a mobile device as simple, easy, and convenient as Web access from a desktop device. "MWI recognizes the mobile device as a first class participant of the Web," said Tim Berners-Lee, W3C Director. W3C thanks MWI Founding Sponsors France Telecom, HP, MobileAware, Segala M Test, Vodafone and Volantis. Read about MWI, how to sponsor MWI and the testimonials and press release.

News

▸ W3C Holds Workshop on XML Schema 1.0 User Experiences

2005-06-20: W3C holds the Workshop on XML Schema 1.0 User Experiences on 21-22 June at the Oracle Conference Center in Redwood Shores, CA, USA. Diverse communities, from XML Schema end users to vendors and the W3C XML Schema Working Group, will share implementation stories and expertise. The Workshop goal is to create a plan of action addressing XML Schema 1.0 interoperability,

Search

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Members

Volantis Systems Ltd

Volantis is a leader in providing

- Consider a typical web page
- Markup consists of:
  - rendering information (e.g., font size and colour)
  - Hyper-links to related content
- Semantic content is accessible to humans but not (easily) to computers…
- Requires (at least) NL understanding

A Semantic Web — First Steps

- Make web resources more accessible to automated processes
- Extend existing rendering markup with semantic markup
  - Metadata annotations that describe content/function of web accessible resources
- Use Ontologies to provide vocabulary for annotations
  - New terms can be formed by combining existing ones
  - “Formal specification” is accessible to machines
- A prerequisite is a standard web ontology language
  - Need to agree common syntax before we can share semantics
  - Syntactic web based on standards such as HTTP and HTML

Technologies for the Semantic Web

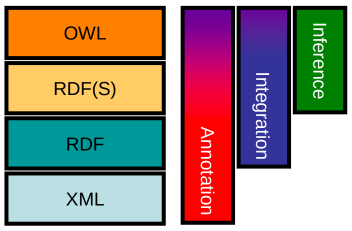
- Metadata
  - Resources are marked-up with descriptions of their content. No good unless everyone **speaks the same language**;
- Terminologies
  - provide shared and common vocabularies of a domain, so search engines, agents, authors and users can communicate. No good unless everyone **means the same thing**;
- Ontologies
  - provide a shared and common understanding of a domain that can be communicated across people and applications, and will play a major role in supporting information exchange and discovery.

Building a Semantic Web

- Annotation
  - Associating metadata with resources
- Integration
  - Integrating information sources
- Inference
  - Reasoning over the information we have.
  - Could be light-weight (taxonomy)
  - Could be heavy-weight (logic-style)
- Interoperation and Sharing are key goals

Languages

- Work on Semantic Web has concentrated on the definition of a collection or “stack” of languages.
  - These languages are then used to support the representation and use of metadata.
- The languages provide basic machinery that we can use to represent the extra semantic information needed for the Semantic Web
  - XML
  - RDF
  - RDF(S)
  - OWL
  - …



Object Oriented Models

- Many languages use an “object oriented model” with
- Objects/Instances/Individuals
  - Elements of the domain of discourse
- Types/Classes/Concepts
  - Sets of objects sharing certain characteristics
- Relations/Properties/Roles
  - Sets of pairs (tuples) of objects
- Such languages are/can be:
  - Well understood
  - Formally specified
  - (Relatively) easy to use
  - Amenable to machine processing

Structure of an Ontology

Ontologies typically have two distinct components:

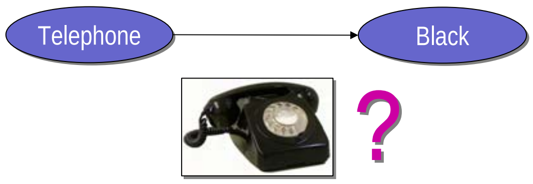
- Names for important concepts in the domain
  - Paper is a concept whose members are a kind of animal
  - Person is a concept whose members are persons
- Background knowledge/constraints on the domain
  - A Paper is a kind of ArgumentativeDocument
  - All participants in a Workshop must be Persons.
  - No individual can be both an InProceedings and a Journal

Formal Languages

- The degree of formality of ontology languages varies widely
- Increased formality makes languages more amenable to machine processing (e.g. automated reasoning).
- The formal semantics provides an unambiguous interpretation of the descriptions.

Why Semantics?

- What does an expression in an ontology **mean**?
- The semantics of a language can tell us precisely how to interpret a complex expression.
- Well defined semantics are vital if we are to support machine interpretability
  - They remove ambiguities in the interpretation of the descriptions.

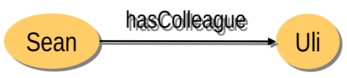


RDF

- RDF stands for Resource Description Framework
- It is a W3C Recommendation
  - http://www.w3.org/RDF
- RDF is a graphical formalism (+ XML syntax)
  - for representing metadata
  - for describing the semantics of information in a machine-accessible way
- Provides a simple data model based on triples.

The RDF Data Model

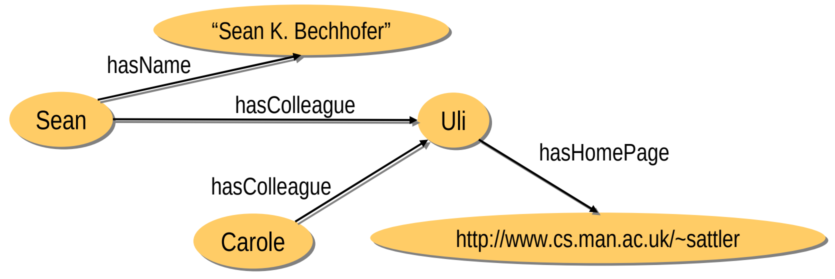
- Statements are <subject, predicate, object> triples:
  - **<Sean,hasColleague,Uli>**
- Can be represented as a graph:



- Statements describe properties of resources
  - Resources are identified by URIs.
- Properties themselves are also resources (URIs)
  - Thus we can also say things about properties.

Linking Statements

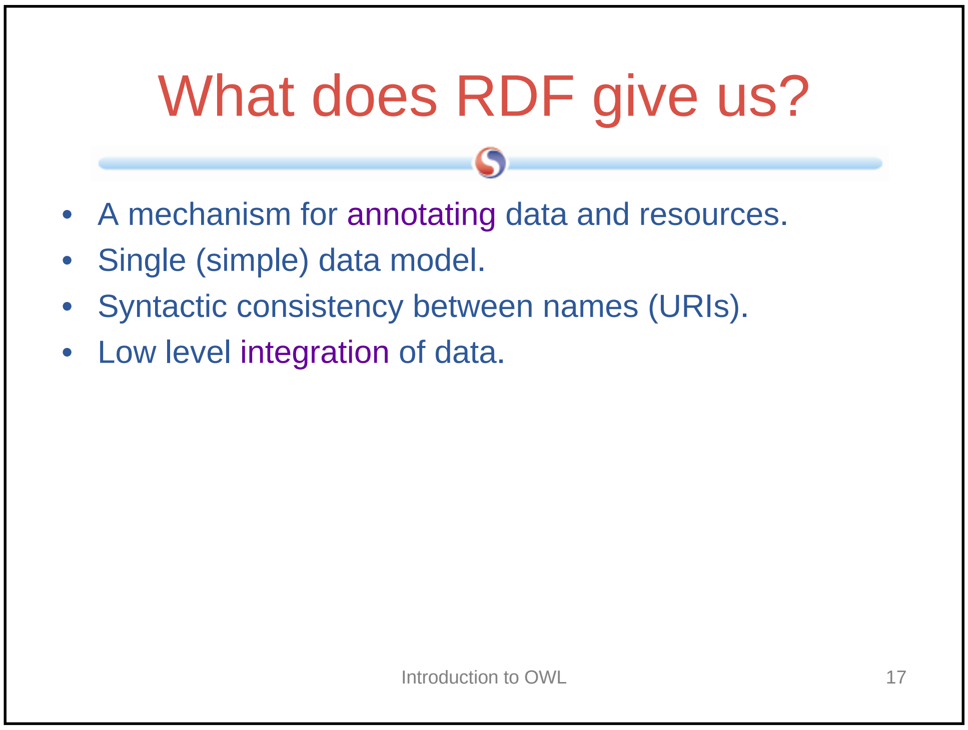
- The subject of one statement can be the object of another
- Such collections of statements form a directed, labeled graph



- Note that the object of a triple can also be a "literal" (a string)

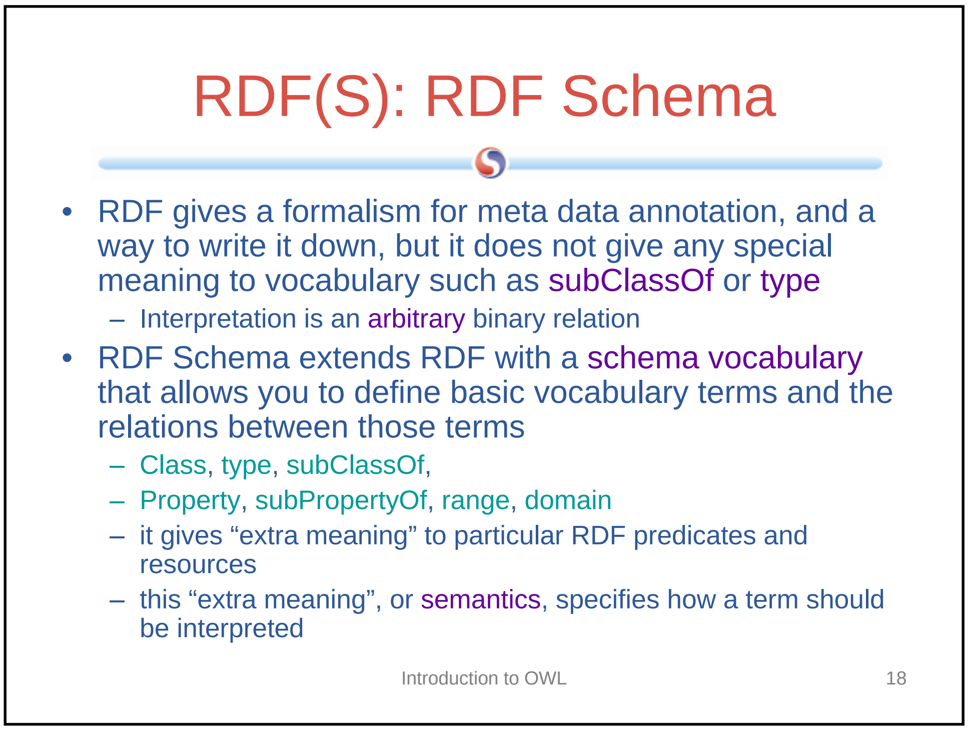
RDF Syntax

- RDF has a number of different concrete syntaxes
  - RDF/XML
  - N3
  - NTriples
  - Turtle
- These all give some way of serializing the RDF graph.



What does RDF give us?

- A mechanism for annotating data and resources.
- Single (simple) data model.
- Syntactic consistency between names (URIs).
- Low level integration of data.



RDF(S): RDF Schema

- RDF gives a formalism for meta data annotation, and a way to write it down, but it does not give any special meaning to vocabulary such as subClassOf or type
  - Interpretation is an arbitrary binary relation
- RDF Schema extends RDF with a schema vocabulary that allows you to define basic vocabulary terms and the relations between those terms
  - Class, type, subClassOf,
  - Property, subPropertyOf, range, domain
  - it gives "extra meaning" to particular RDF predicates and resources
  - this "extra meaning", or semantics, specifies how a term should be interpreted

RDF(S) Examples

- RDF Schema terms (just a few examples):
  - Class; Property
  - type; subClassOf
  - range; domain
- These terms are the RDF Schema building blocks (constructors) used to create vocabularies:
  - `<Person,type,Class>`
  - `<hasColleague,type,Property>`
  - `<Professor,subClassOf,Person>`
  - `<Carole,type,Professor>`
  - `<hasColleague,range,Person>`
  - `<hasColleague,domain,Person>`

RDF/RDF(S) “Liberality”

- No distinction between classes and instances (individuals)

```
<Species,type,Class>
<Lion,type,Species>
<Leo,type,Lion>
```

- Properties can themselves have properties

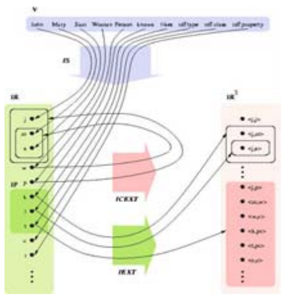
```
<hasDaughter,subPropertyOf,hasChild>
<hasDaughter,type,familyProperty>
```

- No distinction between language constructors and ontology vocabulary, so constructors can be applied to themselves/each other

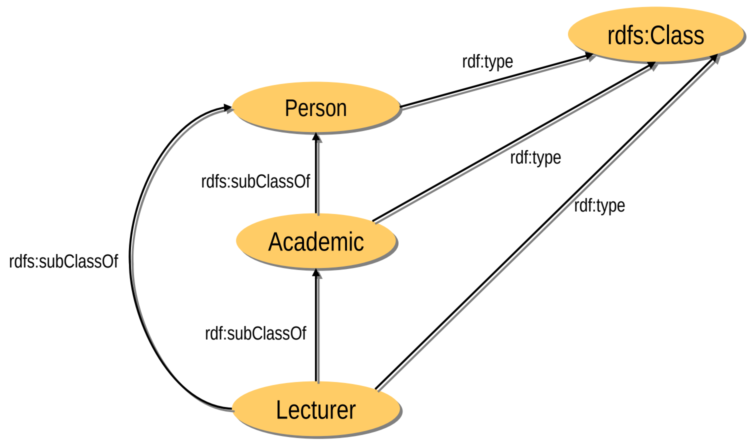
```
<type,range,Class>
<Property,type,Class>
<type,subPropertyOf,subClassOf>
```

RDF/RDF(S) Semantics

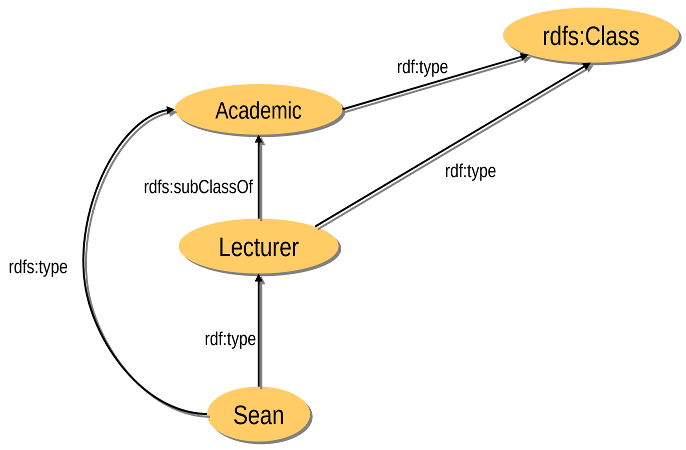
- RDF semantics given by RDF Model Theory (MT)
  - IR, a non-empty set of resources
  - IS, a mapping from V into IR
  - IP, a distinguished subset of IR (the properties)
  - IEXT, a mapping from IP into the powerset of IR£IR
- Class interpretation ICEXT induced by IEXT(IS(type))
  - ICEXT(C) = {x | (x,C) 2 IEXT(IS(type))}
- RDF(S) adds constraints on models
  - {(x,y), (y,z)} µ IEXT(IS(subClassOf))) (x,z) 2 IEXT(IS(subClassOf))



RDF(S) Inference

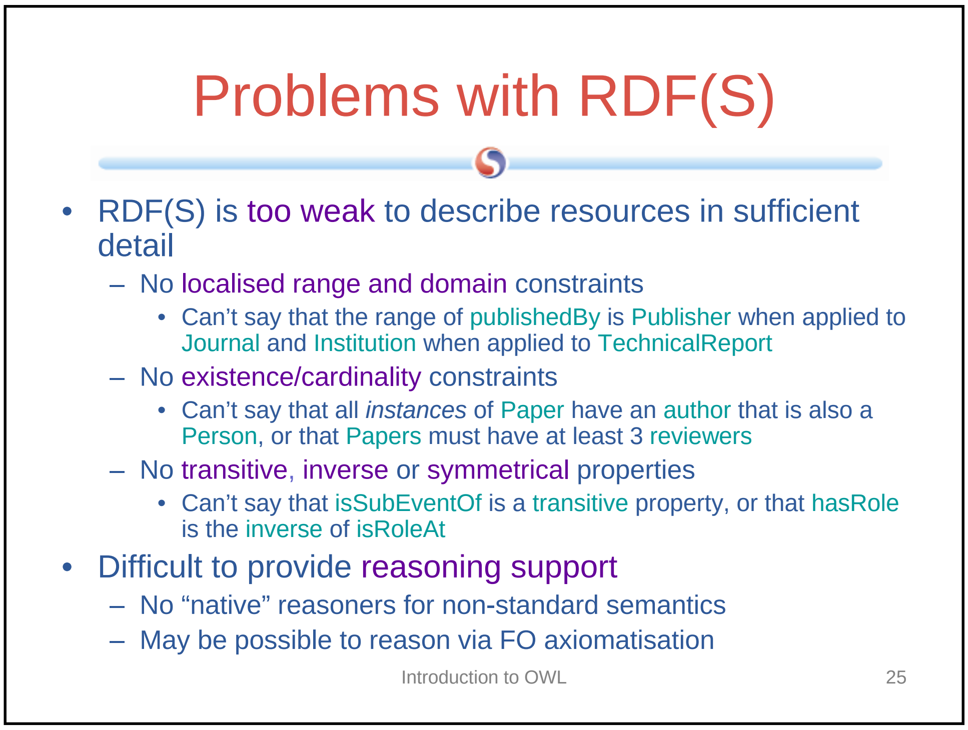


RDF(S) Inference



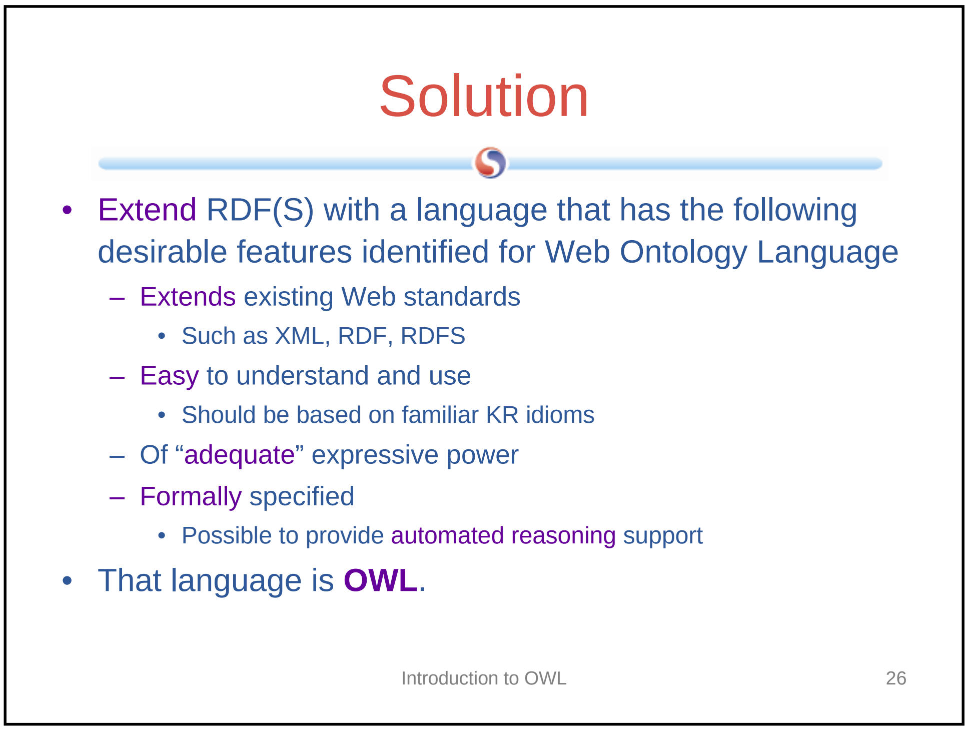
What does RDF(S) give us?

- Ability to use simple schema/vocabularies when describing our resources.
- Consistent vocabulary use and sharing.
- Simple inference



Problems with RDF(S)

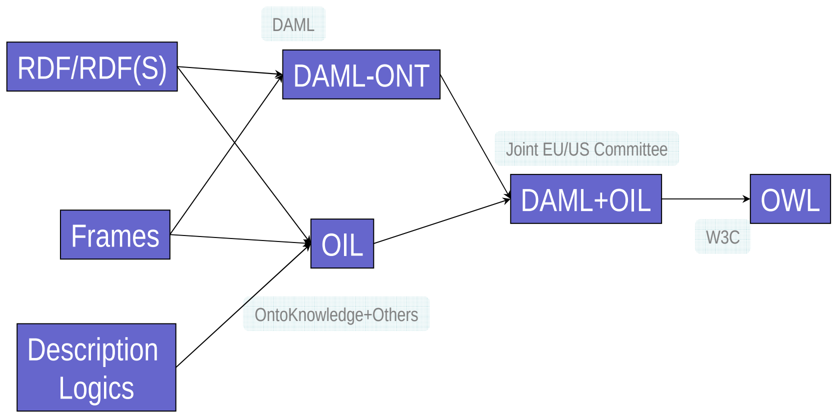
- RDF(S) is too weak to describe resources in sufficient detail
  - No localised range and domain constraints
    - Can’t say that the range of publishedBy is Publisher when applied to Journal and Institution when applied to TechnicalReport
  - No existence/cardinality constraints
    - Can’t say that all *instances* of Paper have an author that is also a Person, or that Papers must have at least 3 reviewers
  - No transitive, inverse or symmetrical properties
    - Can’t say that isSubEventOf is a transitive property, or that hasRole is the inverse of isRoleAt
- Difficult to provide reasoning support
  - No “native” reasoners for non-standard semantics
  - May be possible to reason via FO axiomatisation



Solution

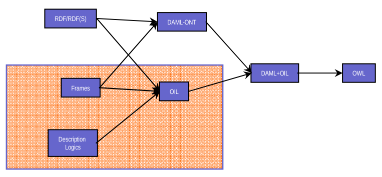
- Extend RDF(S) with a language that has the following desirable features identified for Web Ontology Language
  - Extends existing Web standards
    - Such as XML, RDF, RDFS
  - Easy to understand and use
    - Should be based on familiar KR idioms
  - Of “adequate” expressive power
  - Formally specified
    - Possible to provide automated reasoning support
- That language is **OWL**.

The OWL Family Tree



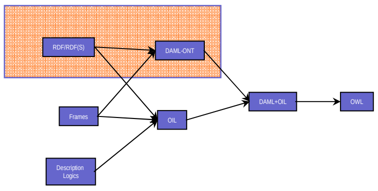
A Brief History of OWL

- **OIL**
  - Developed by group of (largely) European researchers (several from EU OntoKnowledge project)
  - Based on frame-based language
  - Strong emphasis on formal rigour.
  - Semantics in terms of Description Logics
  - RDFS based syntax



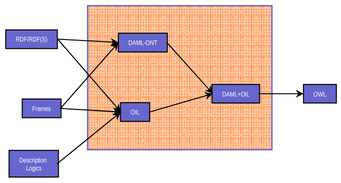
A Brief History of OWL

- **DAML-ONT**
  - Developed by DAML Programme.
    - Largely US based researchers
  - Extended RDFS with constructors from OO and frame-based languages
  - Rather weak semantic specification
    - Problems with machine interpretation
    - Problems with human interpretation



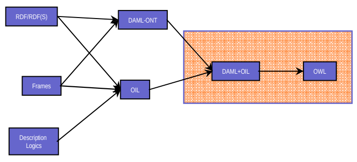
A Brief History of OWL

- **DAML+OIL**
  - Merging of DAML-ONT and OIL
  - Basically a DL with an RDFS-based syntax.
  - Development was carried out by “Joint EU/US Committee on Agent Markup Languages”
  - Extends (“DL subset” of) RDF
- DAML+OIL submitted to W3C as basis for standardisation
  - Web-Ontology (**WebOnt**) Working Group formed



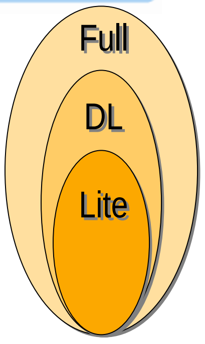
A Brief History of OWL

- **OWL**
  - W3C Recommendation (February 2004)
  - Based largely on the DAML+OIL specification from March 2001.
  - Well defined RDF/XML serializations
  - Formal semantics
    - First Order
    - Relationship with RDF
  - Comprehensive test cases for tools/implementations
  - Growing industrial takeup.

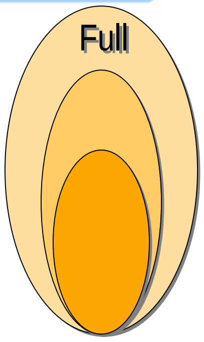


OWL Layering

- Three species of OWL
  - OWL Full is the union of OWL syntax and RDF
  - OWL DL restricted to FOL fragment (¼ DAML+OIL)
    - Corresponds to *SHOIN*(D_n) Description Logic
  - OWL Lite is "simpler" subset of OWL DL
- Syntactic Layering
- Semantic Layering
  - OWL DL semantics = OWL Full semantics (within DL fragment)
  - OWL Lite semantics = OWL DL semantics (within Lite fragment)
- DL semantics are definitive
  - In principle: correspondence proof
  - But: if Full disagrees with DL (in DL fragment), then Full is wrong

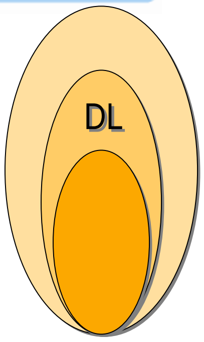


OWL Full



- No restriction on use of OWL vocabulary (as long as legal RDF)
  - Classes as instances (and much more)
- RDF style model theory
  - Reasoning using FOL engines
    - via axiomatisation
  - Semantics should correspond with OWL DL for suitably restricted KBs

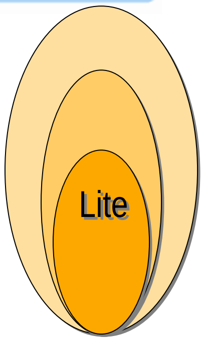
OWL DL



- Use of OWL vocabulary restricted
  - Can’t be used to do “nasty things” (i.e., modify OWL)
  - No classes as instances
  - Defined by abstract syntax + mapping to RDF
- Standard DL/FOL model theory (definitive)
  - Direct correspondence with (first order) logic
- Benefits from years of DL research
  - Well defined semantics
  - Formal properties well understood (complexity, decidability)
  - Known reasoning algorithms
  - Implemented systems (highly optimised)

OWL Lite

- Like DL, but fewer constructs
  - No explicit negation or union
  - Restricted cardinality (zero or one)
  - No nominals (oneOf)
- Semantics as per DL
  - Reasoning via standard DL engines (+datatypes)
    - E.g., FaCT, RACER, Cerebra, Pellet
- In practice, not really used.
  - Possible alternative: “tractable fragments”



Aside: Description Logics

- A family of logic based Knowledge Representation formalisms
  - Descendants of semantic networks and KL-ONE
  - Describe domain in terms of concepts (classes), roles (relationships) and individuals
- Distinguished by:
  - Formal semantics (typically model theoretic)
    - Decidable fragments of FOL
    - Closely related to Propositional Modal & Dynamic Logics
  - Provision of inference services
    - Sound and complete decision procedures for key problems
    - Implemented systems (highly optimised)

DL Semantics

- Model theoretic semantics. An interpretation consists of
  - A domain of discourse (a collection of objects)
  - Functions mapping
    - classes to sets of objects
    - properties to sets of pairs of objects
  - Rules describe how to interpret the constructors and tell us when an interpretation is a model.
- In a DL, a class description is thus a characterisation of the individuals that are members of that class.

OWL Syntaxes

- Abstract Syntax
  - Used in the definition of the language and the DL/Lite semantics
- OWL in RDF (the “official” concrete syntax)
  - RDF/XML presentation
- XML Presentation Syntax
  - XML Schema definition

OWL Class Constructors

- OWL has a number of operators for constructing class expressions.
- These have an associated semantics which is given in terms of a domain:
  - Δ
- And an interpretation function
  - *I*:*concepts* ! ℘(Δ)
  - *I*:*properties* ! ℘(Δ £ Δ)
  - *I*:*individuals* ! Δ
- *I* is then extended to concept expressions.

OWL Class Constructors

Constructor	**Example**	**Interpretation**
Classes	Human	*I(Human)*
intersectionOf	intersectionOf(Human Male)	*I(Human)* Å *I(Male)*
unionOf	unionOf(Doctor Lawyer)	*I(Doctor)* [*I(Lawyer)*
complementOf	complementOf(Male)	Δ n *I(Male)*
oneOf	oneOf(john mary)	{*I(john)*, *I(mary)*}

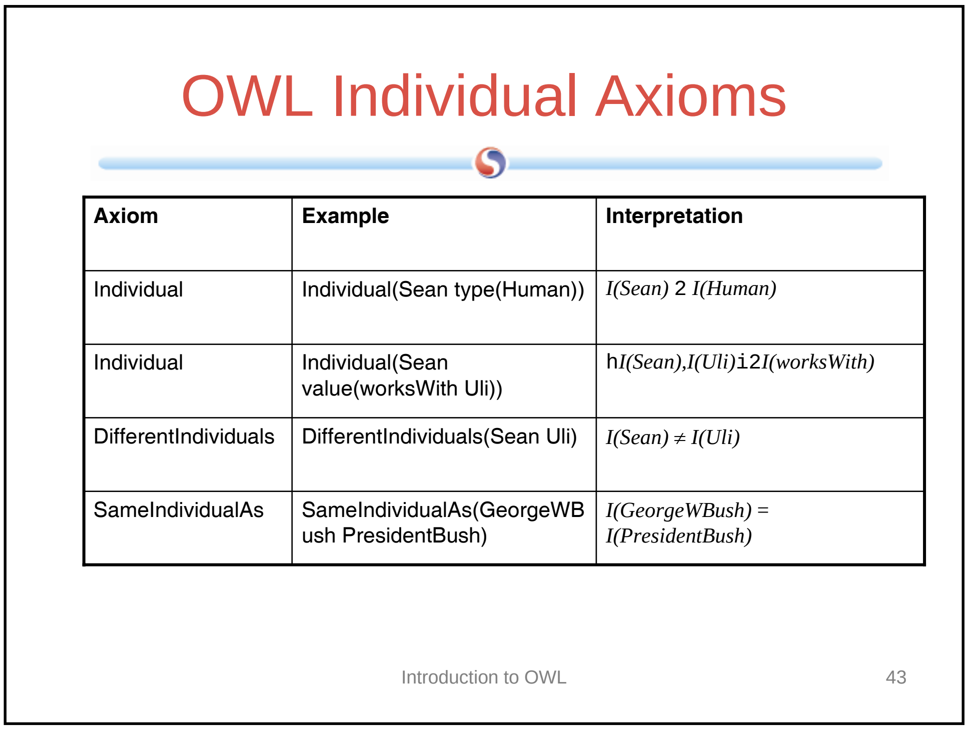
OWL Class Constructors

Constructor	Example	Interpretation
someValuesFrom	restriction(hasChild someValuesFrom Lawyer)	{xj9y.hx,yi2*I(hasChild)*Æ y2*I(Lawyer)*}
allValuesFrom	restriction(hasChild allValuesFrom Doctor)	{xj8y.hx,yi2*I(hasChild)*) y2*I(Doctor)*}
minCardinality	restriction(hasChild minCardinality (2))	{x|#hx,yi2*I(hasChild)* ¸ 2}
maxCardinality	restriction(hasChild maxCardinality (2))	{x|#hx,yi2*I(hasChild)* · 2}

OWL Axioms

- Axioms allow us to add further statements about arbitrary concept expressions and properties
  - Subclasses, Disjointness, Equivalence, transitivity of properties etc.
- An interpretation is then a model of the axioms iff it satisfies every axiom in the model.

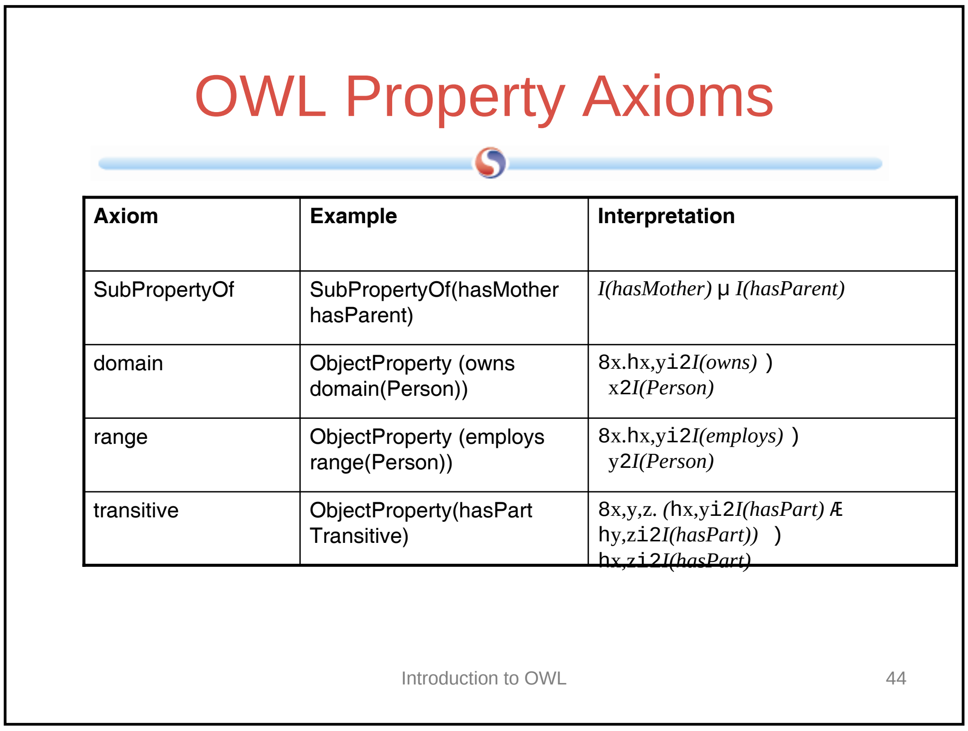
Axiom	Example	Interpretation
SubClassOf	SubClassOf(Human Animal)	*I(Human)* µ *I(Animal)*
EquivalentClasses	EquivalentClass(Man intersectionOf(Human Male))	*I(Man)* = *I(Human)* Å *I(Male)*
DisjointClasses	DisjointClasses(Animal Plant)	*I(Animal)* Å *I(Plant)* = ;



OWL Individual Axioms

Axiom	Example	Interpretation
Individual	Individual(Sean type(Human))	*I(Sean)* 2 *I(Human)*
Individual	Individual(Sean value(worksWith Uli))	h*I(Sean)*,*I(Uli)*i2*I(worksWith)*
DifferentIndividuals	DifferentIndividuals(Sean Uli)	*I(Sean)* ≠ *I(Uli)*
SameIndividualAs	SameIndividualAs(GeorgeWBush PresidentBush)	*I(GeorgeWBush)* = *I(PresidentBush)*

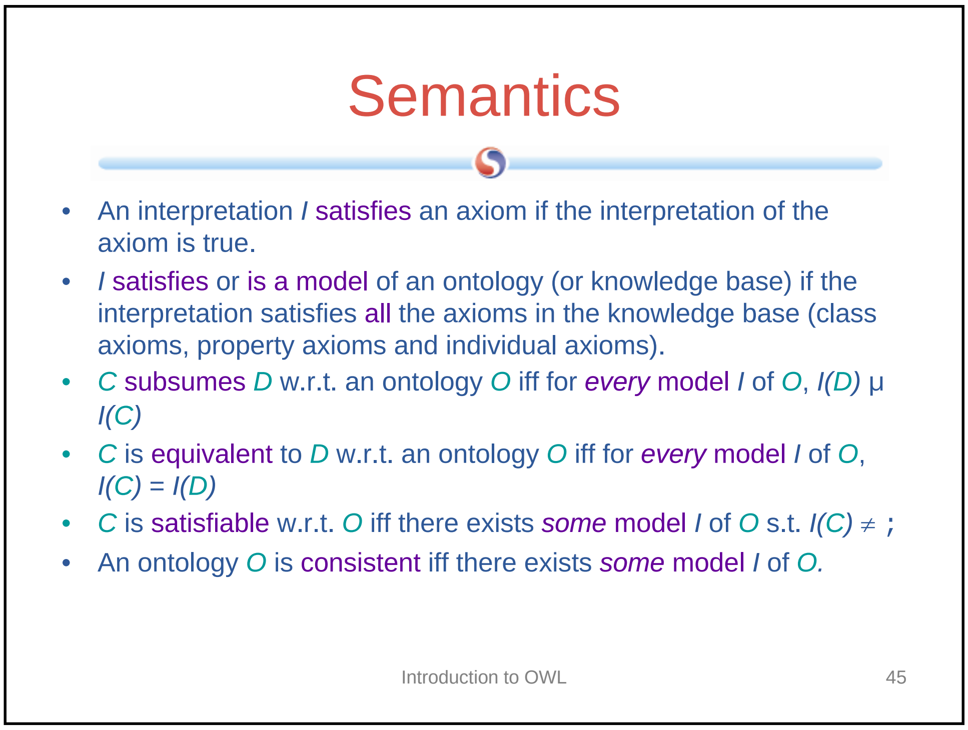
Introduction to OWL 43



OWL Property Axioms

Axiom	Example	Interpretation
SubPropertyOf	SubPropertyOf(hasMother hasParent)	*I(hasMother)* µ *I(hasParent)*
domain	ObjectProperty (owns domain(Person))	8x.hx,yi2*I(owns)*) x2*I(Person)*
range	ObjectProperty (employs range(Person))	8x.hx,yi2*I(employs)*) y2*I(Person)*
transitive	ObjectProperty(hasPart Transitive)	8x,y,z. (hx,yi2*I(hasPart)* Æ hy,zi2*I(hasPart)*)) hx,zi2*I(hasPart)*

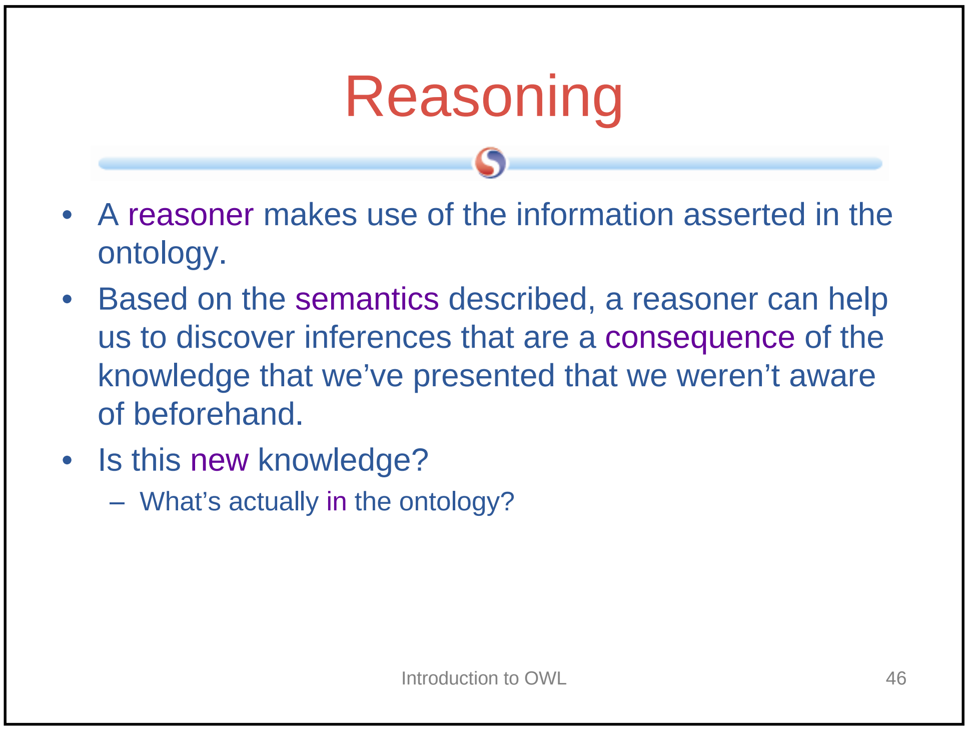
Introduction to OWL 44



Semantics

- An interpretation *I* satisfies an axiom if the interpretation of the axiom is true.
- *I* satisfies or is a model of an ontology (or knowledge base) if the interpretation satisfies all the axioms in the knowledge base (class axioms, property axioms and individual axioms).
- *C* subsumes *D* w.r.t. an ontology *O* iff for *every* model *I* of *O*, *I(D)* µ *I(C)*
- *C* is equivalent to *D* w.r.t. an ontology *O* iff for *every* model *I* of *O*, *I(C)* = *I(D)*
- *C* is satisfiable w.r.t. *O* iff there exists *some* model *I* of *O* s.t. *I(C)* ≠ ;
- An ontology *O* is consistent iff there exists *some* model *I* of *O*.

Introduction to OWL 45



Reasoning

- A reasoner makes use of the information asserted in the ontology.
- Based on the semantics described, a reasoner can help us to discover inferences that are a consequence of the knowledge that we've presented that we weren't aware of beforehand.
- Is this new knowledge?
  - What's actually in the ontology?

Introduction to OWL 46

Reasoning

- Subsumption reasoning
  - Allows us to infer when one class is a subclass of another
  - B is a subclass of A if it is necessarily the case that (in all models), all instances of B *must* be instances of A.
  - This can be either due to an explicit assertion, or through some inference process based on an intensional definition.
  - Can then build concept hierarchies representing the taxonomy.
  - This is classification of classes.
- Satisfiability reasoning
  - Tells us when a concept is unsatisfiable
    - i.e. when there is no model in which the interpretation of the class is non-empty.
  - Allows us to check whether our model is consistent.

Necessary and Sufficient Conditions

- Classes can be described in terms of necessary and sufficient conditions.
  - This differs from some frame-based languages where we only have necessary conditions.
- Necessary conditions
  - Must hold if an object is to be an instance of the class
- Sufficient conditions
  - Those properties an object must have in order to be recognised as a member of the class.
  - Allows us to perform automated classification.

If it looks like a duck and walks like a duck, then it's a duck!

Example

```
Class: Paper
SubClassOf:
      author min 1
```

- All Papers must have at least one author
- This is a *necessary* condition on being a Paper, but doesn’t give us *sufficiency* conditions.

Example

```
Class: GoodPaper
   EquivalentTo:
      Paper
      and author some (Person
                            and member some KoreanInstitute)
```

- A GoodPaper is one with an author from a KoreanInstitute
- This provides *necessary* and *sufficient* conditions for being a GoodPaper. If we know it is a Paper and there is an author from a KoreanInstitute, then it is a GoodPaper

Reasoning

```
Individual: Paper1
Types: Paper
Facts:
  author KimHyunJung
```

```
Individual: KimHyunJung
Facts:
 member DancePopUniversity

Individual: DancePopUniversity
Types: KoreanInstitute
```

- We can now infer that Paper1 is a GoodPaper

Example

```
Class: VeryGoodPaper
    EquivalentTo:
        Paper
        and author only (Person
                              and member some KoreanInstitute)
```

- A VeryGoodPaper is one with only authors from a KoreanInstitute
- This again provides necessary and sufficient conditions for being a VeryGoodPaper. If we know it is a Paper and that all the authors are from a KoreanInstitute, then it is a VeryGoodPaper
- We can also now infer that all VeryGoodPapers are GoodPapers

Closed and Open Worlds

- The standard semantics of OWL makes an Open World Assumption (OWA).
  - We cannot assume that all information is known about all the individuals in a domain.
  - Facilitates reasoning about the intensional definitions of classes.
  - Sometimes strange side effects
- Closed World Assumption (CWA)
  - Named individuals are the only individuals in the domain
- Negation as failure.
  - If we can't deduce that x is an A, then we know it must be a (not A).
  - Facilitate reasoning about a particular state of affairs.

Open Worlds

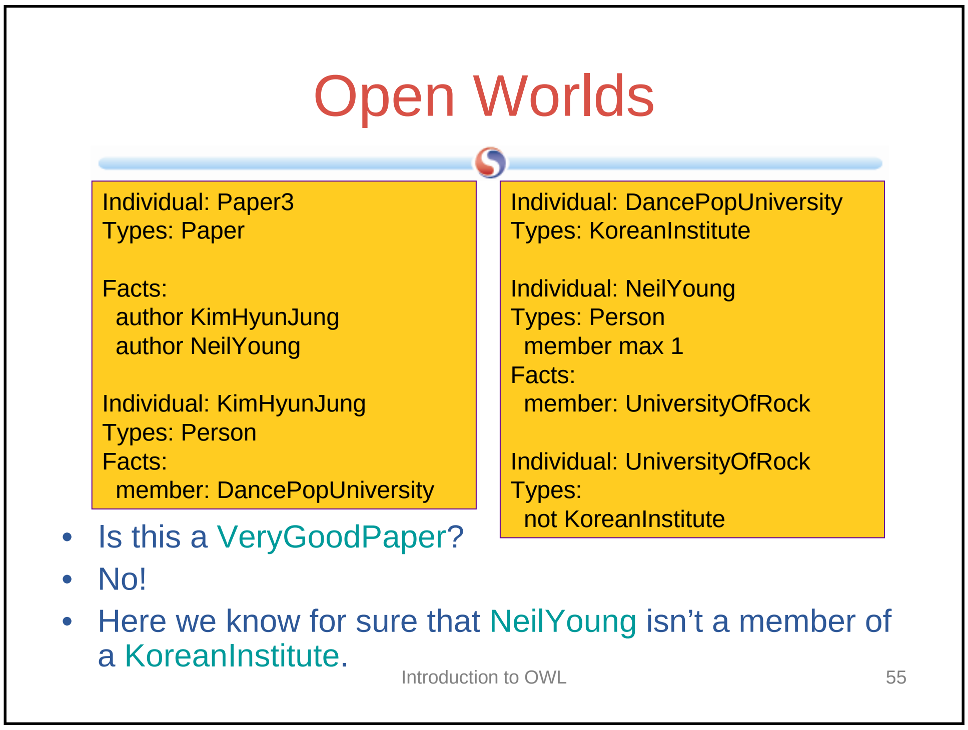
Individual: Paper2
Types: Paper
Facts:
  author KimHyunJung
  author BobDylan

Individual: KimHyunJung
Types: Person
 member: DancePopUniversity

Individual: DancePopUniversity
Types: KoreanInstitute

Individual: BobDylan
Types: Person

- Is this a VeryGoodPaper?
- We don't know!
- Just because it is not stated that BobDylan is a member of a KoreanInstitute, we cannot assume that this is not the case.
- Similarly, there may be other authors of the paper that we do not know about.



Open Worlds

Individual: Paper3
Types: Paper

Facts:
  author KimHyunJung
  author NeilYoung

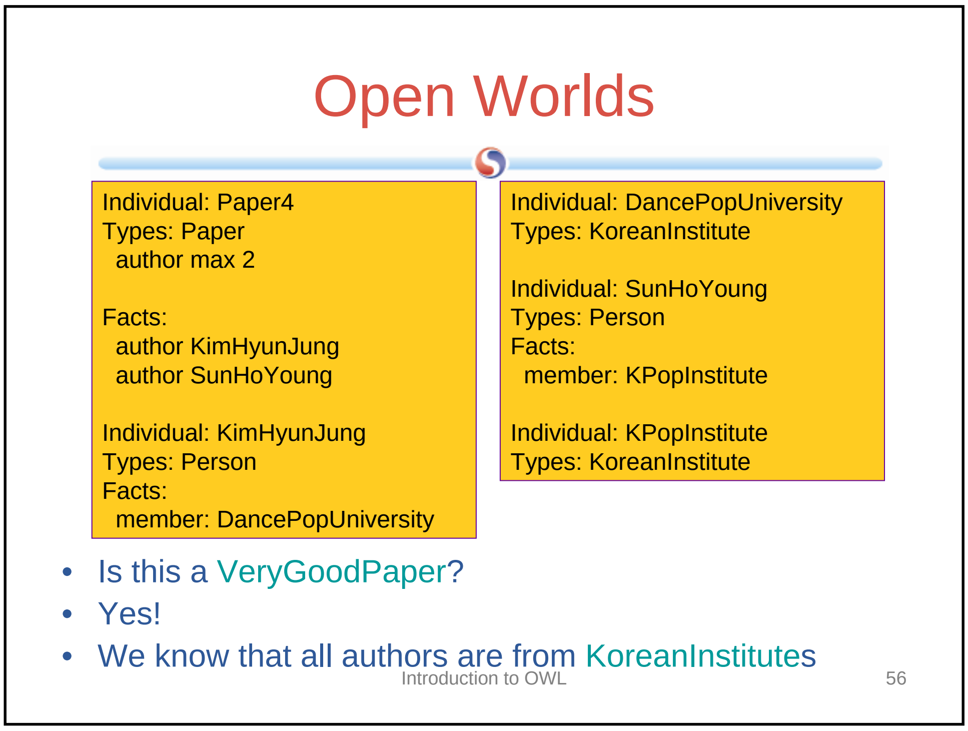
Individual: KimHyunJung
Types: Person
Facts:
  member: DancePopUniversity

Individual: DancePopUniversity
Types: KoreanInstitute

Individual: NeilYoung
Types: Person
  member max 1
Facts:
  member: UniversityOfRock

Individual: UniversityOfRock
Types:
  not KoreanInstitute

- Is this a VeryGoodPaper?
- No!
- Here we know for sure that NeilYoung isn’t a member of a KoreanInstitute.



Open Worlds

Individual: Paper4
Types: Paper
  author max 2

Facts:
  author KimHyunJung
  author SunHoYoung

Individual: KimHyunJung
Types: Person
Facts:
  member: DancePopUniversity

Individual: DancePopUniversity
Types: KoreanInstitute

Individual: SunHoYoung
Types: Person
Facts:
  member: KPopInstitute

Individual: KPopInstitute
Types: KoreanInstitute

- Is this a VeryGoodPaper?
- Yes!
- We know that all authors are from KoreanInstitutes

Why Reasoning?

- Reasoning can be used as a design support tool
  - Check logical consistency of classes
  - Compute implicit class hierarchy
- May be less important in small local ontologies
  - Can still be useful tool for design and maintenance
  - Much more important with larger ontologies/multiple authors
- Valuable tool for integrating and sharing ontologies
  - Use definitions/axioms to establish inter-ontology relationships
  - Check for consistency and (unexpected) implied relationships
- For most DLs, the basic inference problems are decidable (e.g. there is some program that solves the problem in a finite number of steps)

Extensions

- OWL is not intended to be the answer to all our problems.
- There are things that we can't represent using OWL.
- Current work on extending OWL includes:
  - Rules
    - RIF
  - Extending expressivity (within certain bounds)
    - OWL1.1
  - Query
    - SPARQL

Extensions: Rules

- W3C Group chartered with producing a Rules Interchange Format

  http://www.w3.org/2005/rules/
- Current status
  - Use cases and Requirements
  - RIF Core Design
  - Large and somewhat disparate group
  - Production Rules, Business Rules, First Order Logic…..

Extensions: OWL1.1

- A number of domains require expressivity that is not in the current OWL specification
  - Driven by User Requirements and technical advances
  - OWLEd series of workshops
- Much of this functionality can be added in a principled way that preserves the desirable properties of OWL (DL).
- OWL Working Group now chartered:

  http://www.w3.org/2007/OWL/

Extensions: OWL 1.1

- Syntactic Sugar
  - DisjointUnion
  - Negated Property assertions
- Richer Datatypes
- Complex Role Axioms
  - Role inclusion
- Metamodelling and Annotations
  - Punning
- Tractable Fragments
  - Language fragments with desirable computational complexity

OWL1.1: Role Axioms

- Many applications (for example medicine) have requirements to specify interactions between roles:
  - A fracture located in part of the Femur is a fracture of the Femur.
- We **cannot** express such general patterns in OWL.
- Algorithms have been developed to support sound and complete reasoning in a DL extended with complex role inclusions

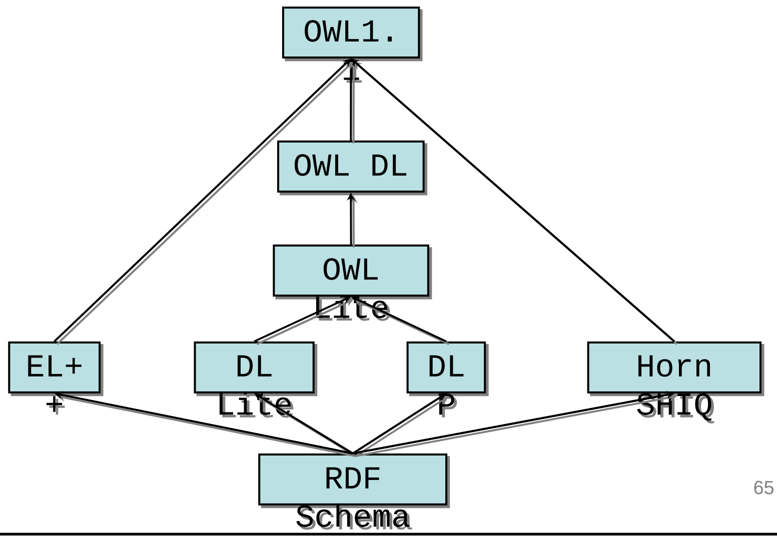
OWL1.1: Metamodelling

- OWL DL has strict rules about separation of namespaces.
- A URI cannot be typed as both a class and individual in the same ontology.
- OWL 1.1 allows punning, where a URI can be used in multiple roles.
  - However, the use of the URI as an individual has no bearing on the use of the URI as a class.
  - Requires explicit context telling us the role that a URI is playing

OWL1.1: Fragments

- EL++
  - Medical Ontologies
  - SNOMED/GALEN
- DL Lite
  - Tailored for handling large numbers of facts
  - Efficient Querying
- DLP
  - Subset of OWL DL and Horn Logic
  - OWL semantics
- Horn-SHIQ
  - Similar to DLP
- RDF Schema
  - RDFS ontologies that are valid OWL1.1

OWL1.1: Fragments



Extensions: Query and Retrieval

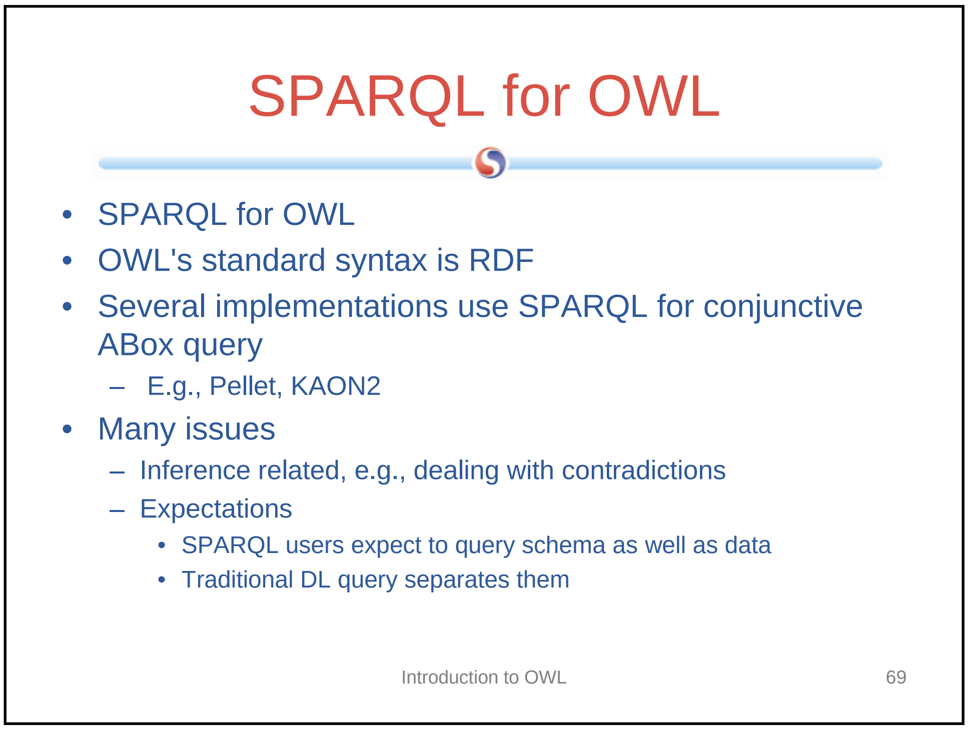
- In standard DLs, reasoning is split into:
  - T-Box: reasoning about classes
  - A-Box: reasoning about instances
- T-Box reasoning is well understood, at least for languages like SHIQ (~OWL Lite)
  - e.g. subsumption & satisfiability testing
- Full A-Box reasoning is much more challenging
  - E.g. instance retrieval & instantiation

Query Languages

- SPARQL is a proposed query language for RDF.
  - http://www.w3.org/TR/rdf-sparql-query/
- SPARQL Protocol, Query Language and results format.
- Query language is the interesting bit
  - Protocol allows query, no update
  - Variety of results formats: XML, JSON (used in web 2.0 apps), and RDF

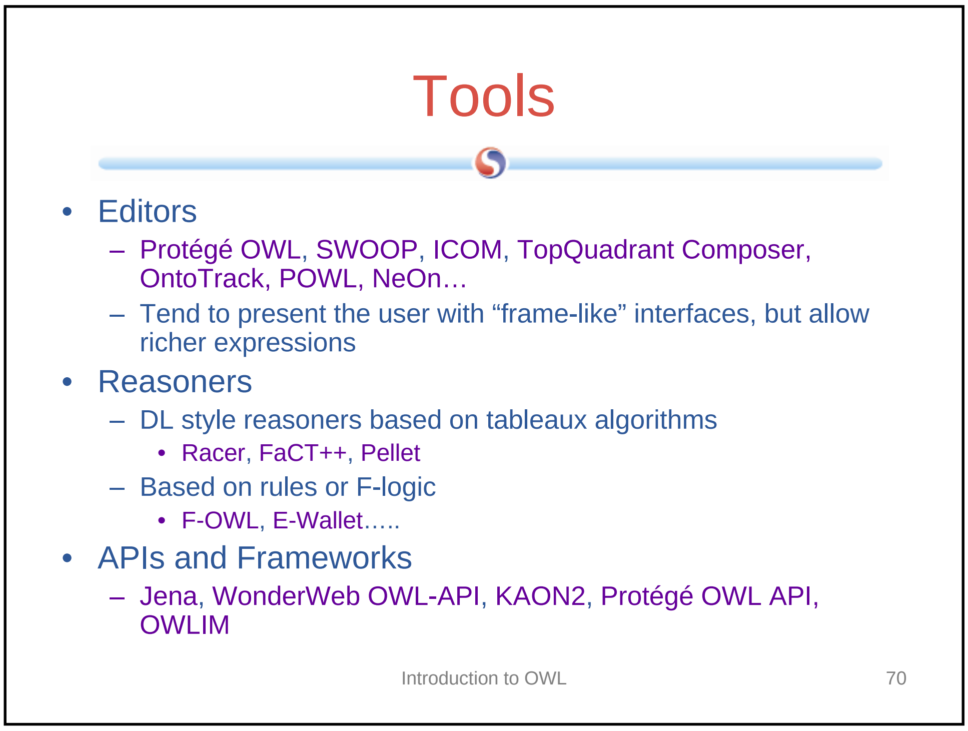
SPARQL

- QL is a Candidate Recommendation as of June 14th
- Implementations
  - Jena
  - Sesame
  - Virtuoso
  - Boca
  - …
- Tightening of the spec since last year
  - In particular, the adoption of a clear algebra



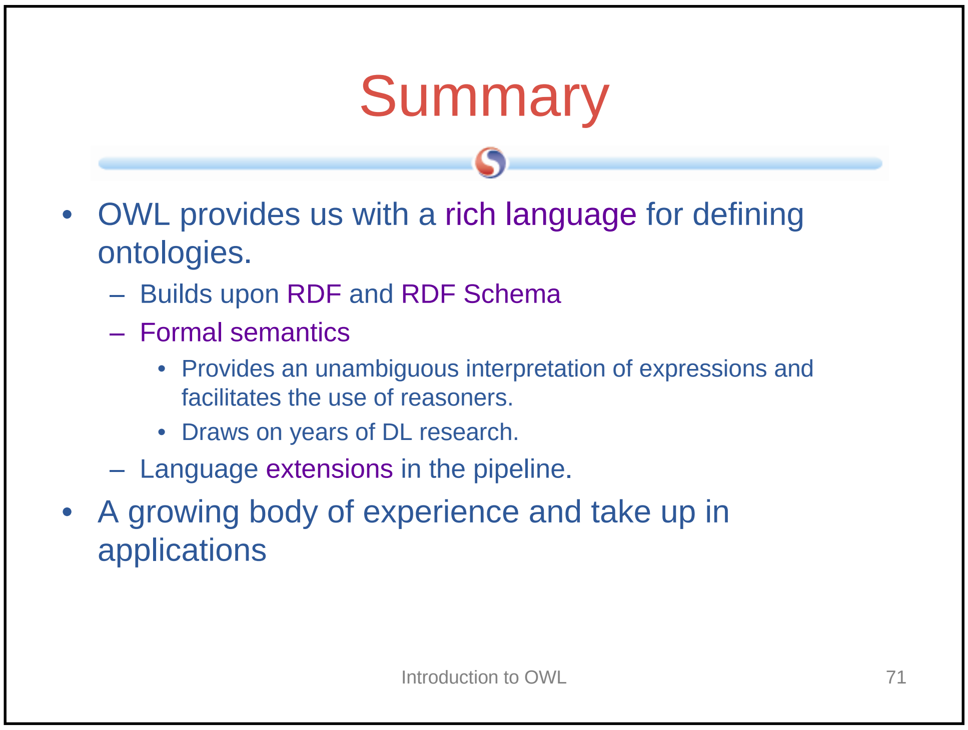
SPARQL for OWL

- SPARQL for OWL
- OWL's standard syntax is RDF
- Several implementations use SPARQL for conjunctive ABox query
  - E.g., Pellet, KAON2
- Many issues
  - Inference related, e.g., dealing with contradictions
  - Expectations
    - SPARQL users expect to query schema as well as data
    - Traditional DL query separates them



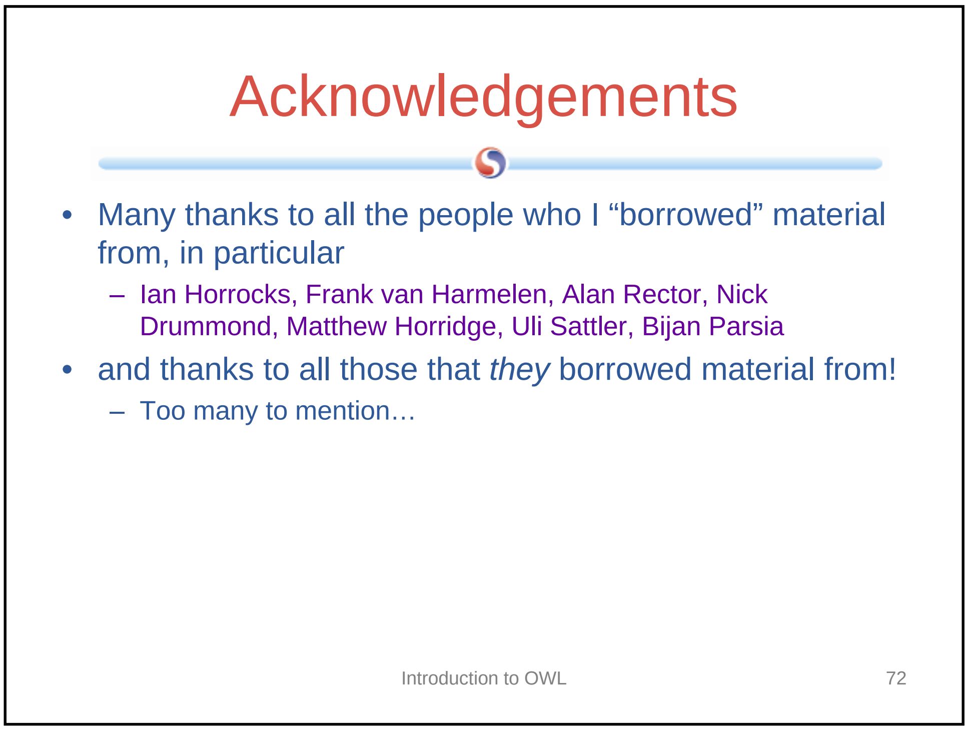
Tools

- Editors
  - Protégé OWL, SWOOP, ICOM, TopQuadrant Composer, OntoTrack, POWL, NeOn…
  - Tend to present the user with “frame-like” interfaces, but allow richer expressions
- Reasoners
  - DL style reasoners based on tableaux algorithms
    - Racer, FaCT++, Pellet
  - Based on rules or F-logic
    - F-OWL, E-Wallet…..
- APIs and Frameworks
  - Jena, WonderWeb OWL-API, KAON2, Protégé OWL API, OWLIM



Summary

- OWL provides us with a rich language for defining ontologies.
  - Builds upon RDF and RDF Schema
  - Formal semantics
    - Provides an unambiguous interpretation of expressions and facilitates the use of reasoners.
    - Draws on years of DL research.
  - Language extensions in the pipeline.
- A growing body of experience and take up in applications



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  - Too many to mention…