The Web Service Modeling Language WSML

An Overview

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June 15, 2005
Outline

Introduction

Recap of WSMO

WSML Language Variants

WSML Syntax

WSML Exchange Syntaxes

Conclusions
The World Wide Web
What is the WWW?

- Largest document repository ever (> 8 billion Web pages indexed by Google)
- Highly distributed
  - Millions of publishers
  - No control over consistency of published content
- Web Technologies
  - HTTP for transferring documents
  - HTML for marking up documents
  - URI for addressing documents
- Most content on the Web is in natural language (HTML)
  - Natural language not suitable for machine reading
  - Current Web is “syntactic”
- Problems in automatically:
  - Retrieving documents
  - Extracting relevant information from retrieved documents
  - Combining information from different sources
The Web Service Modeling Language WSML

Introduction

Semantic Web Services

The Semantic Web

- Making the Web machine-readable
- Publishing data in machine-readable format
- Relating data on the Web to established vocabularies (ontologies)
- Ontologies specified in formal language to allow reasoning
- Ontologies enable automation in:
  - Retrieval of relevant information
  - Extracting relevant information from retrieved document
  - Combination of information from different sources (as long as they are related to the same ontology)
Web Services

- Next step in software engineering:
  - 1960s: Procedural
  - 1980s: Object Orientation
  - 1990s: Component-based
  - 2000s: Web Services

- Loosely coupled, reusable components

- Add new level of functionality to the Web

- Web Service Technologies
  - SOAP for accessing Web Services
  - WSDL for describing Web Services
  - UDDI for publishing and looking up Web Services
Web Services are not enough

- Like the current Web, Web Services are “syntactic”
- No automation in:
  - Finding services
  - Selecting services
  - Negotiation with service provider
  - Composing services
  - Executing services
Combining Semantic Web and Web Services

Semantic Web Services

- Semantic Web + Web Services = Semantic Web Services
- Using Semantic Web technologies to describe Web Services
- Enable automation in:
  - Publication
  - Discovery
  - Selection
  - Composition
  - Mediation
  - Execution
The Web Service Modeling Language WSML

1. A language for the Semantic description of Web Services
2. Based on the Web Service Modeling Ontology WSMO
3. One syntactic framework for a set of layered languages
4. Normative “human-readable” surface syntax
5. Separation of
   - Conceptual modeling
   - Logical modeling
6. Semantics based on well known formalisms
   - Description Logics
   - Logic Programming
   - Frame Logic
7. Web language
8. Frame-based syntax
The Web Service Modeling Ontology WSMO

Introduction

- An ontology for Semantic Web Services
- Provides conceptual model for SWS
- Based on the Web Service Modeling Framework WSMF
- Principles of WSMO:
  - Ontology-based descriptions
  - Strict decoupling of components
  - Strong mediation between components
  - Interface vs. Implementation
The Web Service Modeling Ontology WSMO

Diagram showing the relationships between Goals, Ontologies, Mediators, and Web Services.
The Web Service Modeling Ontology WSMO

Ontologies

▶ Provide terminology for:
  ▶ Data exchanged between service requesters and providers
  ▶ Description of other WSMO elements

▶ Ontologies consist of:
  ▶ Concepts
    ▶ Attributes
  ▶ Relations
  ▶ Functions
  ▶ Instances
  ▶ Axioms
The Web Service Modeling Ontology WSMO

Web Service descriptions

▶ Functionality offered by the Web Service
▶ Functional description, in the form of a capability:
   ▶ Assumptions
     ▶ Cannot be checked
     ▶ Usually indicate dependency on real world
   ▶ Preconditions
     ▶ Conditions over the input
   ▶ Effects
     ▶ Changes in the real world as a result of execution of the Web Service
   ▶ Postconditions
     ▶ Relation between the input and the output
The Web Service Modeling Ontology WSMO
Web Service descriptions (cont’d)

- Behavioral description, in the form of an *interface*:
  - Choreography
    - How to interact with the service
  - Orchestration
    - Use of external Web Service to realize the functionality
  - Both choreography and orchestration are decompositions of the capability
The Web Service Modeling Language WSML

Recap of WSMO

Goals

The Web Service Modeling Ontology WSMO

Goals

- Functionality requested from the Web Service
- Description symmetric to Web Service description:
  - Capability
  - Interface

Goal

Web Service

pre -> post
ass -> effect

pre -> post
ass -> effect

capability

pre -> post
ass -> effect

interface
The Web Service Modeling Ontology WSMO

Mediators

- Connect heterogeneous components
- Resolve heterogeneity in different levels
  - Data - differences in data representation
  - Protocol - differences in interaction styles
  - Process - differences in business processes
The Web Service Modeling Language WSML

Recap of WSMO

Mediators

The Web Service Modeling Ontology WSMO

Types of Mediators

- **OO Mediators**
  - Connect ontologies to any other component (including mediators)
  - Resolve mismatches conflicts between ontologies

- **WW Mediators**
  - Link Web Services to services they depend on
  - Resolve representation differences through OO Mediators

- **WG Mediators**
  - Link Goals and Web Services
  - Resolve differences in data, protocol and process between requester and provider

- **GG Mediators**
  - Connect generic and refined Goals
WSML Language Variants

- WSML-Core
- WSML-DL
- WSML-Flight
- WSML-Rule
- WSML-Full

- Description Logics
- First-Order Logic
- Logic Programming

- First-Order Logic (with nonmonotonic extensions)
- First-Order Logic (with nonmonotonic negation)
## First Order Logic - Syntax

### Symbols

<table>
<thead>
<tr>
<th>Constants</th>
<th>$a, b, john, ...$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Function symbols</td>
<td>$f, g, +, married - to, ...$</td>
</tr>
<tr>
<td>Predicate Symbols</td>
<td>$p, q, &gt;, marriage, ...$</td>
</tr>
<tr>
<td>Variables</td>
<td>$x, y, ...$</td>
</tr>
<tr>
<td>Connectives</td>
<td>$\neg, \land, \lor, \leftarrow, \rightarrow, \leftrightarrow$</td>
</tr>
<tr>
<td>Quantifiers</td>
<td>$\forall, \exists$</td>
</tr>
<tr>
<td>(Equality)</td>
<td>$=$</td>
</tr>
</tbody>
</table>
Terms

- Every constant is a term
  - $a, b, john$
- Every variable is a term
  - $x, y$
- If $f$ is an $n$-place function symbol and $t_1, \ldots, t_n$ are terms, then $f(t_1, \ldots, t_n)$ is a term
  - $f(x), f(a), f(g(a))$
  - $father - of(john), married - to(mary)$
Atomic formulas

- If $p$ is an $n$-place predicate symbol and $t_1, ..., t_n$ are terms, then $p(t_1, ..., t_n)$ is an atomic formula
  - $p(x), q(f(a), y)$
  - $marriage(father \text{−} of(john), mary, date(2005, 4, 6))$

- If $t_1, t_2$ are terms, then $t_1 = t_2$ is an atomic formula
  - $f(x) = a, married \text{−} to(mary) = father \text{−} of(john)$
Formulas

- Any atomic formula is a formula
- If $A, B$ are formulas and $x_1, \ldots, x_n$ are variables then:
  - $\neg A$ is a formula
  - $A \land B$ is a formula
  - $A \lor B$ is a formula
  - $A \leftarrow B$ is a formula
  - $A \rightarrow B$ is a formula
  - $A \leftrightarrow B$ is a formula
  - $\forall x_1, \ldots, x_n : A$ is a formula
  - $\exists x_1, \ldots, x_n : A$ is a formula

- Examples:
  - $\forall x, y, d : marriage(x, y, d) \rightarrow married - to(x) = y \land married - to(y) = x$
  - $\forall x : number(x) \rightarrow \exists y : y > x$
Horn subset

- A Horn formula is a disjunction of literals with one positive literal, with all variables universally quantified:
  - $(\forall) \neg B_1 \lor \ldots \lor \neg B_n \lor H$
- Can be written as an implication:
  - $(\forall) B_1 \land \ldots \land B_n \rightarrow H$
- Horn formulas are the basis for Logic Programming
First-Order Logic - Semantics

Interpretation

- The meaning of a First-Order formula is assigned using an *interpretation*
- An interpretation $\mathcal{I}$ consists of:
  - Domain $\Delta$: a set of objects
  - A set of relations $R: \Delta^1 \times \cdots \times \Delta^n$
  - A set of functions $F: \Delta^1 \times \cdots \times \Delta^n \mapsto \Delta$
  - A mapping function which:
    - Maps constants to objects
    - Maps predicate symbols to relations
    - Maps function symbols to functions
- An interpretation is a *model* of a formula $A$ if it makes the formula *true*:
  - $\mathcal{I} \models A$
Truth of a formula

<table>
<thead>
<tr>
<th>Formula</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$A$ (atomic formula)</td>
<td>is true iff $A^I$ is in the model</td>
</tr>
<tr>
<td>$\neg A$</td>
<td>is true iff $A^I$ is not true</td>
</tr>
<tr>
<td>$A \land B$</td>
<td>is true iff $A^I$ and $B^I$ are true</td>
</tr>
<tr>
<td>$A \lor B$</td>
<td>is true iff $A^I$ or $B^I$ is true (or both)</td>
</tr>
<tr>
<td>$A \rightarrow B$</td>
<td>is true iff in every case where $A^I$ is true, $B^I$ is true</td>
</tr>
</tbody>
</table>
What about variables?

- We have not discussed semantics of variables
- Variables have no semantics
- What to do with variables?
- Assign values to variables using an assignment $B$
  - e.g., $\{x \mapsto a, y \mapsto john\}$
- An interpretation $\mathcal{I}$ makes a formula $A$ true under a variable assignment $B$:
  - $\mathcal{I} \models_B A$
- Quantifiers:
  - $\exists x A$: there exists an assignment for $x$ which makes $A$ true
  - $\forall x A$: for all possible assignments of $x$, $A$ is true
Logic Programming - Syntax

- Any FOL term is a term in LP
- Any FOL atomic formula is an atomic formula in LP
- Any Horn formula is a rule in LP (quantification usually omitted)
  - $H \leftarrow B_1 \land \ldots \land B_n$
- Logic programming is a syntactic subset of FOL
- **Note!** Negation-as-failure in LP is an *extension* of Horn rules
  - $\neg \neq$ *not*
The Herbrand Universe $U_P$ is the set of all ground terms which can be formed from constants and function symbols in program $P$. Example:

$a, b, f(a), f(b), f(f(a)), f(f(b)), f(f(f(a))), ...$

The Herbrand Base $B_P$ is the set of all ground atoms which can be built from predicate symbols in $P$, using ground terms from $U_P$ as arguments. Example: $p(a), p(b), q(a), q(b), p(f(a)), q(f(a)), ...$
Logic Programming - Semantics
Herbrand Interpretation and Least Herbrand Model

- A Herbrand Interpretation IP is a subset of the Herbrand Base BP.
- A Herbrand Model MP is a Herbrand Interpretation which makes every formula true, i.e.:
  - Every fact in $P$ is in $MP$, and
  - For every rule $R$ in $P$ holds: if every positive literal in the body is in $MP$, then also the head literal is in $MP$.

Note: this only works for positive programs, i.e., programs without negation!

- The semantics of a program $P$ is characterized in terms of the least Herbrand Model, which is the intersection of all possible Herbrand Models.
- Each positive program has one unique least Herbrand Model.
Relationship between FOL and LP

- Semantics LP defined in terms of minimal Herbrand model
  - Only one minimal model
- Semantics FOL defined in terms of First-Order models
  - Typically, infinitely many First-Order models
- The minimal Herbrand model is a First-Order model
- In fact, every Herbrand model is a First-Order model
- There exist First-Order models which are not Herbrand models
Entailment in FOL and LP

- General First-Order entailment:
  - $\phi \models \psi$ iff for every interpretation $\mathcal{I}$: if $\mathcal{I} \models \phi$ then $\mathcal{I} \models \psi$
  - Thus, the set of models of $\phi$ $M(\phi)$ is a subset of $M(\psi)$:
    $M(\phi) \subseteq M(\psi)$
  - e.g., $p(x) \land q(x) \models p(x)$

- Ground entailment:
  - $\phi \models \psi_{\text{ground}}$ iff for every interpretation $\mathcal{I}$: if $\mathcal{I} \models \phi$ then $\mathcal{I} \models \psi_{\text{ground}}$ and $\psi_{\text{ground}}$ does not contain variables
  - e.g., $(p(x) \rightarrow q(x)) \land p(a) \models q(a)$

- Logic Programming only defines ground entailment

- Horn Logic (i.e., Horn subset of FOL) is equivalent to Logic Programming wrt. ground entailment
  - For any set of Horn formulas $\phi$ and a ground Horn formula $\psi_{\text{ground}}$: $\phi \models_{\text{FOL}} \psi_{\text{ground}}$ iff $\phi \models_{\text{LP}} \psi_{\text{ground}}$
  - $\models_{\text{FOL}}$ is classical First-Order entailment; $\models_{\text{LP}}$ is LP entailment
Description Logics

- Most DLs similar to 2-variable fragment of FOL
  - No more than 2 variables under the scope of a quantifier
    - 
  - Exception: transitive properties
  - Classes correspond to unary predicates
  - Properties correspond to binary predicates
  - No function symbols

- Most DLs are decidable

- We focus on SHIQ DL (close to the DL underlying OWL DL), and disregard concrete domains (e.g., int, string) for now

- \( SHIQ = \)
  - Concept hierarchies
  - Concept conjunction, disjunction, negation
  - Rule hierarchies
  - Existential, universal quantification
  - Qualified number restrictions (minimal, maximal cardinality)
  - Symmetric, inverse, transitive properties
SHIQ - Syntax
Concept descriptions

\[ C, D \rightarrow A \mid \]
\[ \top \mid \] (atomic concept)
\[ \bot \mid \] (universal concept)
\[ C \sqcap D \mid \] (intersection)
\[ C \sqcup D \mid \] (disjunction)
\[ \neg C \mid \] (negation)
\[ \forall R.C \mid \] (value restriction)
\[ \exists R.C \mid \] (existential quantification)
\[ \geq nR.C \mid \] (minimal cardinality)
\[ \leq nR.C \mid \] (maximal cardinality)
\textbf{SHIQ} - Syntax

Individual assertions

\[ a \in C \]
\[ \langle a, b \rangle \in R \]
SHIQ - Syntax

Axioms

\[ C \sqsubseteq D \] (class subsumption)
\[ C \equiv D \] (equivalence)
\[ Q \sqsubseteq R \] (property subsumption)
\[ R \equiv Q^- \] (inverse roles)
\[ R \equiv R^- \] (symmetric roles)
\[ R^+ \sqsubseteq R \] (transitive properties)
SHIQ Examples

- \( \text{Human} \sqsubseteq \forall \text{hasChild} \cdot \text{Human} \sqcap = 2 \text{hasParent} \cdot \text{Human} \)
- \( \text{Parent} \sqsubseteq \exists \text{hasChild} \cdot \top \)
- \( \text{HumanParent} \equiv \text{Human} \sqcap \text{Parent} \)
- \( \text{hasChild} \equiv \text{hasParent}^- \)

if \( \langle \text{john}, \text{mary} \rangle \in \text{hasChild} \) then \( \langle \text{mary}, \text{john} \rangle \in \text{hasParent} \)
Mapping $\mathcal{SHIQ}$ to FOL

<table>
<thead>
<tr>
<th>$A$ (atomic concept)</th>
<th>$A(x)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\top$</td>
<td>$\top$</td>
</tr>
<tr>
<td>$\bot$</td>
<td>$\bot$</td>
</tr>
<tr>
<td>$\sqcap C \sqcap D$</td>
<td>$\text{tr}(C) \land \text{tr}(D)$</td>
</tr>
<tr>
<td>$\sqcup C \sqcup D$</td>
<td>$\text{tr}(C) \lor \text{tr}(C)$</td>
</tr>
<tr>
<td>$\neg C$</td>
<td>$\neg \text{tr}(C)$</td>
</tr>
<tr>
<td>$\forall R.C$</td>
<td>$\forall y : R(x, y) \rightarrow \text{tr}(C, y)$</td>
</tr>
<tr>
<td>$\exists R.C$</td>
<td>$\exists y : R(x, y) \land \text{tr}(C, y)$</td>
</tr>
<tr>
<td>$\geq nR.C$</td>
<td>$\exists y_1, \ldots, y_n : \land R(X, y_i) \land \text{tr}(C, y_i) \land \land y_i \neq y_j$</td>
</tr>
<tr>
<td>$\leq nR.C$</td>
<td>$\forall y_1, \ldots, y_{n+1} : \land R(X, y_i) \land \text{tr}(C, y_i) \land \rightarrow \lor y_i =$</td>
</tr>
</tbody>
</table>
Mapping $SHIQ$ to FOL

\[
a \in A \quad \quad \quad A(a)
\]
\[
\langle a, b \rangle \in R \quad \quad R(a, b)
\]
\[
C \sqsubseteq D \quad \forall x : tr(C, x) \rightarrow tr(D, x)
\]
\[
C \equiv D \quad \forall x : tr(C, x) \leftrightarrow tr(D, x)
\]
\[
Q \sqsubseteq R \quad \forall x, y : Q(r, y) \rightarrow R(x, y)
\]
\[
R \equiv Q^- \quad \forall x, y : R(x, y) \leftrightarrow Q(y, x)
\]
\[
R^+ \sqsubseteq R \quad \forall x, y, z : R(x, y) \land R(y, z) \rightarrow R(x, z)
\]
Relation between DL and LP
Description Logic Programs

- “Intersection” of Description Logics and Logic Programming
- That part of Description Logics (OWL in particular) which can be translated to a Logic Program
- Horn Logic subset of $SHIQ$, reduced to a Logic Program: Description Logic Program: DLP

General idea:

1. Translate $SHIQ$ axiom to First-Order Logic
2. Rewrite to Horn Logic
   - If rewriting not possible: formula not in DLP
3. Reduce to Logic Program
WSML-Core

- Basic interoperability layer between Description Logics and Logic Programming paradigms
- Based on Description Logic Programs
  - Expressive intersection of Description Logic $SHIQ$ and Datalog
  - Allows to take advantage of many years of established research in Databases and Logic Programming
  - Allows reuse of existing efficient Deductive Database and Logic programming reasoners
- Some limitations in conceptual modeling of Ontologies
  - No cardinality constraints
  - Only “inferring” range of attributes
  - No meta-modeling
WSML-Core Logical Expressions

- Limitations in logical expressions
  - From Description Logic point-of-view, there is a lack of:
    - Existentials
    - Disjunction
    - (Classical) negation
    - Equality
  - From Logic Programming point-of-view, there is a lack of:
    - N-ary predicates
    - Chaining variables over predicates
    - (Default) negation
    - Function symbols
WSML-DL

- Extension of WSML-Core
- Based on the Description Logic $SHIQ$
  - Entailment is decidable
  - Close to DL species of Web Ontology Language OWL
  - Many efficient subsumption reasoners
- Some limitations in conceptual modeling of Ontologies
  - No cardinality constraints
  - Only “inferring” range of attributes
  - No meta-modeling
- Limitations in logical expressions
  - From Logic Programming point-of-view, there is a lack of:
    - N-ary predicates
    - Chaining variables over predicates
    - (Default) negation
WSML-Flight

- Extension of WSML-Core
- Based on the Datalog, with negation under Perfect Model Semantics
  - Ground entailment is decidable
  - Allows to take advantage of many years of established research in Databases and Logic Programming
  - Allows reuse of existing efficient Deductive Database and Logic programming reasoners
- No limitations in conceptual modeling of Ontologies
  - Cardinality constraints
  - Value constraints for attributes
  - Meta-modeling
WSML-Flight Logical Expressions

- Syntax based on Datalog fragment of F-Logic, extended with negation-as-failure
- Arbitrary Datalog rules:
  - N-ary predicates
  - Chaining variables over predicates
- From Description Logic point-of-view, there is a lack of:
  - Existentials
  - Disjunction
  - (Classical) negation
  - Equality
- From Logic Programming point-of-view, there is a lack of:
  - Function symbols
WSML-Rule

- Extension of WSML-Flight
- Based on Horn fragment of F-Logic, with negation under Perfect Model Semantics
  - Ground entailment is undecidable
  - Turing complete
  - Allows to take advantage of many years of established research in Logic Programming
  - Allows reuse of existing efficient Logic programming reasoners
- Extends WSML-Flight logical expressions with:
  - Function symbols
  - Unsafe rules
- From Description Logic point-of-view, there is a lack of:
  - Existentials
  - Disjunction
  - (Classical) negation
  - Equality
WSML-Full

- Extension of WSML-Rule and WSML-DL
- Based on First Order Logic with nonmonotonic extensions
  - Entailment is undecidable
  - Very expressive
- Extends WSML-DL logical expressions with:
  - Chaining variables over predicates
  - Function symbols
  - Nonmonotonic negation
  - N-ary predicates
- Extends WSML-Rule with:
  - Existentials
  - Disjunction
  - Classical negation
  - Equality
- Specification of WSML-Full is open research issue
Identifiers

- Internationalized Resource Identifiers (IRIs) are basic identifiers
  - Concepts, attributes, relations, instances, etc... are all IRIs
  - IRI is successor of URI
  - Using in newer W3C recommendations, e.g., XML, RDF
    - e.g., "http://www.wsmo.org/wsml/wsml-syntax#", "http://example.org/myOntology#myConcept"

- sQNames
  - Abbreviations for IRIs (“serialized QNames”)
    - e.g., wsml#concept, dc#title, ont#location

- Data values
  - Elementary data values: strings, int, decimals
  - Structured data values
    - Derived from XML Schema Datatypes
      - date, float, etc...
    - e.g., date(2005,6,23), float(12.567)
Prologue
By Example

// Specification of the WSML variant
wsmlVariant "http://www.wsmo.org/wsml/wsml-syntax/wsml-flight"

// Namespace prefix declaration
namespace {
    "http://www.example.org/example#",
    dc "http://purl.org/dc/elements/1.1/"
}

// WSML specifications
ontology "http://www.example.org/exampleOntology"
    [...] 
goal "http://www.example.org/exampleGoal"
    [...] 

etc...
WSML Specification

A WSML specification has the following structure:

- Type of specification (Ontology/Web Service/Goal/Mediator)
- Header
  - Non-Functional Properties
  - Imported Ontologies
  - Used Mediators
- Content of the specification
Ontologies

Header

[.. prologue ..]

ontology _”http://www.example.org/ontologies/example”

nonFunctionalProperties
dc#title hasValue ”WSML example ontology”

endNonFunctionalProperties

importsOntology { _”http://www.wsmo.org/ontologies/location” }

usesMediator { _”http://www.wsmo.org/mediators/” }
Concepts

- Form the basic terminology of the domain of discourse
- May be organized in a hierarchy (using `subConceptOf`) 
- Has a number of attributes:
  - Attributes have a type:
    - Type constraint (`ofType`)
    - Type inference (`impliesType`)
  - Attributes may have cardinality constraints
  - Attributes may have a number of features:
    - Transitive
    - Symmetric
    - Reflexive
    - Inverse of another attribute
Concepts

Example

```xml
concept Person subConceptOf {Primate, LegalAgent}

nfp
// Related axiom
  dc#relation hasValue personUncle
endnfp
// A functional attribute (maximal cardinality=1)
  hasName ofType (0 1) _string
// hasParent is the inverse of hasChild
  hasChild inverseOf(hasParent) ofType Person
  hasParent ofType Person
  hasBrother ofType Person
```
Relations

- Inspired by relations in mathematics
- Have arbitrary arity
- May have typing associated with its arguments
- May be organized in a hierarchy (using \texttt{subRelationOf})

relation Marriage (ofType Person, ofType Person, ofType date)

\texttt{nfp}
dc\#description \texttt{hasValue} "Marriage is a relation between two persons, which are the participants in the marriage, and the date in the marriage."

\texttt{endnfp}
Instances

- Are the objects in the domain
- May be member of one or more concepts
- May have a number of attribute values associated with it

```xml
instance john memberOf Person
nfp
dc#description hasValue "The person John Smith"
endnfp
hasName hasValue "John Smith"
```
Relation Instances

- Are tuples in a relation

```xml
relationInstance Marriage(john,mary,\_date\(2005,03,03\))
nfp
dc\#description hasValue "John and Mary married on 2005-03-03."
endnfp
```
Axioms

- Refine concept and relation definitions in Ontologies using logical expressions
- Add arbitrary knowledge and constraints
- Allowed logical expressions depend on WSML variant

axiom personUncle
nfp
dc#description hasValue "The brother of a person’s parent is that person’s uncle."
endnfp
definedBy
?x[hasUncle hasValue ?z] impliedBy ?x[hasParent hasValue ?y] and
?y[hasBrother hasValue ?z].
Web Services

A Web Service specification has the following structure:

▶ Type of specification (webService) and identifier
▶ Header
  ▶ Non-Functional Properties
  ▶ Imported Ontologies
  ▶ Used Mediators
▶ Capability
  ▶ Functional description of Web Service
▶ Interfaces
  ▶ Behavioural description of Web Service
  ▶ Communications pattern of Web Service

webService "http://www.example.org/exampleService"
capability ...
interface ...
Capability

- Syntactical framework for Functional description
- Functionality defined through logical expressions:
  - Preconditions
  - Postconditions
  - Assumptions
  - Effects
- Shared variables
  - Variables shared by description elements
  - Quantified over the entire capability
Capability
Example

capability
  sharedVariables ?x,?y,...
  precondition
  definedBy
  ...
  postcondition
  definedBy
  ...
  assumption
  definedBy
  ...
  effect
  definedBy
  ...
Interfaces

- Choreography
  - Communication interface of Web Service
- Orchestration
  - Usage of external Web Services

Currently, choreography and orchestration are external to WSML

**interface**
- **choreography** "http://example.org/choreographies/1"
- **orchestration** "http://example.org/orchestration/1"
Goals

▶ Describe requested functionality

▶ Description symmetric to Web Services:
  ▶ Header
  ▶ Capability
  ▶ Interfaces

```
goal "http://www.example.org/exampleGoal"
```

capability
...

interface
...

Mediators

Mediators connect WSML elements in two ways:

- Referencing mediators through `usesMediator`
- Specifying `source` and `target` in mediator specification

Mediation is achieved by mediation service (`usesService`):

- Web Service
- Goal

```xml
<wsml>
  <wgMediator/>
  <source>http://www.example.org/exampleGoal</source>
  <target>http://www.example.org/exampleService</target>
  <usesService>http://www.example.org/mediationService</usesService>
</wsml>
```
Logical Expression syntax

- Used for refining Ontologies and specifying Web Service functionality
- Allow to use the full expressive power of the underlying logic
- First-Order Logic with Frame syntax (F-Logic)
- Specific extensions to capture Logic Programming constructs
  - Negation-as-failure
  - LP implication
- Variables are implicitly universally quantified outside the formula
- Symbols resemble natural language and are unambiguous
- WSML variants restrict allowed logical expressions
Examples

// a simple rule; the brother of someone's parent is that person's uncle
?x[hasUncle hasValue ?z] impliedBy ?x[hasParent hasValue ?y] and ?y[hasBrother hasValue ?z].

// the same person cannot be both a man and a woman (constraint)
!− ?x memberOf Man and ?x memberOf Woman.

// every person has a father
?x memberOf Person implies exists ?y (?x[father hasValue ?y]).

// a person is either a Man or a Woman
?x memberOf Person implies ?x memberOf Man or ?x memberOf Woman.
WSML Variants vs. Features

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Table by Holger Lausen
WSML XML Syntax

- Syntax for exchange over the Web
- Translation between human-readable and XML syntax
- XML Schema for WSML has been defined
**WSML XML**

Example

```xml
<!ENTITY ex "http://www.example.org/ontologies/example#" >
<!ENTITY wsml "http://www.wsmo.org/wsml/wsml-syntac#" >
<wsml xmlns="&wsml;" variant=""http://www.wsmo.org/wsml/wsml-syntac/wsml-flight" >
  <importsOntology>
    http://www.wsmo.org/ontologies/ontology/locaton
  </importsOntology>
  <concept name="&ex;Person" >
    <nonFunctionalProperties>[..]</nonFunctionalProperties>
    <attribute name="&ex;hasName" type=""constraining""> 
      <range>&wsml;string</range>
      <maxCardinality>1</maxCardinality>
    </attribute>  
    [..]
  </concept>
  [..]
</wsml>
```
WSML RDF Syntax

- Interoperability with RDF applications
- Maximal reuse of RDF and RDFS vocabulary
- WSML RDF includes most of RDF
- Translation between human-readable and RDF syntax
- For logical expressions, XML literals are used
WSML RDF

Example

```
<http://www.example.org/ontology> rdf#type wsml#ontology
<http://www.example.org/ontology> wsml#variant
  <http://www.wsmo.org/wsml/wsml−syntax/wsml−flight>
<http://www.example.org/ontology> wsml#nfp wn:nfp1
wn:nfp1 dc#title "WSML example ontology"^^xsd#string
<http://www.example.org/ontology> wsml#importsOntology
  <http://www.wsmo.org/ontologies/location>
<http://www.example.org/ontology> wsml#hasConcept ex#Person
  ex#Person wsml#hasAttribute wn:att1
wn:att1 wsml#attribute ex#hasName
wn:att1 wsml#ofType xsd#string
wn:att1 wsml#maxCardinality "1"^^xsd:integer
<http://www.example.org/ontology> wsml#hasAxiom
  ex#personUncle
  ex#personUncle rdfs#isDefinedBy
    "<impliedByLP>..</impliedByLP>"^^rdf#XMLLiteral
```
Conclusions

- WSML is a language for modeling of Semantic Web Services
- Based on the Web Service Modeling Ontology WSMO
- WSML is a Web language:
  - IRIs for object identification
  - XML datatypes
- WSML is based on well-known logical formalisms:
  - Description Logics
  - Logic Programming
  - Frame Logic
- Syntax has two parts:
  - Conceptual modeling
  - Arbitrary logical expressions
- XML and RDF syntaxes for exchange over the Web
WSML resources
http://www.wsmo.org/wsml/wsml-syntax#